Global Warming: Anthropogenic or Natural ?

by Thomas P. Sheahen

In the media, the perception is widespread that all the questions about "global warming" are settled, and all scientists are in agreement. That is not so. This memo strives to restore balance on this topic.

The evidence is very good that the globe is warming, but it has been gradually drifting upward in temperature for 18,000 years. Scientists are not debating that very general point. The controversy of today is whether mankind is causing the current trend (*Anthropogenic Global Warming* = AGW), or whether it's just natural variations at work. This is where the debate is, and which way it goes has great economic consequences.

Over millennia, swings in ocean temperature led to changing amounts of CO_2 in the atmosphere (warmer ocean → more CO_2). For a long time the atmospheric fraction of CO_2 was stable at about 280 parts per million (*ppm*), and this is commonly termed the *pre-industrial baseline*. However, in recent decades the atmospheric level of CO_2 has greatly increased, and most people attribute the increase to mankind burning fossil fuels. Such *anthropogenic* CO_2 is comparable with the CO_2 already in the atmosphere, but may be insignificant compared with CO_2 in the ocean.

The CO_2 increase is considered anthropogenic; but is the *temperature* increase? Wherever there is a correlation, it is standard practice to look for causation. This is a reasonable way of pursuing science, and most scientific theories develop over time via a process in which this is one step. But scientists agree that correlation never proves causation.

The role of this paper is to examine the various arguments that have been made, both for and against AGW, with emphasis on their science content, as contrasted to their "newsworthy" aspects so commonly emphasized by the public media. After reviewing a variety of authoritative presentations, I have concluded that there is *not* a monolithic body of scientific opinion (a consensus) that mankind is causing global warming. What is needed for the immediate future is truly "open" debate in the best scientific sense. The scientific maxim "*Data Trumps Theory"* needs to be restored to a pre-eminent position.

THE GREENHOUSE EFFECT

To understand the earth's temperature variations, it is entirely plausible to think in terms of the *Energy Balance*: Energy reaches the earth from the sun, and leaves the earth by being radiated away into space. In the simplest model, the earth is simply a ball radiating as a black body at an equilibrium temperature. If additional energy is generated on the earth, the outward radiation will increase, the atmospheric gases will warm, and the equilibrium surface temperature will increase as well.

The foremost atmosphere gas that absorbs in the infrared[1] is water vapor, H_2O. High-level clouds also affect the heat transfer outward from the surface. Third in importance is CO_2, which likewise absorbs infrared radiation. It is plausible to think that heat radiation leaving the earth's surface would be captured by H_2O and CO_2 in the atmosphere, and re-radiated back toward the surface; and hence both the surface and the atmosphere would be slightly warmer[2]. (Other gases also present in the atmosphere in small amounts do likewise.) This is known as the *Greenhouse Effect*,[3] and hence H_2O and CO_2 (and the others) are collectively termed *GreenHouse Gases* (GHGs).

The relative magnitudes of gaseous absorption are crucial; H_2O is a much more important greenhouse gas than CO_2. H_2O is responsible for keeping the earth comfortably warm. Also, it is essential to distinguish between water vapor and clouds. Clouds can be separated into two general groups: heavy low-level clouds, and light high-level clouds (cirrus clouds). Generally, low-lying clouds *reflect* more solar energy (back out into space) than they *capture* via the greenhouse effect, which results in a net *cooling*. However, light high-level clouds (cirrus) *enhance* the warming greenhouse effect.

The role of CO_2 in *radiative forcing* was addressed quantitatively over a century ago by Arrhenius[4], who concluded that doubling CO_2 concentration would raise the temperature by 1.6 ^oC. In subsequent decades, more advanced models followed. Computer models have been around for over 30 years that can calculate the attenuation of radiation[5] in selected infrared bands due to the amount of CO_2 in the optical path. Combining such optical models with *Global Circulation Models* (GCMs) has allowed very advanced numerical modeling to take center stage in this field.

Advanced computer models that try to include everything (ocean currents, jet stream, glaciers, vegetation, etc.) quickly become opaque and difficult to understand. On the other hand, modest improvements of the original Arrhenius theory go a long way toward improving the model without introducing great complexity. Robert Knox[6] introduced a two-layer, two-temperature model, which could still be solved analytically. Knox subsequently added a convective flow term[7] which changed the sensitivity of temperature (to radiative forcing) by 20%, all without losing sight of the physics taking place. The importance of varying *emissivity* stands out quite clearly in this model.

