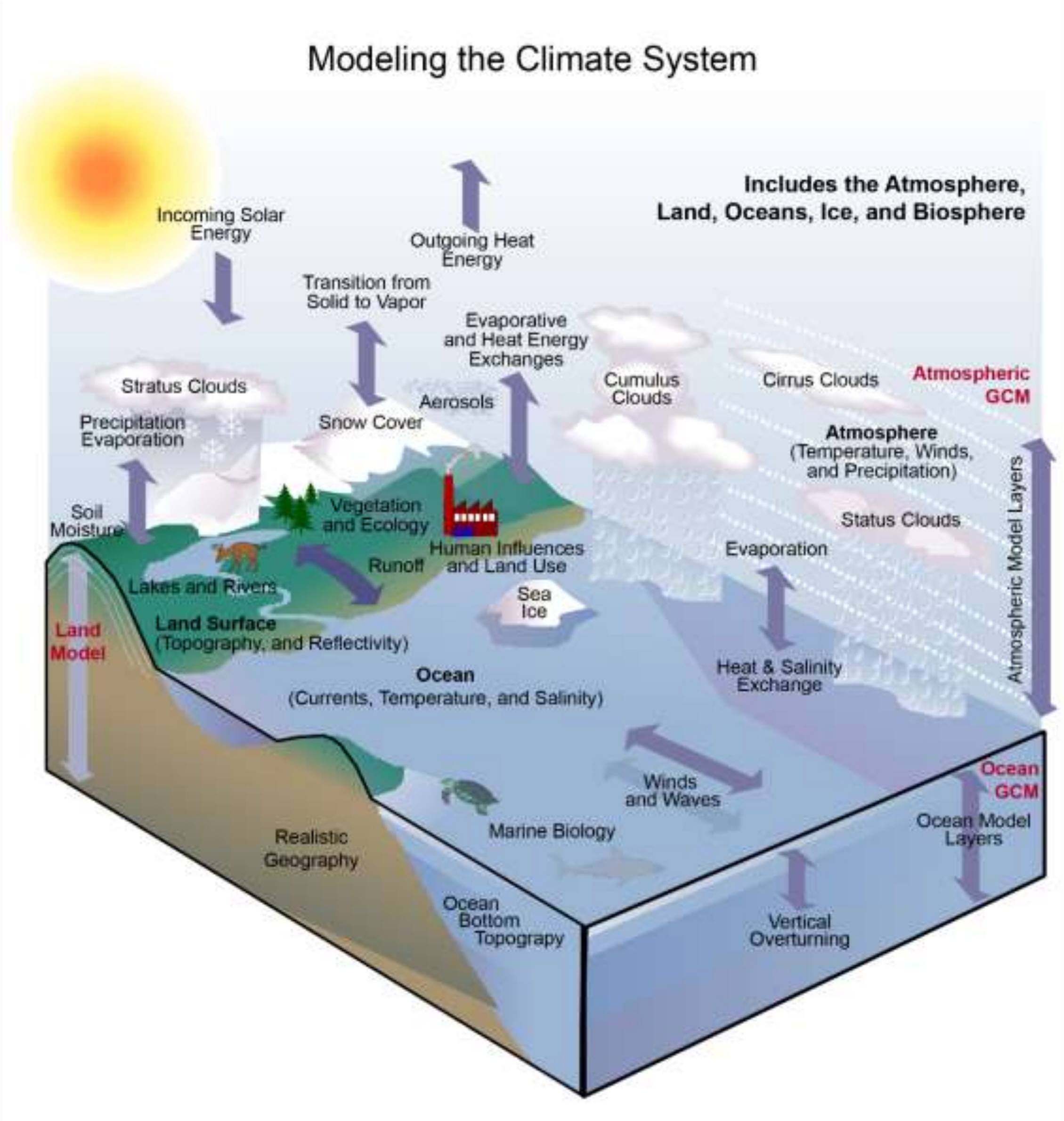
Mathematical Models vs. Real-World Data:

Which Best Predicts Earth's Climatic Future?



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EXECUTIVE SUMMARY

How well are today's climate models able to predict what will happen to earth's climate in the years, decades and centuries to come if the atmosphere's carbon dioxide (CO_2) concentration continues to rise as a result of mankind's continued burning of fossil fuels such as coal, gas and oil? In this document this question is broached via a thorough and careful scrutiny of the pertinent scientific literature that has addressed this topic as it pertains to several important climatic phenomena.

First of all, pouring over some 33 *original* scientific studies of the subject, along with 34 of their relevant *citations* of other such studies -- all of which 67 publications are listed in the Reference section of this document's initial chapter on **Clouds** -- we encounter 188 major documented *errors, inadequacies* or *shortcomings* in all carefully evaluated "hindcasts" of the several climate models therein reviewed, which modelling *failures* the authors of the 33 original studies acknowledge as *still remaining* in the most up-to-date climate models that include the many significant impacts of clouds in their projections of both past and future climate characteristics. And in light of this sad state of affairs, one can only presume that this negative aspect of the quest to successfully predict how earth's climate will evolve over the next several decades will likely not be achieved anytime soon ... or *maybe* not even at all!

In the second chapter on **ENSO** -- i.e., the *El Niño Southern Oscillation* -- we review 31 *other* original papers related to *this* phenomenon; and we include in the chapter's reference list 68 *additional* citations to still *other* pertinent studies, which have proven invaluable in revealing 203 different *inadequacies* in climate model *hindcasts*, which host of negative findings seriously questions the validity of current climate model projections that have been made in relation to this important climatic phenomenon.

In a closely related third chapter on **Monsoons**, we review the findings of 43 *other* original scientific studies, as well as report the major findings of an *additional* 82 studies that were cited by the *first* set of studies, while identifying in this process 326 different ways in which current climate models have failed to accurately represent the major documented characteristics of monsoons of prior years.

In the fourth chapter, we repeat this process for **Oceans** by reviewing the findings of 33 pertinent original publications and 84 other studies therein cited, which together highlight a total of 263 climate model errors and shortcomings related to the roles of earth's seas in influencing global climate change.

In the fifth and much shorter chapter on much-less-studied **Permafrost**, we describe the findings of 13 pertinent papers that reveal a total of 23 climate model errors.

In the sixth and rather large chapter on **Precipitation**, we review the findings of fully 73 original scientific papers and 130 other studies that they cite, *all* of which are found to be plagued by a total of 518 climate model prediction failures.

In the seventh chapter on **Radiation**, we review the findings of a much smaller set of 22 original studies plus 4 others that they cite, which together reveal a total of 49 climate model prediction problems.

In the eighth chapter on **Sea Ice**, we review the findings of a *still* smaller set of 11 original studies plus 14 others that are cited by them, which together produce a total of 73 climate model prediction problems.

In the nineth chapter on **Soil Moisture**, we review the findings of only 6 original studies along with those of 10 other studies they cite, which when combined reveal a total of 40 major model biases.

Last of all, in the tenth and largest chapter on an assortment of **Miscellaneous Phenomena**, we review the findings of 98 original investigations together with those of 148 additional studies cited in the 98 original studies, which when combined together reveal a total of 735 climate model prediction problems.

Altogether, therefore, we find (and document) a total of 2,418 *failures* of today's top-tier climate models to accurately *hindcast* a whole host of climatological phenomena. And with this *extremely poor record of success*, one must greatly wonder how it is that *anyone* would believe what the climate models of *today* project about earth's climate of *tomorrow*, i.e., a few decades to a century or more from now.

CLOUDS

Correctly parameterizing the many influences of clouds on climate is an elusive goal that the creators of atmospheric general circulation models (GCMs) have yet to achieve. One reason for their lack of success in this endeavor has to do with *model resolution* on both vertical and horizontal space scales, since a lack of adequate resolution forces modelers to parameterize the ensemble large-scale effects of processes that occur on smaller scales than their models' are capable of handling. This is especially true of physical processes such as cloud formation and cloud-radiation interactions. It is only natural to wonder, therefore, if the parameterizations used in the models that have prompted calls for severe cuts in anthropogenic CO_2 emissions over the past couple of decades have adequately represented these processes and their interactions. The results of several studies conducted near the turn of the past century did indeed suggest that model parameterizations of that period did *not* succeed in this regard, as reported by Groisman *et al*., 2000); and subsequent studies have suggested that they are *still* not succeeding.

Lane *et al*. (2000), for example, evaluated the sensitivities of cloud-radiation parameterizations utilized in the GCMs of that era to changes in vertical model resolution, varying the latter from 16 to 60 layers in increments of four and comparing the results to observed values. This effort revealed that (1) cloud fraction varied by approximately 10% over the range of resolutions tested, which corresponded to about 20% of the observed cloud cover fraction. Similarly, (2) outgoing longwave radiation varied by 10 to 20 Wm^{-2} as model vertical resolution was varied, amounting to approximately 5 to 10% of observed values, while (3) incoming solar radiation experienced similar significant variations across the range of resolutions tested. What is more, (4) the model results did not converge, even at a resolution of 60 layers.

In an analysis of the multiple roles played by cloud microphysical processes in determining tropical climate, Grabowski (2000) found much the same thing, noting that (1) there were serious problems related to the degree to which computer models failed to correctly incorporate cloud microphysics. And these observations led him to conclude that (2) "it is unlikely that traditional convection parameterizations can be used to address this fundamental question in an effective way." He also was convinced that (3) "classical convection parameterizations do not include realistic elements of cloud physics and (4) they represent interactions among cloud physics, radiative processes, and surface processes within a very limited scope." Consequently, he but stated the obvious when he concluded that (5) "model results must be treated as qualitative rather than quantitative."

Reaching similar conclusions were Gordon *et al*. (2000), who determined that (1) many GCMs of the late 1990s tended to under-predict the presence of subtropical marine stratocumulus clouds, and that (2) they failed to simulate the seasonal cycle of the clouds. These deficiencies were extremely important, because the particular clouds they studied exerted a major cooling influence on the surface temperatures of the sea below them. In the situation Gorden and his colleagues investigated, for example, the removal of the low clouds, as occurred in the normal application of their model, led to sea surface temperature increases on the order of 5.5°C.

Further condemnation of turn-of-the-century model treatments of clouds came from Harries (2000), who wrote that our knowledge of high cirrus clouds was very poor and that (1) "we could easily have uncertainties of many tens of Wm^{-2} in our description of the radiative effects of such clouds, and how these properties may change under climate forcing." This problem was especially noteworthy in light of the fact that the radiative effect of a doubling of the air's CO_2 content is only on the order of low single-digit Wm^{-2}. And, therefore, it was truly an understatement to say, as Harries did, that (2) "uncertainties as large as, or larger than, the doubled CO_2 forcing could easily exist in our modeling of future climate trends, due to uncertainties in the feedback processes."

Moving into the 21st century, Lindzen *et al*. (2001) analyzed cloud cover and sea surface temperature (SST) data over a large portion of the Pacific Ocean, finding a strong inverse relationship between upper-level cloud area and mean SST, such that the area of cirrus cloud coverage normalized by a measure of the area of cumulus coverage decreased by about 22% for each degree C increase in cloudy region SST. *Essentially*, as the three researchers thus described it, "the cloudy-moist region appears to act as an infrared adaptive iris that opens up and closes down the regions free of upper-level clouds, which more effectively permit infrared cooling, in such a manner as to resist changes in tropical surface temperature."

The sensitivity of this negative feedback was calculated by Lindzen *et al*. to be substantial. In fact, they estimated it would "more than cancel all the positive feedbacks in the more sensitive then-current climate models," which were being used at that time to predict the consequences of projected increases in the atmosphere’s CO_2 concentration. And, as one might have expected, evidence for this potential *impediment* to global warming was nowhere to be seen back then, just as it is nowhere to be seen *now*, even in today's most advanced GCMs.

Clearly, this challenge to climatic *political correctness* could not go uncontested; and Hartmann and Michelsen (2002) quickly claimed that the correlation noted by Lindzen *et al*. resulted from variations in subtropical clouds that are not physically connected to deep convection near the equator, and that it was thus "unreasonable to interpret these changes as evidence that deep tropical convective anvils contract in response to SST increases." Fu *et al*. (2002) also chipped away at the adaptive infrared iris concept, arguing that "the contribution of tropical high clouds to the feedback process would be small since the radiative forcing over the tropical high cloud region is near zero and not strongly positive," while additionally claiming to show that water vapor and low cloud effects were overestimated by Lindzen *et al*. by at least 60% and 33% respectively." And as a result, they obtained a feedback factor in the range of -0.15 to -0.51, compared to Lindzen *et al*.'s much larger negative feedback factor of -0.45 to -1.03.

In a simultaneously published reply to this critique, Chou *et al*. (2002) stated that Fu *et al*.'s approach to specifying longwave emission and cloud albedos "appears to be inappropriate for studying the iris effect," and that since "thin cirrus are widespread in the tropics and ... low boundary clouds are optically thick, the cloud albedo calculated by [Fu *et al*.] is too large for cirrus clouds and too small for boundary layer clouds," so that "the near-zero contrast in cloud albedos derived by [Fu *et al*.] has the effect of underestimating the iris effect." In the end, however, Chou *et al*. agreed that Lindzen *et al*. "may indeed have overestimated the iris effect somewhat, though hardly by as much as that suggested by [Fu *et al*.]."

Although there has thus been some convergence in the two extreme views of the subject, the debate over the reality and**/**or magnitude of the adaptive infrared iris effect continued apace; and when some of the meteorological community's best minds continued to clash over the nature and magnitude of the phenomenon, it was amazing that climate alarmists continued to clamor for actions to reduce anthropogenic CO_2 emissions at almost all costs, as if the issue were settled when it clearly was not.

This situation is illustrative of the importance of the advice given two years earlier by Grassel (2000), who in a review of the then-current status of the climate modeling enterprise noted that changes in many climate-related phenomena, including cloud optical and precipitation properties caused by changes in the spectrum of cloud condensation nuclei, were insufficiently well known to provide useful insights into future conditions. His advice in the light of this knowledge gap was that "we must continuously evaluate and improve the GCMs we use," although he was forced to acknowledge that contemporary climate model results were already being "used by many decision-makers, including governments."

This state of affairs has continued to the present day and is very disturbing, as national and international policy is being made on the basis of vastly imperfect mathematical representations of a whole host of physical, chemical and biological phenomena, many of which involve clouds. Although some may think that what we currently know about the subject is sufficient for predictive purposes, a host of questions posed by Grassl -- for which we *still* lack definitive answers -- demonstrates that this assumption is erroneous.

As but a single example, Charlson *et al*. (1987) described a negative feedback process that links biologically-produced dimethyl sulfide (DMS) in the oceans with climate. The basic tenant of this hypothesis derives from the fact that the global radiation balance is significantly influenced by the albedo of marine stratus clouds, and that the albedo of these clouds is a function of cloud droplet concentration, which is dependent upon the availability of condensation nuclei that have their origin in the flux of DMS from the world's oceans to the atmosphere.

Acknowledging that the roles played by DMS oxidation products within the context described above are indeed "diverse and complex" and in many instances "not well understood," Ayers and Gillett (2000) summarized empirical evidence supporting Charlson *et al*.'s hypothesis that was derived from data collected at Cape Grim, Tasmania, and from reports of other pertinent studies in the peer-reviewed scientific literature. And in light of their findings, they reported that (1) the "major links in the feedback chain proposed by Charlson *et al*. (1987) have a sound physical basis," and that there is thus (2) "compelling observational evidence to suggest that DMS and its atmospheric products participate significantly in processes of climate regulation and reactive atmospheric chemistry in the remote marine boundary layer of the Southern Hemisphere."

The empirical evidence analyzed by Ayers and Gillett highlights an important suite of negative feedback processes that act in opposition to model-predicted CO_2-induced global warming over the world's oceans; and these processes are not fully incorporated into even the very best of the current crop of climate models, nor are analogous phenomena that occur over land included in them, such as those discussed by Idso (1990).

Further to this point, O'Dowd *et al*. (2004) measured size-resolved physical and chemical properties of aerosols found in northeast Atlantic marine air arriving at the Mace Head Atmospheric Research station on the west coast of Ireland during phytoplanktonic blooms at various times of the year. And in doing so, they found that in the winter, when biological activity was at its lowest, the organic fraction of the sub-micrometer aerosol mass was about 5%. During the spring through autumn, however, when biological activity was high, they found that "the organic fraction dominates and contributes 63% to the sub-micrometer aerosol mass (about 45% is water-insoluble and about 18% water-soluble)." And based on these findings, they performed model simulations that indicated that (1) the marine-derived organic matter "can enhance the cloud droplet concentration by 15% to more than 100% and is therefore an important component of the aerosol-cloud-climate feedback system involving marine biota."

As for the significance of their findings, O'Dowd *et al*. stated that their data "completely change the picture of what influences marine cloud condensation nuclei given that water-soluble organic carbon, water-insoluble organic carbon and surface-active properties, all of which influence the cloud condensation nuclei activation potential, are typically not parameterized in current climate models," or as they stated in another place in their paper, "an important source of organic matter from the ocean is omitted from current climate-modeling predictions and should be taken into account."

Another perspective on the cloud-climate conundrum was provided by Randall *et al*. (2003), who stated at the outset of their review of the subject that "the representation of cloud processes in global atmospheric models has been recognized for decades as the source of much of the uncertainty surrounding predictions of climate variability." They reported, however, that "despite the best efforts of [the climate modeling] community ... the problem remains largely unsolved." In addition, they said that "at the current rate of progress, cloud parameterization deficiencies will continue to plague us for many more decades into the future."

So what's the problem? "Clouds are complicated," Randall et al. declared, as they began to describe what they called the "appalling complexity" of the cloud parameterization situation. For starters, they stated that (1) "our understanding of the interactions of the hot towers [of cumulus convection] with the global circulation is still in a fairly primitive state." And not knowing all that much about what goes up, it's not surprising that we didn't know all that much about what comes down, as they reported that (2) "downdrafts are either not parameterized or only crudely parameterized in large-scale models."

With respect to stratiform clouds, the situation was no better, as their parameterizations were described by Randall *et al*. as "very rough caricatures of reality." As for *interactions* between convective and stratiform clouds, *forget about it!* ... which is pretty much what many scientists themselves did during the 1970s and 80s, when Randall *et al*. were reporting that "cumulus parameterizations were extensively tested against observations without even accounting for the effects of the attendant stratiform clouds." Even at the time of their study, in fact, they had to report that the concept of detrainment was "somewhat murky," and that (1) the conditions that trigger detrainment were "imperfectly understood." Hence, it should again come as no surprise that "at this time," as they put it, (2) "no existing GCM includes a satisfactory parameterization of the effects of mesoscale cloud circulations."

On top of *these* problems, Randall *et al*. additionally indicated that (3) "the large-scale effects of microphysics, turbulence, and radiation should be parameterized as closely coupled processes acting in concert." But they had to report that (4) only a few GCMs had even *attempted* to do so. And why? Because, as they continued, "the cloud parameterization problem is overwhelmingly complicated," and "cloud parameterization developers," as they called them, were *still* "struggling to identify the most important processes on the basis of woefully incomplete observations." To drive this point home, they also said "there is little question why the cloud parameterization problem is taking a long time to solve: it is very, very hard." In fact, the four scientists concluded that (5) "a sober assessment suggests that with current approaches the cloud parameterization problem will not be 'solved' in any of our lifetimes." That's right – in any of our *lifetimes!*

With such a bleak assessment of where the climate-modeling community stood at that time with respect to just the *single issue* of *cloud parameterization*, it might be well to pause and ask ourselves how anyone could possibly feel confident about what even the best climate models of *today* are predicting about CO_2-induced global warming, where proper cloud responses are critical to reaching a correct conclusion. The answer is so obvious it need not even be stated.

But wait! There appeared to be a *glimmer of light* at the end of the climate-modeling tunnel. It was a long way off ... and it looked to be incredibly expensive ... but it was there. And it beckoned, ever so enticingly.

This shining hope of the climate-modeling community of *today*, as forseen by Randall *et al*., resides in something called "cloud system-resolving models" or CSRMs, which can be compared with single-column models or SCMs that can be "surgically extracted from their host GCMs." These advanced models, as they described them, "have resolutions fine enough to represent individual cloud elements, and space-time domains large enough to encompass many clouds over many cloud lifetimes." Of course, these improvements would mean that "the computational cost of running a CSRM is hundreds or thousands of times greater than that of running an SCM." But in a few more *decades*, according to Randall *et al*., it should become possible to use such global CSRMs "to perform century-scale climate simulations, relevant to such problems as anthropogenic climate change."

Though normally less than a *lifetime*, a few more decades is a little long to have to wait to address an issue that climate alarmists have long been prodding the world to confront. Hence, Randall *et al*. suggested that an approach that could be used very soon (to possibly determine whether or not there even *is* a problem) would be to "run a CSRM as a 'super-parameterization' inside a GCM," which configuration they called a "super-GCM."

So it all comes down to this: either we know enough about how the world's climate system works, so that we don't need the postulated super-GCMs, or we *don't* know enough about how it works and we *do* need them. Unfortunately, the cloud parameterization problem *by itself* is so complex that no one can *validly* claim, at this point in time, that humanity's continued utilization of fossil-fuel energy will result in massive counter-productive climatic changes. There is absolutely no justification for that conclusion in the output of *reliable* super-GCMs, simply because there *are* no such models. And that the basis for this conclusion is robust, and cannot be said to rely upon the less-than-enthusiastic remarks of a handful of exasperated *climate model belivers*, we report the results of two additional studies of the subject that were published subsequent to the analysis of Randall *et al*.

In the first of these studies, which was conducted by *seventeen other climate modelers*, Siebesma *et al*. (2004) reported that "simulations with nine large-scale models [were] carried out for June/July/August 1998 and the quality of the results [was] assessed along a cross-section in the subtropical and tropical North Pacific ranging from (235°E, 35°N) to (187.5°E, 1°S)," in order to "document the performance quality of state-of-the-art GCMs in modeling the first-order characteristics of subtropical and tropical cloud systems." And the *main conclusions* of this study, according to Siebesma *et al*., were that (1,2) "almost all models strongly under-predicted both cloud cover and cloud amount in the stratocumulus regions," while (3,4) "the situation is opposite in the trade-wind region and the tropics," where (5,6) "cloud cover and cloud amount are over-predicted by most models." In fact, they reported that (7) "these deficiencies result in an over-prediction of the downwelling surface short-wave radiation of typically 60 W m^{-2} in the stratocumulus regimes," and (8,9) "a similar under-prediction of 60 W m^{-2} in the trade-wind regions and in the intertropical convergence zone (ITCZ)," which discrepancies are to be compared with a radiative forcing of only a couple of W m^{-2} for a 300-ppm increase in the atmosphere's CO_2 concentration. In addition, they stated that (10, 11) "similar biases for the short-wave radiation were found at the top of the atmosphere, while discrepancies in the outgoing long-wave radiation are most pronounced in the ITCZ."

The seventeen scientists, who hailed from nine different countries, also stated that (12) "the representation of clouds in general-circulation models remains one of the most important as yet unresolved issues in atmospheric modeling," which was partially due, they said, "to the overwhelming variety of clouds observed in the atmosphere, but even more so due to the large number of physical processes governing cloud formation and evolution as well as the great complexity of their interactions." Hence, they concluded that through repeated critical evaluations of the type they conducted, "the scientific community will be forced to develop further physically sound parameterizations that ultimately result in models that are capable of simulating our climate system with increasing realism," which suggests that it would not be wise to put much credence in what admittedly inadequate current state-of-the-art GCMs suggest about the future, nor to actually *mandate* drastic reductions in fossil-fuel energy use on the basis of what the predictions of these models currently suggest.

Moving forward in time a bit more, Zhang *et al*. (2005) compared basic cloud climatologies derived from ten atmospheric GCMs with satellite measurements obtained from the International Satellite Cloud Climatology Project (ISCCP) and the Clouds and Earth's Radiant Energy System (CERES) program, where ISCCP data were available from 1983 to 2001, while data from the CERES program were available for the winter months of 2001 and 2002 and for the summer months of 2000 and 2001, the purpose of their analysis being two-fold: (1) to assess the current status of climate models in simulating clouds so that future progress can be measured more objectively, and (2) to reveal serious deficiencies in the models so as to improve them.

The work of the 20 *additional* climate modelers involved in this exercise revealed a huge list of major model imperfections. First of all, Zhang *et al*. reported there was (1) a four-fold difference in high clouds among the models, and that (2) the majority of the models only simulated 30-40% of the observed middle clouds, with (3) some models simulating less than a quarter of observed middle clouds. For low clouds, they additionally reported that (4) half the models underestimated them, such that (5) the grand mean of low clouds from all models was only 70-80% of what was observed. Furthermore, when stratified in optical thickness ranges, (6) the majority of the models simulated optically thick clouds more than *twice* as frequently as was found to be the case in the satellite observations, while (7,8) the grand mean of all models simulated about 80% of optically intermediate clouds and 60% of optically thin clouds. And (9) in the case of *individual* cloud types, the group of researchers reported that "differences of seasonal amplitudes among the models and satellite measurements can reach several hundred percent."

Two years later, in their introduction to a group of eight research papers published in the *International Journal of Remote Sensing*, Muller and Fischer (2007) reported some of the highlights of the 1997-2000 EU-CLOUDMAP project. Originally designed to improve the measurement and characterization of cirrus and contrail cloud properties, the two researchers described how the project was ultimately broadened "to include properties of clouds at all altitudes, as Cess *et al*. (1993) had shown that depending on how cloud processes are parameterized can lead to an order of magnitude difference in predictions of surface temperature due to changes in CO_2 radiative forcing," which they noted was "by far the largest uncertainty in making accurate forecasts of global warming."

Conducted as a collaborative effort of five university and government research groups in the UK, Germany, Switzerland and the Netherlands, Muller and Fischer noted that "the primary technological motivation of the project was to develop new techniques for deriving cloud-top properties (cloud-top height, amount, microphysics and winds) from a new series of meteorological sensors," and to apply these properties "to the generation of new cloud climatology products," while they wrote that "a secondary goal was to develop an automated technique, based on fuzzy logic, to detect contrails in non-thermal imagery where contrails can only be detected through their unique spatial characteristics." So how did the project fare in terms of contributing to its ultimate goals?

Muller and Fischer *generously* concluded that "the principal scientific goals to improve the measurement and characterization of cirrus and contrail cloud properties as a first priority as well as clouds in general were attained." *However*, they went on to say that (1) "in the future, more extensive investigations on clouds are necessary with respect to global observations to reach the essential knowledge on clouds required for significant improvements in ... climate modeling.”

In a contemporary study that sought out some of that “essential knowledge,” Zhou *et al.* (2007) compared the cloud and precipitation properties observed from the Clouds and the Earth's Radiant Energy System (CERES) and Tropical Rainfall Measuring Mission (TRMM) instruments against simulations obtained from the three-dimensional Goddard Cumulus Ensemble (GCE) model during the South China Sea Monsoon Experiment (SCSMEX) field campaign of 18 May-18 June 1998. And this work revealed, as they described it, that (1) "the GCE rainfall spectrum includes a greater proportion of heavy rains than PR (Precipitation Radar) or TMI (TRMM Microwave Imager) observations," that (2) "the GCE model produces excessive condensed water loading in the column, especially the amount of graupel as indicated by both TMI and PR observations," that (3) "the model also cannot simulate the bright band and the sharp decrease of radar reflectivity above the freezing level in stratiform rain as seen from PR," that (4) "the model has much higher domain-averaged OLR (outgoing longwave radiation) due to smaller total cloud fraction," that (5) "the model has a more skewed distribution of OLR and effective cloud top than CERES observations, indicating that the model's cloud field is insufficient in area extent," that (6) "the GCE is ... not very efficient in stratiform rain conditions because of the large amounts of slowly falling snow and graupel that are simulated," and finally, in summation, that (7) "large differences between models and observations exist in the rain spectrum and the vertical hydrometeor profiles that contribute to the associated cloud field." And in light of these several significant findings, it was made quite clear that *cloud resolving models* still had a long way to go before they would be ready for "prime time" in mankind’s complex quest to properly assess the roles of *various types of clouds* and *forms of precipitation* in the future evolution of earth's climate in response to variations in numerous anthropogenic and background forcings.

Jumping ahead five years -- and while noting that climate modelers had long struggled to adequately represent the sensitivity of convective cloud systems to tropospheric humidity in their mathematical representations of earth's climate system -- Del Genio (2012) reviewed the rate of progress in this important area. And in doing so, he found that a number of important problems related to this particular field of study had yet to be adequately resolved. He noted, for example, that (1) many parameterizations of convective cloud variability "are not sufficiently sensitive to variations in tropospheric humidity," which "lack of sensitivity," as he described it, "can be traced in part to [2] underestimated entrainment of environmental air into rising convective clouds and [3] insufficient evaporation of rain into the environment." And as a result of these deficiencies, he further noted that (4,5) "the parameterizations produce deep convection too easily while stabilizing the environment too quickly to allow the effects of convective mesoscale organization to occur."

To be fair, Del Genio did note that "recent versions of *some* models have increased their sensitivity to tropospheric humidity and improved *some* aspects of their variability," but he said that (6) "a parameterization of mesoscale organization is still absent from *most* models," while stating that (7) "adequately portraying convection in all its realizations remains a difficult problem."

On another note, Del Genio wrote that "to date, metrics for model evaluation have focused almost exclusively on time mean two-dimensional spatial distributions of easily observed parameters," and he indicated that "it has become clear that such metrics have no predictive value for climate feedbacks and climate sensitivity (e.g., Collins *et al*., 2011)," while adding that those metrics "are also probably not helpful for assessing most other important features of future climate projections, because temporal variability gives greater insight into the physical processes at work." And so it was that Del Genio concluded by opining that (8) "given the insensitivity of these models to tropospheric humidity and [9,10] their failure to simulate the Madden-Julian Oscillation and diurnal cycle, ... it seems unlikely that it will ever be possible to establish a general set of metrics that can be used to anoint one subset of models as our most reliable indicators of all aspects of climate change."

Also publishing a pertinent paper in the same year were Li *et al*. (2012), who introduced the report of their study by noting that representing clouds and cloud climate feedback in global climate models (GCMs) remained “a pressing challenge” that needed to be overcome in order to “reduce and quantify uncertainties associated with climate change projections." And two of the primary parameters that needed to be accurately modeled, in this regard, were *cloud ice water content* (CIWC) and *cloud ice water path* (CIWP).

Consequently, Li *et al*. went on to perform "an observationally based evaluation of the cloud ice water content and path of present-day GCMs, notably 20th century CMIP5 simulations," after which they compared the results to a pair of climatic reanalyses. This they did using "three different CloudSat + CALIPSO ice water products and two methods to remove the contribution from the convective core ice mass and/or precipitating cloud hydrometeors with variable sizes and falling speeds so that a robust observational estimate can be obtained for model evaluations."

Unfortunately, the eleven U.S. scientists found that (1,2) "for annual mean CIWP, there are factors of 2-10 in the differences between observations and models for a majority of the GCMs and for a number of regions," additionally noting that (3) "systematic biases in CIWC vertical structure occur below the mid-troposphere where the models overestimate CIWC." And in light of these and other shortcomings they identified, they ultimately concluded that (4) "neither the CMIP5 ensemble mean nor any individual model performs particularly well," adding that (5) "there are still a number of models that exhibit very large biases" and noting that they do so "despite the availability of relevant observations." What is more, even in situations where they felt the models might be providing roughly the correct radiative energy budget," they found that (6) "many are accomplishing it by means of unrealistic cloud characteristics of cloud ice mass at a minimum, which in turn likely indicates [7,8] unrealistic cloud particle sizes and cloud cover."

In a concomitant study, Cesana and Chepfer (2012) made a point of noting that "clouds are the primary modulators of the Earth's radiation budget" and that they therefore constitute "the main source of uncertainty in model estimates of climate sensitivity," citing Randall *et al*. (2007). And as a result of this *fact*, they further stated that (1) the modeling of cloud properties represents "a major limitation to the reliability of climate change projections," additionally citing Dufresne and Bony (2008) in this regard.

Faced with this problem, Cesana and Chepfer indicated that in order "to improve the reliability of climate change projections, it is therefore imperative to improve the representation of cloud processes in models." So how much improving did the models need?

In broaching this important question, the two French researchers compared the then-most-recent cloud representations of five of the climate models involved in the *Coupled Model Intercomparison Project Phase 5* (CMIP5) effort -- which had just recently been described by Taylor *et al*. (2012) -- with real-world satellite-derived observations obtained from the *GCM-Oriented CALIPSO Cloud Product* (GOCCP), which had earlier been described by Chepfer *et al*. (2010). And what did they learn from this exercise?

In the words of Cesana and Chepfer, they learned that (1) "low- and mid-level altitude clouds are underestimated by all the models (except in the Arctic)," that (2) "high altitude cloud cover is overestimated by some models," that (3) "some models shift the altitude of the clouds along the ITCZ by 2 km (higher or lower) compared to observations," that (4) "the models hardly reproduce the cloud free subsidence branch of the Hadley cells," that (5) "the high-level cloud cover is often too large," that (6) "in the tropics, the low-level cloud cover (29% in CALIPSO-GOCCP) is underestimated by all models in subsidence regions (16% to 25%)" and, last of all, that (7) "the pronounced seasonal cycle observed in low-level Arctic clouds is hardly simulated by some models."

Working contemporaneously, Cesana *et al*. (2012) reported that "low-level clouds frequently occur in the Arctic and exert a large influence on Arctic surface radiative fluxes and Arctic climate feedbacks," noting that during winter, in particular, surface net longwave radiation (FLW,NET) has a bi-modal distribution, with extremes that have been termed "radiatively clear" and "radiatively opaque." And in further discussing these clouds, they said that Arctic ***ice*** clouds "tend to have small optical depths and a weak influence on FLW,NET," which explains the "radiatively clear" condition, while adding that Arctic *liquid-containing* clouds "generally have large optical depths and a dominant influence on FLW,NET (Shupe and Intrieri, 2004)," which helps explain the "radiatively opaque" condition, as discussed by Doyle *et al*. (2011).

Getting back to their own study, Cesana *et al*. employed real-world *Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation* (CALIPSO) data to document cloud phases over the Arctic basin (60-82°N) during the five-year period 2006-2011, after which they used the results they obtained "to evaluate the influence of Arctic cloud phase on Arctic cloud radiative flux biases in climate models." This work revealed, as they reported, that their evaluation of climate models participating in the most recent Coupled Model Inter-comparison Project (Taylor *et al*., 2012) indicated that (1) "most climate models are not accurately representing the bimodality of FLW,NET in non-summer seasons." In fact, they found that even when advanced microphysical schemes that predict cloud phase had been used -- such as those employed in the *fifth* version of the *Community Atmosphere Model* (CAM5, Neale *et al*., 2010) -- (2) "insufficient liquid water was predicted." And so it was that Cesana *et al*. concluded from what they had learned that (3) "the simple prescribed relationships between cloud phase and temperature that have historically been used in climate models are incapable of reproducing the Arctic cloud phase observations described here," which finding must inevitably lead to (4,5) similarly inaccurate values of "Arctic surface radiative fluxes and Arctic climate feedbacks," when employed in current state-of-the-art climate models.

In yet another contemporaneous study, Nam *et al*. (2012) wrote that the response of low-level clouds had long been identified as "a key source of uncertainty for model cloud feedbacks under climate change," citing the work of Bony and Dufresne (2005), Webb *et al*. (2006), Wyant *et al*. (2006) and Medeiros *et al*. (2008). And they further stated that "the ability of climate models to simulate low-clouds and their radiative properties" plays a huge role in assessing "our confidence in climate projections."

In studying this important unresolved dilemma, Nam *et al*. analyzed "outputs from multiple climate models participating in the Fifth phase of the Coupled Model Intercomparison Project (CMIP5) using the Cloud Feedback Model Intercomparison Project Observations Simulator Package (COSP), and compared them with different satellite data sets," including "CALIPSO lidar observations, PARASOL mono-directional reflectances, and CERES radiative fluxes at the top of the atmosphere." And what did *they* thereby learn?

In the words of the four French researchers, "the current generation of climate models still experiences difficulties in predicting the low-cloud cover and its radiative effects." In particular, they reported that the models: (1) "under-estimate low-cloud cover in the tropics," (2) "over-estimate optical thickness of low-clouds, particularly in shallow cumulus regimes," (3) "poorly represent the dependence of the low-cloud vertical structure on large-scale environmental conditions," and (4) "predict stratocumulus-type of clouds in regimes where shallow cumulus cloud-types should prevail." However, they said that "the impact of these biases on the Earth's radiation budget ... is reduced by compensating errors," including (5-7) "the tendency of models to under-estimate the low-cloud cover and to over-estimate the occurrence of mid- and high-clouds above low-clouds."

In a relevant study published a year later, Lauer and Hamilton (2013) reported that numerous previous studies from the Coupled Model Intercomparison Project phase 3 (CMIP3) showed (1) *quite large biases* in the simulated cloud climatology affecting *all* GCMs (Global Climate Models), as well as (2) "a remarkable degree of variation among the models that represented the state of the art circa 2005." So what was the case in 2013?

The two researchers provided an update by describing the progress that had been made in the intervening years by comparing mean cloud properties, their interannual variability and the climatological seasonal cycle -- as derived from CMIP5 models -- with results from comparable CMIP3 experiments, as well as with actual *satellite observations*. And these analyses revealed, in Lauer and Hamilton's words, that (1) "the simulated cloud climate feedbacks activated in global warming projections differ enormously among state-of-the-art models," informing us that (2) "this large degree of disagreement has been a constant feature documented for successive generations of GCMs from the time of the first Intergovernmental Panel on Climate Change assessment through the CMIP3 generation models used in the fourth IPCC assessment." And they added that (3) "even the model-simulated cloud climatologies for present-day [2013] conditions are known to depart significantly from observations and, once again, [4] the variation among models is quite remarkable," citing the studies of Weare (2004), Zhang *et al*. (2005), Waliser *et al*. (2007, 2009), Lauer *et al*. (2010) and Chen *et al*. (2011).

As for some other specifics, the two researchers determined that (5) "long-term mean vertically integrated cloud fields have quite significant deficiencies in all the CMIP5 model simulations," that (6) "both the CMIP5 and CMIP3 models display a clear bias in simulating too high LWP [liquid water path] in mid-latitudes," that (7) "this bias is not reduced in the CMIP5 models," that (8,9) there have been "little to no changes in the skill of reproducing the observed LWP and CA [cloud amount]," that (10) "inter-model differences are still large in the CMIP5 simulations," and that (11) "there is very little to no improvement apparent in the tropical and subtropical regions in CMIP5."

In closing, therefore, Lauer and Hamilton indicated there was "only very modest improvement in the simulated cloud climatology in CMIP5 compared with CMIP3," and they sadly stated that even this *slightest of improvements* was "mainly a result of careful model tuning rather than an accurate fundamental representation of cloud processes in the models."

Writing concurrently in the *Journal of Geophysical Research (Atmospheres)*, Wang and Su (2013) noted that "coupled general circulation models (GCMs) are the major tool to predict future climate change, yet cloud-climate feedback constitutes the largest source of uncertainty in these modeled future climate projections." Consequently, they correctly stated that "confidence in the future climate change projections by the coupled GCMs to a large extent depends on how well these models simulate the observed present-day distribution of clouds and their associated radiative fluxes." And in describing how they made this determination, they wrote that in their particular study, "the annual mean climatology of top of the atmosphere (TOA) shortwave and longwave cloud radiative effects in 12 Atmospheric Model Intercomparison Project (AMIP)-type simulations participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) [were] evaluated and investigated using satellite-based observations, with a focus on the tropics."

At the conclusion of this undertaking, the two researchers reported that (1) the CMIP5 AMIPs "produce considerably less cloud amount [than what is observed], particularly in the middle and lower troposphere," that there are "good model simulations in tropical means," but they are (2) "a result of compensating errors over different dynamical regimes," that "over the Maritime Continent, [3] most of the models simulate moderately less high-cloud fraction, leading to [4-6] weaker shortwave cooling and longwave warming and a larger net cooling," that "over subtropical strong subsidence regimes, most of the CMIP5 models [7] strongly underestimate stratocumulus cloud amount and [8] show considerably weaker local shortwave cloud radiative forcings," that "over the transitional trade cumulus regimes, a notable feature is that while at varying amplitudes, [9,10] most of the CMIP5 models consistently simulate a deeper and drier boundary layer, [11] more moist free troposphere, and [12] more high clouds and consequently [13-14] overestimate shortwave cooling and longwave warming effects there," such that, *in the final analysis*, (15) "representing clouds and their TOA radiative effects remains a challenge in the CMIP5 models."

Also publishing in the same timeframe were Evan *et al*. (2013), who wrote as background for their study that "stratocumulus (Sc) cloud cover is a persistent feature of the subtropical North and South Atlantic," further noting that "it is well known that Sc cloud cover increases with decreasing temperatures of the underlying sea surface and that an increase in cloud cover will cool the surface temperatures via increasing the local albedo, otherwise known as the Sc feedback." And, therefore, they used real-world observations to "quantify the magnitude and spatial structure of the Sc feedback in the tropical-extratropical Atlantic Ocean," as well as to "investigate the role of the Sc feedback in shaping the evolution of coupled modes of variability there," especially when utilizing CMIP3 models.

This work revealed, as the four researchers reported, that (1,2) "most models have negative biases in the mean state of Sc cloud cover and do not reproduce the observed spatial structure of Atlantic Sc clouds." In addition, they found that "while the majority of models exhibit some agreement with observations in the meridional structure of the Sc feedback, [3] the vast majority of models underestimate the dependence of Sc cloud cover on the underlying sea surface temperature." So once again, there is another situation where important aspects of both cloud *type* and cloud *cover* are simply not portrayed to an acceptable degree of real-world faithfulness in the *vast majority* of CMIP3 models.

In another same-year publication, Suzuki *et al*. (2013) wrote that "climate models contain various uncertain parameters in the formulations of parameterizations for physical processes," but they additionally noted that "these parameters represent 'tunable knobs' that are typically adjusted to let the models reproduce realistic values of key-observed climate variables." And, therefore, they felt it important to examine "the validity of a tunable cloud parameter," namely, "the threshold particle radius triggering the warm rain formation in a climate model."

The model they chose for this particular purpose was the Geophysical Fluid Dynamics Laboratory (GFDL) Coupled Climate Model version 3 (CM3), because it was known that alternate values of that model's tunable cloud parameter that fall within its real-world range of uncertainty "have been shown to produce severely different historical temperature trends due to differing magnitudes of aerosol indirect forcing."

The results of the three researchers' analysis indicated that (1) "the simulated temperature trend best matches [the] observed trend when the model adopts the threshold radius that worst reproduces satellite-observed microphysical statistics and vice versa." And in light of this finding, the three researchers wrote that (2) "this inconsistency between the 'bottom-up' process-based constraint and the 'top-down' temperature trend constraint implies the presence of compensating errors in the model." And they thus concluded that "if this behavior is not a peculiarity of the GFDL CM3, the contradiction may be occurring in other climate models as well," which is not what one would want to see happen.

About this same time, Karlsson and Svensson (2013) introduced their most recent study of the subject by writing that "clouds significantly influence the Arctic surface energy budget and a realistic representation of this impact is a key for proper simulation of the present-day and future climate," while further indicating that "considerable across-model spread in cloud variables remains in the fifth phase of the Coupled Model Intercomparison Project ensemble and partly explains the substantial across-model spread in the surface radiative effect of the clouds," which further impacts sea-ice extent and albedo. And, therefore, they focused their attention primarily "on how model differences in the parameterization of sea-ice albedo in the fifth phase of the Coupled Model Intercomparison Project (CMIP5) influence the cloud radiative effect on the surface energy budget and the annual cycle of sea-ice concentration."

This work revealed, in the words of the two researchers, that (1,2) "the across-model spread in Arctic cloud cover and cloud condensates is substantial, and no improvement is seen from previous model intercomparisons," citing their own earlier study (Karlsson and Svenson, 2011) in this regard and noting that "this diversity of simulated Arctic clouds in the CMIP5 ensemble contributes to a spread in the models' cloud influence on the surface energy budget." And so it was that in the concluding sentence of their most recent paper, the two Stockholm (Sweden) University scientists reiterated the fact that (3) present-day sea-ice albedo is so badly constrained in GCMs that it “impacts the fidelity of future scenario assessments of the Arctic region and should therefore be a concern for the modeling community."

Still stuck in the same -- but scientifically productive – year, Huang (2013) addressed a pair of issues that concerned the longwave climate feedbacks in transient climate change assessments. The first of these issues was the fact that (1) "the radiative forcing of greenhouse gases, as measured by their impact on the outgoing longwave radiation (OLR), may vary across different climate models even when the concentrations of these gases are identically prescribed," which forcing variation, as Huang continued, (2) "contributes to the discrepancy in these models' projections of surface warming." The second issue was that "the stratosphere is an important factor that affects the OLR in transient climate change," in that stratospheric water vapor and temperature changes may both act as positive feedbacks during global warming and, therefore, "cannot be fully accounted as a 'stratospheric adjustment' of radiative forcing."

And as the Canadian researcher went on to demonstrate in the body of his paper, (3) "neglecting these two issues may cause a bias in the longwave cloud feedback diagnosed as a residual term in the decomposition of OLR variations." And he further noted, in this regard, that his results "and the recent results of others [e.g., the estimate of Zelinka *et al*. (2012) based on cloud property histograms] indicate that (4) there is, in fact, no consensus in terms of the sign of the longwave cloud feedback among the GCMs."

Finally moving on another year, Rosenfeld *et al*. (2014) wrote that "aerosols counteract part of the warming effects of greenhouse gases, mostly by increasing the amount of sunlight reflected back to space." However, they also noted that (1) "the ways in which aerosols affect climate through their interaction with clouds are complex and incompletely captured by climate models." And as a result, the four researchers further acknowledged that (2) "the radiative forcing (that is, the perturbation to Earth's energy budget) caused by human activities is highly uncertain, making it difficult to predict the extent of global warming," while also citing, in this regard, the studies of Anderson *et al*. (2003) and Stocker *et al*. (2013).

Delving still deeper into the subject, Rosenfeld *et al*. further reported that (3) "recent advances have revealed a much more complicated picture of aerosol-cloud interactions than considered previously," while also stating that (4) "further progress is hampered by limited observational capabilities and coarse-resolution models." In addition, they acknowledged that (5) "little is known about the unperturbed aerosol level that existed in the preindustrial era," noting that "this reference level is very important for estimating the radiative forcing from aerosols," citing Carslaw *et al*. (2013).

Also holding up progress was the *fact*, as Rosenfeld *et al*. put it, that (6,7) our "understanding of the formation of ice and its interactions with liquid droplets is even more limited, mainly due to poor ability to measure the ice-nucleating activity of aerosols and the subsequent ice-forming processes in clouds." And in this regard they said that "improved observational tests are essential for validating the results of simulations and ensuring that modeling developments are on the right track." But they also indicated that (8) what they called a "major challenge" in this area was the fact that "the most important aerosol nucleation region is at the bottom of a cloud, which is obscured by the rest of the cloud if measured from above."

Consequently, it was no surprise that Rosenfeld *et al*. concluded that (9) "fully resolved, global, multi-year simulations are not likely to become feasible for many decades." Yes, that's right -- *many decades*. And this analysis of the situation can only make one *wonder* if the world's climate alarmists are not putting the cart ***way*** before the horse, when it comes to pushing for such drastic actions as they continually promote to prevent what may eventually be found to actually be no problem at all.

In another contemporary and intriguing paper, Lin *et al*. (2014) wrote that stratocumulus clouds in the tropics and subtropics have come to be known as "climate refrigerators," in light of the likelihood that "a 5% increase of their coverage would be sufficient to offset the global warming induced by doubling CO_2," due to the clouds' reflecting of an enhanced amount of incoming sunlight back to space, as suggested by the studies of Randall *et al*. (1984), Slingo (1990), Bretherton *et al*. (2004) and Wood (2012). And in light of these several earlier findings, Lin *et al*. went on to examine stratocumulus clouds and associated cloud feedback in the southeast Pacific (SEP), as simulated by eight global climate models that participated in phase 5 of the Coupled Model Intercomparison Project (CMIP5), as well as the Cloud Feedback Model Intercomparison Project (CFMIP), based on "long-term observations of clouds, radiative fluxes, cloud radiative forcing (CRF), sea surface temperature (SST), and [the] large-scale atmospheric environment."

This work revealed, in the words of the three researchers, that "state-of-the-art global climate models still have significant difficulty in simulating the SEP stratocumulus clouds and associated cloud feedback." More specifically, and *compared with observations*, they reported that (1) "the models tend to simulate significantly less cloud cover," (2) "higher cloud tops," (3) "a variety of unrealistic cloud albedos," (4) "overly weak shortwave cloud radiative forcing," (5) "biases in large-scale temperature structure," including (6) "lack of temperature inversion," (7) "insufficient lower troposphere stability [LTS]," and (8) "insufficient reduction of LTS with local SST warming," along with (9) "improper model physics" as it pertains to (10) "insufficient increase of low cloud cover associated with larger LTS." And these findings represent but *one group* of a *host* of global climate model *failures* to adequately "predict the past," which fact raises serious questions about mankind's ability to *ever* correctly predict earth's future climate.

Also contributing to the evaluation of modern-day climate models was Pithan *et al*. (2014), who introduced their study of the subject by noting that "temperature inversions are a common feature of the Arctic wintertime boundary layer," and by going on to say that "they have important impacts on both radiative and turbulent heat fluxes and partly determine local climate-change feedbacks," which led them to *further* state that "understanding the spread in inversion strength modelled by current global climate models is thus an important step in better understanding Arctic climate and its present and future changes." And in a quest to help obtain that "better understanding," Pithan *et al*. went on to show "how the formation of Arctic air masses leads to the emergence of a cloudy and a clear state of the Arctic winter boundary layer," after which they also described the different climatic implications of each of these states.

In the Arctic's *cloudy* state, the three researchers found "little to no surface radiative cooling occurs and inversions are elevated and relatively weak," whereas in the Arctic's *clear* state they found that "surface radiative cooling leads to strong surface-based temperature inversions." And when comparing specific aspects of model output to real-world observations, they determined that (1) the "freezing of super-cooled water at too warm temperatures that occurs in many CMIP5 models leads to a lack of high-emissivity mixed-phase clouds and thus of a cloudy state in these models," and that (2) "models lacking a cloudy state display excessive surface radiative cooling in Arctic winter, which tends to produce strong low-level stability and temperature inversions."

In addition, Pithan *et al*. reported that (3) "few models that allow for cloud liquid water at very low temperatures reproduce both the clear and cloudy state of the boundary layer," that (4) "a second group of models lacks the cloudy state and exhibits strong stability and strong long-wave cooling, that (5) "other models also lack the cloudy state, but generate weak stability despite strong long-wave cooling," that (6) the CMIP5 inter-model spread of typical monthly-mean low-level stability over sea ice in winter is about 10 K, which is similar to that in CMIP3 models," that (7) "15 out of 21 CMIP5 models overestimate low-level stability over sea ice compared to reanalysis data," that (8) "this wide-spread model bias is linked to shortcomings in the representation of mixed-phase cloud microphysics," and that (9) "differences in cloud properties, energy fluxes and inversion strengths between land and sea ice domains remain to be investigated."

In light of these several findings, Pithan *et al*. stated, in the concluding sentence of their paper, that "in order to better represent the Arctic winter boundary layer and surface energy budget in climate models, an important step would be to improve the mixed-phase cloud microphysics and to obtain an adequate representation of the cloudy state." And so we have yet another glaring example of the *fact* that today's CMIP5 models are simply not up to the task of adequately portraying Earth's *current* climate, which must surely be done before we can rely on them to provide valid portrayals of Earth's *future* climatic state.

Another recent stab at dealing with current climate model complexities was taken by Park *et al.* (2014), who wrote that "clouds cool the Earth-atmosphere system by reflecting incoming shortwave (SW) radiation and warm it by absorbing outgoing longwave (LW) radiation from the surface," while further noting that "satellite observations reveal that the net radiative effect of clouds on the Earth-atmosphere system is a cooling of 20-24 Wm^{-2} in the global average," which they note is "about six times larger than the radiative forcing associated with doubled CO_2," citing Ramanathan *et al*. (1989) and Loeb *et al*. (2009). And, hence, it can be appreciated that properly modeling cloud processes is an important aspect of ongoing efforts to predict the future course of Earth's climate.

As for *their* contribution to this important task, the three US researchers devised several unique adjustments to previous versions of the Community Atmosphere Models (CAMs) versions 3 and 4, which are now found in the new-and-improved CAM5 set of models. And "compared with the previous versions," as they wrote, "the cloud parameterizations in CAM5 are more consistent and physically based, due to inclusion of more realistic and complex parameterizations and much attention given to the interactions among them within a more consistent framework."

However, they went on to acknowledge that even with these improvements, "several systematic biases were also identified in the simulated cloud fields in CAM5," which they grouped into three different categories: (1) deficient regional tuning, (2) inconsistency between various physics parameterizations, and (3) incomplete modeled physics. And in the case of the latter category, they listed the following problems: (4) "underestimation of LW CRF [cloud radiative forcing] due to the horizontal heterogeneity assumption of water vapor within each grid layer in the radiation scheme," (5) "overly strong SW CRF and LW CRF in the tropics due to the use of a single-type cloud within the radiation scheme," and (6) "under-frequent shallow convective activity over summer continents due to the neglect of forced convection." And in light of these several remaining problems, they ultimately concluded that "while substantially improved from its predecessors [CAM3**/**CAM4], many aspects of CAM5 can and should be improved in the future," which they described as something "upon which we are continuously working with collaborators." But until such improvements are made, model treatments of clouds should be treated with a healthy dose of skepticism.

Filling out this year of research, Lacagnina and Selten (2014) wrote that "despite the importance of clouds, their representation in general circulation models (GCMs) continues to account for much of the uncertainties in climate projections," citing Cess *et al*. (1996), Stocker *et al*. (2001) and Solomon *et al*. (2007), while noting that "the spread associated with inter-model differences is roughly three times larger than that associated with other main feedbacks," citing Dufresne and Bony (2008). And six years after the last of *these* assessments, they have found little that encourages them.

Working with the EC-Earth GCM version 2.3 that they *coupled* to an ocean GCM based on version 2 of the Nucleus for European Modeling of the Ocean (NEMO) model, the Dutch duo from the Royal Netherlands Meteorological Institute compared the married models' outputs to a wealth of real-world observational data obtained from numerous satellite and land-based sensors that they described in detail and to which they provided profuse references.

These efforts revealed, as they described them, that (1) "EC-Earth exhibits the largest cloud biases in the tropics," where it (2) "underestimates the total cloud cover," but that it (3) "overestimates the optically thick clouds," with the net effect that (4) "clouds exert an overly strong cooling effect in the model," that (5) "the magnitude of the cooling due to the shortwave cloud radiative effect is underestimated for the stratiform low-clouds," because (6) "the model simulates too few of them," that (7) the "shortwave cloud radiative effect is overestimated for trade wind cumulus clouds," because (8) "in the model these are too thick," that (9) "the clouds in the deep convection regions also tend to overestimate the shortwave cloud radiative effect," because (10) "these clouds are generally too thick" and that (11) "there are too few mid and high thin clouds."

As for the ultimate take-home message of these several findings, Lacagnina and Selten (2014) concluded that "the model weaknesses discussed above indicate that more effort is needed to improve the physical parameterizations employed." And that may well be a huge *under*statement of the current status of climate modeling; for after several generations of "improvements," costing multiple hundreds of millions of dollars, these theoretical constructs prove yet again that *they are still not ready for dependable usage!*

At long last, arriving in the year in which this analysis and writing was conducted, Rapp (2015) introduced her study of the subject by writing that (1) “the sensitivity of regimes dominated by low clouds has been identified as the largest contributor to uncertainties in tropical cloud feedback estimates in climate models.” And she thus went on to describe how Atmospheric Model Intercomparison Project [AMIP] simulations of low cloud responses to sea surface temperature (SST) compare with satellite observations in the southeastern Pacific subsidence region, beginning with the (2) “too few, too bright” problem identified by Nam *et al*. (2012).

As for what she *further* learned, Rapp reports that the AMIP models have considerable difficulty in simulating (1) the annual cycle in the cloud radiative effect (CRE), (2) cloud fraction, and (3) liquid water path (LWP), likely due in part to (4,5) “underestimation of the strength of lower tropospheric stability and the depth of the boundary layer,” but also noting that (6) stratocumulus clouds “are not sensitive enough.” In addition, Rapp notes that (7,8) “not only do the seasonal amplitudes disagree but also some models have an annual cycle that is nearly 180 degrees out of phase with the observations.”

“Ultimately,” therefore, Rapp wrote that the results she reported “show that climate models still have difficulty reproducing the observed cloud and radiative sensitivities in a low cloud regime, even when forced with climatological SSTs.”

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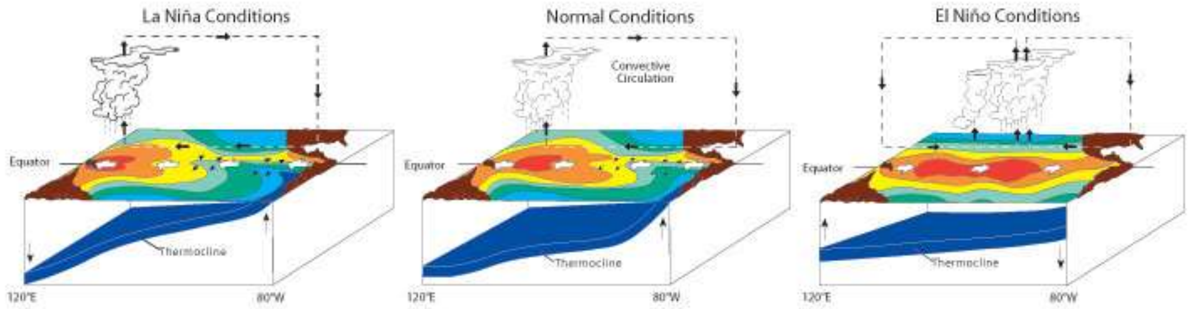
ENSO



Computer model simulations have given rise to three climate-alarmist claims regarding the influence of global warming on El Niño/Southern Oscillation or ENSO events: (1) global warming will increase the *frequency* of ENSO events, (2) global warming will increase the *intensity* of ENSO events, and (3) weather-related disasters will be exacerbated under El Niño conditions. In this chapter, however, we highlight findings that suggest that the virtual world of ENSO, as simulated by state-of-the-art climate models, is at variance with reality in these and still other ways, beginning with several studies that described the status of the problem at the turn of the last century.

In a comparison of 24 coupled ocean-atmosphere climate models, Latif *et al*. (2001) reported that (1) "almost all models (even those employing flux corrections) still have problems in simulating the SST [sea surface temperature] climatology." They also noted that (2) "only a few of the coupled models simulate the El Niño/Southern Oscillation in terms of gross equatorial SST anomalies realistically." And they stated that (3) "no model has been found that simulates realistically all aspects of the interannual SST variability." Consequently, and because "changes in sea surface temperature are both the cause and consequence of wind fluctuations," according to Fedorov and Philander (2000), and because these phenomena figure prominently in the El Niño-La Niña oscillation, it is not surprising that the latter researchers concluded that (4) climate models near the turn of the century did not do a good job of determining the potential effects of global warming on ENSO.

Plain old human ignorance likely also played a role in those models' failures to simulate ENSO. According to Overpeck and Webb (2000), for example, there was evidence that (5) "ENSO may change in ways that we do not yet understand," which "ways" had clearly not yet been modeled. White *et al*. (2001), for example, found that "global warming and cooling during earth's internal mode of interannual climate variability [the ENSO cycle] arise from fluctuations in the global hydrological balance, not the global radiation balance," and they noted that (6) these fluctuations are the result of no known forcing of either anthropogenic or extraterrestrial origin.

Another example of the inability of the most sophisticated of late 20th-century climate models to properly describe El Niño events was provided by Landsea and Knaff (2000), who employed a simple statistical tool to evaluate the skill of twelve state-of-the-art climate models in real-time predictions of the development of the 1997-98 El Niño. In doing so, they found that (1) the models exhibited essentially no skill in forecasting this very strong event at lead times ranging from 0 to 8 months. They also determined that (2) no models were able to anticipate even one-half of the actual amplitude of the El Niño's peak at a medium range lead-time of 6 to 11 months. And, therefore, they stated that (3) "since no models were able to provide useful predictions at the medium and long ranges, *there were no models that provided both useful and skillful forecasts for the entirety of the 1997-98 El Niño*."

Given the inadequacies just discussed, it is little wonder that several scientists criticized model simulations of ENSO behavior at the turn of the century, including Walsh and Pittock (1998), who said that (4) "there is insufficient confidence in the predictions of current models regarding any changes in ENSO," and Fedorov and Philander (2000), who said that (5) "at this time, it is impossible to decide which, if any, are correct."

So what's happened subsequently? Have things improved any?

Huber and Caballero (2003) introduced their contribution to the subject by stating that "studies of future transient global warming with coupled ocean-atmosphere models find a shift to a more El Niño-like state," although they also correctly reported that the "permanent El Niño state" -- which had often been hyped by climate alarmists -- "is by no means uniformly predicted by a majority of models." Hence, to help to resolve this *battle of the models*, they worked with *another* model, as well as real-world data pertaining to the Eocene, which past geologic epoch -- having been much warmer than the recent past -- provided, in their words, "a particularly exacting test of the robustness of ENSO." More specifically, they used the Community Climate System Model of the National Center for Atmospheric Research, which was said by them to yield "a faithful reproduction of modern-day ENSO variability," to "simulate the Eocene climate and determine whether the model predicts significant ENSO variability." In addition, they compared the model results against middle Eocene lake-sediment records from two different regions: the Lake Gosiute complex in Wyoming and Eckfield Maar in Germany.

In describing their findings, Huber and Caballero reported that the model simulations showed little change in ENSO, while further noting that other studies indicated “an ENSO shutdown as recently as ~6000 years ago, a period only slightly warmer than the present." Hence, they concluded that (1) "this result contrasts with theories linking past and future 'hothouse' climates with a shift toward a permanent El Niño-like state," which conclusion represented a significant setback to climate alarmists who were using this unsubstantiated theory to induce unwarranted fear of global warming among the general public.

Three years later, Joseph and Nigam (2006) evaluated the performance of several climate models by examining the extent to which they simulated key features of the leading mode of interannual climate variability: the El Niño-Southern Oscillation or ENSO -- which they described as "a dominant pattern of ocean-atmosphere variability with substantial global climate impact" -- based on "the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (AR4) simulations of twentieth-century climate." This evaluation indicated that different models were found to do well in some respects, but not so well in many others. For example, they found that climate models "are still unable to simulate [1] many features of ENSO variability and its [2] circulation and [3] hydroclimate teleconnections." In fact, they found that (4) the models had only *begun* "to make inroads in simulating key features of ENSO variability."

Quoting the two scientists who made these evaluations, this study clearly suggested that climate system models of that period were clearly (5) "not quite ready for making projections of regional-to-continental scale hydroclimate variability and change." Indeed, it should have made one wonder if they were ready to make *any* valid projections about *anything*, seeing they fared so poorly with respect to simulating the "key features of the leading mode of interannual climate variability," which is "a dominant pattern of ocean-atmosphere variability with substantial global climate impact."

Nevertheless, climate alarmists continued to claim *the science is settled!* Nothing, however, could have been further from the truth, especially since they based their claims on what were still rather crude climate models. Indeed, as Joseph and Nigam concluded, (6) "predicting regional climate variability/change remains an onerous burden on models."

One year later, for example, L'Ecuyer and Stephens (2007) asked themselves how well state-of-the-art climate models reproduced the workings of real-world energy and water cycles, noting that "our ability to model the climate system and its response to natural and anthropogenic forcings requires a faithful representation of the complex interactions that exist between radiation, clouds, and precipitation and their influence on the large-scale energy balance and heat transport in the atmosphere," while further stating "it is also critical to assess response to shorter-term natural variability in environmental forcings using observations."

In the spirit of this logical philosophy, the two researchers decided to use multi-sensor observations of visible, infrared and microwave radiance obtained from the Tropical Rainfall Measuring Mission satellite for the period running from January 1998 through December 1999, in order to evaluate the sensitivity of atmospheric heating (and the factors that modify it) to changes in east-west SST gradients associated with the strong 1998 El Niño event in the tropical Pacific, as expressed by the simulations of nine general circulation models of the atmosphere that were utilized in the IPCC's most recent Fourth Assessment Report, which protocol, in their words, "provides a natural example of a short-term climate change scenario in which clouds, precipitation, and regional energy budgets in the east and west Pacific are observed to respond to the eastward migration of warm sea surface temperatures."

So what did the two researchers learn from this exercise? L'Ecuyer and Stephens reported that (1) "a majority of the models examined did not reproduce the apparent westward transport of energy in the equatorial Pacific during the 1998 El Niño event." They also discovered that (2-4) "the inter-model variability in the responses of precipitation, total heating, and vertical motion

[was] often larger than the intrinsic ENSO signal itself, implying [5] an inherent lack of predictive capability in the ensemble with regard to the response of the mean zonal atmospheric circulation in the tropical Pacific to ENSO." In addition, they found that (6) "many models also misrepresent the radiative impacts of clouds in both regions [the east and west Pacific], implying [7-9] errors in total cloudiness, cloud thickness, and the relative frequency of occurrence of high and low clouds." And in light of these *much*-less-than-adequate findings, they were forced to conclude that (10) "deficiencies remain in the representation of relationships between radiation, clouds, and precipitation in current climate models," while further stating that these deficiencies "cannot be ignored when interpreting their predictions of future climate."

Shortly thereafter, Paeth *et al*. (2008) compared 79 coupled ocean-atmosphere climate simulations derived from twelve different state-of-the-art climate models forced by six different IPCC emission scenarios with observational data in order to evaluate how well they reproduced the spatio-temporal characteristics of ENSO over the 20th century, after which they compared the various models' 21st-century simulations of ENSO and the Indian and West African monsoons among themselves. With respect to the 20th century, this work revealed that "all considered climate models draw a reasonable picture of the key features of ENSO." With respect to the 21st century, on the other hand, they reported that (1) "the differences between the models are stronger than between the emmission scenarios," while (2,3) "the atmospheric component of ENSO and the West African monsoon are barely affected." And their "overall conclusion," therefore, was that (4) "we still cannot say much about the future behavior of tropical climate.

In a contemporary study, Jin *et al*. (2008) investigated the overall skill of ENSO prediction in retrospective forecasts made with ten different state-of-the-art ocean-atmosphere coupled general circulation models with respect to their ability to "hindcast" real-world observations for the 22 years from 1980 to 2001. And in doing so, they found that almost all of the studied models had problems simulating (1) the mean equatorial SST and (2) its annual cycle. In fact, they reported that (3) "none of the models examined attain good performance in simulating the mean annual cycle of SST, even with the advantage of starting from realistic initial conditions," while further noting that (4) "with increasing lead time, this discrepancy gets worse," and stating that "the [5] phase and [6] peak amplitude of westward propagation of the annual cycle in the eastern and central equatorial Pacific are different from those of observed."

What is more, the twelve researchers found that (7) "ENSO-neutral years are far worse predicted than growing warm and cold events," and they thus wrote that (8) "the skill of forecasts that start in February or May drops faster than that of forecasts that start in August or November," which behavior they and others called "the spring predictability barrier," which designation gives an indication of the difficulty of what they were attempting to do. When all was said and done, therefore, Jin *et al*. concluded that (9) "accurately predicting the strength and timing of ENSO events continues to be a critical challenge for dynamical models of all levels of complexity."

Moving ahead one year, Ault *et al*. (2009) reported, as earlier noted by Beniston and Goyette (2007), that “it has been assumed in numerous investigations related to climatic change that a warmer climate may also be a more variable climate (e.g., Katz and Brown, 1992; IPCC, 2001;

Schar *et al*., 2004)," and in this regard they remarked that "such statements are often supported by climate model results, as for example in the analysis of GCM and/or RCM simulated temperature and precipitation (Mearns *et al*., 1990, 1995) or in multiple-model simulations over Europe." And, therefore, noting that "coral records closely track tropical Indo-Pacific variability on interannual to decadal timescales (Urban *et al*., 2000; Cobb *et al*., 2001; Linsley *et al*., 2008)," they used 23 coral $\delta^{18}O$ records from the Indian and Pacific Oceans to extend the observational record of decadal climate variability back in time to cover the period from AD 1850-1990.

This effort revealed, as they described it, the existence of "a strong decadal component of climate variability" that "closely matches instrumental results from the 20th century." In addition, they found that the decadal variance they uncovered was much greater between 1850 and 1920 than it was between 1920 and 1990. As for what this observation implied, the seven scientists suggested that the decadal signal “represents a fundamental timescale of ENSO variability," the enhanced variance of which in the early half of the record "remains to be explained." Likewise, it also remains to be explained why (1) the climate models tended to suggest just the *opposite* of what actually occurs in the real world, i.e., that warming leads to greater climate variability, when real-world data appear to suggest the reverse.

With the dawn of a new decade, it was clear that computer model simulations had given rise to three climate-alarmist contentions regarding the influence of global warming on ENSO events: global warming will increase the *frequency* of ENSO events, global warming will increase the *intensity* of ENSO events, and weather-related disasters will be exacerbated under El Niño conditions. And one year later, seeking to either confirm or refute these climate contentions, Vecchi and Wittenberg (2010) published an enlightening review article in which they explored “our current understanding of these issues," stating that it was of “great interest to understand the character of past and future ENSO variations." And what did they learn as a result of their review of the literature?

The two researchers found that "the amplitude and character of ENSO have been observed to exhibit substantial variations on timescales of decades to centuries," and they reported that "many of these changes over the past millennium resemble those that arise from internally generated climate variations in an unforced climate model." In addition, they noted that "ENSO activity and characteristics have been found to depend on the state of the tropical Pacific climate system, which is expected to change in the 21st century in response to changes in radiative forcing and internal climate variability." *However*, they noted that "the extent and character of the response of ENSO to increases in greenhouse gases are still a topic of considerable research," and they stated that (1) "given the results published to date, we cannot yet rule out possibilities of an increase, decrease, or no change in ENSO activity arising from increases in CO_2." And thus it was that they concluded their review of the subject by stating "we expect the climate system to keep exhibiting large-scale internal variations," but adding that (2) "the ENSO variations we see in decades to come may be different than those seen in recent decades," and *admitting* that (3) "we are not currently at a state to confidently project what those changes will be."

How nice it is to see a bit of scientific humility relative to our understanding of how the real world really works.

Moving ahead another year, Furtado *et al*. (2011) investigated this situation by comparing the output from the 24 coupled climate models used in the IPCC AR4 with observational analyses of sea level pressure (SLP) and sea surface temperature (SST), based on SLP data from the National Centers for Environmental Prediction (NCEP)-National Center for Atmospheric Research (NCAR) Reanalysis Project (Kistler *et al*., 2001), and SST data from the National Oceanic and Atmospheric Administration (NOAA) Extended Reconstruction SST dataset, version 3 (Smith *et al*., 2008), both of which datasets contained monthly mean values from 1950-2008 gridded onto a global 2.5° x 2.5° latitude-longitude grid for SLP and a 2° x 2° grid for SST.

This work revealed, as the four U.S. scientists reported, that (1,2) model-derived "temporal and spatial statistics of the North Pacific Ocean modes exhibit significant discrepancies from observations in their twentieth-century climate, most visibly for the second mode, which has [3] significantly more low-frequency power and [4] higher variance than in observations." They also found that the two dominant modes of North Pacific oceanic variability "do not exhibit significant changes in their spatial and temporal characteristics under greenhouse warming," stating that (5) "the ability of the models to capture the dynamics associated with the leading North Pacific oceanic modes, including their link to corresponding atmospheric forcing patterns and to tropical variability, is questionable."

But there were even *more* "issues with the models," according to Furtado *et al*., who reported that (6) "in contrast with observations, the atmospheric teleconnection excited by the El Niño-Southern Oscillation in the models does not project strongly on the AL [Aleutian low]-PDO coupled mode because of (7) the displacement of the center of action of the AL in most models." In addition, they observed that (8) "most models fail to show the observational connection between El Niño Modoki-central Pacific warming and NPO [North Pacific Oscillation] variability in the North Pacific." In fact, they found that (9) "the atmospheric teleconnections associated with El Niño Modoki in some models have a significant projection on, and excite the AL-PDO coupled mode instead."

As for what it all meant, Furtado *et al*. concluded that (10,11) "for implications on future climate change, the coupled climate models show no consensus on projected future changes in frequency of either the first or second leading pattern of North Pacific SST anomalies," and they said that (12) "the lack of a consensus in changes in either mode also affects confidence in projected changes in the overlying atmospheric circulation." In addition, they noted that (13) the lack of consensus they found "mirrors parallel findings in changes in ENSO behavior conducted by van Oldenborgh *et al*. (2005), Guilyardi (2006) and Merryfield (2006)," and they thus concluded that (14) these significant issues "most certainly impact global climate change predictions." And, one might add, they impact them in *a highly negative way*.

In another study from the same time period, Khider *et al*. (2011) wrote that "the El Niño Southern Oscillation (ENSO), centered in the tropical Pacific Ocean, is the leading mode of interannual climate variability in the global climate system," and they further stated that climate models forced by increased greenhouse gas concentrations can be used to "simulate changes in ENSO variability." However, they made a point of noting that (1) these simulations do not agree on even the *sign* of change they predict, nor on (2) the resultant mean state of the tropical Pacific Ocean. Thus, they rightly stated that paleoclimate records that document past ENSO variability, over a long enough time period to include a significant range of mean global air temperature, "provide a useful reference against which to test models that attempt to simulate the natural behavior of ENSO," as well as what that phenomenon would be like in a warmer world of the future.

