

## Chapter 14 The Limits of Climate Science

*“There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact.”*

— Mark Twain

There are three fundamental problems that limit the effectiveness of climate science. These are lack of understanding of Earth's climate system, inherent uncertainty in baseline data, and reliance on conceptual computer models for prediction of future climate. These three problem areas correspond to the three pillars of climate science: theory, experimentation, and computation. The previous two chapters addressed the incompleteness of climate theory and the inherent uncertainty in climate data. In this chapter, we will address the third and most misunderstood pillar, computation. In the context of climate science, computation is primarily represented by climate models—GCM, complex computer programs that have been under continual development for at least a quarter of a century.

To the layperson, and even many scientists, the pitfalls and problems with modeling of any kind are unknown and unappreciated. To computer scientists who make a study of such things, modeling is fraught with danger for the uninitiated and the unwary. Nevertheless, computer modeling presents a seductive trap for many other wise skeptical scientists. The appeal of running experiments in a clean, mathematically antiseptic world from the comfort of an office can be overwhelming.

Much of the IPCC's case for rapid and accelerating temperature rise in the future is based on the predictions of computer models. Most people unquestionably accept that these results are accurate—after all, they sound very scientific and run on big super computers. What is really not discussed in the public announcements, but is well known by scientists who do computer modeling, is that models are not very accurate. Particularly

when asked to make long-term projections based on limited, short-term data. To understand why this is so, we need to look at how computer modeling is done.

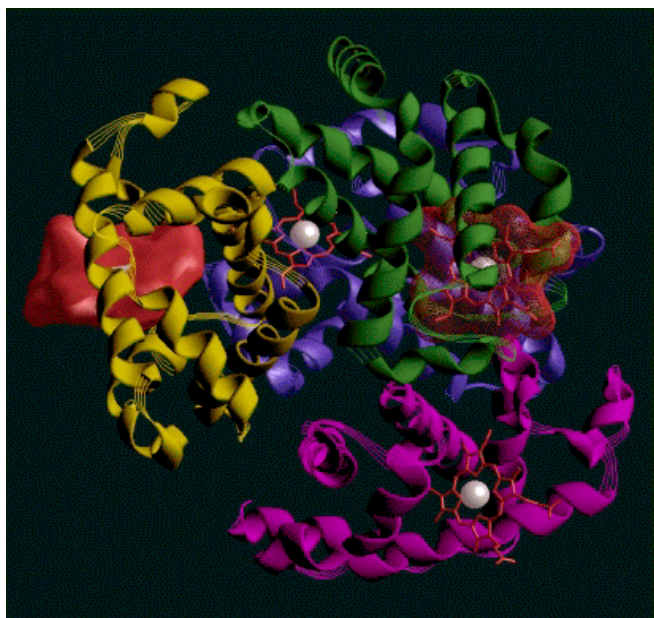
### Why Models Aren't Reliable

A model is a simplified stand-in for some real system; a computer network, a protein molecule, the atmosphere, or Earth's entire climate. A modeler tries to capture the most important aspects of the system being modeled. For a computer network, this could be the amount of network traffic, the speed of the communication links, the way the various computers are connected to each other. For a protein molecule, it could be the types and number of different atoms, the bonds between them, the kinetic energy of the atoms, etc.

During the 1990s, Hoffman was a research professor of Computer Science at the University of North Carolina at Chapel Hill, working on biosequence and protein structure analysis funded by the Human Genome Project. A number of his colleagues were working on the related problem of molecular dynamics simulation (MD), modeling virtual protein molecules with computers. The goal of MD is to calculate the time-dependent behavior of a molecular system. To run these models, some of the fastest super-computers of the time were used. Even so, running the model programs could take weeks and yield only a few milliseconds of simulated time.

Even relatively small protein molecules consist of several hundred atoms. Molecular dynamics simulation is a type of problem called an N-body problem. This is because every atom in the molecule affects all the other atoms. Computer scientists have a concept called *computational complexity*, a way of formally stating how hard it is to solve a computational problem. More specifically, how the amount of time required to perform the computation changes with increasing problem size. N-body problems have a computational complexity of  $O(N^2)$ , pronounced “big O, N squared.” In practical terms, this means if you double the number of atoms in your molecule, the time needed to run the simulation will be two squared ( $2^2$ ) or four times the previous

value. Four times the number of atoms would require 16 times ( $4^2$ ) the computer time.



*Illustration 162: Ribbon model of a protein molecule.  
Generated with MolMol.*

Because the number of atoms in a specific protein cannot be reduced, computer scientists look for other ways to make their models run faster. One parameter that can be adjusted is called the *time step*. All computer models execute in a number of discrete steps. In an MD program, starting with the relative positions of all the atoms, all of the forces acting on each atom are calculated. The effects of these forces acting on the atoms over a short period of time, the time step, are calculated. This results in new positions for each atom in the protein molecule. The process then repeats for the next time step. So, if you double the length of the time step, you can cut the required calculations in half.

Of course, nothing is free and the cost of lengthening the time step is a loss of accuracy. This introduces error into the calculations. What is worse, computer programs also suffer from error propagation. This means that any calculation, where the values used contain errors, will result in answers that contain errors as well. Models that simulate systems over time, like MD and GCM programs, use the output of one time step as input to the next time step's calculations. The result can be ever increasing error that eventually causes the model output to become totally useless.

Hoffman witnessed an example of this at a conference held at the North Carolina Supercomputing Center, in Research Triangle Park. Several of his colleagues presented the results of their efforts to simulate a simple protein molecule surrounded by water at body temperature. Showing the model output as a cartoon movie of the molecule pulsing and vibrating, interacting with the surrounding water molecules, their first example did something spectacular—the protein molecule exploded into several pieces.

