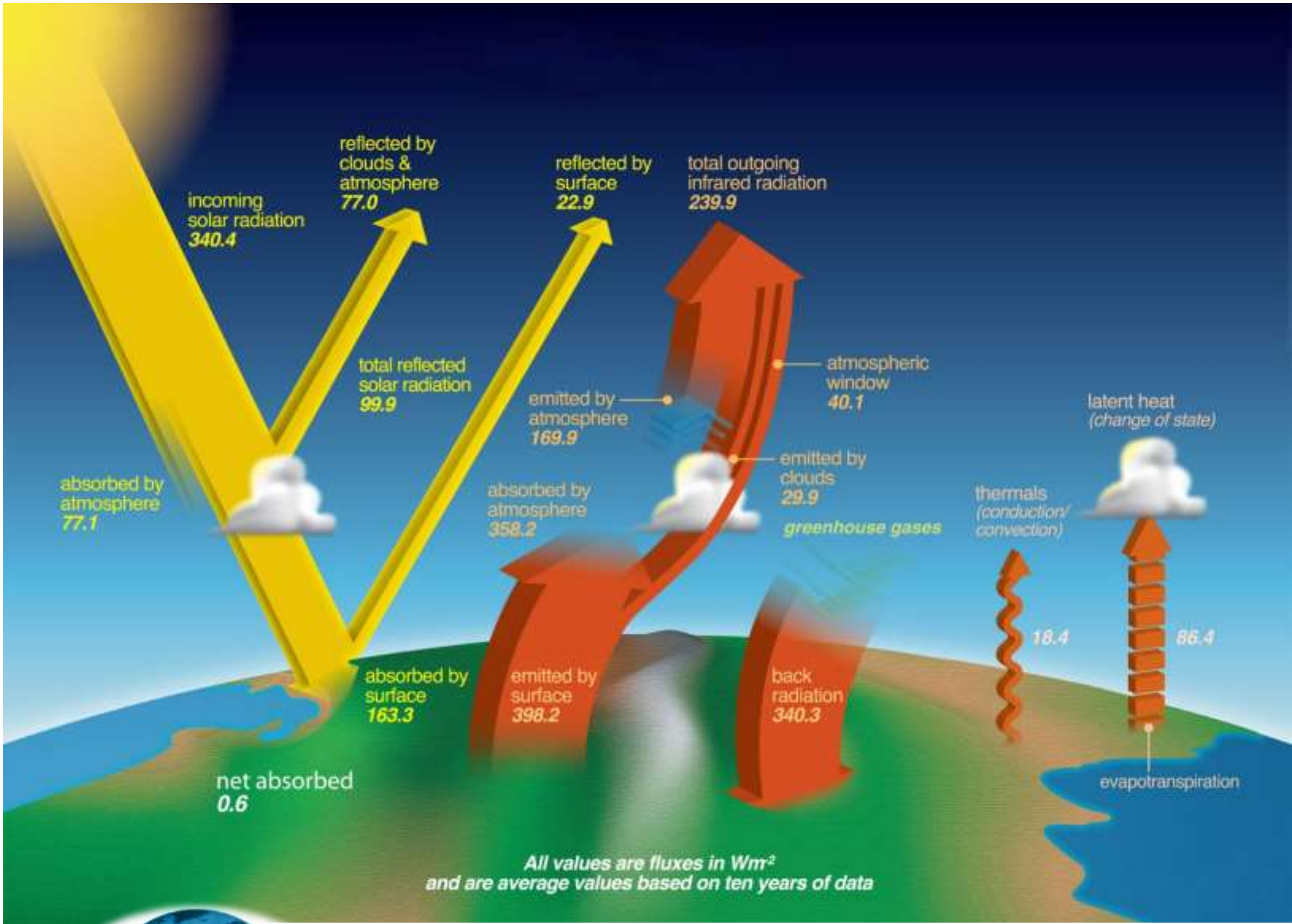
Climate Model Inadequacies of Earth's Radiative Budget



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CLIMATE MODEL INADEQUACIES OF EARTH'S RADIATIVE BUDGET

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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. Of this task, Harries (2000)[1] 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 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 W m^{-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 W m^{-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."