In order to provide such a climatic sounding board, Khider *et al*. developed a history of ENSO variability over a period of time that included both the Medieval Climate Anomaly (MCA, AD 800-1300) and the Little Ice Age (LIA, AD 1500-1850). This they did "by comparing the spread and symmetry of $\delta^{18}O$ values of individual specimens of the thermocline-dwelling planktonic foraminifer *Pulleniatina obliquiloculata* extracted from discrete time horizons of a sediment core collected in the Sulawesi Sea, at the edge of the western tropical Pacific warm pool," and by interpreting the spread of individual $\delta^{18}O$ values "to be a measure of the strength of both phases of ENSO," while the symmetry of the $\delta^{18}O$ distributions was used by them "to evaluate the relative strength/frequency of El Niño and La Niña events." And what did they thereby learn?

The five researchers said their results indicated that "the strength/frequency of ENSO, as inferred from the spread of the $\delta^{18}O$ distributions, during the MCA and during the LIA, was not statistically distinguishable and was comparable to that of the 20th century," but they also noted that their results suggested that "ENSO during the MCA was skewed toward stronger/more frequent La Niña than El Niño," an observation that they said was "consistent with the medieval megadroughts documented from sites in western North America."

On the other hand, they indicated that a coral record from the central Pacific (Cobb *et al*., 2003) suggests that the LIA was characterized by an *increase* in the strength/frequency of ENSO events compared to the MCA and the 20th century. And they acknowledged that whereas the MCA was skewed toward "stronger/more frequent La Niña than El Niño" in *their* reconstruction, the studies of Moy *et al*. (2002) and Conroy *et al*. (2008) "show an increase in the frequency of El Niño events during this time period."

With such discrepancies as these existing among *real-world reconstructions* of the effects of mean global temperature on the ratio of El Niños to La Niñas, it would appear that we don't even have the means for determining which of the similarly-divergent scenarios of current state-of-the-art climate model simulations is correct, or how close or how far from reality they each may be, which surely does not make for a solid foundation for divining what a future warmer world might be like with respect to "the leading mode of interannual climate variability in the global climate system," which sure sounds like something one would want to get right.

In a study published the following year, Catto *et al*. (2012b) tried to do just that, writing that "the El Niño-Southern Oscillation (ENSO) is linked to the interannual climate variability of Australia, in part through its effect on the sea surface temperatures (SSTs) around northern Australia," as had been documented by Hendon (2003) and Catto *et al*. (2012a). And they explained that "it is important that global coupled climate models are able to represent this link between ENSO and north Australian SSTs so that we can have more confidence in the projections of future climate change for the Australian region."

Describing their role in this process, the three researchers stated that "the link between ENSO and north Australian SSTs has been evaluated in the models participating in CMIP5 with a view to comparing them with the CMIP3 models evaluated in Catto *et al*. (2012a)." And in describing the results of this endeavor, they reported that: (1,2) "the CMIP5 models still show a wide range in their ability to represent both ENSO events themselves, and their relationship to north Australian SST," that (3) "most of the models fail to capture the strong seasonal cycle of correlation between the Niño-3.4 and north Australian SSTs," and that (4) "the models in general are still missing some underlying process or mechanism." And so they concluded that "gaining a deeper understanding of the physical mechanism behind the strong link between the SSTs in the Niño-3.4 region and to the north of Australia using these models" is "a vital next step" for this work, which they say is required "to elucidate the processes missing from the models that cannot capture the link."

Contemporaneously, Zhang and Jin (2012) wrote that "ENSO behaviors in coupled models have been widely evaluated," citing Neelin *et al*. (1992), Delecluse *et al*. (1998), Latif *et al*. (2001), Davey *et al*. (2002), AchuataRao and Sperber (2002, 2006), Capotondi *et al*. (2006), Guilyardi (2006) and Zhang *et al*. (2010); yet they said that (1) "coupled models still exhibit large biases in modeling the basic features of ENSO," citing Guilyardi *et al*. (2009), among which biases was (2) "a sea surface temperature (SST) anomaly (SSTA) too tightly confined to the equator (e.g., Stockdale *et al*., 1998; Kang *et al*., 2001)." And more specifically, they said that (3) "it was shown that the ENSO meridional width in the models participating in Phase 3 of the Coupled Model Inter-comparison Project (CMIP3) is only about two thirds of what is observed," citing Zhang *et al*. (2012).

Seeking the anticipated fruits of progress, Zhang and Jin thus asked the obvious question: "Does the systematical narrow bias in ENSO width still exist in current models developed for Phase 5 of the CMIP (CMIP5)?" And they then went on to answer their own question by assessing the ENSO meridional widths simulated by 15 CMIP5 models and 15 CMIP3 models for the period 1900-1999, comparing the results of both groups against *observation-based* monthly SST data from the Hadley Center Sea Ice and Sea Surface Temperature (HadISST) data of Rayner *et al*. (2003).

The results of this endeavor revealed, in their words, that (1) "a systematic narrow bias in ENSO meridional width remains in the CMIP5 models," although they indicated that the newest results represented "a modest improvement over previous models." However, one important question still remains to be answered with respect to this particular aspect of model performance: Is a *modest* improvement *good* enough? ... especially when considering the time, money and scientific effort put into the program that produced it, and *knowing*, in the words of Zhang and

Jin, that "models with a better performance in ENSO width tend to simulate the precipitation response to ENSO over the off-equatorial eastern Pacific more realistically."

One year later, Roxy *et al*. (2013) wrote that recent studies had pointed out the existence of a new phenomenon, referred to as the El Niño Modoki, which is characterized by a warm sea surface temperature (SST) anomaly in the central equatorial Pacific and a cold SST anomaly in the western and eastern Pacific, with some arguing that "the increasing frequency of the El Niño Modoki in recent decades is due to global warming." And they noted that in this context it was *imperative* to examine the changing teleconnection between ENSO/Modoki and the Indian summer monsoon.

Consequently, as they described it, "climate change experiments under the fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) -- namely the twentieth century simulations (20C3M) and Special Report on Emissions Scenarios (SRES) A1B -- were revisited to study whether these models could reproduce the ENSO and ENSO Modoki patterns," as well as "their teleconnections with the Indian summer monsoon, and also the implications for the future," which work revealed, in the words of the four researchers, that (1) "only ~1/4th of the models from 20C3M capture either ENSO or ENSO Modoki patterns in June, July, August and September," that (2) "of this 1/4th, only two models simulate both ENSO and ENSO Modoki patterns as important modes," and that (3) "out of these two, only one model simulates both ENSO and ENSO Modoki as important modes during both summer and winter." In addition, they reported that the two models that *did* demonstrate ENSO Modoki -- as well as ENSO associated variance in both 20C3M and SRES A1B – projected (4) just the *opposite* types of impacts of SRES A1B.

Quoting Roxy *et al*., all of these findings are indicative of "the challenges associated with the limitations of the models in reproducing the variability of the monsoons and ENSO flavors, not to speak of failing in capturing the potential impacts of global warming as they are expected to." However, there was a silver lining in these cloudy results; for as they concluded in the final sentence of their abstract, "more research in improving the current day simulations, improving model capacity to simulate better by improving the Green House Gases and aerosols in the models are some of the important and immediate steps that are necessary." And so it would appear that the saga of global climate models never quite arriving at an adequate level of reliability continues, as does the never-ending stream of money that is poured into the endeavor by cash-strapped governments around the world.

In another paper published around the same time, Koumoutsaris (2013) wrote that (1) "currently, global climate models disagree in their estimates of feedbacks, and this is one of the main reasons for uncertainty in future climate projections," citing Bony *et al*. (2006) and indicating that "in order to unveil the origin of these inter-model differences, model simulations need to be evaluated against observations of present climate." And so it was that Koumoutsaris estimated "the feedbacks from water vapor, lapse-rate, Planck, surface albedo and clouds, using models and observations based on the climate response over the last 30 years," which *short-term* feedbacks "result both from external changes in the forcing (due to greenhouse gas increases, volcanic and industrial aerosol emissions) and internal climate variations (mostly due to ENSO variability)."

This work revealed, in the words of the Swiss scientist, that "CMIP3 models show a much larger inter-decile range for all short-term feedbacks in comparison to the long-term ones," which he noted "is also the case for the three models with the most realistic ENSO representation," citing van Oldenborgh *et al*. (2005). In addition, he indicated that (2,3) the models have difficulty capturing "the position and magnitude of ENSO teleconnection patterns." And he further reported that (4) "the uncertainty in the cloud feedback, using a combination of reanalysis and satellite data, is still very large."

Koumoutsaris thus concluded that his several analyses indicated that (5) "important aspects of the ENSO variability are still poorly understood and**/**or simulated." And (6) in the case of cloud feedback, he said that it is difficult to come to "any firm conclusion" ... even on the *sign* of the feedback. And when these phenomena are so *poorly simulated* -- even to the point where the *direction* of change of one of them remains unknown -- it should be clear to all that the climate-modeling enterprise still has a long, long way to go before it can be considered good enough to serve as a basis for energy policy decisions that are *already* dictating various aspects of human behavior.

In another paper from this era, Landrum *et al*. (2013) wrote that "consistent with our understanding of the records of past forcings," climate scientists associated with phase 3 of the Paleoclimate Modeling Intercomparison Project (PMIP3) and phase 5 of the Coupled Model Intercomparison project (CMIP5) proposed that "modeling groups perform the 'Last Millennium' simulation (LM; 850-1850 Common Era) with the same models and at the same resolutions as simulations being done to simulate the twentieth century and into the future," in order to allow for "an evaluation of the capability of models to capture observed variability on multidecadal and longer time scales." And, therefore, in response to this proposal, Landrum *et al*. conducted just such a study of the Community Climate System Model, version 4 (CCSM4)," comparing its LM simulations to data-based reconstructions of LM temperature, the hydrologic cycle, and modes of climate variability."

This work revealed, in the words of the seven researchers, that "the CCSM4 LM simulation reproduces many large-scale climate patterns suggested by historical and proxy-data records." *However*, they also found that (1) "the LM simulation does not reproduce La Niña-like cooling in the eastern Pacific Ocean during the Medieval Climate Anomaly [MCA] relative to the Little Ice Age [LIA], as has been suggested by proxy reconstructions," that (2) in response to large volcanic eruptions, the CCSM4 simulates cooling "two to three times larger than the Northern Hemisphere summer anomalies estimated from tree-ring or multiproxy reconstructions," that (3) "patterns of simulated precipitation change for the Asian monsoon to large volcanic eruptions have nearly opposite anomalies from those reconstructed from tree-ring chronologies," and that (4) "we do not find a persistent positive NAO [North Atlantic Oscillation] or a prolonged period of negative PDO [Pacific Decadal Oscillation] during the MCA," such as is "suggested by the proxy reconstructions" of MacDonald and Case (2005) and Trouet *et al*. (2009).

And, therefore, noting that some of the detected model deficiencies were also found to be operative in "LM simulations with an earlier version of CCSM," Landrum *et al*. provided further evidence for the *meet the new models, same as the old models* malady, which seems to literally be *plaguing* the climate-change prognosticators of today.

Publishing near simultaneously, Vanniere *et al*. (2013) wrote that "the cold equatorial SST [sea surface temperature] bias in the tropical Pacific that is persistent in many coupled OAGCMs [Ocean-Atmosphere Global Climate Models] severely impacts the fidelity of the simulated climate and variability in this key region, such as the ENSO [El Niño-Southern Oscillation] phenomenon." More specifically, they noted that (1) "the seasonal equatorial cold tongue extends too far west, [2] is too cold in the east Pacific and [3] is associated with too strong trade winds," citing Davey *et al*. (2001), AchutaRao and Sperber (2006) and Lin (2007). In addition, they noted that (4) "a warm SST bias is observed near the coast of South America," which is (5,6) "associated with a lack of low clouds and deficient winds." And they additionally indicated that "mean state biases relevant to ENSO also include [7] too strong easterlies in the west Pacific and [8] the double ITCZ [Inter-Tropical Convergence Zone] syndrome," citing Lin (2007) and de Szoeke and Xie (2008).

In attempting to unscramble and resolve these many problems, Vanniere *et al*. used seasonal *hindcasts* to "track back" the origin of the major cold bias, so that "a time sequence of processes involved in the advent of the final mean state errors can then be proposed," applying this strategy to the ENSEMBLES-FP6 project multi-model hindcasts of the last decades. And when all was said and done -- and there was really *a lot* that was said and done -- the five researchers found that "the models are able to reproduce either El Niño or La Niña close to observations, but [9] not both."

Therefore, quoting Vanniere *et al*., "more work is needed to understand the origin of the zonal wind bias in models," and they indicated, in this regard, that "understanding the dynamical and thermodynamical mechanisms that drive the tropical atmosphere is required both to alleviate OAGCM errors and to describe the full extent of the atmosphere's role in tropical variability, such as ENSO." So in response to the proverbial *are-we-there-yet* question as applied to global climate models, the answer had to be a resounding **No!** And, therefore, the quest continues.

Xue *et al*. (2013) introduced their contribution to the subject by writing that "seasonal climate predictions are now routinely made at operational centers using coupled dynamical models (e.g., Ji *et al*., 1998; Saha *et al*., 2006; Stockdale *et al*., 2011; Barnston *et al*., 2012)," while adding that "in the development of seasonal prediction systems, prediction skill of the tropical Pacific sea surface temperature (SST) anomaly [SSTA] associated with the El Niño-Southern Oscillation (ENSO) is commonly used as a bench mark for evaluating progress." And, therefore, they documented "the prediction skill of ENSO and the biases in the new coupled dynamical model, which was referred to as Climate Forecast System, version 2 (CFSv2)," and which was “implemented at the National Centers for Environmental Prediction (NCEP) in early 2011," with one of the Center's chief objectives being "to evaluate the variability, prediction skill, and predictability of ENSO in CFSv2 over two periods, 1982-1998 and 1999-2010, separately.

This work revealed, in the words of the five U.S. researchers, that (1) "there was a systematic cold bias in the central-eastern equatorial Pacific during 1982-1998 that reached -2.5°C during summer/fall," that (2,3) "at the end of 1998, the cold bias suddenly reduced to about -1°C during summer/fall, and a warm bias of +0.5°C developed during winter/spring," that (4) "this shift of the systematic biases in hindcast SST around 1999 contributed to a spurious warming trend in forecast SSTA based on the 1982-2010 climatology (Kim *et al*., 2012)," such that "the standard deviation (STD) of forecast SSTA agreed well with that of observations in 1982-1998, but in 1999-2010 it was [5] about 200% too strong in the eastern Pacific and [6] 50% too weak near the date line during winter/spring." And when model-estimated standard deviations of different portions of a region suddenly differ by something on the order of 200%, the so-called "progress" being made would appear to have a lot to be desired.

Also joining the sortie of scientists attacking the problem, Ault *et al*. (2013) wrote that "characterizing decadal-to-centennial ("dec-cen") climate fluctuations in the tropical Pacific is critical to understanding how that region may evolve with human-induced climate change." This task, however, may well prove to be impossible to successfully complete, since they indicate that (1) "dec-cen variability in the tropical Pacific may be more prominent than instrumental records alone reveal," and that (2) it is even *less* clear in that region "how external influences and internal processes generate variability at these timescales."

Nevertheless, to explore the issue in more detail, Ault *et al*. evaluated "the magnitude of tropical Pacific dec-cen variability in an extensive suite of data sets including instrumentally-based products, climate model simulations from the Climate Model Intercomparison 5 (CMIP5) archive, and a newly published ensemble of paleoclimate reconstructions (Emile-Geay *et al*., 2013a,b)," which they subsequently refered to as EG13a,b. And what knowledge did they thereby gain?

First of all, the four U.S. researchers reported that on decadal to multi-decadal timescales, the *variability* in the three types of data sets they employed in their analyses was "consistent with the null hypothesis that it arises from 'multivariate red noise' generated from a linear inverse model of tropical ocean-atmosphere dynamics." Second, they stated that "on centennial and longer timescales, both a last millennium simulation performed using the Community Climate System Model 4 (CCSM4) and the paleoclimate reconstructions have variability that is significantly stronger than the null hypothesis," but that (1) "the time series of the model and the reconstruction do not agree with each other." And last of all, they indicated that (2) CMIP5 model results and the reconstructed low-pass time series "mostly range from being uncorrelated to anti-correlated to each other."

Consequently, in the concluding sentence of their paper's abstract, Ault *et al*. wrote that (3) "these findings imply that the response of the tropical Pacific to future forcings may be even more uncertain than portrayed by state-of-the-art models because [4] there are potentially important sources of century-scale variability that these models do not simulate."

In another contribution to the cause, Michael *et al*. (2013) wrote that "validating El Niño and the Southern Oscillation (ENSO) in coupled ocean-atmosphere climate models is considered to be vital to understand and build confidence in the fidelity of the model (Guilyardi *et al*., 2009)," partly because "ENSO is one of the best known natural climate variations (Philander, 1990), which is relatively well observed (Zebiak and Cane, 1987; Battisti, 1988; Battisti and Hirst, 1989; Hayes *et al*., 1991; McPhaden, 1993; Jin, 1997; Neelin *et al*., 1998) and, in comparison with other natural climate signals, is well understood theoretically (Kirtman, 1997; Clarke, 2008)."

Thus it was, as Michael *et al*. described it, that they "examined the surface and sub-surface oceanic variables, the coupled feedbacks, and the atmospheric response associated with ENSO variations in centennial integrations forced with the time varying twentieth century emissions of the CMIP5 historical runs." And in doing so, they found that (1) "the majority of the CMIP5 models continues to display an erroneous split-ITCZ [intertropical convergence zone] feature," with (2) "a cold SST [sea surface temperature] bias in the equatorial oceans," plus (3) "an overly active ITCZ just south of the equator," and that (4) "the warm bias in the stratiform regions of the eastern subtropical oceans is also prominent," that (5) "there was significant diversity in the CMIP5 historical simulations of the ENSO teleconnection with the southeastern U.S. climate," that (6) "many models produced geopotential height patterns over North America [that were] uncharacteristic of the observed ENSO teleconnection, with either the forced variability being [7] too strong or [8] too weak," that (9) "these erroneous teleconnections were also reflected in the corresponding ENSO-forced rainfall anomalies over the southeastern United States," that (10) "the seasonality of the coupled feedback between the zonal wind stress and SST shows apparent issues with the models," and that (11) there is "only a minority of CMIP5 models whose ENSO power spectrum is comparable to the observed spectrum."

Finally creeping ahead one more year, Taschetto *et al*. (2014) wrote that "the environmental and societal impacts of the El Niño-Southern Oscillation (ENSO) set against a gradual warming of the background climate has prompted concerted efforts to improve our understanding of ENSO behavior." As for *their* part in this quest, the six scientists indicated that they "assessed the fidelity of climate models submitted to CMIP phase 5 (CMIP5) in simulating the inter-annual SST [sea surface temperature] variability in the tropical Pacific that is largely associated with ENSO." And what did they learn by so doing?

In describing the many model *shortcomings* they discovered, the six scientists reported that (1) "there is varying fidelity across the models, that (2) "there exist systematic biases in the westward extent of ENSO-related SST anomalies," which are driven by (3) "unrealistic westward displacement" and (4) "enhancement of the equatorial wind stress in the western Pacific," that (5) "most models fail to reproduce the asymmetry between the two types of La Niñas," with (6) "CT [Cold Tongue] stronger than WP [Warm Pool] events, which is opposite to observations," that (7) "the seasonal evolution of ENSO has a large range of behavior across the models," that (8) the CMIP5 models "have biases in the evolution of the other types of events," that (9) "the duration of WP El Niños is overestimated for most of the models," that (10) "simulated CT La Niñas start about two seasons later than observed," that (11) "WP La Niñas end approximately six months earlier than observed," that (12) "the decay of WP El Niños "occurs through heat content discharge in the models rather than the advection of SST via anomalous zonal currents, as seems to occur in observations," and that (13) in the Niño-3 region "only about one-third of the models peak in the correct season."

Subsequently, as if the shortcomings listed above were not enough, Taschetto *et al*. declared -- *in grand understatement* -- that "good skill in simulating other aspects of ENSO seasonality is not guaranteed," while yet another voice, -- that of Danzio (2014) -- declared in a "News and Views" item published in *Nature* that "the episodic warming and cooling of the surface temperature of the tropical Pacific Ocean, known as the El Niño-Southern Oscillation (ENSO), causes year-to-year climate fluctuations, affecting weather, ecosystems and economies around the world," but indicating that "the occurrence of these episodes is not regular."

As an example of this *fact*, the University of Hawaii researcher reported that Wittenberg (2009) had examined a 2,000-year climate simulation based on "a fairly realistic climate model," which showed that (1) "decadal-to-centennial-scale changes in ENSO behavior can be internally generated by the model in the absence of any external forcing, such as increases in greenhouse-gas concentration or variations in solar output." And in a more recent study conducted by Wittenberg *et al*. (2014), using the same GFDL-DM2.1 model, he describes how the five climate scientists found that (2) "multi-decadal epochs of high and low ENSO activity are completely unpredictable."

In commenting on this *extremely* significant finding, Dinezio wrote that it was a *sobering* finding, "because," as he continued, "it suggests that [1] the changes observed in ENSO behavior during the twentieth century could very well be random fluctuations unrelated to natural or man-made changes in the climate of the tropical Pacific." And he added that [2] "it is not known whether even the best climate models simulate the correct mix of the myriad processes that influence ENSO," ending, therefore, with his *ultimate conclusion* that "future attempts to attribute the causes of individual events and their decadal variations now face a much higher bar," which *level of correctness*, it should be obvious to all, has yet to be reached.

In another illuminating study, Bellenger *et al*. (2014) wrote that "the El Niño-Southern Oscillation (ENSO) is the dominant mode of inter-annual climate variability," and that "it is characterized by large-scale sea surface temperature (SST) anomalies in the eastern Equatorial Pacific Ocean," the amplitude of which anomalies "is typically on the order of 1-3°C and is associated with a change in the oceanic thermal structure and a switch in atmospheric circulation and convective activity," which latter phenomena are themselves "characterized by an irregular period ranging between 2 and 7 years." And so it was that the five researchers analyzed the ability of older CMIP3 and more recent CMIP5 coupled ocean-atmosphere general circulation models (CGCMs) to simulate the tropical Pacific Ocean's mean state and its periodically-perturbed El Niño-Southern Oscillation (ENSO) state, hoping to discover some significant progress in transiting from the older to the more recent set of models. And what did they thereby find?

First of all, the five researchers reported that (1) "the CMIP5 multi-model ensemble does not exhibit a quantum leap in ENSO performance compared to CMIP3." And they went on to demonstrate that fact by noting that (2) fundamental ENSO characteristics, such as central Pacific precipitation anomalies, "remain poorly represented," that (3) "the wind-SST feedback is still underestimated by 20-50%," that (4) "shortwave-SST feedbacks remain underestimated by a factor of two," that (5) "ENSO termination tends to occur much more to the west than in observations in both CMIP3 and CMIP5," that (6) "simple metrics of the atmospheric feedbacks that are thought to play a major role in ENSO physics ... show no clear improvement from CMIP3 to CMIP5," that (7) "most CMIP5 models still underestimate the observed positive atmospheric Bjerknes feedback (on average by roughly 30%)," that (8) "the damping surface flux feedback also remains too diverse in CMIP5 models," due to (9) "the difficulty to represent the shortwave feedback and its nonlinearity," and that (10) "there are moreover discrepancies between modelled and observed αsw- (La Niña conditions) and αsw+ (El Niño conditions)."

In concluding, therefore, Bellenger *et al*. wrote that "significant model development work is still needed to correctly represent the basic ENSO characteristics (amplitude, evolution, timescale, seasonal phase lock ...) and the fundamental underlying processes such as the atmospheric Bjerkness and surface fluxes feedbacks."

Contemporaneously, Jha *et al*. (2014) wrote that "sea surface temperature (SST), particularly in the tropical Pacific Ocean associated with the El Niño-Southern Oscillation (ENSO), is closely connected with global climate variations on seasonal and longer time scales," while further noting that the ENSO-associated SST anomaly (SSTA) in the tropical Pacific "is also the major source of climate predictability over the global lands and oceans," citing the National Research Council (2010) and Wang *et al*. (2010). And they therefore declared "it is important that SST variability, particularly in the tropical Pacific associated with ENSO, is simulated well by climate models."

In exploring this subject in greater depth, therefore, Jha *et al*. used historical simulations (1870-2005) derived from ten CMIP5 models forced with observed atmospheric composition changes, reflecting both natural and anthropogenic sources, in order to provide an assessment of the realism of the model-simulated global historical SST and ENSO variability, and to also examine the impact of low-frequency variations on ENSO and its global teleconnections.

In conducting this work, the three U.S. researchers determined that (1) there are "numerous differences in details among the models," that (2) "the amplitude of Niño3.4 SST variability is overestimated in most of the models," that (3) "some models show smaller amplitudes as compared to the observations," that (4) the "frequency of ENSO at the period of 5-6 years is not well simulated by almost all models," that (5) the "majority of the models are unable to capture the spatial pattern of the observed linear trend over the entire analysis period (136 years)," that (6) "low-frequency variations before 1970 are not well captured by the models," that (7,8) the "majority of the models are too cold during 1870-1895, but too warm during 1905-1950," and that (9) the "majority of the models are unable to correctly simulate the spatial pattern of the observed SST trends." Consequently, Jha *et al*. stated, in the concluding sentence of their paper's abstract, that (10) "it is still a challenge to reproduce the features of global historical SST variations with state-of-the-art coupled general circulation models."

Adding to this viewpoint were the findings of Kim *et al*. (2014), who noted as background that (1) "although considerable progress has been made towards more realistic ENSO simulation, systematic errors still persist," citing Capotondi *et al*. (2006), Guilyardi *et al*. (2009), Kim and Jin (2011), Lloyd *et al*. (2009), Lin (2007), and Zhang and Jin (2012)." More particularly, they reported that "the Coupled Model Intercomparison Project phase 3 (CMIP3) models generally underestimate [2] thermodynamic damping and positive feedbacks including [3] zonal advective and [4] thermocline feedbacks (Kim and Jin, 2011; Lloyd *et al*., 2009), which are responsible for ENSO variability and display a large diversity of ENSO amplitude, stability and teleconnections (Guilyardi, 2006; Yu and Kim 2010; Cai *et al*., 2009; Kim and Jin, 2011)." And, therefore, using the Bjerkness stability index as the basis for *their* analysis, Kim *et al*. explored "the overall linear El Niño-Southern Oscillation (ENSO) stability and the relative contribution of positive feedbacks and damping processes to the stability in historical simulations of Coupled Model Intercomparison Project Phase 5 (CMIP5) models."

This effort enabled the four researchers to determine that (5) "a systematic bias persists from CMIP3 to CMIP5," and that "the majority of the CMIP5 models analyzed in this study still underestimate [6] the zonal advective feedback, [7] thermocline feedback, and [8] thermodynamic damping terms, when compared with those estimated from reanalysis." And they went on to say that "this discrepancy turns out to be related to [8] a cold tongue bias in coupled models that causes [9] a weaker atmospheric thermodynamical response to sea surface temperature changes and [10,11] a weaker oceanic response (zonal currents and zonal thermocline slope) to wind changes." And in light of these several sets of findings, there would appear to be a *host* of problems that need to be resolved before the studied models are ready to produce reasonably accurate projections of future ENSO behavior.

In another contemporary study, Brown *et al*. (2014) wrote as background for *their* work that "the equatorial edge of the Western Pacific Warm Pool is operationally identified by one isotherm ranging between 28° and 29°C" that is "chosen to align with the inter-annual variability of strong zonal salinity gradients and the convergence of zonal ocean currents." And they simulated this *edge* in 19 different models that took part in the World Climate Research Program's Coupled Model Intercomparison Project Phase 5 (CMIP5) over the period 1950 to 2000.

Based on their simulations, the three researchers found that various aspects of the *dynamic warm pool edge* or DWPE "remain difficult for coupled models to simulate," including (1) the mean longitude, (2) the inter-annual excursions, and (3) the zonal convergence of ocean currents. In addition, they discovered that some models found it (4) "difficult to even identify a DWPE," and that if they *could* identify one, they found that (5) the models' DWPEs "are generally 1-2°C cooler than observed." And in light of these findings, Brown *et al*. concluded that (6) "the inability of a model to simulate sea surface temperature structure and the location of the DWPE impedes understanding of climate change signals," which is a serious shortcoming that has yet to be rectified.

Forging ahead, Xhang and Sun (2014) reminded us that El Niño and La Niña are not mirror images of each other, noting that "the strongest El Niño is stronger than the strongest La Niña," a fact that has been referred to by Burgers and Stephenson (1999) as *ENSO asymmetry*, the cause of which, according to Zhang and Sun, is "not yet clearly understood." And in light of this lack of understanding, the two U.S. researchers went on to evaluate "the ENSO asymmetry in CMIP5 models," along with "corresponding Atmospheric Model Intercomparison Project (AMIP) runs," in order to "gain more insight into possible causes of the bias in ENSO asymmetry." And what did they learn from their efforts?

With respect to their findings, Zhang and Sun reported the following: (1) "the underestimate of observed positive ENSO asymmetry measured by skewness is still a common problem in CMIP5 coupled models," (2) "all the models are also found to have a weaker ENSO asymmetry than observations," (3) "CMIP5 coupled models have a significant cold bias in the mean sea surface temperature," (4-6) "biases in zonal wind stress, precipitation and subsurface temperatures ... are also too symmetrical with respect to ENSO phases," (7) "sea surface temperature warm anomalies over the far eastern Pacific are found to be weaker in the coupled models than in observations," (8) "most models also have a weaker subsurface temperature warm anomaly over the eastern Pacific," (9) "most models have a weaker precipitation asymmetry over the eastern Pacific," (10) "most AMIP models have a stronger time-mean zonal wind over the equatorial central and eastern Pacific," and (11) they "underestimate the observed positive skewness of zonal winds in the central Pacific."

As time continues to progress, therefore, several elements of the climate-modelling juggernaut appear to be stuck in neutral. But will it always remain that way? A glimpse of what the future may hold in this regard can be derived from the first few papers on the subject that appeared in 2015, begining with the study of Su *et al*. (2015), who evaluated a more than 200-year simulation of the climate system model of the Chinese Academy of Sciences (CAS-ESM-C), focusing on “developing and decaying processes." And what did they thereby learn?

In the words of the four Chinese researchers, they say, *compared with observations*, that (1,2) "the simulated ENSO exhibits a much stronger amplitude and shorter period of 2-3 years," that (3) "the model overestimates the westerly anomaly in the equatorial western Pacific," that (4) "the El Niño tends to develop faster," along with (5) "a faster eastward propagation of the subsurface warm anomaly," that (6,7) "a cold water anomaly and an easterly anomaly are found in the western Pacific" for strong El Nino events, that (8) "the response in the model occurs more frequently," due to (9) "an overestimated intensity of the El Niño," that (10) the "more frequent occurrence of the ENSO in the model is closely related to a shallower thermocline," which (11) "speeds up the zonal redistribution of the heat content in the upper Pacific Ocean," and that (12) "the shallower thermocline can be attributed to the weaker wind stress in the equator." And in light of this set of unfortunate findings, Su *et al*. concluded that "it is necessary to improve the wind bias in the model."

Continuing, we come to the work of Steinhoff *et al.* (2015), who wrote that "due to the importance that the El Niño-Southern Oscillation (ENSO) has on rainfall over the tropical Americas, future changes in ENSO characteristics and teleconnections are important for regional hydroclimate." Thus, they explored projected changes to ENSO mean state and its primary characteristics -- along with resulting impacts on rainfall anomalies over Central America, Colombia and Ecuador during the 21st century -- for several different forcing scenarios, using "a suite of coupled atmosphere-ocean global climate models (AOGCMs) from the fifth phase of the Coupled Model Intercomparison Project (CMIP5). And what did they thereby learn?

The three U.S. researchers found that (1-3) "current and projected future characteristics of ENSO (frequency, duration, amplitude) show a wide range of values across the various AOGCMs," that (4) "the magnitudes of ENSO-related rainfall anomalies are currently underestimated by most of the models," and that (5) "there is not agreement on the changes in ENSO-related rainfall anomalies in future simulations." And with *no agreement* among the models on this extremely basic point, there is essentially nothing *new* -- or necessarily *true* -- that they have to tell us about the subject.

Last of all, Gong *et al*. (2015) described their paper's purpose by writing that "the influence of El Niño-Southern Oscillation (ENSO) upon the East Asian-western Pacific (EAWP) climate in boreal winter is investigated via phase 5 of the Coupled Model Intercomparison Project (CMIP5) model results and then compared to that in the phase 3 (CMIP3) results," which they did by utilizing 36 CMIP5 models and 20 CMIP3 models and focusing on "the role played by the differences among models in ENSO properties, including the amplitude and longitudinal extension of ENSO's sea surface temperature (SST) pattern."

In terms of what they learned via this approach, the six Chinese scientists reported that "an eastward shrinking of ENSO's SST pattern leads to quite weak [1] circulation and [2] climatic responses over the EAWP regions in the models," that (3,4) "resultant precipitation anomalies and lower-tropospheric atmospheric Rossby wave responses both extend unrealistically into the Indian Ocean," that (5) "all these features lead to unrealistic climatic impacts of ENSO over the EAWP regions," that (6) "atmospheric responses over the western Pacific are still located farther west than observed," and that (7-8) "unrealistic temperature and precipitation anomalies are observed over East Asia and Australia," all of which findings, in their words, imply "a common bias of CMIP5 models."

In further commentary on the subject, Gong *et al*. wrote that (9) "an unrealistic longitudinal extent of ENSO's SST pattern is a common bias in coupled general circulation models," citing the work of T. Lee *et al.* (2013). And they went on to additionally draw attention to "the inability of models to simulate [10] the mean state of SST, [11,12] the climatological trade winds over the tropical and subtropical Pacific, and [13] the resultant air-sea interactions via Bjerknes feedback," citing the studies of Kim *et al.* (2014), Magnusson *et al.* (2013) and Li and Xie (2014), all of which shortcomings suggest that the climate modelling community still has a significant way to go before they will be able to *fully rectify* the several ENSO-related problems discussed by Gong *et al.* and the other researchers cited herein.

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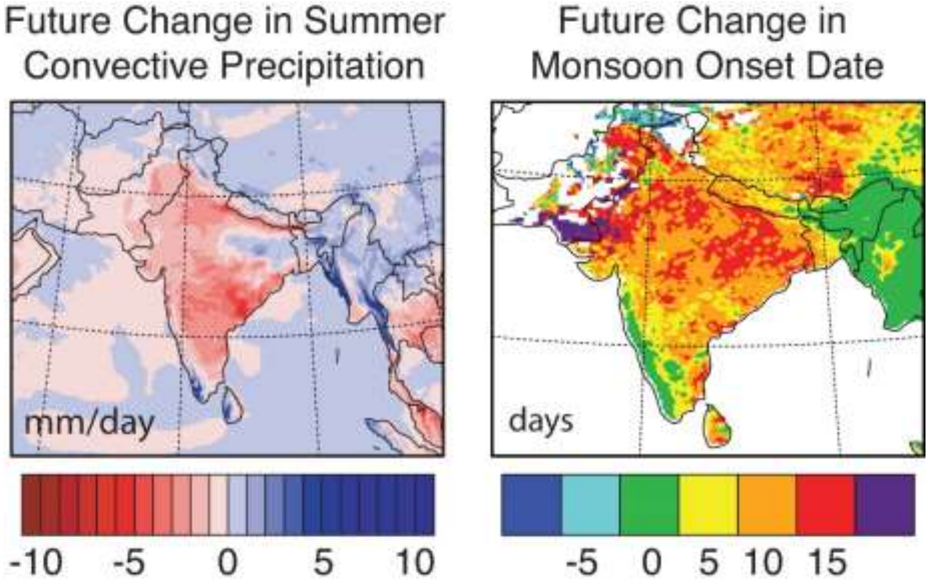
MONSOONS



In one of the earlier studies of the subject, Chase *et al*. (2003) reported that "greenhouse gas warming simulations generally show increased intensity of Asian summer monsoonal circulations," citing the works of Meehl and Washington (1993), Hirakuchi and Giorgi (1995), Li *et al*. (1995), Zwiers and Kharin (1998), Chakraborty and Lal (1994), Suppiah (1995), Zhao and Kellog (1988), Hulme *et al*. (1998) and Wang (1994), as was also found to be the case for Northern Australia during the austral summer season by Whetton *et al*. (1993, 1994) and Suppiah (1995). In addition, the four researchers indicated that much the same would likely be predicted for African monsoons, "given that the tropical atmospheric moisture content, latent heating and overall hydrological cycle have been hypothesized to increase with increasing tropospheric temperature (IPCC, 1996)." So have subsequent analyses of *real-world data* been able to substantiate this plethora of *model-based predictions*?

In broaching this question, Chase *et al*. studied changes in several intensity indices of the planet's four major tropical monsoonal circulations over the period 1950-1998, including the highly contentious final two decades of the 20th century, which were claimed by climate alarmists to have experienced "unprecedented" global warming. For all four of these regions, however, they found (1) "diminished monsoonal circulations over the period of record," as well as (2) "diminished spatial maxima in the global hydrological cycle since 1950." And they also noted that (3) "trends since 1979, the period of strongest reported surface warming, do not indicate any change in monsoon circulations." Consequently, the models of the late 1990s (4) failed to even *qualitatively* describe what was actually happening in the world of nature with respect to monsoonal circulations.

About this same time, in a related study spanning more than twice as many years (1871-2001), Kripalani *et al*. (2003) examined Indian monsoonal rainfall using observational data from the Indian Institute of Tropical Meteorology that were collected from 306 stations scattered across the country. In the course of this work they discovered decadal variations running through the record that revealed "distinct alternate epochs of above and below normal rainfall," which epochs tended to last for about three decades. In addition, they reported that (1,2) "there is no clear evidence to suggest that the strength and variability of the Indian Monsoon Rainfall (IMR) nor [3] the epochal changes are affected by the global warming," adding that (4) "studies by several authors in India have shown there is no statistically significant trend in IMR for the country as a whole."

Before concluding, Kripalani *et al*. additionally noted that "Singh (2001) investigated the long term trends in the frequency of cyclonic disturbances over the Bay of Bengal and the Arabian Sea using 100-year (1890-1999) data and found significant decreasing trends." As a result, they wrote that (1,2) "there seem[s] to be no support for the intensification of the monsoon nor any support for the increased hydrological cycle as hypothesized by [the] greenhouse warming scenario in model simulations." In addition, they noted that (3) "the analysis of observed data for the 131-year period (1871-2001) suggests no clear role of global warming in the variability of monsoon rainfall over India." Hence, the climate models of that period were readily striking out with essentially *all* of their Asian monsoon-related projections.

These several findings mirrored the earlier discoveries of Kripalani and Kulkarni (2001), who studied summer monsoon (June-September) rainfall data from 120 east Asia stations for the period 1881-1998 and who thereby detected the presence of short-term variability in rainfall amounts on decadal and longer time scales, the longer "epochs" of which were found to last for about three decades over India and China and approximately five decades over Japan. Over the entire record, however, they reported that (1) *no significant long-term trends were observed*. And, therefore, the observational history of summer rainfall trends throughout most of east Asia (2) failed to support climate-alarmist claims of intensified monsoonal conditions in this region as a result of CO_2-induced global warming.

In a paper that took a much longer look at the characteristics of expanded African-Asian monsoon variability over the course of the entire Holocene, Overpeck and Webb (2000) found that large abrupt changes in monsoon moisture availability occurred multiple times throughout the past several thousand years, although they said that "a lack of research prevents precise reconstruction, explanation, or modeling of these changes." And in this assessment they clearly appeared to anticipate the concluding comment of Kripalani and Kulkarni, i.e., that (1) the decadal variability they found in their east Asian study "appears to be just a part of natural climate variations."

In another important study, Fleitmann *et al*. (2004) used high-resolution stable isotope records from three stalagmites in a shallow cave in Southern Oman to develop an annually-resolved record of Indian Ocean monsoon rainfall over the past 780 years. This record revealed that (1) over the last eight decades of the 20th-century, when the earth warmed considerably, Indian Ocean monsoon rainfall *declined dramatically*, again in stark *contrast* to what had historically been predicted by most climate models. In addition, the record's other single most substantial decline in monsoon rainfall coincided with a major temperature spike identified by Loehle (2004) in the temperature records of Keigwin (1996) and Holmgren *et al*. (1999, 2001) that began sometime in the early 1400s. This abrupt warming, which was also identified by McIntyre and McKitrick (2003), pushed temperatures above the peak warmth of the 20th century before they fell back to pre-spike levels in the mid-1500s, a rise-and-fall temperature trend that produced just the opposite fall-and-rise trend in the monsoon rainfall record of Fleitmann *et al*. And so it was that these real-world observations provided additional strong evidence that (2) global temperature variations elicit just the *opposite* variations in Indian Ocean monsoon rainfall than what has historically been predicted by global climate models.

One year later, Bingyi (2005) analyzed 43 years (1958-2000) of NCEP-NCAR reanalysis data and station observations (including sea level pressure, geopotential heights, air temperatures and zonal winds at each standard level from 1000 hPa to 200 hPa), looking for possible relationships between tropospheric temperature and the strength of the Indian summer monsoon circulation. This work indicated that (1) the monsoonal circulation underwent two *weakening* processes in recent decades. The first occurred in the mid-1960s and the second in the late 1970s, the latter of which, in Bingyi's words, "may be attributed to significant tropospheric warming over the tropical area from the Indian Ocean to the western Pacific," which "was related with the global warming," once again *in direct contradiction of climate model predictions*.

Contemporaneously, when the 2004 summer monsoon season of India experienced a 13% deficit that was (1) not predicted by either empirical or dynamical models used in making rainfall forecasts, Gadgil *et al*. (2005) decided to perform an historical analysis of the models' skills over the period 1932 to 2004. And in doing so, they found that (2) in spite of numerous model changes and an ever-improving understanding of monsoon variability, Indian monsoon model forecast skill had not improved since 1932, that (3) large differences were often observed when comparing monsoon rainfall measurements with empirical model predictions, and that (4) the models often failed to correctly predict even the *sign* of the precipitation anomaly.

Dynamical models, however, *fared even worse*. In comparing observed versus predicted monsoon rainfall from 20 "state-of-the-art" atmospheric general circulation models and one supposedly superior coupled atmosphere-ocean model, Gadgil *et al*. found that (5) *none* of them were able "to simulate correctly the interannual variation of the summer monsoon rainfall over the Indian region." And like the empirical models, they (6,7) frequently failed to simulate not only the *magnitude*, but also the *sign* of the real-world rainfall anomalies.

One year later -- after defining "a global monsoon rain domain according to annual precipitation range, using simple objective criteria" -- Wang and Ding (2006) derived an ensemble mean of annual global monsoon precipitation for the period 1948-2003, based on four sets of monthly rain-gauge data for a 0.5-degree latitude/longitude grid of the land surface of the globe, as compiled by four different climate diagnostic groups. And in doing so, they discovered (1) "an overall weakening of the global land monsoon precipitation in the last 56 years, primarily due to weakening of the summer monsoon rainfall in the Northern Hemisphere." Since 1980, however, they observed that "the oceanic monsoon precipitation shows an increasing trend," but that (2) "the global land monsoon rainfall has seen no significant trend." As for the *total* (monsoon plus non-monsoon) land-sea combination, the two researchers reported that (3) since 1979 "no trend was seen for the total global precipitation (Allen and Ingram, 2002)," based on the Global Precipitation Climatology Project's 2.5 by 2.5 degree grid of precipitation data, a finding that was also obtained by Smith *et al*. (2006).

Contrary to a long history of climate model predictions, therefore, it was clear that (1,2) the earth's monsoon precipitation did not materially increase in response to the global warming of the past half century, nor did the planet's total precipitation increase in response to the warming of the past quarter century, during which time climate alarmists typically claimed the earth warmed at a rate and to a level that was *unprecedented over the past two millennia*. Thus, there was (3) a major disconnect between the *virtual* world of the climate models, where significant warmings brought significant increases in precipitation, and the *real* world, where actual observational data suggested that such is *not* the case.

Contemporaneously, Shenbin *et al*. (2006) calculated monthly *potential evapotranspiration* estimates for the Tibetan Plateau (TP) by the Penman-Monteith equation using meteorological data from the Meteorology Center of the National Meteorology Bureau of the Peoples' Republic of China for 101 stations having records for the 40-year period 1961 to 2000. This work revealed that potential evapotranspiration (PET) had decreased in all seasons, so that "the average annual evapotranspiration rate decreased by 13.1 mm/decade," or 2.0% of the annual total, over the course of their four-decade study. Their analysis also revealed that wind speed was "the most important meteorological variable affecting changes in PET rates on the TP," and they thus wrote that "decreasing wind speeds have led to decreasing PET rates," which finding, in their words, was "in accordance with Barry (1992) who argues that wind is probably the most important factor controlling PET rates in all high altitude environments."

In light of these observations, Shenbin *et al*. thus concluded that (1) "decreased wind speeds as the primary cause of decreasing PET rates point to changes in the strength of the local circulation system (the monsoon) which in turn would affect a far larger region than the TP alone," noting further that (2) "decreases in the strength of the regional circulation system of the Asian monsoons which may lead to the observed reductions in wind speed on the TP could be responsible for observed lower PET rates in recent years." And this finding, they made a point of stating, is (3) “in contrast to predicted increased monsoonal activity and [4] an increased hydrological cycle under global warming scenarios (IPCC, 2001)."

Two years later, Paeth *et al*. (2008) compared 79 coupled ocean-atmosphere climate simulations derived from twelve different state-of-the-art climate models forced by six different IPCC emission scenarios with observational data in order to evaluate how well they either did or did not reproduce the spatio-temporal characteristics of the El Niño-Southern Oscillation (ENSO) over the 20th century, after which they compared the various models' 21st-century simulations of ENSO and the Indian and West African monsoons among themselves. This work revealed, in their words, that with respect to the past (20th century), "all considered climate models draw a reasonable picture of the key features of ENSO." With respect to the future (21st century), on the other hand, they say that (1) "the differences between the models are stronger than between the emission scenarios," while (2) "the atmospheric component of ENSO and the West African monsoon are barely affected," all of which led them to state that (3) "the overall conclusion is that we still cannot say much about the future behavior of tropical climate."

Moving ahead another year (and to another part of the world), Bombardi and Carvalho (2009) employed real-world data pertaining to the onset, end and total rainfall of the South American Monsoon System (SAMS) -- as characterized by precipitation data for the period 1979-2006 that they obtained from the Global Precipitation Climatology Project – to evaluate the ability of ten IPCC global coupled climate models to simulate real-world SAMS characteristics. This work revealed that (1) over northern South America the annual precipitation cycle "is poorly represented by most models," and, more specifically, that (2) "most models tend to underestimate precipitation during the peak of the rainy season." In addition, they reported that (3) "the misrepresentation of the Inter-Tropical Convergence Zone and its seasonal cycle seems to be one of the main reasons for the unrealistic out-of-phase annual cycles simulated near the equator by many GCMs," and that (4) "poor representation of the total monsoonal precipitation over the Amazon and northeast Brazil is observed in a large majority of the models.” As a consequence, therefore, they reported that (5) "simulations of the total seasonal precipitation, onset and end of the rainy season diverge among models and are notoriously unrealistic over [the] north and northwest Amazon for most models." Once again, therefore, we have another demonstration of the *fact* that when computer-model output is compared with real-world data of the past, the comparison often does not look good (to say the least), which gives one little confidence in the models' abilities to correctly simulate the future.

Jumping ahead three additional years, Zhang *et al*. (2012) used daily precipitable water and 850 hPa monsoon wind data -- which represent large-scale moisture and dynamic conditions for monsoon development – to analyze "potential changes in Asian monsoon onset, retreat and duration simulated by 13 IPCC AR4 models." And what did they thereby find? The Chinese-Australian research team found that (1) there "is no single outstanding model out of the 13 models used in the analysis," noting that (2) "some of the models have shown significant biases in mean onset/retreat dates and [3] some failed to produce the broad features of how [the] monsoon evolves." Over East Asian land, for example, they found that (4) "the models are nearly equally divided about the sign of potential changes of onset/retreat." And sounding rather frustrated, they lament that (5) they "do not know why the models are different in simulating these dominant processes and [6] why in some models the ENSO influence is more significant than others," adding that (7) "it is unclear what are the key parameterizations leading to the differences in simulating ENSO and its responses to global warming," further citing Solomon *et al*. (2007) and Wang *et al*. (2009).

In another study from this same time period, Kim *et al*. (2012) assessed the seasonal prediction skill of the Asian summer monsoon via the use of "retrospective predictions (1982-2009) from the ECMWF System 4 (SYS4) and NCEP CFS version 2 (CFSv2) seasonal prediction systems." And in doing so, in the words of the four researchers, they found that (1) "in both SYS4 and CFSv2, a cold bias of sea-surface temperature is found over the Equatorial Pacific, North Atlantic [and] Indian Oceans," as well as (2) "over a broad region in the Southern Hemisphere relative to observations," while (3) "a warm bias is found over the northern part of the North Pacific and North Atlantic." In addition, they state that (4) "excessive precipitation is found along the Intertropical Convergence Zone, equatorial Atlantic, equatorial Indian Ocean and the maritime continent."

Last of all, Kim *et al*. report that (5,6) "the southwest monsoon flow and the Somali Jet are stronger in SYS4, while (7-9) the south-easterly trade winds over the tropical Indian Ocean, the Somali Jet and the Subtropical northwestern Pacific high are weaker in CFSv2 relative to the reanalysis." And, therefore, with both of the world's most advanced climate modeling systems "performing poorly," as Kim *et al*. put it, in simulating monsoon precipitation that affects *almost half of the world's population*, it would appear that (10) the climate modeling enterprise of that day still had a long way to go before anyone should have gotten too excited about what the fruits of that endeavor were suggesting.

Inching ahead another year, Zheng and Braconnot (2013) wrote that "despite recent progress in the monitoring and understanding of the WAM [West African Monsoon] within the framework of the African Monsoon Multidisciplinary Analysis (AMMA), [1] there are still large uncertainties in projections of future climate in this region, such that [2] even the sign of future precipitation change is uncertain," citing Solomon *et al*. (2007). And, therefore, they went on to revisit the results of PMIP2 [Paleoclimate Modelling Intercomparison Project Phase II] simulations over Africa using two different approaches. The first considered the ensemble of simulations in order to determine how well the PMIP2 models of that day reproduced some of the basic features of the summer monsoon precipitation, while the objective of the second was "to understand model differences by considering model characteristics for present-day climate and their sensitivities to insolation change."

In pursuing this course of study, the two scientists determined that (1) the "meridional temperature gradient is underestimated between 0° and 20°N by the PMIP2 model median, resulting in [2] a smaller gradient of sea level pressure between the Gulf of Guinea and [the] Sahel," which helps to explain (3) "a lower than observed low-level moisture flux and [4] an underestimate of rainfall intensity when compared with observations." In addition, they found that (5) "the northward extent of the rain belt and the intensity of precipitation change are underestimated." They also determined that (6) "the models overestimate the solar radiation." And they acknowledged that (7,8) the models "underestimate the cloud radiative forcing in deep and moderate convective regimes." Last of all, they state that (9) "some of the models have too strong a coupling between the latent heat and convection in deep convective regimes."

About this same time, Bollasina and Ming (2013) wrote that (1) most current general circulation models (GCMs) “show a remarkable positive precipitation bias over the southwestern equatorial Indian Ocean (SWEIO), which can be thought of as a westward expansion of the simulated Indian Ocean convergence zone toward the coast of Africa.” And they further noted, in this regard, that (2) “the bias is common to both coupled and uncoupled models, suggesting that its origin does not stem from the way boundary conditions are specified.”

In studying this situation in some depth, the two researchers further determined that (3,4) "the spatio-temporal evolution of the precipitation and associated three-dimensional atmospheric circulation biases [were] comprehensively characterized by comparing the GFDL [Geophysical Fluid Dynamics Laboratory] AM3 atmospheric model to observations." And this work revealed, as they reported, that (5) "the oceanic bias, which develops in spring and reduces during the monsoon season, is associated [with] a consistent precipitation and circulation anomalous pattern over the whole Indian region," where (6) "in the vertical, the areas are linked by an anomalous Hadley-type meridional circulation, whose northern branch subsides over northeastern India significantly affecting the monsoon evolution (e.g., delaying its onset)." And they further indicated that "the ability of local anomalies over the SWEIO to force a large-scale remote response to the north is further supported by numerical experiments with the GFDL spectral dry dynamical core model."

In summing up their findings, Bollasina and Ming wrote that their study "makes the case that the precipitation bias over the SWEIO is forced by the model excess response to the local meridional sea surface temperature gradient through enhanced near-surface meridional wind convergence," and they therefore concluded that "a detailed investigation into the model physics to identify possible parameters which may alleviate the model bias would be the natural extension of this work."

Working contemporaneously, Chaudhari *et al*. (2013) expressed their concern that "despite the potential for tropical climate predictability, and the advances made in the development of climate models, the seasonal dynamical forecast of [the] Indian summer monsoon remains a challenging problem," which they thus proceeded to explore via a study of model biases and how they create further biases as they wend their way through multiple stages of both simultaneous and sequential processes.

More specifically, Chaudhari *et al*. examined the performance of the National Centers for Environmental Prediction (NCEP) Climate Forecast System (CFS) over the Indian monsoon region in a 100-year-long coupled run, which was framed "in terms of biases of sea surface temperature (SST), rainfall and circulation," while also exploring "the role of feedback processes in maintaining these biases." And what did they thereby learn?

According to the nine researchers, the model (1) shows dry (wet) rainfall bias concomitant with cold (warm) SST bias over the east (west) equatorial Indian Ocean; and they say that these *biases* of SST and rainfall (2) affect both lower- and upper-level circulations in a feedback process, which in turn (3) regulates the SST and rainfall *biases* by maintaining a coupled feedback process.

Subsequently, a dry (wet) rainfall *bias* over the east (west) Indian Ocean (4) induces anomalous low level easterlies over the tropical Indian Ocean and (5) causes a cold SST *bias* over the east Indian Ocean by triggering evaporation and warm SST *biases* over the west Indian Ocean through advection of warm waters. The persistent SST *bias* then (6) retains the zonal asymmetric heating and meridional temperature gradient resulting in a circum-global subtropical westerly jet core, which in turn (7) magnifies the mid-latitude disturbances and (8) decreases the Mascarene high, which in its turn (9) diminishes the strength of monsoon cross-equatorial flow and (10) results in less upwelling as compared to that in the observations, which latter phenomenon (11) increases the SST *bias* over the West Indian Ocean.

And so it was -- and largely still is -- as Chaudhari *et al*. described it, that (12) "the coupled interaction among SST, rainfall and circulation works in tandem through a closed feedback loop to maintain the model *biases* over the tropical Indian Ocean," demonstrating that (13) once significant biases worm their way into the innards of today's complex climate models, they are extremely difficult to expel.

In another study from the same year, Chen and Sun (2013) wrote that "over East Asia, the climate is dominated by the summer monsoon in the rainy season," where the associated rain belt is called the Meiyu in China, the Baiu in Japan, and the Changma in Korea. And noting that (1) "the advance and retreat of the Meiyu belt result in a large variability of precipitation over East Asia and generally lead to many natural disasters, e.g., floods and droughts," they went on to state that "projection of future changes in precipitation and its frequency and intensity is a critical issue for long-term planning for national and regional adaptation and mitigation," implying the need for superlative climate modeling in this regard.

The *ultimate* objective of Chen and Sun was to investigate future changes in precipitation frequency and intensity over the East Asian region; but before they could accomplish that task, it was necessary for them to evaluate the degree to which the *coupled ocean-atmosphere general circulation models* (CGCMs) from CMIP5 reproduce the present-day climate, which they thus proceeded to do. And in doing so, they determined that (1) "most of the models in CMIP5 underestimated the amount of precipitation over China, Korea and Japan," and that (2) some of them even "lacked the Meiyu belt over this region." In addition, they found that (3) "because of the underestimation by most of the models, the MMEs (multi-model ensembles) of all of the models also showed a negative bias."

Continuing, the two researchers also found that (4) a number of the models additionally showed "almost no skill in simulating the precipitation frequency." And they added that (5) "similar to the single models, the frequency was also overestimated by the MMEs in the high- and low-latitude regions of East Asia," while last of all they reported that (6) "most of the models under-estimated the precipitation intensity over eastern China, Korea, Japan and their adjacent oceans."

Consequently, and in light of these many failures to adequately represent the real world, Chen and Sun had little choice but to conclude that (7) "similar to the results based on CMIP3 models, CMIP5 models also show no skill in simulating precipitation variation with time," and, therefore, they logically concluded that "more research is needed in the future to further improve the reliability of climate projections."

About this same time, Roehrig *et al*. (2013) analyzed the degree to which several models of the Coupled Model Intercomparison Project phase 5 (CMIP5) were able to reconstruct the past behavior of the West African Monsoon. And in so doing they found that (1) "CMIP5 climate change projections in surface air temperature and precipitation are found to be very similar to those of CMIP3," that (2,3) "as in CMIP3, the spread of model projections remains very large for both temperature and precipitation," that (4) "the precipitation response tends to be lower than the observed decadal variability in the second half of the twentieth century," that (5) "temperature changes also remain very uncertain," that (6) "CMIP5 coupled models still suffer major sea surface temperature biases in the equatorial Atlantic," that (7) "the averaged Sahel rainfall exhibits a large spread (±50%)," that (8) "the wrong phasing of the diurnal cycle of precipitation remains an issue," that (9) "most CMIP5 models ... have not reached yet a degree of maturity that directly makes them trustable to anticipate climate changes and their impacts," that (10) "many systematic and robust biases of the coupled and atmospheric models have not improved from CMIP3 to CMIP5," and that (11) "large surface radiative biases in arid and semiarid regions are a major issue in current simulations [as] they lead to departure from the observed radiative balance." And so it was that Roehrig *et al*. readily concluded that (12) CMIP5 models "demand further work to achieve a reasonable realism."

In a concomitant study of great similarity, Jones and Carvalho (2013) wrote that the SAMS (South American Monsoon System) "is the most important climatic feature in South America (Kousky, 1988; Horel *et al*., 1989; Zhou and Lau, 1998; Marengo *et al*., 2012) and provides water resources for the millions of people living in the continent (e.g., Berbery and Barros, 2002; Grimm, 2011; Jones *et al*., 2012)," further stating, therefore, that "documenting climate change in South America is necessary to motivate additional studies to further understand potential impacts on environment, societies, and economies."

Consequently, and "motivated by the availability of CMIP5 model simulations," Jones and Carvalho investigated the following two questions: "are there significant trends in the large-scale characteristics of the SAMS?" and "do CMIP5 climate models realistically simulate the observed characteristics of the SAMS?" And in studying these questions, the two researchers found that "some CMIP5 models have significantly improved their representation of the SAMS relative to their CMIP3 versions." *However*, they also noted that "several models have serious deficiencies," including (1) "excessive precipitation over northeast Brazil," (2) "displaced ITCZ [Inter-Tropical Convergence Zone]," (3) "double ITCZ," and (4) "too little precipitation over the eastern Amazon (near the mouth of the Amazon River)."

In discussing these findings, Jones and Carvalho wrote that (5) "the results of this study indicate lack of spatial agreement in the CMIP5 model projections of changes in total wet-season precipitation over South America." And, therefore, they concluded that (6) "how precipitation during the SAMS will change in the coming decades is still an open question."

Simultaneously studying another part of the world were Duan *et al*. (2013), who introduced the report of their work by writing that "the Tibetan Plateau (TP) monsoon is characterized by the remarkable seasonal alternations in wind and precipitation fields that occur over and around the plateau between winter and summer, with the most significant circulation differences in the surface pressure system," citing Tang *et al*. (1979), but adding that simulating monsoon systems "is one of the most challenging problems for atmospheric general circulation models (AGCMs) and coupled general circulation models (CGCMs)." So what, precisely, did the three researchers do? And what did they learn in the process?

In the words of Duan *et al*., "the extensive integrations produced for CMIP5 from the historical runs of 15 CGCMs and AMIP runs from eight AGCMs were used to evaluate the performance of state-of-the-art GCMs in simulating the climatology, annual cycle, interannual variability and trend of the TPSM [Tibetan Plateau Summer Monsoon]." And this work revealed that (1) "no single model consistently performed well in all aspects of the simulation," that (2) "a large bias still exists in the climate mean summer precipitation intensity," that (3) "the observed seesaw pattern in the interannual variability of the TPSM and EASM [East Asian Summer Monsoon] can be reproduced by only a few models," that (4) the simulated tropospheric warming trend of recent decades "was significantly larger than in the observational data," and that (5,6) "the observed cooling trend in the upper troposphere and the decline of the Tibetan high were not simulated by most of the GCMs." And in light of these findings, they felt compelled to conclude that (7) "significant scope still exists for improving the simulation by GCMs of TPSM precipitation and regional climate change, especially in very mountainous areas."

Shifting focus to the Indian Monsoon, Sabeerali *et al*. (2013) introduced their study of the subject by noting that "in almost all years, the onset of the Indian summer monsoon is triggered by a northward propagation of the wet phase of the BSISO [boreal summer intraseasonal oscillation] with considerable inter-annual variations," citing Goswami (2005) and Ajayamohan *et al*. (2008). And they indicated, in this regard, that considering the crucial role that the BSISO plays in the ASM [Asian summer monsoon], "the proper simulation of this variability in the state-of-the-art coupled GCMs is important for the short-term and long-term prediction of the ASM."

Following the implications of their thoughts on the matter, the six researchers evaluated the abilities of 32 CMIP5 models to simulate the BSISO by comparing their projections against observations covering the last twenty years. And this work revealed, in the words of the six scientists, that (1) "most of the models still have great difficulty to simulate the large-scale mean feature of precipitation over the ASM region," that (2) "the magnitude of the annual cycle varies from model to model," that (3) "most of the models underestimate (overestimate) the rainfall during the early (late) stages of the boreal summer monsoon season," that (4) "many models showed a remarkable dry bias over the eastern equatorial Indian Ocean and [5] wet bias over the southwestern equatorial Indian Ocean," that (6) "the majority of the models are unable to simulate the spatial pattern of BSISO variance over the ASM region," that (7) these biases are "mostly due to the erroneous representation of the seasonal mean precipitation," that (8) "many models failed to simulate realistic equatorial eastward propagation," that (9) "the simulated amplitude of the northward propagating band is weak in most of the models," that (10) "most of the models failed to simulate a realistic southward propagating mode as seen in observations," and that (11) "a fundamental error noted in many models is the incorrect evolution of the BSISO." And in light of these several negative findings, Sabeerali *et al*. were forced to conclude that (12) "many models still face difficulties" when it comes to simulating the BSISO.

In introducing their concomitant study of the subject, Sperber *et al*. (2013) wrote that "nearly half of the world's population is dependent on monsoon rainfall for food and energy security," and that "the vagaries of its timing, duration and intensity are of major concern, especially over semi-arid regions where agriculture is the primary source of food." And, therefore, they took it upon themselves to evaluate how well the boreal summer Asian monsoon is represented by 25 Coupled Model Intercomparison Project-5 (CMIP5) and 22 CMIP3 climate models. And what did they find as a result of this exercise?

The eight researchers reported that (1) "the onset of the monsoon over India is typically too late in the models," that (2) "the extension of the monsoon over eastern China, Korea, and Japan is under-estimated," while (3) "it is over-estimated over the subtropical western/central Pacific Ocean." They also noted that (4) "the anti-correlation between anomalies of all-India rainfall and Niño3.4 sea surface temperature is overly strong in CMIP3 and [5] typically too weak in CMIP5," that (6) "for both the ENSO-monsoon teleconnection and the East Asian zonal wind-rainfall teleconnection, the MMM [multi-model mean] inter-annual rainfall anomalies are weak compared to observations," and that (7) "simulation of intra-seasonal variability remains problematic."

In commenting on their several findings, Sperber *et al*. wrote that "the most important take away message is that in terms of the MMM, the CMIP5 models outperform the CMIP3 models for all of the diagnostics," which does indeed represent some degree of progress. But "even so," as they continued, they said that "there are systematic errors that are consistent between the two vintages of models." And these common errors, which are enumerated above, constitute what one could well call the *seven deadly sins* of the CMIP3 *and* CMIP5 climate models.

Therefore, and in a way that forgives the scientists who developed the 47 CMIP models with which they worked, and which continue to commit the seven deadly sins, Sperber *et al*. state that "given the multitude of physical processes and interactions that influence the monsoon, it is no wonder that simulation and prediction of the monsoon remain grand challenge problems," which one can only hope will someday be solved by some grand challenge scientists.

In a study published about the same time, Islam *et al*. (2013) wrote that "an intensive research effort has been made to improve simulation of monsoon systems by climate models," while also noting, in this regard, that "significant progress has been made in recent years." And, therefore, they said it was "of interest and importance to evaluate the ability of these new model versions," which is what they therefore did for Community Atmosphere Models (CAM4 and CAM5) and the most recent Community Climate System Model (CCSM4).

Focusing on the South Asian Monsoon (SAM), Islam *et al*. explored in detail "the strengths and limitations of CAM4, CAM5 and CCSM4 in simulating SAM precipitation with an emphasis on the mean climate, seasonal and inter-annual variability and the relationship between SAM and SST (sea surface temperature, local and remote) in the simulations." And what did they learn?

The following is what could well be called the models' *top ten embarrassments*. In the words of the three Canadian researchers, but with italics added, "both [1] CAM4 *and* [2] CAM5 poorly simulate the ENSO-monsoon teleconnection," while "over the SAM region their simulations show significant large-scale biases such as [3] excessive precipitation over the Arabian bay *and* [4] over the Western Ghats of India, *and* [5] reduced precipitation over the eastern Indian Ocean extending into the Bay of Bengal." In addition, they wrote that [6] "CCSM4 underestimated the precipitation over the equatorial area in the Pacific Ocean," and that [7] it "still has the double ITCZ [Intertropical Convergence Zone] problem that was also present in the previous versions of the CCSM model." Furthermore, they indicated that [8] "CCSM4 showed a systematic cold bias in the simulation of SSTs over the tropical Pacific Ocean" and that it [9] "showed problems in simulating the observed SST-precipitation relationship." And they wrote, last of all, that [10] "significant cold biases over the equatorial Pacific Ocean are found in CCSM4, particularly in winter and early summer."

When all was said and done, therefore, Islam *et al*. were forced to acknowledge -- in spite of some significant improvements over earlier versions of the three models they had studied -- that [11] "many biases are still present" and that [12] the latest versions of the models "still have simulation errors that need further consideration."

In another contemporaneous study, Brown *et al*. (2013) wrote that "the ability of coupled climate models to simulate the characteristics of the monsoon in present day climate is an important condition for the use of such models to make future climate projections." But they said that in the study of Smith *et al*. (2012) "the relationship between seasonal winds and rainfall was not always well represented," while adding that "the observed negative correlation between Indian rainfall and El Niño-Southern Oscillation (ENSO) events was ... too weak in CMIP5 models," citing Sperber *et al*. (2013). And in light of these problems, the four researchers went on to study the ability of 35 models from the Coupled Model Intercomparison Project Phase 5 (CMIP5) to simulate the western Pacific (WP) monsoon over four representative regions around Timor, New Guinea, the Solomon Islands and Palau," where "coupled model simulations [were] compared with atmosphere-only model simulations (with observed sea surface temperatures, SSTs) to determine the impact of SST biases on model performance."

As a result of these endeavors, the four Australian researchers report that they (1) "identified a number of biases including westerly summer monsoon winds that do not extend far enough east in many models," that they found that (2) "the AMIP [Atmospheric Model Intercomparison Project] models do not simulate the seasonal cycle of rainfall substantially better than CMIP5 [by] failing to capture the correct seasonal cycle over the Palau domain," that (3) "both CMIP5 and AMIP models appear to share problems in simulating the processes producing tropical rainfall, such as deep convection," that (4) CMIP5 models tend to simulate the boundary between positive and negative anomalies too far west," that this leads to (5) "incorrect sign anomalies over the Solomon Islands," and that (6) the models "substantially underestimate negative rainfall anomalies over the Maritime Continent region (including New Guinea and Timor)," all of which findings led them to conclude that "further investigation of the mechanisms determining the response of the monsoon in individual models is required to understand the reasons for model disagreement and to determine which aspects of projected monsoon change are most robust."

In yet another study published in the same year, this one focusing on the North American Monsoon System (NAMS), which covers an area that includes much of the Mexican Plateau and the Desert Southwest of the United States, the NAMS was modeled by both CMIP3 and CMIP5 participants. And in a study of the results of *those* studies (21 in number), Geil *et al*. (2013) examined the results that were obtained for precipitation, geopotential height and wind fields, in order to determine, as they phrased it, "how well this generation of general circulation models represents the NAMS."

Among their *top ten findings*, the three researchers reported that (1) "there has been no improvement in the magnitude (rms error and bias) of the mean annual cycle of monthly precipitation over the core NAMS region since CMIP3," that (2) "a few models do not have a recognizable monsoon signal at all," that (3) "the multimodel mean annual cycle is biased wet," that it (4) "exhibits the common problem of late monsoon termination," that (5) "the multimodel mean onset and retreat dates are 23 days early and 9 days late, respectively," that (6) "yearly model retreat variability is much greater than what is seen in the observations," that (7) "even the best models poorly represent monsoon retreat," that (8) there is a "prevailing wet bias in model precipitation," that (9) "neither the composite of best models nor the composite of worst models realistically captures the retreat of the NAMS because of an extended connection to tropical moisture that causes excessive fall and winter precipitation," and that (10) "even the highest resolution model examined is still too coarse to capture small-scale topographically-influenced processes." Hence, it would appear that essentially *all* of the CMIP5 models studied by Geil *et al*. continue to exhibit *several* of the Top Ten Shortcomings they discovered in their analyses of the models' abilities to simulate the defining characteristics of the North American Monsoon System.

Finally advancing to the next calendar year, Zhang and Zhou (2014) took part in evaluating the performance of supposedly "new-and-improved" versions of pre-existing climate models that many had hoped had gotten better at representing reality. And in doing so, they focused on Version 2 of the Flexible Global Ocean-Atmosphere-Land System model (FGOALS-s2) in simulating global monsoon precipitation (GMP).

This work revealed, as the two researchers reported, that "the main deficiency of FGOALS-s2 is that the northwestern Pacific monsoon (NWPM) has [1] a weaker monsoon mode and [2] a stronger negative pattern in spring-fall asymmetric mode," noting that "the smaller NWPM domain in FGOALS-s2 is due to [3] its simulated colder SST over the western Pacific warm pool," and that [4] "the simulated precipitation anomaly over the South African monsoon region-South Indian Ocean during La Niña years is opposite to the observation," which leads to [5,6] "stronger upper-troposphere (lower-troposphere) divergence (convergence) over the Indian Ocean, and [7**,**8] artificial vertical ascent (decent) over the Southwest Indian Ocean (South African monsoon region), inducing [9**,**10] local excessive (deficient) rainfall."

Consequently, and in spite of improvements in other modeling aspects that may have been made in progressing from FGOALS-s1 to FGOALS-s2, it would appear that there is still much that remains to be done before the newest version is truly ready for what could be called *prime-time applications*.

Also publishing a pertinent paper in the same year were Prodhomme *et al*. (2014), who began by noting that "the Asian Summer Monsoon is one of the most dominant tropical atmospheric circulations, and the economies and livelihoods of the populations of India and Southeast Asia depend heavily on its rainfall," citing Wang (2006). However, they noted that "important SST [Sea Surface Temperature] biases in coupled models drastically limit our understanding of the physical processes involved in the climate fluctuations, especially those associated with the ISM [Indian Summer Monsoon] and Indian Ocean Dipole," as reported by Bollasina and Nigam (2009), Fischer *et al*. (2005), Terray *et al*. (2012) and Levine and Turner (2012).

In this study, therefore, and according to Prodhomme *et al*., the impact of the ocean-atmosphere coupling on the atmospheric mean state over the Indian Ocean and the ISM was examined within the framework of the SINTEX-F2 coupled model through forced and coupled control simulations and several sensitivity-coupled experiments. And what were the pertinent findings of this effort?

Quoting the six scientists, they determined that (1) "during boreal winter and spring, most of the Indian Ocean biases are common in forced and coupled simulations, suggesting that the errors originate from the atmospheric model," that (2) "during boreal summer, the air-sea coupling decreases the ISM rainfall over South India and the monsoon strength to realistic amplitude, but at the expense of important degradations of the rainfall and SST mean states in the Indian Ocean," that (3) "strong SST biases of opposite sign are observed over the western (WIO) and eastern (EIO) tropical Indian Ocean," that (4) "rainfall amounts over the ocean (land) are systematically higher (lower) in the Northern Hemisphere," that (5) "the south equatorial Indian Ocean rainfall band is missing in the control coupled simulation," and that (6) "during boreal fall, positive dipole-like errors emerge in the mean state of the coupled model, with warm and wet (cold and dry) biases in the WIO (EIO), suggesting again a significant impact of the SST errors."

Also publishing near simultaneously, Kothe *et al*. (2014) wrote that "the West African Monsoon (WAM) is a seasonal wind reversal that is mainly caused by a temperature gradient between the ocean and land surface," whereby "high temperatures over the Sahara and Sahel region induce development of a heat low, which initiates a northward displacement of the inter-tropical convergence zone (ITCZ) and transport of moist air over West Africa," which phenomenon brings West Africa most of its precipitation.

Quoting Kothe *et al*., "this study investigated the WAM representation, and the impact of surface temperature uncertainties in three regional climate simulations with the model COnsortium for

Small-scale MOdelling-Climate Limited-area Model (COSMO-CLM)," where they said that "regional simulations were driven by present-day climate simulations with the global climate model ECHAM5, and by the re-analysis data ERA-Interim." And what did they thereby learn?