This was obviously not correct, since the protein in question was known to be stable at body temperature. The second example was much better, at least the protein didn't tear itself apart. What was the difference between the two simulations? The time step used. As it turned out, if a time step greater than two femtoseconds was used, propagated error built up until the molecule self-destructed. A femtosecond is an extremely short period of time. For a computer with a clock rate of 1GHz, every tick of its clock takes one nanosecond, or one billionth of a second. A femtosecond is one millionth of a nanosecond. If a femtosecond took one second, a second would last about 32 million years.

This story illustrates some of the problems inherent in computer modeling, regardless of the physical system that is being studied. Even very small changes to the model's parameters can cause the output to change from realistic to catastrophically wrong. Identifying the source of the problem in a model is often a matter of trial and error—this was the case with the MD simulation. The MD researchers were lucky, their model was obviously giving the wrong answers because the real molecule didn't act like the simulated one. They had volumes of reliable baseline data to work from—this is often not the case for other models. There is an old truism in computer science: “garbage in, garbage out.” The trick is being able to recognize garbage.

Modeling the atmosphere is even more complex, requiring knowledge of incoming solar radiation, the movement of air currents over the land and sea, heat convection, the amount of water vapor, the effects of clouds, and on and on. People have been

trying to model Earth's atmosphere for decades, primarily to predict the weather. The weather forecasts you hear on your evening news are all based on computer models. How accurate are these models? In the near term, a few days from today, local weather forecasts are about 60% accurate when predicting high temperatures.<sup>375</sup>

Hurricane models suffer from the same problems as GCM programs. Because hurricanes often intensify or lose strength quickly, models have trouble accurately predicting their strength. According to Hugh Willoughby, an atmospheric scientist at Florida International University, if a model's data points are not closer than 5 km apart, the simulated storms end up “larger, weaker cartoons of their counterparts in nature.”<sup>376</sup>

Storm track prediction is an example of *quantitative modeling*, where the expected results of a model are hard numbers. In the case of hurricanes, a storm's track and changes in strength over time are the desired results. Climate change modeling is usually an example of *qualitative modeling*. These types of models result in general trends and overall effects of parameter modification. They are used to provide insight into processes where scientists' intuition fails. A qualitative model can tell us that adding more CO<sub>2</sub> to the atmosphere will cause warming. But qualitative models should not be used to make concrete predictions of future conditions, such as the global average temperature for the next 100 years. Or, as Richard W. Hamming<sup>†</sup> put it, “The purpose of computing is insight, not numbers.”

Climate modelers will protest that their models are not the same as short-term weather forecasting models or hurricane path models. They are correct, longer term models are more complicated. There are a number of services, both governmental and commercial, that do longer term predictions. Long-term, meaning for the next season or the next year. These claim to be 80-85% accurate, but they usually concentrate on trend predictions, how many days will it be dry or rainy, how many days will have above-average temperature. An 85% accuracy

sounds pretty good—but this is only for a year or so into the future. What do the professional climate predictors say about looking farther into the future? According to the *Weather 2000* web site:

“Trends can be misleading. Examining 30, 40 or even 50 years worth of historical data might only encompass 10 - 20% of the full potential of climate variability. Since quality data only goes back 50 years at best, standard deviations and extreme records based on that data can be gross underestimations, and trends can overestimate the true climate state.”<sup>377</sup>

The same source goes on to say, “It is very dangerous to draw conclusions based on the most recent 5 or 10 years worth of historical data.” Remember that this is with regard to one year predictions, the IPCC models are trying to predict 100 years or more into the future.

### Sources of Modeling Error

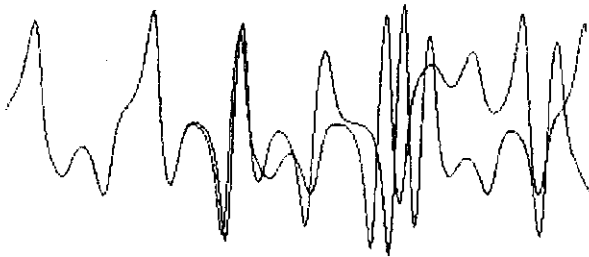
There are numerous sources of error that can impact the accuracy of a model. Peter Haff, Professor of Geology and Civil and Environmental Engineering at Duke University, lists seven sources:

1. Model imperfection.
2. Omission of important processes.
3. Lack of knowledge of initial conditions.
4. Sensitivity to initial conditions.
5. Unresolved heterogeneity.
6. Occurrence of external forcing.
7. Inapplicability of the factor of safety concept.

Several of these points seem obvious; if the model is flawed, if important parts have been left out, or the initial conditions are incorrect, no model can provide trustworthy answers. Pilkey states, “it is an axiom of mathematical modeling of natural processes that only a fraction of the various events, large and small, that constitute the process are actually expressed in the equations.”<sup>378</sup> The other points may not be so self-evident.

<sup>†</sup> Richard Wesley Hamming (1915-1998) American mathematician and computer scientist, Turing Prize winner most noted for developing error correction codes.

Sensitivity to initial conditions is a result of non-linear responses in the system being modeled. In engineered systems, these types of unexpected and unplanned for responses are called *emergent* behavior. In natural systems, this type of behavior is often called *chaotic*. The discovery of chaotic behavior in 1960, by meteorologist Edward Lorenz while developing a weather model, led to the establishment of a new scientific discipline—chaos theory. Lorenz had constructed a computer model, with a set of twelve equations, to study weather prediction. One day, he attempted to restart a prediction run from an intermediate point using values from a printout. To his surprise, the second curve deviated wildly from the initial run. The difference was eventually traced to the number of digits in the parameters used to restart the simulation—by dropping the last few digits from the parameter values, Lorenz had inadvertently discovered the non-linearity lurking in his model.<sup>379</sup> Since Lorenz's experiment, chaotic behavior has been found in many natural systems.



*Illustration 163: Lorenz's experiment: the difference between the starting point of the two curves is 0.000127. Source Ian Stewart.*

Heterogeneity, the quality of being diverse or made up of many different components, tends to increase with the size of the system being modeled. A model that may work well for some geographic regions, may fail simulating others. Desert environments are different from woodlands, open ocean different from coastal areas, mountains different from grassy planes. Heterogeneity tends to make large systems hard to model, and Earth's climate system is very large.