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Illustrative of a related problem was the work of Zender (1999)[2], 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,

[1] http://www.co2science.org/articles/V4/N3/C3.php
[2] http://www.co2science.org/articles/V3/N4/C5.php

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)[3] 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 the model predictions were much too small. Indeed, regional and seasonal model underestimation biases were as high as *30 Wm*$^{-2}$, primarily because the models failed to properly account for spatial and temporal variations in atmospheric aerosol concentrations, as well as the fact that Wild found that the models likely underestimated the amount of solar radiation absorbed by water vapor and clouds.

Indeed, regional and seasonal model underestimation biases were as high as 30 Wm^{-2}*, primarily because the models failed to properly account for spatial and temporal variations in atmospheric aerosol concentrations, as well as the fact that Wild found that 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)[4], 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 "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 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)[5], most of the many nonlinear responses to solar activity variability were inadequately represented (in fact, they were essentially ignored) in the global

[3] http://www.co2science.org/articles/V3/N4/C2.php
[4] http://www.co2science.org/articles/V2/N23/C5.php
[5] http://www.co2science.org/articles/V3/N1/C1.php

climate models used by the Intergovernmental Panel on Climate Change (IPCC) to predict future greenhouse gas-induced global warming, while at the same time *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 that 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 suit their purposes, they use them; but when they don't suit their purposes, they don't use them.

In setting the stage for the next study of climate model inadequacies related to radiative forcing, Ghan *et al*. (2001)[6] stated that "present-day radiative forcing by anthropogenic greenhouse gases is estimated to be 2.1 to 2.8 Wm^{-2}; 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}," so 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 *clearly* "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, requires achieving "profound reductions in the uncertainties of direct and indirect forcing by anthropogenic aerosols," which is what they 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 "one could easily add the usual list of uncertainties in the representation of clouds, etc." Consequently, the bottom line, in their words, was that "much remains to be done before the estimates are reliable enough to base energy policy decisions upon."

> **"Much remains to be done before the estimates are reliable enough to base energy policy decisions upon."**

[6] http://www.co2science.org/articles/V4/N46/C1.php

Also studying the aerosol-induced radiative forcing of climate were Vogelmann *et al*. (2003)[7], who report 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 say that "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." forcing."

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. In doing so, 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 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 "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 they have been ignoring?

Shifting gears just a bit, two papers published one year earlier in the same issue of *Science*[8] (Chen *et al*., 2002; Wielicki *et al*., 2002) revealed what Hartmann (2002) 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

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[7] http://www.co2science.org/articles/V7/N18/C1.php
[8] http://www.co2science.org/articles/V5/N14/EDIT.php

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.

The results were truly pathetic. No significant decadal variability was exhibited by any of the models; and they all failed to reproduce even the cyclical seasonal change in tropical albedo.

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 past two decades. The results were truly pathetic. No significant decadal variability was exhibited by *any* of the models; and they *all* failed to reproduce even the cyclical seasonal change in tropical albedo. The administrators of the test thus kindly concluded that "the missing variability in the models highlights the critical need to improve cloud modeling in the tropics so that prediction of tropical climate on interannual and decadal time scales can be improved."

Hartmann, on the other hand, was considerably more candid in his scoring of the test, saying that the results indicated "the models are deficient." Expanding on this assessment, he further noted that "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, as to do so is simply illogical.

Also concentrating on the tropics, Bellon *et al*. (2003)[9] 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 intraseasonal to millennial." Hence, they suggested that "identifying the stabilizing feedback(s) that help(s) 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 was further buttressed by the study of Pierrehumbert (1995), which "clearly demonstrates," in the words of

[9] http://www.co2science.org/articles/V6/N50/C2.php

Bellon *et al*., "that the tropical climate is not determined locally, but globally." Also, they noted that Pierrehumbert's work demonstrates that 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 describe 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 say 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 is not closed on either the *source* or the *significance* of the maximum "allowable" SSTs of tropical regions; and, hence, neither is the case closed on the degree to which the planet may warm in response to continued increases in the atmospheric concentrations of carbon dioxide and other greenhouse gases, in stark contrast to what is suggested by the climate models promoted by the IPCC.