The three researchers reported that (1) "in large parts of the African tropics, precipitation was underestimated by up to 50%," that (2) "even larger overestimations occurred along the Western coastlines and the Ethiopian Highlands," that (3) "an overestimation of precipitation in the Sahel region resulted from a northerly overextension of the monsoon system in the model simulations," that (4) there was "a tendency of COSMO-CLM to produce too much convection," that (5) "precipitation was underestimated in large parts of the African tropics," that (6) there was "a negative bias (too low) in OLR [outgoing longwave radiation], arising from high convective clouds being far too optically thick (due to the excessive ice/liquid in the clouds)," that (7) there was "a negative bias in precipitation (too much condensed water stays in clouds and does not rain out)," that (8) "the convective activity of COSMO-CLM, measured by an OLR-based index, was especially over the Angola Basin much too high," that (9) "precipitation was underestimated in large parts of the continental African tropics," and that (10) "the model strongly overestimated convection in particular over the Gulf of Guinea."

In concluding their study, therefore, Kothe *et al*. wrote that "a lot of work has been done in the last years in the field of convection schemes (Braconnot *et al*., 2007; Zanis *et al*., 2009), but [1] the convection schemes are still a major error source," with the result that [2] "even with state-of-the-art climate models the simulation of complex atmospheric systems, such as the West African Monsoon, is still subject to errors (and will probably always be)."

In another contemporaneous study, Gong *et al*. (2014) noted that "the east Asian winter monsoon (EAWM) is an important system in the Northern Hemisphere during boreal winter" -- citing Lau and Li (1984), Chang *et al*. (2006) and Huang *et al*. (2012) -- which season, in their words, "is characterized by the cold Siberian high and the warm Aleutian low at the surface, the low-level northerlies or northeasterlies along the coast of East Asia in the lower troposphere, the East Asian trough in the mid-troposphere, and the East Asian jet stream in the upper troposphere," citing Chen *et al*. (2000), Jhun and Lee (2004), Kang *et al*. (2006) and Zeng *et al*. (2011). And proceeding from there, Gong *et al*. went on to describe how "model outputs from the Coupled Model Intercomparison Project (CMIP) phase 5 (CMIP5) are used to examine the climatology and inter-annual variability of the East Asian winter monsoon (EAWM)."

With respect to *unresolved difficulties* they encountered, the six Chinese scientists reported that (1) "the simulated surface air temperature still suffers from a cold bias over East Asia," that (2,3) "the inter-model spread is large for the lower-tropospheric meridional *wind* and *precipitation* along the East Asian coast," that (4) "the simulated variability is slightly weaker than in the observations," that (5) "the northeasterly anomalies over East Asia cannot be captured to the south of 30°N," due to what they call *inadequacies* of (6) "the EAWM index" and (7) "the ability of models to capture the EAWM-related tropical-extratropical interactions," that (8) "the models cannot capture the Pacific Decadal Oscillation," and, in much broader terms, that (9) the "changing ENSO-EAWM relationship can hardly be reproduced in CMIP models." And, therefore, as is being found to be the case by many other researchers involved in the testing of various state-of-the-art climate models, almost all of them have significant deficiencies that have yet to be fully rectified.

In a closely related study, Song and Zhou (2014) wrote that the East Asian summer monsoon (EASM) "is an important climate system and plays a crucial role in the livelihood of more than one billion people" -- citing Tao and Chen (1987), Webster *et al*. (1998) and Zhou *et al*. (2009) -- while noting that it exhibits "large inter-annual variability" and that the droughts and floods that sometimes accompany it "can cause great economic loss and casualty, such as drought in 1994 and flooding in 1998," as described by Park and Schubert (1997) and Zong and Chen (2000). So what, exactly, did Song and Zhou do?

As they described it, the climatology and inter-annual variability of the EASM were investigated "by using 13 atmospheric general circulation models (AGCMs) from phase 3 of the Coupled Model Intercomparison Project (CMIP3) and 19 AGCMs from CMIP5." And this work revealed, as they reported, that (1) "a northward shift of the western Pacific subtropical high" was "not reasonably reproduced," that (2) "the monsoon rainband known as mei-u**/**baiu**/**changma (28°-38°N, 105°-150°E) is poorly simulated," that (3) the observed dipole rainfall pattern is only "partly reproduced in CMIP3 and CMIP5," that (4,5) the pattern had "two deficiencies: a weaker magnitude and a southward shift of the dipole rainfall pattern," which were closely related to a (6) "weaker" and (7) "southward shift of the western Pacific anticyclone (WPAC)."

And so it seems that whatever advancements are achieved as climate models continue to be "perfected," there are always a handful of stubborn problems that either remain (or crop up) to plague the models' developers. And, therefore, we continue to review a number of other recent findings of this never-ending endeavor, beginning with the study of Ramesh and Goswami (2014), who appropriately noted that "accurate projections of regional climate systems, like the Continental Indian Monsoon (CIM), are critical for assessing the sustainability of a large section of the world's population and to determine the future of the global climate system," noting in this regard, however, that "assessing reliability of climate change projections, especially at regional scales, remains a major challenge."

Taking up this challenge, therefore, the two researchers noted that an important fact to be learned in this regard would be "the degree of progress made since the earlier IPCC simulations (CMIP3) to the latest recently completed CMIP5." And using the Continental Indian Monsoon as a case study, Ramesh and Goswami say they applied "a hierarchial approach for assessing reliability, using the accuracy in simulating the historical trend as the primary criterion" and considering only CIM rainfall (June-September), which "allowed a robust analysis with multiple sets of observations."

This work revealed, as they reported, that (1,2) "both CMIP3 and CMIP5 simulations exhibit large spreads in simulations of average monsoon rainfall and their inter-annual variability." In addition, they noted that (3) "the all-simulation ensemble of CMIP5 shows a decadal variability but with phases essentially opposite to those of observations," leading them to admit that (4) CMIP5 models "have poorer quality than the CMIP3 in simulating the observed features of CIM." And, therefore, Ramesh and Goswami were forced to report that their results showed that (5) “no significant progress has been achieved in our ability to simulate basic quantities like observed seasonal mean and trend, and hence to project the regional climate system, namely CIM, with reasonable certainty." which suggests that this aspect of the climate modeling enterprise of the past few years may have actually led to a bit of *retrogression* rather than *progression*.

But climate modelers never give up; and Syed *et al*. (2014) concomitantly assessed a number of uncertainties in *regional* climate models (RCMs) by analyzing the driving *global* data of ERA40 reanalysis and the output of ECHAM5 general circulation models in conjunction with the *downscaled* output of two RCMs (RegCM4 and PRECIS) over South-Asia for present-day simulations (1971-2000) of the South-Asian Summer Monsoon (SASM). And in doing so, the four Pakistani scientists determined that (1) "the RCMs have systematic biases" that (2) "seem to come from the physics parameterization of the RCMs," and that as a result, (3) "the RCMs are not able to capture the inter-annual variability," that (4) "RegCM4 has a cold bias over the whole domain," that (5) "this cold bias is more than 5°C over the high mountains in the north of Pakistan and India," that (6) "PRECIS has a warm bias of more than 2°C over the central parts of Pakistan," but that (7) "the cold bias over the northern high mountains is similar to that of RegCM4,"that (8) "the RegCM4 has a dry bias over central India," that (9) its penetration "into Pakistan is not very well simulated," that (10,11) "both the RCMs have poorly captured the inter-annual variability" of both temperature and rainfall, that (12) "both the RCMs show very low values of correlations, <0.5 over most of the selected regions," such that (13) "both the RCMs have systematic biases in simulating the SASM." And in light of these several findings, Syed *et al*. logically concluded that "further research is required to further understand the uncertainties in the RCMs and the driving GCMs."

In another contemporary study of the subject, Shashikanth *et al*. (2014) wrote that "Indian summer monsoon rainfall (ISMR) provides more than 80% of the total annual rainfall in the country [of India] and directly relates to water resources, agriculture, ecosystem, health and food security," citing Webster *et al*. (1998) and Turner and Annamalai (2012). And, therefore, they felt it important to compare the performances of the newer CMIP5 models with those of the older CMIP3 models, in order to see what progress may have been made in this ever-evolving field of research.

More specifically, as Shashikanth *et al*. reported, a comparative study of ISMR projections was performed with the original ISMR results derived from the two sets of general circulation models (CMIP3 and CMIP5) and the statistically downscaled outputs of five GCMs from each of the two CMIP populations. And this work revealed that (1) the multi-model average of the more recent CMIP5 simulations did not exhibit any visible improvements in bias over the older CMIP3 simulations. In addition, they also noted that the CMIP5 simulations (2) "have more multi-model uncertainty than those of CMIP3."

As stated in their concluding remarks, therefore, Shashikanth *et al*. indicated that their results highlight the facts that "even with the improvements in understanding of climate physics of

CMIP5 (Taylor *et al*., 2012), the simulations of ISMR with coarse resolution climate models have become *worse,* with [1] similar bias, but with [2] higher uncertainties."

Also with a pertinent publication in the same year were Feng *et al*. (2014), who wrote that "the East Asian summer monsoon (EASM) is a distinctive component of the Asian climate system," which they indicated is "characterized by wind reversal and heavy precipitation during summer over East Asia," citing Lau and Li (1984). And while further noting that "the evolution and variability of the monsoon have a big impact on human society across the region," they also suggested that "better prediction of the monsoon's variation may greatly benefit those people inhabiting the region."

Consequently, and in a quest to determine the abilities of atmospheric general circulation models (AGCMs) to capture the major features of the EASM, ten different models that participated in the *Coupled Model Intercomparison Project***/***Atmospheric Model Intercomparison Project* (CMIP5**/**AMIP) -- which used observational sea surface temperature (SST) and sea ice data to drive the AGCMs during the period 1979-2008 -- were evaluated by comparing their outputs with observations and AMIP II simulations.

This work revealed -- in regard to model *shortcomings* in the Meiyu**/**Changma**/**Baiyu rainbelt -- that (1) "the intensity of rainfall is underestimated in all the models," that these biases are caused by (2) "a weak western Pacific subtropical high" and (3) "accompanying eastward southwesterly winds in group I models," as well as by (4) "a too strong and west-extended western Pacific subtropical high," plus (5) "westerly winds in group II models." In addition, they reported that (6) "considerable systematic errors exist in the simulated seasonal migration of rainfall," and that (7) "notable northward jumps" and (8) "rainfall persistence remain a challenge for all the models." And in light of these several model deficiencies, it is clear that the world's climate modelers have not yet acquired the knowledge needed to accurately represent the many facets of the various phenomena that converge to establish the ever-shifting nature of different aspects of earth's complex climate system, as represented in *this* study of the East Asian summer monsoon.

In another revealing paper from the same time period, Abhik *et al*. (2014) wrote that the Indian Summer Monsoon (ISM) experiences what they refered to as Boreal Summer Intra-Seasonal Oscillations (BSISOs), which manifest themselves "in the form of enhanced (active) and reduced (break) spells of precipitation over the central and northern regions of the Indian subcontinent," as described by Ramamurthy (1969). But they stated that "the ability to represent the complexity of the BSISO in the current general circulation models (GCMs) remains a great challenge," citing the studies of Waliser *et al*. (2003), Kim *et al*. (2008), Lin *et al*. (2008), Sperber and Annamalai (2008), Goswami (2011), Jiang *et al*. (2011) and Joseph *et al*. (2012). In *their* study of the subject, therefore, Abhik *et al*. attempted to diagnose the BSISO simulation in an AGCM at two different vertical resolutions, choosing for this task the ECHAM5 model described by Roeckner *et al*. (2003, 2006), because they said that it "shows certain ability to reproduce some of the features of the BSISO" and "is among the few AGCMs which have a reasonable cloud microphysics to include the warm and cold cloud processes."

In describing what they thereby learned, the three researchers reported that the ECHAM5 model had (1,2) "a significant problem in simulating JJAS mean precipitation and low-level specific humidity," that at both of the vertical resolutions it (3) "overestimates the seasonal mean precipitation over the ocean," but that it (4) "underestimates the precipitation over the Indian landmass," that (5) "moderate rain events are less frequent than the observed," that (6) "over-estimation of the heavy precipitation degrades the skill over the Bay of Bengal," that (7) "overestimation of the lighter rainfall and shallow heating distribution indicate the lack of 'slow moistening processes' in the model," that (8) "lower atmospheric moisture distribution in the model sharply contrasts with observations," that (9) "the model systematically underestimates the mean meridional specific humidity gradient," that (10) there is an "erroneous simulation of the mean low-level moisture," that (11) "ECHAM5 produces weaker spectral peaks for both meridional as well as zonally propagating components of the BSISO," that (12) "both northward propagation and eastward propagation appear at lower frequencies than in observations," that (13) "spectral power is about 40% less than [that of] the observations," that (14) ECHAM5 "fails to show the eastward propagation of the convection across the Maritime Continent," that (15) "the model shows unrealistic westward propagation that originates over the tropical western Pacific region," that (16,17) "the model fails to capture the observed phase-relationship of the dynamical as well as the thermodynamical parameters associated with the northward propagation," that (18) "the model also fails to reproduce the lower atmospheric convective instability that is conducive for triggering the new convection ahead of the existing convection," that (19) there is an "unusual tilting of the rainband" that is different "than the observed," that (20) "the asymmetric meridional moisture distribution is found to be shallower in the model," and that (21) vertical moisture transport "is also simulated weaker than the observed."

This study by Abhik *et al*. clearly illustrates the *fact* that in spite of all that the world's climate modelers have accomplished in many different areas, they have only just *begun* to traverse the long-and-winding road that leads to ultimate climate modeling success; for as they learn ever more about the various facets of Earth's climatic system, they begin to discover there is even more out there in the 'great beyond' that they must successfully reduce to functionally-correct mathematical expressions that can be incorporated into their computer-driven models.

In a contemporary study of monsoonal rainfall over India, Nair *et al*. (2014) noted that atmospheric general circulation models (GCMs) have historically had "serious difficulties in correctly reproducing monthly or seasonal precipitation," citing the findings of Wang *et al*. (2008); and, therefore, they set out to further explore what advances may have been made in this area of climatological research over the intervening six years, in a study where they said that "precipitation outputs from retrospective seasonal forecasts made by nine GCMs are used to investigate historical Indian summer monsoon seasonal rainfall variability and predictability over India." And what did they thereby learn?

Nair *et al*. reported that (1) "most of the models are not able to simulate the climatological mean rainfall structure," that (2) over North India "predicted magnitudes are also underestimated," that (3) the inter-annual variability (IAV) of JJAS seasonal precipitation ranges from 0 to 10 mm**/**day *in reality*, whereas in the *models* "it is from 0 to 2 mm**/**day," such that all of the tested models (4) "underestimate the observed all-India precipitation," along with (5) "its variability," that (6) "all these models tend to exaggerate the ENSO teleconnection pattern," that (7) they "are not able to simulate the weakening of ENSO's influence on the Indian monsoon in the recent decades," that (8,9) "the monsoon meridional circulation and its related convective activity over the monsoon region need to be modelled in a better way," that (10) "there is still inadequacy in GCM performance and understanding of the monsoon dynamics," that (11) "there is a need to diagnose the GCM's outputs, in order to bring out their flaws," that (12-15) the models' ensemble mean or MME "is not able to simulate the climatology, IAV, temporal evolution and trend of observation," that (16) "the models are overly biased towards stronger ENSO's influence, with (17) "characteristic ENSO SST anomaly patterns much stronger than those observed." Last of all, therefore, in the concluding sentence of their paper, Nair *et al*. wrote that their results suggest that "the air-sea coupled processes associated with the DMI [dipole mode index], moisture fluxes and convection associated with monsoon meridional circulation need to be improved in the models in order to better simulate**/**predict the monsoon rainfall over India."

In another contemporary study of the thorny subject, Wei *et al*. (2014) noted that the East Asian Winter Monsoon (EAWM) influences not only East Asia but also convection and sea surface temperatures near the maritime continent (Chang *et al*., 1979; Bueh and Ji, 1999), the Australian summer monsoon (Zhang and Zhang, 2010), the climate of North America (Yang *et al*., 2002) the evolution, intensity and periodicity of ENSO (Lau and Peng, 1987; Huang *et al*., 2004; Li *et al*., 2007) and the Asian Summer Monsoon (Sun and Sun, 1994; Chen *et al*., 2000; Yan *et al*., 2011), which facts point to the importance of climate models being able to adequately represent the EAWM, which much-needed skill is the reason why Wei *et al*. conducted *their* evaluation of the abilities of the most up-to-date CMIP5 models (plus some earlier CMIP3 models) to accomplish this important task.

This significant endeavor revealed that (1) "both the CMIP3 and CMIP5 models overestimate the precipitation over the East Asia oceanic region, that (2) "the overestimation of precipitation by the CMIP3 and CMIP5 models is most likely due to the overestimation of convective clouds in East Asia," that in the case of the CMIP5 models (3) "the near surface northerlies are weaker than suggested by observations and the CMIP3 models," that (4) "the zonal sea level pressure difference between the Siberian high and Aleutian low is weaker than in observations and the CMIP3 models," that (5) the 500-hPa major trough strength is too strong in East Asia," and that (6) "the cold bias still exists in the current CMIP5 models." And in light of these multiple and demonstrable s*hortcomings* – plus the actual *regressions* noted in points 3 and 4 above – the five Chinese scientists concluded that "additional model improvements are still required to better simulate the EAWM."

Moving on -- and in prefacing *their* work on the subject -- Sandeep and Ajayamohan (2014) wrote that "sea surface temperature (SST) biases are arguably the most prominent error in Coupled General Circulation Model (CGCM) simulations," citing Large and Danabasoglu (2006), while further noting that these biases "can result in amplification of model error due to the feedback between different components of the climate system," citing Cai *et al*. (2011). More specifically, they reported that (1) a "tropics-wide bias in SSTs in the fifth phase of the Coupled Model Intercomparison Project (CMIP5) models has been traced to [2,3] biases in the simulations of clouds and thermocline depth by the coupled models," citing Li and Xie (2012). And they additionally noted that (4,5) both "local and large-scale oceanic and atmospheric processes are dominant elements for the SST biases," citing the findings of Toniazzo and Woolnough (2013), Xu *et al*. (2013) and Vanniere *et al*. (2014).

To further explore this important issue, therefore, Sandeep and Ajayamohan focused on "the pre-monsoon SST bias over the Arabian Sea in CMIP5 historical simulations," specifically studying "the possible presence of an equator-ward bias in STJs [Sub-Tropical Jet Streams]," in view of "the wake of known biases in ITCZ and eddy driven jets," citing Ceppi *et al*. (2013) and Hwang and Frierson (2013). And what rewards did these efforts yield them?

The two researchers found that the biases in the location and strength of the STJs "are explained by the location of northern hemispheric Hadley Cell subsidence," while "biases in the strength and location of Hadley Cell subsidence may be linked to the biases in the radiative forcing," citing Hwang and Frierson (2013). In addition, they wrote that "the equator-ward shift coupled with enhanced strength of the subtropical jet produce a stronger upper tropospheric convergence, leading to a subsidence and divergence at lower levels over the Arabian deserts," such that "the low entropy air flowing from the Arabian land mass cools the northern Arabian Sea." And they said that "the weaker meridional temperature gradients in the colder models substantially weaken Indian Summer Monsoon precipitation," all of which leads one to wonder when we will ever be able to say "bye, bye to biases" in the ever-evolving -- but never quite getting there -- climate models.

About this same time, Yang and Riyu (2014) wrote that the East Asian Winter Monsoon (EAWM) "is an important climate feature over East Asia, and is one of the most significant components of the global circulation system," citing Huang *et al*. (2003), Chan and Li (2004), Chang *et al*. (2006) and Huang *et al*. (2007). And in light of this fact, they thought it important to investigate the seasonal predictability of various EAWM indices based on hindcasts of five state-of-the-art global coupled atmosphere-ocean climate models for the 46-year period of 1961-2006, which "fully coupled prediction systems," as they described them, "come from a new seasonal-to-annual multi-model named ENSEMBLES" that was developed by "an EU-funded integrated project" that is described by van der Linden and Mitchell (2009). And what did they thereby learn?

The two Chinese researchers reported that the ENSEMBLES multi-model predicted 5 out of the 21 EAWM indices rather well. *However*, they discovered that (1) *all other indices* exhibited *low* predictability, including "two residual lower-tropospheric wind indices and all the east-west pressure gradient and East Asian trough indices." They also discovered that (2) "the prediction skill for surface air temperature is low over the majority of the East Asian region." And they found that (3) "the models cannot reproduce the observed relationship between the indices in different categories, implying that (4) the current models may not capture the tropical-extratropical interaction related to the EAWM variability."

In light of these several negative findings, the two climate scientists concluded their paper by stating the obvious, i.e., that "the relationship between EAWM predictability and atmosphere-ocean interaction needs to be further investigated." Indeed, success in only *five* out of a total of *twenty-one separate challenges* is a far, far cry from satisfactory.

In one final bad-news message to come out of 2014, Saha *et al*. wrote that "the impacts of climate change on Indian Summer Monsoon Rainfall (ISMR) and the growing population pose a major threat to water and food security in India," *noting* that "adapting to such changes needs reliable projections of ISMR by general circulation models." However, they further noted that their analysis of the subject indicated that (1) the majority of CMIP5 models simply "fail to simulate the post-1950 decreasing trend of the ISMR," as does their multi-model average.

As for why this was so, the four Indian scientists stated that the weakening of the monsoon is associated with "the warming of the Southern Indian Ocean and strengthening of cyclonic formation in the tropical Pacific Ocean," while acknowledging that (2) "these large-scale changes are not captured by CMIP5 models," which was, pure and simple, "the reason of this failure," as they put it. As for the *ramifications* of their findings, Saha *et al*. concluded that (3) "using CMIP5 multi-model projections of ISMR for adaptation planning may lead to incorrect policies." And with potential major *threats* to food and water security in India, that message is not going to help the country very much, *if at all!*

Finally moving out of 2014, and writing in the *Journal of Meteorological Research*, Li *et al.* (2015) noted that "the South Asian Summer Monsoon (SASM) is a major component of the Asian-Australian monsoon system [that] dominates the rainfall distribution over South Asia and has important economic and social effects," citing Wu *et al.* (2009), after which they described how they assessed the abilities of CMIP5 models to reproduce the features of the SASM, El Niño, and their various connections. And what did they learn from this exercise?

Their efforts revealed, in the words of the four Chinese researchers, that (1) "the main rainfall period from the multi-model ensemble mean lags that of the reanalysis [data] by one month," that "in most of the models" the magnitudes of (2) SST, (3) precipitation and (4) atmospheric circulation in an El Niño event "are underestimated," and that (5) "if the external forcing is moderate, the change of correlation between El Niño and SASM is difficult to ascertain."

And so they concluded -- and not surprisingly -- that "further diagnostic work on the relationship between snow and SASM in CMIP5 is clearly required." But after so many years of *failing* to accomplish what is clearly *needed*, one wonders if the world's climate models will *ever* get to the point where they can *accurately* forecast Earth's climate.

Working at institutions located in four different countries (Belgium, India, South Korea and the United Kingdom), Singh *et al*. (2015) assessed the skills of 11 Asia-Pacific Economic Cooperation Climate Center (APCC) global climate models (both coupled and uncoupled) in simulating the seasonal summer (June-August) monsoon rainfall variability over Asia (especially over India and East Asia) based on analyses of hind-cast data (3 months advance) generated from APCC models that provide regional climate product services based on "multi-model ensemble dynamical seasonal prediction systems." And what did that assessment reveal?

When all was said and done, Singh *et al*. reported that (1,2) "the majority of the models have negative bias over some parts of the Asian land mass and over equatorial zones (Indian and west Pacific Oceans)," that (3,4) "large variability in simulated Asian summer monsoon rainfall was found from model to model and from region to region in uncoupled models compared to coupled models," that (5) "most of the models underestimated the rainfall over high rainfall belts," that (6) "atmospheric chaotic dynamics uncertainties in the representation of unresolved sub-grid scales in the models may cause large bias in the models," that (7) there were "large spreads in individual members of the model," and that (8) "these spreads were as large as the spread of ensemble means of different models," that there was (9) "a large variation in producing inter-annual variability especially over Indian and west Pacific Oceans," potentially due to (10) "poor representation of air-sea interaction," and that (11) "the exact amount of simulated summer monsoon rainfall in the multi-model ensemble over Asia is not fully captured."

And, therefore, in light of their many negative findings, Singh *et al.* concluded that "there is a need to fully understand the physical processes used for improving the individual model skills rather than the methods of multi-model ensemble for producing better seasonal rainfall prediction systems."

Last of all, writing in the *Journal of Climate*, Li *et al*. (2015) described how a common equatorial easterly wind bias forces a westward-propagating down-welling Rossby wave in the southern Indian Ocean (IO) that “induces too deep a thermocline dome over the southwestern IO (SWIO) in state-of-the-art climate models.” And they indicated that “such a deep SWIO thermocline weakens the influence of subsurface variability on sea surface temperature (SST), reducing the Indian Ocean Basin (IOB) amplitude and possibly limiting the models’ skill of regional climate predictions.”

In further studying this knotty problem, they also noted that (1) “the westerly wind over the equatorial IO is too weak during SON [Sept, Oct, Nov] in most CMIP5 CGCMs [coupled general circulation models],” that (2) “the deep thermocline dome bias over the SWIO in CMIP5 CGCMs could significantly reduce the effect of subsurface thermocline variability on SST [sea surface temperature] there,” that (3) “too weak a thermocline-SST feedback over the SWIO in CMIP5 CGCMs results in a deficiency in the simulated amplitude for the IOB mode of inter-annual variability,” that this phenomenon (4) “also lowers their skill in predicting the IOB warming following El Niño,” that (5) “the easterly wind error in CGCMs can result in a too steep eastward shoaling of [the] thermocline in the equatorial IO,” that (6) “the unrealistically steep thermocline slope generates too strong a thermocline feedback on SST,” and thus (7) “develops an excessively large IOD amplitude of inter-annual variability in CGCMs,” which (8) “exerts profound social and economic consequences for the IO rim countries such as Indonesia and Kenya,” that (9) the “too weak cross-equatorial easterly wind bias can be traced back to errors in the South Asian summer monsoon,” that (10) the “too weak cross-equatorial monsoon over the western basin in JJA [Jun, Jul, Aug] causes a sustained warm SST bias in the western equatorial IO,” that (11) “in SON, Bjerknes feedback helps amplify this SST error into an IOD-like pattern," with (12) "a strong equatorial easterly bias accompanied by a physically consistent bias in the precipitation dipole."

And these results, in the words of the three Chinese researchers, "imply that reducing the monsoon errors in CGCMs will improve climate simulation and prediction for the IO and rim countries, and increase our confidence in their application for regional climate projection." But in light of the multiple problems that remain to be resolved – and if past is prologue to the future – that confidence may well be weakened, or possibly even *shattered*, before we're half-way there.

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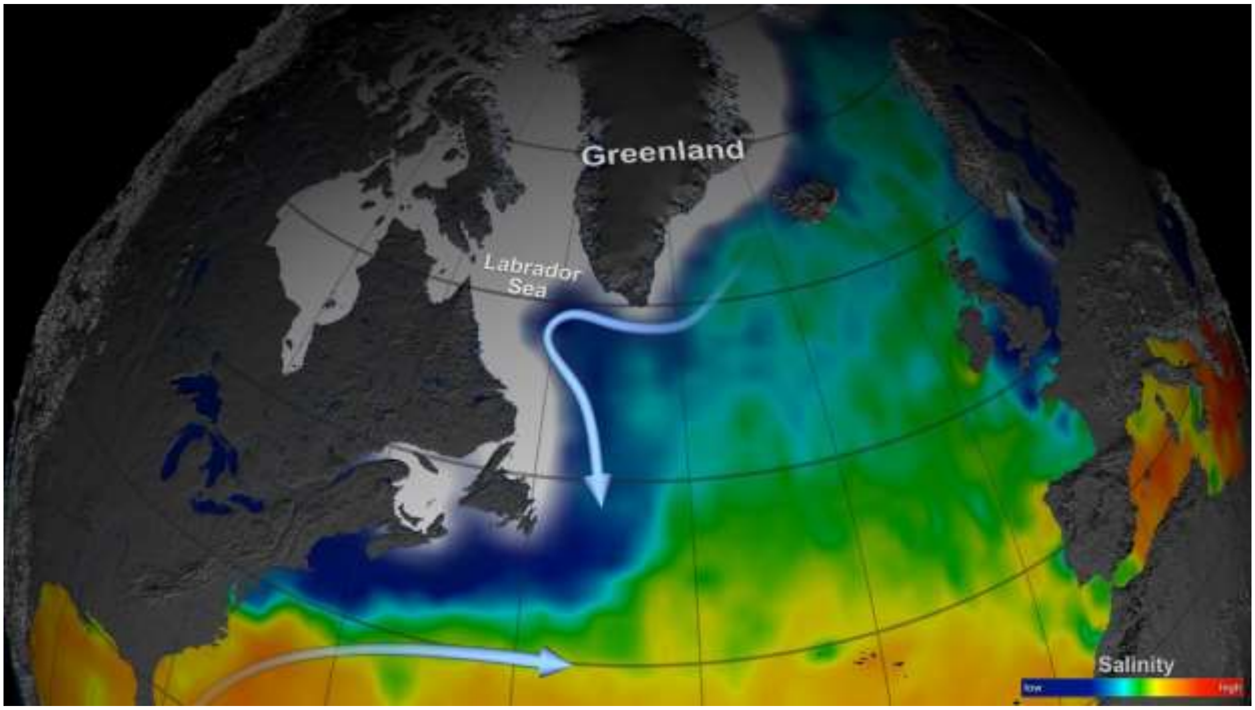

The ongoing role of the world's oceans in determining the future climatic history of the earth begins here with the study of Lui *et al*. (2008), who assessed how well state-of-the-art coupled global climate models were reproducing the annual mean, seasonal cycle, variability and trend of observed surface air temperatures [SATs] over the Arctic Ocean throughout the late 20th century, where sea ice changes had been largest. And in doing so, they discovered that (1) "large uncertainties are still found in simulating the climate of the 20th century," while noting that on an annual basis (2) "almost two thirds of the IPCC AR4 [Fourth Assessment Report] models have biases that [are] greater than the standard deviation of the observed SAT variability," while additionally noting that the models (3,4) "cannot capture the observed dominant SAT mode variability in winter and seasonality of SAT trends," while further noting that (5) "the majority of the models show an out-of-phase relationship between the sea ice area and SAT biases," and that (6) "there is no obvious improvement since the IPCC Third Assessment Report."

Three years later, Furtado *et al*. (2011) wrote that the North Pacific Decadal Variability (NPDV) "is a key component in predictability studies of both regional and global climate change," noting that "two patterns of climate variability in the North Pacific generally characterize NPDV," with these two "dominant modes" being the Pacific Decadal Oscillation (PDO; Mantua *et al*., 1997) and the recently identified North Pacific Gyre Oscillation (NPGO; Di Lorenzo *et al*., 2008). And they *emphasized* that given the links between both the PDO and the NPGO with global climate, the accurate characterization and the degree of predictability of these two modes in coupled climate models is an important "open question in climate dynamics" that needs to be addressed.

Furtado *et al*. thus investigated this situation by comparing the output from the 24 coupled climate models used in the IPCC AR4 with observational analyses of sea level pressure (SLP) and sea surface temperature (SST), based on SLP data from the National Centers for Environmental Prediction (NCEP)-National Center for Atmospheric Research (NCAR) Reanalysis Project (Kistler *et al*., 2001), and SST data from the National Oceanic and Atmospheric Administration (NOAA) Extended Reconstruction SST dataset, version 3 (Smith *et al*., 2008), both of which datasets contained monthly mean values from 1950-2008 gridded onto a global 2.5° x 2.5° latitude-longitude grid for SLP and a 2° x 2° grid for SST.

As a result of this work, the four U.S. scientists discovered that (1) model-derived "temporal and spatial statistics of the North Pacific Ocean modes exhibit significant discrepancies from observations in their twentieth-century climate, most visibly for the second mode, which has [2] significantly more low-frequency power and higher variance than in observations." They also found that (3) the two dominant modes of North Pacific oceanic variability "do not exhibit significant changes in their spatial and temporal characteristics under greenhouse warming," stating that (4) "the ability of the models to capture the dynamics associated with the leading North Pacific oceanic modes, including their link to corresponding atmospheric forcing patterns and to tropical variability, is questionable."

But there were even *more* "issues with the models," in the words of Furtado *et al*., who wrote that (5) "in contrast with observations, the atmospheric teleconnection excited by the El Niño-Southern Oscillation in the models does not project strongly on the AL [Aleutian low]-PDO coupled mode because of [6] the displacement of the center of action of the AL in most models." In addition, they noted that (7) "most models fail to show the observational connection between El Niño Modoki-central Pacific warming and NPO [*North Pacific Oscillation*] variability in the North Pacific." In fact, they stated that (8) "the atmospheric teleconnections associated with El Niño Modoki in some models have a significant projection on, and excite the AL-PDO coupled mode instead."

Furtado *et al*. thus concluded that (9) "for implications on future climate change, the coupled climate models show no consensus on projected future changes in frequency of either the first or second leading pattern of North Pacific SST anomalies," and they noted that (10) "the lack of a consensus in changes in either mode also affects confidence in projected changes in the overlying atmospheric circulation." In addition, they stated that (11) the lack of consensus they found "mirrors parallel findings in changes in ENSO behavior conducted by van Oldenborgh *et al*. (2005), Guilyardi (2006) and Merryfield (2006)," further stating that (12) these significant issues "most certainly impact global climate change predictions." And they impact them in *a highly negative way*.

Concurrently, while noting that climate in the Southeast Pacific (SEP) near the coast of Peru and Chile "is controlled by complex upper-ocean, marine boundary layer and land processes and their interactions," Zheng *et al*. (2011) wrote that variations in this system have "significant impacts on global climate," citing Ma *et al*. (1996), Miller (1977), Gordon *et al*. (2000) and Xie (2004). However, they noted that (1) "it is well known that coupled atmosphere-ocean general circulation models tend to have systematic errors in the SEP region, including [2] a warm bias in sea surface temperature and [3] too little cloud cover," as demonstrated by Mechoso *et al*. (1995), Ma *et al*. (1996), Gordon *et al*. (2000), McAvaney *et al*. (2001), Kiehl and Gent (2004), Large and Danabasoglu (2006), Wittenberg *et al*. (2006) and Lin (2007). And even though these biases have what they called "important impacts" on the simulation of earth's radiation budget and climate sensitivity, they said that (4) "it is still uncertain" whether a similar bias is evident in most state-of-the-art coupled general circulation models [CGCMs] and to what extent the sea surface temperature [SST] biases are model dependent."

Hoping to lessen this uncertainty, and based on 20-year (1980-1999) model runs of the "Climate of the Twentieth Century" simulations of the nineteen CGCMs that figured prominently in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), Zheng *et al*. examined systematic biases in SSTs under the stratus cloud deck in the SEP and upper-ocean processes relevant to those biases, attempting to isolate their causes. And what did they find in so doing?

The four U.S. researchers learned that (1) "pronounced warm SST biases in a large portion of the southeast Pacific stratus region are found in all models," that (2) "negative biases in net surface heat fluxes are evident in most of the models," that (3) "biases in heat transport by Ekman currents largely contribute to warm SST biases both near the coast and the open ocean," that (4) "in the coastal area, southwestward Ekman currents and upwelling in most models are much weaker than observed," that (5) "in the open ocean, warm advection due to Ekman currents is overestimated," that (6) "negative biases (cooling the ocean) in net surface heat flux are found in most CGCMs," that (7) "positive biases in shortwave radiation are found in most models," because (8) most models "do not generate sufficient stratus clouds," and, last of all, that (9) "most CGCMs underestimate alongshore winds and coastal upwelling."

With such unresolved problems associated with nearly all of the CGCMs that were employed in the preparation of the IPCC's AR4 Report, and which pertain to processes that are said to have *important impacts* on earth's *climate sensitivity*, it is no wonder that the projections of those models are greeted with a solid dose of skepticism by those who realize that it is the height of folly to use the output of such imperfect models as the reason for wanting to *entirely restructure* the way mankind acquires the energy that makes possible our current level of industrial and technological development.

In some other studies from the same time period, Dare and McBride (2011) and Park *et al*. (2011) demonstrated that tropical cyclones (TCs) can significantly cool the surface waters in their wakes for periods of several days to weeks, while Manucharyan *et al*. (2011) wrote that "TC-induced ocean mixing can have global climate impacts as well, including changes in poleward heat transport, ocean circulation, and thermal structure." The latter researchers also noted that "in several previous modeling studies devoted to this problem, the TC mixing was treated as a permanent (constant in time) source of additional vertical diffusion in the upper ocean," and, therefore, they went on to explore what they called the "highly intermittent character of the mixing" and what it likely portended for global climate, using a global ocean-atmosphere coupled model and a simple heat transfer model of the upper ocean. So what did they therefore do? And what did they thereby learn?

The three U.S. researchers mimicked the effects of tropical cyclones using several representative cases of time-dependent mixing that yield the same annual mean values of vertical diffusivity, conforming with the studies of Jansen and Ferrari (2009) and Fedorov *et al*. (2010), wherein spatially uniform (but varying in time) mixing is imposed on zonal bands in the upper ocean. This work revealed "a weak surface cooling at the location of the mixing (~0.3°C), a strong warming of the equatorial cold tongue (~2°C), and a moderate warming in middle to high latitudes (0.5°C-1°C)," together with "a deepening of the tropical thermocline with subsurface temperature anomalies extending to 500 m [depth]." And they said that "additional mixing leads to an enhanced oceanic heat transport from the regions of increased mixing toward high latitudes and the equatorial region."

So what did it all mean? "Ultimately," in the words of the researchers, "simulations with TC-resolving climate models will be necessary to fully understand the role of tropical cyclones in climate," for they noted, in this regard, that (1) "the current generation of GCMs are only slowly approaching this limit and are still unable to reproduce many characteristics of the observed hurricanes, especially of the strongest storms critical for the ocean mixing (e.g., Gualdi *et al*., 2008; Scoccimarro *et al*., 2011)."

One year later, Weijer *et al*. (2012) had a paper published in which they wrote that "the Southern Ocean is a region of extremes: it is exposed to the most severe winds on the earth (Wunsch, 1998), the largest ice shelves (Scambos *et al*., 2007), and the most extensive seasonal sea ice cover (Thomas and Dieckmann, 2003)." They also noted that various interactions among the atmosphere, ocean, and cryosphere in this region "greatly influence the dynamics of the entire climate system through the formation of water masses and the sequestration of heat, freshwater, carbon, and other properties (Rintoul *et al*., 2001)." And so it was thus only natural, as they noted, that they "explored several key aspects of the Southern Ocean and its climate in the new Community Climate System Model, version 4 (CCSM4)," including "the surface climatology and inter-annual variability, simulation of key climate water masses (Antarctic Bottom Water [AABW], Subantarctic Mode Water [SAMW], and Antarctic Intermediate Water [AAIW]), the transport and structure of the Antarctic Circumpolar Current [ACC], and inter-basin exchange via the Agulhas and Tasman leakages and at the Brazil-Malvinas Confluence [BMC]." And what did they find in doing so?

The nine researchers stated that "the CCSM4 has varying degrees of accuracy in the simulation of the climate of the Southern Ocean when compared with observations," noting that (1) "the seasonally ice-covered regions are mildly colder (ΔSST > -2°C) than observations," that (2) "sea ice extent is significantly larger than observed," that (3,4) "north of the seasonal ice edge, there is a strong (-4°C < ΔSST < -1°C) cold bias in the entire Pacific sector south of 50°S and in the western Australian-Antarctic Basin," that (5,6) "positive biases (1° < ΔSST < 4°C) are found in the Indian and Atlantic sectors of the Southern Ocean," that (7,8) "significant differences are found in the Indian and Pacific sectors north of the ACC, with the CCSM4 model being too cold (< -2°C) and fresh (<-0.3 psu)," that (9) "AABW adjacent to the Antarctic continent is too dense," that (10) "North Atlantic Deep Water is too salty (>0.2 psu)," that (11,12) "in the Indian and Pacific sectors of the Southern Ocean, north of 50°S and below 3000 meters, the too-salty AABW penetrates northward, resulting in a denser-than-observed abyssal ocean in CCSM4,"that (13,14) "the model underestimates the depth of the deep winter mixed layers in the Indian and eastern Pacific sectors of the Southern Ocean north of the ACC," that (15,16) "in the southern Tasman Sea and along the eastern Indian Ocean boundary ... the model mixed layer depth is deeper than observed by more than 400 meters," that (17) "in all sectors of the Southern Ocean, Model CFC-11 concentrations in the lower thermocline and intermediate waters are lower than observed," that (18) "model CFC-11 concentrations in the deep ocean (below 2000 meters) are lower than observed in the basins adjacent to the Antarctic continent," that (19) "model surface CFC-11 concentrations are higher than observed," that (20) "the production of overflow waters in the Ross Sea is too low by about a factor of 2 relative to the limited observations," that (21) "the depth at which the product water settles was also shown to be too shallow by about a factor of 2," that (22) "the subtropical gyre of the South Atlantic is too strong by almost a factor of 2, associated with a strong bias in the wind stress," that (23) the mean position of the BMC is too far south in the CCSM4," and that (24) "the model variability in the position of the BMC is significantly less than observations."

And in light of these many disappointing findings, Weijer *et al*. concluded that as the CCSM4 currently stood, it (25-27) "may underestimate the sequestration of heat, carbon, and other properties to the interior ocean," with the result that its parameterizations may (28) "lead to significant biases in the representation of the Southern Ocean and its climate."

About this same time, Zheng *et al*. (2012) had a paper published in which they wrote that "the equatorial Pacific is observed to have a minimum sea surface temperature (SST) that extends from the west coasts of the Americas into the central Pacific," which "extension of cool water is commonly referred to as the cold tongue (Wyrtki, 1981)." And they also indicated that "it is generally argued that the Pacific cold tongue is maintained by horizontal advection of cold water from the east and by upwelling of cold water from the subsurface."

Driven to learn more about this phenomenon, Zheng *et al*. examined "the contribution of ocean dynamics to sea surface temperature biases in the eastern Pacific cold tongue region in fifteen coupled general circulation models (CGCMs) participating in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4)," analyzing twenty years (1980-1999) of twentieth-century climate simulations from each model.

In describing what the three researchers learned, we quote them directly; but we add italics to the many words they used that were indicative of various *failures* of the models to do specific things correctly. In their words, then, (1,2) "e*rrors* in both net surface heat flux and total upper ocean heat advection significantly contribute to [3] the *excessive* cold tongue in the equatorial Pacific," while (4) "the *stronger* heat advection in the models is caused by [5] *overly strong* horizontal heat advection associated with [6] *too strong* zonal currents, and [7]*overly strong* vertical heat advection due to [8] *excessive* upwelling and the vertical gradient of temperature."

In addition, they wrote that (9) "the Bjerknes feedback in the coupled models is shown to be *weaker than in observations*, which may be related to (10) the *insufficient* response of surface zonal winds to SST in the models and (11) an *erroneous* subsurface temperature structure," such that (12) "the cold tongue becomes *colder than the cold tongue in the observations*."

In the final parting words of Zheng *et al*., they thus advised that "more work is needed on the role of the ocean model and ocean-atmosphere feedback in the growth of the double-ITCZ pattern." And this was but *one* of *many* aspects of the challenge of attempting to correctly chart the development of global climate change over the coming decades and centuries. And with so many unresolved problems associated with the ocean model's development, it is depressing to contemplate the sorry state of the grand design of the world's climate modelers to develop a trustworthy climate model for the *entire* planet.

In another paper from the same time period, Kim *et al*. (2012) wrote that "the Coupled Model Intercomparison Project Phase 5 (CMIP5) has devised an innovative experimental design to assess the predictability and prediction skill on decadal time scales of state-of-the-art climate models, in support of the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report," citing Taylor *et al*. (2012). To that point in time, however, they said that decadal predictions from different CMIP5 models had not been evaluated and compared using the same evaluation matrix. And, therefore, Kim *et al*. assessed the CMIP5 decadal hindcast-forecast simulations of seven state-of-the-art ocean-atmosphere coupled models for situations where "each decadal prediction consists of simulations over a 10-year period, each of which are initialized every five years from climate states of 1960**/**1961 to 2005**/**2006." And what did they thereby find?

In regard to *problems* they uncovered with the models via this methodology, the three U.S. researchers reported that (1) "most of the models overestimate trends," whereby they (2,3) "predict less warming or even cooling in the earlier decades compared to observations and [4] too much warming in recent decades." They also stated that (5) "low prediction skill is found over the equatorial and North Pacific Ocean," and that (6) "the predictive skill for the Pacific Decadal Oscillation index is relatively low for the entire period."

Contemporaneously, Li and Xie (2012) prefaced their study of the subject by writing that (1) "state-of-the-art coupled ocean-atmosphere general circulation models (CGCMs) suffer from large errors in simulating tropical climate, limiting their utility in climate prediction and projection," while further noting in this regard that (2) the models' "sea surface temperature (SST) errors are comparable or larger in magnitude than observed inter-annual variability and projected change in the 21st century." The most well-known of these errors, as they continued, include (3) "too weak a zonal SST gradient along the equatorial Atlantic (Davey *et al*., 2002; Richter and Xie, 2008), [4] an equatorial cold tongue that penetrates too far westward in the Pacific (Mechoso *et al*., 1995; de Szoeke and Xie, 2008), [5] too warm SSTs over the tropical Southeast Pacific and Atlantic, and [6] a spurious double inter-tropical convergence zone (Lin, 2007)."

In terms of their contribution to this multi-faceted dilemma, Li and Xie analyzed the nature and sources of various offset errors in tropical SSTs in the Coupled Model Intercomparison Project (CMIP) phase 3 and 5 multi-model ensembles. And in doing so, they found two sets of SST biases: "one with [7] a broad meridional structure and of the same sign across all basins that is highly correlated with the tropical mean; and one with [8] large inter-model variability in the cold tongues of the equatorial Pacific and Atlantic." In the case of the first type of bias, they reported that it (9) "can be traced back to biases in atmospheric simulations of cloud cover, with cloudy models biasing low in tropical-wide SST," while they indicated that (10) "the second type originates from the diversity among models in representing the thermocline depth," such that (11) "models with a deep thermocline feature a warm cold tongue on the equator." And they also added that (12) these problems "have persisted in several generations of models for more than a decade."

Still stuck in 2012, which was a very good year for discovering climate model inadequacies and errors, Keeley *et al*. (2012) wrote that (1) "current state-of-the-art climate models fail to capture accurately the path of the Gulf Stream and North Atlantic Current," which *model* failure led to what they described as (2) "a warm bias near the North American coast, where the modeled Gulf Stream separates from the coast further north, and [3] a cold anomaly to the east of the Grand Banks of Newfoundland, where the North Atlantic Current remains too zonal." And, therefore, using a high-resolution coupled atmosphere-ocean model (HiGEM) that is described in detail by Shaffrey *et al*. (2009), Keeley *et al*. analyzed the impacts of the sea surface temperature (SST) biases created by the model in the North Atlantic in winter (approximately 8°C too cold to the east of the Grand Banks of Newfoundland, and 6°C too warm near the east coast of North America) on the mean climatic state of the North Atlantic European region, along with the variability associated with those model-induced SST biases.

In discussing their findings, the three UK researchers said their results showed that (4) the model-induced SST errors produce a mean sea-level pressure response that is similar in magnitude and pattern to the atmospheric circulation errors in the coupled climate model," adding that (5) "errors in the coupled model storm tracks and North Atlantic Oscillation, compared to reanalysis data, can also be explained partly by these SST errors."

In the concluding sentence of the abstract of their paper, therefore, Keeley *et al*. suggested that "both [6] the error in the Gulf Stream separation location and [7] the path of the North Atlantic Current around the Grand Banks play important roles in affecting the atmospheric circulation," and they thus concluded that "reducing these coupled model errors could improve significantly the representation of the large-scale atmospheric circulation of the North Atlantic and European region."

Concurrently, in an intriguing paper published in the *Journal of Geophysical Research*, Guemas *et al*. (2012) wrote that "the North Pacific region has a strong influence on North American and Asian climate," noting that it is "the area with the worst performance in several state-of-the-art decadal climate predictions." And they added that (1) the failure of essentially *all climate models* "to represent two major warm sea surface temperature events occurring around 1963 and 1968 largely contributes to this poor skill," stating that "understanding the causes of these major warm events is thus of primary concern to improve prediction of North Pacific, North American and Asian climate."

In attempting to forge ahead in this direction, the five researchers investigated "the reasons for this particularly low skill," identifying and describing the two major warm events that they said had been "consistently missed by every climate forecast system."

Based on their study of eleven observational data sets, the five researchers suggested that the 1963 warm event "stemmed from the propagation of a warm anomaly along the Kuroshio-Oyashio extension," while the 1968 warm event "originated from the upward transfer of a warm water mass centered at 200 meters depth." And on this basis they concluded that (1) "biases in ocean mixing processes present in many climate prediction models seem to explain the inability to predict these two major events," which *themselves* needed to be predicted in order to adequately project decadal climate changes in the North Pacific region.

Most interestingly, and in spite of the stated *fact* that "reducing systematic biases in ocean stratification and improving the representation of ocean mixing processes had been a long-standing effort," Guemas *et al*. wrote that their findings suggested that allocating still more resources to "improving simulation of ocean mixing has the potential to significantly improve decadal climate prediction."

About this same time, Bates *et al*. (2012) reiterated the self-evident *fact* that "eliminating the mean bias in climate models continues to be a principal motivating goal in climate science." And, therefore they investigated “mean biases in air-sea heat and freshwater flux components in the Community Climate System Model version 4 [CCSM4]." This they did by comparing current mean biases, variability errors, and late twentieth-century trend differences derived from the CCSM4 with real-world information obtained from the Coordinated Ocean-Ice Reference Experiment (CORE) data set.

This undertaking revealed, in the words of Bates *et al*. that: "although regional biases in some components are improved, [1] others are still present and [2] some are made worse," that (3) "the largest degradation in the transition from CCSM3 to CCSM4 in mean flux bias is found in the greater shortwave radiation reaching the ocean's surface," that (4) "this degradation is a global, nearly uniform increase with many regional averages falling outside the range of observation-based estimates," that (5) "enhanced evaporation leads to net air-sea freshwater fluxes that can be outside the range of observation-based estimates, and thus [6,7] lead to erroneous ocean salinity and density," that (8) "enhanced evaporation can also lead to an enhanced hydrological cycle with more precipitation over both the ocean and land," that (9) "annual variability [in air-sea flux fields] is substantially in error in virtually all regions with [10] the likelihood of robust CCSM4-CORE disagreement – based on the wavelet probability analysis of Stevenson *et al*. (2010) – almost always above 90%," that (11) "the net shortwave radiation has the largest errors on all time scales (mean, annual, and interannual)," and that (12) "the pattern of errors is different for each time scale, suggesting that [13] cloud activity at each time scale may be flawed with different patterns."

Moving ahead another year, Nagura *et al*. (2013) introduced their analysis of the subject by noting that the term *Seychelles Dome* refers to the shallow climatological thermocline in the southwestern Indian Ocean, "where ocean wave dynamics efficiently affect sea surface temperature [SST], allowing SST anomalies to be predicted up to 1-2 years in advance." They then indicated that this ability was quite significant; for they said that "the anomalous SSTs in the dome region subsequently impact various atmospheric phenomena, such as tropical cyclones (Xie *et al*., 2002), the onset of the Indian summer monsoon (Joseph *et al*., 1994; Annamalai *et al*., 2005) and precipitation over India and Africa (Annamalai *et al*., 2007; Izumo *et al*., 2008)." And as further background for their work, they reported that "Yokoi *et al*. (2009) examined the outputs from models used in phase three of the Coupled Model Intercomparison Project (CMIP3) and found that [1] many CMIP3 models have serious biases in this region."

Hoping to find some improvement in this regard over the subsequent four years, Nagura *et al*. examined model biases associated with the Scychelles Dome using state-of-the-art ocean-atmosphere *coupled general circulation models* (CGCMs), "including those from phase five of the Coupled Model Intercomparison Project (CMIP5)." And what did they thereby learn?

The six scientists reported that (1) several of the tested models "erroneously produce an upwelling dome in the eastern half of the basin, whereas the observed Seychelles Dome is located in the southwestern tropical Indian Ocean," that (2) "the annual mean Ekman pumping velocity in these models is found to be almost zero in the southern off-equatorial region," which (3) "is inconsistent with observations, in which Ekman upwelling acts as the main cause of the Seychelles Dome," that (4) "in the models reproducing an eastward-displaced dome, easterly biases are prominent along the equator in boreal summer and fall," resulting in (5) "shallow thermocline biases along the Java and Sumatra coasts via Kelvin wave dynamics and [6] a spurious upwelling dome in the region." And in a revealing final assessment of their findings, Nagura *et al*. reported that (7) "compared to the CMIP3 models, the CMIP5 models are even worse in simulating the dome longitudes."

Working concurrently, Heuze *et al*. (2013) introduced their study of the subject by writing that "the ability of a model to adequately depict bottom water formation is crucial for accurate prediction of changes in the thermohaline circulation," citing Hay (1993), while also noting that "Southern Ocean deep water properties and formation processes in climate models are indicative of their capability to simulate future climate, heat and carbon uptake, and sea level rise." And, therefore, to determine how some of mankind's best climate modelers had been doing in this regard, they reviewed "how dense water is formed in climate models, and how this impacts the representation of ocean properties at the sea bed," *because*, as they continued "the models' ability to depict the present observed state of the climate system [is] a prerequisite for reliable future prediction."

This they did for the Southern Ocean, therefore, in terms of potential temperature, salinity, density and sea ice concentration in 15 CMIP5 historical simulations, where 20-year mean model fields were compared with historical hydrographic data on a grid spacing of 0.5° x 0.5°, as per Gouretski and Koltermann (2004), and with Hadley Centre sea ice climatologies, as described by Rayner *et al*. (2003). And what did they thereby learn? The four researchers reported that (1) "no model" -- that's right, *no model* -- "reproduces the process of Antarctic bottom water formation accurately." Quite to the contrary, in fact, they reported that "instead of forming dense water on the continental shelf and allowing it to spill off," (2) the "models present extensive areas of deep convection, thus leading to [3] an unrealistic, un-stratified open ocean."

Contemporaneously, Sallee *et al*. (2013) wrote that "the Southern Ocean is the dominant anthropogenic carbon sink of the world's oceans and plays a central role in the redistribution of physical and biogeochemical properties around the globe," citing Sarmiento *et al*. (2004). And they therefore stated that "one of the most pressing issues in oceanography is to understand the rate, the structure and the controls of the water mass overturning circulation in the Southern Ocean and to accurately represent these aspects in climate models."

Focusing on five water masses that are *crucial* for the Southern Ocean overturning circulation – surface subTropical Water (TW), Mode Water (MW), Intermediate Water (IW), Circumpolar Deep Water (CDW) and Antarctic Bottom Water (AABW) – Sallee *et al*. studied the ability of 21 of the CMIP5 models to simulate what they described as *the most basic properties* of each of the water masses (temperature, salinity, volume, outcrop area). And this work revealed that (1,2) "the water masses of the Southern Ocean in the CMIP5 models are too warm and light over the entire water column," that (3) “the mode water layer is poorly represented in the models,” that (4,5) “both mode and intermediate water have a significant fresh bias," that (6) "in contrast to observations (e.g., Rintoul, 2007), bottom water is simulated to become slightly saltier," and that when compared to observation-based reconstructions, the models "exhibit [7] a slightly larger rate of overturning at shallow to intermediate depths, and [8] a slower rate of overturning deeper in the water column."

In another pertinent paper from this time period, Weller and Cai (2013) noted that "variability in the Indian Ocean, important for understanding climate on the inter-annual time scale for many surrounding countries, has become an active topic of research in recent decades," citing Schott *et al*. (2009). And they went on to state, in this regard, that "previous studies focusing on the performance of models in phase 3 of the Coupled Model Intercomparison Project (CMIP3) have shown that [1-7] large diversity exists in the IOD [Indian Ocean dipole] strength (Saji *et al*., 2006; Cai *et al*., 2011), dynamical and thermodynamical feedbacks (Liu *et al*., 2011), coherence with ENSO (Saji *et al*., 2006), and its local and remote rainfall teleconnections (Cai *et al*., 2009, 2011)." And in light of these significant shortcomings, Weller and Cai decided to assess how well 20 different climate models that had taken part in phase 5 of the Coupled Model Intercomparison Project (CMIP5) perform when simulating the IOD.

These efforts revealed that (1,2) "compared with models in phase 3 (CMIP3), no substantial improvement is evident in the simulation of the IOD pattern and/or amplitude during austral spring [September-November (SON)]," that (3,4) "the majority of models in CMIP5 generate a larger variance of sea surface temperature (SST) in the Sumatra-Java upwelling region and an IOD amplitude that is far greater than is observed," that (5) "the diversity of the simulated IOD amplitudes in models in CMIP5 (and CMIP 3), which tend to be overly large, results in a wide range of future modeled SON rainfall trends over IOD-influenced regions," and that (6) "most models in CMIP5 and CMIP3 generate an IOD that is too strong relative to observations."

In light of these facts, Weller and Cai wrote that their results "highlight the importance of realistically simulating the present-day IOD properties and suggest that caution should be exercised in interpreting climate projections in the IOD-affected regions." And, by inference, they further implied that (7) climate models still have a considerable way to go before they can *adequately* do what people in lands impacted by the Indian Ocean likely *wish* they could do.

Also hard at work at this point in time were Long *et al*. (2013), who indicated that over the last two centuries the world's oceans had absorbed 25-30% of the total amount of CO_2 emitted to the atmosphere by fossil-fuel burning, cement production and land-use changes, citing Sabine *et al*. (2004) and Le Quere *et al*. (2009); and they stated that this oceanic carbon sink had partially mitigated the CO_2-induced warming of the globe by slowing the rate-of-rise in the air's CO_2 content. And, therefore, they further stated that the "mechanistic representation of oceanic carbon uptake and storage is essential to robust climate prediction."

Working towards this end, Long *et al*. compared ocean carbon uptake and storage -- as simulated by the Community Earth System Model, version 1-Biogeochemistry [CESM1(BGC)] -- where ocean and ice component models were forced by atmospheric observations and reanalyses, and where biogeochemical fields were initialized using data-based climatologies, after which the fully coupled model was integrated for a period of 1000 years, in order to allow the deep ocean to approach equilibrium. In their paper reviewed here, therefore, Long *et al*. examined two 20th-century simulations that branched off this steady-state run after 150 years of integration.

And what did the five researchers learn? They reported that (1) "modeled ΔpCO_2 [= $pCO_2^{seawater}$ - $pCO_2^{atmosphere}$] is larger than observed in the eastern equatorial Pacific and over much of the Southern Ocean north of about 60°S," and that (2) "the term ΔpCO_2 is under-estimated, by contrast, in the polar Southern Ocean." In this latter region, in fact, they found that (3) "the model predicts ΔpCO_2 values of the opposite sign" than what is actually observed there, as per Takahashi *et al*. (2009). They also reported that (4) "modeled salinity-normalized surface dissolved inorganic carbon and alkalinity concentrations tend to be too low over much of the ocean." In fact, they found that (5) "salinity-normalized surface alkalinity is underestimated virtually everywhere," although (6) alkalinity is "over-estimated at depth."

Long *et al*. additionally noted that (7) "in the polar Southern Ocean, annual-mean $pCO_2^{seawater}$ is substantially lower in the model than in observations," and that (8) "the model predicts stronger seasonality, with much lower austral summer December-February $pCO_2^{seawater}$ values than in the Takahashi *et al*. (2009) climatology." And they also discovered that (9) "summertime mixed layer depths along the Antarctic Circumpolar Current are too shallow in the model by 20-50 meters."

In the North Atlantic (49-80°N), on the other hand, the five U.S. scientists found that the CESM1 predicted an annual-mean $p\mathrm{CO_2}^{\mathrm{seawater}}$ that was actually comparable to observations. *However*, they indicated that (10) "the amplitude of the seasonal cycle in the model is ~5-fold larger." In addition, they noted that (11) "high chlorophyll biases in this region indicate that the magnitude of the simulated Arctic phytoplankton bloom is too strong," citing Moore *et al*. (2013). And they noted that "while the amplitude of the high-latitude seasonal cycle in $p\mathrm{CO_2}^{\mathrm{seawater}}$ is generally much larger than inter-annual variability, (12) "the opposite is true in the tropics."

The five researchers also wrote that (13) "contemporary CO_2 uptake is weaker than $\Delta p\mathrm{CO_2}$-based flux estimates between about 40 and 55°S," whereas [14] "south of 60°S the models show stronger uptake." And they went on to state that (15) "Southern Hemisphere sea ice coverage is far too extensive," as currently modeled, and that (16) "the total sea ice area is consistently about 62% greater than satellite observations over the seasonal cycle," citing Landrum *et al*. (2012), which aberration, they say, is (17) "likely due to westerly winds in the coupled model that are stronger than observed," citing Danabasoglu *et al*. (2012).

When all was said and done, therefore, Long *et al*.'s final conclusion was that "substantial improvements in the physical parameterizations controlling mixing and overturning in the model are necessary to improve the representation of ventilation," and that presently lacking such, "the current CESM configuration can be expected to continue to underestimate anthropogenic CO_2 uptake under twenty-first-century scenarios."

In another contemporary paper, Zermeño-Diaz and Zhang (2013) wrote that "most global climate models (GCMs) suffer from biases of [1] a reversed zonal gradient in sea surface temperature (SST) and [2] weak surface easterlies (the westerly bias) in the equatorial Atlantic during boreal spring," adding that [3] "these biases exist in the atmospheric GCMs (AGCMs) and [4] are amplified by air-sea interactions in atmospheric-oceanic GCMs," while further noting that "this problem has persisted despite considerable model improvements in other aspects."

Therefore, as they described it, Zermeño-Diaz and Zhang "used a simple model for a well-mixed boundary layer over the tropical oceans and simulations from eight AGCMs to diagnose possible root causes of the surface westerly bias over the Atlantic during boreal spring," *examining* "the possible roles of the vertical structure of diabatic heating and zonal momentum entrainment across the top of the boundary layer." And what knowledge did they gain from this exercise? Apparently not very much of significance, as the two researchers remarked that their work merely laid the *foundation* for a mere *hypothesis*.

And what are the implications of these "results"? Quoting the two researchers themselves, "the implication of our results is that there might be no simple or single remedy for the westerly bias in GCMs." And they said that "this may be why this problem has been so stubborn and persistent up to the new generation of CMIP5 models." And, we might add, why the problem still remains *unresolved!*

Focusing next on *seasonal to decadal forecasts* of climate change, Ho *et al*. (2013) explained that "since skillful decadal climate forecasts could bring benefits to climate change adaptation planning, there has been significant development of such predictions in recent years, using global climate models (GCMs) initialized with atmospheric and oceanic observations." *However*, they noted that "previous assessments of the quality of forecasts from ensemble decadal prediction systems have almost always focused on the accuracy of ensemble mean forecasts," noting that "a useful ensemble prediction system should also give *reliable* forecasts, which means that the forecast probabilities match the observed relative frequencies."

With these thoughts in mind, Ho *et al*. evaluated model "dispersion characteristics" – which they deemed "a necessary condition for ensemble reliability – of SST [sea surface temperature] forecasts from the UK Met Office Decadal Prediction System (DePreSys)." This they did by examining "how the dispersion characteristics vary spatially with forecast lead time from seasonal to decadal timescales." And in so doing, they made three important discoveries: (1) "Dispersion characteristics of decadal prediction ensembles for SSTs vary considerably, both spatially and with forecast lead time." (2) "For lead times of less than two years, the initialized ensembles tend to be under-dispersed and give over-confident and, hence, unreliable forecasts, especially in the tropics, consistent with many previous studies on this timescale." (3) "For longer lead times, up to 9 years, the ensembles become over-dispersed in most regions and thus give under-confident and also unreliable forecasts."

And so it was that the team of UK scientists said their findings "highlight the need to carefully evaluate simulated variability in seasonal and decadal prediction systems." And it would also be good if the creators of the models they studied would actually *do something* about the host of inadequacies that Ho *et al*. discovered in them.

About this same time, Frankignoul *et al*. (2013) wrote that in order "for climate forecasts to have predictive value, the relevant air-sea interactions must be realistic in climate models." And they thus stated that the aim of *their* study was "to determine whether AMOC [Atlantic Meridional Overturning Circulation] variability in the (relatively) high-resolution T85 version of the Climate Community System Model, version 3 (CCSM3) (Collins *et al*., 2006), has a significant impact onto the large-scale atmospheric circulation and to evaluate the degree of realism of such air-sea interactions." Consequently, they investigated the influence of AMOC variability on atmospheric circulation "in a control simulation of the CCSM3, where the AMOC evolves from an oscillatory regime into a red noise regime."

In this situation, the three researchers reported that "an AMOC intensification is followed during winter by a positive North Atlantic Oscillation (NAO)," that "the atmospheric response is robust and controlled by AMOC-driven SST anomalies, which shift the heat release to the atmosphere northward near the Gulf Stream/North Atlantic Current," that "this alters the low-level atmospheric baroclinicity and shifts the maximum eddy growth northward, affecting the storm track and favoring a positive NAO," that "the AMOC influence is detected in the relation between seasonal upper-ocean heat content or SST [sea surface temperature] anomalies and winter sea level pressure," that "in the oscillatory regime, no direct AMOC influence is detected in winter," that “an upper-ocean heat content anomaly resembling the AMOC footprint precedes a negative NAO," that "this opposite NAO polarity seems due to the southward shift of the Gulf Stream during AMOC intensification, displacing the maximum baroclinicity southward near the jet exit," and that "as the mode has somewhat different patterns when using SST, the wintertime impact of the AMOC lacks robustness in this regime."

However, as they subsequently commented, *none* of the seven signals “compares well with the observed influence of North Atlantic SST anomalies on the NAO." And as a result of these facts, Frankignoul *et al*. stated, in the concluding sentence of their paper's abstract, that (1) "although there is some potential climate predictability in CCSM3, it is not realistic." And as they say in the second to the last sentence in the body of their paper, "although the AMOC influence on the atmosphere that we have documented for CCSM3 raises the hope that some low-frequency NAO variations might be predictable, in particular in the red noise regime, [2] the signal will not be realistic."

Focusing next on the Southern Ocean, Bodas-Salcedo *et al*. (2014) noted that it "plays an important role in the earth's climate," as it is "a region of upwelling of intermediate waters and also of formation of deep waters farther south, connecting the ocean interior with the surface (e.g., Marshall and Speer, 2012)," which facts, as they continued, make it "an important part of the meridional overturning circulation." And as "one of the few areas where the deep ocean is connected to the surface," they said "it also plays a key role in CO_2 and heat uptake (Calderia and Duffy, 2000; Kuhlbrodt and Gregory, 2012)," while noting that "details of the circulation in the Southern Ocean play a crucial role in determining the evolution of the Antarctic ice sheets and sea level," citing Holland *et al*. (2010) and Bouttes *et al*. (2012).

In an attempt to promote progress in modelling these important aspects of earth's climate system, Bodas-Salcedo *et al*. "studied the role of clouds in the Southern Ocean's solar radiation budget in the atmosphere-only simulations of the Cloud Feedback Model Intercomparison Project phase 2 (CFMIP2)," noting that the clouds of this region "may have a leading role in controlling the solar radiation that is absorbed by the climate system in those latitudes."

Seeking to determine if such was really the case, the international team of ten researchers hailing from six different countries concluded from their several analyses that the midlevel cloud regime "is the main contributor to reflected shortwave radiation biases." And, therefore, they suggested that "improving the simulation of these cloud types should help reduce the biases in the simulation of the solar radiation budget in the Southern Ocean in climate models."

The *final conclusions* of Bodas-Salcedo *et al*. were thus that *future* work should "focus on quantifying the role of these clouds in the radiation budget over the Southern Ocean," and that "this should help elucidate the relative contribution of these situations to the solar radiation budget over the Southern Ocean." And these statements clearly indicate that (1) we are *still* not at the point where we have *an acceptable working model* of the Southern Ocean that adequately portrays its impact on earth's global climate.

In another study from the same year, Richter *et al*. (2014) wrote that "the tropical Atlantic is characterized by significant inter-annual variability in sea surface temperatures (SSTs) that exert an important influence on precipitation over the surrounding continents," citing Folland *et al*. (1986) and Nobre and Shukla (1996). And, therefore, they evaluated the performance of several general circulation models (GCMs) that participated in the Coupled Model Intercomparison Project Phase 5 (CMIP5) and were based on real-world observations and reanalysis products that characterize the evolution of Atlantic Niños in terms of surface winds, thermocline depth and SSTs, focusing on the lag between western equatorial surface wind forcing and cold tongue SST response.

As a result of this effort, the five researchers determined that "in terms of the mean state, 29 out of 33 models examined continue to suffer from serious biases including (1) an annual mean zonal equatorial SST gradient whose sign is opposite to observations," plus the facts that "the seasonal evolution of model biases ... involve [2] weakening of the equatorial easterlies in boreal spring, [3] subsequent deepening of the eastern equatorial thermocline, and [4] maximum cold tongue SST bias during the boreal summer upwelling season," as well as the facts that (5-7) "March-April-May surface wind biases are incipient in the atmospheric model components forced with observed SST," that (8,9) "they are associated with precipitation biases over the adjacent landmasses and a southward shift of the marine ITCZ [Intertropical Convergence Zone]," that (10,11) "both magnitude and seasonal evolution of the biases are very similar to what was found previously for CMIP3 models, indicating that [interim] improvements have only been modest," and, finally, that (12) "the weaker than observed equatorial easterlies are also simulated by atmospheric GCMs forced with observed SSTs." And thus it would appear -- from this study -- that if one is trying to divine the future climate of the earth, CMIP5 models are *not* the place to look ... at least at the present time.

But there always seems to be “another” study, which supposedly performs better. Unfortunately, such is generally found to *not* be the case, as subsequent studies continue to reveal.

Consider, for instance, the study of Chu *et al*. (2014), who reported how the Indian Ocean sea surface temperature (SST) variability had been represented at different times by two dominant variability modes: the Indian Ocean basin-wide (IOBW) and dipole (IOD) modes. Investigating potential changes in the two variability modes and the relationships between their mean states and the El Niño and Southern Oscillation (ENSO) phenomenon, Chu *et al*. employed 20 coupled models that participated in phase five of the Coupled Model Intercomparison Project (CMIP5) to assess their ability to simulate the climatology and variability of the Indian Ocean SST during the historical period of 1950-2005.

In so doing, the six scientists reported that they identified "considerable biases" in the models' simulations over the Indian Ocean. One notable bias was that (1) "more than half of the CMIP5 coupled models have difficulty in capturing the spatial distribution of the IOD mode, particularly over the equatorial Indian Ocean." Another bias was that (2) some models tended to have negative anomalies that extended far west along the equator in the positive phase of the IOD, while yet another anomaly was that (3) a few of the models had north-south dipoles rather than east-west ones. And in light of their several findings, Chu *et al*. thus concluded their paper by indicating that an understanding of the models' deficiencies – three of which they identified – is of importance for more reliable estimations of future changes in Indian Ocean variability.

In a contemporary paper introducing their study of the subject, Liu *et al*. (2014) described how they evaluated the abilities of 21 Coupled Model Intercomparison Project Phase 5 (CMIP5) models to simulate the Indian Ocean Dipole (IOD) mode of Earth's climate, and to thereby determine to what degree this set of models may have improved in this regard compared to the prior set of CMIP3 models. And what did they learn from this exercise?

The seven scientists reported that (1) "while observations show a positive feedback among the wind, evaporation and sea surface temperature during the IOD developing phase, about half of the CMIP5 models failed to capture this thermodynamic air-sea feedback," specifically noting that (2) "the CMIP5 ensemble ... produces a worse Bjerknes dynamic feedback than CMIP3," that (3) "the wind response to sea surface temperature forcing ... is underestimated in the newer generation models," that (4) "the thermocline response to surface wind forcing is overestimated," and that (5) "the overall CMIP5 performance in the IOD simulation does not show remarkable improvement compared to the CMIP3 simulations." In some cases, in fact, they indicated that (6) their analysis actually depicted a *decrease* in model performance from CMIP3 to CMIP5, as is reported in points 2 and 3 above.

All things considered, therefore, and in regard to the *specific climatic phenomenon studied by Liu et al.* – the Indian Ocean Zonal Dipole – it would appear that (7) essentially *no progress has been made* in the world of climate modelling between the Fourth and Fifth Assessment Reports of the Intergovernmental Panel on Climate Change.

In another revealing study of this period, Kwiatkowski *et al*. (2014) wrote that "Earth system models (ESMs) provide high resolution simulations of variables such as sea surface temperature (SST) that are often used in off-line biological impact models." This is done, they said, in order "to project both regional and global changes to coral growth and bleaching frequency." They noted, however, that "accurately simulating the coastal zones represents a significant challenge for ESMs due to the complex local physics, biogeochemical and biophysical interactions in these regions, driven by strong bathymetric constraints on circulation, and the impacts of terrestrial and sedimentary geochemical fluxes," citing Holt *et al*. (2009) and Allen *et al*. (2010). And as a result of these *challenging complexities*, they set about to assess "model skill at capturing sub-regional climatologies and patterns of historical warming," working with a set of twelve CMIP5 models in five different regions that support coral reefs.

As for what they learned from so doing, the four researchers found that (1) CMIP5 models have typically very poor skill and *often* perform *worse than chance* at capturing spatial patterns of SST warming anomalies between 1960-1980 and 1985-2005 in the coral regions analyzed." And as a result, they concluded that (2) the "output from current generation ESMs is not yet suitable for making sub-regional projections of change in coral bleaching frequency and other marine processes linked to SST warming," leaving much of importance to yet be accomplished in this regard.