Earth's climate system is definitely affected by external forcing factors; radiant energy from the Sun most obviously. As we have seen, physicists suspect that complex interactions involving cosmic radiation, the solar system's path through the

galaxy, and the Sun's magnetic field, have significant impact on low-level cloud formation. This, in turn, affects Earth's albedo, one of the most sensitive regulators of climate. Models that cannot account for cloud cover, cannot begin to address the effects of this external forcing factor. Yet, many climate scientists reject the possibility that these factors are important and refuse to consider them.

The concept of a safety factor comes from engineering, where more robust systems are built by designing in margins of error—"over engineering" them. Bridges are built to support more than their expected load, aircraft wings are designed to safely bend far beyond the range expected in normal flight, scuba tanks are constructed so they won't burst even if they are filled to pressures higher than their rated level. But, environmental systems are not designed, they are created by the interactions of natural forces.

In environmental modeling, the equivalent of a factor of safety is the "worst-case scenario" prediction. Unfortunately, "where relationships between variables are highly nonlinear, and a clear understanding of the controlling variables does not exist, as in many natural and environmental systems, the factor of safety concept is inapplicable."<sup>380</sup> As we have seen, climate models are highly nonlinear and many relationships among the controlling variables remain unknown.

Even addressing these factors may not be sufficient to ensure an accurate model. Dr. Haff has stated, "sources of uncertainty that are unimportant or that can be controlled at small scales and over short times become important in large-scale applications and over long time scales."<sup>381</sup> These factors, combined with the nonlinear nature of natural systems, which leads to emergent (unexpected) behavior, may mean climate systems cannot be modeled at all.

### **Computational Error**

Even if the data used to feed a model was totally accurate, error would still arise. This is because of the nature of computers themselves. Computers represent real numbers by approximations called *floating-point* numbers. In nature, there are no artificial restrictions on the values of quantities but

in computers, a value is represented by a limited number of digits. This causes two types of error; representational error and roundoff error.

Representational error can be readily demonstrated with a pocket calculator. The value  $1/3$  cannot be accurately represented by the finite number of digits available to a calculator. Entering a 1 and dividing by 3 will yield a result of 0.33333... to some number of digits. This is because there is no exact representation for  $1/3$  using the decimal, or base 10, number system. This problem is not unique to base 10, all number systems have representational problems.

The other type of error, roundoff, is familiar from daily life in the form of sales tax. If a locale has a 7% sales tax and a purchase totals \$0.50 the added tax should be \$0.035 but, since currency isn't available for a  $\frac{1}{2}$  cent, the tax added is only \$0.03 dropping the lowest digit. The tax value was truncated or rounded down in order to fit the available number of digits. In computers, multiplication and division often result in more digits than can be maintained by the machine's limited representation. Arithmetic operations can be ordered to minimize the error introduced due to roundoff, but some error will still creep into the calculations.

After the uncertainties present in data are combined with errors introduced by representation and roundoff, a third type of computational error arises—propagated error. What this means is that errors present in values are passed on through calculations, propagated into the resulting values. In this book, values have often been presented as a number followed by another number prefaced with the symbol “±” which is read “plus or minus.” This notation is used to express uncertainty or error present in a value:  $10 \pm 2$  represents a range of values from 8 to 12, centered on a value of 10.

When numbers containing error ranges are used in calculations, rules exist that describe how the error they contain is passed along. The simplest rule is for addition: the two error ranges are added to yield the error range for the result. For example, adding  $10 \pm 2$  to  $8 \pm 3$  gives a result of  $18 \pm 5$ . There are other, more complicated rules for multiplication and

division, but the concept is the same. When dealing with complicated equations and functions, like sines and cosines, how error propagates is determined using partial differential equations. The mathematics of error propagation rapidly becomes very complex and, as seen in the MD example related above, errors can build up until the model is overwhelmed.

```
#!/usr/bin/perl
#
for ($n=1; $n<11;$n++) {
    $x[$n] = 1/$n;
    $results[$n][1] = $x[$n];

    for ($j=0; $j<10; $j++) {
        $x[$n] = ($n+1)*$x[$n] - 1;
    }
    # --- 10x result
    $results[$n][2] = $x[$n];

    for ($j=0; $j<20; $j++) {
        $x[$n] = ($n+1)*$x[$n] - 1;
    }
    # --- 30x result
    $results[$n][3] = $x[$n];
}

for ($n=1; $n<11;$n++) {
    printf "%2d %-18.16g %-18.16g %-18.16g\n",
        $n,$results[$n][1],$results[$n][2],
        $results[$n][3];
}

```

*Text 1: Perl source code to demonstrate computational and propagated error.*

To demonstrate how these sources of computational error can overwhelm the results of even simple calculations, consider the following example. This example cannot be explained without using equations, but understanding them is not essential—only understanding the final result is important. Having said that, let  $n$  be a positive integer and let  $x(n)=1/n$ . Instructing a computer to compute  $x=(n+1)*x-1$  should not change the value of  $x$ . Source code for this program, written in the Perl language, is given in Text 1.

This program will generate a table of numbers, with the number  $n$  varying from 1 to 10. The value the function  $x$  is calculated for each value of  $n$ . Then the equation  $x=(n+1)*x-1$  is computed first ten and then thirty times. Each time the equation is computed, the newly calculated value of  $x$  replaces the old value, so that the new value of  $x$  from each

n	x = 1/n	10 iterations	30 iterations
1	1	1	1
2	0.5	0.5	0.5
3	0.3333333333333333	0.3333333333139308	-21
4	0.25	0.25	0.25
5	0.2	0.200000017901584	6545103.021815777
6	0.1666666666666667	0.1666666606931329	-476641800.7969146
7	0.1428571428571428	0.1428571343421936	-9817068105
8	0.125	0.125	0.125
9	0.1111111111111111	0.1111111604543567	4934324553889.695
10	0.1	0.1000002094278254	140892568471739.2

*Text 2: Results from running the example program.*

step is used as the input value of  $x$  for the next step. This process is called iteration. If the computer's internal representation of  $x$  is exact, the values produced by the second equation should not change.

