CLIMATE MODEL INADEQUACIES (SEA ICE)

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Near the start of the current century, Holland (2001)[1] wrote that with respect to contemporary state-of-the-art global climate models, "some physical processes are absent from the models," while noting that in light of the coarse-resolution grids employed by the models, "some physical processes are ill resolved" and that others are actually "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 so it was that he thus 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 "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 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)[2] 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 (1) "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 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

[1] http://www.co2science.org/articles/V4/N24/C1.php
[2] http://www.co2science.org/articles/V6/N50/C1.php

ice pack, produced by greenhouse warming," which represents still another significant strike against the models.

> **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."**

In summing up their discussion of the subject, therefore, Laxon *et al.* simply state that their results "show that errors are present in current simulations of Arctic sea ice," and they thus conclude, in the closing sentence of their paper, that "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)[3] 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 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 in light of these machinations, 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 cannot be detected by current observing systems and require only exceedingly small adjustments of the model-generated radiation fields," and, therefore, they additionally conclude that "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

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

in absorption of solar energy due to changes in the area covered by the highly reflective sea ice," Comiso and Nishio (2008)[4] 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 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 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 contend they should, it would appear that 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, one could not claim that rising atmospheric CO_2 concentrations cause *global* warming.

Another study of interest was that of Kwok (2011)[5], 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) conclude 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 "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

> "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."

[4] http://www.co2science.org/articles/V11/N29/C2.php
[5] http://www.co2science.org/articles/V15/N3/C2.php

poor," noting that "model-data differences and inter-model scatter of the sea ice parameters in the summarizing statistics are high," and that "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 "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, "because the model simulations have difficulties reproducing the mean patterns of Arctic circulation and thickness," as Kwok writes in his concluding paragraph, " he says his analysis suggests there are "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 the problems he finds with the models, who really knows how good those latter projections are?

A couple more years down the road, Turner *et al.* (2013)[6] 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.* state that "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)[7] 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 "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 describe 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 report that "the across-model spread in Arctic cloud cover and cloud condensates is substantial, and no improvement is seen from

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7 http://www.co2science.org/articles/V16/N49/C3.php

"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."

previous model intercomparisons (Karlsson and Svenson, 2011)." And they further note 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." Therefore, in the concluding sentence of their paper, the two Swedish scientists state that "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)[8] state that Lefebvre and Goosse (2008) analyzed the Antarctic sea ice distributions of the CMIP3 climate models and found that "the modelled trends were too negative compared to observations." Likewise, they say that 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, "the representations of Antarctic sea ice in CMIP5 models have not improved compared to CMIP3," in that "the spread in sea ice area is not reduced compared to the previous models." Most important of all, however, was their finding that 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.

[8] http://www.co2science.org/articles/V17/N2/C1.php

Last of all, and most recently, Koenigk *et al*. (2014)[9] -- citing Winton (2006) and Serreze et al. (2009) - write 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.* say 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 write 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 too cold temperatures in August causing an earlier refreezing in the models," such that (13) "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.* conclude that "the Arctic climate system can thus not correctly be simulated (other than with compensating errors) if the large-scale atmospheric and oceanic

"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."

[9] http://www.co2science.org/articles/V17/N24/C1.php

circulation determining the input of mass, heat and momentum into the Arctic is not correctly simulated." And they also remark that "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."

So when shopping for Arctic sea ice models when all is said and done, it is not surprising that the word on the street is *buyer beware*!

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