Also around this time, and acknowledging that the *coupled general circulations models* (CGCMs) of the Coupled Model Intercomparison Project Phase 3 (CMIP3) were pretty much failures in their ability to accurately model the seasonal sea surface temperature (SST) cycle of the *eastern equatorial Pacific* (EEP), Song *et al*. (2014) set out to see how well the new-and-improved CMIP5 models performed in this regard. And what did they learn by so doing?

The five researchers found that although the newer models could do certain things better than the CMIP3 models, they (1) still fell short of adequately portraying reality when it came to reproducing the in-phase SST relationship between EEP region 1 (EP1) and EEP region 2 (EP2) in August and September of each year. In terms of amplitude simulations, for example, they noted that (2) "the model SST in EP1 shows weaker seasonal variation than the observations, due to (3) the large warm SST biases from the southeastern tropical Pacific in the boreal autumn." And in the case of EP2, they said that (4) there is "a quasi-constant cold bias associated with poor cold tongue simulations in the CGCMs."

As a result of these findings, Song *et al*. wrote, in the concluding sentence of their paper, that "to improve the capability of the CGCMs in simulating a realistic SST seasonal cycle in the EEP, both the local and remote climatological SST biases (Wang *et al*., 2014) that exist in both CMIP3 and CMIP5 CGCMs, such as the climatological simulation of the cold tongue region and the southeastern tropical Pacific, must be resolved."

Introducing the lengthy *abstract* of their work, which was published in *Climate Dynamics*, Xu *et al*. (2014) wrote that (1) warm *sea-surface temperature* (SST) biases in the southeastern tropical Atlantic (SETA) are "a common problem in many current and previous generation climate models," while noting that the Coupled Model Intercomparison Project Phase 5 (CMIP5) ensemble "provides a useful framework to tackle the complex issues concerning causes of the SST bias." And in exploring this framework, they came to the following conclusions.

(1) "The multi-model mean shows a positive shortwave radiation bias of ~20 W/m^2, consistent with [2] the models' deficiency in simulating low-level clouds." However, they note that [3] this shortwave radiation error "is overwhelmed by [4,5] larger errors in the simulated surface turbulent heat and longwave radiation fluxes, resulting in [6] excessive heat loss from the ocean," although they state that [7] "the shortwave radiation bias caused by poorly simulated low-level clouds is not the leading cause of the warm SST bias."

Continuing, they wrote that (8) "the majority of CMIP5 models underestimate upwelling strength along the Benguela coast," which is linked to (9) "the unrealistically weak alongshore wind stress simulated by the models." But they said that (10) "the deficient coastal upwelling in the models is not simply related to the warm SST bias via vertical heat advection," noting that (11) "SETA SST biases in CMIP5 models are correlated with [12,13] surface and subsurface ocean temperature biases in the equatorial region," further suggesting that (14) "the equatorial temperature bias remotely contributes to the SETA SST bias."

Xu *et al*. additionally stated that they found that (15) "all CMIP5 models simulate a southward displaced Angola-Benguela front (ABF), which in many models is more than 10 degrees south of its observed location." And they also reported that (16) "SETA SST biases are most significantly correlated with ABF latitude, which suggests that [17] the inability of CMIP5 models to accurately simulate the ABF is a leading cause of the SETA SST bias." And they thus stated that (18) "even with the observationally-derived surface atmospheric forcing, the ocean model generates a significant warm SST bias near the ABF."

Last of all, Xu *et al*. said that their results (19) "indicate a remote influence of the SETA SST bias on global model simulations of tropical climate, underscoring the importance and urgency to reduce the SETA SST bias in global climate models."

In another paper from the same year, Laepple and Huybers (2014b) wrote that "variations in sea surface temperature (SST) have widespread implications for society and are the basis of most regional decadal prediction efforts." This relationship seemed to work fine at *synoptic and interannual timescales*, where they indicated there was overall agreement between observational and General Circulation Model (GCM) estimates of SST variability. But at *decadal* timescales they found that (1) instrumental records typically showed *greater* regional SST variability than what was found to be the case with the Coupled Model Intercomparison Project Phase 5 (CMIP5) ensemble of GCM simulations, as they themselves had recently demonstrated (Laepple and Huybers, 2014a) and as had earlier been shown would likely be the case by Stott and Tett (1998), Davey *et al*. (2002) and DelSole (2006).

Because of what had been learned from these *short*-term studies, the two U.S. researchers went on to analyze 33 high-resolution *proxy* temperature records that had been *reconstructed*, based on materials found in lengthy marine sediment cores, some of which extended back in time as much as 7,000 years. And these results, as they reported, "indicate that centennial and millennial variations are substantially larger than those found at decadal timescales, as has been previously noted," citing the studies of deMenocal *et al*. (2000), Huybers and Curry (2006), Black *et al*. (2007) and Sachs (2007).

So just how big is *substantially larger*? Quoting Laepple and Huybers, the "discrepancies in variability are largest at low latitudes ... reaching two orders of magnitude for tropical variability at millennial timescales." And because a discrepancy of *two orders of magnitude* is difficult to ignore, they said their result "implies major deficiencies in observational estimates or model simulations, or both, and has implications for the attribution of past variations and prediction of future change."

About this same time, Flannaghan *et al*. (2014) noted that "comparison of temperature trends from CMIP5 model runs with prescribed sea surface temperatures (SSTs) for the period 1981-2008 shows that some models do better than others when compared to observations," citing Po-

Chedley and Fu (2012), who had found that (1) "nearly all AMIP models" -- i.e. those associated with the Atmospheric Model Intercomparison Project (Gates, 1992) for the period 1981-2008 -- "overestimate warming in the tropical upper troposphere," and that "those models that perform best when compared to the observations use the HadlSST1 data set (Rayner, 2003), whereas the other models use a different data set (Hurrell *et al*. (2008)."

Thereby prompted to further explore the subject, the six scientists ran the Geophysical Fluid Dynamics Laboratory HiRAM model with the HadlSST1 and Hurrell SST data sets, finding that (1) "subtle (but systematic) differences in the two SST data sets induce an unexpectedly large difference in upper tropospheric temperature trends." And *how* large a difference, you may ask? How about, as they put it, (2) "a factor 3 larger than expected from moist adiabatic scaling of the tropical average SST trend difference." And in light of this stunning finding, Flannaghan *et al*. went on to conclude that "systematic uncertainties in SSTs need to be resolved before the fidelity of climate models' tropical temperature trend profiles can be assessed."

In another pertinent study, Zhang *et al*. (2014) began the report of their recent work by noting that (1) "most state-of-the-art climate models show significant systematic biases in the tropical south-eastern Pacific (SEP) and tropical North Atlantic (TNA)," which (2) "manifest themselves as the sea surface temperature (SST) in the SEP being too warm and the SST in the TNA being too cold," with the result that (3) "as the cold SST biases appear in the TNA, the warm SST biases also occur in the SEP," which indicates that (4) "if climate models cannot succeed in simulating the TNA variability, they will also fail at least partially in the SEP."

In discussing the subject further, the four researchers stated that (5) "most climate models fail to reproduce the observed seasonal cycle in the eastern tropical Pacific," citing Szoeke and Xie (2008) and Mechoso *et al*. (1995), while further noting that (6) "one of the most common errors in climate models is a warm SST bias in the SEP, with the warm bias extending thousands of kilometers off the coast of Peru."

Based on the output of 18 Coupled Model Intercomparison Project Phase 5 (CMIP5) GCM runs corresponding to the historical collection of simulations assembled by Taylor *et al.* (2012), Zhang *et al*. next went on to demonstrate that (7) "model simulations in CMIP5 show a large cold SST bias in the TNA, with ensemble mean amplitude up to 2.5°C." And they added that (8) "similar to the cold bias in the TNA, the SEP warm SST bias is significant in all models and occurs in all seasons."

Clearly, therefore, even the world's most advanced climate models *still* (9) fall short of what is required to provide even a *glimpse* of what the future might possibly hold for these regions in terms of these local biases; and Zhang *et al*. thus (10) bemoan the many real-world complexities of "regional feedbacks between stratocumulus clouds, surface winds, upwelling, coastal currents and SST in the SEP region," which they said (11) "are poorly represented in many climate models."

Finally reaching the current year, Wang *et al*. (2015) took it upon themselves to “evaluate the CMIP models' skill in simulating the natural internal spatial structure of sea surface temperature

(SST) variability in all major ocean basins." And what did they learn from this exercise? The three Australian researchers reported that (1) "most models show substantial deviations from the observations and [2] from each other in most domains," that (3) "the CMIP models tend to largely overestimate the effective spatial number [of] degrees of freedom," that (4) the models "simulate too strongly localized patterns of SST variability at [5] the wrong locations with [6] structures that are different from the observed," and that (7) "the mismatch between the models is as big as the mismatch with the observations."

This spate of problems, as they continued, can (8) "be easily found in fully coupled GCMs as the atmospheric, oceanic and coupling processes could all introduce errors and even amplify the errors from each other," citing the studies of Delecluse *et al*. (1998), Grenier *et al*. (2000), Cai *et al*. (2011) and Gupta *et al*. (2013). And they thus concluded their report by stating that (9) "current state-of-the-art CGCMs do not resolve oceanic meso-scale dynamics.

In a second recent study, Yang and Wu (2015) described how they investigated changes in air-sea coupling that occurred over the North Atlantic Ocean during the 20th century by means of both observational data and climate model simulations. And in discussing their work on this subject, they reported that the ocean-to-air feedback over the North Atlantic was significantly intensified in the second half of the 20th century, and that "this coupled feedback is characterized by the association between summer North Atlantic Horseshoe (NAH) sea surface temperature anomalies and the following winter North Atlantic Oscillation (NAO). But after all was said and done, they were forced to report that (1) "most IPCC AR4 climate models fail to capture the observed NAO**/**NAH coupled feedback."

As for what was *responsible* for this significant failure, the two Chinese researchers stated that (2) "the poor ability of climate models in simulating the coupling between the winter atmosphere and preceding summer SST remains an obstacle in predicting the climate variability over the North Atlantic," while noting that (3) "only 2 out of 24 models can capture this coupling found in the observations during 1950-99," and that (4) "over half of the models fail to simulate the summer NAH pattern." And when all was said and done, therefore, Yang and Wu were forced to conclude that (5) "it remains a great challenge to improve model ability in simulating and predicting the North Atlantic climate variability."

In one final paper from the current year, Li *et al.* (2015) described how (1) a common equatorial easterly wind bias forces a westward-propagating down-welling Rossby wave in the southern Indian Ocean (IO) that (2) "induces too deep a thermocline dome over the southwestern IO (SWIO) in state-of-the-art climate models." And they indicate that (3) "such a deep SWIO thermocline weakens the influence of subsurface variability on sea surface temperature (SST)," thereby (4) "reducing the Indian Ocean Basin (IOB) amplitude and possibly limiting the models' skill of regional climate predictions."

In further studying this knotty problem, Li *et al*. also noted that (5) "the westerly wind over the equatorial IO is too weak during SON [Sept, Oct, Nov] in most CMIP5 CGCMs [coupled general circulation models]," that (6) "the deep thermocline dome bias over the SWIO in CMIP5 CGCMs could significantly reduce the effect of subsurface thermocline variability on SST [sea surface temperature] there," that (7) "too weak a thermocline-SST feedback over the SWIO in CMIP5 CGCMs results in a deficiency in the simulated amplitude for the IOB mode of inter-annual variability," that this phenomenon (8) "also lowers their skill in predicting the IOB warming following El Niño," that (9) "the easterly wind error in CGCMs can result in a too steep eastward shoaling of [the] thermocline in the equatorial IO," that (10) "the unrealistically steep thermocline slope generates too strong a thermocline feedback on SST," and thus (11) "develops an excessively large IOD amplitude of inter-annual variability in CGCMs," which (12) "exerts profound social and economic consequences for the IO rim countries such as Indonesia and Kenya," that (13) the "too weak cross-equatorial easterly wind bias can be traced back to errors in the South Asian summer monsoon," that (14) the "too weak cross-equatorial monsoon over the western basin in JJA [Jun, Jul, Aug] causes a sustained warm SST bias in the western equatorial IO," that (15) "in SON, Bjerknes feedback helps amplify this SST error into an IOD-like pattern," with (16) "a strong equatorial easterly bias accompanied by a physically consistent bias in the precipitation dipole."

And all of these results, in the words of the three Chinese researchers, "imply that reducing the monsoon errors in CGCMs will improve climate simulation and prediction for the IO and rim countries, and increase our confidence in their application for regional climate projection." But in light of the multiple problems that remain to be resolved -- and if past is prologue to the future -- that confidence may well be weakened, or possibly even *shattered*, before we're half-way there.

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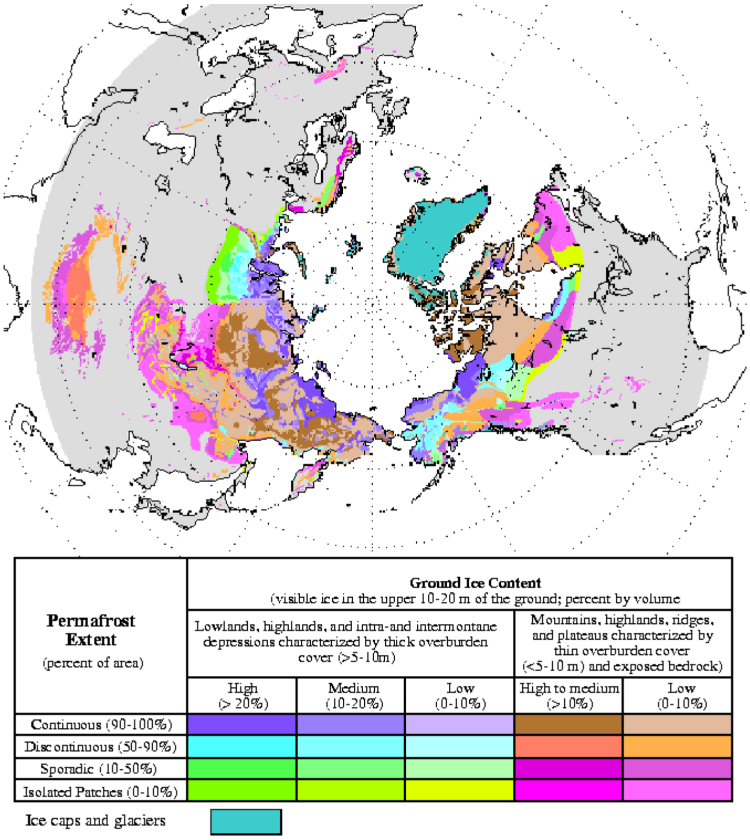
PERMAFROST



Assessments of the potential impacts of climate change on the world's permafrost had long been based on a two-layer model that incorporates a seasonally frozen active layer and an underlying perennially frozen soil, until Shur *et al*. (2005) examined the virtues of adding an in-between or *transition zone* layer to produce a more realistic three-layer model. And what did they conclude from so doing?

Based on a through a review of the literature and theoretical and data analyses, the three scientists showed, among other things, that the transition zone alternates between seasonally frozen ground and permafrost over sub-decadal to centennial time scales, functioning as a buffer between the active layer and the underlying perennial permafrost by increasing the latent heat required for thaw. And, therefore, according to Shur *et al*., use of a two-layer conceptual model in permafrost studies (1) "obscures effective understanding of the formation and properties of the upper permafrost and syngenetic permafrost, and [2] makes a realistic determination of the stability of arctic geosystems under climatic fluctuations virtually impossible." Consequently, the three researchers concluded that (3) "the impacts of possible global warming in permafrost regions cannot be understood fully without consideration of a more realistic three-layer model." And why? Because, as they noted, (4) if the transition zone does indeed act as a buffer at sub-decadal to centennial time scales, then current permafrost trends are likely to be manifestations of *past* climatic trends, some of which may have taken place several decades earlier, *or more!*

Fully eight years later, Koven *et al*. (2013) noted that "permafrost is a critical component of high-latitude land and determines the character of the hydrology, ecology, and biogeochemistry of the region." And, therefore, they said there was "widespread interest in the use of coupled atmosphere-ocean-land surface models to predict the fate of permafrost over the next centuries because permafrost contains the largest organic carbon (C) reservoir in the terrestrial system (Tarnocai *et al*., 2009), permafrost stability is primarily dependent on temperature, and global warming is expected to be relatively larger over the permafrost domain because of arctic amplification processes (Holland and Bitz, 2003)."

Therefore, as they described it, Koven *et al*. analyzed "output from a set of earth system models (ESMs) that participated in phase 5 of the Coupled Model Intercomparison Project (CMIP5) (Taylor *et al*., 2009) to evaluate the permafrost model predictions against observations and theoretical expectations and to compare the predicted fate of permafrost under warming scenarios." And what did they thereby learn?

The three U.S. researchers determined that (1) "the models show a wide range of behaviors under the current climate, with many failing to agree with fundamental aspects of the observed soil thermal regime at high latitudes." More specifically, they reported that "under future climate change, [2,3] the models differ in their degree of warming, both globally and at high latitudes, and also in [4] the response of permafrost to this warming," that (5) "there is a wide range of possible magnitudes in their responses, from 6% to 29% permafrost loss per 1°C high-latitude warming," that (6) several of the models predict that substantial permafrost degradation has already occurred (ranging from 3% gain to 49% loss relative to 1850 conditions)," that (7) "the majority of models at the high end of relative twentieth-century permafrost loss also show unrealistically small preindustrial permafrost extent," that (8) "there is wide model disagreement on the value of the difference in mean temperature across the air-soil interface, with several of the models predicting the wrong sign for this statistic," and that (9,10) "there is wide model disagreement in the changes of [the] mean and [the] amplitude of soil temperatures with depth." And in commenting on their findings, Koven *et al*. concluded by stating that (11) "with this analysis, we show that widespread disagreement exists among this generation of ESMs," which once again suggests that current earth system models are not yet ready for real-world applications.

One year later, Lupascu *et al*. (2014) wrote that "the Arctic is greening (Bhatt *et al*., 2010; Epstein *et al*., 2013) and sequestering increasing amounts of atmospheric CO_2 (Epstein *et al*., 2013)," while "at the same time, permafrost thawing is releasing ancient soil C (Schuur *et al*., 2013) to the atmosphere." And they noted, in this regard, that "the timing and balance of these two processes determine the sign and strength of the Arctic's C cycle feedbacks to climate change," citing Schaefer *et al*. (2011).

In light of these facts, Lupascu *et al*. quantified net ecosystem exchange of CO_2, gross primary productivity and ecosystem respiration in a High Arctic semi-desert in a set of long-term (about 10 years) summer warming and/or wetting treatments in northwest Greenland, while also measuring sources of ecosystem respiration and below-ground CO_2 based on their radiocarbon (^{14}C) contents, which approach allowed them to detect changes in land-atmosphere C exchange and within-soil C dynamics.

As a result of these efforts, the six scientists were able to report that (1) *warming* (by 4°C) decreased the summer CO_2 sink strength of the semi-deserts they studied by up to 55%; but they indicated that (2) warming *combined with wetting* (equivalent to an extra 50% of summer precipitation) *increased* the CO_2 sink strength by *a full order of magnitude*, totally dwarfing and countering the warming-alone effect, due in large part to the fact that wetting relocated recently assimilated plant C deeper into the soil and thereby decreased old C loss compared to that experienced in the warming-only treatment.

Therefore, and due to the fact, as Lupascu *et al*. put it, that "an overall wetting of the Arctic is expected as a consequence of increased moisture in the atmosphere due to reduced sea ice (Higgins and Cassano, 2009) and added transport into the Arctic (Zhang *et al*., 2013)," it would appear that the warming expected by many climate scientists to occur in response to rising atmospheric CO_2 concentrations should produce a *significant negative feedback throughout the high Arctic* that would tend to reduce the degree of warming that has historically been projected to occur there, producing, one might say, chaos out of order.

About this same time, Mishra and Riley (2014) wrote that "predicted active-layer (AL) thicknesses of permafrost-affected soils influence Earth system model predictions of carbon-climate feedbacks," yet they said that "only a few observation-based studies have estimated AL thicknesses across large regions and at the spatial scale at which they vary." Consequently, they went on to use spatially-referenced soil profile description data and environmental variables (topography, climate and land cover) in a geographically-weighted regression approach designed to *predict* the spatial variability of AL thicknesses across Alaska at a 60-meter spatial resolution.

This work of the two researchers revealed that "mean annual surface air temperature, land cover type, and slope gradient were primary controllers of AL thickness spatial variability." But when they compared their results with those that employed climate output obtained from Coupled Model Intercomparison Project Phase 5 (CMIP5) predictions, they found that (1) there were "large interquartile ranges in predicted AL thicknesses (0.35-4.4 m), indicating [2] substantial overestimate of current AL thickness in Alaska, which [3] might result in higher positive permafrost carbon feedback under future warming scenarios." And they further noted, in this regard, that (4,5) "the CMIP5 predictions of AL thickness and spatial heterogeneity were unrealistic when compared with observations," adding that (6) the *prediction* errors were *several times larger* compared to errors associated with their *observation*-based approach.

As for what this all means, the two scientists said their results indicated a "need for better process representations and representation of natural spatial heterogeneity due to local environment (topography, vegetation and soil properties) in Earth system models to generate a realistic variation of regional scale AL thickness, which could reduce the existing uncertainty in predicting permafrost carbon-climate feedbacks."

And thus it would appear that the modelling of permafrost, based on CMIP5 climate change output, is something in which one ought not put much faith.

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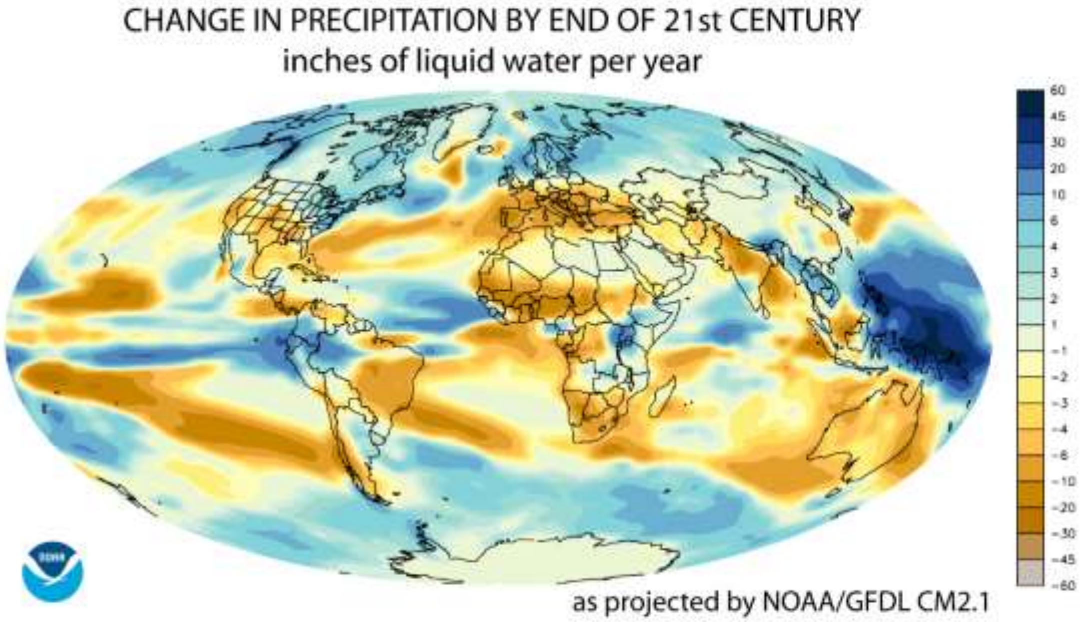
PRECIPITATION



One of the basic predictions of atmospheric general circulation models or GCMs is that the planet's hydrologic cycle will intensify as the world warms, leading to an increase in both the frequency and intensity of extreme precipitation events. In an early review of the subject, for example, Walsh and Pittock (1998) reported that "there is some evidence from climate model studies that, in a warmer climate, rainfall events will be more intense," and that "there is considerable evidence that the frequency of extreme rainfall events may increase in the tropics." Upon further study, however, they were forced to conclude that "because of the insufficient resolution of climate models and their generally crude representation of sub-grid scale and convective processes, little confidence can be placed in any definite predictions of such effects."

Two years later, Lebel *et al*. (2000) compared rainfall simulations produced by a GCM with real-world observations from West Africa for the period 1960-1990. Their analysis revealed that (1) the model output was affected by a number of temporal and spatial biases that led to significant differences between observed and modeled data. Simulated rainfall totals, for example, were (2,3) significantly greater than what was typically observed, exceeding real-world values by 25% during the dry season and 75% during the rainy season. In addition, (4) the seasonal cycle of precipitation was not well simulated, as the researchers found that (5) the simulated rainy season began too early and that (6) the increase in precipitation was not rapid enough. Shortcomings were also evident in (7) the GCM's inability to accurately simulate convective rainfall events, as (8) it typically predicted far too much precipitation. Furthermore, it was found that (9) "interannual variability [was] seriously disturbed in the GCM as compared to what it [was] in the observations." And as for *why* the GCM performed so poorly in these several respects, Lebel *et* *al*. gave two main reasons. They said (10) the parameterization of rainfall processes in the GCM was much too simple and that (11) the spatial resolution was much too coarse.

Following the passage of an additional three years, Woodhouse (2003) generated a tree-ring-based history of snow water equivalent (SWE) characteristic of the first day of April for each year of the period 1569-1999 for the drainage basin of the Gunnison River of western Colorado, USA. Then, because "an understanding of the long-term characteristics of snowpack variability is useful for guiding expectations for future variability," as she phrased it, she analyzed the reconstructed SWE data in such a way as to determine if there was anything unusual about the SWE record of the 20th century, which hundred-year period is claimed by climate alarmists to have experienced a warming that was *unprecedented over the past two millennia*.

So did Woodhouse find anything unusual? Yes, she did. She found that the twentieth century was notable for several periods that *lacked* extreme years. More specifically, she determined that (1,2) "the twentieth century is notable for several periods that contain few or no extreme years, for (3,4) both low and high SWE extremes," and she said that (5) "the twentieth century also contains the lowest percent of extreme low SWE years." These results, of course, were in direct contradiction of what state-of-the-art GCMs typically predicted should occur in response to global warming; and their failure in this regard was especially damning, knowing it occurred during a period of global warming that was said by many to have been the most significant of the past 20 centuries.

Two years later, and as a result of the fact that the 2004 summer monsoon season of India experienced (1) a 13% precipitation deficit that was not predicted by any of the empirical or dynamical models regularly used in making rainfall forecasts, Gadgil *et al*. (2005) performed an historical analysis of the models' forecast skill over the period 1932-2004. Interestingly, and despite numerous model advancements and an ever-improving understanding of monsoon variability, they found that (2) the models' skill in forecasting the Indian monsoon's characteristics had not improved since the very first versions of the models were applied to the task some *seven decades earlier*.

In the case of the empirical models Gadgil *et al*. evaluated, (3) large differences were generally observed between monsoon rainfall measurements and model predictions. In addition, the models often failed to correctly predict even the *sign* of the precipitation anomaly, frequently (4) predicting excess rainfall when drought occurred and (5) drought when excess rainfall was received.

The dynamical models fared even worse. In comparing observed monsoon rainfall totals with simulated values obtained from 20 state-of-the-art GCMs and a supposedly superior coupled atmosphere-ocean model, Gadgil *et al*. reported that (6) not a single one of these many models was able "to simulate correctly the interannual variation of the summer monsoon rainfall over the Indian region." And as with the empirical models, (7) the dynamical models also frequently failed to correctly capture even the *sign* of the observed rainfall anomalies. In addition, the researchers noted that Brankovic and Molteni (2004) attempted to model the Indian monsoon with a much higher-resolution GCM, but that (8) its output *also* proved to be "not realistic."

Consequently, and in spite of the *billions of dollars* that had been spent by the United States alone on developing and improving climate models, the taxpayers of those days achieved essentially *no return on their investment* in terms of the models' abilities to correctly simulate one of the largest and most regionally-important of earth's atmospheric phenomena -- the tropical Indian monsoon. And after more than *70 years* of trying to remake the models into better predictive tools, one would surely have expected *some* improvement in this regard, even if only by *accident*. That there had been absolutely *none* to that point in time was a sad commentary, indeed, on the state of the climate modeling enterprise.

Advancing one more year in time, Lau *et al*. (2006) considered the Sahel drought of the 1970s-90s to provide "an ideal test bed for evaluating the capability of CGCMs [coupled general circulation models] in simulating long-term drought, as well as the veracity of the models' representation of coupled atmosphere-ocean-land processes and their interactions." Hence, they decided to "explore the roles of sea surface temperature coupling and land surface processes in producing the Sahel drought in CGCMs that participated in the twentieth-century coupled climate simulations of the Intergovernmental Panel on Climate Change [IPCC] Assessment Report 4," in which the 19 CGCMs were "driven by combinations of realistic prescribed external forcing, including anthropogenic increase in greenhouse gases and sulfate aerosols, long-term variation in solar radiation, and volcanic eruptions."

In performing this analysis, the climate scientists found, in their words, that only eight models produce a reasonable Sahel drought signal, while (1) “seven models produce excessive rainfall over [the] Sahel during the observed drought period,” and (2) “four models show no significant deviation from normal." In addition, they noted that "even the model with the highest skill for the Sahel drought could only simulate the increasing trend of severe drought events but not their [3] magnitude, nor the [4] beginning time and [5] duration of the events." Consequently, since all 19 of the CGCMs employed in the IPCC's Fourth Assessment Report failed to adequately simulate the basic characteristics of "one of the most pronounced signals of climate change" of the past century -- as defined by its start date, severity and duration -- the results of this "ideal test" for evaluating the models' capacity for accurately simulating "long-term drought" and "coupled atmosphere-ocean-land processes and their interactions" would almost *mandate* that it would be unwise to rely on their output as a guide to the future, especially when the tested models were "driven by combinations of realistic prescribed external forcing" and (6) they *still* could not properly simulate the past.

During the following year of 2007, a number of other pertinent papers appeared. In an intriguing report in *Science*, Wentz *et al*. (2007) noted that the Coupled Model Intercomparison Project, as well as various climate modeling analyses, predicted an increase in precipitation on the order of one to three percent per °C of surface global warming. Hence, they decided to see what had happened in the real world in this regard over the prior 19 years (1987-2006) of supposedly *unprecedented global warming*, when data from the Global Historical Climatology Network and satellite measurements of the lower troposphere indicated there had been a global temperature rise on the order of 0.20°C per decade.

Using satellite observations obtained from the Special Sensor Microwave Imager (SSM/I), the four *Remote Sensing Systems* scientists derived precipitation trends for the world's *oceans* over this period; and using data obtained from the Global Precipitation Climatology Project that were acquired from both satellite and rain gauge measurements, they derived precipitation trends for earth's *continents*. Appropriately combining the results of these two endeavors, they derived a real-*world* increase in precipitation on the order of 7% per °C of surface global warming, which (1) was somewhere between 2.3 and 7 times *larger* than what was predicted by state-of-the-art climate models. So how was this horrendous discrepancy to be resolved?

In discussing these embarrassing results, Wentz *et al*. correctly stated that (2) "the reason for the discrepancy between the observational data and the GCMs is not clear." They also rightly stated that (3) this dramatic difference between the real world of nature and the virtual world of climate modeling "has enormous impact," concluding that (4) the questions raised by the discrepancy "are far from being settled." And until these "enormous impact questions" *are* settled, one wonders how anyone could conceivably think of acting upon the global energy policy prescriptions of those who speak and write as if there was little more to do in the realm of climate-change prediction than a bit of fine-tuning.

In another intriguing bit of research, Allan and Soden (2007) quantified trends in precipitation within ascending and descending branches of the planet's tropical circulation and compared their results with simulations of the present day and projections of future changes provided by some 16 state-of-the-art climate models. The precipitation data for this analysis came from the Global Precipitation Climatology Project (GPCP) of Adler *et al*. (2003) and the Climate Prediction Center Merged Analysis of Precipitation (CMAP) data of Xie and Arkin (1998) for the period 1979-2006, while for the period 1987-2006 they came from the monthly mean inter-calibrated Version 6 Special Sensor Microwave Imager (SSM/I) precipitation data described by Wentz *et al*. (2007). And what did the researchers learn?

Allan and Soden reported that "an emerging signal of rising precipitation trends in the ascending regions and decreasing trends in the descending regions are detected in the observational datasets," but they said that "these trends are substantially larger in magnitude than present-day simulations and projections into the 21st century," especially in the case of the descending regions. More specifically, they stated that, (1) for the tropics, "the GPCP trend is about 2-3 times larger than the model ensemble mean trend, consistent with previous findings (Wentz *et al*., 2007) and supported by the analysis of Yu and Weller (2007)," who additionally contended that (2) "observed increases of evaporation over the ocean are substantially greater than those simulated by climate models." What is more, Allan and Soden noted that (3) "observed precipitation changes over land also appear larger than model simulations over the 20th century (Zhang *et al*., 2007)."

What was one to make of this conflict between models and measurements? Noting that the difference between the two "has important implications for future predictions of climate change," Allan and Soden said that "the discrepancy cannot be explained by changes in the reanalysis fields used to subsample the observations but instead must relate to errors in the satellite data or in [4] the model parameterizations." This same dilemma was also faced by Wentz *et al*. (2007); and they too stated that the resolution of the issue "has enormous impact," likewise concluding that (5) the questions raised by the discrepancy "are far from being settled."

To many people the issue seems a bit less difficult. Given a choice between *model **simulations*** and *observational **reality***, they cast their lot with the latter grouping every chance they get. Granted, this choice implies a huge problem with the models. But why should that be a surprise to anyone? The earth, with its oceans and atmosphere and its myriad life forms, is a complex place. And to believe that we have condensed all of its many climate-related phenomena -- many of which are shrouded in mystery, and some of which may even remain undetected -- to a set of equations that can rigorously define our climatic future in response to an increase in the air's CO_2 concentration, would appear to be *irrationality incarnate*.

In a contemporaneous study, L'Ecuyer and Stephens (2007) wrote that "our ability to model the climate system and its response to natural and anthropogenic forcings requires a faithful representation of the complex interactions that exist between radiation, clouds, and precipitation and their influence on the large-scale energy balance and heat transport in the atmosphere," *further* noting that "it is also critical to assess [model] response to shorter-term natural variability in environmental forcings using observations." And in the spirit of this logical philosophy, the two researchers decided to use multi-sensor observations of visible, infrared and microwave radiance obtained from the Tropical Rainfall Measuring Mission satellite for the period running from January 1998 through December 1999, in order to evaluate the sensitivity of atmospheric heating -- and the factors that modify it -- to changes in east-west sea surface temperature gradients associated with the strong 1998 El Niño event in the tropical Pacific, as expressed by the simulations of nine general circulation models of the atmosphere that were utilized in the Intergovernmental Panel on Climate Change's most recent Fourth Assessment Report, which protocol, in their words, "provides a natural example of a short-term climate change scenario in which clouds, precipitation, and regional energy budgets in the east and west Pacific are observed to respond to the eastward migration of warm sea surface temperatures," which was somewhat akin to the *natural experiment* approach of Idso (1998). So what did they learn from this exercise?

L'Ecuyer and Stephens reported that (1) "a majority of the models examined do not reproduce the apparent westward transport of energy in the equatorial Pacific during the 1998 El Niño event." They also stated that (2) "the intermodel variability in the responses of precipitation, total heating, and vertical motion is often larger than the intrinsic ENSO signal itself, implying [3] an inherent lack of predictive capability in the ensemble with regard to the response of the mean zonal atmospheric circulation in the tropical Pacific to ENSO." In addition, they noted that (4) "many models also misrepresent the radiative impacts of clouds in both regions [the east and west Pacific], implying [5-8] errors in total cloudiness, cloud thickness, and the relative frequency of occurrence of high and low clouds." And in light of these much-less-than-adequate findings, the two researchers concluded that [9] "deficiencies remain in the representation of relationships between radiation, clouds, and precipitation in current climate models," and they avowed that these deficiencies (10) "cannot be ignored when interpreting their predictions of future climate."

In another paper from the same year, Lin (2007) stated that "a good simulation of tropical mean climate by the climate models is a prerequisite for their good simulations/predictions of tropical variabilities and global teleconnections," but, unfortunately, that (1) "the tropical mean climate has not been well simulated by the coupled general circulation models (CGCMs) used for climate predictions and projections," noting that (2) "most of the CGCMs produce a double-intertropical convergence zone (ITCZ) pattern," and acknowledging that (3) "a synthetic view of the double-ITCZ problem is still elusive."

To explore the nature of this problem in greater depth, therefore, and to hopefully make some progress in resolving it, Lin analyzed tropical mean climate simulations of the 20-year period 1979-99 provided by 22 Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) CGCMs, together with concurrent Atmospheric Model Intercomparison Project (AMIP) runs from 12 of them.

This work revealed, in Lin's words, that (1) "most of the current state-of-the-art CGCMs have some degree of the double-ITCZ problem, which is characterized by [2] excessive precipitation over much of the Tropics (e.g., Northern Hemisphere ITCZ, Southern Hemisphere SPCZ [South Pacific Convergence Zone], Maritime Continent, and equatorial Indian Ocean), and is often associated with [3] insufficient precipitation over the equatorial Pacific," as well as (4) "overly strong trade winds, [5] excessive LHF [latent heat flux], and [6] insufficient SWF [shortwave flux], leading to [7] significant cold SST (sea surface temperature) bias in much of the tropical oceans," while additionally noting that (8,9) "most of the models also simulate insufficient latitudinal asymmetry in precipitation and SST over the eastern Pacific and Atlantic Oceans," *further* stating that [10] "the AMIP runs also produce excessive precipitation over much of the Tropics including the equatorial Pacific, which [11-13] also leads to overly strong trade winds, excessive LHF, and insufficient SWF," which suggests that (14) "the excessive tropical precipitation is an intrinsic error of the atmospheric models." And as if that was not enough, Lin added that (15) "over the eastern Pacific stratus region, most of the models produce insufficient stratus-SST feedback associated with [16] insufficient sensitivity of stratus cloud amount to SST."

With the solutions to *all* of these long-standing problems continuing to remain "elusive," and with Lin suggesting that the sought-for solutions were in fact *prerequisites* for what he called "good simulations/predictions" of future climate, there was significant reason to conclude that the then-current state-of-the-art CGCM predictions of CO_2-induced global warming ought not to have been considered all that reliable. And to cite these predictions as the *primary basis* for *totally revamping* the way the world obtains the energy used to power modern societies, would seem to be the height of folly.

In still another contemporary paper, Zhou *et al*. (2007) noted that clouds and precipitation play key roles in linking earth's energy and water cycles, indicating that "the sensitivity of deep convective cloud systems and their associated precipitation efficiency in response to climate change are key factors in predicting the future climate." And in this context they also reported that *cloud resolving models* or CRMs "have become one of the primary tools to develop the physical parameterizations of moist and other subgrid-scale processes in global circulation and climate models," and that CRMs could someday be used in place of traditional cloud parameterizations in such models.

In this regard, however, they indicated that "CRMs still need parameterizations on scales smaller than their grid resolutions and have many known and unknown deficiencies." To help stimulate progress in these areas, therefore, the nine scientists compared the cloud and precipitation properties observed from the Clouds and the Earth's Radiant Energy System (CERES) and Tropical Rainfall Measuring Mission (TRMM) instruments against simulations obtained from the three-dimensional Goddard Cumulus Ensemble (GCE) model during the South China Sea Monsoon Experiment (SCSMEX) field campaign of 18 May-18 June 1998. And what did the researchers learn from these efforts?

Zhou *et al*. reported that, in the way of problems: (1) "the GCE rainfall spectrum includes a greater proportion of heavy rains than PR (Precipitation Radar) or TMI (TRMM Microwave Imager) observations," that (2) "the GCE model produces excessive condensed water loading in the column, especially the amount of graupel as indicated by both TMI and PR observations," that (3,4) "the model also cannot simulate the bright band and the sharp decrease of radar reflectivity above the freezing level in stratiform rain as seen from PR," that (5) "the model has much higher domain-averaged OLR (outgoing longwave radiation) due to smaller total cloud fraction," that (6,7) "the model has a more skewed distribution of OLR and effective cloud top than CERES observations, indicating that [8] the model's cloud field is insufficient in area extent," that (9) "the GCE is ... not very efficient in stratiform rain conditions because of the large amounts of slowly falling snow and graupel that are simulated," and finally, in summation, that (10,11) "large differences between model and observations exist in the rain spectrum and the vertical hydrometeor profiles that contribute to the associated cloud field."

In light of these several significant findings, it should be clear that CRMs still have a long way to go before they are ready to be used in the complex quest to properly assess the roles of *various types of clouds* and *forms of precipitation* in the future evolution of earth's climate in response to variations in numerous anthropogenic and background forcings. This evaluation is not meant to denigrate the CRMs in any way; it is merely done to indicate that the climate modeling enterprise is not yet at the stage where implicit faith should be placed in what it *currently* may suggest about earth's climatic response to the ongoing rise in the air's CO_2 content.

Still stuck in the same year, Kiktiv *et al*. (2007) introduced their study of the subject by stating the obvious (but extremely important) *fact* that "comparing climate modeling results with historical observations is important to further develop climate models and to understand the capabilities and limitations of climate change projections." This they then proceeded to do by analyzing the abilities of five global coupled climate models -- which played important roles in the IPCC's Fourth Assessment Report -- to simulate temporal trends over the second half of the 20th century of five annual indices of extremes in surface temperature (annual percentage of days with Tmin < 10th percentile, with Tmax < 10th percentile, with Tmin > 90th percentile, with Tmax > 90th percentile, and annual number of frost days, i.e., Tmin < 0°C), as well as five annual indices of extremes in precipitation, the observational data for which analyses they obtained from the HadEX global data set that contained gridded annual and seasonal values of the ten extreme indices that were calculated from series of *in situ* daily measurements (Alexander *et al*., 2006).

As for what they learned from this endeavor, the international research team, hailing from Australia, Japan, Russia and the United Kingdom, found that (1-3) the results mostly show *moderate* skill for temperature indices and *low* skill or its *absence* for precipitation indices. And if the nations of the world were planning to use such climate model results as the basis for mandating a complete overhaul of modern man's energy system -- as the world's climate alarmists continue to suggest they do -- one would logically like to have those models possess much more than *moderate* skill. One would especially not want them to have *low* skill. And to rely on models that have *no* skill would be *insanity incarnate.*

A couple years later, O'Gorman and Schneider (2009) assessed how precipitation extremes changed in simulations with 11 different climate models in the World Climate Research Program's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) archive." And based on their findings, as well as those of others, they reported that (1) "in simulations with comprehensive climate models, the rate of increase in precipitation extremes varies widely among models, especially in the tropics," citing Kharin *et al*. (2007). They also noted, in this regard, that (2) "the variations among models in the tropics indicate that simulated precipitation extremes may depend sensitively on the parameterization of unresolved and poorly understood processes," citing the work of Wilcox and Donner (2007). In fact, they found that "climate models [3] do not correctly reproduce the interannual variability of precipitation extremes in the tropics (Allan and Soden, 2008), or [4,5] the frequency and intensity distribution of precipitation generally (Wilcox and Donner, 2007; Dai, 2006; Sun *et al*., 2006)." And the two researchers thus had little choice but to say that their results implied that (6) "current climate models cannot reliably predict changes in tropical precipitation extremes," noting that (7,8) "inaccurate simulation of the upward velocities may explain not only the intermodal scatter in changes in tropical precipitation extremes but also the inability of models to reproduce observed interannual variability."

Also with a pertinent paper appearing in the same year were Bombardi and Carvalho (2009), *who* -- based on real-world data pertaining to the onset, end and total rainfall of the South American Monsoon System (SAMS), as characterized by precipitation data for the period 1979-2006 that they derived from the Global Precipitation Climatology Project -- evaluated the ability of ten IPCC global coupled climate models (with distinct physics and resolutions) to simulate real-world SAMS characteristics.

This work revealed, as reported by the two researchers, that (1) over northern South America the annual precipitation cycle "is poorly represented by most models," and, more specifically, that (2) "most models tend to underestimate precipitation during the peak of the rainy season." In addition, they found that (3) "the misrepresentation of the Inter-Tropical Convergence Zone and its seasonal cycle seems to be one of the main reasons for the unrealistic out-of-phase annual cycles simulated near the equator by many GCMs," and that (4) "poor representation of the total monsoonal precipitation over the Amazon and northeast Brazil is observed in a large majority of the models."

As a consequence of *these* facts, they further noted that (5-7) "simulations of the total seasonal precipitation, onset and end of the rainy season diverge among models and are notoriously unrealistic over [the] north and northwest Amazon for most models." So once again we have a demonstration of the *fact* that when computer-model output is compared with real-world data of the *past*, the comparison often does not look good, giving one little confidence in the ability of climate models to correctly simulate the future.

Moving on another year, Stephens *et al*. (2010) noted that in prior studies of the subject, "land surface observations of the daily-accumulated rainfall intensities of rates >1 mm/day were compiled from the Global Historical Climatology Network by Sun *et al*. (2006) and compared to analogous model accumulated precipitation," and in so doing they reported finding that -- "as in other studies (e.g., Dai and Trenberth, 2004) -- the Sun *et al*. comparison revealed [1] a general overestimate in the frequency of modeled precipitation and [2] an associated underestimate of intensity," while noting that "Wilcox and Donner (2007) reached a similar conclusion."

To *further* examine this issue -- and to extend the scope of its relevance -- the nine researchers focused on the much larger portion of the planet that is occupied by its oceans, where they used "new and definitive measures of precipitation frequency provided by CloudSat [e.g., Haynes *et al*., 2009]" to assess the realism of global model precipitation via an analysis that employed five different computational techniques representing "state-of-the-art weather prediction models, state-of-the-art climate models, and the emerging high-resolution global cloud 'resolving' models." And what did they thereby learn?

Stephens *et al*. determined that (1) "the character of liquid precipitation (defined as a combination of accumulation, frequency, and intensity) over the global oceans is significantly different from the character of liquid precipitation produced by global weather and climate models," noting that (2) "the differences between observed and modeled precipitation are larger than can be explained by observational retrieval errors or by the inherent sampling differences between observations and models." More specifically, they said that for the global ocean as a whole, (3) "the mean model intensity lies between 1.3 and 1.9 times less than the averaged observations," while (4) occurrences "are approximately twice the frequency of observations." In addition, they reported that the models (5) "produce too much precipitation over the tropical oceans" and (6) "too little mid-latitude precipitation." And they further indicated that the large model errors (7) "are not merely a consequence of inadequate upscaling of observations but indicative of a systemic problem of models more generally."

In concluding their paper, the US, UK and Australian researchers thus wrote that their results imply that state-of-the-art weather and climate models have (8) "little skill in precipitation calculated at individual grid points," and that (9) "applications involving downscaling of grid point precipitation to yet even finer-scale resolution has little foundation and relevance to the real earth system," which is not too encouraging a result, considering it is the "real earth system" in which we live and for which we thus have great concern.

Moving another year closer to the present, Waliser *et al.* (2011) noted that contrary to the proper use of satellite retrievals in the evaluation of modeled cloud ice and liquid was the fact that (1) many global climate model representations of their day ignored or diagnostically treated the falling hydrometeor components (e.g., rain, snow) and (2) only considered -- for the purposes of radiation calculations -- the 'suspended' component of water that the models deemed 'clouds.' And they also remarked that (3) "the variations in the annual mean integrated ice water path and liquid water path between global climate models contributing to the IPCC AR4 range over two orders of magnitude," citing Li *et al*. (2008) and Waliser *et al*. (2009).

Employing estimates of cloud and precipitating ice mass and characterizations of its vertical structure supplied by CloudSat retrievals, Waliser *et al*. thus performed radiative transfer calculations "to examine the impact of excluding precipitating ice on atmospheric radiative fluxes and heating rates." And in doing so they found that exclusion of precipitating ice (4-6) "can result in underestimates of the reflective shortwave flux at the top of the atmosphere (TOA) and overestimates of the down-welling surface shortwave and emitted TOA longwave flux, with the differences being about 5-10 Wm^{-2} in the most convective and rainfall intensive areas." In addition, they said that (7,8) "there are also considerable differences (~10-25%) in the vertical profiles of shortwave and longwave heating, resulting in [9] an overestimation (~up to 10%) of the integrated column cooling." And they further found that (10) "the magnitude of these potential errors is on the order of the radiative heating changes associated with a doubling of atmospheric carbon dioxide."

Waliser *et al*. further said that "when the above results are considered in the context of a climate model simulation, the changes would not only impact the radiative heating of the atmosphere but would be expected to impact the circulation, and possibly even the manner the model adjusts to external forcings such as increasing greenhouse gases." In addition, they noted that since the "models are tuned to get the right TOA radiation balance, the implications here are that without considering the ice in precipitating hydrometeors explicitly, [11] the models will be getting the right result (i.e., TOA balance) for the wrong reasons," and that "in doing so,[12] there are likely to be compensating errors in other quantities such as cloud cover, cloud particle effective radius and/or cloud mass." Consequently, it would appear that climate modelers still have a long way to go in their quest to adequately represent the intricate complexity of earth's climatic system.

Contemporaneously, Mass *et al*. (2011) wrote that "a number of articles in the media and reports by some non-governmental organizations have suggested an increasing number of heavy precipitation events over portions of the western United States and have proposed that anthropogenic global warming could be the cause." So in a review of the subject designed to evaluate this proposal, Mass *et al*. analyzed "trends in heavy precipitation for the period 1950-2009 by examining the decadal distributions of the top 60, 40 and 20 two-day precipitation events for a collection of stations along the coastal zone of the United States and British Columbia [Canada], as well as the decadal distribution of maximum daily discharge for unregulated rivers from northern California to Washington State."

As a result of these efforts, the three researchers from the University of Washington's Department of Atmospheric Sciences reported that "during the past 60 years there has been a modest increase in heavy precipitation events over southern and central coastal California, a decline in heavy events from northern California through the central Oregon coast, a substantial increase in major events over Washington, and a modest increase over coastal British Columbia," although they noted that "most of these trends are not significantly different from zero at the 95% level." In addition, they found that "trends in maximum daily discharge of unregulated rivers are consistent with the above pattern, with increasing discharges over the past three decades over Washington and northern Oregon and declines over the remainder of Oregon and northern California.

So just how "consistent" are these results with what climate models suggest should occur in response to rising temperatures? Mass *et al*. stated that the results of the two climate models analyzed by Chen *et al*. (2003) suggested (1) "a pattern quite different from the one described above," and they said that the model employed by Kim (2005) also produced (2) "a pattern quite distinct from that observed since 1950." In addition, they noted that the models studied by Tebaldi *et al*. (2006) produced (3) "a pattern closer, but not identical to, that observed over the past 60 years," while they noted that Duffy *et al*. (2006) "analyzed the precipitation produced over the western United States by four regional climate models," finding (4) the spatial distributions of precipitation they produced to "vary substantially," even among themselves.

In their paper's concluding paragraph, therefore, Mass *et al*. wrote that "considering the large variability in precipitation trends among the various general circulation models in the above studies and their associated regional climate models, and the differences between the simulated trend distributions and the observed trend patterns found in this study and others, it is [4] unclear whether anthropogenic global warming is the source of past spatial patterns of extreme precipitation trends along the west coast of North America," leaving the matter essentially unresolved.

In another contemporary paper, Trenberth (2011) compared the projections of state-of-the-art climate models with what was known at that time about the real world with respect to extreme meteorological events related to atmospheric moisture, such as precipitation and various types of storm systems, as well as subsequent extreme consequences such as droughts, floods and wind damage. So what did *he* find?

In the concluding sentence of his paper's abstract, the U.S. researcher -- a Distinguished Senior Scientist in the Climate Analysis Section at the National Center for Atmospheric Research -- stated that model-simulated precipitation "[1] occurs prematurely and [2] too often, and [3] with insufficient intensity, resulting in [4] recycling that is too large and [5] a lifetime of moisture in the atmosphere that is too short, which affects runoff and soil moisture," while in the text of the paper he writes that (6) "all models contain large errors in precipitation simulations, both in terms of mean fields and their annual cycle (such as the spurious migration of the Intertropical Convergence Zone into the other hemisphere), as well as their characteristics: the intensity, frequency, and duration of precipitation, plus the amount (e.g. IPCC, 2007; Bosilovich *et al*., 2008; Liepert and Previdi, 2009)." And he further states that "it appears that many, perhaps all, global climate and numerical weather prediction models and even many high-resolution regional models have [7] a premature onset of convection and [8] overly frequent precipitation with [9] insufficient intensity," citing the work of Yang and Slingo (2001) and Dai and Trenberth (2004).

Continuing, Trenberth stated that (10) "confidence in model results for changes in extremes is tempered by the large scatter among the extremes in modeling today's climate, especially in the tropics and subtropics (Kharin *et al*., 2007), which relates to poor depiction of [11] transient tropical disturbances, including [12] easterly waves, [13] Madden-Julian Oscillations, [14] tropical storms, and [15] hurricanes (Lin *et al*., 2006)," which phenomena, in his words, "are very resolution dependent, but also depend on parameterizations of sub-grid-scale convection, the shortcomings of which are revealed in diurnal cycle simulations," wherein [16,17] "models produce precipitation that is too frequent and with insufficient intensity (Yang and Slingo, 2001; Trenberth *et al*., 2003; Dai and Trenberth, 2004; Dai, 2006)."

In light of these several observations, Trenberth readily concluded that [18] "major challenges remain to improve model simulations of the hydrological cycle." And until such is accomplished and it is proven that climate models can correctly simulate something as basic as *precipitation*, it would seem to have been unwise in the extreme to have made major global-economy-impacting political decisions on so flimsy a basis as what 2011's climate models were predicting, not only with respect to the meteorological phenomena that were discussed by Trenberth, but with respect to the many other extreme weather and climatic events that the world's climate alarmists continue to use to terrorize the public on a never-ending basis via their over-the-top rhetoric about impending catastrophic consequences if anthropogenic CO_2 emissions are not drastically reduced.

Concurrently, Cerezo-Mota *et al*. (2011) wrote that "the North American monsoon (NAM) is the regional-scale atmospheric circulation system (Stensrud *et al*., 1997) responsible for the dramatic increase in precipitation during the summer in northwestern Mexico and the southwest United States (Grantz *et al*., 2007)," and they said that "understanding the mechanisms that govern the timing and intensity, as well as the impacts of climate change on the NAM, is a priority for the scientific community, watershed managers and farmers in the NAM area," since "the impacts of droughts/floods are devastating."

In light of the great significance of the NAM system, therefore, Cerezo-Mota *et al*. investigated the degree of realism in its simulation by a major *regional climate model* (RCM) -- the Hadley Centre Regional Model version 3P (HadRM3P) -- analyzing the moisture sources of the NAM by employing two different boundary-condition datasets used to drive the model, which allowed them to assess the ability of the RCM to reproduce rainfall under climate-change conditions in the NAM region as predicted by *global climate models* (GCMs). And as a result of their various tests, the three UK researchers determined that (1,2) "two of the most commonly used GCMs that simulate well the NAM precipitation (HadCM3 and MIROC) do not reproduce correctly the Great Plains low-level jet nor the moisture in the Gulf of Mexico," both of which factors play major roles in the northern portion of the NAM.

The ultimate implication of their results, in the words of Cerezo-Mota *et al*., was thus that (3) "precipitation in Arizona-New Mexico would not be correctly represented by a regional model driven by these GCMs." And so it was that they concluded that (4) RCMs driven by the "most commonly used" GCMs "would not give realistic simulations of the current climate of the region and therefore would not offer a realistic projection of climate change of the NAM."

Also publishing a pertinent paper in the same year were Soncini and Bocchiola (2011), who wrote that "General Circulation Models (GCMs) are widely adopted tools to achieve future climate projections." But they noted that "one needs to assess their accuracy, which is only possible by comparison of GCMs' control runs against past observed data," which they thus proceeded to do in the case of snowfall regimes within the Italian Alps. More particularly, the two Italian researchers investigated the accuracy of simulations of snowfall throughout the Italian Alps that were provided by two GCMs (*HadCM3, CCSM3*) that had been included in the family of models employed by the IPCC, which they did by comparing the models' output with a set of comprehensive ground data obtained from some 400 snow-gauging stations located within the region of interest for the period 1990-2009.

This work ultimately revealed, in the words of Soncini and Bocchiola, that (1,2) "the investigated GCMs provide poor depiction of the snowfall timing and amount upon the Italian Alps," noting, in fact, that the *HadCM3* model actually (3) "displays considerable snowfall during summer," which they indicate (4) "is clearly not supported by ground data." In addition, they reported obtaining (5) "contrasting results between the two models," with the *HadCM3* model providing substantially *constant* volumes of snow received over time, and *CCSM3* projecting *decreasing* snowfall volumes. Consequently, the two researchers concluded that "given the poor depiction of snowfall by the GCMs here tested, we suggest that care should be taken when using their outputs for predictive purposes." Or, as others might have suggested, (6) the two models should probably *not be used at all*.

In another significant study from this time period, Stewart *et al*. (2011) noted that "regional climate models project that future climate warming in Central Europe will bring more intense summer-autumn heavy precipitation and floods as the atmospheric concentration of water vapor increases and cyclones intensify," citing the studies of Arnell and Liu (2001), Christensen and Christensen (2003) and Kundzewicz *et al*. (2005). And in an exercise designed to assess the *reasonableness* of these projections, Stewart *et al*. further wrote that “a complete record of paleofloods, regional glacier length changes (and associated climate phases) and regional glacier advances and retreats (and associated climate transitions) were derived from varved sediments of Lake Silvaplana (ca. 1450 BC-AD 420; Upper Engadine, Switzerland)," while indicating that "these records provide insight into the behavior of floods (i.e. frequency) under a wide range of climate conditions." And what did they thereby learn?

The five researchers reported uncovering pertinent data from the period they investigated that suggested "an increase in the frequency of paleofloods during cool and**/**or wet climates and windows of cooler June-July-August temperatures," which finding further suggests – as they also noted – that the frequency of flooding "was reduced during warm and**/**or dry climates." And reiterating the *fact* that "the findings of this study suggest that the frequency of extreme summer-autumn precipitation events (i.e. flood events) and the associated atmospheric pattern in the Eastern Swiss Alps was not enhanced during warmer (or drier) periods," Stewart *et al*. had no choice but to acknowledge that (1) "evidence could not be found that summer-autumn floods would increase in the Eastern Swiss Alps in a warmer climate of the 21st century," pretty much debunking the projections of the regional climate models that had suggested otherwise.

About this same time, Buntgen *et al*. (2011) wrote that anthropogenically-induced climate change is projected by climate models to increase the frequency, severity and probability of extreme meteorological phenomena, noting that many climate alarmists claim we have been experiencing this effect of global warming for some time now. On the other hand, they also wrote that a *palaeoclimatic perspective* is "indispensable to place modern trends and events in a pre-industrial context," citing Battipaglia *et al*. (2010), and that it is also needed "to disentangle effects of human greenhouse gas emission from natural forcing and internal oscillation," citing Hegerl *et al*. (2011), while *further* stating that it "remains unclear if long-term changes in climatic mean stages, such as those associated with the Medieval Climate Anomaly (AD ~900-1300), the Little Ice Age (AD ~1300-1850), and the Recent Global Warming (AD ~1850-present), [have] affected the probability of extremes."

To help develop this essential *palaeoclimatic perspective*, the nine researchers analyzed 11,873 annually-resolved and absolutely-dated ring-width measurement series from living and historical fir (*Abies alba* Mill.) trees that had been sampled across France, Switzerland, Germany and the Czech Republic, and which continuously spanned the AD 962-2007 period, while demonstrating that ring-width extremes were triggered by anomalous variations in Central European April-June precipitation.

This work revealed, in their words, that there was "a fairly uniform distribution of hydroclimatic extremes throughout the Medieval Climate Anomaly, Little Ice Age and Recent Global Warming," which result brought into question, in their opinion, "the common belief that the frequency and severity of such events closely relates to climate mean states." And so it was that for the portion of Europe involved in their study, extreme hydroclimatic phenomena were found to *not* be amplified in either *number* or *strength* in response to global warming, which leads one to suspect that the same may also hold true for other portions of the planet, in contradiction of vociferous climate-alarmist claims to the contrary.

Inching another year closer to the present, Mishra *et al*. (2012) compared precipitation output from all *regional climate models* (RCMs) that participated in the North American Regional Climate

Change Assessment Program (NARCCAP) with observations made at 100 urban U.S. weather stations that each had data for the period 1950-2009. This work involved two distinct RCM simulations: one that was forced by output from the National Center for Environmental Prediction**/**Department of Energy (NCEP**/**DOE) reanalysis (Kanamitsu *et al*., 2002) for the period 1979-2000, and one forced by selected *global circulation models* (GCMs) that provided RCM boundary conditions for the period 1968-2000.

This work revealed, "for most urban areas in the western and southeastern U.S.," in the words of the three researchers, that (1) "the seasonality of 3-hour precipitation extremes was not successfully reproduced by the RCMs with either reanalysis or GCM boundary conditions," since (2) "the RCMs tended to predict 3-hour precipitation maxima in winter, whereas the observations indicated summer." They also found that the RCMs (3,4) "largely underestimated 3-hour precipitation maxima means and 100-year return period magnitudes at most locations across the United States for both reanalysis and GCM boundary conditions." And for 3- and 24-hour annual precipitation maxima, they demonstrated that (5) "RCMs with reanalysis boundary conditions underestimated interannual variability," while they (6) "overestimated interannual variability with GCM boundary conditions."

With respect to the ultimate *utility* of the RCM projections, therefore, Mishra *et al*. indicated that (7) performance deemed acceptable for *city stormwater infrastructure design* was only adequate at about 25% of the urban areas, while they stated, irrespective of boundary conditions, that (8) "RCM-simulated 3-hour precipitation maxima at a 100-year return period could only be considered acceptable for stormwater infrastructure design at less than 12% of the 100 urban areas," which findings suggest that (9) there is still a long, long way to go before RCMs are likely to tell us anything of value. Right now, in fact, they could well be considered to be *dangerously misleading*.

In a somewhat related paper, Soares *et al*. (2012) introduced their study of the subject by writing that "Regional Climate Models (RCMs) are increasingly used to assess the impact of climate change at regional and local scales (Giorgi and Mearns, 1999; Wang *et al*., 2004; Christensen and Christensen, 2007)," because "in regions where local features affecting the atmospheric flow, such as topography and coastal processes, are prevalent, finer resolution simulations with state-of-the-art mesoscale models are required to reproduce observed weather and climate," citing in this regard the studies of Mass *et al*. (2002) and Salathe *et al*. (2008). And, consequently, as described by Soares *et al*., "a new data set of daily gridded observations of precipitation, computed from over 400 stations in Portugal, was used to assess the relevant performances of 12 regional climate models at 25-km resolution, from the ENSEMBLES set, which were all forced by ERA-40 boundary conditions, for the 1961-2000 period," while "standard point error statistics, calculated from grid point and basin aggregated data, and precipitation related climate indices were used to analyze the performance of the different models in representing the main spatial and temporal features of the regional climate, and its extreme events."

As for what they thereby learned, the five Portuguese researchers concluded that the models achieved what they called a "good representation" of the features listed above. But in addition, they also listed a number of *less*-than-hoped-for results, noting that (1) "10 of the 12 analyzed models under-predict Portuguese precipitation," that (2) "half of the models under-represent observed variability of daily precipitation," that (3) the "models were found to underestimate the number of wet days," that (4) "grid point percentiles of precipitation are generally under-predicted," that (5) "in all cases, there is a significant model spread," that (6) "the 95th percentile is under-predicted by all models in most of the country," and that (7) "there is an important model spread in all analyzed variables."

Contemporaneously, Salzmann and Mearns (2012) wrote that "climate impact assessments require primarily regional- to local-scale climate data for the past and the present and scenarios for the future," noting, with respect to the future, that "regional climate models (RCMs) are among the most promising tools to simulate climate on the regional scale." However, they also noted that "the effective benefit of each of these RCMs and their ensembles for specific climate impact assessments remains to be proven for individual impact studies." And, therefore, they explored this issue within the context of the North American Regional Climate Change Program (NARCCAP; Mearns *et al*., 2009) with regard to the seasonal snow regime of the Upper Colorado River Basin, which they did by comparing NARCCAP results with in situ observations and data obtained from various reanalysis projects. And what did they thereby learn?

The two researchers from the National Center for Atmospheric Research in Boulder, Colorado (USA) reported – quite bluntly and to the point – that "the RCMs are generally [1] too dry, [2] too warm, [3] simulate too little snow water equivalent, and have a [4] too-short snow cover duration with a [5] too-late start and a [6] too-early end of a significant snow cover." And to these problems they added the fact that [7] "attributing the found biases to specific features of the RCMs remains difficult or even impossible without detailed knowledge of the physical and technical specification of the models." Consequently, and in light of these several negative findings, it would appear that state-of-the-art RCMs still have a long, long way to go before they can be trusted to do what it is their intended mandate to do.

In another study from this time period, Wilhelm *et al*. (2012) began their report of it by noting that "mountain-river floods triggered by extreme precipitation events can cause substantial human and economic losses," citing Gaume *et al*. (2009) and further noting that "global warming is expected to lead to an increase in the frequency and/or intensity of such events," citing the IPCC (2007) and indicating that this is expected to occur "especially in the Mediterranean region," citing Giorgi and Lionello (2008). And, therefore, working at Lake Allos (44°14'N, 6°42'35" E) -- a 1-km-long by 700-m-wide high-altitude lake in the French Alps -- Wilhelm *et al*. carried out a coupled bathymetric and seismic survey of the lake's sediment infill, analyzing three sediment cores for grain size, geochemical composition, total organic carbon content, and pollen content and identity; while small-size vegetal macro-remains (pine needles, buds, twigs and leaves) were sampled at the base of the flood deposits and used for AMS ^{14}C analysis, which was conducted at France's LMC14 carbon-dating laboratory. And although acknowledging the complicating fact that changes in vegetation and/or land-use can modify soil stability/erodibility, they reported that "the size of the coarsest sediment fraction still reflects stream flow velocity," citing Beierle *et al*. (2002) and Francus *et al*. (2002).

When all these analyses were finally completed, the thirteen French scientists compared some 160 graded layers of sedimentary deposits laid down over the last 1400 years with records of historic floods; and they found that these comparisons "support the interpretation of flood deposits and suggest that most recorded flood events are the result of intense meso-scale precipitation events." And they also made a point of noting that the temporal history of these deposits revealed [1] "a low flood frequency during the Medieval Warm Period and [2,3] more frequent and more intense events during the Little Ice Age." So once again we have another example of climate-alarmist (IPCC) contentions *widely missing the mark* when it comes to predicting which temperature extreme -- hot or cold -- produces both more *frequent* and more *intense* precipitation events, as well as the *flooding* that accompanies them.

In a contemporary paper entitled "Recent progress in studies of climate change in China," which was published in *Advances in Atmospheric Sciences*, Ren *et al*. (2012) presented an overview of some of the more salient findings of recent years that pertain to this important subject. And most basic of all their findings, the seven scientists reported that China's *surface air temperature* (SAT) rose by only 0.3 to 1.2°C over the past century. And tempering even this modest finding was the *fact*, as they put it, that "climate warming was more evident in winter and spring than in other seasons," while "the warming trend in summer was found the weakest almost everywhere." In fact, they reported that "in the Yangtze River and Huaihe River basins, the summer mean temperature even dropped slightly." And they stated that in the country's annual mean SAT series from 1960 to 2004, "at least 27% of the warming could be attributed to the urbanization effect," which left very little warming to get very excited about, which is probably why they said very little about the likelihood that annual mean SAT in the past few decades "may not have exceeded the highest level of the Medieval Warm Period."

Next on the Chinese researchers' list of concerns, they stated that over the past 50 to 100 years, “no significant trends were detected in annual mean precipitation in the country overall." And in two related matters, they indicated that "the frequency of extreme drought and/or flood events in eastern China in the 20th century did not surpass the highest level in the past 2000 years, but approached the level of 'normal years'." In addition, they noted that a decreasing trend was found in the frequency of tropical cyclones or typhoons making landfall and affecting the southeastern coastal areas; and they repored that "the frequency and intensity of dust storms in northern China and thunderstorms over a few areas investigated in eastern China decreased."

It is not surprising, therefore, that "thus far," as Ren *et al*. wrote in concluding their report, "global and regional climate models have not performed well in [1,2] capturing basic changes in precipitation and extreme climate events." And they consequently ended their paper with the comment that (3) confidence in the models' projections "is low."

In another paper published around this same time, Li *et al*. (2012) wrote that "representing clouds and cloud climate feedback in global climate models (GCMs) remains a pressing challenge," but they noted that it was a challenge that was *needed* to be overcome in order to “reduce and quantify uncertainties associated with climate change projections."

Two of the primary parameters they worked with in this regard were *cloud ice water content* (CIWC) and *cloud ice water path* (CIWP), conducting "an observationally-based evaluation of the cloud ice water content and path of then-current GCMs, notably 20th century CMIP5 simulations," after which they compared the results to two recent reanalyses, using "three different CloudSat + CALIPSO ice water products and two methods to remove the contribution from the convective core ice mass and/or precipitating cloud hydrometeors with variable sizes and falling speeds," so that a robust observational estimate could be ultimately obtained for model evaluations.

Unfortunately, the eleven U.S. scientists found that (1) "for annual mean CIWP, there are factors of 2-10 in the differences between observations and models for a majority of the GCMs and for a number of regions," additionally noting that (2) "systematic biases in CIWC vertical structure occur below the mid-troposphere where [3] the models overestimate CIWC." And in light of these and other shortcomings they identified, they ultimately concluded that (4) "neither the CMIP5 ensemble mean nor [5] any individual model performs particularly well," adding that (6) "there are still a number of models that exhibit very large biases," and that (7) they do this "despite the availability of relevant observations." What is more, even in cases where they indicated "the models may be providing roughly the correct radiative energy budget," they found that (8) "many are accomplishing it by means of unrealistic cloud characteristics of cloud ice mass," which in turn (9,10) "likely indicates unrealistic cloud particle sizes and cloud cover." And with that, Li *et al*. concluded that (11) "cloud feedback will undoubtedly still represent a key uncertainty in the next IPCC assessment report." And in *that* prediction they are probably correct.

Contemporaneously, Kataoka *et al*. (2012) had a paper published in which they wrote that the *Indian Ocean Subtropical Dipole* (IOSD; Behera *et al*., 2000; Behera and Yamagata, 2001) is one of the climate modes that generate climate variations in the Southern Hemisphere and thus have a great impact on the surrounding countries through their influence on rainfall, citing in this regard Behera and Yamagata (2001), Reason (2001) and Washington and Preston (2006), while noting that the IOSD is characterized by "a dipole pattern in the sea surface temperature anomaly in the southern Indian Ocean with a warm (cold) southwestern pole and cold (warm) northeastern pole during austral summer," and further noting that "since southern Africa is one of the most vulnerable regions to abnormal weather events, an accurate prediction of the IOSD together with its influence on rainfall is necessary to mitigate the impacts."

Consequently, using real-world observational data and mathematical outputs from 22 state-of-the-art *coupled general circulation models* (CGCMs) that had been submitted to the World Climate Research Programme's *Coupled Model Intercomparison Project phase 3* (CMIP3), Kataoka *et al*. assessed each model's ability to simulate the IOSD and its influence on rainfall anomalies over southern Africa. This work revealed, as the four Japanese researchers reported, that (1,2) the locations and orientations of the sea surface temperature anomaly poles "differ considerably" from one model to another, owing primarily to (3) model biases in sea level pressure anomalies, which finding, as they described it, supports (4) "the earlier results of Morioka *et al*. (2010) based on an ocean general circulation model." And this problem, in their words, “may partly explain [5] the poor skills of CGCMs in simulating the influence of the IOSD on the rainfall anomalies." In addition, they stated that (6) "some models fail to simulate the statistical relation between the positive (negative) rainfall anomaly and La Niña (El Niño)." And so it was that Kataoka *et al*.’s parting words to us, as expressed in the final sentence of their paper, were that their study suggested that (7) "more accurate simulation of the IOSD as well as the influence of the ENSO is necessary to improve the seasonal prediction of southern African rainfall."

In another concurrent study, Kelly *et al*. (2012) described how both summer and winter precipitation over the Mediterranean Sea and their trends since 1950 as simulated by the newest generation of global climate models -- the Coupled Model Intercomparison Project phase 5 (CMIP5) -- were evaluated with respect to observations and the projections of the previous generation of models (CMIP3) that were used in the IPCC’s Fourth Assessment Report, with the objective of determining "to what extent we can trust the multi-model mean (MMM) trends as representing the externally forced trends."

This work revealed, in Kelly *et al*.’s words, that (1) "the Mediterranean precipitation trends of the last half century in the CMIP5 MMMs and the observations differ significantly, particularly in winter and over the northern Mediterranean region." The CMIP5 MMM trend, for example, indicated (2) "a modest drying throughout the seasonal cycle, with the strongest drying in the March, April and May spring season," while the observed trend showed "a predominantly winter drying," of which they said "it is not entirely clear what causes this discrepancy." And they thus concluded that their findings "reinforce the need for further research and better understanding of the mechanisms driving the region's hydroclimate."

Also publishing concurrently were Miao *et al*. (2012), who wrote that the accuracy of any GCM or *global climate model* "should be established through validation studies before using it to predict future climate scenarios," while adding that "although accurate simulation of the present climate does not guarantee that forecasts of future climate will be reliable, it is generally accepted that the agreement of model predictions with present observations is a necessary prerequisite in order to have confidence in the quality of a model."

Working within this conceptual framework, therefore, Miao *et al*. assessed the performance of the AR4 GCMs -- otherwise known as the CMIP3 models -- in simulating precipitation and temperature in China from 1960 to 1999 by comparing the model simulations with observed data, using "system bias, root-mean-square error, Pearson correlation coefficient and Nash-Sutcliffe model efficiency" as evaluation metrics. This work revealed that (1) certain of the CMIP3 models were "unsuitable for application to China, with little capacity to simulate the spatial variations in climate across the country," that (2) all of them gave "unsatisfactory simulations of the inter-annual temporal variability" and that (3) "each AR4 GCM performs differently in different regions of China." And in light of these findings, Miao *et al*. further concluded that (4,5) "the inter-annual simulations (temperature and precipitation) by AR4 GCMs are not suitable for direct application," and, therefore, that (6) "caution should be applied when using outputs from the AR4 GCMs in hydrological and ecological assessments" due to their "poor performance."