The output from running the example program is shown in Text 2. The value of  $n$  is given in the first column and the initial value of  $x$  is in the second column. The values of  $x$  after 10 and 30 iterations are given in columns three and four, respectively. Notice that for some values of  $n$  the computed values of  $x$  do remain unchanged, but for others the results diverge—slightly after 10 iterations, then wildly after 30.

The reason that the  $x$  values for 1, 2, 4, and 8 do not diverge is because computers use binary arithmetic, representing numbers in base 2. The rows of results that did not diverge began with numbers that are integer powers of 2. These numbers are represented inside the computer exactly, and the iterative computation does not change the resulting values of  $x$ . The other numbers cannot be represented exactly so the computation blows up. The same thing happens in any computer program that perform iterative computations—like climate simulation models.

If all of these complicating factors—data errors, incomplete and erroneous models, non-linear model response, roundoff and representational error, and error propagation—are not daunting enough, different computer hardware can introduce different amounts of error for different arithmetic operations. This means that running a model on a Sun computer can yield different results than an Intel

based computer or an SGI computer.<sup>382</sup> To say the least, computer modeling is not an exact science.

### Modeling Earth's Climate

Earth's climate is far too complex for the human intellect to fully encompass—no set of equations can capture it completely. A normal procedure in science is to isolate parts of a more complex system in hopes of understanding the smaller, simpler pieces. Computer scientists call this type of approach “divide and conquer,” breaking down a problem into sub-problems until they become simple enough to be solved directly. The fundamental assumption with this problem solving approach is that the parts, when reassembled into a whole, will accurately reflect the original problem. This is often an invalid assumption—it certainly is when dealing with Earth's climate.

Modeling inaccuracy occurs because many of the processes that influence climate also influence each other. We saw examples of positive feedback mechanisms in earlier chapters:

- Increasing CO<sub>2</sub> levels cause increasing temperatures, resulting in the release of more CO<sub>2</sub>.
- A colder climate increases the area covered with highly reflective ice and snow, causing Earth to cool, causing more ice and snow.
- Melting sea ice, which is highly reflective, exposes more open ocean, which has a much lower albedo, causing greater warming.

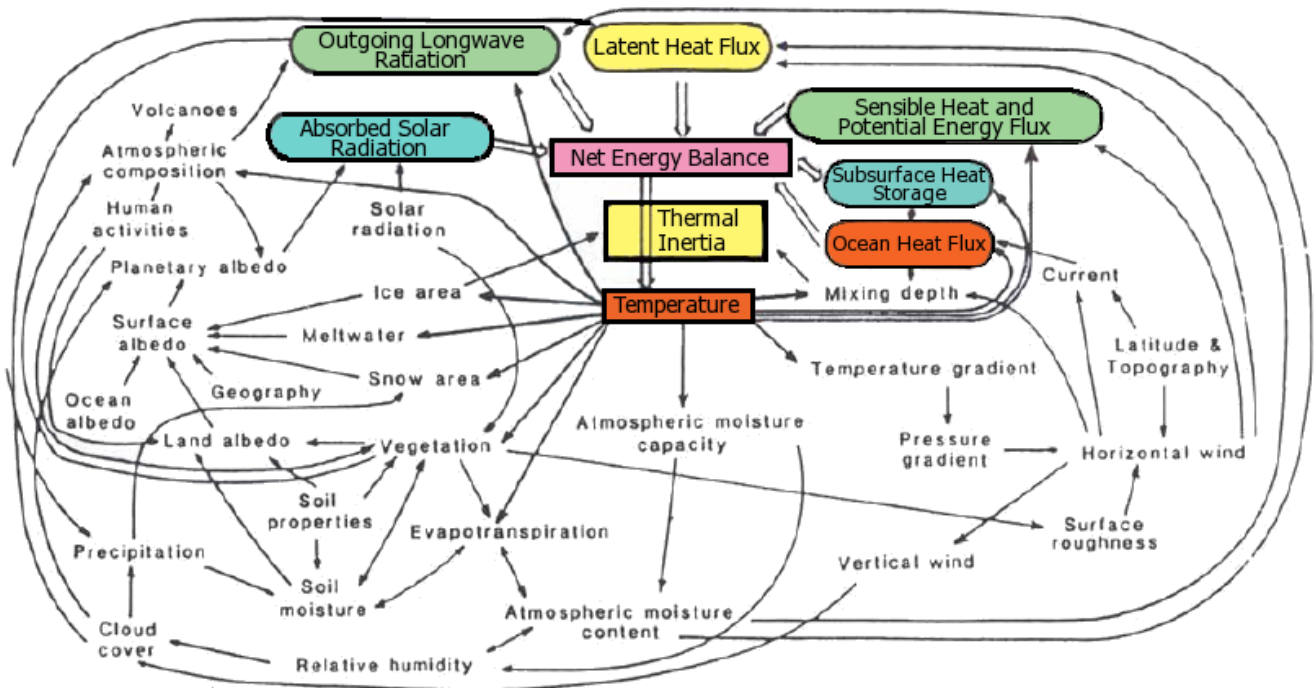


Illustration 164: Flow diagram of the climate system illustrating the massive and complicated physical processes and multiple feedback loops. Source: Robock, 1985.

But, we have also seen examples of negative feedback where warming creates more water vapor that increases snowfall in colder regions leading to cooler climate. Sometimes the same response of nature can result in contradictory effects. For example; increasing forests, which absorb CO<sub>2</sub>, cooling the planet, also decreases Earth's albedo, leading to greater warming. So, are forests good or bad with respect to global warming? Illustration 164 shows some of the feedback relationships in Earth's climate system.

A simpler view of the main climate factors is shown as a block diagram in Illustration 165. The actions of feedback linkages are represented by the heavy black arrows. Even this simplified view demonstrates how complex and confusing Earth's climate mechanisms are.