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1 See, for example, H. D. Young & R. A. Freedman, *Sears and Zemansky's University Physics*, (10th ed. © Addison-Wesley: 2000)

2 F. W. Taylor, *Elementary Climate Physics*, (© Oxford Univ. Press: 2005)

3 See, for example, J.D. Wilson and A.J.Buffa, *College Physics*, (4th ed., © Prentice Hall: 2000)

4 S. Arrhenius, "On the influence of carbonic acid in the air upon the temperature of the ground," *Philosophical Magazine* 41, 237 (1896); and "The possible cause for climate variability" (in German), *Meddelander fran K. Vetenskapsakademiens Nobelinstitut*, 1:2, 1 ff.

5 LOWTRAN, written circa 1970s by U.S. Air Force Cambridge Research Laboratory

6 R. S. Knox, "Physical aspects of the greenhouse effect and global warming," *Amer J. Physics* 67, 1227 (1999)

7 R. S. Knox, "Non-radiative energy flow in elementary climate models," *Physics Letters A* 329, 250 (2004)

The significance of the sensitivity of temperature to *radiative forcing* will come up again in a later section of this paper.

However, there is an important difference between H_2O and CO_2: Once emitted, H_2O stays in the atmosphere for a few days, then becomes part of the water cycle (evaporation/clouds/rain) of the earth. CO_2, on the other hand, doesn't just "go away." It has much longer[8] residence time in the atmosphere, only slowly being taken up by plant life or the oceans when they cool naturally. That time scale is decades, or perhaps centuries. Therefore, when mankind changes the CO_2 content, it's approximately "permanent" on the time scale of interest.

There are other greenhouse gases, such as methane (CH_4) and nitrous oxide (N_2O), but the number of such molecules in the atmosphere is small and all of them add up to only equal CO_2, a fraction of the effect of H_2O.

One point that is often overlooked is that the infrared-absorption effect of greenhouse gases *saturates*, that is, absorption does not increase linearly with increasing CO_2 content, but grows only logarithmically. For example, the additional energy absorbed if CO_2 goes from 450 to 600 ppm is much less than when CO_2 goes from 300 to 450 ppm. The result is that the total heating of the Earth cannot "run away."

As the CO_2 content of the atmosphere increases, there is one obvious immediate result: trees have more to eat. However, no one thinks things are that simple; rather, the secondary effects might be unprecedented. Furthermore, looking 40+ years ahead, the developing world is going to contribute annually about 4 times as much CO_2 to the atmosphere as the *developed* countries already do now.[9] So we are going to have to deal with a *lot* more CO_2. Being unable to foresee all possible consequences, it seems imprudent to allow so great a change in the atmosphere to occur unsupervised.

This worry about the unknown effects of the growing magnitude of atmospheric CO_2 is the primary driver of concern about the future.

ACCEPTED WISDOM

As sketched above, it is entirely plausible that radiation absorbed by CO_2 warms the earth. The idea that CO_2 *causes* global warming has moved rapidly from hypothesis to plausible explanation to accepted wisdom to public knowledge. It is the basic premise of the Anthropogenic Global Warming position.

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[8] See, for example, R. Chang *Chemistry*, 3rd ed., (Random House: 1988) pp. 862-864.

[9] T.P. Sheahen, "Electricity Demand Growth in Developing Countries," Proc. ASME Int'l Joint Power Generation Conference , v. 1, p. 565 ff (Baltimore MD, August 1998)

Today there is already considerable momentum behind the notion that CO_2 is the cause of increasing global temperatures. The series of reports[10] by the *Intergovernmental Panel on Climate Change* (IPCC) began the momentum, and others have followed suit. For example, the Pentagon invited 10 retired Admirals and Generals to write essays on the military implications of global warming. The ground rules for the essays began with the *presumption* that the temperature was going to increase according to the IPCC reports. The collection of those essays[11] has become a starting point for military forecasts. No one challenged the basic premise. There are now many military planners going down that road.

The *American Physical Society* (the national association of physicists), has taken a position that says "the evidence is incontrovertible" [implying that CO_2 causes global warming] (see adjacent box). A high-prestige group like that cannot be brushed aside; it must be recognized that the correlation has clearly led very serious scientists to accept AGW. Is it possible that they have been too easily influenced by the public statements of advocates, rather than carefully examining all the relevant scientific literature? If their opinion is to be opposed, it must be by equally prestigious scientists with knowledge about climate science. A key point here is that such scientists are numerous.

At present, a high percentage of the general public believes in AGW because others have told them that "all scientists" think so. A lot of second-hand knowledge has risen to prominence and turned *accepted wisdom* into *public knowledge*.