In yet another same-year study, Khoi and Suetsugi (2012) wrote that "many general circulation models (GCMs) consistently predict increases in frequency and magnitudes of extreme climate events and variability of precipitation (IPCC, 2007)," noting that "this will affect terrestrial water resources in the future, perhaps severely (Srikanthan and McMahon, 2001; Xu and Singh, 2004; Chen *et al*., 2011)." And, therefore, they conducted a study to see what aspect of the climate modeling enterprise led to the greatest degree of uncertainty in predicting rates of streamflow in Vietnam's Be River Catchment.

The climate scenarios employed by Khoi and Suetsugi within this context were generated from seven CMIP3 GCMs -- CCCMA CGCM3.1, CSIRO Mk30, IPSL CM4, MPI ECHAM5, NCAR CCSM3.0, UKMO HadGEM1, UKMO Had CM3 -- using SRES emission scenarios A1B, A2, B1 and B2, along with prescribed increases in global mean temperature ranging from 0.5 to 6°C. And they revealed, in the words of the two Vietnamese researchers, that "the greatest source of uncertainty in impact of climate change on streamflow is GCM structure (choice of GCM)." And they said that this result "is in accordance with findings of other authors who also suggest that the choice of the GCM is the largest source of uncertainty in hydrological projection," citing Kingston and Taylor (2010), Kingston *et al*. (2011), Nobrega *et al*. (2011), Thorne (2011) and Xu *et al*. (2011)," and while adding that the range of uncertainty could increase even further if the analysis employed a larger number of GCMs. In concluding, therefore, Khoi and Suetsugi stated that (1) "single GCMs or GCMs ensemble mean evaluations of climate change impact are unlikely to provide a representative depiction of possible future changes in streamflow."

In another paper from the same year, Ault *et al*. (2012) wrote that the last generation of models, those comprising the Climate Model Intercomparison Project III (CMIP3) archive, was (1) “unable to capture key statistics characterizing decadal to multidecadal (D2M) precipitation fluctuations," noting specifically that (2) "CMIP3 simulations overestimated the magnitude of high frequency fluctuations and consequently [3] underestimated the risk of future decadal-scale droughts." And they also noted that since "a new generation of coupled general circulation models (GCMs) had been developed and made publicly available as part of the Climate Model Intercomparison Project 5 (CMIP5) effort," it was *critical* "to evaluate the ability of these models to simulate realistic 20th century variability regionally and across a variety of timescales," which they thus went on to do.

Using gridded (2.5 x 2.5) version 4 reanalysis product data made available to them by the Global Precipitation Climatology Centre (Rudolf *et al*., 2005) -- which spanned the period January 1901 through December 2007 -- Ault *et al*. assessed the magnitude of D2M variability in new CMIP5 simulations. And what did they find by so doing? The three U.S. researchers said their results suggested that (1) "CMIP5 simulations of the historical era (1850-2005) underestimate the importance [of] D2M variability in several regions where such behavior is prominent and linked to drought," namely, "northern Africa (e.g., Giannini *et al*., 2008), Australia (Cai *et al*., 2009; Leblanc *et al*., 2012), western North America (Seager, 2007; Overpeck and Udall, 2010), and the Amazon (Marengo *et al*., 2011)." And they went on to state that "the mismatch between 20th century observations and simulations suggests that [2] model projections of the future may not fully represent all sources of D2M variations," noting that "if observed estimates of decadal variance are accurate, then [3] the current generation of models depict D2M precipitation fluctuations that are too weak, implying that [4] model hindcasts and predictions may be unable to capture the full magnitude of realizable D2M fluctuations in hydroclimate," with the ultimate result that (5) "the risk of prolonged droughts and pluvials in the future may be greater than portrayed by these models."

In another eye-opening study, Sun *et al*. (2012) wrote that "with global warming, climate models project increased precipitation variability in most regions at daily (O'Gorman and Schneider, 2009), monthly (Benestad, 2006) and inter-annual (Rind *et al*., 1989; Held and Soden, 2006; Boer, 2009; Wetherald, 2010) timescales," while additionally noting that "expectations are for precipitation extremes in storm events to increase with the saturation vapor pressure in the atmosphere," citing Trenberth *et al*. (2003). And, therefore, in a study designed to assess the virtues (or not!) of climate model precipitation projections, Sun *et al*. analyzed "observations of monthly precipitation (1940-2009) over the global land surface using a new theoretical framework that can distinguish changes in global precipitation variance between space and time."

This work indicated that "on average, dry regions**/**months became wetter and wet regions**/**months became drier over the 1940-2009 period," and they indicated that "this conclusion holds in all available databases and also holds for 1940-1999." In addition, they remarked that the patterns observed (1) "show no relationship to local or global changes in temperature," and that "if anything, [2] these results constitute a slight decline in meteorological drought over the last 70 years."

Moving ahead another year, Barkhordarian *et al*. (2013) assessed the role of anthropogenic forcing -- due to greenhouse gases and sulphate aerosols (GS) -- in precipitation trends over the Mediterranean region in order to determine if the observed trends over the period 1966-2005 (over land) and 1979-2008 (over land and sea) "are consistent with what 22 models project as response of precipitation to GS forcing," where significance was estimated using 9,000-year control runs derived from the CMIP3 archive.

This work revealed, as they reported, that (1) the observed trends were markedly inconsistent with expected changes due to GS forcing, noting that (2) the observed changes were “several times larger than the projected response to GS forcing in the models" and that (3) "the most striking inconsistency" was "the contradiction between projected drying and the observed increase in precipitation in late summer and autumn."

Therefore, coming to a conclusion that simply could not be avoided, Barkhordarian *et al*. stated that (4) "the detection of an outright sign mismatch of observed and projected trends in autumn and late summer, leads us to conclude that the recently observed trends cannot be used as an illustration of plausible future expected change in the Mediterranean region," once again illustrating the folly of placing too much faith in even the best of climate model projections.

Also ringing in the new year with a new study were Landrum *et al*. (2013), who wrote that "consistent with our understanding of the records of past forcings," climate scientists associated with phase 3 of the Paleoclimate Modeling Intercomparison Project (PMIP3) and phase 5 of the Coupled Model Intercomparison project (CMIP5) had proposed that "modeling groups perform the 'Last Millennium' simulation (LM; 850-1850 Common Era) with the same models and at the same resolutions as simulations being done to simulate the twentieth century and into the future," in order to allow for "an evaluation of the capability of models to capture observed variability on multi-decadal and longer time scales."

In response to their own proposal, the seven scientists conducted just such a study of the Community Climate System Model, version 4 (CCSM4), comparing its LM simulations to data-based reconstructions of LM temperature, hydrologic cycle, and modes of climate variability. And in reporting what they thereby learned, Landrum *et al*. wrote that "the CCSM4 LM simulation reproduces many large-scale climate patterns suggested by historical and proxy-data records." *However*, they also reported that (1) "the LM simulation does not reproduce La Niña-like cooling in the eastern Pacific Ocean during the Medieval Climate Anomaly [MCA] relative to the Little Ice Age [LIA], as has been suggested by proxy reconstructions," that (2) in response to large volcanic eruptions, the CCSM4 simulates cooling "two to three times larger than the Northern Hemisphere summer anomalies estimated from tree-ring or multiproxy reconstructions," that (3) "patterns of simulated precipitation change for the Asian monsoon to large volcanic eruptions have nearly opposite anomalies from those reconstructed from tree-ring chronologies," and that (4) "we do not find a persistent positive NAO [North Atlantic Oscillation] or a prolonged period of negative PDO [Pacific Decadal Oscillation] during the MCA," such as is "suggested by the proxy reconstructions" of MacDonald and Case (2005) and Trouet *et al*. (2009), thus providing further evidence for the "meet the new models, same as the old models" malady, which seems to literally be *plaguing* the climate-change prognosticators of today.

About this same time, Zheng and Braconnot (2013) wrote that "despite recent progress in the monitoring and understanding of the WAM [West African Monsoon] within the framework of the African Monsoon Multidisciplinary Analysis (AMMA), there are still large uncertainties in projections of future climate in this region, such that even the sign of future precipitation change is uncertain," citing Solomon *et al*. (2007). And, therefore they revisited "the results of PMIP2 simulations over Africa using two approaches." The first, as they described it, "considers the ensemble of simulations in order to determine how well the PMIP2 models reproduce some of the basic features of the summer monsoon precipitation," while the objective of the second was "to understand model differences by considering model characteristics for present-day climate and their sensitivities to insolation change." And what did they thereby learn?

First of all, the two scientists found that (1) the "meridional temperature gradient is underestimated between 0° and 20°N by the PMIP2 model median, resulting in [2] a smaller gradient of sea level pressure between the Gulf of Guinea and [the] Sahel," which helps to explain [3] "a lower than observed low-level moisture flux and [4] an underestimate of rainfall intensity when compared with observations." Second, they wrote that [5,6] "the northward extent of the rain belt and the intensity of precipitation change are underestimated." Third, they indicated that

[7] "the models overestimate the solar radiation." Fourth, they acknowledged that [8,9] the models "underestimate the cloud radiative forcing in deep and moderate convective regimes." And fifth, they said that [10] "some of the models have too strong a coupling between the latent heat and convection in deep convective regimes."

Quite clearly, therefore, there is still an immense amount of work that needs to be done by the climate modeling community before their models are, as the saying goes, "ready for prime time," especially in the case of the West African Monsoon.

In another important study from this same time period, Rossow *et al*. (2013) wrote that "some of the concern about possible negative impacts of a warming climate is focused on possible increases of precipitation extremes," and, therefore, they went on, as they described it, to "exploit more than a decade of independent cloud and precipitation data products covering the whole tropics (15°S-15°N) to more clearly separate the contributions to average precipitation intensity and daily average accumulation rate made by the different types of deep convective systems," focusing on the period 1998-2008.

As a result of this effort, the four researchers determined that "the whole distribution of instantaneous precipitation intensity and daily average accumulation rate is composed of (at least) two separate distributions representing distinctly different types of deep convection associated with different meteorological conditions." In particular, they found that the extreme portion of the tropical precipitation *intensity* distribution "is produced by 40% of the larger, longer-lived mesoscale-organized type of convection with only about 10% of the ordinary convection occurrences producing such intensities." And when *accumulation rates* were considered, they found that "essentially all of the values above 2 mm/hour are produced by the mesoscale systems."

Unfortunately, Rossow *et al*. also noted that (1) "today's atmospheric models do not represent mesoscale-organized deep convective systems that are generally larger than current-day circulation model grid cell sizes but smaller than the resolved dynamical scales," while further noting that these mesoscale convective systems {2} "last longer than the typical physics time steps."

So what was the ultimate consequence of these model deficiencies? In the concluding sentence of their paper, the four researchers stated that (3) "until the full range of deep convective processes in the tropics is more realistically represented in climate models, they cannot be used to predict the changes of extreme precipitation events in a changing (warming) climate."

In another example of this fact, Bollasina and Ming (2013) noted that (1) most current general circulation models (GCMs) "show a remarkable positive precipitation bias over the southwestern equatorial Indian Ocean (SWEIO), which can be thought of as a westward expansion of the simulated Indian Ocean convergence zone toward the coast of Africa." And they also noted, in this regard, that (2) "the bias is common to both coupled and uncoupled models, suggesting that its origin does not stem from the way boundary conditions are specified."

Instead, in the words of the two researchers, (3) "the oceanic bias, which develops in spring and reduces during the monsoon season, is associated [with] a consistent precipitation and circulation anomalous pattern over the whole Indian region," where "in the vertical, the areas are linked by [4] an anomalous Hadley-type meridional circulation, whose northern branch subsides over northeastern India significantly affecting the monsoon evolution (e.g., delaying its onset)." And they indicate that "the ability of local anomalies over the SWEIO to force a large-scale remote response to the north is further supported by numerical experiments with the GFDL spectral dry dynamical core model."

So what does it all mean? Bollasina and Ming say that their study (5) "makes the case that the precipitation bias over the SWEIO is forced by the model excess response to the local meridional sea surface temperature gradient through enhanced near-surface meridional wind convergence," and they thus conclude that "a detailed investigation into the model physics to identify possible parameters which may alleviate the model bias would be the natural extension of this work."

Publishing concurrently, Jiang *et al*. (2013) wrote that the "multi-scale temporal variability of precipitation has an established relationship with floods and droughts," and that General Circulation Models (GCMs) can provide "important avenues to climate change impact assessment and adaptation planning," but *only* if they possess an "ability to capture the climatic variability at appropriate scales." And, therefore, in an attempt to determine if today's climate models do indeed have that capability (*or not*), Jiang *et al*. assessed "the ability of 16 GCMs from the Bias Corrected and Downscaled (BCSD) World Climate Research Program's (WCRP's) Coupled Model Intercomparison Project Phase 3 (CMIP3) projections and 10 Regional Climate Models (RCMs) that participated in the North American Regional Climate Change Assessment Program (NARCCAP) to represent multi-scale temporal variability determined from observed station data," focusing on four regions in the Southwest United States (Los Angeles, Las Vegas, Tucson and Cimarron), since these places "represent four different precipitation regions classified by clustering method." And in so doing, they specifically investigated "how storm properties and seasonal, inter-annual, and decadal precipitation variabilities differed between GCMs/RCMs and observed records in these regions."

In pursuing this course of action, the four U.S. researchers found that "RCMs tend to simulate [1] longer duration, [2] shorter inter-storm periods, and [3] lower storm intensity than observed." Moreover, they said that (4) "RCMs fail to simulate high average storm intensity during the summer period as seen in observed precipitation records." They also said that (5) bias-corrected and downscaled GCMs "lack the ability to reproduce observed monthly precipitation patterns." In addition, they noted that (6) "observed precipitation tends to be above average during the PDO warm phase, while [7] precipitation during the PDO cold phase is below average," and that (8) "most of the considered GCMs failed to reproduce similar variability." And, last of all, they reported that their wavelet analysis revealed that (9) "even the successful GCMs on reproducing the low-frequency variability associated with ENSO and PDO, showed inconsistency in the occurrence or timing of 2-8-year bands."

And so it was that Jiang *et al*. concluded that (10) their "comparative analyses suggest that current GCMs/RCMs do not adequately capture multi-scale temporal variability of precipitation," and, therefore, they further concluded that (11) "using GCM/RCM output to conduct future flood projections is not creditable."

Also publishing concurrently were Blazquez and Nuñez (2013), who wrote that "nowadays climate models are the main tool to analyze the behavior of meteorological events and to study their development and evolution," while noting that "in recent years they have been used to evaluate the impact of increased anthropogenic greenhouse gas emissions to the atmosphere." And in regard to this particular function, they added that "the first step to understand climate changes that are likely to occur in the future is the assessment of the present climate," which "allows determining the model deficiencies."

Taking their own advice to heart, the two researchers wrote that their paper "evaluates a present climate simulation over southern South America performed with the Meteorological Research Institute/Japanese Meteorological Agency (MRI/JMA) high resolution global model." And in comparing their simulated wind results with data from the European Centre Medium Range Weather Forecasts (ECMWF) 40-year Reanalysis (ERA 40), and their temperature and precipitation simulations with data from various meteorological stations, they discovered that (1,2) speeds of the low level jet and the westerlies "are generally underestimated," that (3) at upper levels "the westerlies are overestimated over central Argentina," that (4-7) during December-February, March-May and September-November, "the MRI/JMA global model underestimates the temperature over east of Argentina, west of Uruguay, south of Chile and over tropical latitudes," that (8) contemporaneously, "overestimates are observed over central Argentina," while (9-11) "in June-August the model underestimates the temperature over most of Argentina, south of Chile and to the north of 20°S," that (12) "the model overestimates temperature interannual variability in all regions and all seasons, except in JJA," and of most interest to the primary subject of this review, that (13-19) in all seasons the model yields "an underestimation of the precipitation in the southeast of Brazil and south of Peru and an overestimation in Bolivia, Uruguay, north and central Chile and north of Peru," while (20,21) "during the dry season (JJA) the model greatly overestimates the precipitation over northeastern and central Argentina, that (22) "in regions located over mountainous areas the model presents a poor reproduction of the annual cycle," and that (23) "observed precipitation trends are generally positive whereas simulated ones are negative." And these 23 sets of errors make one wonder how it is possible for a climate model to be so wrong so often!

In another same-year paper, Van Haren *et al*. (2013) wrote that "estimates of future changes in extremes of multi-day precipitation sums are critical for estimates of future discharge extremes of large river basins and changes in [the] frequency of major flooding events," citing Kew *et al*. (2010); and they also indicated, in this regard, that "a correct representation of past changes is an important condition to have confidence in projections for the future."

In an attempt to achieve some of that all-important *confidence*, van Haren *et al*. studied changes in multi-day precipitation extremes in late winter in Europe and the Rhine river basin over the prior 60 years using daily precipitation data and "state-of-the-art gridded high resolution (0.5°) precipitation fields of the European ENSEMBLES project version 7.0 (Haylock *et al*. 2008)," where "observations [were] averaged to the same regular 1.5° grid when compared directly with the model results." And what did they thereby learn?

The four researchers determined that the climate models (1) "underestimate the trend in extreme precipitation in the northern half of Europe" because they (2) "underestimate the change in circulation over the past century and as a result [3] have a much smaller (extreme) precipitation response." More specifically, they stated that "a dipole in the sea-level pressure trend over continental Europe causes positive trends in extremes in northern Europe and negative trends in the Iberian Peninsula," while the climate models they used have [4] a much weaker pressure trend dipole and as a result [5] a much weaker (extreme) precipitation response." And in light of these several negative findings, Van Haren *et al*. concluded their report by stating "it is important that we improve our understanding of circulation changes, in particular related to the cause of the apparent mismatch between observed and modeled circulation trends over the past century," citing Haarsma *et al*. (2013); for if the models don't improve in this regard, neither will their precipitation predictions improve.

Also with a paper published in the same year were Su *et al*. (2013), who wrote that "testing models' abilities to reproduce 'present climate' and past climate changes is an important part of evaluating the GCM projections," citing Phillips and Gleckler (2006), Randall *et al*. (2007), Walsh *et al*. (2008) and Mote and Salathe (2010). In fact, one could truthfully say that such testing is *essential*. So what, precisely, did Su *et al*. do in this regard?

In the words of the five researchers, "the performance of 24 GCMs available in the fifth phase of the Coupled Model Intercomparison Project (CMIP5) was evaluated over the eastern Tibetan Plateau (TP) by comparing the model outputs with ground observations for the period 1961-2005," focusing their attention on both temperature and precipitation. And in so doing, Su *et al*. discovered that with respect to *temperature*, "most GCMs reasonably capture the climatological patterns and spatial variations of the observed climate," but they said that (1) "the majority of the models have cold biases, with a mean underestimation of 1.1°-2.5°C for the months December-May, and less than 1°C for June-October." As for *precipitation*, they said that (2) "the simulations of all models overestimate the observations in climatological annual means by 62.0%-183.0%," while noting that (3) "only half of the 24 GCMs are able to reproduce the observed seasonal pattern," including (4) "the sharp contrast between dry winters and wet summers."

The totality of these observations clearly suggests, as Su *et al*. note, that there is "a critical need to improve precipitation-related processes in these models." And the fact that they found 90-year forward projections of both precipitation *and* temperature to (5) "differ much more among various models than among emissions scenarios" suggests that (6) temperature-related processes have a critical need to be improved upon as well.

In yet another contemporary paper, Kumar *et al*. (2013) "analyzed twentieth-century temperature and precipitation trends and long-term persistence from 19 climate models participating in phase 5 of the Coupled Model Intercomparison Project (CMIP5)," focusing on “continental areas (60°S-60°N) during 1930-2004 to ensure higher reliability in the observations." This they did via a "nonparametric trend detection method," while "long-term persistence was quantified using the Hurst coefficient, taken from the hydrology literature."

Although some of these things were done well by the participating models, others were not. For example, Kumar *et al*. reported that "the models capture the long-term persistence in temperature reasonably well," but they said that (1) "the models have limited capability to capture the long-term persistence in precipitation." They also stated that (2) "most climate models underestimate the spatial variability in temperature trends," and they said there were (3) "large uncertainties in the simulation of regional/local-scale temperature and precipitation trends." In addition, they said that "Sakaguchi *et al*. (2012a,b) have evaluated the simulation skill for temperature trends from selected CMIP3 and CMIP5 climate models," finding (4) "limited skill in the simulation of temperature trends at regional scales in these climate models."

Finally, "from a regional natural resource planning perspective," the four scientists wrote that the multimodel-ensemble averages provide what they *kindly* called "conservative value for planning or design." And as an example, they noted that (5) "the India and West Africa regions are drying much faster (-20 mm/decade) in the observations than simulations by the multimodel-ensemble average (-5 mm/decade)," while similarly noting that (6) "north-central Asia is warming twice as fast as the global-average warming." Clearly, therefore, the best climate models of the present are still not up to doing what we really need them to be doing to be of much service.

In yet another paper from this busy climate-modeling year, Langenbrunner and Neelin (2013) wrote that "the accurate representation of precipitation is a recurring issue in climate models," and they noted, in this regard, that "El Nino-Southern Oscillation (ENSO) precipitation teleconnections provide a test bed for comparison of modeled to observed precipitation." So what did they do? As one might have expected, they assessed the simulation quality of the atmospheric component of models in the Coupled Model Intercomparison Project (CMIP) phase 5 (CMIP5) by comparing the ensemble of runs driven by observed sea surface temperatures (SSTs) to observations made during 1979-2005 and to the ensemble results of CMIP phase 3 (CMIP3).

This work revealed, as they reported, that (1) "within regions of strong observed teleconnections (equatorial South America, the western Equatorial Pacific, and a southern section of North America), there is little improvement in the CMIP5 ensemble relative to CMIP3 in amplitude and spatial correlation metrics of precipitation," that (2) "spatial patterns within each region exhibit substantial departures from observations, with spatial correlation coefficients typically less than 0.5," and that (3) the amplitude of the multi-model ensemble mean "is systematically smaller (by about 30%-40%) in the selected teleconnection regions."

Hard on the heels of the above-discussed paper, Kim *et al*. (2013) wrote that "even with the expected increases in computer resources that will allow GCMs [Global Climate Models] to run at higher horizontal resolutions, RCMs [Regional Climate Models] will remain essential to the processes [needed] for regional climate projections, climate change impact assessments, and policy making for the foreseeable future." And this being the case, they went on to describe how surface air temperature, precipitation and insolation over the conterminous United States – which had been derived from the North American Regional Climate Change Assessment Program's regional climate model (RCM) hindcast study – were evaluated using the Jet Propulsion Laboratory's Regional Climate Model Evaluation System (RCMES)," which makes comparisons between *modeled* data and surface- and satellite-based *observational* data.

In following this protocol, the eleven U.S. researchers discovered that (1-3) "the most noticeable systematic errors in the annual-mean surface air temperatures are the warm biases in the Great Plains and the cold biases in the Atlantic and Gulf of Mexico coasts," that (4-7) "for the winter, the most outstanding RCM errors include the warm bias in the Atlantic coast and Florida regions and cold bias in northern California and Arizona-western New Mexico," that (8-10) "the most notable common errors in simulating the annual precipitation [are] the wet bias in the mountainous northwestern United States and dry bias in the Gulf Coast region and the southern Great Plains," that (11-15) "in the summer, most RCMs underestimate precipitation in Southern California, Arizona, New Mexico, the Great Plains, and western Texas," while they (16-18) "overestimate in all three coastal regions," that (19) "all RCMs show especially poor performance in simulating the summer monsoon rainfall in the Arizona-western new Mexico region," and that (20) "the model bias in surface insolation varies widely according to RCMs."

Once again, therefore, we note the *fact* that as complex and powerful as today's GCMs and RCMs are, they are still in their *infancy* when it comes to trying to not only *replicate*, but to *accurately predict* various aspects of real-world climate (in this case precipitation), not only in the *near-term*, but far into the *future* as well.

Also with little positive news to report, Song *et al*. (2013) introduced their study of the subject by noting that (1) precipitation is one of the most poorly parameterized physical processes in general circulation models (GCMs). In fact, they said that it was difficult for them to (2-4) simulate precipitation features as fundamental as diurnal variation, frequency and intensity. And, therefore, to see what progress may have recently been made along these lines, the eight researchers evaluated the performances of seven *single-column models* (SCMs) by comparing model-simulated surface precipitation with observations made during the *Atmospheric Radiation Measurement* (ARM) Program at the *Southern Great Plains* (SGP) site from January 1999 to December 2001.

These efforts, in the words of Song *et al*., indicated that (1) "in the warm season, most SCMs produce more rain events in the daytime than in the nighttime, while the observations have more rain events in the nighttime," that (2,3) "the mean intensities of rain events in most SCMs are much stronger (weaker) in the daytime (nighttime) than the observations," that (4,5) "in the daytime, most SCMs have a higher frequency of moderate-to-strong precipitation events than the observations for both the warm and cold seasons," that for the precipitation events for which all the SCMs simulate the total precipitation well, (6) “different SCMs achieve the good performance by different combinations of compensating errors between the number of precipitation events and the mean precipitation intensity," that (7) "most SCMs produce a spurious precipitation peak around the regime of weak vertical motions," that (8) "model underestimation events occur in the strong ascending regimes with negative low-level horizontal heat and moisture advection," while (8,9) "model overestimation events occur in the weak (in the daytime) or moderate (in the nighttime) ascending regimes with positive low-level horizontal heat and moisture advection."

Appearing concurrently in an eye-popping article published in *Environmental Research Letters*, Ramirez-Villegas *et al*. (2013) wrote that "future outlooks of agricultural production and food security are contingent on the skill of GCMs [global climate models] in reproducing seasonal rainfall and temperatures," citing Berg *et al*. (2010), Ines *et al*. (2011) and Lobell *et al*. (2012). And, hence, they proceeded to determine just how well then-current GCMs were able to do so, by "assessing the skill of 24 CMIP3 and 26 CMIP5 GCMs in five regions of the tropical world (the Andes, West Africa, East Africa, Southern Africa and South Asia)," which they selected "due to their vulnerability to climate change."

This assessment focused on four key variables that exert significant control on crops: mean temperature, daily temperature extremes (i.e., diurnal temperature range), precipitation, and wet-day frequency," the data for which they obtained from the University of East Anglia Climatic Research Unit (New *et al*., 2002), World Clim (Hijmans *et al*., 2005), various sources of weather stations, and the ERA-40 reanalysis (Uppala *et al*., 2005)."

When all that they had planned to do was finally said and done, the four researchers discovered that (1) "climatological means of seasonal mean temperatures depict mean errors between 1 and 18°C (2-130% with respect to mean), whereas [2] seasonal precipitation and wet-day frequency depict larger errors, often offsetting observed means and variability beyond 100%." In fact, they found that (3) "no single GCM matches observations in more than 30% of the areas for monthly precipitation and wet-day frequency, 50% for diurnal range and 70% for mean temperatures."

However, all was not lost, for there were *some* "improvements" in mean climate skill: "5-15% for climatological mean temperatures, 3-5% for diurnal range and 1-2% in precipitation." And so it was that Ramirez-Villegas *et al*. concluded that (4) "at these improvement rates, we estimate that at least 5-30 years of CMIP work is required to improve regional temperature simulations and at least 30-50 years for precipitation simulations, for these to be directly input into impact models," all of which makes one wonder why someone whould place *any confidence at all* in *current* GCMs.

In yet another concomitant study, Toreti *et al*. (2013) wrote that "exposure and vulnerability to weather and climate-related natural hazards largely determine the severity of impacts of these extremes," and since planning requires reliable knowledge of the relevant climate phenomena, they stated that "a robust characterization in terms of frequency and intensity of current and future extreme precipitation is of great relevance." But they readily admited that "global climate models still cannot adequately capture the [1] frequency, [2] intensity, [3] tendency, and [4] spatial distribution of observed precipitation extremes over large regions in the world," citing Sun *et al*. (2006), Allan and Soden (2008), O'Gorman and Schneider (2009) and Min *et al*. (2011).

Hoping to improve on this sorry situation, Toreti *et al*. evaluated "simulated daily precipitation extremes in the twentieth century assuming stationary processes," and in doing so they provided "for the first time,” as they described it, “a comprehensive global assessment of seasonal future changes in daily precipitation extremes identifying regions where both consistency (i.e., models agreement) and reliability (i.e., goodness of fit of the applied statistical model) are achieved." And this work revealed, as the nine researchers reported, that (1,2) "for the subtropics and tropics, the lack of reliable and consistent estimations found for both the historical and future simulations might be connected with model deficiencies in the representation of organized convective systems." In addition, they stated that (3) "a reliable characterization of daily extreme precipitation cannot be achieved for larger areas of the world, where an estimation of the return levels cannot be obtained." And they added, in closing, that (4) "a glance at the individual simulations reveals remarkable intermodal differences."

Also with a pertinent paper published in the same year, Nair *et al*. (2013) wrote that "because of its variability," the northeast monsoon (Oct-Nov-Dec) "is very important" in that "the rainfall during this period is of huge societal significance because it supports the main cultivation season, known as Rabi, over southern peninsular India," citing the work of Zubair (2002). And, therefore, working with eight different *general circulation models* (GCMs), the five scientists analyzed their outputs (forecasts for the whole season issued in September) by comparing them with high-resolution observed and gridded rainfall data obtained from the India-Meteorological Department for the period 1982-2010.

This work revealed, as the five Indian researchers quickly discovered, that (1) "the predictive power of the models," as they phrased it, "was usually very low." For example, they found that although the models were able "somewhat" to represent "some" of the characteristic features revealed in the observations, the correlation coefficients between the model-simulated rainfall and the observed rainfall revealed (2) "the incapability of GCMs to model the observations," as well as the facts that (3,4) the "signal-to-noise ratio and external variance to error variance for the models was also unsatisfactory." And they *ultimately* determined that (5) "the models are not able to capture the interannual variability present in northeast monsoon rainfall."

"It can be concluded," therefore, according to the scientists who conducted the study, that (6) "the models are not able to capture the inter-annual variability present in northeast monsoon rainfall." And they say that this failure arises (7) "because of deviations of these patterns from those of their observed counterparts, which suggests the models tend to either [8] overestimate or [9] underestimate the observations."

In another study from what a climate modeler might consider “unlucky” AD 2013, Siam *et al*. wrote that "general circulation models (GCMs) are the best available tools to predict climate change associated with future scenarios of greenhouse gas concentrations." Unfortunately, they also felt compelled to acknowledge that (1) "an analysis of their outputs reveals that these models do not accurately reproduce the past and current climates," noting that (2) "this is particularly the case for hydrological variables (e.g., precipitation) that show large inconsistency, especially over Africa," citing in this regard the analysis of Christensen *et al*. (2007).

In still further discussing this problem, the three researchers added that (3) "many uncertainties lie behind the choice of a downscaling method, which may amplify inherent errors in GCM outputs and increase uncertainties associated with climate change predictions of the hydrological cycle at smaller scale, such as over river basins," citing Boe *et al*. (2009). And they additionally indicated that (4) these errors are reflected in disagreements among GCM predictions on the magnitudes and even the *signs* of changes in river runoff in major African basins, citing the studies of Strzepek and Yates (1996), Conway and Hulme (1996), Yates and Strzepek (1998), Nohara *et al*. (2006) and Kim *et al*. (2008).

With respect to their own work on the subject, Siam *et al*. evaluated the hydrological cycle hindcasts of 28 GCMs of the CMIP3 and CMIP5 projects, finding that (1) *most* of them exhibited strong biases in the hydrological cycles over the Congo and Upper Blue Nile river basins by (2,3) overestimating precipitation and runoff compared to observations. As for *why* this was so, they wrote that "several reasons that are under investigation could be responsible for improving the hydrological cycle simulation," specifically highlighting those that are associated with increasing horizontal model resolution. And in light of the many frustrations that were associated with this undertaking, one can only hope that *some* modeling group will ultimately succeed in this difficult endeavor.

Purich *et al*. (2013) continued to add to the large number of analyses of climate models in regard to their ability to forecast future changes in precipitation at various places throughout the world, noting that "in recent decades, Southern Hemisphere mid-latitude regions such as southern Africa, southeastern Australia, and southern Chile have experienced a reduction in austral autumn precipitation, the cause of which is poorly understood." And to thus see if they might *better* understand this shift in climate, the four researchers analyzed "the ability of global climate models that form part of the Coupled Model Intercomparison Project phase 5 [CMIP5] to simulate these trends." At the conclusion of their study, however, they were forced to report that the CMIP5 models "underestimate both [1] the historical autumn poleward expansion of the subtropical dry zone and [2] the positive southern annular mode (SAM) trend," while further adding that (3) a "multi-model ensemble was also unable to capture the spatial pattern of observed precipitation trends across semiarid mid-latitude regions." And, therefore, in terms of Purich *et al*.'s stated purpose for conducting the analyses they performed, it was clear that the CMIP5 models were clearly not up to the task required of them.

Also concerned about the subject, Yin *et al*. (2013) wrote that "underestimated rainfall over Amazonia was a common problem for the Coupled Model Intercomparison Project phase 3 (CMIP3) models," and, therefore, they went on to investigate “whether it still exists in the CMIP phase 5 (CMIP5) models." More specifically, the four researchers evaluated the performance of "eleven CMIP5 models for historical rainfall seasonality over Amazonia by comparing them to the

GPCP [Global Precipitation Climatology Project] and CMAP [CPC merged analysis of precipitation, where CPC is rainfall datasets], the ERA-Interim reanalysis product and NOAA/NCDC sea surface temperatures." And what did they thereby learn?

The three U.S. researchers reported that (1) "some models still underestimate rainfall over Amazonia," that (2,3) "during the *dry* season, both convective and large-scale precipitation is underestimated in most models," that (4) "during the *wet* season, large-scale precipitation is still underestimated in most models," that (5) "in some models, overestimates of rainfall are associated with the adjacent tropical and eastern Pacific ITCZs [Intertropical Convergence Zones]," that (6-8) "during the transition season, low pre-seasonal latent heat, high sensible flux, and a weaker influence of cold air incursions contribute to the dry bias," that (9) "about half the models can capture, but overestimate, the influences of teleconnection," that (10) "the majority of the models either overestimate the Atlantic ITCZ or the eastern Pacific ITCZ or both," that (11) "no models realistically represent the observed distribution pattern of rain rates," that (12) the models "generally underestimate large-scale rainfall in all seasons and all four regions " that they studied, that (13) "almost all the models overestimate surface net solar radiation," which leads to (14) "a high bias in surface net radiation," that (15) during Dec, Jan and Feb "the weak westerly wind area, representing the anti-cyclonic center, is overestimated over most of the models," and that (16) "dry biases during the dry and transition seasons still exist in the majority of the models." And in comparing the CMIP5 models with the CMIP3 models, therefore, some progress is noted; but (17) there is still a long, long way to go before *climate reality* is replicated by *computers*.

Contemporaneously, Joetzjer *et al*. (2013) wrote that their rather similar study aimed at “evaluating and comparing precipitation over the Amazon in two sets of historical and future climate simulations based on phase 3 (CMIP3) and 5 (CMIP5) of the Coupled Model Intercomparison Project," wherein they selected thirteen models to answer the following questions: (1) Is there any improvement in the models' ability to capture present-day precipitation in terms of its mean annual cycle, spatial distribution and inter-annual variability? and (2) Is there any change in the models' response to climate change and any reduction in the associated uncertainties? And in undertaking these tasks, they said they employed the Global Precipitation Climatology Center data set (Rudolf *et al*., 2011) and the Hadley Centre HadSST monthly SST [sea surface temperature] climatology (Rayner *et al*., 2003)," both of which provided data at 1° resolution for the 1901-2009 period.

After completing their analysis, the four researchers wrote that while "significant improvements have been made from CMIP3 to CMIP5 to capture present-day precipitation over the Amazon basin," they said that (1) "strong uncertainties remain in the climate projections" that "arise from contrasted anomalies in both moisture convergence and evapotranspiration," which they say "might be related to the diverse response of tropical SST and ENSO (El Niño Southern Oscillation) variability, as well as to (2) spurious behaviors among the models that show the most extreme response." And, therefore, as Joetzjer *et al*. succinctly summarized the implications of their findings in the concluding sentence of their paper's abstract, (3) "model improvements of present-day climate do not necessarily translate into more reliable projections and [4] further efforts are needed for constraining the pattern of the SST response and the soil moisture feedback in global climate scenarios."

In a somewhat similar study conducted in the same time frame, Rosa and Collins (2013) wrote that the occurrence of extreme rainfall that causes floods and landslides is (1) "under-estimated in Global Climate Models (GCMs)," citing Stephens *et al*. (2010); and they additionally said that (2) "this bias can affect decisions at both the individual and the community level," which makes the *current* state of affairs a *sad* state of affairs.

Hoping to chart a course that could lead to our extricating ourselves from this undesirable situation, and noting that heavy rainfall is mainly due to cloud *cumulus convection* (CC), Rosa and Collins investigated which approaches best estimate the observed frequency distribution of heavy rainfall by analyzing data from the archives of conventional GCMs that have different CC parameterizations and that were part of the Coupled Model Intercomparison Project Phase 5 (CMIP5), as well as the results of a multi-scale GCM "which resolves cloud processes explicitly and has been shown to compare better to observations (Li *et al*., 2012)." And what did they thereby learn?

The two researchers reported that the CMIP5 GCMs (1) "react too quickly to local convective instability" and, therefore, that they (2) "overestimate the incidence of middle rainfall events," and that they (3-5) "underestimate the incidence of no, little, and heavy rainfall events," while they (6) "overestimate the persistence of heavy precipitation" and (7,8) "underestimate the persistence of no and light precipitation," while noting that (9) "the multiscale GCM has the best estimate of the diurnal cycle and a good estimate of heavy rainfall persistence." And so it would appear that the vast majority (all but one?) of the "latest and greatest" of the world's host of GCMs -- the CMIP5 group -- still fall short of what is desired of them in the area of modelling precipitation.

In another study of where we stand in our ability to correctly (or not) model precipitation around various parts of the earth, Weller and Cai (2013) began by noting that "recent studies have shown that the impact of the Indian Ocean dipole (IOD) on southern Australia occurs via equivalent barotropic Rossby wave trains triggered by convective heating in the tropical Indian Ocean," and by further noting that these phenomena have played "a significant role in the region's rainfall reduction in recent decades," and that it is therefore *essential* "that climate models used for future projections simulate these features."

To determine whether or not they actually do so, Weller and Cai went on to assess and then benchmark how well the CMIP5 generation of climate models simulates the IOD and ENSO-induced teleconnections and asymmetries that propagate to the extratropics in September-November, which is the time of the Southern Hemisphere's austral spring. And this investigation revealed that although the models get some things right, they get other things wrong. The two Australian researchers reported, for example, that (1) "the asymmetry in the impact of the IOD is distorted by two factors," such that (2) "the tropical and extratropical response to La Niña is situated unrealistically too far westward," and that (3) it is thus "too close to Australia," leading to (4) "an overly strong impact on southeast Australia." In addition, they noted that (5) "the majority of models simulate a positive SST [sea surface temperature] skewness in the eastern Pacific that is too weak," which leads to (6) "overestimating the impact of La Niña relative to that of El Niño," as well as the possibility that (7) "low model resolution may help generate a pan-Australia rainfall effect exacerbating the tropical bias."

In the closing words of Weller and Cai, therefore, they wrote that "most models simulate a slower warming rate in the eastern tropical Indian Ocean than in the western tropical Indian Ocean, inducing a positive IOD-like mean state change, in terms of zonal SST gradients." They also noted that "given that the mean state change will influence mean rainfall trends, [1] rainfall projections are likely to be distorted by the biases in the Pacific as well, making it harder for the rainfall trends to emerge." And they thus concluded by noting that their results highlight [2] "the importance of reducing the distortion in future projections of rainfall changes in IOD-affected regions such as Australia."

In yet another contemporaneous study (will they ever cease?), Rupp *et al*. (2013) wrote that "how well the CMIP5 [Coupled Model Intercomparison Project Phase 5] GCMs [global climate models] simulate climate at regional scales is of great interest to researchers and resource managers," *because,* as they said in stating the obvious, "a model that fails to reproduce aspects of the past climate will be less likely to produce a correct projection of future climate." And, therefore, in describing how work in this line of study had been progressing, Rupp *et al*. explained how they compared monthly temperature and precipitation projections from 41 CMIP5 GCMs with real-world observations for the 20th century, focusing on the United States Pacific Northwest (PNW) and surrounding regions. So what did they find?

First of all, the four U.S. researchers reported that *individually*, "the models generated a wide range of values for many metrics," and that *as a group,* they "performed less well as judged by the precipitation-based metrics." More specifically, they noted that (1) "a cursory comparison with 24 CMIP3 models [an earlier group of models] revealed few differences between the two generations of models with respect to the statistics analyzed," after which they went on to report that (2) "the change in precipitation persistence as represented by the Hurst exponent was actually in the direction away from the observed value," that (3) "the models generated a wide range of values for many metrics," that (4) "the models as a group, performed less well as judged by the precipitation-based metrics," that (5) "five observation data sets were 0.8°C warmer than the median of the simulated mean annual temperatures," that (6) "all but one model generated more precipitation than observed," that (7) "the amplitude of the seasonal cycle [of temperature] varied widely among models," that (8) "the models generated a wide range of amplitudes of the seasonal precipitation cycle, with a handful of models severely under-simulating the strength of the seasonal variation," that (9) "the multi-model mean generated a larger seasonal amplitude (by ~5°C) in southeastern Idaho than was evident in [the data]," that (10) "simulated DTR [diurnal temperature range] tended to be about 2.5-3.5°C too low throughout the year compared to [the data]," that (11) "with very few exceptions, the individual GCMs generated a DTR that was too small, irrespective of season," that (12) "over much of western North America and over the ocean west of Mexico, the multi-model mean gave too much precipitation," that (13) "there was no consistency in seasonal differences between simulations and observations, i.e., the seasons with greater observed warming were not those with greater simulated warming," that (14) "overall, the CMIP5 models tended to produce too much interannual-to-decadal variability in PNW-averaged time series of temperature relative to the observations," that (15) "in the case of precipitation, nearly all models generated less temporal variability than seen in observations," that (16) "the simulated variances in general decreased too rapidly with increasing scale," and that (17) "absent from the response ... was the tongue of observed positive (wetter) response that extends northward through eastern Oregon and Washington."

Finally progressing from 2013 to the following year, Ibrahim *et al*. (2014) wrote that "with a focus on West Africa, [1] climate models project different trends for the annual rainfall amount over the 21st century," citing Hulme *et al*. (2001), De wit and Stankiewicz (2006) and Paeth *et al*. (2009), while further noting that [2] several simulations of the annual rainfall amount over the West African Sahel unfortunately show "a wide range of changes in the annual rainfall amount without [3,4] any consensus either from the GCMs [Global Climate Models] or from the RCMs [Regional Climate Models]." And in an attempt to significantly improve this situation, Ibrahim *et al*. analyzed the evolution of the rainfall regime over Burkina Faso, in the West African Sahel, "with regard to the changes in eight characteristics of the rainy season (date of the season onset, date of the end of season, season duration, number of rain days, mean daily rainfall, maximum daily rainfall, annual rainfall amount, and mean dry spell length)." And what did they thereby learn?

The five researchers reported that (1) "the simulated relationship between changed annual rainfall amounts and the number of rain days or their intensity varies strongly from one model to another," that (2) "the climate models' simulations do not show any consensus in the trends of the annual rainfall amount over the West African Sahel during the 21st century, even when they are run under the same climate change scenario at a high spatial resolution," and that (3) "some changes do not correspond to what is observed for the rainfall variability over the last 50 years."

In light of what they learned, Ibrahim *et al*. thus concluded that (4) it is "unlikely that the uncertainty in rainfall changes projected for West Africa will decrease unless the parameterizations of convection are substantially improved (Grandpeix and Lafore, 2010) or the resolution of the RCM is sufficiently high to simulate some aspects of convection explicitly." And even if the latter two conditions are ultimately met, there is still the possibility that something else might be further foiling the project.

In another paper from the “new” year, Langford *et al*. (2014) wrote that "climate records derived from tree core measurements (e.g., Stahle *et al*., 2007; Cook *et al*., 2004; Woodhouse *et al*., 2006) or vegetation growth in lake beds (e.g., Stine, 1994) from the past millennia indicate that the southwestern United States is susceptible to severe impacts from multi-decade droughts or "megadroughts," as described by Woodhouse and Overpeck (1998) and Meehl and Hu (2006). And they further stated that "the potential economic and social cost of such intense and sustained events such as these motivates the need to understand the mechanisms for drought variability and persistence," which led them to conduct the research described herein.

In terms of what was done, Langford *et al*. examined the mechanisms responsible for decadal precipitation variability in 47 global climate model historical simulations that were performed for phase 5 of the Coupled Model Intercomparison Project (CMIP5). And this work revealed, as the three researchers reported, that (1) "the CMIP5 models have higher climatological precipitation in southwestern North America than reanalysis products," that (2) "shortcomings in summer precipitation in southwestern North America are more severe than for winter precipitation," and that (3) "climatological winds along the Gulf of California in July are misrepresented in CMIP5 models." On the other hand, they noted that "robust coincident anomaly patterns in the tropical and North Pacific Ocean and low-frequency (5 yr) winter California precipitation exist in the CMIP5 historical simulations," but they say that these associations are (4) "unable to explain more than 20% of the decadal variability."

In discussing the significance of their findings, Langford *et al*. thus concluded that "the small fraction of explained variance will limit the predictability of precipitation associated with the decadal variability and persistence offered by the ocean," which means that it's *back to the drawing board* -- or in this case to the super computers – in order to try once again to get the models to where they need to be in order to do humanity any real good.

In another of the more recent studies of the subject, Martin (2014) wrote that (1) "despite their obvious environmental, societal and economic importance, our understanding of the causes and magnitude of the variations in the global water cycle is still unsatisfactory," while further noting that (2) "uncertainties in hydrological predictions from the current generation of models pose a serious challenge to the reliability of forecasts and projections across time and space scales." And, therefore, hoping to illuminate the way forward in this regard, Martin said that the purpose of his paper was to provide "an overview of the current issues and challenges in modelling various aspects of the Earth's hydrological cycle." And he indicated, in this regard, that "the challenge to quantify and reduce uncertainty in the large-scale response of the global water cycle is immense, not least because the hydrological cycle involves almost every component of the climate system," which he subsequently went on to identify and describe in considerable detail.

More specifically, in the words of the UK's Met Office Hadley Centre researcher, he identified the *essential components* of the way forward as including "the global water budget and water conservation, the role of model resolution and parameterization of precipitation-generating processes on the representation of the global and regional hydrological cycle, representation of clouds and microphysical processes, rainfall variability, the influence of land-atmosphere coupling on rainfall patterns and their variability, monsoon processes and teleconnections, and ocean and cryosphere modelling."

And in light of the many aspects of this broad undertaking, Martin concluded that "continued collaborative activity in the areas of model development across timescales, process studies and climate change studies will provide better understanding of how and why the hydrological cycle may change, and better estimation of uncertainty in model projections of changes in the global water cycle," all of which elements of this gigantic task suggested that (1) we still have a long, long way to go before we will be capable of producing projections of the global water cycle that have even a *modest* degree of reliability. So until that time, somewhere in the future, we need to take *current* model projections of the world's water cycle with a good bit of skepticism.

About this same time, Trenberth *et al*. (2014) made a point of noting that (1) "several recently published studies have produced apparently conflicting results of how drought is changing under climate change," and they said that (2) "the reason is thought to lie in the formulation of the Palmer Drought Severity Index (PDSI) and the data sets used to determine the evapotranspiration component." And as might have been expected, the international research team made "an assessment of the issues with the PDSI." And in so doing, they also discovered (3) "several other sources of discrepancy," including "how precipitation has changed and is analyzed."

The seven scientists -- hailing from France, Saudi Arabia, the Netherlands, the United States and the United Kingdom -- discovered that (1) "uncertainties have not always been adequately appreciated," that (2) "the PDSI model itself contains uncertainties," that (3) "there remain substantial issues on how to best deal with changes in evapotranspiration," that (4) "what is more surprising, and disappointing, are the disparities between precipitation data sets," that (5) "the general availability of precipitation data and differences in the primary precipitation data sets continue to be a concern," and that (6) "the other major issue is the role of natural variability, especially ENSO, which biases the land precipitation towards wetter conditions, and with less drought globally under La Niña conditions."

In light of these several observations, it was only to be expected that Trenberth *et al*. ultimately concluded that (1) "it is probably not possible to determine reliable decadal and longer-term trends in drought due to climate change without first accounting for the effects of ENSO and the Pacific Decadal Oscillation," the former of which phenomena they described as "the most common source of episodic droughts around the world." And so it would appear that (2) there are still *numerous significant problems* that need to be resolved before the desired results can be obtained. And until this occurs, drought predictions should be looked at with a jaundiced eye.

In another contemporary paper, Rocheta *et al*. (2014) wrote that "simulating hydrological variables under enhanced greenhouse gas emissions using general circulation models (GCMs) is essential for hydrological impact assessment," citing Fowler *et al*. (2007), Giorgi *et al*. (2001) and Ines and Hansen (2006)." But they also noted that (1) "GCM precipitation simulations are less robust than other GCM fields, such as temperature," due to the facts that "precipitation simulations [2] fail to replicate some characteristics of observed twentieth-century precipitation (Goddard *et al*., 2001; Perkins *et al*., 2007; Sun *et al*., 2006), [3] differ substantially across GCMs for future simulations (Johnson and Sharma, 2009), and [4] fail to adequately capture important precipitation characteristics such as persistence (Johnson *et al*., 2011)."

Consequently, in *their* study, Rocheta *et al*. presented "a performance metric, the aggregated persistence score (APS), which is used to assess the reliability of GCMs in simulating low-frequency rainfall variability," where "the APS identifies regions where GCMs poorly represent the amount of variability seen in the observed precipitation." And this approach revealed, in the words of the five Australian researchers, that (1) “there were large spatial variations in the skill of GCMs to capture observed rainfall persistence, [2] widespread under-simulation of rainfall persistence characteristics in GCMs,” although with (3) “substantial improvement in rainfall persistence, but [4] only "after applying bias correction." And as has been found to be the case in so many other studies of the integrity of state-of-the-art climate models, the findings of Rocheta *et al*. clearly indicated that current GCMs are not yet up to the task of reliably representing low-frequency rainfall variability.

In another paper from the same year, Perez-Sanz *et al*. (2014) reported analyzing "the spatial expression of seasonal climates of the Mediterranean and northern Africa in pre-industrial and mid-Holocene simulations from the fifth phase of the Coupled Model Intercomparison Project (CMIP5)," which they did by comparing the CMIP5 simulations with "modern observations from the CRU TS3.1 data set," and by evaluating "mid-Holocene simulations using quantitative climate reconstructions derived from pollen records."

This work revealed, as they described it, that (1,2) "the CMIP5 models fail to reproduce key aspects of both the modern and mid-Holocene climate of the northern Africa and Mediterranean region, including [3] the correct geographical location of zonal precipitation regimes in the pre-industrial simulation and [4] the magnitude of mid-Holocene changes in these regimes." More specifically, they reported that most models [5] "overestimate the extent of monsoon influence and [6] underestimate the extent of desert." And they determined that the models also [7] "fail to reproduce the amount of precipitation in each zone," while noting that [8] "most models underestimate the mid-Holocene changes in annual precipitation."

When all was said and done, therefore, the four researchers were forced to acknowledge that (1) "there are still important discrepancies between the simulated and observed magnitude of changes in precipitation, despite the increasing complexity and resolution of the CMIP5 models compared to earlier generations of models." And they stated, in the concluding sentence of their paper, that (2,3) "the failure to simulate observed mid-Holocene changes in the north African monsoon and the potentially linked failure to simulate the observed shift in rainfall seasonality in the Mediterranean raises concerns about the reliability of model projections of future climates in these regions."

In another model-testing paper of this period, Cretat *et al*. (2014) introduced their approach to the subject by writing that "the capability of state-of-the-art climate models to capture the main observed characteristics of daily intense rainfall events has not been quantified over Africa," and they thus stated that a clear evaluation of the models' "strengths and limitations to simulate them is necessary." Consequently, in an effort to provide this much-needed evaluation, Cretat *et al*. analyzed regional climate model (RCM) simulations at 90- and 30-km-long intervals, together with output from four atmospheric general circulation models (AGCMs) and several coupled atmosphere-ocean general circulation models (AOGCMs) of the Climate Model Intercomparison Project 5 (CMIP5).

Via this endeavor, the three U.S. researchers determined that both sets of RCM simulations "accurately capture the spatial and temporal characteristics of intense events." *However*, they reported that they also (1) "tend to overestimate their number" and (2) "underestimate their intensity." In addition, they found that (3,4) "the majority of the AGCMs and AOGCMs greatly overestimate the frequency of intense events, particularly in the tropics," that they (5) "generally fail at simulating the observed intensity," and that they (6) "systematically overestimate their spatial coverage."

These findings, in the words of Cretat *et al*., indicate that (7) "state-of-the-art climate models still cannot realistically simulate daily intense rainfall events with high accuracy," suggesting that there are (8) "physical parameterization deficiencies" for the ranges of horizontal resolution used in their study, while further stating that (9) "the fact that both RCM and, to a greater extent, GCM simulations overestimate the frequency of intense daily rainfall events suggests that erroneous or, at least, overly simplified assumptions are used in the convective schemes of most climate models."

Working concomitantly on the same issue, Ryu and Hayhoe (2014) assessed "the ability of Global Climate Models participating in phases 3 and 5 of the Coupled Model Intercomparison Project (CMIP3 and CMIP5) to simulate observed annual precipitation cycles over the Caribbean," after which they compared their predictions "to weather station records and gridded observations." And in doing so, the two U.S. researchers found that "both CMIP3 and CMIP5 models can be grouped into three categories: models that correctly simulate a bimodal distribution with two rainfall maxima in May-June and September-October, punctuated by a mid-summer drought (MSD) in July-August; models that reproduce the MSD and the second precipitation maxima only; and models that simulate only one precipitation maxima, beginning in early summer." And they were thereby able to report that "more models are now able to reproduce the bimodal structure of the annual cycle of Caribbean precipitation in the CMIP5 simulations as compared to CMIP 3."

However, they also found that "many of the 'Bimodal' and 'Single with MSD' models from both the CMIP3 and CMIP5 simulations continue to [1] underestimate the magnitude of the early wet season, while [2] over-estimating the second wet season in the fall." And in light of these latter findings, Ryu and Hayoe concluded that various hypotheses regarding the origin of the observed biases in the model simulations "remain to be explored in future research," which fact reminds us that *we're still not where we need to be* when it comes to adequately simulating the annual pattern of Caribbean precipitation.

In another enlightening contemporary paper, Yang *et al*. (2014) wrote that the "decadal variability of the East African precipitation during the season of March-May (long rains) is examined and the performance of a series of models in simulating the observed features is assessed," which effort also included doing the same for the season of October-December (short rains). And what did the examination and simulation reveal?

The four researchers reported that "the multi-model mean of the fully-coupled models of the CMIP5 historical experiment [1] underestimates the East African long rains and [2] overestimates the short rains with [3] a considerable range of performance among the individual models." And they also note that [4,5] "this lack of coupled model skill casts doubt on projections of future East African precipitation and on the use of these models to understand past variations," as has also been suggested by the work of Tierney *et al*. (2013).

In light of these findings, therefore, Yang *et al*. concluded that (1) "it should not be assumed that recent drying trends represent an anthropogenically-forced precipitation change and that the trends will continue." *Nor*, as they continue, (2) "should it be assumed that the model projection of wetting in response to rising greenhouse gases is correct." Indeed, they say that (3) "we are distressingly far from an adequate understanding or a usable ability to model climate variability and change in this socially critical region."

In a timely study appertaining to India, Tiwary *et al*. (2014) introduced what they did in terms of climate model evaluations by noting that the northern part of India -- known as the *wheat bowl* -- receives most of its precipitation during the winter season, which *moisture*, in their words "is critically important for the agriculture and economy of the country." And in light of these facts, they conducted a study designed to determine whether five different *general circulation models* or GCMs were capable of correctly forecasting the strength of this important seasonal weather phenomenon. More specifically, they compared GCM outputs (seasonal mean precipitation forecasts issued in November) produced by various organizations with observed high-resolution gridded rainfall data that they obtained from the India Meteorological Department for the period 1982-2009. And what did they thereby learn?

The seven scientists found that (1) "skill of predictions is too low," that (2) "most of the GCMs do not respond to sea surface temperature variability over the Pacific in a realistic manner," that (3) "only two of the five GCMs get the observed simultaneous teleconnection correctly," that (4) "only one of these two models has the observed phase lag with the strongest correlation as observed," that (5,6) "the GCMs in general underestimate the observed climatology and inter-annual variability of precipitation," that (7) "none of the models is able to depict the observed inter-annual variability correctly," and that (8) "a simple multi-model ensemble approach with all the models getting the same weight does not improve much the forecast skill." And to the time of this writing, the above-noted shortcomings of the five GCMs Tiwary *et al*. studied have yet to be overcome, and, therefore, (9) present-day general circulation models are simply not up to the task of providing what is needed to properly project future crop yields in this important food producing region.

In another contemporary study of this type, Zhao *et al*. (2014) used CRU TS3.1 monthly temperature and GPCC V6 monthly precipitation datasets to conduct a systematic assessment of 17 CMIP5 climate models, focusing on long-term trends of precipitation in arid and semi-arid areas. And this work revealed, as they described it, that (1,2) "simulated precipitation is only about one-third the intensity of that seen in observations, and one-fifth the long-term trend of observations," that (3) "there are huge spreads among the models in their reproduction of precipitation long-term changes," that (4) "long-term climate trends in the simulated results get weaker than those in the observations," that (5) "over certain areas, precipitation simulations have even gotten worse from CMIP3 to CMIP5," that (6,7) "the increasing of precipitation over central Africa and the south-drier/north-wetter dipole precipitation structure over East China are not in agreement with observations," and that (8,9) "the poor simulation of precipitation is possibly due to model limitations in representing cloud changes [plus] the associated feedback over tropical and sub-tropical areas," as has previously been described by Lauer and Kevin (2013). In concluding their paper, therefore, and in light of this significant list of still-unresolved problems, the three Chinese researchers stated that, in general, (10) "model simulations of precipitation seem to still have a long way to go," while noting more specifically that (11) "the application of CMIP5 multi-model simulations requires further dynamical downscaling adjustment at regional scales."

Prefacing the findings of their study of the subject, Mehrotra *et al*. (2014) wrote that several century-scale simulations of hydrological variables for Australia that have been produced by General Circulation Models (GCMs) yield results that are "[1] highly uncertain with [2] a number of limitations which reduce their usefulness to guide local decision-making," citing the work of Suppiah *et al*. (2007), Perkins *et al.* (2007) and Maximo *et al*. (2008), while specifically noting in this regard: the (3) "coarser resolution of GCMs," (4) their "biases," and (5) their "limited representation of sub-continental scale topography," as well as their limited representation of (6) "important offshore processes." So what did the five Australian researchers do to try to improve upon this sorry state of affairs?

As they described it, they explored "the potential skill of Coupled Model Intercomparison Project (CMIP5) decadal hindcasts from 9 GCMs and their ensembles [78 for rainfall] over the period 1960-2010 from a hydrological perspective." And what did they thereby learn? Quoting them again, they said that (1) "the CMIP5 decadal simulations of rainfall exhibit very low skill when assessed across Australia and across a range of time-scales from yearly to longer which extend to the entire decade." And it was this finding that led them to ultimately conclude that the current state of precipitation predictability "is [2] not enough to drive impact models at decadal timescales and [3] to influence policy and decision making."

Finally reaching the year in which this review of the climate modeling enterprise was written, we come to the study of Anandhi and Nanjundiah (2015), who examined several Coupled General Circulation Models (CGCMs) that were utilized in the development of the Intergovernmental Panel on Climate Change's fourth assessment report (IPCC AR4), and who analyzed the several models' abilities to simulate daily precipitation over India on a 2.5° x 2.5° latitude by longitude basis throughout the 20th century, which they did by comparing the models' outputs with a similar but *observational* dataset for India that had been created by the National Climate Centre of the Indian Meteorological Department, based on measurements obtained at 2,140 rain gauge stations over the period 1951-2004. And what did the two researchers thereby learn? Very simply, they found that (1) "no single model performs best for all the categories and zones considered," that (2) "most models underestimated the daily precipitation rate in the 0-1 mm/day range," and that they (3) "overestimated it in the 1-15 mm/day range," all of which findings suggest that if current climate models cannot accurately "predict the past," why should we believe they can accurately predict the future?

In another recently published study, Moufouma-Okia and Jones (2015) introduced their work on the subject by writing that their study reveals "the effect of horizontal resolution on the ability of the Met Office third-generation Global Atmosphere Regional Climate Model (HadGEM3-RA)" -- a regional atmospheric configuration of the HadGEM3 model -- "to simulate rainfall variability over Africa," based on "six 20-year-long Regional Climate Model simulations driven by ERA-Interim reanalysis and performed at 12, 25, 50, 70, 90 and 150 km over the CORDEX-Africa domain."

With respect to the relevant *findings* derived from this exercise, the two researchers reported that (1) "in Central Equatorial Africa, HadGEM3-RA indicates excessive wet biases," as well as (2) "large root-mean square errors." In addition, they found that the model also (3) "exaggerates rainfall maxima around the Darfur highlands," that it (4) "underestimates the maximum of precipitation over the West African monsoon region," that it (5) produces "a weaker simulated meridional transport of moisture inland during the West Africa Monsoon," and that (6) "this situation worsens with increasing the model horizontal resolution," which ultimately (7) "leads to reduction of seasonal rainfall total in West Africa."

On the *bright* side of things, however, Moufouma-Okia and Jones wrote in their paper’s concluding paragraph that their study "provides insights on the challenges surrounding modelling of the climate variations across Africa and exemplifies the potential of HadGEM3-RA for investigating the local scale drivers of climate model errors in this region," as well as "the need for high resolution datasets for model validation and improved understanding of the physical processes that govern climate variability in Africa." We note, however, that such remarks sound a lot like an enterprise that is *ever progressing* ... but never quite getting to where it needs to go.

In another paper from the same culminating year of our review, Chen *et al*. (2015) began their study by noting that (1) "climate model outputs are generally considered too biased to be used as direct inputs in environmental models for climate change impact studies," citing in this regard the studies of Sharma *et al.* (2007), Christensen *et al.* (2008), Maraun *et al.* (2010) and Chen *et al.* (2013a). And with respect to previous attempts to overcome this problem, they stated that "several bias correction methods have been developed and used in hundreds of climate change impact studies," citing as examples the studies of Mpelasoka and Chiew (2009), Johnson and Sharma (2011), Teutschbein and Seibert (2012), Themeßl *et al*. (2011) and Chen *et al.* (2013b).

The approach taken by Chen *et al.* (2015) in addressing this particular subject, however, was to test the bias stationarity of several climate model outputs over Canada and the contiguous United States by comparing model outputs with corresponding observations over two 20-year periods (1961-1980 and 1981-2000)," *because*, as they continued, "all bias correction approaches ranging from simple scaling to sophisticated distribution mapping are based on an assumption that climate model biases are stationary over time," citing Hewitson and Crane (2006), Piani *et al.* (2010), Maraun (2012) and Maurer *et al.* (2013). But is this truly the case?

In the study the three researchers conducted to explore this simple but important question, they found that such was *not* the case, and that (1)"the typical 10 to 20% projected precipitation change in many impact studies ... is possibly of the same magnitude as the uncertainty error brought in by the assumption of bias stationarity," which leaves this particular field of scientific endeavor (climate modeling) in a *real*-world of hurt.

In another contemporary paper on this particular subject, namely, that of Steinhoff *et al*. (2015), who wrote that "due to the importance that the El Niño-Southern Oscillation (ENSO) has on rainfall over the tropical Americas, future changes in ENSO characteristics and teleconnections are important for regional hydroclimate." And, therefore, they explored projected changes to ENSO mean state and its primary characteristics -- along with resulting impacts on rainfall anomalies over Central America, Colombia and Ecuador during the 21st century -- for several different forcing scenarios, using "a suite of coupled atmosphere-ocean global climate models (AOGCMs) from the fifth phase of the Coupled Model Intercomparison Project (CMIP5). And what did they thereby learn?

The three U.S. researchers found that (1-3) "current and projected future characteristics of ENSO (frequency, duration, amplitude) show a wide range of values across the various AOGCMs," that (4) "the magnitudes of ENSO-related rainfall anomalies are currently underestimated by most of the models," and that (5) "there is no agreement on the changes in ENSO-related rainfall anomalies in future simulations." And with *no agreement* among the models on this extremely basic point, there is essentially nothing *new* -- or necessarily *true* -- that they have to tell us about earth's future climate.

In yet another contemporary study of the subject, Wenting and Renguang (2015) described how they evaluated “the precipitation variability over the South China Sea (SCS) and its relationship to tropical Indo-Pacific sea surface temperature anomalies [SSTAs] during the spring-to-summer transition (April-May-Jun, AMJ) simulated by 23 coupled models.” And what did they thereby discover?

The two Chinese scientists found that based on an inter-model Empirical Orthogonal Function introduced by Li and Xie (2012 and 2014), “the leading model biases in the SCS feature [1] excessive precipitation and [2] warmer SST in the central SCS, with [3] an anomalous cyclonic circulation.” Furthermore, as they continued, “[4] deficient precipitation and [5] colder SST in the EP is detected as the leading model bias mode, plus [6] negative SSTA over the SCS, [7] the northern Indian Ocean, and [8] the northwest of Australia.”

And as a result of these several anomalous findings, Wenting and Renguang rightly concluded that “further work remains to be conducted to unravel the specific reasons for the discrepancies between models and observations in various aspects,” which is essentially what all of the other studies of the subject have suggested as well.

Before concluding this section, however, there is one other recent significant study that should be mentioned; and that is the study of Smith *et al.* (2015), *who*, working with 20 CMIP5 climate models, developed a model comparison focused on the interannual to multi-decadal connections between historical Pacific Ocean SSTs and U.S. Great Basin (GB) precipitation. More specifically, as they described it, the three researchers evaluated the historical connectivity between GB precipitation and Pacific Ocean sea surface temperatures on interannual to multi-decadal time scales, finding that (1,2) "the simulated influence of these two modes on GB precipitation tended to be too strong for ENSO and too weak for PDO [the Pacific Decadal Oscillation]." They also found that (3) "few models captured the connectivity at a quasi-decadal period influenced by the transition phase of the Pacific quasi-decadal oscillation (QDO; a recently identified climate mode that influences GB precipitation)." And they went on to note that (4) "some of the discrepancies appear to stem from models not capturing the observed tendency for the PDO to modulate the sign of the ENSO-GB precipitation teleconnection."

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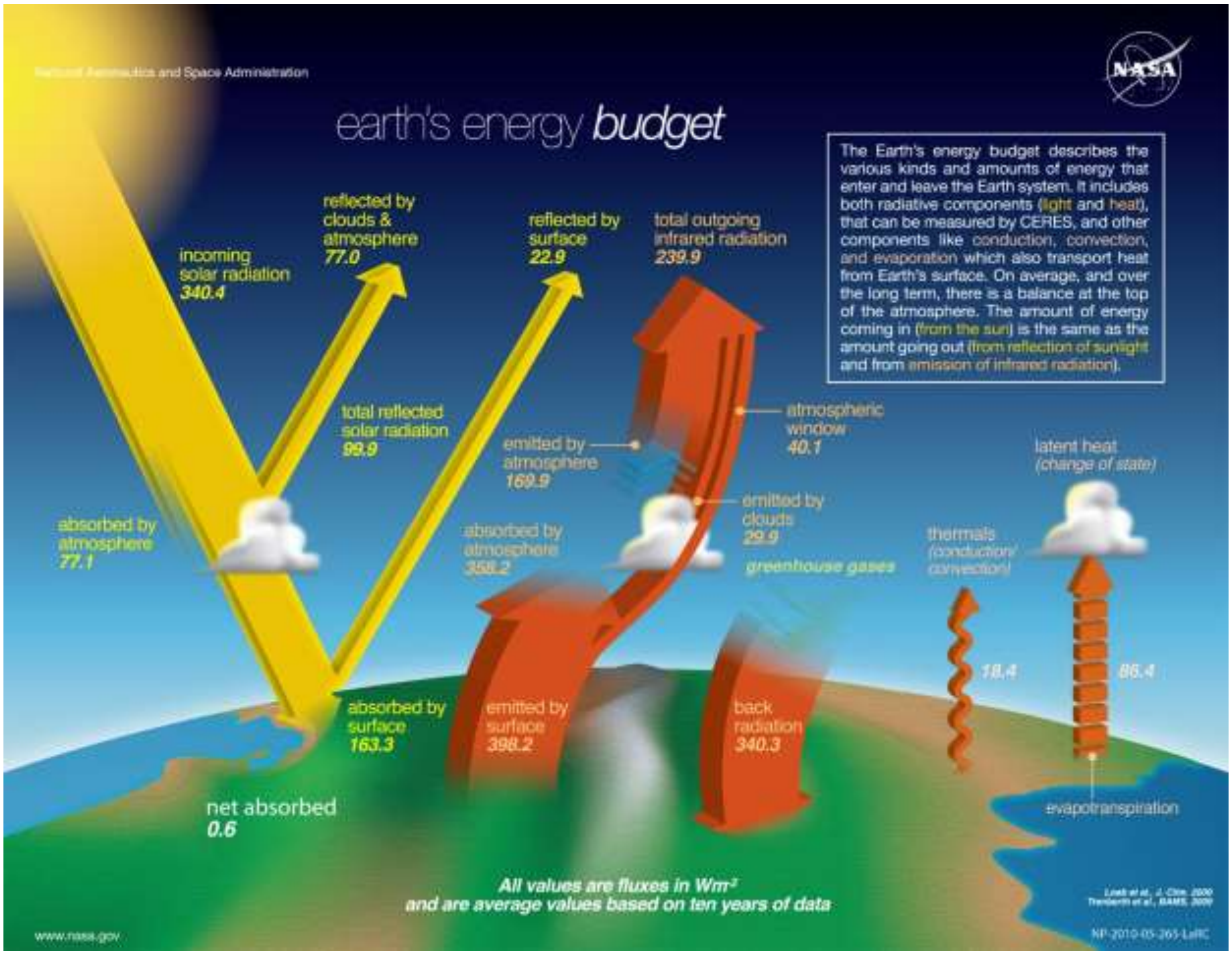
RADIATION



The Earth's energy budget describes the various kinds and amounts of energy that enter and leave the Earth system. It includes both radiative components (light and heat), that can be measured by CERES, and other components like conduction, convection, and evaporation which also transport heat from Earth's surface. On average, and over the long term, there is a balance at the top of the atmosphere. The amount of energy coming in (from the sun) is the same as the amount going out (from reflection of sunlight and from emission of infrared radiation).

One of the most challenging and important problems facing today's general circulation models of the atmosphere is how to accurately simulate the physics of earth's radiative energy balance. And of this task, back at the turn of the century, Harries (2000) wrote that "progress is excellent, on-going research is fascinating, but we have still a great deal to understand about the physics of climate."

Warning against excessive hubris, Harries thus went on to say "we must exercise great caution over the true depth of our understanding, and our ability to forecast future climate trends." As an example, he stated that our knowledge of high cirrus clouds was very poor, noting that "we could easily have uncertainties of many tens of Wm^{-2} in our description of the radiative effect of such clouds, and how these properties may change under climate forcing."

This state of affairs was extremely disconcerting, especially in light of the fact that the radiative effect of a doubling of the air's CO_2 content is in the lower single-digit range of Wm^{-2}, and, to quote Harries, that "uncertainties as large as, or larger than, the doubled CO_2 forcing could easily exist in our modeling of future climate trends, due to uncertainties in the feedback processes."

Furthermore, because of the vast complexity of the subject, Harries rightly declared that "even if [our] understanding were perfect, our ability to describe the system sufficiently well in even the largest computer models is a problem."

Illustrative of a related problem was the work of Zender (1999), who characterized the spectral, vertical, regional and seasonal atmospheric heating caused by the oxygen collision pairs $O_2 \cdot O_2$ and $O_2 \cdot N_2$, which had earlier been found to absorb a small but significant fraction of the globally-incident solar radiation. This work revealed that these molecular collisions lead to the absorption of about 1 Wm^{-2} of solar radiation, globally and annually averaged, which discovery, in Zender's words, "alters the long-standing view that H_2O, O_3, O_2, CO_2 and NO_2 are the only significant gaseous solar absorbers in Earth's atmosphere," which led him to suggest that this phenomenon should therefore be included in "large-scale atmospheric models used to simulate climate and climate change." And *this* situation raised the possibility that there may well be still *other* yet-to-be-discovered processes that should be included in the models that are used to simulate earth's climate, and that until we are confident there is little likelihood of further such surprises, we ought not rely too heavily on what the models of today are telling us about the climate of tomorrow.

In another revealing study, Wild (1999) compared the observed amount of solar radiation absorbed in the atmosphere over equatorial Africa with what was predicted by three general circulation models of the atmosphere, finding that (1) the model predictions were much too small. Indeed, regional and seasonal model underestimation biases were as high as *30* Wm^{-2}, primarily because (2,3) the models failed to properly account for spatial and temporal variations in atmospheric aerosol concentrations, as well as the fact that Wild had concluded that (4,5) the models likely underestimated the amount of solar radiation absorbed by water vapor and clouds.

