Global Warming Models: Are they Adequate for use in Policy Development?

*By Gerald T. Westbrook**

Introduction - Reliance on Computer Data

What is the evidence to support the claims that anthropogenic (man-made) global warming will be the major issue it has been depicted to be? Clearly there is no global warming laboratory, no global warming pilot plant in which to conduct relevent experiments. Computer models of the climate have been inserted into such roles. A very major portion of the global warming case is based on results from such models. How good are these? What are their limitations? How can one know that computer simulations of the climate 100 years from now will have any legitimacy? Should they be used in policy developments in areas where the costs could be in the hundreds of billions of dollars? A broader question is how does our government reach sound strategic decisions in areas where science is a dominant factor? There are significant problems looming in this area of society's ability to interface with science, comprehend what is going on and to utilize it's findings. Carl Sagan has indicated that 95 percent of our population may be scientifically illiterate. In addition, there seems to be a rebirth of pseudo-science underway. Finally scientists are caught right square in the middle of the global warming debate and face substantial stress from the politicalization process. This is a situation where one can see the potential for real problems.

A stronger understanding of the computer models behind global warming assessments will provide one with a better position to both understand this controversial issue and to answer some of the above questions. A recent publication[1] provides an excellent and balanced situation review on global warming in general. The objective of this paper will be to provide a situation review on the status of the models used in the global warming field. This review will first highlight the challenge involved in modeling the climate. The complexity involved is staggering. This complexity mandates the use of huge simulation models - the General Circulation Models — abbreviated the GCMs. A very brief summary of the nature of these models will be provided, followed by concerns on their structure/logic and on their performance. This will lead to a discussion of the uncertainties involved in this field.

It is suggested that these climate simulation models, while very useful for research planning and education roles, just might not yet be valid as a basis for national or international policy steps.

The Complexity of Our Climate

The temperature[2] behavior from 1880 to 1995, based on NASA/GISS data, shows three trends:

- a warming of ~ 0.6 °C from 1880 to1939,
- a cooling of ~ 0.2 °C from 1939 to1965,
- an additional warming of ~ 0.4 °C from 1965 to1995.

The total rise in this data set amounts to ~ 0.8°C. (Note that other global data sets show less warming over this period. Indeed, the last UN position on temperature increase over this period was 0.3°C to 0.6°C.)

What are the forces that have shaped this record? Proponents[3] have argued it was the change in the atmospheric concentration of greenhouse gases. If that were the case one would expect a gradual, monotonically increasing profile, with a noticeable upturn after 1945. Instead we get the above three distinct trends. Further, most of the warming occurred over the first trend, whereas most of the greenhouse gas emissions occurred over the third trend. Clearly these emissions could not cause the warming in the first period. Hence, almost all of the 0.6 °C warming in the first trend must be part of the natural rhythm of the climate. It follows that at least some of the remaining trends must also be due to natural forces.

More recently other variables, in addition to the greenhouse gases, have been studied. These have included stratospheric ozone concentration, man made aerosols, volcanic eruptions and solar output anomalies. This writer has periodically strived to enumerate the number of variables that might have some influence on our climate. This has grown to the following sets of variables, listed alphabetically:

- ASLs - Aerosols: would include both natural and manmade species. The natural ASLs would include dust, sea salt, marine based SO_2[4], and volcanic contributions. The anthropogenic ASLs would include SO_2 and SO_x from combustion.
- DMYs - Dummy variables: these are used in econometrics to capture random events. The volcanoes would include such eruptions as Mt. Toba and Mt. Pinnatubo. The melt water pulses would be inflows of fresh water for example by the collapse of ice dams.
- EMAs - Earth Motion Anomalies: are the eccentricity of the Earth's orbit, its tilt and its wobbles. These vary over 100, 41 and 23/19 K year cycles, and lead to major variation in solar insolation time series, the solar energy reaching the Earth at various latitudes and seasons.
- FBKs - Feedbacks: would represent the many complex interactions that exist in our climate.
- GACs - Global Air Circulations and
- GSCs - Global Sea Circulations: these two fields would include such phenomena as the El Nino, and the Southern Oscillation (ENSO); and ocean and deep thermo-haline circulations.
- GHGs-Greenhouse gases: would include[4] CO_2, CH_4, CO, H_2O_V, H_2O_L, O_3, CFCs, N_2O and Others.
- LAGs - Lagged variables: these might be included for independent and/or dependent variables.
- SOAs - Solar Output Anomalies: would include brightness changes over the 11 year sunspot cycle; UV changes over long-term lulls in sunspot activity; and changes in sunspot cycle length.
- SSAs - Solar System Anomalies: would include the orbital

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[1] See footnotes at end of text.

tilt, asteroidal dust and interstellar dust.

Other variables would become important as interest increases on timing and location, such as:

- Location: Hemisphere, Latitude, Altitude; and
- Temporal: Summer/Fall/Winter/Spring, Night/Day.

A Description of the General Circulation Models - the GCMs

The delineation of the spectrum of climate variables has been used as a vehicle to help convey the complexity of the task at hand. While multiple regression models have been used in this field, it was decided long ago that the overall job could only be tackled by very large simulation models.

The development of the GCMs has been striking, and represents the outstanding creativity in the scientific community today. Many models have been built. In 1990, modeling of the global climate was being carried out intensively by at least 14 major groups in the U.S. and about the same number in the rest of the world. These models were originally designed for research planning and education, not policy development. This begs the question: are they good enough for this more demanding task?

The GCMs are based on dividing the world up into a multiplicity of cells. One report indicates models vary from 800 to 11,000 rectangles and 5 to 15 layers. The physical processes in each cell would be simulated and both material and energy transfer would be permitted between cells. Typically temperature, humidity, air pressure and wind speed would be included in each cell in the atmosphere. Simulation of the ocean would be done in a like fashion, but the interface with the atmosphere would likely be weak. Finally the system would then be subject to some external forcing mechanism, such as incremental radiation retention via an increased concentration of GHGs. Again the key question remains: Is it good enough?

Concerns about the GCMs: Structure and Logic

1 Model Stability: Several years ago separate atmospheric and hydrospheric (ocean) models were coupled, but the simulation was less than perfect and in some cases, unstable. The practice[5] has been to arbitrarily adjust the amount of heat and moisture flowing between these spheres until the model produces a reasonable representation of the present climate. In most cases these factors have been large.

2 Model Sensitivity: The variety of GCMs yield a range of forecasts from 1 to 5°C when forced with a doubling of CO_2 - or an equivalent CO_2 doubling (ECD)[6] -, a range far too broad to be acceptable.

3 Role of Water Vapor - H_2O_v: The GCMs would not predict very much warming due to CO_2 changes alone. The models rely on a major amplification factor[7] from the estimated H_2O_v in the atmosphere. The simulation of this feedback is controversial and, in general, not accepted by the skeptics.

4 Atmospheric Retention of CO_2: The GCMs tend to exaggerate the CO_2 retained in the atmosphere. These models use a constant retention[8], typically around 56 percent. Recent studies have shown this area is very complex and dynamic, aspects not captured in the models. For example, one paper[9] reported, over a 12 year period, values from 24 percent to 81 percent to 43 percent to 85 percent and finally back down to 21 percent retention.

5 Impact of Inclusion of Man-made Aerosols in the Models: Proponents claim addition of ASLs dramatically improves the GCMs. Skeptics note that inclusion, while a step in the right direction, actually worsens the comparison in North America and Europe. These are the two regions with the maximum emission of ASLs. They are the regions where the ASL effect should be the strongest. Data[10] in the Table 1 summarizes results for past 100 years and highlights this discrepancy. While the inclusion of ASLs in the global simulation brings GCM results very close to the observed, the opposite is true for the two key regions.