We have also seen that some mechanisms do not respond gradually, but are instead non-linear. The great ocean conveyor belt, the global circulation of water that redistributes heat around the globe, is known to have been disrupted by glacial melt water during the early years of the Holocene warming. The results of these disruptions were several brief,

sharp returns to colder conditions. Scientists fear this might happen again if the climate continues to warm, but they have no way of predicting such an event.

Many climate mechanisms have sensitive dependence on initial conditions, the so-called "butterfly effect." Over time, systems that show this type of response become unpredictable. This concept is often illustrated by a butterfly flapping its wings in one area of the world, causing a storm

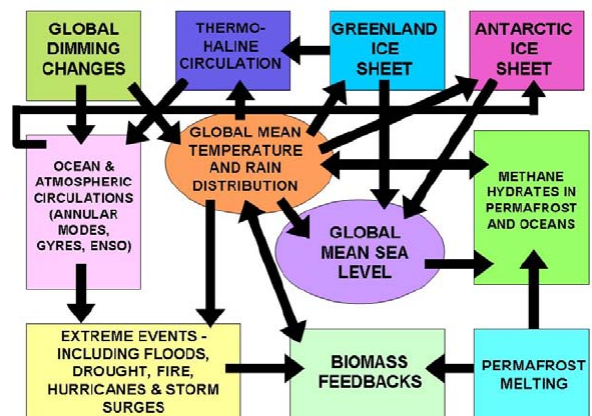


Illustration 165: interacting loops of Earth's climate system. After Pittock.

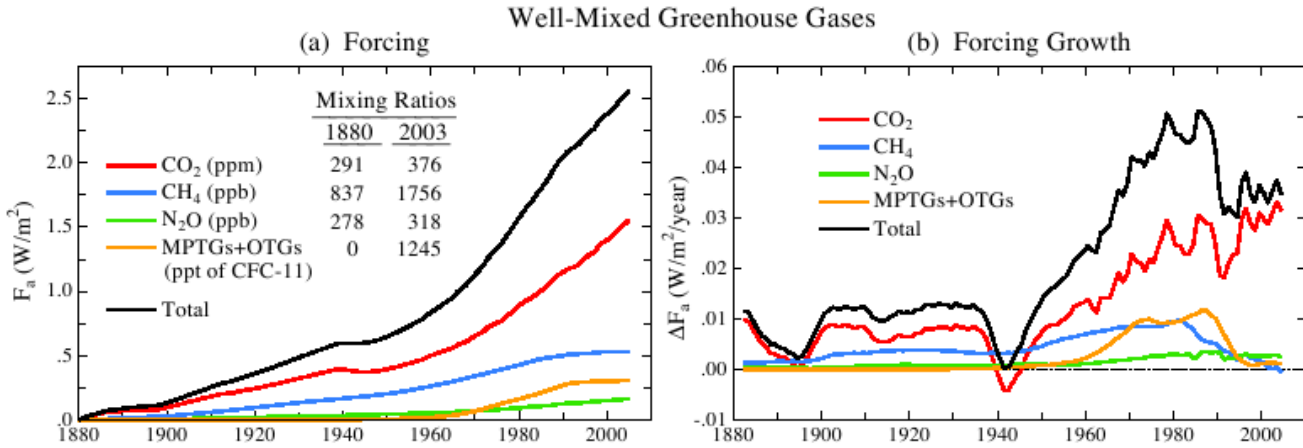


Illustration 166: Growth of GHG, the primary forcing for modelE. Source Hansen et al, 2007.

to occur much later, in another part of the world. Such nonlinear systems are central to chaos theory, exhibiting fantastically complex and unpredictable behavior. According to the IPCC:

“The physical climate system is highly complex, has aspects that are inherently chaotic, and involves non-linear feedbacks operating on a wide variety of time scales. Our empirical knowledge of how these operate ranges from being good on decadal time scales, moderate over time scales of 100-1000 years, to being quite limited at 10000 years and longer.”<sup>383</sup>

From the shaky foundation of incomplete theory, with input and defining data from an uncertain and error laden climate history, climate scientists have boldly constructed GCM computer programs, confidently basing their public pronouncements on the models' dubious predictions.

### GISS modelE

The GCM used to provide predictions for the IPCC's latest report is called *GISS modelE*, specifically model III, a version of modelE frozen in 2004. ModelE is actually a composite of an atmospheric model and four different ocean circulation models, along with other factors. ModelE is driven by ten measured or estimated climate forcings. A large team of NASA investigators, led by Hansen and Ruedy, produced an in-depth, eye-opening study of modelE's

strengths and weaknesses in their 2006 paper titled “Climate Simulations for 1880-2003 with GISS Model E.”

As Jeff Kiehl noted, “models produce a lot more information than we have observations for, and this is not a satisfactory situation.” This has not stopped the IPCC, and others, from using models to produce a deluge of data with which to inundate the public and the media. Some of the illustrations in the Hansen report are revealing. For instance, Figure 1 from the report shows the relative strengths and growth in the primary forcing used to drive modelE, well-mixed greenhouse gases (Illustration 166). It should come as no surprise that CO<sub>2</sub> concentration dominates.

When all the driving forcings are viewed together, the result is still clear—CO<sub>2</sub> is the main driving factor of modelE. This is shown in Figure 5 from the report (Illustration 167). Notice that there is a conspicuous lack in forcing variability during the 1940s, a period of time when global temperature hit a peak and then went into decline. “The model's fit with peak warmth near 1940 depends in part on unforced temperature fluctuations,” states the report, adding “It may be fruitless to search for an external forcing to produce peak warmth around 1940.” This is an admission that modelE is incapable of accurately reproducing the observed temperature fluctuations of the past 120 years. Yet we are asked to accept that the IPCC's projections for the next 100 years, using modelE, are accurate.