Similar large model underestimations were discovered by Wild and Ohmura (1999), who analyzed a comprehensive observational dataset consisting of solar radiation fluxes measured at 720 sites across the earth's surface and corresponding top-of-the-atmosphere locations to assess the true amount of solar radiation absorbed within the atmosphere. These results were compared with estimates of solar radiation absorption derived from four atmospheric general circulation models (GCMs); and, again, it was shown that (1) "GCM atmospheres are generally too transparent for solar radiation," as they produced a rather substantial mean error close to 20% below actual observations.

Another solar-related deficiency of turn-of-the-century state-of-the-art GCMs was (1) their failure to properly account for solar-driven variations in earth-atmosphere processes that operate over a range of timescales extending from the 11-year solar cycle to century- and millennial-scale cycles. And although the absolute solar flux variations associated with these phenomena are rather small, there are a number of "multiplier effects" that could significantly amplify their impacts.

According to Chambers *et al*. (1999), (1) most of the many nonlinear responses to solar activity variability were inadequately represented (in fact, they were essentially ignored) in the global climate models used by the Intergovernmental Panel on Climate Change (IPCC) to predict future greenhouse gas-induced global warming, while at the same time (2,3) *other* amplifier effects were used to model past glacial/interglacial cycles and even the hypothesized CO_2-induced warming of the future, where CO_2 is *not* the major cause of the predicted temperature increase but rather an initial perturber of the climate system which, according to the IPCC, sets other more powerful forces in motion that produce the bulk of the ultimate warming. Hence, there appeared to be a *double standard* within the climate modeling community that may best be described as an inherent reluctance to deal even-handedly with different aspects of climate change. When multiplier effects suited their purposes, they were quick to use them; but when they didn't suit their purposes, they responded much slower.

In setting the stage for the next study of climate model inadequacies related to radiative forcing, therefore, Ghan *et al*. (2001) stated that "present-day radiative forcing by anthropogenic greenhouse gases is estimated to be 2.1 to 2.8 Wm^{-2}," that "the direct forcing by anthropogenic aerosols is estimated to be -0.3 to -1.5 Wm^{-2}," while "the indirect forcing by anthropogenic aerosols is estimated to be 0 to -1.5 Wm^{-2}," with the result that "estimates of the total global mean present-day anthropogenic forcing range from 3 Wm^{-2} to -1 Wm^{-2}," which implies a climate change somewhere between a modest warming and a slight cooling, which would seem to be a rather shaky justification for mandating draconian measures to combat the first of these possibilities. Hence, they declared that "the great uncertainty in the radiative forcing must be reduced if the observed climate record is to be reconciled with model predictions and if estimates of future climate change are to be useful in formulating emission policies."

Pursuit of this goal, as they described it, required achieving "profound reductions in the uncertainties of direct and indirect forcing by anthropogenic aerosols," which is what they thus set out to do in their analysis of the situation, which consisted of "a combination of process studies designed to improve understanding of the key processes involved in the forcing, closure experiments designed to evaluate that understanding, and integrated models that treat all of the necessary processes together and estimate the forcing."

At the conclusion of this laborious set of operations, Ghan *et al*. came up with some numbers that considerably reduced the range of uncertainty in the "total global mean present-day anthropogenic forcing," but that still implied a set of climate changes stretching from a small cooling to a modest warming. And, therefore, they provided a long list of *other* things that needed to be done in order to obtain a more definitive result, after which they acknowledged that even *this* list was "hardly complete." In fact, they concluded their analysis by saying that "one could easily add the usual list of uncertainties in the representation of clouds, etc." And, consequently, the bottom line of their view of the situation was that (1) "much remains to be done before the estimates are reliable enough to base energy policy decisions upon."

Also studying the aerosol-induced radiative forcing of climate were Vogelmann *et al*. (2003), who reported that "mineral aerosols have complex, highly varied optical properties that, for equal loadings, can cause differences in the surface IR flux between 7 and 25 Wm^{-2} (Sokolik *et al*., 1998)," but who said that (1) "only a few large-scale climate models currently consider aerosol IR effects (e.g., Tegen *et al*., 1996; Jacobson, 2001) despite their potentially large forcing." And because of these facts, and in an attempt to persuade climate modelers to rectify the situation, Vogelmann *et al*. used high-resolution spectra to calculate the surface IR radiative forcing created by aerosols encountered in the outflow of air from northeastern Asia, based on measurements made by the Marine-Atmospheric Emitted Radiance Interferometer aboard the NOAA Ship *Ronald H. Brown* during the Aerosol Characterization Experiment-Asia. And in so doing, they determined, in their words, that "daytime surface IR forcings are often a few Wm^{-2} and can reach almost 10 Wm^{-2} for large aerosol loadings," which values, in their words, are (2) "comparable to or larger than the 1 to 2 Wm^{-2} change in the globally averaged surface IR forcing caused by greenhouse gas increases since pre-industrial times." And in a massive understatement of fact, the researchers thus concluded that their results (3) "highlight the importance of aerosol IR forcing which should be included in climate model simulations," causing one to wonder that if a forcing of this magnitude was *not* included in then-current state-of-the-art climate models, what other major forcings might the scientists of that era been ignoring?

Shifting gears just a bit, two papers published one year earlier in the same issue of *Science* (Chen *et al*., 2002; Wielicki *et al*., 2002) revealed what Hartmann (2002) had called a pair of "tropical surprises." The first of the seminal discoveries was the common finding of both groups of researchers that the amount of thermal radiation emitted to space at the top of the tropical atmosphere increased by about 4 Wm^{-2} between the 1980s and the 1990s, while the second was that the amount of reflected sunlight decreased by 1 to 2 Wm^{-2} over the same period, with the *net* result that *more* total radiant energy exited the tropics in the latter decade. In addition, the measured thermal radiative energy loss at the top of the tropical atmosphere was of the same magnitude as the thermal radiative energy gain that is generally predicted to result from an instantaneous doubling of the air's CO_2 content. Yet as Hartman correctly noted, "only very small changes in average tropical surface temperature were observed during this time."

So what went wrong? Or, as one probably more correctly should phrase the question, what went *right*?

One thing was the change in solar radiation reception that was driven by changes in cloud cover, which allowed more solar radiation to reach the surface of the earth's tropical region and warm it. These changes were produced by what Chen *et al*. determined to be "a decadal-time-scale strengthening of the tropical Hadley and Walker circulations." Another helping-hand was likely provided by the prior quarter-century's slowdown in the meridional overturning circulation of the upper 100 to 400 meters of the tropical Pacific Ocean (McPhaden and Zhang, 2002), which circulation slowdown also promotes tropical sea surface warming by reducing the rate-of-supply of relatively colder water to the region of equatorial upwelling.

So what did these observations have to do with evaluating the ability of climate models to correctly predict the future? For one thing, they provided several new phenomena for the models to replicate as a test of their ability to properly represent the real-world. As an example, in the words of McPhaden and Zhang, the time-varying meridional overturning circulation of the upper Pacific Ocean provides "an important dynamical constraint for model studies that attempt to simulate recent observed decadal changes in the Pacific." And if it were found that the climate models couldn't reconstruct this simple wind-driven circulation, for example, one would have to wonder why we should believe anything else the models tell us.

In an eye-opening application of this principle, Wielicki *et al*. tested the ability of four state-of-the-art climate models and one weather assimilation model to reproduce the observed decadal changes in top-of-the-atmosphere thermal and solar radiative energy fluxes that occurred over the prior two decades. The results were truly pathetic: (1) no significant decadal variability was exhibited by *any* of the models; and (2) they *all* failed to reproduce even the cyclical seasonal change in tropical albedo. The administrators of the test thus kindly concluded that (3) "the missing variability in the models highlights the critical need to improve cloud modeling in the tropics so that prediction of tropical climate on inter-annual and decadal time scales can be improved."

Hartmann, on the other hand, was considerably more candid in his scoring of the test, simply stating that the results indicated (1) "the models are deficient." Expanding on this assessment, he further noted that (2) "if the energy budget can vary substantially in the absence of obvious forcing," as it did over the prior two decades, "then the climate of earth has modes of variability that are not yet fully understood and cannot yet be accurately represented in climate models," which leads one to wonder why anyone would put any faith in them at all.

Also concentrating on the tropics, Bellon *et al*. (2003) noted that "observed tropical sea-surface temperatures (SSTs) exhibit a maximum around 30°C," and that "this maximum appears to be robust on various timescales, from intra-seasonal to millennial." Hence, they suggested that "identifying the stabilizing feedbacks that help maintain this threshold is essential in order to understand how the tropical climate reacts to an external perturbation," which knowledge is needed for understanding how the *global* climate reacts to perturbations such as those produced by solar variability and the ongoing rise in the air's CO_2 content.

This contention had also been buttressed by the earlier study of Pierrehumbert (1995), which "clearly demonstrates," in the words of Bellon *et al*., "that [1] the tropical climate is not determined locally, but globally." Also, they noted that Pierrehumbert's work demonstrated that (2) interactions between moist and dry regions are an essential part of tropical climate stability, which hearkens back to the *adaptive infrared iris concept* of Lindzen *et al*. (2001).

Noting that previous box models of tropical climate had shown it to be rather sensitive to the relative areas of *moist and dry regions of the tropics*, Bellon *et al*. additionally analyzed a number of feedbacks associated with this sensitivity in a four-box model of the tropical climate in order "to show how they modulate the response of the tropical temperature to a radiative perturbation." And they investigated the influence of the model's surface-wind parameterization in an attempt to shed further light on the nature of the underlying feedbacks that help define the global climate system that is responsible for the tropical climate observations of constrained maximum SSTs.

The totality of Bellon *et al*.'s work, as they described it, "suggests the presence of an important and as-yet-unexplored feedback in earth's tropical climate, that could contribute to maintain the 'lid' on tropical SSTs," much like the adaptive infrared iris concept of Lindzen *et al*. does. They also said that the demonstrated "dependence of the surface wind on the large-scale circulation has an important effect on the sensitivity of the tropical system," specifically stating that "this dependence reduces significantly the SST sensitivity to radiative perturbations by enhancing the evaporation feedback," which injects more heat into the atmosphere and allows the atmospheric circulation to export more energy to the subtropical free troposphere, where it can be radiated to space.

Clearly, therefore, the case was not closed on either the *source* or the *significance* of the maximum "allowable" SSTs of tropical regions; and, hence, neither was the case closed on the degree to which the planet may warm in response to continued increases in atmospheric CO_2 concentrations, as well as those of other greenhouse gases, in stark contrast to what was then being suggested by the climate models promoted by the IPCC.

Moving forward in time a few years, Eisenman *et al*. (2007) used two standard thermodynamic models of sea ice to calculate equilibrium Arctic ice thickness based on simulated Arctic cloud cover derived from sixteen different global climate models (GCMs) that were evaluated for the IPCC's Fourth Assessment Report. And in doing so, they found (1) there was a 40 Wm^{-2} spread among the sixteen models in terms of their calculated downward longwave radiation, for which (2) both sea ice models calculated an equilibrium ice thickness ranging from *one* to *more than ten meters*. However, they noted that the mean 1980-1999 Arctic sea ice thickness simulated by the sixteen GCMs ranged from only 1.0 to 3.9 meters, which is a far smaller inter-model spread. Hence, they said that they were "forced to ask how the GCM simulations produce such similar present-day ice conditions in spite of the differences in simulated downward longwave radiative fluxes?"

Answering their own question, the three researchers stated that "a frequently used approach" to resolving this problem "is to tune the parameters associated with the ice surface albedo" to get a more realistic answer. "In other words," as they continued, "errors in parameter values are being introduced to the GCM sea ice components to compensate simulation errors in the atmospheric components." And so it was that the three researchers concluded that "the thinning of Arctic sea ice over the past half-century can be explained by minuscule changes of the radiative forcing that [1] cannot be detected by current observing systems and require only exceedingly small adjustments of the model-generated radiation fields," which further leads to the unsavory conclusion -- *as stated by them* – that (2) "the results of current GCMs cannot be relied upon at face value for credible predictions of future Arctic sea ice."

Two years later, Mishchenko *et al*. (2009) wrote that "because of the global nature of aerosol climate forcings, satellite observations have been and will be an indispensable source of information about aerosol characteristics for use in various assessments of climate and climate change," adding that "there have been parallel claims of unprecedented accuracy of aerosol retrievals with the moderate-resolution imaging spectroradiometer (MODIS) and the multi-angle imaging spectroradiometer (MISR)." And if both of these aerosol retrieval systems are as good as they have been claimed to be, they should agree on a pixel-by-pixel basis as well as globally. Consequently, and noting that "both instruments have been flown for many years on the same Terra platform, which provides a unique opportunity to compare fully collocated pixel-level MODIS and MISR aerosol retrievals directly," Mishchenko *et al*. decided to see how they compared in this regard by analyzing eight years of such data. And what did they thereby learn?

The six scientists from NASA's Goddard Institute for Space Studies reported finding what they described as (1,2) "unexpected significant disagreements at the pixel level as well as between long-term and spatially averaged aerosol properties." In fact, they said that "the only point on which both datasets seem to fully agree is that there may have been a weak increasing tendency in the globally averaged aerosol optical thickness (AOT) over the land and no long-term AOT tendency over the oceans." Therefore, they concluded that (3) "current knowledge of the global distribution of the AOT and, especially, aerosol microphysical characteristics remains unsatisfactory." And since this knowledge was said by them to be "indispensable for use in various assessments of climate and climate change," it would appear that assessments of greenhouse-gas forcing of climate made by the very best models in use only a mere half-decade prior to that time (4) may have been of very little worth in describing the real world of nature.

Also publishing a pertinent paper about the same time as Mishchenko *et al*. were Androvo *et al*. (2009), who "used satellite-based broadband radiation observations to construct a long-term continuous 1985-2005 record of the radiative budget components at the *top of the atmosphere* (TOA) for the tropical region (20°S-20°N)," after which they "derived the most conservative estimate of their trends" and "compared the interannual variability of the net radiative fluxes at the top of the tropical atmosphere with model simulations from the Intergovernmental Panel on Climate Change *fourth assessment report* (AR4) archive available up to 2000."

This effort revealed, first of all, that "the tropical system became both less reflective and more absorbing at the TOA," and that "combined with a reduction in total cloudiness (Norris, 2007), this would mean that the tropical atmosphere had recently become more transparent to incoming solar radiation, which would allow more shortwave energy to reach earth's surface." Secondly, they found that (1) "none of the models simulates the overall 'net radiative heating' signature of the earth's radiative budget over the time period from 1985-2000."

With respect to the *first* of these findings, as well as the associated finding of Norris (2007), Andronova *et al*. confirmed that these observations "are consistent with the observed near-surface temperature increase in recent years," which provides an independent validation of the TOA radiation measurements. With respect to their *second* finding, however, (2) the failure of *all* of the AR4 climate models to adequately simulate the TOA radiation measurements basically (3) *discredits* the models; and it (4) reveals the *irrationality* of using them to inform international policy with regard to the need (or *non*-need) to regulate anthropogenic CO_2 emissions. And the *combination* of these two conclusions suggests that (5) the historical rise in the air's CO_2 content has likely played a next-to-negligible role in the post-Little Ice Age warming of the world.

Also concurrently publishing a paper on this subject were Lindzen and Choi (2009), who used the National Centers for Environmental Prediction's 16-year (1985-1999) monthly record of sea surface temperature (SST), together with corresponding radiation data from the Earth Radiation Budget Experiment, to estimate the sign and magnitude of climate feedback over the oceanic portion of the tropics and thus obtain an *empirical* evaluation of earth's thermal sensitivity, as opposed to the *model-based* evaluation employed by the IPCC. And what did this work reveal?

Lindzen and Choi reported that all eleven models employed in the IPCC's analysis "agree as to positive feedback," but they found that (1) they all *disagree* -- and disagree "very sharply" -- with the real-world observations that they (Lindzen and Choi) utilized, which implied that *negative* feedback actually prevails. And the presence of that negative feedback reduces the CO_2-induced propensity for warming to the extent that their analysis of the real-world observational data only yielded a mean SST increase "of ~0.5°C for a doubling of CO_2."

So how does one decide which of the two results is the more correct? Real-world data would be the obvious standard against which to compare model-derived results; but since Lindzen and Choi's results *were* based on real-world measurements, the only alternative we have is to seek *other* real-world results. And, fortunately, there are several such findings, many of which were summarized in the review paper of Idso (1998), who described eight "natural experiments" that he personally employed in prior studies designed to determine "how earth's near-surface air temperature responds to surface radiative perturbations."

The eight naturally-occurring phenomena employed by Idso were (a) the change in the air's water vapor content that occurs at Phoenix, Arizona, with the advent of the summer monsoon, (b) the naturally-occurring vertical redistribution of dust that occurs at Phoenix between summer and winter, (c) the annual cycle of surface air temperature that is caused by the annual cycle of solar radiation absorption at the earth's surface, (d) the warming effect of the entire atmosphere caused by its mean flux of thermal radiation to the surface of the earth, (e) the annually-averaged equator-to-pole air temperature gradient that is sustained by the annually-averaged equator-to-pole gradient of total surface-absorbed radiant energy, (f) the mean surface temperatures of Earth, Mars and Venus relative to the amounts of CO_2 contained in their respective atmospheres, (g) the paradox of the faint early sun and its implications for earth's thermal history, and (h) the greenhouse effect of water vapor over the tropical oceans and its impact on sea surface temperatures.

These eight analyses, in the words of Idso, "suggest that a 300 to 600 ppm doubling of the atmosphere's CO_2 concentration could raise the planet's mean surface air temperature by only about 0.4°C," which is right in line with Lindzen and Choi's deduced warming of ~0.5°C for a nominal doubling of the air's CO_2 content. Hence, there would appear to be a goodly amount of *real-world data* that argue *strongly* against the *over-inflated* CO_2-induced global warming that was – and still is -- being predicted by state-of-the-art climate models.

Moving ahead two more years, Shin and Sardeshmukh (2011) noted that there was an increased interest in the ability of climate models to simulate -- and thus *predict* -- surface temperature and precipitation changes on sub-continental scales; and they noted that these regional trend patterns had been "strongly influenced by the warming pattern of the tropical oceans," which in turn suggested that correctly simulating the warming pattern of the tropical oceans is a *prerequisite* for correctly simulating sub-continental-scale warming patterns.

In exploring this subject further, Shin and Sardeshmukh compared several multi-model ensemble simulations of the last half-century with corresponding observations, focusing on the world's tropical oceans, as well as the land masses surrounding the North Atlantic Ocean, including North America, Greenland, Europe, and North Africa. This was done, as they described it, using "all available coupled [atmosphere-ocean] model simulations of the period 1951-1999 from 18 international modeling centers, generated as part of the IPCC's 20th century climate simulations with prescribed time-varying radiative forcings associated with greenhouse gases, aerosols, and solar variations." And what did they thereby learn?

The two researchers determined that (1) "the tropical oceanic warming pattern is poorly represented in the coupled simulations," and they thus concluded that (2) their analysis "points to model error rather than unpredictable climate noise as a major cause of this discrepancy with respect to the observed trends." And because of this problem, they found that (3) "the patterns of recent climate trends over North America, Greenland, Europe, and North Africa are generally not well captured by state-of-the-art coupled atmosphere-ocean models with prescribed observed radiative forcing changes."

As for the significance of this finding, Shin and Sardeshmukh wrote that "the fact that [4] even with full atmosphere-ocean coupling, climate models with prescribed observed radiative forcing changes do not capture the pattern of the observed tropical oceanic warming suggests that either (5) the radiatively forced component of this warming pattern was sufficiently small in recent decades to be dwarfed by natural tropical SST variability, or that (6) the coupled models are misrepresenting some important tropical physics." And since the greenhouse-gas forcing of climate "in recent decades" is claimed by climate alarmists to have been *unprecedented over the past millennium or more*, it would appear that the models are indeed (7) "misrepresenting some important tropical physics."

Moving forward three additional years, Crook and Foster (2014) wrote that "snow and ice albedo feedback plays an important role in the greater warming of the Arctic compared to the tropics." But they noted there had been "no estimates of surface albedo feedback from observations globally." And, therefore, in an attempt to expand the area of coverage of this phenomenon, they estimated "observed surface albedo feedback, extending coverage to the Southern Hemisphere and non-cryosphere regions," in an attempt to ascertain "whether the seasonal cycle can be used to estimate climate change feedback in regions other than Northern Hemisphere extra-tropical land."

This work revealed that (1) the "hemisphere extra-tropical feedback is considerably higher for observations (potentially 3.1 ± 1.3 $W/m^2/K$) than for models (0.4-1.2 $W/m^2/K$)," that (2) the "models underestimate the Northern Hemisphere extratropical climate change feedback," and that (3) "in Antarctica the climate change feedback is negative in observations and positive in models." And in light of their several findings, Crook and Foster concluded that "understanding reasons for the low Northern Hemisphere extra-tropical climate change feedback for both land and sea in the current generation of climate models should be a priority," which clearly indicates that we are not yet at the point where the output of the studied models can be given much credence when it comes to surface albedo feedback.

About this same time, Ma *et al*. (2014) wrote that "atmospheric downward longwave radiation at the surface (*Ld*) quantifies the atmospheric greenhouse effect," which makes its evaluation "one of the primary objectives of those who seek to divine its future impact on the planet." And in light of this fact, the modeled *Ld* of 44 general circulation models (GCMs) that participated in the CMIP5 program were compared by Ma *et al*. with land-based observations acquired at 47 sites of the Baseline Surface Radiation Network (BSRN), 51 sites of the Coordinated Energy and water cycle Observations Project (CEOP), 34 sites from the AmeriFlux network over the United States, 18 sites from the AsiaFlux network in Asia, and 12 sites where buoy-based measurements were made over tropical oceans over the period 1992-2005.

Among a number of other things, the three researchers thereby determined that (1) "GCMs in CMIP5 could not accurately simulate the diurnal variation of surface temperature and water vapor," and that (2) "CMIP5 GCMs are still poor in producing monthly anomalies of *Ld*," which they say is likely due to (3-5) "the GCM's poor performance in simulating seasonal variation of clouds and monthly anomalies of air temperature and water vapor." And in light of these shortcomings, we have to ask ourselves the proverbial question about the integrity of the world's most up-to-date climate models: *are we there yet?* Apparently not; for however close the models may *seem* to be getting in regard to replicating reality, they still fall significantly short of the mark.

In conclusion, there appear to be a number of major inadequacies in the ways in which several aspects of earth's radiative energy balance are treated in contemporary general circulation models of the atmosphere, as well as numerous other inadequacies stemming from the *non*-treatment of pertinent phenomena that are nowhere to be found in the models. Hence, there is no rational basis for any of the IPCC-inspired predictions of *catastrophic climatic changes* due to continued anthropogenic CO_2 emissions. The scary scenarios they promulgate are simply unwarranted projections that have far outpaced what can be soundly supported by the current state of the climate modeling enterprise.

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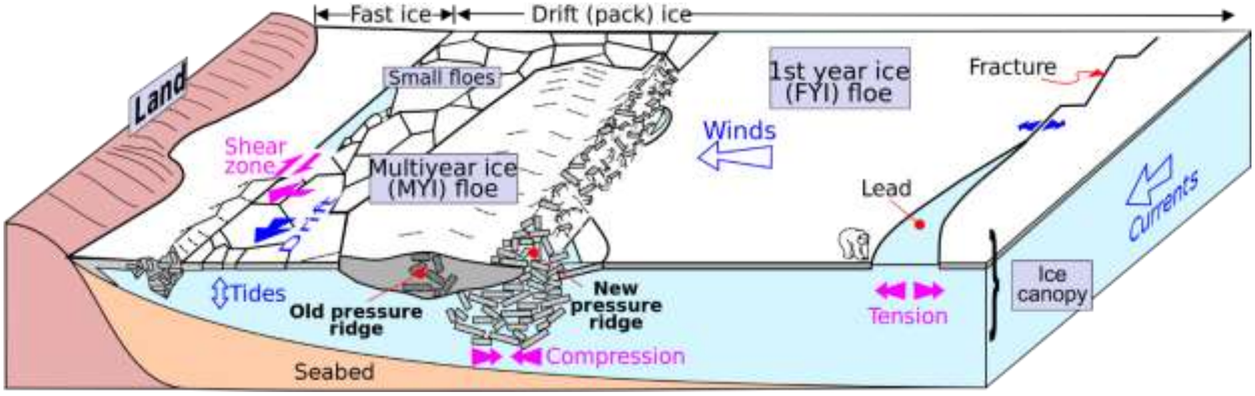
SEA ICE



Near the start of the current century, Holland (2001) wrote that, with respect to contemporary state-of-the-art global climate models, (1) "some physical processes are absent from the models," additionally noting that in light of the coarse-resolution grids employed by the models, (2) "some physical processes are ill resolved" and that others are actually (3) "missing from the simulations," which facts led him to *question*, as he put it, "whether the simulations obtained from such models are in fact physically meaningful." And, therefore, he went on to conduct his *own* analysis of the subject, which he designed to determine the difference in model evolution of *sea ice cover* using a relatively coarse-resolution grid verses a fine-resolution grid, with specific emphasis placed on the *presence* and *treatment* of a mesoscale ocean eddy and its influence on sea ice cover.

Holland's resolving of the ocean eddy field using the fine-resolution model was found to have a measurable impact on sea ice concentration, implying that a "fine-resolution grid may have a more efficient atmosphere-sea ice-ocean thermodynamic exchange than a coarse one." Put another way, he reported that the results of his study demonstrated "yet again" that (4) "coarse-resolution coupled climate models are not reaching fine enough resolution in the polar regions of the world ocean to claim that their numerical solutions have reached convergence," clearly indicating that (5) the models still had a long way to go before their resolution would be fine enough to include (or adequately parameterize) all the important physical processes related to sea ice cover, and possibly those of many other climate phenomena as well.

Two years later, Laxon *et al.* (2003) used an eight-year time series (1993-2001) of Arctic sea-ice thickness derived from measurements of ice freeboard made by 13.8-GHz radar altimeters carried aboard ERS-1 and 2 satellites to determine the mean thickness and variability of Arctic sea ice between latitudes 65 and 81.5°N, which region covers the entire circumference of the Arctic Ocean, including the Beaufort, Chukchi, East Siberian, Kara, Laptev, Barents and Greenland Seas. This huge but worthy effort revealed that "mean winter sea-ice thickness over the region of coverage was found to be 2.73 meters with a standard deviation of ± 9% of the average, which [1] variability was 50% greater than that predicted by climate models," that (2) "the inter-annual variability in thickness [9%] compares with a variability in mean annual ice extent of 1.7% during the same period," that (3) there was "a significant ($R^2 = 0.924$) correlation between the change in the altimeter-derived thickness between consecutive winters and the melt season length during the intervening summer," which meant that (4) there was an "observed dominant control of summer melt on the inter-annual variability of mean ice thickness," which was (5) "in sharp contrast with the majority of models," which suggests that (6) "ice thickness variability in the Arctic Ocean is controlled mainly by wind and ocean forcing," and that (7) "sea ice mass can change by up to 16% within one year," which (8) "contrasts with the concept of a slowly dwindling ice pack, produced by greenhouse warming," which represents still another significant strike against the models.

In summing up their discussion of the subject, therefore, Laxon *et al.* simply stated that their results (9) "show that errors are present in current simulations of Arctic sea ice," and they thus concluded, in the closing sentence of their paper, that (10) "until models properly reproduce the observed high-frequency, and thermodynamically driven, variability in sea ice thickness, simulations of both recent, and future, changes in Arctic ice cover will be open to question."

Jumping ahead four years, Eisenman *et al.* (2007) used two standard thermodynamic models of sea ice to calculate equilibrium Arctic ice thickness based on simulated Arctic cloud cover derived from sixteen different *global climate models* (GCMs) that were evaluated for the IPCC's Fourth Assessment Report. This work revealed there was a 40 Wm^{-2} spread among the sixteen models in terms of their calculated downward longwave radiation, for which both sea ice models calculated an equilibrium ice thickness ranging from one to more than ten meters. However, they noted that (11) the mean 1980-1999 Arctic sea ice thickness simulated by the sixteen GCMs ranged from only 1.0 to 3.9 meters, which is a far smaller inter-model spread. Hence, they said that they were "forced to ask how the GCM simulations produce such similar present-day ice conditions in spite of the differences in simulated downward longwave radiative fluxes."

Answering their own question, the three researchers stated that "a frequently used approach" to resolving this problem "is to tune the parameters associated with the ice surface albedo" to get a more realistic answer. "In other words," as they continued, (12) "errors in parameter values are being introduced to the GCM sea ice components to compensate simulation errors in the atmospheric components." And in light of these machinations, the three researchers concluded that (13) "the thinning of Arctic sea ice over the past half-century can be explained by minuscule changes of the radiative forcing that cannot be detected by current observing systems and require only exceedingly small adjustments of the model-generated radiation fields." And, therefore, they additionally concluded that (14) "the results of current GCMs cannot be relied upon at face value for credible predictions of future Arctic sea ice."

One year later, while noting that earth's polar regions "are expected to provide early signals of a climate change primarily because of the 'ice-albedo feedback' which is associated with changes in absorption of solar energy due to changes in the area covered by the highly reflective sea ice," Comiso and Nishio (2008) set about to provide updated and improved estimates of trends in Arctic and Antarctic sea ice cover for the period extending from November 1978 to December 2006, based on data obtained from the Advanced Microwave Scanning Radiometer (AMSR-E), the Special Scanning Microwave Imager (SSM/I) and the Scanning Multichannel Microwave Radiometer (SMMR), where the data from the last two instruments were adjusted to be consistent with the AMSR-E data.

This work revealed that (1) trends in sea ice *extent* and *area* in the Arctic over the period of the two researcher's analyses were -3.4 ± 0.2 and -4.0 ± 0.2% per decade, respectively; but it also revealed that (2) simultaneous corresponding trends in the Antarctic were +0.9 ± 0.2 and +1.7 ± 0.3% per decade. And, therefore, if it indeed is true that earth's polar regions should "provide early signals of a climate change," as many climate alarmists have contended they should, it would appear that (3) the Northern and Southern Hemispheres are scheduled to go their own separate ways in response to a continuation of whatever caused them to behave as they did over the prior three decades, during which time the atmosphere's CO_2 concentration rose substantially. But if such *were* the case, (4) one could not claim that rising atmospheric CO_2 concentrations cause *global* warming.

Another study of interest was that of Kwok (2011), who introduced his work by noting that near the mid-point of the prior decade, simulations of Arctic Ocean sea ice characteristics produced by the climate models included in the World Climate Research Programme's *Coupled Model Intercomparison Project* phase *3* (CMIP3) were *far* from what it might have been hoped they would be. Specifically, he wrote that (1) "Zhang and Walsh (2006) noted that even though the CMIP3 models capture the negative trend in sea ice area, the inter-model scatter is large," that (2) "Stroeve *et al*. (2007) show that few models exhibit negative trends that are comparable to observations," and that (3) "Eisenman *et al.* (2007) concluded that the results of current CMIP3 models cannot be relied upon for credible projections of sea ice behavior." And, therefore, in *his* more recent analysis of the subject -- based on the multi-model data set of Meehl *et al.* (2007) -- the Jet Propulsion Laboratory researcher compared CMIP3 model simulations with observations of sea ice motion, export, extent and thickness, along with analyses of fields of sea level pressure and geostrophic wind of the Arctic Ocean.

Kwok's analysis demonstrated, as he described it, that (1) "the skill of the CMIP3 models (as a group) in simulation of observed Arctic sea ice motion, Fram Strait export, extent and thickness between 1979 and 2008 seems rather poor," noting that (2) "model-data differences and inter-model scatter of the sea ice parameters in the summarizing statistics are high," and that (3) "the spatial pattern of Arctic sea ice thickness, a large-scale slowly varying climatic feature of the ice cover, is not reproduced in a majority of the models." Consequently, he concluded that (4) "the models will not get the main features of natural sea ice variability that may be dominating recent sea ice extent declines, as well as the long-term greenhouse response."

Therefore, and because (5) “the model simulations have difficulties reproducing the mean patterns of Arctic circulation and thickness," as Kwok wrote in his concluding paragraph, he says his analysis suggests there are (6) "considerable uncertainties in the projected rates of sea ice decline even though the CMIP3 data set agrees that increased greenhouse gas concentrations will result in a reduction of Arctic sea ice area and volume." But with all of the problems he found with the models, who really knows how good those latter projections are?

A couple more years down the road, Turner *et al.* (2013) wrote that "Phase 5 of CMIP (CMIP5) will provide the model output that will form the basis of the Fifth Assessment Report (AR5) of the IPCC," and they therefore thought it important to determine how well these models represent reality. Thus, they examined "the annual cycle and trends in Antarctic sea ice extent (SIE) for 18 models used in phase 5 of the Coupled Model Intercomparison Project that were run with historical forcing for the 1850s to 2005." This work revealed that (1) "the majority of models have too small of an SIE at the minimum in February," that (2) "several of the models have less than two-thirds of the observed SIE at the September maximum," that (3) "in contrast to the satellite data, which exhibit a slight increase in SIE, the mean SIE of the models over 1979-2005 shows a decrease in each month," that (4) "the models have very large differences in SIE over 1860-2005," and that (5) "the negative SIE trends in most of the model runs over 1979-2005 are a continuation of an earlier decline, suggesting that the processes responsible for the observed increase over the last 30 years are not being simulated correctly." And in light of these findings, Turner *et al.* stated that (6) "as with CMIP3, the models do not simulate the recent increase in Antarctic SIE observed in the satellite data."

Around this same time, Karlsson and Svensson (2013) wrote that "clouds significantly influence the Arctic surface energy budget and a realistic representation of this impact is a key for proper simulation of the present-day and future climate." However, they went on to report that (1) "considerable across-model spread in cloud variables remains in the fifth phase of the Coupled Model Intercomparison Project ensemble and partly explains the substantial across-model spread in the surface radiative effect of the clouds," which further impacts sea-ice extent and albedo. And, therefore, the main focus of their study, as they described it, was on the question of "how model differences in the parameterization of sea-ice albedo in the fifth phase of the Coupled Model Intercomparison Project (CMIP5) influence the cloud radiative effect on the surface energy budget and the annual cycle of sea-ice concentration."

In pursuing this course of action, the two researchers reported that (2) "the across-model spread in Arctic cloud cover and cloud condensates is substantial, and no improvement is seen from previous model intercomparisons (Karlsson and Svenson, 2011)." And they further noted that (3) "this diversity of simulated Arctic clouds in the CMIP5 ensemble contributes to a spread in the models' cloud influence on the surface energy budget." Therefore, in the concluding sentence of their paper, the two Swedish scientists state that (4) "the fact that present-day sea-ice albedo is so badly constrained in global climate models impacts the fidelity of future scenario assessments of the Arctic region and should therefore be a concern for the modeling community." Or in other words, *we're not there yet* ... and we've been stalled in our forward progress in this area for several years.

In yet another pertinent paper from the same year, Mahlstein *et al.* (2013) wrote that Lefebvre and Goosse (2008) analyzed the Antarctic sea ice distributions of the CMIP3 climate models and found that (1) "the modelled trends were too negative compared to observations." Likewise, they said that (2) Turner *et al.* (2013) also reported "a negative sea ice trend for most CMIP5 models." And so it was that they decided they would also investigate the subject, to see if things were really as bad as what they appeared to be in these two prior model assessments.

Using historical runs from as many as 25 CMIP5 climate models, Mahlstein *et al.* compared their hind-casted sea-ice trends for the area around Antarctica against observational data for the period 1980 to 2001, which are archived by the Met Office Hadley Centre (Rayner *et al.*, 2003) and the U.S. National Snow and Ice Data Center (Comiso, 1999, updated 2012). And what did they learn from this endeavor?

Quoting the three researchers, (1) "the representations of Antarctic sea ice in CMIP5 models have not improved compared to CMIP3," in that (2) "the spread in sea ice area is not reduced compared to the previous models." Most important of all, however, was their finding that (3) whereas most CMIP5 climate models "simulate a decrease in Antarctic sea ice over the recent past," real-world data demonstrate that the "average Antarctic sea ice area is not retreating but has slowly increased since satellite measurements began in 1979." And it is difficult for a climate model to be more wrong than when it *hind*-casts just the *opposite* of what has been observed to be happening over the past three and a half decades in the real world, which is what most of the CMIP5 models apparently do.

More recently, but only by one year, Koenigk *et al*. (2014) -- citing Winton (2006) and Serreze *et al*. (2009) - wrote that "it seems to be beyond question that the ice-albedo feedback is an important contributor to Arctic temperature amplification and changes in sea ice conditions," while noting that "the observed Arctic temperature amplification compared to lower latitudes has led to an intensive discussion on the role of the surface albedo," citing the additional study of Riihela *et al*. (2013b).

As for their role in broaching the subject, Koenigk *et al.* said they "used the surface albedo product from the Satellite Application Facility on Climate Monitoring (CM-SAF) clouds, albedo and radiation data set (CLARA-SAL, Ruhela *et al.*, 2013a; Karlsson *et al.,* 2013) and sea ice concentration from the Ocean and Sea Ice Satellite Application Facility (OSI-SAF) data set (Eastwood *et al.*, 2010) as comparison for the model data," which were derived from 21 different CMIP5 models.

In reporting their long list of findings, the three Swedish researchers wrote that (1) "summer sea ice albedo varies substantially among CMIP5 models," that (2) "many models show large biases compared to the CLARA-SAL product," that (3) "single summer months show an extreme spread of ice albedo among models," that (4) "July values vary between 0.3 and 0.7 for individual models," that (5) "the CMIP5 ensemble mean ... shows too high ice albedo near the ice edges and coasts," that (6) "in most models, the ice albedo is spatially too uniformly distributed," that (7) "the summer-to-summer variations seem to be underestimated in many global models," that (8) "almost no model is able to reproduce the temporal evolution of ice albedo throughout the summer fully," that (9) "while the satellite observations indicate the lowest ice albedos during August, the models show minimum values in July and substantially higher values in August," that (10) "June values are often lower in the models than in the satellite observations," due to (11) "too high surface temperatures in June," leading to (12) "an early start of the melt season and [13] too cold temperatures in August causing an earlier refreezing in the models," such that (14) "the impact of the ice albedo on the sea ice conditions in the CMIP5 models is not clearly visible."

In light of these several findings, Koenigk *et al.* concluded that (15) "the Arctic climate system can thus not correctly be simulated (other than with compensating errors) if the large-scale atmospheric and oceanic circulation determining the input of mass, heat and momentum into the Arctic is not correctly simulated." And they also remarked that (16) "strong tuning of the albedo in order to achieve realistic Arctic ice and climate conditions in 20th century simulations might lead to unrealistic amplification rates in future simulations."

Following Koenigk *et al*., Turner *et al*. (2015) noted that in a world in which increasing atmospheric CO_2 concentrations are being blamed for what is claimed to be a spate of *unprecedented global warming*, we are repeatedly told by climate alarmists that this warming is leading to the melting of vast amounts of polar sea ice, which in turn will lead to a subsequent significant sea level rise. And, therefore, it is only natural that some of the world’s climate scientists would be measuring just how much of the sea ice surrounding Antarctica may have disappeared lately, and how well that loss could be “hindcast” by the most up-to-date state-of-the-art climate models.

Taking on this challenge, and working with sea ice data obtained from the U.S. National Snow and Ice Data Center, Turner *et al*. (2015) discovered that (1) “total sea ice extent (SIE) across the Southern Ocean [which surrounds Antarctica] has increased since the late 1970s, with the annual mean increasing at a rate of 186 x 10^3 km^2 per decade.” And with not even the *sign* (positive or negative) of the observed change in SIE meshing with climate alarmist contentions, they next went on to see if the CMIP5 climate *models* could do any better in this regard, which one would surely hope that they could.

However, the results of this exercise revealed, in Turner *et al*.'s words, that (2) "most of the historical runs of the CMIP5 models had Southern Ocean sea ice *decreasing* in extent over 1979-2005," just like the world's climate alarmists had also been both wrongly *predicting* and *claiming*. In point of fact, however, the CMIP5 multi-model mean SIE, as Turner *et al*. reported, (3) "had sea ice decreasing in every month of the year, with the largest percentage loss of about 12% per decade occurring in February." And, therefore, the CMIP5 climate models, as well as their CMIP3 predecessors, would appear to be (4) *totally unsuited* for predicting the future course of earth's sea ice extent.

Further evidence to support this conclusion was provided by Scafetta land Mazzarella (2015) , who studied both Arctic and Antarctic sea-ice records provided by the National Snow and Ice Data Center, which records revealed (1) "an opposite climatic behavior." Since 1978, for example, (2) the *Arctic* sea-ice area *decreased* as that region *warmed*, while (3) the *Antarctic* sea-ice area *increased* as that region *cooled*. In addition, they noted that (4) during the last seven years of the study, the Arctic sea-ice area stabilized, while (5) the Antarctic sea-ice area increased at a rate significantly higher than that of the previous decades. And they report that they also found that (6) "a significant 4-5-year natural oscillation characterizes the climate of these sea-ice polar areas."

Further noting that "CMIP5 global climate models have predicted significant warming of both the Arctic and the Antarctic sea-ice areas," Scafetta and Mazzarella go on to say that while this prediction "could correlate with the observed reduction of the Arctic sea-ice area, the model prediction is clearly incompatible with the Antarctic data," which indicate that (7) "the Antarctic sea-ice area has increased consistently during the last decades and in particular during the last seven years, indicating general cooling of the sea region surrounding the continent."

On another point, the two researchers note that (8) "the CMIP5 GCMs also fail in reproducing the 4-5-year oscillation found in both the Arctic and the Antarctic sea-ice area records, which has been also found in the ENSO index," citing the study of Mazzarella *et al*. (2010). And, therefore, they further conclude that their results imply that earth's climate (9) "is regulated by natural mechanisms and natural oscillations that are not included yet in the climate models," citing Scafetta (2013 and 2015).

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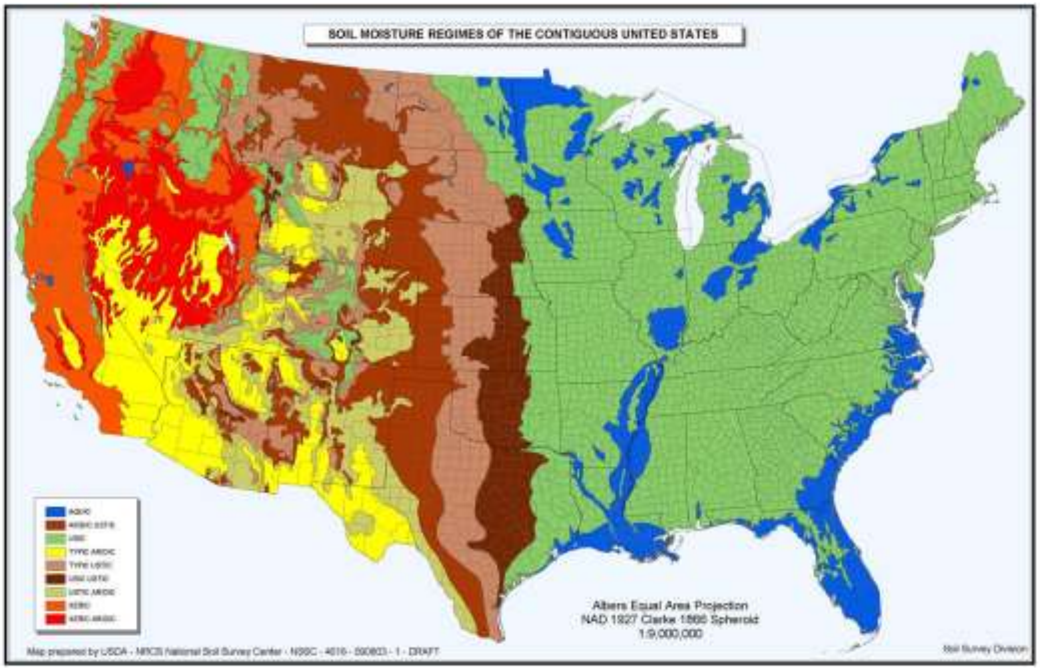
SOIL MOISTURE



Climate models have long suggested that CO_2-induced global warming will tend to increase evapotranspiration, causing decreases in soil moisture content that may offset modest increases in continental precipitation and lead to greater aridity in both water-limited natural ecosystems and lands devoted to agriculture, as per the studies of Manabe and Wetherald (1986), Rind (1988), Gleick (1989), Vlades *et al*. (1994), Gregory *et al*. (1997) and Komescu *et al*. (1998). This prognosis is certainly a bleak one, which probably means that *it's wrong*; for doom-and-gloom prognostications about the climatic consequences of the ongoing rise in the air's CO_2 content are often so tenuous that they are later demonstrated to be a hundred and eighty degrees out of phase with reality.

So is this climate-alarmist claim just another one of those "scare stories" that certain people feel justified in feeding to the public to achieve ends they consider lofty enough to justify such less-than-noble means? Let's take a look at the pertinent scientific literature and see what *real-world data* have to say about the subject.

In a turn-of-the century evaluation of how climate modelers had progressed in their efforts to improve their simulations of soil moisture content over the prior few years, Srinivasan *et al*. (2000) examined "the impacts of model revisions, particularly the land surface representations, on soil moisture simulations." This they did by comparing the simulations to actual soil moisture observations. And in summarizing their findings, they stated that (1) "the revised models do not show any systematic improvement in their ability to simulate observed seasonal variations of soil moisture over the regions studied." And if those words were not clear enough, they also said (2) "there are no indications of conceptually more realistic land surface representations producing better soil moisture simulations in the revised climate models." In fact, they reported (3) there was actually a "tendency toward unrealistic summer drying in several models."

Although Srinivasan *et al*. noted that "simpler land-surface parameterization schemes were being replaced by conceptually realistic treatments" as the climate modeling enterprise moved ever forward, they stated that the improvements gained by these changes were (4) "not very apparent."
This fact was truly astounding; for one would have thought that in an avowed attempt to improve this particular aspect of climate modeling, there would have been at least *some* improvement. But these were the conclusions of those who had studied the subject in depth as of the publication date of their journal article (16 November 2000); and in view of their findings, we are forced to conclude that (5) *at that time* there had indeed been *no real progress*.

More evidence for the validity of this conclusion was supplied in the very same year by Robock *et al*. (2000), who developed a massive collection of soil moisture data for over 600 stations from a wide variety of climatic regimes found within the former Soviet Union, China, Mongolia, India and the United States. In describing these datasets they also stated an important ground rule. *Sometimes*, they said, "the word 'data' is used to describe output from theoretical model calculations, or values derived from theoretical analysis of radiances from remote sensing." However, as they put it, "we prefer to reserve this word for actual physical observations," noting that "all the data in our data bank are actual *in situ* observations."

This distinction is important, for one of the illuminating analyses Robock *et al*. performed with their data was to check summer soil moisture trends simulated by the Geophysical Fluid Dynamics Laboratory's general circulation model of the atmosphere as forced by transient CO_2 and tropospheric sulfate aerosols for specific periods and regions for which they had actual soil moisture data. What they learned from this exercise, in their words, was that (1) "although this model predicts summer desiccation in the next century, it [2] does not in general reproduce the observed upward trends in soil moisture very well," which is a huge understatement, indeed, considering that (3) the predictions and observations went in *opposite directions!*

Unfortunately, the predictions of sophisticated global climate models are sometimes treated with a reverence as great as -- or even greater than -- actual real-world data. This study is a classic in demonstrating the dangers inherent in such behavior, which has actually led to the creation of an international treaty of wrenching economic and social implications based on faulty premises. In the case considered here, for example, Robock *et al*. wrote that (4) "in contrast to predictions of summer desiccation with increasing temperatures, for the stations with the longest records, summer soil moisture in the top 1 m has increased while temperatures have risen."

The moral of this story is that when model predictions and actual measurements fail to coincide, or actually *diverge*, as in this study, *the data must rule!* Indeed, it was Robock *et al*.'s hope that the real-world data they had assembled in their data bank might help "improve simulations of the recent past so we may have more confidence in predictions for the next century."

Skipping ahead five years, we come to another important report on the subject from Robock *et al*. (2005), who noted that "most global climate model simulations of the future, when forced with increasing greenhouse gases and anthropogenic aerosols, predict summer desiccation in the mid-latitudes of the Northern Hemisphere (e.g., Gregory *et al*., 1997; Wetherald and Manabe, 1999; Cubasch *et al*., 2001)," and who wrote that "this predicted soil moisture reduction, the product of increased evaporative demand with higher temperatures overwhelming any increased precipitation, is one of the gravest threats of global warming, potentially having large impacts on our food supply."

With the explicit purpose "to evaluate these model simulations," the three American and two Ukrainian scientists thus went on to develop "the longest data set of observed soil moisture available in the world, 45 years of gravimetrically-observed plant available soil moisture for the top 1 m of soil, observed every 10 days for April-October for 141 stations from fields with either winter or spring cereals from the Ukraine for 1958-2002." And as they described it, these observations showed (1) "a positive soil moisture trend for the entire period of observation, with the trend leveling off in the last two decades," while they further noted that (2) "even though for the entire period there is a small upward trend in temperature and a downward trend in summer precipitation, the soil moisture still has an upward trend for both winter and summer cereals."

As a result of these real-world observations, Robock *et al*. noted that (3) "although models of global warming predict summer desiccation in a greenhouse-warmed world, there is no evidence for this in the observations yet, even though the region has been warming for the entire period." In attempting to explain this dichotomy, therefore, they opined that the real-world increase in soil moisture content possibly may have been driven by a downward trend in evaporation caused by the controversial "global dimming" hypothesis (Liepert *et al*., 2004). Alternatively, they said that (4) "it may have been driven by the well-known anti-transpiration effect of atmospheric CO_2 enrichment, which tends to conserve water in the soils beneath crops and thereby leads to enhanced soil moisture contents," as has been demonstrated in a host of experiments conducted in real-world field situations.

One especially outstanding study, in this regard, was that of Zaveleta *et al*. (2003), who tested the climate alarmist hypothesis that soil moisture contents may decline in a CO_2-enriched and warmer world in a two-year study of an annual-dominated California grassland at the Jasper Ridge Biological Preserve, Stanford, California, USA, where they delivered extra heating to a number of FACE plots (enriched with an extra 300 ppm of CO_2) via IR heat lamps suspended over the plots that warmed the surface of the soil beneath them by 0.8-1.0°C.

The individual effects of atmospheric CO_2 enrichment and soil warming in this study were of similar magnitude; and (1) acting together they enhanced mean spring soil moisture content by about 15% over that of the control treatment. This effect of the extra CO_2 was produced primarily as a consequence of its ability to cause partial stomatal closure and thereby reduce season-long plant water loss via transpiration; while in the case of warming, there was an acceleration of canopy senescence that further increased soil moisture by reducing the period of time over which transpiration losses occur, all without any decrease in total plant production.

Zaveleta *et al*. thus went on to note that their findings (2) "illustrate the potential for organism-environment interactions to modify the direction as well as the magnitude of global change effects on ecosystem functioning." Indeed, whereas for the past many years the world has been bombarded with climate-alarmist predictions of vast reaches of agricultural land drying up and being lost to profitable production in a CO_2-enriched world of the future, this study suggested that just the *opposite* could well occur. As the six researchers described it, (3) "we suggest that in at least some ecosystems, declines in plant transpiration mediated by changes in phenology can offset direct increases in evaporative water losses under future warming."

In light of these several real-world observations, it would appear that essentially all climate models employed to that point in time had greatly erred with respect to what Robock *et al*. (2005) described as "one of the gravest threats of global warming." Not only did the model-predicted decline in Northern Hemispheric mid-latitude soil moisture contents *fail to materialize* under the combined influence of many decades of rising atmospheric CO_2 concentrations and temperatures, it (4) actually became *less* of a threat, possibly as a direct consequence of biological impacts of the ongoing rise in the air's CO_2 content.

One year later, Guo and Dirmeyer (2006) compared soil moisture *simulations* made by eleven different models within the context of the Second Global Soil Wetness Project (a multi-institutional modeling research activity intended to produce a complete multi-model set of land surface state variables and fluxes by using current state-of-the-art land surface models driven by the 10-year period of data provided by the International Satellite Land Surface Climatology Project Initiative II) against real-world *observations* made on the top meter of grassland and agricultural soils located within parts of the former Soviet Union, the United States (Illinois), China and Mongolia, which were archived in the Global Soil Moisture Data Bank.

In so doing, the two researchers found that (1) "simulating the actual values of observed soil moisture is still a challenging task for all models," noting that (2) "both the root mean square of errors (RMSE) and the spread of RMSE across models are large," and that (3) "the absolute values of soil moisture are poorly simulated by most models." In addition, they found that (4) "within regions there can be tremendous variations of any model to simulate the time series of soil moisture at different stations."

So just how serious were these *large errors* and *tremendous variations?* It would appear that they were *very* serious, based on a number of explanatory statements made by Guo and Dirmeyer. First of all, the two researchers said that (5) "the land surface plays a vital role in the global climate system through interactions with the atmosphere." Second, they stated that (6) "accurate simulation of land surface states is critical to the skill of weather and climate forecasts." And third, they wrote that soil moisture (7) "is the definitive land surface state variable, key for model initial conditions from which the global weather and climate forecasts begin integrations," and that (8) soil moisture is "a vital factor affecting surface heat fluxes and land surface temperature."

Therefore, in consequence of what "those in the know" thus describe as *large errors* and *tremendous variations* in what they readily characterize as *vital, critical, definitive* and *key* elements of state-of-the-art land surface model simulations of soil wetness (which is a pretty basic parameter), it would appear that (9) little faith should be placed in what those models portend about the future.

With the passing of another year, Li *et al*. (2007) had a paper published wherein they wrote that because (1) "soil moisture trends, particularly during the growing season, are an important possible consequence of global warming," climate model simulations of future soil moisture changes should be (2) "made with models that can produce reliable simulations of soil moisture for past climate changes," which is a proposition with which almost everyone would have to agree.

So what did they find when they compared soil moisture simulations derived from the IPCC's Fourth Assessment climate models (which were driven by *observed climate forcings*) for the period 1958-1999 with actual measurements of soil moisture made at over 140 stations or districts in the mid-latitudes of the Northern Hemisphere, which were averaged in such a way as to yield six regional results: one each for the Ukraine, Russia, Mongolia, Northern China, Central China and Illinois (USA)?

The three researchers reported that although the models showed realistic seasonal cycles for the Ukraine, Russia and Illinois, they showed (1) "generally poor seasonal cycles for Mongolia and China." In addition, they noted that (2) the Ukraine and Russia experienced soil moisture increases in summer "that were larger than most trends in the model simulations." In fact, they found that (3) only two out of 25 model realizations showed trends comparable to observations; and they noted that (4) the two realistic model-derived trends were "due to internal model variability rather than a result of external forcing," which means that (5) the two reasonable matches were actually *accidental*.

Noting further that "changes in precipitation and temperature cannot fully explain soil moisture increases for Ukraine and Russia," Li *et al*. wrote that (6) "other factors might have played a dominant role in the observed patterns for soil moisture." And in this regard they mentioned *solar dimming*, as well as the fact that (7) in response to elevated atmospheric CO_2 concentrations, "many plant species reduce their stomatal openings, leading to a reduction in evaporation to the atmosphere," so that (8) "more water is likely to be stored in the soil or [diverted to] runoff," correctly reporting that (9) this phenomenon had recently been detected in continental river runoff data by Gedney *et al*. (2006).

Consequently, and in light of this wealth of real-world data, (10) the climate models employed in the IPCC's Fourth Assessment were clearly deficient in their ability to correctly simulate soil moisture trends, even when applied to the *past* and when driven by *observed climate forcings*. In other words, (11) they failed the most basic type of test imaginable; and in the words of Li *et al*., this fact suggests that (12) "global climate models should better integrate the biological, chemical, and physical components of the earth system."

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MISCELLANEOUS PHENOMENA

Shortly after the turn of the last century and using newly-developed advanced methods from statistical physics, i.e., wavelet techniques and detrended fluctuation analysis, which Bunde *et al*. (2001) said were "able to distinguish between trends and persistence," the four scientists compared the outputs of several atmosphere-ocean (AO) general circulation models (GCMs) against real-world characteristics of these latter two phenomena, i.e., climatic trends and persistence.

Based on their earlier work in this area, Bunde *et al*. had determined that "a universal long range power law correlation may exist which governs atmospheric variability at all spatiotemporal scales." And in their 2001 study this conclusion was vindicated using real-world temperature data from a number of places around the world, which enabled them to conclude that "the power law behavior can serve as an ideal test for climate models." When several prominent AOGCMs were given this test, however, they (1) displayed wide performance differences and (2) actually failed to reproduce the universal power law behavior of the persistence. And the fact that Bunde *et al*. had found that (3,4) "the models tend to underestimate persistence while overestimating trends" implied, in their words, that (5) “the models exaggerate the expected global warming of the atmosphere." And they thus concluded that it therefore (6) "cannot be excluded that the global warming in the next 100 years will be less pronounced than predicted by the models," which is merely a kinder way of saying that the models are probably *way off-base*.

One year later, Franks (2002) reviewed what was then known about the abilities of atmospheric general circulation models (GCMs) to represent real-world processes of significance to climate change, while also discussing the usefulness of GCMs in providing impact assessments of projected climate changes that were presumed at that point in time to be driven by increases in atmospheric concentrations of various greenhouse gases, which analyses were conducted within the context of hydrological concerns and were contrasted with similar assessments that could be made on the basis of empirical correlations of climate with various solar phenomena.

In pursuing this course of action, Franks found that (1) an obvious weak point of GCMs was “their inability to model properly the physics of clouds," in that (2) "GCMs vary considerably, and often produce quite different results," which is not what one wants to hear in attempting to anticipate the future. Franks also correctly noted that other problems with state-of-the-art GCMs included (3) "grossly uncertain land surface representations, [4] the problem of sub-pixel heterogeneity, and, perhaps most seriously, [5] the attendant problems of translating GCM output into hydrologically meaningful variables." Last of all, Franks concluded that (6) "in a strict Popperian view of science, the testing of GCMs is inadequate, as [7] model structures (i.e. different sets of hypotheses) are not rigorously evaluated."

To truly understand the potential impacts of rising atmospheric CO_2 concentrations on climate, therefore, Franks noted that "greater knowledge of natural climate variability is required." And in this context he described several climate shifts that had occurred at different times of the past century, after which he reviewed what might have caused these decadal and multi-decadal changes, concluding that there is a tremendous amount of evidence for "an external solar control," as had been proposed over the years by Reid (1991, 1997, 1999, 2000).

Franks' final conclusion, therefore, was that the coherence displayed by temperature and solar irradiance trends over the 20th century strongly suggested that "documented hydrological changes in regional climates ... may be driven by solar-terrestrial interactions," implying that this linkage may hold the key to making future hydrological forecasts. However, "until GCMs can elucidate the mechanisms of hydrological variability," as he put it, Franks wisely warned that any of their projections of long-term future climate changes "must be viewed with obvious caution."

In a contemporary study of the same subject, and noting that "confidence in the simulation and prediction skills of global climate models is a crucial precondition for formulating climate protection policies," Govindan *et al*. (2002) tested the scaling performance of seven state-of-the-art global climate models for two scenarios using detrended fluctuation analysis. The first scenario considered only the effect of greenhouse gas forcing, taken from observations until 1990 and then increased at a rate of 1% per year thereafter. The second scenario added the effect of aerosols, but with only direct sulfate forcing considered, where historical sulfate data were utilized until 1990 and then increased linearly after that.

As for what they thereby learned, according to the six scientists, all the models used in their study were shown to be capable of reproducing the current mean state of the atmosphere to various degrees of accuracy. In addition, they noted that the models had been "validated" by comparing their output to historical data, as well as via intercomparison among themselves.

So this being the case, should one accept the model-based vision of CO_2-induced global warming as the gospel truth? *No way* ... for the results of Govindan *et al*.'s analysis clearly revealed that in spite of how well the models reproduced the current mean state of the atmosphere, and in spite of the belief of many that the models had thus been validated, the simulated records of both scenarios displayed (1) "wide performance differences" and (2) *failed* "to reproduce the universal scaling behavior of the observed records," as demonstrated by their underestimation of the long-range persistence of the atmosphere and overestimation of observed trends.

Based on their *negative* findings, the six scientists thus concluded that (3) "anticipated global warming is also overestimated by the models." And the moral of this review, therefore, was to not be fooled into believing that just because models can simulate mean climate fairly well, or because they all produce the same results, they can correctly predict the future. It just doesn't work that way. In fact, as we learn from this study, all then-current models still had a long way to go before we could possibly put sufficient faith in them to formulate enlightened energy policies.

In another study from this same time period, Gettelman *et al*. (2002) began the report of their work by writing that "convective available potential energy (CAPE), which can be calculated from radiosonde observations, is a measure of the conditional stability of the troposphere to a finite vertical displacement, as occurs during moist convection," while additionally noting that "long-term changes in CAPE might be associated with changes in convective activity and the atmospheric energy budget" and that "CAPE is thus a potential indicator of climate change."

Such being the case, the four researchers used radiosonde observations from fifteen stations in the tropics with "long stable records" to calculate CAPE over the period 1958-1997, after which these records were "compared to a calculation of CAPE from a climate model simulation forced by observed sea surface temperatures," where the model used for this purpose was the National Center for Atmospheric Research (NCAR) Community Climate Model version 3 (CCM3). And in doing so they observed increases in CAPE at 12 of the 15 tropical radiosonde stations over the period of their study, which increases, as they commented, appeared to have been driven "by increases in near-surface temperature and/or humidity." In addition, they reported that the overall increase in CAPE appeared to have been largely caused "by a shift in the middle 1970s" that was "consistent with the time of an apparent shift of the background state of the climate." The climate model, however, even though *forced* by observed sea surface temperatures, (1) did *not* reproduce the overall increase in CAPE.

In light of this failure, the authors next coupled the atmospheric model to an ocean model and ran a simulation "with changing greenhouse gases and aerosols," as had been observed in the 20th century. Once again, however, they found that (2) "like the atmospheric GCM, the coupled model did not reproduce the observed trends in CAPE over the period examined." And in light of these findings, Gettelman *et al*. were forced to report that (3) "observed CAPE has mostly statistically significant positive trends over the period of 1958-1997 in the tropics, yet [4] a modern climate model is not able to reproduce these trends." And they thus stated, in an implied challenge to climate modelers to correct this situation, that "ensuring future models can faithfully reproduce such trends is perhaps quite important for enhancing confidence in model predictions of future climate changes."

Finally moving ahead one year, Kripalani *et al*. (2003) wrote that monsoon rainfall is an important socio-economic feature of India, and that climate models suggest that global averaged temperatures are projected to rise under all scenarios of future energy use (IPCC, 2001), leading to "increased variability and strength of the Asian monsoon." Hence, they examined Indian monsoon rainfall using observational data maintained by the Indian Institute of Tropical Meteorology that were collected from 306 stations distributed across the country over the 131-year period 1871-2001. And this work revealed the existence of decadal variations running through the record that reveal "distinct alternate epochs of above and below normal rainfall," which epochs "tend to last for about three decades."

However, they also reported that (1-3) "there is no clear evidence to suggest that the strength and variability of the Indian Monsoon Rainfall (IMR) nor the epochal changes are affected by the global warming," while also reporting that (4) "studies by several authors in India have shown that there is no statistically significant trend in IMR for the country as a whole." And last of all, they indicate that (5) "Singh (2001) investigated the long term trends in the frequency of cyclonic disturbances over the Bay of Bengal and the Arabian Sea using 100-year (1890-1999) data and found significant decreasing trends." As for the *significance* of their findings, the four researchers wrote that (6,7) "there seem[s] to be no support for the intensification of the monsoon nor any support for the increased hydrological cycle as hypothesized by [the] greenhouse warming scenario in model simulations."

In another paper from the same year, Chase *et al*. (2003) introduced their work on the subject by noting that "greenhouse gas warming simulations generally show increased intensity of Asian summer monsoonal circulations (e.g., Meehl and Washington, 1993; Hirakuchi and Giorgi, 1995; Li *et al*., 1995; Zwiers and Kharin, 1998; Chakraborty and Lal, 1994; Suppiah, 1995; Zhao and Kellog, 1988; Hulme *et al*., 1998; Wang, 1994)," as was also the case for Northern Australia during the austral summer season (Whetton *et al*., 1993, 1994; Suppiah, 1995). In addition, they also said that much the same thing would likely be predicted for the African monsoons, "given that the tropical atmospheric moisture content, latent heating and overall hydrological cycle have been hypothesized to increase with increasing tropospheric temperature (e.g., IPCC, 1996)."

To test this hypothesis of the climate modeling community, Chase *et al*. examined changes in several independent intensity indices of the four major tropical monsoonal circulations over the period 1950-1998, or over the last half of what climate alarmists typically referred to as the prior millennium's most dramatic century of warming, which included the highly contentious final two decades of the 20th century that were supposed to represent truly "unprecedented" global warming. And what did they thereby learn?

In each of the four regions examined, Chase *et al*. reported finding (1) "diminished monsoonal circulations over the period of record," as well as (2) "evidence of diminished spatial maxima in the global hydrological cycle since 1950." In addition, they said that (3) "trends since 1979, the period of strongest reported surface warming, do not indicate any change in monsoon circulations."

Interestingly, and although noting that then-current state-of-the-art models of earth's climate system "generally simulate a strong relationship between globally averaged warming and increasing extremes in the hydrological cycle including monsoonal strength," they had to admit that after their careful analysis of real-world meteorological observations, they were forced to write that (4) "we find no evidence to support this model hypothesis in these data." And once again, therefore, the best climate models of that day and age (5) failed to even *qualitatively* describe what was happening in the world of nature.

One year later, Chase *et al*. (2004) wrote that "an important test of model predictive ability and usefulness for impact studies is how well models simulate the observed vertical temperature structure of the troposphere under anthropogenically-induced change scenarios." And why was this so? It was because one of the most fundamental features of then-current climate-model simulations was "a larger warming in the free troposphere than at the surface when forced by increasing atmospheric greenhouse-gas concentrations and the direct effect of sulfate aerosols (IPCC 1996, 2001)." If this predicted feature of global warming is not evident in the real world, therefore, there is little reason to believe anything else the models might predict, including both the cause and (or) magnitude of the observed surface warming.

Continuing on, then, Chase *et al*. assessed the likelihood "that such a disparity between model projection and observations could be generated by forcing uncertainties or chance model fluctuations, by comparing all possible 22-year temperature trends [for the years 1979-2000, which were similarly studied by the IPCC and a special committee of the U.S. National Academy of Sciences] in a series of climate simulations." And, in their words, (1) "at no time, in any model realization, forced or unforced, did any model simulate the then-observed situation of a large and highly significant surface warming accompanied with no warming whatsoever aloft," which observations were openly acknowledged to represent the real world in both the IPCC (2001) report and the National Academy Report (2000).

And so it was that Chase *et al*. thus concluded that these "significant errors in the simulations of globally averaged tropospheric temperature structure indicate likely errors in [2] tropospheric water-vapor content and therefore [3-5] total greenhouse-gas forcing, precipitable water and convectively forced large-scale circulations," noting that (6) "such errors argue for extreme caution in applying simulation results to future climate-change assessment activities and to attribution studies (e.g. Zwiers and Zhang, 2003) and [7] call into question the predictive ability of recent generation model simulations."

In a contemporary publication, Hoar *et al*. (2004) conducted "an evaluation of the performance over western Europe of an ensemble of General Circulation Models (GCMs) used to simulate climates at the present-day, the mid-Holocene and the Last Glacial Maximum (LGM)," which they did by comparing simulations of surface air temperature and precipitation among the different models and with observed and proxy data sets.

This work revealed, in the words of the three scientists, that "for absolute values, there was a higher inter-model correlation for temperature than there was for precipitation for all months and all time slices." In terms of *differences* between the present and the mid-Holocene, however, they found that (1) the temperature correlations "are no longer robust and show a large variation ... where [2] any climate signal was swamped by the inter-model variability."

Hoar *et al*. also found that "experiments performed with models from the same institution tend to cluster," and that (3-5) "statistical comparisons of the models with observed and proxy data sets demonstrate a lack of consistency in model performance between months, transects and time slices."

Most amazing of all, perhaps, the three East Anglia researchers found that (6) for the LGM, "a more realistic simulation of the ocean, as given in the sensitivity study of Kitoh *et al*. (2001), widened the difference between simulated and proxy derived winter temperatures in western Europe." And in their very next sentence, they said "this does not necessarily imply that the models are getting worse (although there is undoubtedly a need for further development), but rather emphasizes the need for more accurate and better spatially resolved palaeoproxy data sets for the LGM."

Taken as a whole, the several findings of Hoar *et al*. reveal a number of serious model deficiencies. The one just mentioned, however, is *astounding*: incorporation of a *more realistic* simulation of the ocean actually leads to temperature simulations that are *worse* than they are with a *less realistic* ocean, demonstrating that while a little knowledge can be a dangerous thing, a little *more* knowledge may sometimes be even more *dangerous.*

Just because climate models tend to become more complex with the passage of time does *not* insure that they are getting any *better*; for they may well be *stagnating* or actually on a *retrograde* course in terms of their ability to faithfully represent the final climatic outcome of a small perturbation of the atmosphere's composition, especially when that perturbation involves the concentration of a trace gas (CO_2) that stimulates all sorts of phenomena in nearly all of earth's plants, many of the physiological processes of which have significant climatic implications. Consequently, the discrepancy between simulated and proxy temperatures discovered by Hoar *et al*. may well indicate a need for greater model introspection and less questioning of the palaeoproxy data sets with which the model simulations disagree.

Also with a concomitant publication was Schwartz (2004), who reviewed the history of climate model predictions of greenhouse-gas-induced global warming and the uncertain role played by aerosols in this frustrating enterprise. He began by noting that the National Research Council (1979) had concluded that "climate sensitivity [to CO_2 doubling] is likely to be in the range 1.5-4.5°C," and that, "remarkably, despite some two decades of intervening work, neither the central value nor the uncertainty range has changed." And this continuing uncertainty, as he noted, "precludes meaningful model evaluation by comparison with observed global temperature change or empirical determination of climate sensitivity," while it instead "raises questions regarding claims of [models] having reproduced observed large-scale changes in surface temperature over the 20th century."

But not stopping there, Schwartz went on to contend that climate model predictions of CO_2-induced global warming "are limited at present by uncertainty in radiative forcing of climate change over the industrial period, which is dominated by uncertainty in forcing by aerosols." And he said that if this situation is not improved, "it is likely that in another 20 years it will still not be possible to specify the climate sensitivity with an uncertainty range appreciably narrower than it is at present." Indeed, he stated that (1) "the need for reducing the uncertainty from its present estimated value by at least a factor of 3 and perhaps a factor of 10 or more seems inescapable if the uncertainty in climate sensitivity is to be reduced to an extent where it becomes useful for formulating policy to deal with global change," which surely suggests that (2) even the best climate models of Schwartz's day were wholly inadequate for this purpose.

Moving on another year, Williams (2005) began his review of the subject by noting that "the major difficulty of climate modeling stems from the coexistence of climatological phenomena on a vast range of scales," some of which are simply too small to be adequately modeled at the present time. Among the latter "important unresolved features," as he described them, are "ocean eddies, gravity waves, atmospheric convection, clouds and small-scale turbulence, all of which are known to be key aspects of the climate system." Furthermore, he stated as his opinion that (1) "the full spectrum of spatial and temporal scales exhibited by the climate system will not be resolvable by models for decades, if ever."

In spite of this gloomy outlook, Williams encouraged climate modelers to not be "dismayed by the enormity of the challenge facing them," and he suggested that "stochastic techniques offer an immediate, convenient and computationally cheap solution." However, he acknowledged in his very next sentence that "much is still unknown about the potential of stochastic physics to improve climate models." And faced with the potentially unsolvable problem of improving climate models, for which the most promising solution has an unknown potential for success, it is strange, indeed, that the outputs of these vastly imperfect tools are considered by some to be so sound as to justify a complete restructuring of the way the world produces and uses energy.

Soon thereafter, Stott *et al*. (2006) set the stage for their study of the subject by emphasizing that "care should be taken not to over-interpret good agreement between climate models and past observed global mean warming," *because*, as they continued, (1) "with large uncertainties in climate forcings, especially that due to aerosols, agreement when models include all the most important anthropogenic and natural forcings could be obtained fortuitously as a result of, for example, balancing too much (or too little) greenhouse gas warming by too much (or too little) aerosol cooling."

Consequently, in an attempt to resolve this problem using three coupled climate models with very different sensitivities and aerosol forcings, Stott *et al*. performed an *optimal detection* *analysis*, wherein "the spatial and temporal nature of observed twentieth-century temperature change constrains the component of past warming attributable to anthropogenic greenhouse gases." This work revealed, as the seven climate scientists reported, that "all three models, when constrained by observations, suggest that [20th-century] warming attributable to greenhouse gases is between 0.7 and 1.3 K (5 and 95 percentiles) and therefore probably greater than the observed warming of 0.6 K over the century." And this being the case, they concluded that the "transient climate response under a 1% [per year] increase in carbon dioxide has a range of 2.2-4.0 K (5-95 percentiles)."

So was this the climate modeling community's *final answer*? Probably not; for Stott *et al*. appropriately acknowledged that "all our results are subject to [1] unquantified uncertainties arising from [2] missing forcings and [3] imperfect representation of climate physics." And since there is no way to know the impacts of "unquantified" uncertainties, "missing" forcings and "imperfect" representations of climate physics (and there will not be until the time that these respective elements *are* quantified, *are* no longer missing and *are* at least *close* to perfected), there will be (4) no way to know the climatic significance of either past or projected increases in the air's CO_2 content *via the use of climate models*.