Table 1

Region	ΔT °C Actual	ΔT GCM Results °C GHGs	GHGs/ASLs
Globe	0.50	0.78	0.48
N. America	0.83	1.09	0.19
Europe	0.77	0.51	0.13

6 Grid Spacings: These vary between GCMs, from 10° by 10° (Latitude, Longitude) down. The smallest grid spacing noted by this writer is 2.8° by 2.8°. The atmosphere would also be divided into as many as 18 layers. With a 5° by 5° grid size, one is talking of large, non-homogeneous regions the size of New Mexico, or from San Francisco to Lake Tahoe to Death Valley and back to LA. Improved models will generally need more spatial detail to better simulate the processes involved. For example ASLs are released in a very non uniform manner over the globe. Unlike CO_2, they have a short shelf life. More spatial detail would be useful here. The down side of this type of change is a huge increase in computer time.

Concerns about the GCMs: Performance

1 Temperature Changes over past 100 years: Ground Based Data (GBD), vs GCM Predictions - For the GBD increase the most recent UN estimate is 0.3 to 0.6°C. For the GCMs, with some allowance for the ASL cooling effect, recent case studies have predicted warming from the 0.48°C reported above, to ~ 1.5°C[11], a range of about 0.5 to 1.5°C. While the low end of this range overlaps the GBD range, the GBD data contains a significant portion of natural warming. Hence it is fair to conclude that the GCMs still exaggerate the amount of warming that is occurring.

2 Temperature Changes over past 100 years: Satellite Based Data (SBD), vs GCM predictions - The SBD[12] shows almost zero warming in the 18 year satellite record. Proponents argue that the SBD is flawed[13]. Skeptics reject that position. To the extent that the SBD can be considered a surrogate for the surface temperature, the disparity between SBD and GCMs is even greater than for GBD.

3 Night vs Day Warming: The spread[14] between daily maximum and minimum temperatures is getting smaller. This is thought to be due to a gradually increased level of clouds. This change could be due to the observed warming, to the increase in ASLs, to the increase in GHGs in general, to jet aircraft exhausts, to natural forces or a combination of all of the above. Increased clouds will reduce energy coming in during the day and help retain more of this energy at night. Hence, most of the warming that has occurred has been at nighttime. Daytime temperatures display little or no warm-

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ing. One report cited values of 0.84 to 0.28 °C or a ratio of 3/1. In contrast, the GCMs have predicted a ratio of 11/10.

4 Winter vs Summer Warming: The ratio of winter to summer warming has been reported at 4.2/1, consistent with more nighttime during the winter. One scientist noted: *Know of no GCMs that predicted such a desirable result.* This is a favorable trend in the sense that it would lengthen the growing season.

5 Arctic Warming: The GCMs have always predicted maximum warming would occur in the polar regions. Actual results show little warming. For example, three studies, based on an average span of 72 years, averaged 0.1 °C warming (Range -1.5 to +1.1 °C). Three other reports on GCM results, over an average time span of 36 years, predicted 2.0 °C warming (Range 1.7 to +2.3 °C), in only half the time.

Uncertainties

It is easy to get the conviction that there is a consensus from the scientific community that global warming is here and action must be taken immediately. Indeed, many proponents are making this claim every chance they get. Yet this area is endemic with uncertainties and an on-going debate exists. Clearly there are major problems with the computer models. In addition there are major uncertainties in the background processes and on how to simulate these. One report[15] by the noted sceptic, R. Lindzen, charges the amplification mechanisms used in the GCMs depend on what is likely to be a severe misrepresentation of the relevant physical processes. A second report [16] – by a writer who has been more than friendly to the proponent's side in the past – summarized: we shouldn't be surprised by the shortcomings of the GCMs given the number of climate processes that are poorly understood or totally unknown.