Moving forward in time a few years, Eisenman *et al*. (2007)[10] 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. In doing so, they found 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 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

[10] http://www.co2science.org/articles/V11/N47/C2.php

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," which further leads to the unsavory conclusion – as stated by them – that "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)[11] 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 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 "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 "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 ago may have been of very little worth in describing the real world of nature.

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Also publishing a pertinent paper about the same time as Mishchenko *et al*. were Androvo *et al*. (2009)[12], 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 (1) "derived the most conservative estimate of their

[11] http://www.co2science.org/articles/V12/N29/C1.php
[12] http://www.co2science.org/articles/V12/N43/C1.php

trends" and (2) "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 "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, the failure of *all* of the AR4 climate models to adequately simulate the TOA radiation measurements basically *discredits* the models; and it 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 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)[13], 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 they all *disagree* -- and disagree "very sharply" -- with the real-world observations that they (Lindzen and Choi) utilized, which imply 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."

[13] http://www.co2science.org/articles/V12/N48/EDIT.php

The eight naturally-occurring phenomena employed by Idso were (1) the change in the air's water vapor content that occurs at Phoenix, Arizona, with the advent of the summer monsoon, (2) the naturally-occurring vertical redistribution of dust that occurs at Phoenix between summer and winter, (3) the annual cycle of surface air temperature that is caused by the annual cycle of solar radiation absorption at the earth's surface, (4) the warming effect of the entire atmosphere caused by its mean flux of thermal radiation to the surface of the earth, (5) 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, (6) the mean surface temperatures of Earth, Mars and Venus relative to the amounts of CO_2 contained in their respective atmospheres, (7) the paradox of the faint early sun and its implications for earth's thermal history, and (8) 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 is being predicted by state-of-the-art climate models.

Moving ahead two more years, Shin and Sardeshmukh (2011)[14] 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 describe 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 "the tropical oceanic warming pattern is poorly represented in the coupled simulations," and they thus concluded that 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 "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."

[14] http://www.co2science.org/articles/V14/N20/C2.php

As for the significance of this finding, Shin and Sardeshmukh wrote that "the fact that 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 the radiatively forced component of this warming pattern was sufficiently small in recent decades to be dwarfed by natural tropical SST variability, or that 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 "misrepresenting some important tropical physics."

"The fact that 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 the radiatively forced component of this warming pattern was sufficiently small in recent decades to be dwarfed by natural tropical SST variability, or that the coupled models are misrepresenting some important tropical physics."

Moving forward three additional years, Crook and Foster (2014)[15] 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

[15] http://www.co2science.org/articles/V17/N29/C2.php

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)[16] 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 is likely due to (3) "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 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.

References

Andronova, N., Penner, J.E. and Wong, T. 2009. Observed and modeled evolution of the tropical mean radiation budget at the top of the atmosphere since 1985. *Journal of Geophysical Research* **114**: 10.1029/2008JD011560.

Bellon, G., Le Treut, H. and Ghil, M. 2003. Large-scale and evaporation-wind feedbacks in a box model of the tropical climate. *Geophysical Research Letters* **30**: 10.1029/2003GL017895.

Chambers, F.M., Ogle, M.I. and Blackford, J.J. 1999. Palaeoenvironmental evidence for solar forcing of Holocene climate: linkages to solar science. *Progress in Physical Geography* **23**: 181-204.

[16] http://www.co2science.org/articles/V17/N35/C2.php

Chen, J., Carlson, B.E. and Del Genio, A.D. 2002. Evidence for strengthening of the tropical general circulation in the 1990s. *Science* **295**: 838-841.

Crook, J.A. and Forster, P.M. 2014. Comparison of surface albedo feedback in climate models and observations. *Geophysical Research Letters* **41**: 1717-1723.

Eisenman, I., Untersteiner, N. and Wettlaufer, J.S. 2007. On the reliability of simulated Arctic sea ice in global climate models. *Geophysical Research Letters* **34**: 10.1029/2007GL029914.