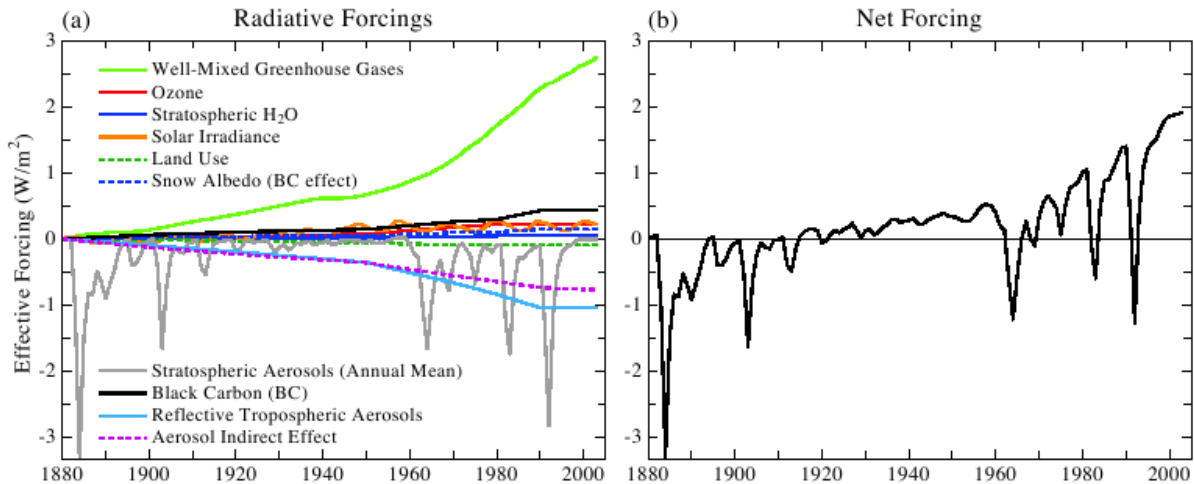


Illustration 167: Net forcings used to drive modelE. Source Hansen et al, 2007.

They also report that the “greatest uncertainties in the forcings are the temporal and spatial variations of anthropogenic aerosols and their indirect effects on clouds.” This statement reinforces the concerns of others regarding the inability of current models to accurately represent cloud cover and cloud formation mechanisms due to weak theory and even weaker experimental data. Recall that the IPCC's report listed understanding of aerosols' role in climate regulation at only 10% (Illustration 14, page 18).

Graphs of output from modelE illustrate the model's problem areas. This is shown in Figure 6 from the Hansen report, reproduced in Illustration 168. Atmospheric temperatures, shown in the three graphs on the left, are mostly in agreement with historical measurements but become less accurate in the most recent two decades. It is interesting that these values become more inaccurate just when CO<sub>2</sub> levels start rising. Surface temperature, shown in the upper right hand graph, performs significantly worse. The model does not accurately reproduce the variability of recorded surface temperature and there are decade-spanning periods where it consistently underestimates or overestimates surface temperatures. But worst of all are the predictions for ocean ice coverage, which overestimates sea ice for one hundred years, and then underestimates it for the past twenty years. Still, the true accuracy of the model is hard to discern from the data plots.

A better idea of the accuracy of modelE's backcast predictions for the past 120 years can be found in the Hansen report's written narrative. This fifty page report contains a frank assessment of the accuracy of the IPCC's favorite GCM. Here are some of the major problems cited in the study:

- The atmospheric model produces polar temperatures as much as 5-10°C too cold in the lower stratosphere during winter and the model produces sudden stratospheric warming at only one quarter of the observed frequency.
- A 25% regional deficiency in summer stratus cloud cover of the west coasts of the continents—resulting in excessive absorption of solar radiation of as much as 50 W/m<sup>2</sup>.
- A net deficiency in solar radiation absorbed over tropical regions of 20 W/m<sup>2</sup>.
- Sea level air pressure readings are too high by 4-8 hPa<sup>†</sup> during winter in the Arctic and 2-4 hPa too low year-round in the tropics.
- A 20% shortfall in rain over the Amazon basin.

<sup>†</sup> Hectopascal (hPa), a unit used worldwide for air pressure. One hectopascal corresponds to about 0.1% of atmospheric pressure at sea level.