One year later, Lucarini *et al*. (2007) compared, for the overlapping time frame 1962-2000, "the estimate of the Northern Hemisphere mid-latitude winter atmospheric variability within the available 20th century simulations of 19 global climate models included in the Intergovernmental Panel on Climate Change [IPCC] 4th Assessment Report" with "the NCEP-NCAR and ECMWF reanalyses," i.e., compilations of real-world observations produced by the National Center for Environmental Prediction (NCEP), in collaboration with the National Center for Atmospheric Research (NCAR), and by the European Center for Mid-Range Weather Forecast (ECMWF). And what did they thereby learn?

The five Italian researchers report that (1) "large biases, in several cases larger than 20%, are found in all the considered metrics between the wave climatologies of most IPCC models and the reanalyses, while [2] the span of the climatologies of the various models is, in all cases, around 50%." They also report that (3) "the traveling baroclinic waves are typically overestimated by the climate models, while [4] the planetary waves are usually underestimated," and that (5) "the model results do not cluster around their ensemble mean," which is but another way of saying that (6) the model results *are all over the place!*

In conclusion, therefore, and quoting once again the scientists who performed the model tests, "this study suggests caveats with respect to the ability of most of the presently available climate models in representing the statistical properties of the global scale atmospheric dynamics of the present climate” and, all the more, “in the perspective of modeling [*future*] climate change." Indeed, it gives one pause to question most *everything* the models might suggest about the future.

Concomitantly, John and Sodon (2007) had a paper published wherein they began by stating the fact that "atmospheric water vapor is widely recognized to be a key climate variable," primarily because "it is the dominant greenhouse gas and provides a key feedback for amplifying the sensitivity of the climate to external forcings." And as a result of these facts, they indicated there had been “a considerable effort to assess the credibility of model simulations of atmospheric water vapor," which is what they thus went on to do for vertical profiles of both water vapor *and temperature*, as generated by 16 fully-coupled ocean-atmosphere climate models, against which they compared observational temperature and humidity fields obtained from ECMWR (Uppala *et al*., 2005) and NCEP (Kalnay *et al*., 1996) reanalysis data for the period 1990-1999, and from the Atmospheric Infrared Sounder (AIRS), a high spectral resolution radiometer with 2378 bands in the thermal infrared and 4 bands in the visible, for the period August 2002-July 2006. And what did they learn from these endeavors?

The two researchers reported that they "identified significant biases in the ability of current climate models to simulate the zonal, annual mean distribution of [1] water vapor and [2] temperature." More specifically, they discovered that (3) the models exhibited a major moist bias in the free troposphere, which for the mean of all the models they studied approached 75% in the upper troposphere, although they said that (4) "it can exceed 200% for individual models." Likewise, they noted that (5) "model simulated temperatures are systematically colder by 1-4°C throughout the troposphere," and that (6) the bias increases with altitude, "with maxima located near 200 hPa in the extra-tropics where [7] the bias exceeds 6°C compared to all three observational data sets."

About this same time, Lin (2007) wrote that "a good simulation of tropical mean climate by the climate models is a prerequisite for their good simulations**/**predictions of tropical variabilities and global teleconnections," but that (1) "unfortunately, the tropical mean climate has not been well simulated by the coupled general circulation models (CGCMs) used for climate predictions and projections," due to the fact that (2) "most of the CGCMs produce a double-intertropical convergence zone (ITCZ) pattern," and that (3) "a synthetic view of the double-ITCZ problem is still elusive."

To explore the nature of this problem in greater depth, and to hopefully make some progress in resolving it, Lin analyzed tropical mean climate simulations of the 20-year period 1979-99 provided by 22 Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) CGCMs, together with concurrent Atmospheric Model Intercomparison Project (AMIP) runs from 12 of them.

This work revealed, in Lin's words, that (1) "most of the current state-of-the-art CGCMs have some degree of the double-ITCZ problem, which is characterized by [2] excessive precipitation over much of the Tropics (e.g., Northern Hemisphere ITCZ, Southern Hemisphere SPCZ [South Pacific Convergence Zone], Maritime Continent, and equatorial Indian Ocean), and is [3] often associated with insufficient precipitation over the equatorial Pacific," as well as (4) “overly strong trade winds, [5] excessive LHF [latent heat flux], and [6] insufficient SWF [shortwave flux], leading to [7] significant cold SST (sea surface temperature) bias in much of the tropical oceans," while additionally noting that (8,9) "most of the models also simulate insufficient latitudinal asymmetry in precipitation and SST over the eastern Pacific and Atlantic Oceans," and further stating that

(10) "the AMIP runs also produce excessive precipitation over much of the Tropics including the equatorial Pacific, which also leads to [11] overly strong trade winds, [12] excessive LHF, and [13] insufficient SWF," which in turn suggests that (14) "the excessive tropical precipitation is an intrinsic error of the atmospheric models." And as if that was not enough, Lin added that (15) "over the eastern Pacific stratus region, most of the models produce insufficient stratus-SST feedback associated with [16] insufficient sensitivity of stratus cloud amount to SST."

And with the solutions to all of these long-standing problems continuing to remain "elusive," and with Lin suggesting that the long-sought-for solutions were actually *prerequisites* for "good simulations**/**predictions" of future climate characteristics, there was – and still is – significant reason to conclude that [17] the then-current state-of-the-art CGCM predictions of CO_2-induced global warming ought not to have been considered all that reliable. And to continue to cite these predictions as the *primary basis* for totally revamping the way in which the world obtains the energy used to power modern societies, would seem to be the height of folly.

In another study from this time period, Kiktiv *et al*. (2007) began their report of its findings by stating the obvious (but extremely important) *fact* that "comparing climate modeling results with historical observations is important to further develop climate models and to understand the capabilities and limitations of climate change projections." And in their specific case, Kiktev *et al*. analyzed the abilities of five global coupled climate models that played important roles in the IPCC's Fourth Assessment Report to simulate temporal trends over the second half of the 20th century of five annual indices of extremes in surface temperature (annual percentage of days with Tmin < 10th percentile, with Tmax < 10th percentile, with Tmin > 90th percentile, with Tmax > 90th percentile, and the annual number of frost days, i.e., Tmin < 0°C), as well as five annual indices of extremes in precipitation, the observational data for which analyses they obtained from the HadEX global data set that contained gridded annual and seasonal values of the ten extreme indices that were calculated from multiple series of *in situ* daily measurements (Alexander *et al*., 2006).

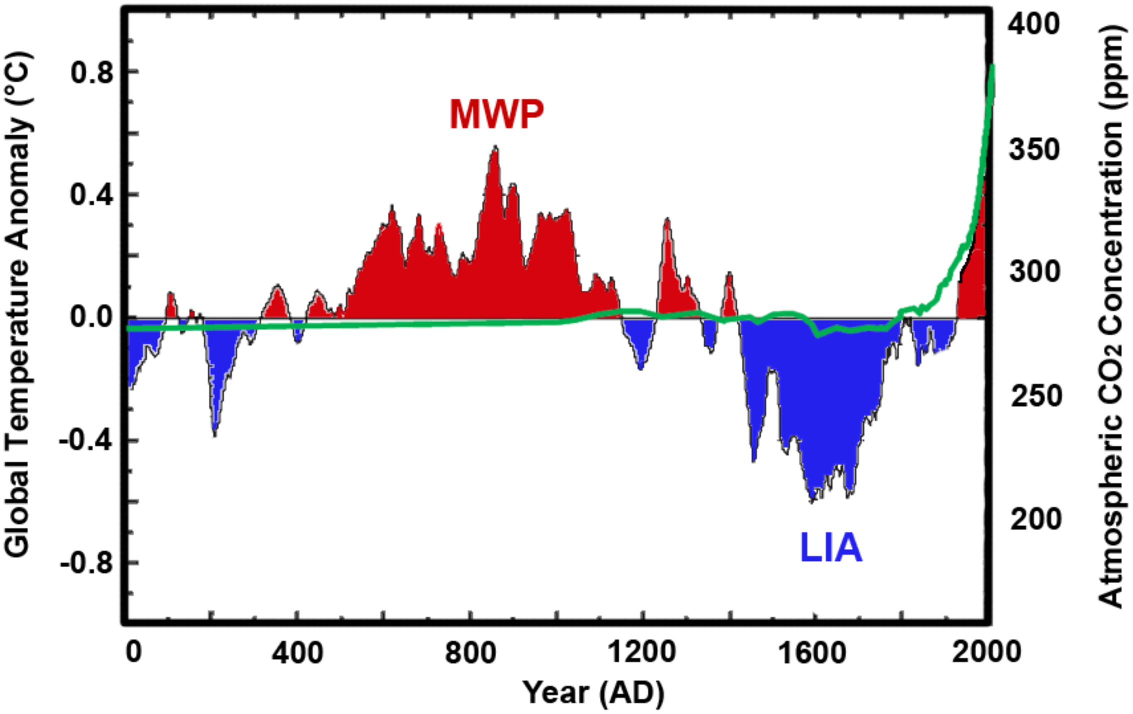
This international research team, hailing from Australia, Japan, Russia and the United Kingdom, found that the results they obtained mostly showed *moderate* skill for temperature indices and (1) *low* skill or its (2) *absence* for precipitation indices. And if one was going to use climate model results as the basis for mandating a complete overhaul of the world's energy system -- as the world's climate alarmists have long attempted to do -- one would like to have those models possess considerably more than *moderate* skill. Most rational people, in fact, would definitely *not* want them to have *low* skill. And to employ models that had a total *absence* of skill would pretty much teeter on the verge of *insanity*.

Moving ahead another year, and in a somewhat similar type of study designed "to distinguish between simultaneous natural and anthropogenic impacts on surface temperature, regionally as well as globally," Lean and Rind (2008) performed a robust multivariate analysis using the best available estimates of each, together with the observed surface temperature record from 1889 to 2006. And this work revealed, in the words of the two researchers, that (1) "contrary to recent assessments based on theoretical models (IPCC, 2007) the anthropogenic warming estimated directly from the historical observations is more pronounced between 45°S and 50°N than at higher latitudes," which finding, in their words, "is [2] the approximate inverse of the model-simulated anthropogenic plus natural temperature trends ... which have minimum values in the tropics and increase steadily from 30 to 70°N." *Furthermore*, as they continued, "the empirically-derived zonal mean anthropogenic changes have approximate hemispheric symmetry whereas the mid-to-high latitude modeled changes are larger in the Northern Hemisphere."

Because of what their analysis revealed, the two researchers concluded that (1) "climate models may therefore lack -- or incorrectly parameterize -- fundamental processes by which surface temperatures respond to radiative forcings," which is a conclusion with which all of the world's "climate skeptics" would probably agree, and which should give all of the world's "climate alarmists" pause to consider the rationality of their calls for dramatic worldwide curtailment of anthropogenic CO_2 emissions. To promote such unprecedented and coercive measures on the basis of *model scenarios* that "lack -- or incorrectly parameterize -- fundamental processes by which surface temperatures respond to radiative forcings" would appear to be the height of folly.

One year later, in a paper published in the *Proceedings of the National Academy of Sciences of the United States of America,* Solomon *et al*. (2009) described a climate modeling exercise that claimed to show that any "climate change that takes place due to increases in carbon dioxide concentration is largely irreversible for 1,000 years after emissions stop." And in the virtual world of computer-run climate models, such may well be so; but that need *not* be the case in the *real* world, where researchers still struggle to even *understand* -- much less model -- the suite of complex interactions that occur among the many physical, chemical and biological phenomena that combine to determine the planet's multi-faceted climatic trajectory in response to a rise in the air's CO_2 content. Hence, there is a great need to carefully evaluate Solomon *et al*.'s claim.

Beginning with their *assumption* that atmospheric warming is already occurring, and that there is evidence for anthropogenic (i.e., CO_2-induced) contributions to it, it should be noted that the global warming of the past few decades was actually part of a much *longer* warming, which began in many places throughout the world a little over three centuries ago (about 1680) with the dramatic "beginning of the end" of the Little Ice Age (LIA, see figure below), *well before there was any significant increase in the air's* CO_2 *content*. And this observation suggests that a continuation of whatever phenomenon -- or combination of phenomena -- may have caused the greater initial warming could well have caused the lesser final warming, the total effect of which was to transport the earth from the chilly depths of the Little Ice Age into the relative balm of the Current Warm Period.



The mean relative temperature history of the earth (blue, cool; red, warm) over the past two millennia - adapted from Loehle and McCulloch (2008) - highlighting the Medieval Warm Period (MWP) and Little Ice Age (LIA), together with a concomitant history of the atmosphere's CO_2 concentration (green).

It should also be noted that earth's current temperature is no higher now (and maybe just a tad less, in fact) than it was during the peak warmth of the Medieval Warm Period (MWP), when (just as at the "beginning of the end" of the LIA) there was over 100 ppm *less* CO_2 in the air than there is today. Consequently, and since the great MWP-to-LIA cooling occurred *without any significant change in the atmosphere's* CO_2 *concentration*, just the opposite could occur just as easily, and the planet could *warm*, and by an equal amount -- just as it did over the past three centuries -- without any help from an increase in the atmosphere's CO_2 content, which remained essentially constant for the first 1850 years of the 2000-year record depicted in the figure above, and which did not begin to really “take off” until just the last few decades of the 20th century, which brief period of correlation is simply too short to use as justification for claiming that the late 20th-century CO_2 increase was responsible for the late 20th-century warming of the globe, and especially since that warming actually *ceased* at the end of the 20th century, even though the atmosphere's CO_2 content has subsequently continued to climb at an unprecedented rate and to ever greater heights.

In light of these several observations, it should thus be clear to all that Solomon *et al.*'s analyses of the *irreversibility* of climate-model-based atmospheric warming projections due to projected increases in the air's CO_2 content are utterly meaningless, *because the projections themselves are* *meaningless*, due to (1) their being based on overly-inflated values of the strength of the CO_2 greenhouse effect, and (2) the long history of the *non*-correlation between historical climate change (both warming and cooling) and the concomitant history of the air's CO_2 content (mostly flat-lining) over the past two millennia.

In another pertinent study from the same year, Lindzen and Choi (2009) used the National Centers for Environmental Prediction's 16-year (1985-1999) monthly record of sea surface temperature (SST), together with corresponding radiation data from the Earth Radiation Budget Experiment, to estimate the sign and magnitude of climate feedback over the oceanic portion of the tropics and thus obtain an *empirical* evaluation of earth's thermal sensitivity, as opposed to the *model-based* evaluation employed by the IPCC. So what did the two researchers learn?

Lindzen and Choi reported that all eleven models employed in the IPCC's analysis "agree as to positive feedback," but they found that they all *disagreed* -- and disagreed "very sharply" -- with the real-world observations that they (Lindzen and Choi) utilized, which clearly indicated that *negative* feedback actually prevails. And the presence of that negative feedback reduces the CO_2-induced propensity for warming to the extent that their analysis of the real-world observational data only yielded a mean SST increase "of ~0.5°C for a doubling of CO_2."

So how does one decide which of the two results is the more correct? Real-world data would be the obvious standard against which to compare model-derived results; but since Lindzen and Choi's results *are* based on real-world measurements, the only alternative we have is to seek *other* real-world results. And, fortunately, there are several such findings, many of which are summarized in the review paper of Idso (1998), who described eight "natural experiments" that he personally employed in prior studies designed to determine "how earth's near-surface air temperature responds to surface radiative perturbations."

The eight naturally-occurring phenomena employed by Idso were (a) the change in the air's water vapor content that occurs at Phoenix, Arizona, with the advent of the summer monsoon, (b) the naturally-occurring vertical redistribution of dust that occurs at Phoenix between summer and winter, (c) the annual cycle of surface air temperature that is caused by the annual cycle of solar radiation absorption at the earth's surface, (d) the warming effect of the entire atmosphere caused by its mean flux of thermal radiation to the surface of the earth, (e) the annually-averaged equator-to-pole air temperature gradient that is sustained by the annually-averaged equator-to-pole gradient of total surface-absorbed radiant energy, (f) the mean surface temperatures of Earth, Mars and Venus relative to the amounts of CO_2 contained in their respective atmospheres, (g) the paradox of the faint early sun and its implications for earth's thermal history, and (h) the greenhouse effect of water vapor over the tropical oceans and its impact on sea surface temperatures.

These eight analyses, in the words of Idso, "suggest that a 300 to 600 ppm doubling of the atmosphere's CO_2 concentration could raise the planet's mean surface air temperature by only about 0.4°C," which is right in line with Lindzen and Choi's deduced warming of ~0.5°C for a nominal doubling of the air's CO_2 content. And, hence, there would appear to be a goodly amount of real-world data that argue *strongly* against the *over-inflated* CO_2-induced global warming that was -- and still is -- being predicted by state-of-the-art climate models.

One year later, Lindzen (2010) summed up his evaluation of the then-current conglomerate of climate models by writing that (1) "the physics of unresolved phenomena such as clouds and other turbulent elements is not understood to the extent needed for incorporation into models," so that (2) models are presently merely "experimental tools whose relation to the real world is questionable," that (3) "current models depend heavily on undemonstrated positive feedback factors to predict high levels of warming," that (4) "there is compelling evidence for all the known feedback factors to actually be negative," that (5) "even supercomputers are inadequate to allow long-term integrations of the relevant equations at adequate spatial resolutions," that "current models all predict that warmer climates will be accompanied by increasing humidity at all levels" but that (6) "such behavior is an artifact of the models since they have neither the physics nor the numerical accuracy to deal with water vapor," and that (7) "the models' predictions for the past century incorrectly describe the pattern of warming and greatly overestimate its magnitude."

In this regard, Lindzen further stated that a doubling of the air's 2010 CO_2 content might lead to a warming of only "0.5 to 1.2 degrees centigrade," which is in harmony with the earlier analyses of Idso (1998), who employed a total of eight *separate and independent* "natural experiments" to demonstrate that in the *real* world, "a 300 to 600 ppm doubling of the air's CO_2 concentration" -- which is somewhat less than the doubling of the atmosphere's 2010 CO_2 concentration referred to by Lindzen -- "could raise the planet's mean surface air temperature by only about 0.4°C."

And in light of these facts, Lindzen concluded that (8) "with poor and uncertain models in wide use, predictions of ominous situations are virtually inevitable -- regardless of reality," and, therefore, he wrote that (9) "it goes almost without saying that the dangers and costs of those economic and social consequences [of doing what the world's climate alarmists want everyone to do in the way of anthropogenic CO_2 emissions] may be far greater than the original environmental danger."

About this same time, Lo and Hsu (2010) wrote that "widespread abrupt warming in the extratropical Northern Hemisphere occurred in the late 1980s," and they noted that this warming was associated with a change in the relative influence of a Pacific Decadal Oscillation (PDO)-like pattern and an Arctic Oscillation (AO)-like pattern. And utilizing land surface temperature data obtained from the University of East Anglia's Climate Research Unit (Mitchell *et al*., 2004), plus sea surface temperature data obtained from the UK's Meteorological Office (Rayner *et al*., 2003), they explored the nature of the temperature increase and tested the ability of IPCC/CMIP3 models to simulate it. And in so doing, the two Taiwanese researchers found that the emergence of an AO-like pattern in the late 1980s and the concomitant weakening of the prior prevailing PDO-like pattern -- occurring in tandem -- were what led to the "accelerated warming in the Northern Hemisphere." And they added that these results, together with results obtained from current IPCC/CMIP3 models, (1) "do not support the scenario that the emerging influence of the AO-like pattern in the 1980s can be attributed to the anthropogenic greenhouse effect." As for *other* implications of their findings, Lo and Hsu stated in the concluding paragraph of their paper that "this study indicates the importance of the changing behavior of the decadal fluctuations in the recent climate regime shift," and they highlight in this regard what they call (2) "the insufficient capability of the present state-of-the-art IPCC**/**CMIP3 models in simulating this change."

Shortly thereafter, Lang and Waugh (2011) conducted a study of model assessments of changes in the frequency of Northern Hemisphere summer cyclones, noting that "understanding the characteristics and trends in summer cyclones is important not only for understanding mid-latitude weather systems and extreme events, but it is also important for understanding the Arctic hydrological cycle and radiation budget (e.g., Orsolini and Sortberg, 2009)." In addition, they noted that "the surface concentrations of ozone and aerosols, and as a result surface air quality, depend on a range of meteorological factors [that] are closely connected with cyclones (e.g., Jacobs and Winner, 2009)."

Therefore, in an attempt to get some feel for the degree of confidence one should place in the projections of state-of-the-art climate models in regard to these subjects, Lang and Waugh examined "the robustness of trends in Northern Hemisphere (NH) summer cyclones in the World Climate Research Programme's Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model data set that was used in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007)."

As a result of their thorough examination of this subject, the two researchers reported that (1) they could find "little consistency" among the sixteen models they studied. In fact, they found that there was (2) "no consistency among the models as to whether the frequency of hemispheric-averaged summer cyclones will increase or decrease" in response to global warming. For some sub-regions, however, the sign of the trend was consistent among most of the models; but even then, as they noted, (3) "there is still a large spread in the magnitude of the trend from individual models, and, hence, [4] a large uncertainty in the trends from a single model." And, therefore, in the not-so-comforting words of the two scientists, (5)"the general lack of consistency among models indicates that care is required when interpreting projected changes in summer weather systems."

In another paper from this era, Scherrer (2011) wrote that "in the past, climate model verification primarily focused on the representation of climatological means." However, as he continued, "a good representation of second-order moments (i.e., variability) on different time scales (e.g., daily, month-to-month or interannual, etc.) is crucial and probably provides an even better test as to whether [real-world] physical processes are well represented in the models."

Working with 20th-century climate model runs prepared within the context of the IPCC AR4 assessment (then called the CMIP3 data set), Scherrer compared model simulations of the *inter-annual variability* (IAV) of *2-m-height air temperature (T)*, *sea level pressure (SLP)* and *precipitation (P)* over the 20th-century with observational and reanalysis data sets for the same time period using standard deviation-based variability indices. And as a result, the Swiss scientist encountered a number of problems with the CMIP3 models.

With respect to *SLP*, the simulations were pretty good, as he noted that only minor IAV problems were found. With respect to *temperature*, however, he reported that (1) differences between observations and models were, in general, "larger than those for *SLP*." And for *precipitation* he said that (2) "IAV is 'all over the place' and [3,4] no clear relations with *T* and *SLP* IAV problems can be established."

Concentrating thereafter mostly on temperature, Scherrer noted that (5) "a few models represent *T* IAV much worse than others and create [6] spurious relations of IAV representation and the climate change signal." Among the "better" IAV models, he also found that [7] "the 'good' IAV models in the tropics are in general not also the 'good' IAV models in the extra-tropics," and that [8] "the 'good' IAV models over the sea are in general not the 'good' IAV models over land," while noting that [9] similar results were found for "the relation between T IAV representation and the amplitude of projected changes in temperature."

"In general," therefore, as Scherrer wrote in the final paragraph of his paper, "it is concluded that, [10] aggregated over very large regions, hardly any robust relations exist between the models' ability to correctly represent IAV and the projected temperature change." And he said that these results represent (11) "a plea to remove the 'obviously wrong' models (e.g., like those that have sea ice extending to below 50°N in the Atlantic and DJF temperature biases of ~40°C in Iceland, cf. Raisanen, 2007) before doing climate analyses." Even then, however, the CMIP3 models would likely *still* have problems with their temperature projections; and they would probably continue to produce precipitation projections that would be, to borrow a quote from Scherrer, "all over the place."

In another assessment of climate model performance, Fu *et al*. (2011b) wrote that the general circulation models (GCMs) of the IPCC's *Fourth Assessment Report* (AR4) predict a tropical tropospheric warming that increases with height, reaches a maximum at ~200 hPa, and then decreases to zero near the tropical tropopause, while additionally noting that this feature has important implications for climate sensitivity "because of its impact on water vapor, lapse rate and cloud feedbacks and to the change of atmospheric circulations." Therefore, they felt it was "critically important to observationally test the GCM-simulated maximum warming in the tropical upper troposphere," which is what they thus proceeded to do.

More specifically, as Fu *et al*. described it, they examined trends in the *temperature difference* (ΔT) between the tropical upper- and lower-middle-troposphere based on satellite *microwave sounding unit* (MSU) data -- as interpreted by both the *University of Alabama at Huntsville* (UAH) and the *Remote Sensing System* (RSS) research teams -- comparing both sets of results with AR4 GCM ΔT simulations for the period 1979-2010. And what did this exercise reveal?

The three researchers found that the RSS and UAH ΔT time series "agree well with each other," while also noting that they show little trend over the period of record. On the other hand, they discovered there was "a steady positive trend" in the model-simulated ΔT results, leading them to conclude that (1) the significantly smaller ΔT trends from both the RSS and UAH teams "indicate possible common errors among AR4 GCMs." In addition, they discovered that (2) the tropical *surface* temperature trend of the multi-model ensemble mean was *more than 60% large*r than that derived from observations, *indicating* in their words, that (3) "AR4 GCMs overestimate the warming in the tropics for 1979-2010."

Last of all, Fu *et al*. wrote that in addition to *greatly* overestimating the tropical surface temperature trend, (4) "it is evident that the AR4 GCMs exaggerate the increase in static stability between [the] tropical middle and upper troposphere during the last three decades," which findings (5) do not bode well for the climate-modeling enterprise that is the foundational basis of the IPCC's unsupported claims of significant CO_2-induced climate change.

In another contemporary paper, Wan *et al*. (2011) wrote that (1) "the notorious tropical bias problem in climate simulations of global coupled general circulation models (e.g., Mechoso *et al*., 1995; Latif *et al*., 2001; Davey *et al*., 2002; Meehl *et al*., 2005) manifests itself particularly strongly in the tropical Atlantic," and they said that "while progress towards reducing tropical climate biases has been made in the tropical Pacific over the past decades (e.g., Deser *et al*., 2006), (2) little or no progress has been made in the tropical Atlantic (Breugem *et al*., 2006; Richter and Xie, 2008; Wahl *et al*., 2009)." In fact, they stated that (3) "the climate bias problem is still so severe that one of the most basic features of the equatorial Atlantic Ocean -- the eastward shoaling thermocline -- cannot be reproduced by most of the Intergovernmental Panel on Climate Change (IPCC) assessment report (AR4) models," citing Richter and Xie (2008). So what was one to do about it?

Wan *et al*., as they described it, took up the challenge to "show that the bias in the eastern equatorial Atlantic has a major effect on sea-surface temperature (SST) response to a rapid change in the Atlantic Meridional Overturning Circulation (AMOC)." This they did by exemplifying the problem "through an inter-model comparison study of tropical Atlantic response to an abrupt change in [the] AMOC using the Geophysical Fluid Dynamics Laboratory (GFDL) Coupled Climate Model (CM2.1) and the National Center for Atmospheric Research (NCAR) Community Climate System Model (CCSM3)," and by dissecting the oceanic mechanisms responsible for the difference in the models' SST responses.

In doing these things, the four researchers found that (1) the different SST responses of the two models "is plausibly attributed to systematic differences in the simulated tropical Atlantic ocean circulation." And the ultimate implication of Wan *et al*.'s findings was, in their words, that (2) "in order to accurately simulate past abrupt climate changes and project future changes, the bias in climate models must be reduced." But if (3) "little or no progress" on this problem has been made in the tropical Atlantic "over the past decades," as noted by the four of them, (4) the outlook is not very promising for such a positive development any time soon, as is also suggested by the study of Latif and Keenlyside (2011), a brief review of which begins in the following paragraph.

"Climate variability," in the words of Latif and Keenlyside, "can be either generated internally by interactions within or between the individual climate subcomponents (e.g., atmosphere, ocean and sea ice) or externally by e.g., volcanic eruptions, variations in the solar insolation at the top of the atmosphere, or changed atmospheric greenhouse gas concentrations in response to anthropogenic emissions." Some examples of these internal variations are the North Atlantic Oscillation (NAO), the El Niño/Southern Oscillation (ENSO), the Pacific Decadal Variability (PDV), and the Atlantic Multidecadal Variability (AMV), all of which were said by the two researchers to (1) "project on global or hemispheric *surface air temperature* (SAT), thereby masking anthropogenic climate change."

In their review of this extremely complex subject, Latif and Keenlyside -- who held positions at Germany's Leibniz-Institute for Meerewissenschaften at the University of Kiel -- first described various mechanisms that are responsible for internal variability, giving special attention to the variability of the Atlantic Meridional Overturning Circulation (AMOC), which they suggest is likely the origin of a considerable part of the decadal variability within the Atlantic Sector, after which they discussed the challenge of decadal SAT predictability and various factors limiting its realization.

The two researchers first listed numerous problems that hamper decadal climate predictability, among which was the fact that (1) "the models suffer from large biases." In the cases of annual mean sea surface temperature (SST) and SAT over land, for example, they stated that (2) "typical errors can amount up to 10°C in certain regions," as found by Randall *et al*. (2007) to be the case for many of the IPCC-AR4 models. And they further added that (3) several models also "fail to simulate a realistic El Niño/Southern Oscillation," while additionally indicating that (4) "several assumptions have generally to be made about the process under consideration that cannot be rigorously justified," which they also note "is a major source of uncertainty."

Another problem they discused was the fact that (5) "some components of the climate system are not well represented or not at all part of standard climate models," one example being the models' neglect of the stratosphere. This omission is quite serious, as Latif and Keenlyside note that (6) "recent studies indicate that the mid-latitudinal response to both tropical and extra-tropical SST anomalies over the North Atlantic Sector may critically depend on stratospheric feedbacks," noting that Ineson and Scaife (2009) present evidence for (7) "an active stratospheric role in the transition to cold conditions in northern Europe and mild conditions in southern Europe in late winter during El Niño years."

An additional common model shortcoming, even in stand-alone integrations with models forced by observed SSTs, is that (8) model simulations of rainfall in the Sahel, as they described them, "fail to reproduce the correct magnitude of the decadal precipitation anomalies." Still another failure is the *fact*, as shown by Stroeve *et al*. (2007), that (9) "virtually all climate models considerably underestimate the observed Arctic sea ice decline during the recent decades in the so-called 20th century integrations with prescribed (known natural and anthropogenic) observed forcing." And added to these problems is the fact that (10) "atmospheric chemistry and aerosol processes are still not well incorporated into current climate models."

In summing up their findings, therefore, which included those noted above as well as a whole lot more, Latif and Keenlyside stated that (11) "a sufficient understanding of the mechanisms of decadal-to-multidecadal variability is lacking," that (12) "state-of-the-art climate models suffer from large biases," that (13) "they are incomplete and do not incorporate potentially important physics," that (14) various mechanisms "differ strongly from model to model," that (15) "the poor observational database does not allow a distinction between 'realistic' and 'unrealistic' simulations," and that (16) many models "still fail to simulate a realistic El Niño/Southern Oscillation." And so they concluded that (17) "it cannot be assumed that current climate models are well suited to realize the full decadal predictability potential," which is a somewhat obscure but kinder-and-gentler way of stating that (18) current state-of-the-art climate models are simply not good enough to make reasonably accurate simulations of climate change over a period of time (either in the past or the future) that is measured in mere decades.

In another concurrent publication of great interest, Crook and Forester (2011) introduced their study of the subject by noting that "predicting our future influence on climate requires us to have confidence in the climate models used to make predictions, and in particular that the models' climate sensitivity and ocean heat storage characteristics are realistic." And they went on to say, in this regard, that that confidence may be gained "by assessing how well climate models reproduce current climatology and climate variability, and how their feedback parameters compare with estimates from observations."

In pursuit of these important goals, Crook and Forster first determined, as they described it, "the surface temperature response contributions due to long-term radiative feedbacks, atmosphere-adjusted forcing, and heat storage and transport for a number of coupled ocean-atmosphere climate models," after which they compared "the linear trends of global mean, Arctic mean and tropical mean surface temperature responses of these models with observations over several time periods." They also investigated "why models do or do not reproduce the observed temperature response patterns," and they performed "optimal fingerprinting analyses on the components of surface temperature response to test their forcing, feedback and heat storage responses."

The models involved in these tests were those of the World Climate Research Programme's *Coupled Model Intercomparison Project phase 3* or CMIP3, while the real-world data employed were those of the HadCRUT3 database. And in doing what they had planned to do, the two University of Leeds (UK) researchers found that (1) tropical 20th-century warming was too large and (2) Arctic amplification too low in the Geophysical Fluid Dynamics Laboratory CM2.1 model, the Meteorological Research Institute CGCM232a model, and the MIROC3(hires) model because of (3) unrealistic forcing distributions." And they also determined that (4) "the Arctic amplification in both National Center for Atmospheric Research models was unrealistically high because of [5] high feedback contributions in the Arctic compared to the tropics." In addition, they determined that (6) "few models reproduce the strong observed warming trend from 1918 to 1940," noting that (7) "the simulated trend is too low, particularly in the tropics, even allowing for internal variability," which findings suggest that (8,9) "there is too little positive forcing or too much negative forcing in the models at this time."

Also with a concurrent publication were Mazzarella and Scafetta (2011), who -- focusing their attention on the monthly North Atlantic Oscillation (NAO) multi-secular reconstruction proposed by Luterbacher *et al*. (1999, 2002) for the period from 1659 onwards -- used the historical Length of Day record of Stephenson and Morrison (1995) and the global instrumental sea surface temperature record of Brohan *et al*. (2006) to argue that the time-integrated record of the NAO is "a reliable global climate proxy," comparing its oscillations with "those observed in the European historical record of middle latitude aurorae (Krivsky and Pejml, 1998) to claim that a ~60-year oscillation exists in the global climate and likely has an astronomical origin, as previously proposed (Scafetta, 2010)."

As for the *significance* of these observations, Mazzarella and Scafetta wrote that their findings and analysis indicate that "the global climate likely presents a ~60-year oscillation since at least 1700," and that "this natural oscillation was in its warm phase during the period 1970-2000 and has likely largely contributed to the global warming during this period," which finding, in their words, "confirms a quasi-60-year cycle in the climate system that further confirms the result of Loehle and Scafetta (2011)," i.e., that (1) "the climate models used by the IPCC have significantly overestimated the anthropogenic effect on climate since 1950 by three to four times."

And it should be further noted, in this regard, that (1) the several real-world or "natural" experiments of Idso (1998) suggest that even the anthropogenic-induced warming component of Loehle and Scafetta's study is likely too large; because (2) ever-accumulating real-world evidence continues to suggest that the historical warming of the past century or more has had little to do with anthropogenic CO_2 emissions and is (3) likely nothing more than the natural recovery of the earth from the naturally-induced global chill of the Little Ice Age (Idso, 1988).

About this same time, in setting the stage for *their* study of the subject, Fu *et al*. (2011a) wrote that the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) concluded that climate projections based on models that consider both human and natural factors provide "credible quantitative estimates of future climate change." *However*, as they continued, (1) *mismatches* between IPCC AR4 model ensembles and observations, especially the multi-decadal variability (MDV), "have cast shadows on the confidence of the model-based decadal projections of future climate," as had also been noted by Meehl *et al*. (2009), who indicated that considerably more work needed to be done in this important area.

In an exercise designed to illustrate the extent of this model failure, Fu *et al*. evaluated "many individual runs of AR4 models in the simulation of past global mean temperature," focusing on the performance of *individual runs* of models included in the Coupled Model Intercomparison Project phase three (CMIP3) in simulating the *multi-decadal variability* of the past global mean temperature. And in doing so, the three researchers determined that (2) "most of the individual model runs fail to reproduce the MDV of past climate, which [3] may have led to the overestimation of the projection of global warming for the next 40 years or so." More specifically, they noted that [4] simply taking into account the impact of the Atlantic Multi-decadal Oscillation or AMO, "the global average temperature could level off during the 2020s-2040s," so that (5) the true temperature change between 2011 and 2050 "could be much smaller than the AR4 projection."

Apparently, therefore, the models upon which the IPCC bases its climate projections still fail to include the physics necessary to faithfully replicate even well-known features of earth's climate system, which should give one pause to wonder what else of a more *stealth*-type nature they might be missing.

Still stuck in the same timeframe, Humlum *et al*. (2011) introduced their study of the subject by noting that "analytic climate models have provided the means to predict potential impacts on future climate by anthropogenic changes in atmospheric composition." However, they indicated that "future climate development will not only be influenced by anthropogenic changes, but also by natural variations." And they said that knowledge of these variations is incomplete.

Knowing this to be the case, Humlum *et al*. developed a new technique for identifying the character of natural climatic variations by means of Fourier and wavelet analyses that decompose climate series into time-frequency space, in order to extract information on periodic signals that may be embedded in the series and to determine their amplitudes and variations over time, after which they employed this technique to analyze two climate series: the Svalbard (78°N) surface air temperature series of 1912-2010, and the last 4000 years of the reconstructed GISP2 surface temperature series from central Greenland.

By so doing, the four Norwegian researchers clearly demonstrated that "the present warm period following the Little Ice Age [LIA] since about AD 1800 can be reproduced by a simple three input period only approach, based on the Greenland GISP2 temperature record." And they said that the application of this technique suggests that "the present period of warming since the LIA to a high degree may be the result of natural climatic variations, known to characterize at least the previous 4000 years."

In terms of what may be looming on the horizon, Humlum *et al*. further noted that "natural cycles that have remained strong over several decades or centuries are likely to continue without major changes into at least the near future, and will therefore be essential for forecasting any future climatic development." And when the results of *their* findings were projected into the future, they found that such forecasting "suggests that the present post-LIA warm period is likely to continue for most of the 21st century, before the overall Late Holocene cooling may again dominate."

In yet another same-year climate model assessment, Lienert *et al*. (2011) reported that "climate models are increasingly being used to forecast future climate on time scales of seasons to decades," and they indicated that "since the quality of such predictions of the future evolution of the PDO [Pacific Decadal Oscillation] likely depends on the models' abilities to represent observed PDO characteristics, it is important that the PDO in climate models be evaluated," which they thus set out to do.

Working with observed monthly-mean SST (sea surface temperature) anomalies they obtained from the Met Office Hadley Centre Sea Ice and Sea Surface Temperature version-1 (Rayner *et al*., 2003) dataset for 1871-1999, as well as the extended reconstructed SST version-3b dataset (Smith *et al*., 2008), Lienert *et al*. assessed the ability of 13 atmosphere-ocean global climate models from the third phase of the Coupled Model Intercomparison Project (CMIP3) -- which was conducted in support of the IPCC Fourth Assessment Report (Solomon *et al*., 2007) -- to "reproduce the observed relationship between tropical Pacific forcing associated with ENSO [El Niño Southern Oscillation] and North Pacific SST variability associated with the PDO." And what did they thereby learn?

In the words of the three Canadian researchers, they found that (1) "the simulated response to ENSO forcing is generally delayed relative to the observed response," a tendency that they say "is consistent with [2,3] model biases toward deeper oceanic mixed layers and weaker air-sea feedbacks," that (4) "the simulated amplitude of the ENSO-related signal in the North Pacific is overestimated by about 30%," and that (5) "model power spectra of the PDO signal and its ENSO-forced component are redder than observed because of errors originating in the tropics and extratropics."

So what are the ramifications of these five important "strikes" against the climate models? There are, according to Lienert *et al*., three unfortunate implications. First, they say that (1) "because the simulated North Pacific response lags ENSO unrealistically, seasonal forecasts may tend to exhibit insufficient North Pacific responses to developing El Niño and La Niña events in the first few forecast months." Second, they indicate that (2) "at longer forecast lead times, North Pacific SST anomalies driven by ENSO may tend to be overestimated in models having an overly strong ENSO, as the models drift away from observation-based initial conditions and this bias sets in." And third, they note that (3) "the relative preponderance of low-frequency variability in the models suggests that climate forecasts may overestimate decadal to multidecadal variability in the North Pacific." And in light of these three egregious *fumbles*, it is not unreasonable to suggest that (4) the 13 global climate models that participated in the CMIP3 *games* should probably be "retired."

Finally advancing into the next year, we find deBoer *et al*. (2012) writing that "observed and projected changes in the Arctic region are some of the most striking concerns surrounding climate trends," as they note by way of explanation that these trends "likely have important consequences both within the Arctic and globally." And they further report, in this regard, that "a new generation of earth system models has been utilized to prepare climate projections for the fifth phase of the Coupled Model Intercomparison Project (CMIP5)," the results of which they anticipated would be used "in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5)." Hence, it was only natural that they would want to determine how well these models actually *do* -- or *fail* to do -- what they are *supposed* to do.

The closest they could come to conducting such a test at this point in time was to investigate the models used in the AR4 report of the IPCC. Thus, de Boer *et al*. simulated key features of the Arctic atmosphere in the Community Climate System Model, version 4 (CCSM4), and compared the results of those simulations "against observational and reanalysis datasets for the present-day (1981-2005)." And what did they thereby learn?

Quoting the seven scientists with respect to *problems* they encountered in this endeavor, deBoer *et al*. reported that: (1) "simulated surface air temperatures are found to be slightly too cold," (2) "evaluation of the sea level pressure [SLP] demonstrates some large biases, most noticeably an under simulation of the Beaufort High during spring and autumn," (3) "monthly Arctic-wide SLP biases of up to 13 mb are reported," (4) "cloud cover is under-predicted for all but summer months," (5) "cloud phase is demonstrated to be different from observations," (6) "simulated all-sky liquid water paths are too high," (7) the "ice water path was generally too low," (8) "precipitation is found to be excessive over much of the Arctic compared to ERA-40 and the Global Precipitation Climatology Project estimates," (9) "biases of 40% to 150% are calculated over northern North America, northern Greenland, and the Arctic Ocean," while (10) "over the Norwegian Sea … evaporation is over-simulated by up to 3.5 mm/day," such that (11) "P-E is generally too high over much of the Arctic, particularly over coastal Greenland," (12) "CCSM4 over-predicts surface energy fluxes during summer months," and (13) "under-predicts them during winter," while (14) "the strengths of surface inversions were found to be too great in CCSM4 when compared to ERA-40, with distributions showing a near-doubling of strength," and (15) "CCSM4 is found to have more inversions than ERA-40 for all months."

Contemporaneously, Grodsky *et al*. (2012) wrote that "the seasonal climate of the tropical Atlantic Ocean is notoriously difficult to simulate accurately in coupled models," noting that a long history of studies, including those of Zeng *et al*. (1996), Davey *et al*. (2002), Deser *et al*. (2006), Chang *et al*. (2007) and Richter and Xie (2008), "have linked the ultimate causes of the persistent model biases to problems in simulating winds and clouds by the atmospheric model component." And in an effort designed to "revisit" this unsolved problem, Grodsky *et al*. utilized the Community Climate System Model, version 4 (CCSM4; Gent *et al*., 2011), which is a coupled climate model that simultaneously simulates earth's atmosphere, ocean, land surface and sea ice processes. This they did by comparing 20th-century runs forced by time-varying solar output, greenhouse gas, volcanic and other aerosol concentrations for the period 1850-2005 with observed (real world) monthly variability computed from observational analyses during the 26-year period 1980-2005. And what did they thereby learn?

In the enlightening words of the four researchers, they say that the atmospheric component of CCSM4 has (1) "abnormally intense surface subtropical high pressure systems" and [2] "abnormally low polar low pressure systems," that in the tropics and subtropics (3) "the trade wind winds are 1-2 m/sec too strong," that (4) "latent heat loss is too large," that (5) "sea surface temperature in the southeast has a warm bias," due in part to (6) "erroneously weak equatorial winds," that (7) "the warm bias evident along the coast of southern Africa is also partly a result of insufficient local upwelling," that (8) "excess radiation is evident in the south stratocumulus region of up to 60 W/m^2," that (9) there is "excess precipitation in the Southern Hemisphere," and that (10) "errors in cloud parameterization lead to "massively excess solar radiation in austral winter and spring in CCSM4."

Also with a paper published in the same year were Sen Gupta *et al*. (2012), who wrote that (1) "even in the absence of external forcing, climate models often exhibit long-term trends that cannot be attributed to natural variability," and they said that "this so-called climate drift arises for various reasons," such as (2,3) "deficiencies in either the model representation of the real world or the procedure used to initialize the model." They note, however, that "significant efforts by the climate modeling community have gone into reducing climate drift." But they have to admit that in spite of these efforts (4) "climate drift still persists."

In light of the latter unfortunate fact -- i.e., that climate drift still persists -- Sen Gupta *et al*. quantified “the size of drift relative to twentieth-century trends in climate models taking part in the Coupled Model Intercomparison Project phase 3 (CMIP3)," which they said "was used to inform the Intergovernmental Panel on Climate Change (IPCC) Forth Assessment Report (AR4)." And via this effort the seven Australian scientists determined that below 1-2 km in the deep ocean, or for depth-integrated properties, drift generally dominates over *any* forced trend. In fact, they reported that (1) drift in sea level can be large enough to actually *reverse the sign* of the forced change, "both regionally and in some models for the global average." In addition, because surface drift is spatially heterogeneous, they observed that (2) "the regional importance of drift for individual models can be much larger than the global figures suggest." And as an example, they noted that (3) *a typical error* in calculating a regional forced sea surface temperature trend in the Bjerknes Center for Climate Research Bergen Climate Model, version 2.0 (BCM2.0), CSIRO Mk3.0, and GISS-EH models without accounting for drift would be fully 30% to 40%." And because this is an *average* value, (4) even still *larger* errors would be expected at some locations.

Although providing some suggestions for chipping away at these problems, Sen Gupta *et al*. went on to write that "in the absence of a clear direction forward to alleviate climate drift in the near term, it seems important to keep open the question of flux adjustment within climate models that suffer from considerable drift." However, they additionally indicated that (5) "flux adjustments are nonphysical and therefore inherently undesirable," which means that (6) "they may also fundamentally alter the evolution of a transient climate response," citing the work of Neelin and Dijkstra (1995) and Tziperman (2000), all of which observations pretty much place climate modelers somewhere between the proverbial *rock and a hard place*.

In another contemporary paper, Driscoll *et al*. (2012) described how Stenchikov *et al*. (2006) analyzed seven models used in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) that "included all the models that specifically represented volcanic eruptions," *finding* that (1,2) the strength and spatial pattern of the surface temperature anomalies predicted by them were *not* "well reproduced." And thus hoping to find some improvement in more recent versions of the models, they repeated the analysis of Stenchikov *et al*. (2006), using 13 model simulations from the Coupled Model Intercomparison Project phase 5

(CMIP5) -- an overview of which is given by Taylor *et al*. (2011) -- while focusing their analysis on the regional impacts of the largest volcanic eruptions on the Northern Hemisphere (NH) large-scale circulation during the winter season. And what did they thereby discover?

In the words of the five researchers, (1) "the models generally fail to capture the NH dynamical response following eruptions." More specifically, they found that the models "do not sufficiently simulate [2] the observed post-volcanic strengthened NH polar vortex, [3] positive North Atlantic Oscillation, or [4] NH Eurasian warming pattern, and that (5) they tend to overestimate the cooling in the tropical troposphere." They also stated that (6) "none of the models simulate a sufficiently strong reduction in the geopotential height at high latitudes," and, correspondingly, that (7,8) "the mean sea level pressure fields and temperature fields show major differences with respect to the observed anomalies." In addition, they discovered that (9) "all models show considerably less variability in high-latitude stratospheric winds than observed," and they went on to report that (10) "none of the models tested have a Quasi-Biennial Oscillation in them."

"With substantially different dynamics between the models," Driscoll *et al*. said they had "hoped to find at least one model simulation that was dynamically consistent with observations, showing improvement since Stenchikov *et al*. (2006)." But "disappointingly," as they continued, they found that (11) "despite relatively consistent post volcanic radiative changes, none of the models manage to simulate a sufficiently strong dynamical response." And so they concluded that their study (12) "confirms previous similar evaluations and raises concern for the ability of current climate models to simulate the response of a major mode of global circulation variability to external forcings," indicating that (13) "this is also of concern for the accuracy of geoengineering modeling studies that assess the atmospheric response to stratosphere-injected particles."

Working and publishing concomitantly, Miao *et al*. (2012) introduced their findings by noting that the accuracy of any GCM or *global climate model* "should be established through validation studies before using it to predict future climate scenarios," while adding, however, that "although accurate simulation of the present climate does not guarantee that forecasts of future climate will be reliable, it is generally accepted that the agreement of model predictions with present observations is a necessary prerequisite in order to have confidence in the quality of a model."

Operating within this conceptual framework, Miao *et al*. thus assessed the performance of the AR4 GCMs, otherwise known as the CMIP3 models, in simulating precipitation and temperature in China from 1960 to 1999 by comparing the model simulations with observed data, using "system bias (*B*), root-mean-square error (*RMSE*), Pearson correlation coefficient (*R*) and Nash-Sutcliffe model efficiency (*E*)" as evaluation metrics. And according to the four researchers, their results demonstrated that certain of the CMIP3 models (1) "are unsuitable for application to China, with little capacity to simulate the spatial variations in climate across the country," and adding that (2) *all of them* "give unsatisfactory simulations of the inter-annual temporal variability." Also, they found that (3) "each AR4 GCM performs differently in different regions of China." And in light of these findings, Miao *et al*. concluded that (4) "the inter-annual simulations (temperature and precipitation) by AR4 GCMs are not suitable for direct application," and that

(5) "caution should be applied when using outputs from the AR4 GCMs in hydrological and ecological assessments" due to their "poor performance."

In another revealing study of this time period, Ehret *et al*. (2012) introduced their work on the subject by writing that (1) "despite considerable progress in recent years, the output of both global and regional circulation models is still afflicted with biases to a degree that precludes its direct use, especially in climate change impact studies," while also noting that "this is well known," and that "to overcome this problem, bias correction (BC, i.e., the correction of model output towards observations in a post-processing step) has now become a standard procedure in climate change impact studies." And, therefore, they went on to present "a brief overview of state-of-the-art bias correction methods," to discuss "the related assumptions and implications," to "draw conclusions on the validity of bias correction," and to "propose ways to cope with biased output of circulation models."

At the completion of these four steps, the five German researchers had discovered that (1) "BC methods often impair the advantages of circulation models by altering spatiotemporal field consistency, relations among variables, and by violating conservation principles," that (2) "currently used BC methods largely neglect feedback mechanisms," that (3) "it is unclear whether they are time-invariant under climate change conditions," that (4) "applying BC increases agreement of climate model output with observations in hindcasts and hence narrows the uncertainty range of simulations and predictions," but that (5) this is often done "without providing a satisfactory physical justification," which *sleight of hand*, as it were, "is in most cases not transparent to the end user."

All things considered, therefore, Ehret *et al*. argued that this set of negative consequences of bias correction (1) "hides rather than reduces uncertainty," which they suggest may lead to (2) "avoidable forejudging of end users and decision makers." And they thus concluded that BC is often (3) "not a valid procedure."

In another eye-opening study, Kim *et al*. (2012) wrote that "climate models are forever being tested and reworked with the goal of developing ever more accurate representations of how the real world's climate system operates, so as to be able to make ever more accurate projections of earth's climatic future." And in in *their* foray into this important field of study, they went on to assess the seasonal prediction skill for Northern Hemisphere winters based on retrospective predictions (1982-2010) obtained from the ECMWF System 4 (Sys4) and the National Center for Environmental Prediction (NCEP) CFS version 2 (CFSv2) coupled atmosphere-ocean seasonal climate prediction systems. And what did they learn by so doing?

Quoting Kim *et al*., they found that: (1) "for the Sys4, a cold bias is found across the equatorial Pacific," that (2-4) "the CFSv2 has [a] strong warm bias from the cold tongue region of the Pacific to the equatorial central Pacific and [a] cold bias in broad areas of the North Pacific and the North Atlantic," that (5,6) "a cold bias over large regions of the Southern Hemisphere is a common property of both reforecasts," that (7-9) "with respect to precipitation, the Sys4 produced excesses along the Intertropical Convergence Zone, the equatorial Indian Ocean and the western

Pacific," that (10-12) "in the CFSv2, a strong wet bias is found along the South Pacific Convergence Zone and the southern Indian Ocean, as well as in the western Pacific," that (13-21) "a dry bias is found for both modeling systems over South America and northern Australia and wet bias[es] in East Asia and the equatorial Atlantic," and (21-29) "both models have difficulty in forecasting the North Atlantic Oscillation and the year-to-year winter temperature variability over North America and northern Europe."

And so it would appear that with all the things climate models have been able to accomplish over the past several decades, even the *best* of them still have *numerous significant deficiencies* that have yet to be overcome.

In another 2012 climate model assessment study, Handorf and Dethloff (2012) wrote that "atmospheric teleconnections describe important aspects of the low-frequency atmospheric variability on time-scales of months and longer," and that "in light of the increased need to provide reliable statements about seasonal to decadal predictability, it is necessary that state-of-the-art climate models simulate the spatial and temporal behavior of atmospheric teleconnections satisfactorily." And, therefore, they advised that "an evaluation of climate models requires the evaluation of the simulated climate variability in terms of teleconnection patterns."

Taking their own advice, Handorf and Dethloff thus went on to evaluate "the ability of state-of-the-art climate models to reproduce the low-frequency variability of the mid-tropospheric winter flow of the Northern Hemisphere in terms of atmospheric teleconnection patterns." This they did using the CMIP3 multi-model ensemble for the period 1958-1999, for which reliable re-analysis data were available for comparison. And at the end of this undertaking, the two researchers concluded that (1) "current state-of-the-art climate models are not able to reproduce the temporal behavior, in particular the exact phasing of the dominant patterns due to internally generated model variability." In addition, they concluded that (2) "state-of-the-art climate models are not able to capture the observed frequency behavior and characteristic time scales for the coupled runs satisfactorily ... in accordance with Stoner *et al*. (2009) and Casado and Pastor (2012)," both of which studies concluded that (3) "the models are not able to reproduce the temporal characteristics of atmospheric teleconnection time-series."

Based on these findings, therefore, and "in light of the strong need to provide reliable assessments of decadal predictability," Handorf and Dethloff wrote that "the potential of atmospheric teleconnections for decadal predictability needs further investigations" that "require a better understanding of [1,2] the underlying mechanisms of variability patterns and flow regimes, [3,4] an improvement of the skill of state-of-the-art climate and Earth system models in reproducing atmospheric teleconnections and [5] the identification of sources for long-range predictive skill of teleconnecdtions," all of which requirements clearly suggest that *we aren't there yet*, in terms of doing what needs to be done.

Also hard at work in the same time frame were Po-Chedley and Fu (2012), who introduced *their* newest study of the subject by writing that "recent studies of temperature trend amplification in the tropical upper troposphere relative to the lower-middle troposphere found that [1] coupled atmosphere-ocean models from CMIP3 exaggerated this amplification compared to satellite microwave sounding unit (Fu *et al*., 2011b) and radiosonde (Seidel *et al*., 2012) observations." And, therefore, they revisited the issue "using atmospheric GCMs [global circulation models] with prescribed historical sea surface temperatures and coupled atmosphere-ocean GCMs that participated in the latest model intercomparison project, CMIP5."

This effort demonstrated, as they described it, that (1) "even with historical SSTs as a boundary condition, most atmospheric models exhibit excessive tropical upper tropospheric warming relative to the lower-middle troposphere as compared with satellite-borne microwave sounding unit measurements." And they also reported that (2) "the results from CMIP5 coupled atmosphere-ocean GCMs are similar to findings from CMIP3 coupled GCMs." Thus, we *once again* have numerous climate model results that (3) deviate significantly from real-world measurements; and we see (4) no improvement in this regard between the CMIP3 set of models and the new and *supposedly* improved CMIP5 models, which is not what most rational people would call progress.

Focusing on another aspect of climate, Chen *et al*. (2012) began the report of their work by noting that "several recent studies have reported declines in observed *in situ* near-surface wind speeds during the past 30-50 years over parts of North America (Klink, 1999; Pryor *et al*., 2009; Tuller, 2004), regions of Europe (Brazdil *et al*., 2009; Pirazzoli and Tomasin, 2003) and Australia (McVicar *et al*., 2008)." And they likewise noted that "prior analyses of *in situ* daily average wind speed data from China have also indicated recent declines," citing Fu *et al*. (2011) and Jiang *et al*. (2010).

As for how well climate models have been able to simulate this phenomenon in the past, the three researchers report that when such was attempted by several of the Coupled Model Intercomparison Project Phase 3 (CMIP3) generation of AOGCMs (atmosphere-ocean general circulation models), (1) substantial bias in oceanic wind stress was found for several of them by Swart and Fyfe (2012), while "based on the performance of 19 AOGCMs against reanalysis winds during 1981-2000," they note that (2) "McInnes *et al*. (2011) found the multi-model ensemble to exhibit low skill over land areas."

Consequently, in an attempt to determine what progress may have subsequently been made in this area of climate modeling, Chen *et al*. quantified and compared "the magnitude, historical trends and temporal variability in 10-m wind speeds derived from direct observations, reanalysis products and output from AOGCMs," using nine more up-to-date CMIP-5 models that were to be featured in the upcoming IPCC AR5 report. And what did they thereby learn?

In the blunt but true words of the three researchers, (1) "all models exhibit lower inter-annual variability than reanalysis data and observations, and [2] none of the models reproduce the recent decline in wind speed that is manifest in the near-surface observations." And thus it can be readily understood that progress in this specific area of climate model development prior to the most recent IPCC report could well be described as *pitiful* ... because there simply *was* no progress.

Finally moving on another year, we encounter the study of Chang *et al*. (2013), who set the stage for their work by stating that "mid-latitude storm tracks are marked by regions frequented by baroclinic waves and their associated surface cyclones" that bring with them "strong winds and heavy precipitation, seriously affecting regional weather and climate," and who further noted that such storms "transport large amounts of heat, momentum and moisture poleward," making up "an important part of the global circulation." And in light of these facts, they stated that how these storm tracks may change as a result of global warming "is thus of huge societal interest."

This being the case, Chang *et al*. used storm-track activity derived from ERA-Interim data (Uppala *et al*., 2005) as the current best estimate to assess how well models that participated in phase 3 of the Coupled Model Intercomparison Project (CMIP3; Meehl *et al*. 2007) could do in simulating storm-track activity. And what they found was rather disturbing; for the four researchers reported that (1) "only 2 of the 17 models have both the Northern Hemisphere [NH] and Southern Hemisphere [SH] storm-track activity within 10% of that based on ERA-Interim data," that (2) "four models simulate storm tracks that are either both significantly (>20%) too strong or too weak," that (3) "the SH to NH ratio of storm-track activity ... is biased in some model simulations due to biases in mid-tropospheric temperature gradients," that (4) "storm tracks in most CMIP3 models exhibit an equatorward bias in both hemispheres," that (5) "some models exhibit biases in the amplitude of the seasonal cycle," that (6) “models having a strong (weak) bias in storm-track activity also have a strong (weak) bias in poleward eddy momentum and heat fluxes, suggesting that (7) wave-mean flow interactions may not be accurately simulated by these models," and that (8) "preliminary analyses of Fifth Assessment Report (AR5)**/**CMIP5 model data suggest that CMIP5 model simulations also exhibit somewhat similar behaviors," which is *not* what one would hope would be the case.

Concomitantly, Santer *et al*. (2013) conducted what they called “a multi-model detection and attribution study with climate model simulation output and satellite-based measurements of tropospheric and stratospheric temperature change," using "simulation output from 20 climate models participating in phase 5 of the Coupled Model Intercomparison Project [CMIP5]," which provided, in their words, “estimates of the signal pattern in response to combined anthropogenic and natural external forcing and the noise of internally generated variability."

As for what they learned from this exercise, the 21 researchers reported that (1) "most models do not replicate the size of the observed changes," in that (2,3) "the models analyzed underestimate the observed cooling of the lower stratosphere and overestimate the warming of the troposphere," where warming -- *in their opinion* (Santer *et al*., 2003; Hansen *et al*., 2005) -- "is mainly driven by human-caused increases in well-mixed greenhouse gases," and where (4) "CMIP5 estimates of variability on 5- to 20-year timescales are (on average) 55-69% larger than in observations." Speculating somewhat, one could thus conclude that (5) the models are *not quite there yet*, especially in terms of where one would logically hope they would be, in light of the ungodly amounts of money that had been spent on their development and testing over the prior several decades.

In another study from this period, Landrum *et al*. (2013) wrote that "consistent with our understanding of the records of past forcings," climate scientists associated with phase 3 of the Paleoclimate Modeling Intercomparison Project (PMIP3) and phase 5 of the Coupled Model Intercomparison project (CMIP5) proposed that "modeling groups perform the 'Last Millennium' simulation (LM; 850-1850 Common Era) with the same models and at the same resolutions as simulations being done to simulate the twentieth century and into the future," in order to allow for "an evaluation of the capability of models to capture observed variability on multi-decadal and longer time scales." And in response to this proposal, Landrum *et al*. conducted just such a study of the Community Climate System Model, version 4 (CCSM4), "comparing its LM simulations to data-based reconstructions of LM temperature, the hydrologic cycle, and modes of climate variability."

This undertaking revealed, in the words of the seven scientists, that "the CCSM4 LM simulation reproduces many large-scale climate patterns suggested by historical and proxy-data records." *However*, they also report that (1) "the LM simulation does not reproduce La Niña-like cooling in the eastern Pacific Ocean during the Medieval Climate Anomaly [MCA] relative to the Little Ice Age [LIA], as has been suggested by proxy reconstructions," that (2) in response to large volcanic eruptions, the CCSM4 simulates cooling "two to three times larger than the Northern Hemisphere summer anomalies estimated from tree-ring or multiproxy reconstructions," that (3) "patterns of simulated precipitation change for the Asian monsoon to large volcanic eruptions have nearly opposite anomalies from those reconstructed from tree-ring chronologies," and that (4,5) "we do not find a persistent positive NAO [North Atlantic Oscillation] or a prolonged period of negative PDO [Pacific Decadal Oscillation] during the MCA," such as is suggested by the proxy reconstructions of MacDonald and Case (2005) and Trouet *et al*. (2009).

Consequently, and noting that some of the detected model deficiencies were also found to be operative in "LM simulations with an earlier version of CCSM," Landrum *et al*. provided further evidence for the "meet the new models, same as the old models" malady, which seems to literally be *plaguing* the climate-change prognosticators of today.

In another paper published in *Nature Climate Change* about the same time, Knutti and Sedlacek (2013) wrote that "estimates of impacts from anthropogenic climate change rely on projections from climate models," but they say that "uncertainties in those have often been a limiting factor, particularly on local scales." However, as they continued, "a new generation of more complex models running scenarios for the upcoming Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5) is widely, and perhaps naively, expected to provide more detailed and more certain projections." But were these expectations really being met?

Exploring the subject for themselves, the two researchers performed what they described as "a first comparison between projections from CMIP3 and CMIP5," in order to see to what extent *real progress* in the modeling of earth's global climate may have been being made. And what did they find? In the words of Knutti and Sedlacek, they found that (1) "projected global temperature change from the new models is remarkably similar to that from those used in IPCC AR4 after accounting for the different underlying scenarios," that (2) "the local model spread has not changed much despite substantial model development and a massive increase in computational capacity," that (3) "there is ... little evidence from CMIP5 that our ability to constrain the large-scale climate feedbacks has improved significantly," that (4) "model mean patterns of temperature and precipitation change ... are remarkably similar in CMIP3 and CMIP5," and that (5) "robustness over land is slightly higher but also similar in CMIP3 and CMIP5," which fact they described as "troublesome."

In light of these five findings, therefore, and "if the past is a guide to the future," as the two researchers put it, then (6) “uncertainties in climate change are unlikely to decrease quickly, and may even grow temporarily." And they further state that they have actually "illustrated this for seasonal temperature and precipitation," while adding that (7) "it is likely that impact-relevant predictions, for example of extreme weather events, may be even harder to improve."

Next to appear on the scene was the paper of Blazquez and Nuñez (2013), who wrote that "nowadays climate models are the main tool to analyze the behavior of meteorological events and to study their development and evolution," while further noting that they have also been used “to evaluate the impact of increased anthropogenic greenhouse gas emissions to the atmosphere." And in regard to *this* particular function, they indicated that the first step to understand climate changes that are likely to occur in the future is “the assessment of the present climate," which "allows determining the model deficiencies." So how does it work?

Quoting the two researchers, thier paper “evaluates a present climate simulation over southern South America performed with the Meteorological Research Institute/Japanese Meteorological Agency (MRI/JMA) high resolution global model." And comparing their simulated wind results with data from the European Centre Medium Range Weather Forecasts (ECMWF) 40-year Reanalysis (ERA 40), and their temperature and precipitation simulations with data from various meteorological stations, the two Argentinian researchers reported discovering that (1) the speeds of the low level jet and the westerlies "are generally underestimated," that (2) at upper levels "the westerlies are overestimated over central Argentina," that (3) during December-February, March-May and September-November, "the MRI/JMA global model underestimates the temperature over east of Argentina, west of Uruguay, south of Chile and over tropical latitudes," that (4) contemporaneously, "overestimates are observed over central Argentina," while (5) "in June-August the model underestimates the temperature over most of Argentina, south of Chile and to the north of 20°S," that (6) "the model overestimates temperature inter-annual variability in all regions and all seasons, except in JJA," that (7) in all seasons the model yields "an underestimation of the precipitation in the southeast of Brazil and south of Peru and an overestimation in Bolivia, Uruguay, north and central Chile and north of Peru," while (8) "during the dry season (JJA) the model greatly overestimates the precipitation over northeastern and central Argentina, that (9) "in regions located over mountainous areas the model presents a poor reproduction of the annual cycle," and that (10) "observed precipitation trends are generally positive whereas simulated ones are negative."

Also with a pertinent paper published during this same timeframe were Su *et al*. (2013), who wrote that "testing models' abilities to reproduce 'present climate' and past climate changes is an important part of evaluating the GCM projections," citing Phillips and Gleckler (2006), Randall *et al*. (2007), Walsh *et al*. (2008) and Mote and Salathe (2010). In fact, one could truthfully say that such testing is *essential*. And, therefore, as Su *et al*. described it, "the performance of 24 GCMs available in the fifth phase of the Coupled Model Intercomparison Project (CMIP5) was evaluated over the eastern Tibetan Plateau (TP) by comparing the model outputs with ground observations for the period 1961-2005."

As for what they thereby learned, the five researchers reported that with respect to *temperature*, "most GCMs reasonably capture the climatological patterns and spatial variations of the observed climate," *but* they say that (1) "the majority of the models have cold biases, with a mean underestimation of 1.1°-2.5°C for the months December-May, and less than 1°C for June-October." As for *precipitation*, they state that (2) "the simulations of all models overestimate the observations in climatological annual means by 62.0%-183.0%," while noting that (3) "only half of the 24 GCMs are able to reproduce the observed seasonal pattern," including "the sharp contrast between dry winters and wet summers."

The last of these observations clearly suggests, as Su *et al*. noted, that (4) there is "a critical need to improve precipitation-related processes in these models." And the fact that they found 90-year forward projections of both precipitation *and* temperature to "differ much more among various models than among emissions scenarios" suggests that (5) temperature-related processes have a critical need to be improved upon as well.

Moving along, Bhend and Whetton (2013) wrote that "over the past decade, demand for spatially explicit climate change information for impact and adaptation assessment has been steadily increasing." But they noted that (1) "a comprehensive assessment of climate model performance at the grid box scale in simulating recent change ... is not available at present." And, therefore, they set about to try to fill that void.

What the two of them did was to compare seasonal temperature, sea level pressure (SLP) and precipitation data for the most recent 50-year period common to both observations and simulations, with the temperature observations coming from the Goddard Institute for Space Studies (Hansen *et al*., 2010) with 1200-km smoothing, the SLP observations coming from the gridded HadSLP2 data set (Allan and Ansell, 2006) aggregated to 5° x 5° blocks, and the precipitation observations coming from the Global Precipitation Climatology Centre (Beck *et al*., 2005) on a 2.5° x 2.5° grid basis.

These efforts revealed, according to the two Australian researchers, that (1) with respect to *temperature*, "significant inconsistencies can be found in the majority of CMIP3 and CMIP5 models in the Indian Ocean and Indonesia, the Arctic, and north-western Africa and south-western Europe in boreal summer (JJA), and central Asia in DJF where [2] models underestimate the observed warming." In addition, they found that (3) the models "do not reproduce the regional cooling or lack of warming over parts of the southern Ocean and western Atlantic and the north-eastern and south-eastern Pacific."

With respect to *sea level pressure*, they said that (4) "the majority of the models significantly underestimate the magnitude of the observed decrease in SLP in parts of the high latitudes in the respective winter months," and that (5) "most of the models underestimate the magnitude of the observed increase over Africa and tropical South America in DJF, and a smaller fraction of the models also in the tropical Atlantic and the eastern Indian Ocean."

Finally, with respect to *precipitation*, the real-world data indicated it to be "strongly variable in space and large in magnitude in some regions," while "the simulated changes are considerably weaker but generally consistent with the observed change, except in boreal spring," when there are "some coherent areas of inconsistencies shared across models."

Most importantly of all, however, Bhend and Whetton said they (1-3) "find no improvement from CMIP3 to CMIP5 with respect to consistency of simulated local trends per degree warming in near-surface temperature, SLP, and precipitation with the observed change." Or as they also more bluntly put it, (4) "recent model development has not significantly altered our understanding and description of long-term regional change in these variables." Clearly, progress in climate modeling of this nature over the past several years has essentially been *no progress at all*.

Contemporaneously, Kumar *et al*. (2013) analyzed twentieth-century temperature and precipitation trends and long-term persistence from 19 climate models participating in phase 5 of the Coupled Model Intercomparison Project (CMIP5), focusing on "continental areas (60°S-60°N) during 1930-2004 to ensure higher reliability in the observations." This they did via a "nonparametric trend detection method," while "long-term persistence was quantified using the Hurst coefficient, taken from the hydrology literature."

Although some of these things were done well by the participating models, others were not. Kumar *et al*. reported, for example, that "the models capture the long-term persistence in temperature reasonably well," but they said that (1) "the models have limited capability to capture the long-term persistence in precipitation." They also stated that (2) "most climate models underestimate the spatial variability in temperature trends," and they noted that (3) there were "large uncertainties in the simulation of regional/local-scale temperature and precipitation trends." In addition, they reported that "Sakaguchi *et al*. (2012a,b) have evaluated the simulation skill for temperature trends from selected CMIP3 and CMIP5 climate models," finding (4) "limited skill in the simulation of temperature trends at regional scales in these climate models."

Finally, "from a regional natural resource planning perspective," the four scientists wrote that the multimodel-ensemble averages provided what they *kindly* called "conservative value for planning or design." As an example, they noted that (5) "the India and West Africa regions are drying much faster (-20 mm/decade) in the observations than simulations by the multi-model ensemble average (-5 mm/decade)," while similarly noting that (6) "north-central Asia is warming twice as fast as the global-average warming," which is something "not found in the multimodel-ensemble average."

Clearly, the best climate models of the present are still not up to doing what we really *need* them to be doing in order to be of much service. In fact, they could potentially be leading us in a direction we may soon find to be *detrimental* to the well-being of the biosphere, including ourselves.

In another study from this time period, Knutti and Sedlacek (2013) introduced their contribution to the subject by stating that a new generation of more complex models that had been running scenarios for the then-upcoming Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5) was "widely, and perhaps naively, expected to provide more detailed and more certain projections." But were these expectations actually met?

In a study devoted to addressing this question, Knutti and Sedlacek performed what they called "a first comparison between projections from CMIP3 and CMIP5," in order to see what had happened in this regard to that point in time. And in so doing, the two Swiss researchers found that (1) "the model spread relative to the model mean change for a given scenario is similar or in some cases slightly larger, implying that the models have not converged in their projections," that (2,3) "the local model spread has not changed much despite substantial model development and a massive increase in computational capacity," that (4) there is "little evidence from CMIP5 that our ability to constrain large-scale climate feedbacks has improved significantly," that (5) "model mean patterns of temperature and precipitation change … are remarkably similar in CMIP3 and CMIP5," that (6) there is "little increase in model agreement in CMIP5 for precipitation changes," that (7) "robustness over land is slightly higher but also similar in CMIP3 and CMIP5," that (8) "the new models are likely to be better in the sense of being physically more plausible, but it is difficult to quantify the impact of that on projection accuracy," that (9) "if the past is a guide to the future then uncertainties in climate change are unlikely to decrease quickly, and may even grow temporarily," and, last of all, that (10) "it is likely that impact-relevant predictions, for example of extreme weather events, may be even harder to improve."

And people call this progress???

In another study of the same nature, Lee *et al*. (2013) wrote that "the reliability of future climate projections using climate models depends heavily on the fidelity of the climate models," and they noted in this regard that "the latter can be assessed by evaluating the ability of the climate models to simulate the present climate using available observations," citing Pierce *et al*. (2006), Gleckler *et al*. (2008), Waliser *et al*. (2009) and Su *et al*. (2013), which is something that should be clear to all rational people. And, therefore, Lee *et al*. took it upon themselves to describe how "wind stress measurements from the Quick Scatterometer (QuikSCAT) satellite and two atmospheric reanalysis [NCEP-1 and ERA-Interim] products were used by them to evaluate the annual mean and seasonal cycle of wind stress simulated by phases 3 and 5 of the Coupled Model Intercomparison Project (CMIP3 and CMIP5)." And what did this undertaking reveal?

The five researchers were able to report that (1) "generally speaking, there is a lack of significant improvement of CMIP5 over CMIP3," that (2) "the CMIP ensemble-average zonal wind stress has eastward biases at mid-latitude westerly wind regions (30°-50°N and 30°-50°S, with CMIP being too strong by as much as 55%)," that (3) there are "westward biases in subtropical-tropical easterly wind regions (15°-25°N and 15°-25°S)," that (4) there are "westward biases at high-latitude regions (poleward of 55°S and 55°N)" that "correspond to too strong anticyclonic (cyclonic) wind stress curl over the subtropical (subpolar) ocean gyres," that (5) "in the equatorial Atlantic and Indian Oceans, CMIP ensemble zonal wind stresses are too weak and result in too small of an east-west gradient of sea level," that (6,7) "in the equatorial Pacific Ocean, CMIP zonal wind stresses are too weak in the central and too strong in the western Pacific," and that (8) "the CMIP [models] as a whole overestimate the magnitude of seasonal variability by almost 50% when averaged over the entire global ocean." And thus we learn that even the most up-to-date CMIP5 models are still a long, long way from where they need to be for mankind to place much faith in what they predict in the way of CO_2-induced global warming and its imagined negative consequences.