A recent report[17] provided an estimate of eight potential climate change forcings, including the basic greenhouse gases. The other seven forcings included a mix of ASL forcings and a fairly narrow and limited solar forcing. These were estimated in Table 2 as, in watts per square meter:

Table 2

Forcing	Expected Value W/m²	Range W/m²	Confidence
Basic gases – CO_2, CH_4, N_2O, CFCs	2.4	2.1 to 2.8	High
Sum of the eight forcings reviewed	2.7	-0.6 to 4.1	Very Low

The above expected values can be compared to the 153 W/m² energy input from the sun, and the 299 W/m² basic greenhouse energy flux.

Additional inputs on uncertainties found in climate simulations has been given in recent testimony.[18] *....the effect of humidity alone is about 20 W/m². An additional uncertainty of 25 W/m² stems from calculating the heat flow from the equator to the polar regions. This gives rise, finally, to area-by-area "flux adjustments" of up to 100 W/m² in some areas of the coupled ocean-atmosphere simulations.*

Summary

This critique of the GCMs does not mean to imply they have no merit. Rather, its purpose is to argue that the results of the GCMs needs to be put into a better and more objective frame of reference. The models, while surely useful, are far from perfect and as such they shouldn't be placed on a pedestal and treated with awe. The noted hurricane forecaster, Dr William Gray, recently commented[19] on this subject. His remarks are paraphrased as follows: *The models have been superb when used for the next 5-10 days, but when modelers move out onto the climate area the complexity becomes too damn much.*

The above rather damming summary of logic and performance concerns, plus the very high level of uncertainty present would suggest the GCMs are not yet sufficiently developed and tested for use in the policy arena. One proponent, in what otherwise was a very good paper[20], has presented, what to this writer is a rather incredible argument namely: that the burden of proof that a model result is not valid, should be on the critic not on the modeler. This is 180 degrees opposite to the situation in industry, where anyone who developed a new computer system to simulate or optimize, say large petroleum or chemical processes, had to prove to hard nosed management that what they had was right. It is 180 degrees opposite the situation faced by any software company that wants to market, for example, a new econometric model. The burden of proof is on the developer. The developers/users of the GCMs should be no different.

Footnotes

[1] National Geographic Research & Exploration, Global Warming Debate, Spring 1993.

[2] The estimation of the average annual temperature for the Earth is a difficult task. Several major databases have been developed that differ in geographic coverage; in extent of inclusion of measurements from land, sea and ice-snow surfaces and in the tightness of admission standards. This work involves obtaining temperature records from tens of thousands of measurement systems (weather stations, ships, other). It involves understanding the history of each system and its surroundings and an assessment on whether it can be accepted into the data set and if so if any corrections are needed for possible biases.

[3] In this essay proponents refer to those who believe that serious consequences are imminent unless mankind reduces its emissions of greenhouse gases immediately. Skeptics do not believe that case has been made yet, for such a future.

[4]

CFCs – Chloroflourocarbons	CH_4 – Methane
CO – Carbon Monoxide	CO_2 – Carbon Dioxide
H_2O_V – Water vapor	H_2O_L – Water, liquid
N_2O – Dinitrogen oxide	NO_x – Misc. Nit. Oxides
O_3 – Ozone	SO_2 – Sulfur Dioxide
SO_x – Misc. Sulfur Oxides	

[5] Kerr, R., Climate Modeling's Fudge Factor, *Science*, 265, 9-9-94.

[6] Each greenhouse gas contributes a unique amount to the overall greenhouse effect. As such the impact of a doubling of CO_2 can be defined by CO_2 alone, or by the sum of the contributions, referred to as the ECD – the Equivalent CO_2 Doubling.

[7] Lindzen, R., "Errors Hurt Global Warming Theories," *NY Times*, 11-30-90.

[8] Keeling, C. D. et al, "Atmospheric Retention of CO_2," *Nature*, 375, 6-22-95.