Coupled Atmosphere-Ocean Model

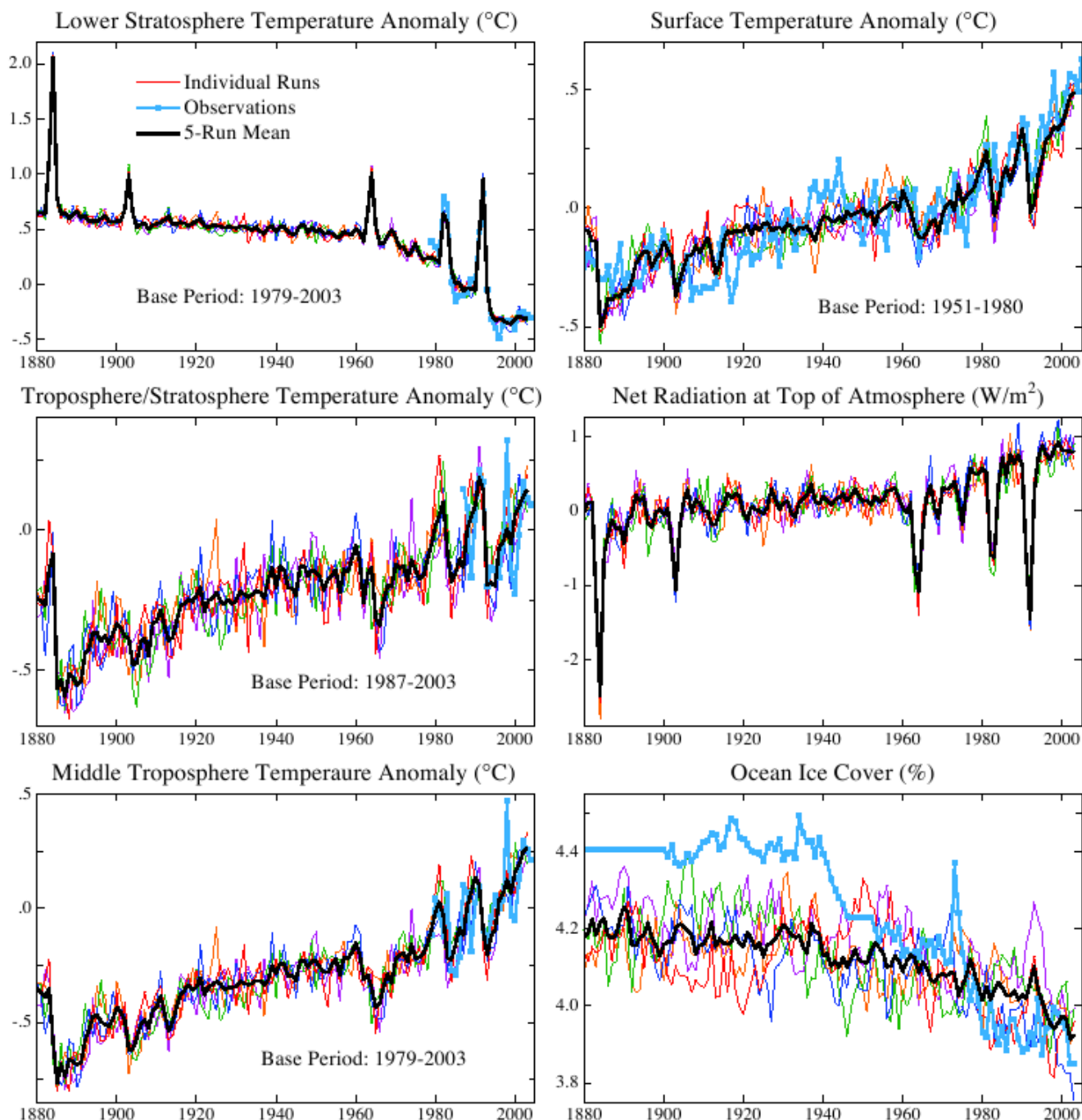


Illustration 168: Results from modelE taken from Hansen et al, 2007, figure 6.

- A 25% deficiency in summer cloud cover in the western United States and central Asia, causing summer temperatures to be ~5°C too high in these regions.
- Global sea ice cover is deemed realistic but the distribution of sea ice is not, with too much sea ice in the Northern Hemisphere and too little in the Southern Hemisphere.

- Too much sea ice remains in the Arctic summer affecting climate feedback rates.
- Unrealistically weak tropical El Niño-like variability.

Despite all these shortcomings, modelE “fares about as well as the typical global model in the verisimilitude of its climatology” in IPCC model comparisons.<sup>384</sup> We have already mentioned the study of 108 different models that found predicted temperature increases of 0.29-15.6°F (0.16-8.7°C)<sup>385</sup> so perhaps modelE does fare about as well as other models.

In all, Hansen's report is a blunt admission that, after 30 years of development and more than \$50 billion in funded research, current climate models are just not up to the job. In fact, if the predictions of the Third Annual Report are compared with the predictions in Annual Report 4, the IPCC's efforts are moving in reverse—the new predictions in AR4 have a wider range of uncertainty than those in the TAR (1.1-6.4°C vs 1.5-5.8°C).

### Modeling Invalidated

In a famous paper, entitled “Ground-water models cannot be validated,” Leonard F. Konikow and John D. Bredehoeft, state that some natural systems cannot be accurately modeled. They state, “testing the predictive capability of a model is best characterized as calibration or history matching; it is only a limited demonstration of the reliability of the model.”<sup>386</sup> If testing a model cannot prove its ability to provide accurate predictions then there is no way climate modeling, as a technique, can be trusted. They summarize their findings, saying the emphasis in trying to understand natural processes should shift “away from building false confidence into model predictions.”

Konikow and Bredehoeft are not members of the scientific fringe. Their paper won the Meinzer prize from the Geological Society of America, the highest honor in the field of hydrogeology in the US.<sup>387</sup> They are not the only modeling experts to warn about the fundamental problems of modeling complex natural processes.

Hendrik Tennekes, Professor of Aeronautical Engineering at Pennsylvania State University and the former director of research at the Royal Dutch Meteorological Institute, was a pioneer in multi-modal weather forecasting. Though a strong proponent of scientific modeling, he has challenged the use of unproven scientific models to predict the future course of global warming. Pointing to the complexity of Earth's climate and the incomplete nature of climate models, Tennekes has said, “if I try to look at climate modeling from this perspective, I’m almost fainting.”<sup>388</sup>

An expert in modeling complex systems, Tennekes scoffs at those who think that computer models which implicate CO<sub>2</sub> levels as the primary control for Earth's climate can be trusted, or that trying to regulate the world's temperature by manipulating CO<sub>2</sub> levels is a rational idea. In a newspaper op-ed piece, printed in the *Amsterdam De Volkskrant* on March 28, 2007, Professor Tennekes takes those who believe that CO<sub>2</sub> can be used to control climate to task.

“I protest vigorously the idea that the climate reacts like a home heating system to a changed setting of the thermostat: just turn the dial, and the desired temperature will soon be reached. We cannot run the climate as we wish. That is fortunate, because a bad season for farmers may be a boon for the tourist industry, deteriorating conditions for French farmers may mean improving conditions for their Polish colleagues, what is good for winter wheat may make things worse for corn, and so on. We are not dealing with a machine, but with Nature herself, and she is not easily mocked.”<sup>389</sup>

The limitations of computer models are well recognized by many of the scientists working on climate predictions. This includes scientists associated with the IPCC reports, such as Michael Oppenheimer, Professor of Geosciences and International Affairs at Princeton University. Dr. Oppenheimer was a lead author and contributing author to the IPCC Fourth Assessment Report, and was a lead author or contributing author to various chapters of the Second and Third Assessment Reports of IPCC. Here are some comments taken from an article by Oppenheimer in *Risk Analysis*:

“As with WAIS, the ice mass balance depends on the difference between the ice loss rate and ice accumulation, but the models have not predicted the current loss rate correctly, particularly at the GIS periphery. It is noteworthy that a local acceleration of GIS in response to surface melting that appears to lubricate the ice sheet base has been observed. This process is not incorporated in ice sheet models, and we have no idea how generally it might function over the ice sheet.”<sup>390</sup>

The abbreviation WAIS stands for “Western Antarctic Ice Sheet” and GIS for “Greenland Ice Sheet.” Note that this comment concerns ice sheet models—only one component of building a comprehensive model for Earth's entire climate system. Even addressing a relatively simple sub-problem, the models used are incomplete, give incorrect answers, and the researchers have no idea how the missing factors would affect their results.