Ghan, S.J., Easter, R.C., Chapman, E.G., Abdul-Razzak, H., Zhang, Y., Leung, L.R., Laulainen, N.S., Saylor, R.D. and Zaveri, R.A. 2001. A physically based estimate of radiative forcing by anthropogenic sulfate aerosol. *Journal of Geophysical Research* **106**: 5279-5293.

Harries, J.E. 2000. Physics of the earth's radiative energy balance. *Contemporary Physics* **41**: 309-322.

Hartmann, D.L. 2002. Tropical surprises. *Science* **295**: 811-812.

Idso, S.B. 1998. CO_2-induced global warming: a skeptic's view of potential climate change. *Climate Research* **10**: 69-82.

Jacobson, M.Z. 2001. Global direct radiative forcing due to multicomponent anthropogenic and natural aerosols. *Journal of Geophysical Research* **106**: 1551-1568.

Lindzen, R.S. and Choi, Y.-S. 2009. On the determination of climate feedbacks from ERBE data. *Geophysical Research Letters* **36**: 10.1029/2009GL039628.

Lindzen, R.S., Chou, M.-D. and Hou, A.Y. 2001. Does the earth have an adaptive infrared iris? *Bulletin of the American Meteorological Society* **82**: 417-432.

Ma, Q., Wang, K. and Wild, M. 2014. Evaluations of atmospheric downward longwave radiation from 44 coupled general circulation models of CMIP5. *Journal of Geophysical Research: Atmospheres* **119**: 4486-4497.

McPhaden, M.J. and Zhang, D. 2002. Slowdown of the meridional overturning circulation in the upper Pacific Ocean. *Nature* **415**: 603-608.

Mishchenko, M.I., Geogdzhayev, I.V., Liu, L., Lacis, A.A., Cairns, B. and Travis, L.D. 2009. Toward unified satellite climatology of aerosol properties: What do fully compatible MODIS and MISR aerosol pixels tell us? *Journal of Quantitative Spectroscopy & Radiative Transfer* **110**: 402-408.

Norris, J.R. 2007. Observed interdecadal changes in cloudiness: Real or spurious? In: Broennimann, S. *et al*. (Eds.) *Climate Variability and Extremes During the Past 100 Years*. Springer, New York, New York, USA, pp. 169-178.

Pierrehumbert, R.T. 1995. Thermostats, radiator fins, and the local runaway greenhouse. *Journal of the Atmospheric Sciences* **52**: 1784-1806.

Shin, S.-I. and Sardeshmukh, P.D. 2011. Critical influence of the pattern of Tropical Ocean warming on remote climate trends. *Climate Dynamics* **36**: 1577-1591.

Sokolik, I.N., Toon, O.B. and Bergstrom, R.W. 1998. Modeling the radiative characteristics of airborne mineral aerosols at infrared wavelengths. *Journal of Geophysical Research* **103**: 8813-8826.

Tegen, I., Lacis, A.A. and Fung, I. 1996. The influence on climate forcing of mineral aerosols from disturbed soils. *Nature* **380**: 419-422.

Vogelmann, A.M., Flatau, P.J., Szczodrak, M., Markowicz, K.M. and Minnet, J. 2003. Observations of large aerosol infrared forcing at the surface. *Geophysical Research Letters* **30**: 10.1029**/**2002GL016829.

Wielicki, B.A., Wong, T., Allan, R.P., Slingo, A., Kiehl, J.T., Soden, B.J., Gordon, C.T., Miller, A.J., Yang, S.-K., Randall, D.A., Robertson, F., Susskind, J. and Jacobowitz, H. 2002. Evidence for large decadal variability in the tropical mean radiative energy budget. *Science* **295**: 841-844.

Wild, M. 1999. Discrepancies between model-calculated and observed shortwave atmospheric absorption in areas with high aerosol loadings. *Journal of Geophysical Research* **104**: 27,361-27,371.

Wild, M. and Ohmura, A. 1999. The role of clouds and the cloud-free atmosphere in the problem of underestimated absorption of solar radiation in GCM atmospheres. *Physics and Chemistry of the Earth* **24B**: 261-268.

Zender, C.S. 1999. Global climatology of abundance and solar absorption of oxygen collision complexes. *Journal of Geophysical Research* **104**: 24,471-24,484.

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