[9] Francey, R., "Changes in oceanic and terrestrial CO_2

uptake," *Nature*, 373, 1-26-95.

[10] George C. Marshall Institute, "Are Human Activities Causing Global Warming, 1996."

[11] Mitchell, J.F.B., et al, "On Surface Temp., GHGs, and ASLs: Models and Observations," *J. of Climate*, 8, 10-95.

[12] In concept, the satellite based data (SBD) should be far superior to the ground based data (GBD), except for its short history. Instrument changes and station environment problems are far better defined. And there is no comparison on the degree of coverage of the planet. However proponents argue there are several things wrong with the SBD, such as it does not measure the Earth's surface temperature and its values are obfuscated via ozone depletion. On the first point a comparison of SBD and weather balloon data (WBD) shows an excellent agreement between 5000 and 30,000 feet, with neither record showing a warming trend. On the second point comparisons of temperature trends per decade, between GBD and SBD, shows flaws in the O_3 hypothesis. For example, in the tropics, with ~ zero O_3 depletion, data shows the largest gap between GBD and SBD trends. And in the Antarctica, a region of maximum O_3 depletion, get the best fit. Hence the O_3 hypothesis can be rejected.

[13] World Climate Report, "Does O_3 Fall Explain Differences between Satellite & Ground Based Temp.?", 1, 3-4-96.

[14] Karl, T., et al, "Asymmetric Trends of Daily Max. and Min. Temp.", B.of the American Meteorol. Soc., 74, 1993.

[15] Lindzen, R., "Absence of a Scientific Basis," *National Geographic Research & Exploration*, 9(2), 1993.

[16] Kerr, R., "Dark Clouds Promise Brighter GCM Future," *Science*, 267, 1-27-95.

[17] Schwartz, S., et al, "Uncertainties in Climate Change Caused by Aerosols," *Science*, 272, 5-24-96.

[18] Baliunas, S., "Uncertainties in Climate Modeling," Testimony to the Senate Committee on Energy and Nat. Res., 9-17-96.

[19] Gray, W., Colorado State University, "Predicted Hurricane Activity for 1997: Is Global Warming Causing More and Bigger Hurricanes?", Speech at the National Hurricane Association meeting, Houston, TX, 4-25-97.

[20] Trenberth, K., "The Use and Abuse of Climate Models," *Nature* 386, 3-13-97This critique of the GCMs does not mean to imply they have no merit. Rather, its purpose is to argue that the results of the GCMs needs to be put into a better and more objective frame of reference. The models, while surely useful, are far from perfect and as such they shouldn't be placed on a pedestal and treated with awe. The noted hurricane forecaster, Dr William Gray, recently commented (19) on this subject. His remarks are paraphrased as follows: The models have been superb when used for the next 5-10 days, but when modelers move out onto the climate area the complexity becomes too damn much.

London Week

December 6-10, 1997

- Saturday 6 December: European Affiliates EFCEE/IAEE meeting including working lunch.
- Sunday 7 December/Monday am 8 December - transfer from London to Warwick University.
- Monday and Tuesday 8 & 9 December – BIEE/Warwick Second Conference on:

The International Energy Experience: Markets, Regulation and Environment

This is a residential conference - See "Call for Papers"

- Wednesday 10 December: East European Workshop No. 5.

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AIEE Energy and Economics Books

The Energy Sources Between Crisis and Development by Vittorio D'Ermo is published.

The Italian Affiliate, AIEE, has started to publish a collection of books on energy economics addressed both to energy sector experts and the public at large.

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The book covers the trend of energy sources and their development, particularly in the last few years, as well as new perspectives on European energy markets resulting from privatization and deregulation. It will be used as a basic textbook of the Master in Economics of Energy Sources organized by AIEE with the LUISS Guido Carli University of Rome.

The book is in Italian and its selling price is ITL 16,000 (US$ 10).