Perhaps the best synopsis of climate modeling comes from a scientific outsider, Freeman Dyson, Professor of Physics at the Institute for Advanced Study, in Princeton:

“My first heresy says that all the fuss about global warming is grossly exaggerated. Here I am opposing the holy brotherhood of climate model experts and the crowd of deluded citizens who believe the numbers predicted by the computer models. Of course, they say, I have no degree in meteorology and I am therefore not qualified to speak. But I have studied the climate models and I know what they can do. The models solve the equations of fluid dynamics, and they do a very good job of describing the fluid motions of the atmosphere and the oceans. They do a very poor job of describing the clouds, the dust, the chemistry and the biology of fields and farms and forests. They do not begin to describe the real world that we live in. The real world is muddy and messy and full of things that we do not yet understand. It is much easier for a scientist to sit in an air-conditioned building and run computer models, than to put on winter clothes and measure what is really happening outside in the swamps and the clouds. That is why the climate model experts end up believing their own models.”<sup>391</sup>

## The IPCC Report Reexamined

Computation is widely recognized as one of the three pillars of modern science, along with theory and experiment. For climate science, theory translates to understanding how Earth's climate system works, experiment is the collection of data from various sources, and computation is computer modeling. As we have seen, all three pillars of climate science are weak and wobbly.

Here we see the limits of climate science: incomplete, subjective data are used to feed simplistic, unverifiable models in an attempt to make predictions about a complex system that is only partially understood. Climate science is simply too immature to be relied on for definitive predictions about future climate change. Despite widespread recognition of the pitfalls and limitations of modeling, the IPCC would ask us to base worldwide technological, environmental, economic and political policy on model predictions.

In an issue of the Royal Society's journal, *Philosophical Transactions*, an article appeared that discussed the difference in Pascal's approach to statistics and the Bayesian approach. Pascal considered each statistical event, such as a coin toss, as independent of any previous events, while Bayes allowed prior events to influence subsequent ones. Scientists almost always use the statistically independent model, in order to avoid having bad assumptions bias their models. Unfortunately, including prior assumptions into climate models is impossible to avoid. By their nature, climate models contain a multitude of variables that are interrelated in complex ways—effectively, Bayesian assumptions. To quote from the *Economist* regarding this situation:

“Climate models have hundreds of parameters that might somehow be related in this sort of way. To be sure you are seeing valid results rather than artifacts of the models, you need to take account of all the ways that can happen. That logistical nightmare is only now being addressed, and its practical consequences have yet to be worked out.”<sup>392</sup>

The use of computer models has been passed off as science fact when it is actually a technique used

when real observations and genuine understanding are not available. As fundamentally weak as the IPCC's methodology is, the press and the public are convinced that the facts have been established and consensus has been reached in the scientific community. What do scientists think about model-based climate science? Again quoting from Dr. Pilkey and Dr. Pilkey-Jarvis:

“We believe that global change modelers fall into two categories. There are the true believers who take no prisoners, believe every word, every model prediction, and feel that criticism is unwarranted or even un-American. A much larger group is uncomfortably aware of the insurmountable nature of the complexities in global change models.”<sup>393</sup>

Consensus? Hardly. Still, a continual parade of boffins appears before government agencies and the public urging action. On National Public Radio, on May 31, 2007, NASA Administrator Michael Griffin commented on the American space agency's role in fighting global warming:

“I have no doubt that ... a trend of global warming exists. I am not sure that it is fair to say that it is a problem we must wrestle with. To assume that it is a problem is to assume that the state of Earth's climate today is the optimal climate, the best climate that we could have or ever have had and that we need to take steps to make sure that it doesn't change. First of all, I don't think it's within the power of human beings to assure that the climate does not change, as millions of years of history have shown. And second of all, I guess I would ask which human beings — where and when — are to be accorded the privilege of deciding that this particular climate that we have right here today, right now is the best climate for all other human beings. I think that's a rather arrogant position for people to take.”<sup>394</sup>

In all, a thoughtful and measured reply to the host's question, “do you have any doubt that this is a problem that mankind has to wrestle with?” Before the day was out, Steven Edwards, writing on the *Wired Magazine* blog, asked, “Does this guy deserve his position as NASA's administrator?”<sup>395</sup> We would guess that Edwards, a non-scientist, falls into the true believer, take no prisoners category.

The subject has become so politicized that rational public debate is no longer possible. Battle lines are drawn, positions cast in concrete, and the charge is led by the IPCC. Bob Carter, a research geologist and Professor of Geology at James Cook University, Townsville, offers his opinion of the IPCC:

“It's received advice from many excellent scientists and they're still involved with the IPCC, but it's not primarily a scientific body. In the end, it's a political body with a life of its own and, as such, the advice to policy makers that the IPCC releases no longer gives primacy to scientific reasoning. It actually gives primacy to political advice.”<sup>396</sup>

Here is the crux of the matter—political interests have taken immature and incomplete science, and inflated it into a global crisis. We need to be mindful of the environment. Mankind should eliminate excessive emissions of any type. But, we do not need to follow the tainted advice of bureaucrats and politicians who have turned scientific conjecture into a crusade in favor of their own opinions and a jihad against those whose ideas they dislike.