Examining another feature of the climate modeling enterprise, Zappa *et al*. (2013) wrote that "a large fraction of the meridional transport of heat, momentum and moisture in mid-latitudes is carried by extratropical cyclones (Peixoto and Oort, 1992), which makes them fundamental in determining the equilibrium state of the climate system." And this being the case, it is very important that these particular cyclonic systems are modeled correctly; and, therefore, Zappa *et al*. "inspected the ability of CMIP5 models to capture the observed behavior of the North Atlantic extratropical cyclones," which they did by evaluating "the number, intensity and spatial distribution of North Atlantic extratropical cyclones across a wide range of climate models" and comparing their simulations "against four recent reanalyses including ERA-Interim (1980-2009)."

After completing this exercise, the three UK researchers had to unfortunately report that (1-3) "the majority of CMIP5 models still have a too-zonal storm track, so that too many North Atlantic cyclones propagate toward Europe and too few propagate toward the Norwegian Sea area," that (4) "a group of models also tends to place the storm track too far south in the central Atlantic," that (5) "some CMIP5 models tend to underestimate the total number of North Atlantic extratropical cyclones," and that (6) "CMIP5 models tend to underestimate the intensity of cyclones in both DJF [December, January and February] and JJA [June, July and August]." In addition, they noted that (7) "the tendency to place the North Atlantic storm track too far south is also found in the recent CMIP5 study by Chang *et al*. (2012)." And in their paper’s concluding paragraph, Zappa *et al*. therefore declared that "the tendency of CMIP5 models to have weak cyclones and a too-zonal North Atlantic storm track in DJF is certainly a source of concern for interpreting their future projections."

Next, and focusing their attention on the United States, Kim *et al*. (2013) introduced their assessment of various aspects of the climate modeling enterprise by writing that "even with the expected increases in computer resources that will allow GCMs [Global Climate Models] to run at higher horizontal resolutions, RCMs [Regional Climate Models] will remain essential to the processes [needed] for regional climate projections, climate change impact assessments, and policy making for the foreseeable future." And this being the case, they went on to describe how "surface air temperature, precipitation and insolation over the conterminous United Stages [derived] from the North American Regional Climate Change Assessment Program (NARCCAP) regional climate model (RCM) hindcast study [were] evaluated using the Jet Propulsion Laboratory (JPL) Regional Climate Model Evaluation System (RCMES)," which makes comparisons between *modeled* data and surface- and satellite-based *observational* data.

This work revealed, according to the eleven U.S. researchers, that (1,2) "the most noticeable systematic errors in the annual-mean surface air temperatures are the warm biases in the Great Plains and the cold bias in the Atlantic and Gulf of Mexico coasts," that (3,4) "for the winter, the most outstanding RCM errors include the warm bias in the Atlantic coast and Florida regions and cold bias in northern California and Arizona-western New Mexico," that (5-7) "the most notable common errors in simulating the annual precipitation [are] the wet bias in the mountainous northwestern United States and dry bias in the Gulf Coast region and the southern Great Plains," that (8-13) "in the summer, most RCMs underestimate precipitation in Southern California, Arizona, New Mexico, the Great Plains, and western Texas," while they (14-16) "overestimate in all three coastal regions," that (17) "all RCMs show especially poor performance in simulating the summer monsoon rainfall in the Arizona-western new Mexico region," and that (18) "the model bias in surface insolation varies widely according to RCMs." And once again, therefore, we note the *fact* that as complex and powerful as today's GCMs and RCMs are, they are still in their *infancy* when it comes to trying to not only *replicate*, but to accurately *predict* real-world climate, not only in the *near-term*, but far into the future as well. Clearly, the models' *reach* vastly exceeds their *grasp*.

In another contemporary study of the climate modeling enterprise, Hosking *et al*. (2013) wrote that "the Amundsen-Bellingshausen Seas low (ABSL) is a quasi-stationary area of climatological low pressure that exists over the South Pacific sector of the Southern Ocean between the Antarctic Peninsula and the Ross Sea," and in doing so they made a special point of noting that (1,2) "the minimum mean sea level pressure (MSLP) associated with the ABSL is characterized by large seasonal variability in both location and central pressure," which variability, in their words, "strongly influences the climate of West Antarctica by controlling the meridional component of the large-scale atmospheric circulation, with consequences for 10-m meridional wind velocity, near-surface (2-m) air temperature, precipitation, and sea ice concentration," citing Turner *et al*. (2009) and Kuttel *et al*. (2012).

With these facts as background, Hosking *et al*. thus investigated "the representation of ABSL variability (as well as the associated representation of West Antarctic climate) in the set of climate models participating in phase 5 of the Coupled Model Intercomparison Project (CMIP5; Taylor *et al*. 2012), as used in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5)." And what did they thereby learn?

The five UK researchers with the British Antarctic Survey reported that (1) "investigation of 17 CMIP5 climate models run with historical forcing showed that the majority of the models have statistically significant and systematic biases," that (2) "a few of the models even simulate an ABSL longitudinal migration that is the reverse of reality," and that (3) "the majority of them show a significant bias in at least one winter month" that "is more or less evenly split in terms of negative and positive biases."

The implications of these findings, in the words of Hosking *et al*., were that (1) "the majority of CMIP5 models will have a correspondingly poor representation of West Antarctic climate due to difficulties in representing the ABSL annual cycle, particularly its longitudinal position." In addition, they noted that (2) "Turner *et al*. (2013) showed that the majority of the CMIP5 models have a seasonal cycle of sea ice extent that differs markedly from the observations," and that Zunz *et al*. (2012) showed that (3) the CMIP5 multi-model mean underestimates (overestimates) the sea ice extent in the ABS and Ross Sea sectors over the period from 1979 to 2005 in February (September), which are the months where the sea ice cover reaches its minimum (maximum)."

In another of the many pertinent studies published in 2013, Hung *et al*. evaluated the simulation of the Madden-Julian oscillation (MJO) and convectively coupled equatorial waves (CCEWs) in 20 models from the Coupled Model Intercomparison Project (CMIP) phase 5 (CMIP5) in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) and compared the results with the simulation of CMIP phase 3 (CMIP3) models in the IPCC Fourth Assessment Report (AR4). And, interestingly, although they reported that their results showed that "the CMIP5 models exhibit an overall improvement over the CMIP3 models in the simulation of tropical intra-seasonal variability, especially the MJO and several CCEWs," they had to concede that (1) "the phase speeds of the model MJO tend to be too slow and [2] the period is longer than observations as part of [3] an over-reddened spectrum, which in turn is associated with [4] too strong persistence of equatorial precipitation," that (5) "the persistence of precipitation in many CMIP5 models is still larger than observations, which is also reflected by [6,7] the too red precipitation and space-time spectra," and that (8) "only one of the 20 models is able to simulate a realistic eastward propagation of the MJO."

In a somewhat different type of study, Scafetta (2013) wrote that "global surface temperature records (e.g. HadCRUT4) since 1850 are characterized by climatic oscillations synchronous with specific solar, planetary and lunar harmonics superimposed on a background warming modulation," which he said was "related to a long millennial solar oscillation and to changes in the chemical composition of the atmosphere (e.g. aerosols and greenhouse gases)." And he made a point of noting that (1) "current general circulation climate models, e.g. the CMIP5 GCMs, to be used in the AR5 IPCC Report in 2013, fail to reconstruct the observed climatic oscillations."

As an alternative to the IPCC's approach to the subject, therefore, Scafetta described an empirical model that used "a specific set of decadal, multi-decadal, secular and millennial astronomic harmonics to simulate the observed climatic oscillations," plus "a 0.45 attenuation of the GCM ensemble mean simulation to model the anthropogenic and volcano forcing effects." And what were the results of this approach?

Scafetta reported that his proposed empirical model "outperforms the GCMs by better hind-casting the observed 1850-2012 climatic patterns." More specifically, he noted that "about 50-60% of the warming observed since 1850 and since 1970 was induced by natural oscillations likely resulting from harmonic astronomical forcings that are not yet included in the GCMs." And from this viewpoint, as Scafetta concluded, (1) "the results of this analysis indicate that the GCMs do not yet include important physical mechanisms associated with natural oscillations of the climate system." And, therefore, he went on to suggest that (2,3) interpretations and predictions of climate change based on current GCMs, including the CMIP5 GCMs to be used in the IPCC AR5, were what he called "questionable."

Also raising some new issues around this time were Masata *et al*. (2013), who tackled the subject of *atmospheric blocking,* which is a crucial dynamic phenomenon of the extratropics, where large-scale patterns develop in the atmospheric pressure field and remain nearly stationary, effectively "blocking" or redirecting migratory cyclones, which often remain in place for several days, or sometimes even weeks, causing the areas affected by them to have the same kind of weather for an extended period of time. In Europe, for example, they noted that blocking has a huge impact on regional climate, citing Trigo *et al*. (2004) and Masato *et al*. (2012), which generally leads to "extreme cold conditions in winter and warmth during summer," citing Buehler *et al*. (2011). And in studying the subject further, Masato *et al*. analyzed characteristics of atmospheric blocking in both winter and summer throughout the latter part of the 20th century in the Northern Hemisphere, as represented by 12 models that participated in phase 5 of the Coupled Model Intercomparison Project or CMIP5, where the real-world data involved were obtained from the 40-year ERA-40 reanalysis work of Uppala *et al*. (2005) for the period 1958-2001.

As a result of this undertaking, the three UK researchers discovered that in the case of *winter blocking*, (1) "the greatest model bias is found over Europe, where the multi-model blocking frequency is less than half of that in ERA-40," and that (2) "Atlantic blocking is overall underestimated on its southern edge," which suggests that (3) "most models are deficient in their representation of blocking over Europe." And in the case of *summer blocking*, they found that (4) "Eastern European and Russian blocking is too weak and [5] oceanic blocking is too strong," that (6) "in the Pacific the error is mainly over the extreme subpolar region," and that (7) "there is an overall tendency for models to overestimate the Atlantic signal (80°W-0°), with [8] an opposite behavior for the European and Asian region (0°-100°E)." And in their concluding words, Masato *et al*., wrote that (9) "all these findings suggest that there is no unique way to improve the representation of blocking," and they thus added that (10) "further analyses will be necessary to learn more about this issue."

Setting the stage for describing *their* modeling work, the 18-member team of Stevens *et al*. (2013) wrote that "ECHAM6 is the sixth generation of the atmospheric general circulation model ECHAM, developed by the Max Planck Institute for Meteorology in Hamburg, Germany," while further noting that their primary goal in producing this paper was "to document, in the open literature, ECHAM6," and to assess its current status "in the context of over a quarter-century of development."

As for the unique characteristics of the new-and-improved model, Stevens *et al*. indicated that "ECHAM6 better simulates many aspects of the present climate as compared to ECHAM5," while acknowledging, however, that "a number of stubborn biases endure." These biases were said by them to be the enumerated *facts* that (1) "there has been relatively little improvement in the representation of precipitation since the introduction of ECHAM3, (2) "precipitation over land is too weak," (3) "there is a global tendency of precipitation features, from the South Pacific Convergence Zone to precipitation over the Gulf Stream, to be shifted too far northward," (4) "biases in the representation of marine boundary layer clouds remain large," (5) "cloud layers appear too infrequently in the simulations," but are (6) "too bright when they do appear," (7) "ECHAM6 continues to have large (3 K) cold biases in upper tropospheric temperatures," (8) "tropical temperature biases only vanish with very high (300-m) vertical resolution in the upper troposphere," (9) "the tropical and mid-latitude convective stability of the troposphere remains more unstable relative to observations, particularly in the southern Hemisphere in its summer season," and (10) "the extra-tropical jets maximize at somewhat lower latitudes than observed."

And with this many things *wrong* with it, the ECHAM6 climate model should probably not be called "new-and-improved," as *reworked-but-still-not-there* would seem to be more appropriate.

In another paper from the same time period, Kim *et al*. (2013) wrote that "the coldest level in the tropical tropopause layer, the cold-point tropopause (CPT), is known to play a crucial role in stratosphere-troposphere exchange," citing Holton *et al*. (1995) and while noting that "the CPT temperature largely determines the concentration of water vapor in the lower stratosphere (e.g., Mote *et al*., 1996), which serves as a key radiative constituent for surface climate (Forster and Shine, 2002; Solomon *et al*., 2010)." And they therefore went on, as Kim *et al*. described it, to examine the climatology, seasonality, and intra-seasonal to inter-annual variability of the temperature field near the cold-point tropopause using the state-of-the-art climate models that participated in the Coupled Model Intercomparison Project phase 5 (CMIP5). And what did they thus learn?

The three researchers reported that "the models have several notable limitations" and "show non-negligible biases in several aspects." Enumerating a few of the most significant problems, they stated that (1) "most models have a warm bias around the CPT," that (2) "large inter-model differences occur in the amplitude of the seasonal cycle in 100 hPa temperature," that (3) "several models overestimate lower stratospheric warming in response to volcanic aerosols," that (4)" temperature variability associated with the quasi-biennnial oscillation and Madden-Julian oscillation is absent in most models," and that (5) "equatorial waves near the CPT exhibit a wide range of variations among the models."

As a result of these and other problems, Kim *et al*. concluded that (6) "the fine-scale processes that govern stratospheric water vapor and the CPT temperature are unlikely to be well represented in CMIP5 models," and that (7) "the coarse vertical resolution of the models and their non-negligible biases in the climatology, seasonal cycle and variability of the tropical tropopause layer limit their accuracy in the assessment of past, present and future climates."

About this same time, in a Commentary published in the Opinion & Comment section of *Nature Climate Change*, Fyfe *et al*. (2013) introduced their study of the subject by stating that "global mean surface temperature over the past 20 years (1993-2012) rose at a rate of 0.14 ± 0.06°C per decade," and by noting that this warming rate was "significantly slower than that simulated by the climate models participating in Phase 5 of the Coupled Model Intercomparison Project (CMIP5)." And they went on from there to look for a reason for why such a discrepancy should exist.

The first step of the three researchers was to derive 117 *simulated* global temperature histories at locations where corresponding *observations* existed; and in doing so, they obtained "an average simulated rise in global mean surface temperature of 0.30 ± 0.02°C," which was (1) *more than twice as large* as the real-world *measured* rate of warming, which was 0.14 ± 0.06°C per decade. And they also reported that the inconsistency between observed and simulated global warming was even *more* striking for temperature trends computed over the past fifteen years (1998-2012), for which period they say (2) the *observed* trend of 0.05 ± 0.08°C "was more than four times smaller than the average simulated trend of 0.21 ± 0.03°C." And they also pointed out that the observed trend over this period, which was *not significantly different from zero*, actually suggested "a temporary 'hiatus' in global warming," further citing the studies of Easterling and Wehner (2009) and Fyfe *et al*. (2011) in this regard.

Interjecting some other phenomena worthy of consideration in this discussion, Li and Sharma (2013) wrote that "explosive volcanic eruptions inject into the lower stratosphere millions of tons of chemically and micro-physically active gases and solid aerosol particles." And noting that these substances "are recognized as an important climate forcing," they went on to report that "efforts are underway to accommodate their impact in the assessment of future climates in recent IPPC reports."

The objective of this undertaking, according to Li and Sharma, had historically been sought by "assessing the response of hydrometeorological variables, especially atmospheric water vapor, to volcanic eruptions by using climate data from GCMs, reanalysis products, and observations." And they said, in this context, that the focus of *their* investigation was "to assess whether atmospheric water vapor as well as other hydrological variables (pressure, specific humidity, latent heat and precipitation) are affected by large-scale volcanic eruptions and whether model simulations of this effect on atmospheric water vapor exhibit similarity to what is noted in observations and reanalysis data."

As a result of their efforts in this regard, the two Australian researchers reported discovering that (1) "the percentage of global area with volcanic impacts on water vapor was overestimated based on a CMIP3 multi-model average and a single CMIP5 model," that (2) "the spatial pattern of the water vapor variability following the Pinatubo eruption was not well captured by GCMs," that (3) "the amplitude of the water vapor change from the model simulations is much smaller than that from observed and reanalysis data," that (4) "the observed temporal pattern of the water vapor variability was also not as distinct as depicted in GCMs," that (5) "the model-simulated strong negative correlation between atmospheric water vapor residual and aerosol optical depth in the tropics was also not found to be representative of the observed and reanalysis data," and that (6) "the effect of volcanic forcing may have been represented in an overly simplified manner in the CMIP3 multi-model mean ... resulting in [7] water vapor simulations that exhibit different distributional attributes compared to the observed record."

In concluding their report, therefore, Li and Sharma wrote that "despite the remarkable improvements of GCMs over the past years, it is still a challenge to simulate volcanic impacts for all GCMs, which has also been confirmed by Driscoll *et al*. (2012), who examined 12 CMIP5 GCMs and found that (1) they all overestimated the cooling in the tropical troposphere following the nine explosive eruptions in the nineteenth and twentieth centuries."

Still stuck in 2013 and noting that (1) "it is becoming increasingly recognized that resolving the stratosphere and modeling its variability are necessary to correctly simulate tropospheric weather and climate," Marsh *et al*. (2013) wrote that the U.S. National Center for Atmospheric Research's Earth System Model (CESM) "now includes an atmospheric component that extends in altitude to the lower thermosphere." And they said that this model, "known as the Whole Atmosphere Community Climate Model (WACCM), includes fully interactive chemistry, allowing, for example, a self-consistent representation of the development and recovery of the stratospheric ozone hole and its effect on the troposphere." And, therefore, their study of the subject focused “on analysis of an ensemble of transient simulations using CESM1 (WACCM), covering the period from the preindustrial era to present day [1850-2005], conducted as part of phase 5 of the Coupled Model Intercomparison Project [CMIP5]."

As for what they learned from this exercise, the six scientists reported that "in comparison of tropospheric climate predictions with those from a version of CESM that does not fully resolve the stratosphere, (1) the global-mean temperature trends are indistinguishable," which suggests [2] *no improvement* in the new model over the old model. However, they further stated that (3) "systematic differences do exist in other climate variables, particularly in the extratropics." And they stated that (4) "the magnitude of the difference can be as large as the climate change response itself."

In addition, Marsh *et al*. reported that (1) "both models overestimate the short-term cooling following large volcanic eruptions." And they further noted that (2-4) "WACCM predicts significantly larger changes in precipitation over Europe, the Mediterranean, and northern Africa," once again stating that (5) "the differences in predicted changes between the two models can be larger than the magnitude of the climate change prediction itself." And in regard to this unsettling *fact* that keeps popping up, again and again, they concluded that "when quantifying uncertainty in past and future climate change predictions, it will be important to consider the systematic errors introduced by the choices made on how the upper atmosphere is represented in the model," which suggests that the quest for the Holy Grail of climate modeling has yet to be satisfactorily consummated.

Continuing in this vein, Kavvada *et al*. (2013) introduced their climate-modelling study by noting that the planetary-scale mode of sea surface temperature swings in the North Atlantic basin, known as the Atlantic Multi-decadal Oscillation or AMO, "has attracted considerable attention in recent years due to its extensive impact on regional as well as global weather and climate," citing

Ting *et al*. (2011). And in light of this fact, they compared and evaluated "the representation of AMO-related features both in observations and in historical simulations of the twentieth century climate from models participating in the IPCC's CMIP5 project," namely, CCSM4, GFDL-CM3, UKMO-HadCM3 and ECHAM6/MPI-ESM-LR. And what did they discover as a result?

The three researchers reported that most of the models exhibit a region of positive anomalies in the mid-latitudes, but that (1) they place "the maximum of the anomalies further to the east (southeast-ward of Greenland) than observations show," that (2) "the models also exhibit weaker positive anomalies over (3) the Davis Strait and the Labrador Sea," that (4) they show "a weaker secondary maximum off of the northwestern African coast, in comparison to observations," that (5) "anomalies are also shown over the equatorial Pacific, a feature not present in observations," that (6) the GFDL-CM3 and CCSM4 models depict "anomalies over the equatorial Pacific that are not present in observations," that (7) both the ECHAM6/MPI-ESM-LR and the UKMO-HadCM3 models "appear unable to capture the magnitude of the observed anomalies in the subtropical/tropical Atlantic," that (8) in terms of the temporal features of the AMO indices, "the majority of the models have poor correlation with observations and under-estimate the observed variability," that (9) "higher frequency variability remains present in the model indices, in contrast to the observed AMO index," that (10) "even though the models do capture the northward focus of the observed SST anomaly maxima, they lack the ability to effectively reproduce their structure and evolution," that (11) "none of the models is able to simulate the positive salinity anomalies over the Straits around Greenland," that (12) "the models appear challenged in portraying the position and magnitude of AMO-related salinity anomalies," that (13) "most of them are unable to capture the atmospheric seasonality that is characterized by a summer minimum in the anomalies," that (14) “none of the models captures the fall wave pattern over North America and parts of the northeastern Atlantic," that (15) “most of the models tend to place the maximum SST anomalies in the North Atlantic too far to the east of the Labrador Sea, in comparison to observations," that (16) “the broad region of enhanced rainfall over the Guinean zone in Africa is also problematic for all four models," that (17) "AMO-related fall surface air temperature anomalies are not being fully captured, in magnitude or position, by any of the four model simulations," that (18) "the broad extension of the warming over northwestern Africa is also weakly and sparsely simulated by all four models," that (19) the models "underestimate the life span of the phenomenon by increasing variability in the 10-20 year range, to the extent that it becomes more dominant than variability in the 70-80 year range," that (20) the four CMIP5 models are "unable to portray the extension of same-sign anomalies into the tropics, during the pre- and post-mature phases of the AMO," that (21) "none of the four models employed in this study is able to capture the anomalous circulation pattern that is seen in observations during the fall season," and that (22) "the models remain unable to efficiently depict a holistic perspective of the AMO-related oceanic and atmospheric features."

In their closing remarks about the far-less-than-perfect abilities of the four AR5 models to adequately replicate real-world observations of the AMO, Kavvada *et al*. stated that (23) "without a proper incorporation of low-frequency natural variability in climate simulations, decadal predictability and the accuracy of climate projections under different climate change scenarios remain compromised."

As time progresses, however, so too does work on climate models also progress, from one stage to another, with an important step forward being that which was taken in advancing from the group of CMIP3 models to the group of CMIP5 models. And, therefore, focusing on a core set of 17 CMIP5 models that "represent a large set of climate centers and model types," Sheffield *et al*. (2013) evaluated the abilities of these models to reproduce a number of observational data sets. And in doing so, the 27 researchers discovered that (1) "the performance of the CMIP5 models in representing observed climate features has not improved dramatically compared to CMIP3," noting, for example, that "there are some models that have improved for certain features (e.g., the timing of the North American monsoon)," but they say that others (2) "have become worse" in terms of the more basic "continental seasonal surface climate." And, "furthermore," as they concluded, (3) "the uncertainty in the future projections across models can also be of the same magnitude [as] the model spread for the historic period."

Also evaluating CMIP5 models about this same time were Cattiaux *et al*. (2013), who analyzed 33 GCMs that participated in the CMIP5 project, based on comparisons they made between various model output parameters for the period 1979-2008 and corresponding real-world observations. These efforts revealed that (1) "on average, CMIP5 models exhibit a cold bias in winter, especially in Northern Europe," that (2) "they over-estimate summer temperatures in Central Europe," that (3) they predict "a greater diurnal range than observed," and that (4) "in winter, CMIP5 models simulate a stronger North Atlantic jet stream than observed." And since the parameters evaluated by Cattiaux *et al*. were rather basic -- almost mundane, in fact -- it was surprising to find that the *latest and greatest* in GCMs did not come through with flying colors.

In another assessment of GCM performance that was also conducted about the same time, Fu *et al*. (2013) used the comprehensive archive of Australian gridded climate data -- the *SILO Data Drill* (Jeffrey *et al*., 2001) -- to evaluate GCM performance across southeastern Australia for 25 different CMIP3 GCMs, where the study period was 1961-2000 and the 25 GCM runs were "forced by 20th-century emissions scenarios, i.e., IPCC AR4 20th-century experiment scenario 20C3M."

This work revealed, as the five researchers reported, that (1) "the mean observed annual rainfall for the study region is 502 mm, whereas the GCM values vary from 195 to 807 mm," that (2) "12 out of 25 GCMs produce a negative correlation coefficient of [the] monthly rainfall annual cycle," that (3) the "GCMs overestimate [the] trend magnitude for temperature," but that (4) they "underestimate for rainfall," that (5) "the observed annual temperature trend is +0.007°C/year, while both the median and mean GCM values are +0.013°C/year, which is almost double the observed magnitude," and that (6) "the observed annual rainfall trend is +0.62mm**/**year, while the median and mean values of 25 GCMs are 0.21 and 0.36 mm**/**year, respectively."

In light of these several findings -- *and more*, with some CMIP5 models -- Fu *et al*. concluded that (1) "GCMs currently do not provide reliable rainfall information on regional scales as required by many climate change impacts studies," while adding to emphasize this fact that (2) "the 'best'

GCM is a CMIP3 GCM and (3) [the] four 'worst' GCMs are CMIP5 models." And there are people who call this progress???

In yet another study from the same year, Camargo (2013) noted there was “a huge interest in the potential change of tropical cyclone [TC] behavior with global warming due to the large impacts of TCs on coastal communities around the world." And, therefore, she went on to examine the ability of fourteen models from phase 5 of the Coupled Model Intercomparison Project (CMIP5) "to simulate TC-like storms and determine whether the models show robust global and regional responses to warming," while further analyzing "changes in large-scale environmental variables associated with TCs."

This work revealed, in Camargo’s words, that (1) "the simulation of TC activity in the CMIP5 models is not as good as in higher-resolution simulations," that (2) "the CMIP5 global TC frequency is much lower than observed," that (3) "there is significant deficiency in the geographical patterns of TC tracks and formation," that (4) "the models present a wide range of global TC frequency," that (5) "a cold SST [sea surface temperature] bias could potentially contribute to the low number of TCs in the models," that (6) "the models show no consensus regarding the difference of TC activity in two warming scenarios and the historical simulation," and that (7) "there is no robust signal across the CMIP5 models in global and regional TC changes in activity for future scenarios."

And so it *is* that after many years of trying to mathematically simulate the many important aspects of global climate change, the climate modeling community has yet to produce a realistic replica of associated changes in real-world TC characteristics and behaviors.

Finally moving ahead another year, we encounter the study of Silva *et al*. (2014), who introduced the relevant paper they produced by stating that “Ocean-Atmosphere Global Climate Models (OAGCMs) have become indispensable tools for the climate sciences," and who also noted that "many efforts have been made to improve [them] in recent years," while *further* noting that “the Climate Forecast System version 2 (CFSv2) model is one example of such progress," which they then went on to describe in considerable detail.

Recounting what they had done in this regard and what they had learned by doing it, Silva *et al*. reported that their study "examined the area-average skill over the continents, the interannual variability, the global-mean state, and the main patterns of variability over the Equatorial Pacific and extratropics in both hemispheres produced by the CFSv2 model," which was done by comparing the model's hindcasts for Dec-Jan-Feb (DJF) and Jun-Jul-Aug (JJA) seasons of the 1983-2010 period with both "observations and reanalyses."

This work revealed, in the words of the five Brazilian scientists, that (1) "at the 0-month lead time ... large biases occur over the oceans," that (2) "improvements in CFSv2 were not enough to eliminate the double-ITCZ [Intertropical Convergence Zone] bias during DJF," that (3) there is a "warm SST [sea surface temperature] bias over eastern oceans during DJF and JJA," that (4) for JJA there is an "SST cold bias over the central-equatorial Pacific," that (5) "during DJF CFSv2 presents a cold bias in the troposphere, mainly over the central-eastern North Pacific," that (6) there is a "strengthening of the subtropical jet that leads to precipitation overestimations by the persistence of low pressures over subtropical and mid-latitude regions," that (7) "CFSv2 shows large precipitation biases over the eastern South Africa and Oceania," that (8) there is a "wind-stress bias in the tropics," that (9) "errors in the simulated Aleutian low seem to degrade the simulated NAM [Northern Annular Mode]," that (10) "the wave pattern associated with the SAM [Southern Annular Mode] is not well reproduced by CFSv2," that (11) there are "biases in the upper-level zonal wind over the tropics and mid-latitudes of the Southern Hemisphere," and that (12) "the major spatial features related to the shape and orientation of SAM are not properly captured by CFSv2."

Silva *et al*.'s "overall evaluations," therefore, led them to conclude that "further investigations are still needed." And they suggested that these projected studies "should be carried out to help in understanding in further details the reasons for the CFSv2 deficiencies."

In a second study from the “new” year, Steinhaeuser and Tsonis (2014) wrote that *today* "there are more than two dozen different climate models which are used to make climate simulations and future climate projections." But although it has been said "there is strength in numbers," most rational people would still like to know how well this specific set of models does at simulating what has already occurred in the way of *historical* climate change, before they would be ready to believe what the models predict about earth's *future* climate. And, therefore, the two U.S. researchers began their study of 28 pre-industrial control runs, as well as 70 20th-century forced runs, derived from 23 different climate models, by analyzing how well the models did in *hind-casting* "networks for the 500 hPa, surface air temperature (SAT), sea level pressure (SLP), and precipitation for each run." And what did they thereby learn?

In the words of Steinhaeuser and Tsonis, they found that (1-3) "the models are in significant disagreement when it comes to their SLP, SAT, and precipitation community structure," that (4) "none of the models comes close to the community structure of the actual observations," that (5) "not only do the models not agree well with each other, they do not agree with reality," that (6) "the models are not capable to simulate the spatial structure of the temperature, sea level pressure, and precipitation field in a reliable and consistent way," and that (7) "no model or models emerge as superior."

In light of their several sad findings, the *team of two* suggested that "maybe the time has come to correct this modeling Babel and to seek a consensus climate model by developing methods which will combine ingredients from several models or a supermodel made up of a network of different models." But with *all* of the models they tested proving to be incapable of replicating *any* of the tested aspects of past reality, even this approach would not appear to have any promise of success.

Following in their footsteps, Kim *et al*. (2014) wrote that "regional climate model (RCM) data are essential for assessing the impact of climate change on water resources, agriculture, security and natural ecosystems," while also stating that "the primary tools for projecting climate are global climate models (GCMs)." But noting that typical impact assessment models require inputs at much finer spatial resolution than what is provided by GCMs, they went on to say that "GCM data are often downscaled using RCMs."

In a study that was thus designed to learn how well downscaling performs in the case of Africa, Kim *et al*. conducted an RCM hindcast for the period 1989-2008 that employed boundary conditions derived from the ERA-Interim reanalysis, focusing on 21 sub-regions of the continent and utilizing gridded surface observational data sets obtained from the University of East Anglia's Climatic Research Unit. And this study revealed that there were significant systematic biases in all ten of the RCMs they tested.

In the case of *precipitation*, for example, they found that (1) "most RCMs overestimate the magnitude of its spatial variability," that (2) a "large ENS [multi-model ensemble] precipitation bias occurs in the northern Sahara, South Africa, and Arabian Peninsula," that (3) "most RCMs suffer difficulties in simulating the annual cycle in these dry/semi-dry regions," that in the case of *temperature*, the ENS (4) "overestimates TMIN," which (5) "results in underestimation of diurnal temperature range," while the most noticeable ENS TAVG errors are (6) "the cold biases in the tropical west coast, east coast, and much of the Sahara regions" and (7) "the warm biases in the eastern Arabian Peninsula and the subtropical west coast regions," and that in the case of *clouds*, (8) "a majority of RCMs underestimate the overland-mean cloudiness," as well as (9) cloud "spatial variability." And in their final comment on their findings, Kim *et al*. thus wrote that "the systematic variations in RCM skill may indicate common weaknesses in physics parameterizations used in these models."

Half-way through the year, Maloney *et al*. (2014) provided a summary of projected twenty-first-century North America (NA) climate changes, as spewed out by 25 updated state-of-the-art climate and Earth system models used in CMIP5, i.e., phase 5 of the Coupled Model Intercomparison Project, focusing largely on the representative concentration pathway 8.5 (RCP8.5) in a core set of 17 CMIP5 models. And what did they thereby learn?

In terms of what most people would describe as *shortcomings* (or maybe even *failures*), they said that (1) "the sign of mean precipitation changes across the southern United States is inconsistent among the models, as is the annual mean precipitation change in the core NA monsoon region," that (2) the models "also disagree on snow water equivalent changes on a regional basis, especially in transitional regions where competing effects occur because of greater snowfall and warming temperatures," that (3) "the western United States is characterized by large inter-model variability in changes in the number of frost days," that (4) "substantial inter-model spread exists for projections of how ENSO teleconnection changes will affect precipitation and temperature variability in western NA," that (5) "projected changes in seasonal mean Atlantic and east Pacific tropical cyclone activity are inconsistent among models, which disagree on the sign and amplitude of changes in environmental factors that modulate tropical cyclone activity," that (6) "models have substantial difficulties in simulating the historical distribution of persistent drought and wet spells," and that (7) "model success in producing historical climate has little bearing on regional projections," as demonstrated previously by Pierce *et al*. (2009).

Perhaps most important of all, however, was the 31 researchers' conclusion that "even areas of substantial agreement among models may not imply more confidence that projections are correct, as common errors or deficiencies in model parameterizations may provide false confidence in the robustness of future projections," which mental condition of *false confidence* seems to be a common malady shared by a host of international political activists who want to drastically redefine how the people of the world should restructure their lives *and laws*, in order to live in accordance with their *unsubstantiated speculations* and contrary to what is known about the many *proven benefits* of atmospheric CO_2 enrichment, which are described in great detail on the *co2science.org* website.

About this same time, in a paper published in *Nature Climate Change*, Wang *et al*. (2014) noted that the IPCC Fifth Assessment Report "largely depends on simulations, predictions and projections by climate models," but they added that most of the models upon which they relied "have [1] deficiencies and [2] biases that raise large uncertainties in their products." And, therefore, they said that over the past several *decades*, a tremendous effort had been made “to improve model performance in the simulation of special regions and aspects of the climate system." So what was the status of the most up-to-date CMIP5 models at the time of their writing?

Wang *et al*. forthrightly acknowledged that sea surface temperatures or SSTs "simulated by CMIP5 models generally show [1] too low values in the Northern Hemisphere and [2] too high values in the Southern Hemisphere," and they said that (3) these "annual-mean SST error magnitudes can be several degrees Celsius." In addition, they noted that (4,5) "misrepresentation of local processes and/or ocean-atmosphere interactions has caused some of the biases," giving as examples the *facts* that in the models there is (6) "excessive heat flux into the ocean under [7] insufficient coverage by stratocumulus clouds (Mechoso *et al*., 2007; Huang *et al*., 2007)," as well as (8) "insufficient cooling by ocean transients from the upwelling regions along the eastern coasts (Colas *et al*., 2012)."

Continuing, the five researchers also reported that "the cold SST bias in the equatorial and tropical southwestern Pacific has been associated with [9] an excessive westward extension of the cold tongue from the eastern equatorial Pacific in association with [10,11] difficulties in the representation of surface winds and ocean mixing processes (Mechoso *et al*., 2007; Davey *et al*., 2002)." And they further noted that (12) according to the study Hwang and Frierson (2013), ”cloud errors over the Southern Ocean may be responsible for the generation of a spurious intertropical convergence zone south of the Equator in most CMIP5 models."

As for their own work, Wang *et al*. linked SST biases for different regions to simulations of the *Atlantic meridional overturning circulation* (AMOC), finding that (13) "improving climate models cannot be reduced to improved representation of regional processes," that (14) "much is to be done for a better understanding of the global teleconnections that ultimately affect climate model performance," and that (15) "an improvement of the simulated AMOC in climate models is needed for better climate predictions and projections."

In closing, however, Wang *et al*. warned that even if the AMOC *strength* is correctly simulated, (16) if it happens to be too *shallow*, "the associated northward heat transport could be too weak," which possibility, in their words, *is readily supported* by a well-known model deficiency that suggests that (17) "North Atlantic Deep Water is too shallow," as indicated by the work of Yeager and Danabasoglu (2012). Clearly, therefore, the world's climate modelers still have a long and winding road to travel, in order to get to the point where *they*, or anyone else, can place any real confidence in their "simulations, predictions and projections."

About this same time, Neukom *et al*. (2014) wrote that "earth's climate system is driven by a complex interplay of internal chaotic dynamics and natural and anthropogenic external forcing," noting that "recent instrumental data have shown a remarkable degree of asynchronicity between Northern Hemisphere and Southern Hemisphere temperature fluctuations, thereby questioning the relative importance of internal versus external [i.e., anthropogenic] drivers of past as well as future climate variability," citing the supportive work of Thompson *et al*. (2010), Deser *et al*. (2012) and Friedmann *et al*. (2013).

Simultaneously, Fan *et al*. (2014) produced additional data germane to this issue by examining "the relationships among Antarctic sea ice concentration, Southern Ocean sea surface temperature (SST), surface air temperature (SAT), sea level pressure (SLP), and surface zonal wind (U) trends over the period 1979-2011, using un-interpolated gridded surface marine data sets, land station archives, atmospheric reanalysis and satellite products," after which they extended their analysis of Southern Ocean climate trends "back to earlier decades (1950-1978) to illustrate the low-frequency behavior of surface climate trends over the Southern Ocean." And what did they learn by so doing?

"For the Southern Ocean as a whole," in the words of the three U.S. researchers, "sea surface temperature has decreased by approximately 0.6°C in December-February (0.4°C in the annual mean) while Antarctic sea ice cover has increased by approximately 9% in December-February (12% in the annual mean) during 1979-2011." In addition, they found that "all data sets (SST, SAT, SLP and U) show a consistent reversal in sign of the Southern Ocean surface climate trends between 1979-2011 and 1950-1978." And they also say that "the meridional extent of the Southern Ocean surface climate trends shows a consistent northward expansion of approximately 10° of latitude during 1950-1978 compared to 1979-2011 in all data sets," thereby providing "a broader context for the recent increase in Antarctic sea ice."

As for the *cause* of what they documented, Fan *et al*. said it could have been "low-frequency variability generated by tropical dynamics," citing Okumura *et al*. (2012) and Schneider and Noone (2012). Be that as it may, it is clear that (1) the strong inter-hemispheric coupling that Neukom *et al*. (2014) found to be characteristic of the CMIP5 *models* is not what is found in *real-world data*, which suggests, in the words of Neukom *et al*., that (2) "models overestimate the strength of externally-forced [i.e., anthropogenic] relative to internal climate system variability, therefore implying (3) more limited predictability not only on regional (Dreser *et al*., 2012;

Braconnot *et al*., 2012) but also hemispheric scales," which conclusion has been confirmed by the work of Fan *et al*. (2014).

Also chiming in on what was being learned on the subject, Ding *et al*. (2014) wrote that "the recent Fifth Assessment Report of the Intergovernmental Panel on Climate Change anticipates the continuing retreat of sea ice and warming accompanying future anthropogenic emissions of greenhouses gases and aerosols." *However*, they said that (1) "natural variability, such as that associated with the Atlantic Multi-decadal Oscillation (Chylek *et al*., 2009), has been suggested to be an important driver of climate variations in the Arctic region and responsible for a portion of the recent warming trend." And they further stated that (2) "recent results also indicate that sea surface temperature (SST) changes outside the Arctic have played a role in forcing the recent tropospheric warming in the Arctic," citing Screen *et al*. (2012).

To study the subject in more detail for greater clarification, Ding *et al*. employed "observational analyses and modelling to explore the relative contributions of anthropogenic forcing and natural variability to recent warming trends in the Arctic," based on "post-1979 observations only, because the analyses of geopotential height and other variables over the Northern Hemisphere polar region are more reliable during the modern satellite era," citing Bromwich *et al*. (2007) in this regard. So what did they find?

First of all, the seven scientists determined that "the most prominent annual mean surface and tropospheric warming in the Arctic since 1979 has occurred in northeastern Canada and Greenland." And they also showed that "the recent warming in this region is strongly associated with a negative trend in the North Atlantic Oscillation, which is a response to anomalous Rossby wave-train activity originating in the tropical Pacific." In addition, they said that "experiments from the Coupled Model Intercomparison Project Phase 5 [CMIP5] models with prescribed anthropogenic forcing showed no similar circulation changes related to the North Atlantic Oscillation or associated tropospheric warming," while noting that "the most salient circulation feature in the observations is the pronounced localized rise in upper-tropospheric geopotential height and surface and tropospheric temperature over northeastern Canada and Greenland," which features they again noted (1) "are not reproduced in the ensemble average of the historical simulations using the CMIP5 models."

As for what this all meant, Ding *et al*. wrote that these several findings suggested that (1) "a substantial portion of recent warming in the northeastern Canada and Greenland sector of the Arctic arises from unforced natural variability," that (2) this natural variability "is intrinsic to the coupled atmosphere-ocean system," that (3) "these features are not reproduced in the ensemble average of the historical simulations using the CMIP5 models," which further implies that (4) the output of the most up-to-date CMIP5 models is still a far, far cry from the fullness of reality.

In another meticulous evaluation of PMIP2 and CMIP5 climate models, Harrison *et al*. (2014) used paleo-climatic reconstructions of the Last Glacial Maximum (LGM, ca 21,000 years ago) and the mid-Holocene (MH, ca 6,000 years ago) to evaluate the abilities of today's state-of-the-art climate models to adequately *replicate* these two significant global climates of Earth's distant past, which, if they could do so successfully, would suggest that they could probably equally well describe Earth's climate in a CO_2-enriched future. So how did they do in this endeavor? ... and what did they thereby learn?

With respect to the *glacial oceans*, the nine researchers say that (1) "most models overestimate the ocean cooling," that (2) "they do not capture the heterogeneity seen in the reconstructions," that (3) "spatial patterns in reconstructed LGM annual SST [sea surface temperature] anomalies ... are not well predicted by the models," and that (4) "the seasonal SST anomalies show no correlation with the reconstructions."

As for the *glacial continents*, Harrison *et al*. found that (5) "all but two models underestimate the reconstructed annual cooling, with the largest median bias nearly 3.5°C and eight models having a bias larger than 1°C," that (6) "all the models underestimate the mean temperature of the coldest month reduction," with the smallest median bias being +2.4°C and the largest +7.3°C," that (7) "all models underestimate the LGM reduction in mean annual precipitation over land," and that (8) "most models also underestimate the increase in aridity."

Moving on to the *mid-Holocene ocean*, the nine climate scientists indicated that (9) "the models underestimate the reconstructed warming in northern mid-latitudes," and they say that they (10) "consistently underestimate the heterogeneity in sea surface temperatures." At the same time, they reported that on the *mid-Holocene continents*, (11) "the models overestimate summer warming by 0.56-2.27°C," that (12) "the models consistently underestimate the reconstructed change in mean annual precipitation," while they also report that (13) "the models overestimate the ratio of actual to equilibrium evapotranspiration," and that (14) "simulated MH land climates show consistently less spatial variability than the reconstructed climates."

More generally, Harrison *et al*. reported that (15, 16) "ocean temperatures are globally low and land temperatures globally high, compared with the reconstructions," that (17) "the present generation of models tends to overestimate SST cooling in the tropics," that (18) "the models underestimate precipitation changes in the regions with the largest summer warming," reflecting the fact that (19) there are "problems in the simulation of land-atmosphere heat fluxes." And, nearing the end of their list of problems, they stated that (20) "all models overestimate the reconstructed summer cooling of the tropics at the LGM," just as (21) "all models underestimate the MH increase of Afro-Asian monsoon precipitation."

At the end of the day, therefore, Harrison *et al*. declared that (22) "there are still shortcomings in the amplitude of simulated changes," and that (23) there is still a "need for continued efforts by modelling groups to achieve accurate simulations of fundamental climate processes."

About this same time, Liu *et al*. (2014) -- in an article published in the *Proceedings of the National Academy of Sciences USA* -- noted that "in the latest reconstruction of the global surface temperature throughout the Holocene (Marcott *et al*., 2013), the most striking feature is a pronounced cooling trend of ~0.5°C following the Holocene Thermal Maximum ... with the Neoglacial cooling culminating in the Little Ice Age." But they said that "this inferred global annual cooling in the Holocene is puzzling." And why was that? *Because*, as they answered their own question, "with no direct net contribution from the orbital insolation, the global annual mean radiative forcing in the Holocene should be dominated by the retreating ice sheets and rising atmospheric greenhouse gases, with both favoring a globally averaged warming." And they thus asked themselves the question of the day: "How can the global annual temperature exhibit a cooling trend in response to global warming forcing ... mainly in response to rising CO_2 and the retreat of ice sheets?"

Extremely intrigued by this conundrum, the team of ten researchers -- hailing from four different countries (China, Germany, the United States and the United Kingdom) -- went on to compare the global temperature reconstruction of Marcott *et al*. with three different transient climate model simulations. This analysis also resulted in "a robust warming trend in current climate models" that they note was "opposite from the cooling in the Marcott *et al*. reconstruction," leaving us with what they called an *unexplained* "model-data inconsistency in global annual temperature of ~1°C."

In concluding their report, Liu *et al*. thus wrote that if the climatic reconstruction of Marcott *et al*. is correct -- and there is little reason to believe otherwise -- it will imply the existence of what they described as "major biases" across the entire spectrum of what they called the "current generation of climatic models." And so we *await* further studies of this important -- but not yet fully resolved -- *climatic conundrum*, which would appear to be the *path of prudence*.

In another contemporary study, Davini and Cagnazzo (2014) wrote that the North Atlantic Oscillation or NAO "is the most prominent pattern of regional wintertime variability of the Northern Hemisphere," citing Wallace and Gutzler (1981) and Hurrell *et al*. (2003); and they went on to state that the NAO "is characterized by a surface pressure dipole between the low pressure mid-latitude system and the high-pressure subtropical system over the North Atlantic," the positive phase of which "identifies a stronger-than-usual meridional gradient of geopotential height over the North Atlantic and the evident split between the subtropical and eddy-driven jet streams, with the latter blowing over Northern Europe," while "the negative phase is associated with a reduced gradient and with the merging of the two jets." And "making use of the idea of teleconnection patterns," they reported that "the NAO has been commonly defined as the leading empirical orthogonal function (EOF) of the Euro-Atlantic region," citing Ambaum *et al*. (2001).

In light of the significance of this phenomenon, the two Italian researchers "analyzed a group of the CMIP5 models in order to detect which models are able to replicate the correct connection between blocking/cyclonic Rossby wave breaking over Greenland and the negative phase of the NAO proposed by Woollings *et al*. (2008, 2010)." This they did for the winters of 1951-2005 for 23 models, "comparing their results with the NCEP/NCAR Reanalysis and Twentieth Century Reanalysis," while additionally "making use of several jet and blocking diagnostics."

As a result of these efforts, Davini and Cagnazzo discovered that (1) several state-of-the-art climate models were, as they described it, "unable to correctly simulate the physical processes connected to the NAO," which they found to be (2) "especially true for models with a strongly underestimated frequency of high-latitude blocking over Greenland." In fact, they reported that (3) "in these models the first empirical orthogonal function (EOF1) of the Euro-Atlantic sector can represent at least three different categories of dominant modes of variability associated with different prevalent regions of blocking occurrence and jet stream displacements." And they concluded that (4) "it is therefore possible to show that such 'biased NAOs' are connected with different dynamical processes with respect to the canonical NAO seen in observations."

Ultimately enlarging upon these latter observations, Davini and Cagnazzo wrote that since the models with the largest issues in replicating the NAO dynamical processes "are models with a poleward displaced eddy-driven jet stream, it would be possible that misinterpretations of the EOF-based NAO will be more frequent in a warmer world." More specifically, or "in other words," as they continued, "it would be possible that we will face the rupture of the paradigm that connects the leading EOF of the North Atlantic and the NAO."

Also about this same time, and providing some background for their analysis of how well the most up-to-date CMIP5 climate models represent *aeolian dust*, Evan *et al*. (2014) wrote that "aeolian dust is a key aspect of the climate system," since "dust can modify the Earth's energy budget, provide long-range transport of nutrients, and influence land surface processes via erosion." However, they noted that the representation of dust in state-of-the-art climate models has not been systematically evaluated," and they thus proceeded to fill this important analytic void.

Focusing on observations related to dust emission and transport from northern Africa -- which they said was the world's largest source of airborne dust, citing Washington *et al*. (2003) -- the four researchers evaluated African dust in 23 state-of-the-art global climate models used in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, and in doing so, they discovered that (1) "all models fail to reproduce basic aspects of dust emission and transport over the second half of the twentieth century," and that they (2) "systematically underestimate dust emission, transport, and optical depth," while (3) "year-to-year changes in these properties bear little resemblance to observations."

In light of their several findings, Evan *et al*. came to the conclusion that (4) "there is no reason to assume that the projections of dust emission and concentration for the 21st century have any validity." And they added that their results (5) "also cast doubt on the representation of other features of coupled Earth systems that are affected by aeolian dust, including regional land and ocean surface temperatures (Evan *et al*., 2009), precipitation and cloud processes (Kaufman *et al*., 2005; Yoshioka *et al*., 2007), coupled equatorial processes (Evan *et al*., 2011), and terrestrial (Das *et al*., 2013) and oceanic biogeochemistry (Mahowald *et al*., 2010)." And in light of this terrible indictment of the models, one wonders how in the world the IPCC and others have so long claimed such certainty in regard to the models' future projections of climate.

In another paper from the same year, Grose *et al*. (2014) wrote that "an important influence on confidence in model projections is the realism with which the models simulate the current climate mean and variability." And they noted, in this regard, that "while models are now sufficiently reliable to provide useful insights into many aspects of the climate system in the region, systematic biases in the simulation of some important features in the Pacific region persist." So what are these still-unresolvable biases? And how significant are they?

Quoting the nine Australian researchers, "there is evidence to [1] reject one model as unsuitable for making climate projections in the region, and [2,3] another two models unsuitable for analysis of the South Pacific Convergence Zone (SPCZ)." And they add that (4) "many of the systematic model biases in the mean climate in CMIP3 are also present in the CMIP5 models," specifically identifying (5,6) "biases in the position and orientation of the SPCZ and Inter-Tropical Convergence Zone, as well as the [7] spatial pattern, [8] variability and [9] teleconnections of the West Pacific monsoon, and [10] the simulation of El Niño Southern Oscillation." In addition, they indicate that [11,12] unresolved problems also prohibit successful modeling of the region's cold tongue and the West Pacific monsoon, *further* adding that [13,14] there are still "several regions in the world where CMIP5 models show significant differences to observed trends in temperature and mean sea level pressure."

As for the *significance* of these many biases in the current crop of CMIP5 models, one can get a sense of their importance in Grose *et al*.'s concluding opinion that "all projections must account for the uncertainty introduced by the presence of these biases."

In another revealing study of the ability of CMIP5 models to simulate Pacific Ocean sea surface temperature, zonal wind stress and surface flux trends, Solomon (2014) used decadal hindcasts archived in the CMIP5 database (Taylor *et al*. 2012) that were initialized yearly from 1960 to 2009 and run ten times with perturbed initial conditions for each start date, in order to be able to assess simulations of 1970-2009 equatorial Pacific SST, zonal wind stress and surface flux trends that take account of changes in external forcings such as greenhouse gases, solar activity, stratospheric aerosols associated with volcanic eruptions and anthropogenic aerosols. And what did this arduous effort reveal?

Solomon reported that the decadal hindcasts (1) "do not produce an unambiguous weakening or strengthening of the Walker circulation over the 1970-2009 period," that they (2,3) forecast "ocean mixed layer and net surface heat flux trends with an opposite sign to air-sea datasets," that they (4) "do not produce an unambiguous zonal SST gradient response to an increase in external forcing," that (5) "year-1 forecasts produce a positive shortwave feedback on decadal time scales," whereas (6) "year 6-10 forecasts produce a negative or statistically insignificant shortwave flux feedback on decadal time scales," and that (7) "in the cold-tongue region, all three initialized ensembles forecast a positive net radiative flux trend even though the shortwave flux trend is negative."

Once again, therefore, as in the case of the study of Tiwari *et al*. (2014), we have another set of "seven sins" running rampant throughout the climate modeling enterprise, which all continue to cry out for significant redemptive actions.

In another contemporary paper, Mauri *et al*. (2014) presented a new seasonal (summer and winter) gridded temperature and precipitation reconstruction for mid-Holocene (MH, 6000 years BP) Europe, based on fossil and modern pollen data sets that they described as "greatly improved in both size and quality compared with previous studies," after which they compared their climate reconstructions with "the latest PMIP3/CMIP5 global climate model (GCM) simulations." And as a result of this comparison, they found (1) "little agreement between the reconstructed anomalies and those from 14 GCMs that performed mid-Holocene experiments as part of the PMIP3/CMIP5 project, which showed a much greater sensitivity to top-of-the-atmosphere changes in solar radiation." In addition, they reported that their data-model comparisons on *contemporary* timescales indicated that the models *also* (2) "underestimate the role of atmospheric circulation in recent climate change." And in terms of both the old and the new, therefore, today's climate models would appear to be unable to accurately describe reality in the case of atmospheric circulation over Europe.

In another illuminating study of CMIP5 models, Cheruy *et al*. (2014) began by noting that (1) "most state-of-the-art climate models from the Coupled Model Intercomparison Project (CMIP) tend to over-predict the summer near-surface temperature at mid-latitudes," citing the work of Christensen and Boberg (2012) and Mueller and Seneviratne (2014), while also noting that (2) "it is the case for Regional Climate Models as well," citing Boberg and Christensen (2012) and Vautard *et al*. (2013). And in light of these disturbing facts, they employed a new "multi-model approach in an attempt to identify statistically robust relationships between various temperature and surface energy budget indices," relying mostly on linear multi-model regressions, based on a multi-model ensemble from the CMIP Phase 5 (CMIP5) database of Taylor *et al*. (2012).

When all of what they had purposed to do was finally completed, the four French researchers found that (3) "over land, most state-of-the-art climate models contributing to Coupled Model Intercomparison Project Phase 5 (CMIP5) share a strong summertime warm bias in mid-latitude areas," that (4) "the most biased models overestimate solar incoming radiation," because of (5) "cloud deficit" and the fact that they (6) "have difficulty to sustain evaporation," as well as the fact that they (7) "overestimate the present climate net shortwave radiation," which (8) "increases more than average in the future," plus the fact that (9) "they also show a higher-than-average reduction of evaporative fraction in areas with soil moisture-limited evaporation regimes." And in summing up their findings, Cheruy *et al*. stated that "the above deficiencies of the present climate simulations impact future climate projections," in that "the same feedback mechanisms identified for the warm-biased areas for the present climate are in play for future climate projections," which unfortunate state of affairs can artificially amplify predicted climate warming at regional scales.

Writing contemporaneously about the Beijing Normal University Earth System Model (BNU-ESM), Ji *et al*. (2014) noted right from the start that *the new model* -- which was being used “to study mechanisms of ocean-atmosphere interactions, natural climate variability and carbon-climate feedbacks at inter-annual to inter-decadal time scales" -- had a number of "important biases with regard to observations ... including [1] warm SST discrepancies in the major upwelling regions, [2] equatorward drift of mid-latitude westerly wind bands, and [3] tropical precipitation bias over the ocean that is related to [4] the double Inter-Tropical Convergence Zone (ITCZ)."

More specifically, the sixteen scientists said that with (5) "the annual temperature underestimated and [6] the annual precipitation overestimated over global land areas excluding Antarctica," the model (7) "has a tendency to have excessive ice extent during winter seasons," that (8) "the Madden-Julian Oscillation signal in large scale circulation is not as well simulated as it is in convection (precipitation)," that (9,10) "the northward and eastward propagating motions are both weaker than observed," that "BNU-ESM has significant biases that need to be improved, such as [11] a tropical precipitation bias over oceans related to the double ITCZ," which they say "has long been a problem among many climate models," citing Lin (2007) and also stating that (12) "further parameterization improvements are certainly required," while noting that (13) "land surface-air temperatures simulated for the last few decades of the 20th century exhibit a mean bias greater than 2°C over significant regions compared with observations," that (14) "modeled temperatures increase significantly during the last few years of the historical simulation relative to observations," that (15) "this is very likely related to the lack of indirect aerosol effects in the atmospheric component (e.g., Gent *et al*., 2011)," that (16) there are "positive SST biases prevailing at major coastal up-welling regions," that (17) there are "cold biases in mean SST along the equator in the Pacific Ocean," that (18) "the negative SST bias in the southern ocean and excessive sea ice extent in the Antarctic suggest a need to correct the wind stress field to ensure sufficient southern ocean heat transport and proper ocean gyre boundaries," that (19,20) "BNU-ESM underestimates both the positive Bjerkness and the negative heat flux feedbacks by about 45 and 50% respectively."

And in spite of *all of these deficiencies*, Ji *et al*. reported that the BNU-ESM model "is being actively used by many researchers in prognostic simulations for both anthropogenic and geo-engineering forcing scenarios." About all one can say about this situation is *Heaven help us!*

In another study of climate model biases, Davy and Esau (2014) described how they used "a statistical measure of model fidelity (Gleckler *et al*., 2008) to determine model departure from reanalysis [data] for the historical simulations of the CMIP5 program, over the period 1979-2005." This analysis revealed that (1) the largest biases were seen in shallow, stably-stratified *atmospheric boundary layers* or ABLs, which exhibited "mean-model biases in excess of 10 K in very shallow layers" In addition, the two researchers reported that (2) the climate models they studied "have trouble representing the ABL depth under strongly convective conditions, as [3] many physical processes that occur in these conditions (e.g. self-organization of turbulent structures) are not accounted for in their parameterization schemes."

Nearing the end of their report, Davy and Esau thus stated that (4) their "assessment of the CMIP5 model biases and error, with respect to observations and reanalysis, has highlighted the relatively poor performance of these models in stably-stratified conditions." And they further stated that "it is in these conditions that [5] the models show the greatest departure from observations, and [6] there is the greatest difference between the models in their representation of surface conditions.”

About this same time, and citing 15 different studies in the introduction to their work, Sanap *et al*. (2014) wrote that "aerosols can have significant impacts on regional climate through changes in radiative budget and modifications in precipitation processes, cloud properties and dynamical state of the atmosphere." And, therefore, they examined aerosol distributions over the Indian subcontinent "as represented in 21 models from Coupled Model Inter-comparison Project Phase 5 (CMIP5) simulations, wherein model-simulated aerosol optical depth (AOD) is compared with Moderate Resolution Imaging Spectro-radiometer (MODIS) satellite observations," with the overall objective of determining the models' abilities to capture the spatial and temporal distributions of different aerosol species over the Indian subcontinent.

In reporting their findings, the four Indian researchers said their study revealed that (1) "most of the CMIP5 models were unable to simulate the aerosol distribution correctly over the Indian subcontinent." More specifically, they wrote that (2) the "majority of the CMIP5 models seriously underestimates the spatio-temporal variability of aerosol species over the Indian subcontinent," that (3) the *magnitude* of dust loading "is underestimated in [the] majority of the models," that (4) the "majority of the models show huge negative bias (underestimation) in AOD simulation over [the] Indo-Gangetic Plain," that (5) "biases in winds at 850 hPa (which play an important role in aerosol transport) are significantly large in most of the CMIP5 models)," that (6) "the aerosol concentration is found to be overestimated during monsoon season in some models," while (7) "it is underestimated in [the] majority of the models."

In light of these several disturbing discoveries, Sanap *et al*. concluded -- and rightly so – that "[8] aerosol sources**/**sinks, [9] seasonal variation and [10] associated aerosol chemistry need to be improved in those [CMIP5] models for better representation of the aerosol distribution over the Indian subcontinent," as well as for better assessments of their associated climatic impacts.

Finally reaching the year in which this review of the literature was written, Nowack *et al*. (2015) wrote that "state-of-the-art climate models now include more climate processes simulated at higher spatial resolution than ever." But they also indicated that "some processes, such as atmospheric chemical feedbacks, are still computationally expensive," and they said they are therefore (1) "often ignored in climate simulations," citing the studies of Taylor *et al*. (2012) and Kravitz *et al*. (2013).

In further exploring the various ramifications of this neglect, the eight UK researchers used "a comprehensive atmosphere-ocean chemistry-climate model" to find "an increase in global mean surface warming of around 1°C after 75 years when ozone is prescribed at pre-industrial levels compared with when it is allowed to evolve self-consistently in response to an abrupt 4 x CO_2 forcing." And in light of these facts, they concluded that model- and scenario-consistent representations of *ozone* are *required*, in contrast to the procedure that is widely applied in current climate change assessments, where "participating models often use simplified treatments of atmospheric composition changes that are [1,2] consistent with neither the specified greenhouse gas forcing scenario nor the associated atmospheric circulation feedbacks," citing the studies of Cionni *et al*. (2011), Jones *et al*. (2011) and Eyring *et al*. (2013).

In further discussing the results of Nowack *et al*.'s analysis, Stevenson (2015) wrote that current research "shows that the details of how stratospheric ozone is represented in models can have a strong influence on warming projections." And as Previdi and Polyani (2014) had also found to be the case, ozone recovery following the phasing out of the use of ozone-depleting substances "will figure prominently in future climate change, with its impacts expected to largely cancel the impacts of increasing greenhouse gases during the next half-century."

In a second significant paper, Kociuba and Power (2015) wrote that earth's Walker Circulation (WC) "is one of the world's most prominent and important atmospheric systems," in that "it extends across the entire tropical Pacific Ocean, encompassing the trade winds blowing from east to west; air forced to rise over the western Pacific, Southeast Asia, and northern Australia through enhanced convection; winds blowing counter to the trades aloft; and air descending over the eastern Pacific Ocean." And in light of these several significant aspects of the WC, they went on to evaluate how well they were replicated by CMIP5 climate models between 1980 and 2012. And what did they learn by so doing?

The two Australian researchers reported that "on the one hand, 78% of the models show a weakening of the WC over the twentieth century, consistent with the observations." But on the *other* hand, they found that "the observations also exhibit a strengthening in the last three decades (i.e., from 1980 to 2012) that is statistically significant at the 95% level," whereas the models (1) "show no consensus on the sign of change, and [2] none of the models shows a statistically significant strengthening over the same period." Therefore, and in light of the fact that "the reasons for the inconsistency between modeled and observed trends in the last three decades are not fully understood," Kociuba and Power rightly stated that "confidence in the model projections is reduced."

Moving on, and writing in the *Journal of Climate*, Roberts *et al*. (2015) said "there is an increasing need for skillful climate information at regional and local scales, particularly for considering variability and extremes," but they noted that (1) the "current phase 5 of the Coupled Model Intercomparison Project (CMIP5)-class models (Taylor *et al*., 2012) generally fall short of being able to provide information on these small space and time scales," citing the study of Christensen *et al*. (2014). And, hence, they proceeded to report the results of their latest "objective, resolution-independent feature-tracking methodology," which they used to identify and track tropical cyclone (TC)-like features in several of the CMIP5 models that they then compared with real-world observations.

This work revealed, in the words of the nine UK researchers, that (1) "all model storms are weak compared to observations, particularly with regard to 10-m wind speed ... but also applying to wind at other levels," that (2) "the models produce typically too few TCs in the NA [North Atlantic]," as well as (3) "too many in the EP [Eastern Pacific]," that (4) "the models also generate storms in the South Atlantic [SA], where hurricanes are observed to be rare," that (5) "increased model resolution enhances an error in the CP [Central Pacific], where the density becomes too high compared to observations," along with (6) "tracks that are too zonal," together with (7) "fewer storms being generated nearer to the equator in the western Pacific than seen in the observations," that (8) "an additional model bias lies in the Gulf of Mexico/EP region, where the track density is again too high," that (9) "in the Southern Hemisphere, the main error in distribution is found in the SWI [Southwestern Indian Ocean] basin, where the track density is strongly enhanced to the west near Madagascar," that (10) "in the NA [North Atlantic] the season starts too early," that (11) it "does not increase strongly through July-September, as seen in the observations," that (12) "the EP has too many storms in the higher-resolution models," that (13) there are "too many easterly waves propagating into this region" with (14) "a dip in September that is not seen in observations," that (15) there is "poor simulation of the Indian monsoon," that (16) "in general, the Southern Hemisphere has too many storms," and that (17) the mean ACE [accumulated cyclone energy] in the models "is much smaller than observed, typically by 3-10 times," all of which findings are not exactly a ringing endorsement of the current state of the climate modeling enterprise.

In another concurrent study, and in what must have been a difficult acknowledgement to make, Oueslati and Bellon (2015) wrote that (1) "the double intertropical convergence zone (ITCZ) bias still affects all the models that participate in CMIP5," while further noting that (2) "as an ensemble, general circulation models have improved little between CMIP3 and CMIP5 as far as the double ITCZ is concerned." And, therefore, they proceeded to discuss some of the many *other* problems that have ultimately led to *this* problem.

The two French researchers begin by noting that (1) "the double ITCZ bias affecting the central Pacific can be connected to the simulation of a too-zonally elongated South Pacific convergence zone," as well as (2) "a too-zonally elongated SPCZ and a spurious ITCZ in the Eastern Pacific, that (3) the spatial distribution of sea surface temperature is "poorly simulated in coupled ocean-atmosphere GCMs (OAGCMs)," with (4) "a positive SST bias over the southeastern Pacific," as well as (5) "an excessive equatorial cold tongue extending too far west in the Pacific," which latter biases are attributed to coupled ocean-atmosphere feeedbacks such as (6) "the SST-wind-induced surface fluxes feedback," (7) "the SST-stratus feedback," and (8) "the SST gradient-trade wind feedback associated with vertical upwelling."

And after further studying this sad situation, Oueslati and Bellon *additionally*, and quite rationally, came to the conclusion that (9) "overestimated ascending regimes suggest that processes inhibiting deep convection (e.g. convective entrainment, downdrafts and large-scale subsidence) are still poorly represented in CMIP5 models," all of which makes one wonder if it will *ever* be possible to correctly represent these several interacting phenomena in a fail-safe climate model.

Continuing, and while noting that no systematic multi-model comparison had previously been conducted with the goal of assessing model performance and future projections of the climatological activity of the Arctic summer storm track, Nishii *et al.* (2015) wrote that such an undertaking is *crucial* for obtaining "a deeper understanding of the Arctic climate and its better future projection." And, therefore, they proceeded to describe the findings of just such a study that *they* had conducted.

In this study, as the three researchers reported, Arctic summer storm tracks were derived from the outputs of 17 CMIP3 models and 17 CMIP5 models, after which their results were compared to six locally-measured reanalysis data sets that described the variance of sub-weekly fluctuations of sea level pressure. And what did these efforts reveal?

Quoting Nishii *et al*., they said they had learned that (1,2) "most of the CMIP3**/**5 models have negative biases (i.e., underestimation) in summertime storm-track activity and westerly wind speed around the Arctic Ocean compared to reanalysis data," that (3) there is a "fairly large inter-model spread in the projected storm-tract activity over the Arctic Ocean Cyclone Maximum (AOCM)," that (4) "the CMIP3**/**5 models generally underestimate the summertime cyclone intensity," citing Zappa *et al*. (2013), that (5) there are "fewer cyclones in most of the climate models than in the reanalysis data," and that (6) "the underestimation of the number of intense cyclones in most of the CMIP5 models is also found over the North Atlantic," once again citing Zappa *et al*. (2013). Consequently, and in light of these several model shortcomings, Nishii *et al* concluded that "further clarification of those processes that influence storm-track activity over the Arctic is necessary for more reliable future projections of the Arctic climate."

In another climate model assessment study, in the words of Ao *et al.* (2015), the 13 scientists hailing from six different countries described how they conducted "a detailed comparison of geopotential height fields between the Coupled Model Inter-Comparison Project phase 5 (CMIP5) models and satellite observations from GPS radio occultation (RO)," focusing on "the annual mean, seasonal cycle, and inter-annual variability of 200 hPa geopotential height in the years 2002-2008." And what did they learn by so doing?

The international research team reported that (1) in the annual mean "there was considerable spread among the models," that (2) "in the Southern Hemisphere high latitudes, the majority of the models showed a negative bias relative to observations," that (3) "in the Northern Hemisphere extratropics, the intermodal bias shows large seasonal variations," with (4) "positive bias during the summer" and (5) "mainly negative bias during the rest of the year," while in the Southern Hemisphere extratropics, (6) "the negative bias is present through all seasons and peaks in autumn," that (7) "for the seasonal cycle, the models were found to have excessive seasonal variability relative to the observations," that (8) for interannual variability "the correlation was shown to be very low in the subtropics and the extratropics," which finding (9) "likely reflects the deficiency of models in capturing baroclinic variabilities in the extratropics."

So what was the take-home message of these several findings? Although it has come a very long way from the time of its inception, the climate modeling enterprise still has a very long way to go before it achieves the ability to present a reasonably accurate reflection of reality in the case of geopotential height field behavior.

In another study published in the year of this writing, and as background for their interesting research, Wang *et al.* (2015) wrote that "although the double intertropical convergence zone (ITCZ) is an observed phenomenon in the tropical central-eastern Pacific during boreal spring, it is often overemphasized in general circulation models (GCMs) and is a common bias that has plagued GCMs for a few decades." And, therefore, they set about to revisit this issue by analyzing the double ITCZ bias in a set of simulations produced by the Community Atmosphere Model version five (CAM5) and the Community Earth System Model version one (CESM1). And what did they discover by so doing in terms of relevant problems?

The four researchers from Taiwan report that in CAM5 alone they found a (1) "weaker-than-observed equatorial easterly in the tropical eastern South Pacific" that leads to (2) "weaker evaporation" and (3) "an increase in local sea surface temperature," that (4) "the shallow meridional circulation overly converges in the same region in the CAM 5 stand-alone simulation," that (5,6) "the planetary boundary layer and middle troposphere are too humid," that (7) "the large-scale subsidence is too weak at the middle levels," and that these problems (8) "may result from excessive shallow convection behavior in CAM5."

In the ocean model (CESM1), Wang *et al*. further found that (9) "the South Equatorial Current is underestimated," that (10) "the North Equatorial Counter-current is located too close to the equator," which causes (11) "a warm SST bias in the southeastern Pacific," and (12) "a cold bias in the northeastern Pacific." In addition, Wang *et al*. reported that (13) "these sea surface temperature biases feed back to the atmosphere and further influence convection and the surface wind biases in the coupled simulation," with the ultimate end result of these many model errors and deficiencies being (14) the *erroneously-predicted* Double Intertropical Convergence Zone.

Last of all, and most recently, Kumar and Wang (2015) began their analysis of this intriguing but disturbing subject by reporting that "considerable efforts have been devoted to predicting the evolution of climate with a lead time of 1-30 years," while noting that these *decadal predictions* rely on our ability to predict "the low-frequency modes of coupled ocean-atmosphere variability," two examples of which are the Pacific Decadal Oscillation (PDO) and the Atlantic Multi-decadal Oscillation (AMO), as discussed by Soloman *et al.* (2011) and Meehl *et al.* (2013).

In further exploring this situation, therefore, the two researchers reported finding that (1) "of the analyses that do provide an assessment of skill over terrestrial regions -- Teng *et al.* (2011), van Oldenborgh *et al.* (2012), MacLeod *et al.* (2012), Kim *et al.* (2012), Muller *et al.* (2012), Goddard *et al.* (2013), Doblas-Reyes *et al.* (2013) -- the results have not been encouraging," that (2) "for ensemble mean prediction the observed associations between the sea surface temperature [SST] fingerprint of low-frequency modes of SST variability and the atmospheric and terrestrial variability are not replicated," citing Teng *et al.* (2011), van Oldenborgh *et al.* (2012) and Muller *et al.* (2012)," that (3) "a different set of observational studies analyzing the predictive value of SST associated with low-frequency modes such as the PDO done in forecast mode has not shown promising results," citing Davis (1976) and Guztler *et al*. (2002), and that (4) "inferences based on general circulation model simulations have also found little influence of extratropical SSTs in constraining atmospheric and terrestrial variability," citing Pierce (2002) and Kumar *et al.* (2013).

In concluding their analysis of the matter, therefore, Kumar and Wang stated that their work provides *explanations* for why (5) "the skill of atmospheric and terrestrial quantities in initialized decadal predictions is not much better than their uninitialized counterpart," for why (6) "the observed teleconnection between SST and atmospheric and terrestrial quantities is not replicated in the ensemble of initialized decadal prediction runs," and why (7) "similar teleconnection relationships on a seasonal time scale have not translated to their application towards improving skill of seasonal predictions," all of which findings ultimately led them to the conclusion that for *far into the future* (8) "the constraint of the coupled ocean-atmosphere variability will still be a basic limitation on prediction skill."

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ABOUT THE CENTER

The *Center for the Study of Carbon Dioxide and Global Change* was founded as a non-profit organization in 1998 to provide regular reviews and commentary on new developments in the world-wide scientific quest to determine the climatic and biological consequences of the ongoing rise in the air's CO_2 content. It achieves this objective primarily through the weekly online publication of '*CO_2 Science*,' which is freely available on the Internet at **www.co2science.org**, and contains reviews of recently published peer-reviewed scientific journal articles, original research, and other educational materials germane to the debate over carbon dioxide and global change.

The Center's main focus is to separate reality from rhetoric in the emotionally-charged debate that swirls around the subject of carbon dioxide and global change and to avoid the stigma of biased advocacy by utilizing sound science. It has a stated commitment to empirical evidence and its position on global warming may be summarized as follows. There is little doubt the carbon dioxide concentration of the atmosphere has risen significantly over the past 100 to 150 years from humanity's use of fossil fuels and that the Earth has warmed slightly over the same period; but there is no compelling reason to believe that the rise in temperature was caused primarily by the rise in carbon dioxide. Moreover, real world data provide no compelling evidence to suggest that the ongoing rise in the carbon dioxide concentration of the atmosphere will lead to significant global warming or changes in Earth's climate.

In the 18-year period since its creation, the Center has published over 6,000 timely and objective reviews of scientific research reports on both the biological and climatological effects of atmospheric CO_2 enrichment. Accompanying each review is the full peer-reviewed scientific journal reference from which the review was derived, so that patrons may independently obtain the original journal articles and verify the information for themselves.