The American Physical Society's governing council issued this statement in November 2007:

"Emissions of greenhouse gases from human activities are changing the atmosphere in ways that affect the Earth's climate. Greenhouse gases include carbon dioxide as well as methane, nitrous oxide and other gases. They are emitted from fossil fuel combustion and a range of industrial and agricultural processes. The evidence is incontrovertible: Global warming is occurring. If no mitigating actions are taken, significant disruptions in the Earth's physical and ecological systems, social systems, security and human health are likely to occur. We must reduce emissions of greenhouse gases beginning now. Because the complexity of the climate makes accurate prediction difficult, the APS urges an enhanced effort to understand the effects of human activity on the Earth's climate, and to provide the technological options for meeting the climate challenge in the near and longer terms. The APS also urges governments, universities, national laboratories and its membership to support policies and actions that will reduce the emission of greenhouse gases."

-- from *A P S News*, January 2008

[10] Intergovernmental Panel on Climate Change, *First Assessment Report* (Cambridge Univ. Press, 1990); *Second Assessment Report* (1996); *Third Assessment Report* (2001); *Fourth Assessment Report* (2007)

[11] *National Security and the Threat of Climate Change*, (© CNA Corporation: 2007)

PUBLICITY VS. SCIENCE

The media push the CO_2-climate connection, because it makes a good story. Indeed, some phenomena provide good visual images, and hence find their way onto TV, and thus the presumption of AGW is enhanced.

CO_2 itself is an invisible, odorless gas, exhaled by all animal life constantly. Watching the grass grow faster is not the kind of footage that increases TV viewership. Tying CO_2 to something perceptible is required to get the public's attention, and global warming is much more tangible, particularly if man can do something about it.

Among those who support the AGW position, some have resorted to alarmism, hoping to raise awareness and concern by overstating possible consequences. The name "Al Gore" immediately comes to mind, but there are many who are sympathetic to his strategy. For example, in reviewing Al Gore's book and movie[12] for *Science* magazine in 2007, former Congressional Science Fellow and now Congressman Rush Holt[13] excused Gore's exaggerations saying "Not what a scientist would do, perhaps, but …" and went on to essentially say that getting people concerned was more important than sticking to the scientific truth. I wholeheartedly reject Rush Holt's philosophy.

The media coverage suggesting a uniform scientific consensus is simply not true. Because the reports issued by the *Intergovernmental Panel on Climate Change* (IPCC) are signed by about 2500 people, the media jumped to the conclusion that they are all qualified scientists. In reality, the cadre of climate modelers involved is a small fraction of the signatories, who are otherwise mostly officials of various countries' governments.

HISTORICAL QUOTATION

Elsewhere in the January 2008 edition of A P S News, there is reprinted a speech from 1899 by Henry Rowland, the first president of the American Physical Society. Rowland said, in part:

"It is a common error which young physicists are apt to fall into to obtain a law, a curve, or a mathematical expression for given experimental limits and then to apply it to points outside those limits. This is sometimes called extrapolation. Such a process, unless carefully guarded, ceases to be a reasoning process and becomes one of pure imagination specially liable to error when the distance is too great."

12 *An Inconvenient Truth*, movie and book by Al Gore

13 R. Holt, "Trying to Get Us to Change Course," *Science* 317, 198 (13 July 2007)

Simultaneously, hundreds of scientists active in meteorology and climate measurements have signed letters opposing the IPCC views, but their protests were generally ignored. The dismissive epithet "global warming skeptic" fails to discern that they are only skeptical about it being *anthropogenic*. However, in 2008, recognition is finally being given to dissenting voices. As one example, Frederick Seitz, former head of the National Academy of Sciences, led a petition drive in opposition to the AGW hypothesis just before he died. The number of such eminently respectable scientists is too great to brush aside any longer.

The bias of editors is toward supporting the AGW hypothesis. This has become very worrisome in the case of the respected magazines *Nature* and *Science*, which (because of their swiftness of publication and widespread circulation) are usually preferred to alternate venues such as *Geophysical Research Letters* (American Geophysical Union) and similar journals of professional organizations of specialists. However, it should be noted that it is exactly these specialists who understand climate science much better than the great majority of IPCC participants. One must look back over two centuries (to the battle about Oxygen between Priestley in London and Lavosier in Paris) to find a similar example of editors holding fixed positions. If *Nature* and *Science* were on opposite sides of the issue, truth would more easily emerge.

MIT CLUB LECTURES

Each year, the MIT Club of WashingtonDC holds a series of monthly dinner-lectures on a single topic, inviting distinguished lecturers including some MIT professors. For 2007-08 the topic was deliberately entitled "The Great Climate Change Debate," in part to underline that it is still a *debate*, not settled or final at all.

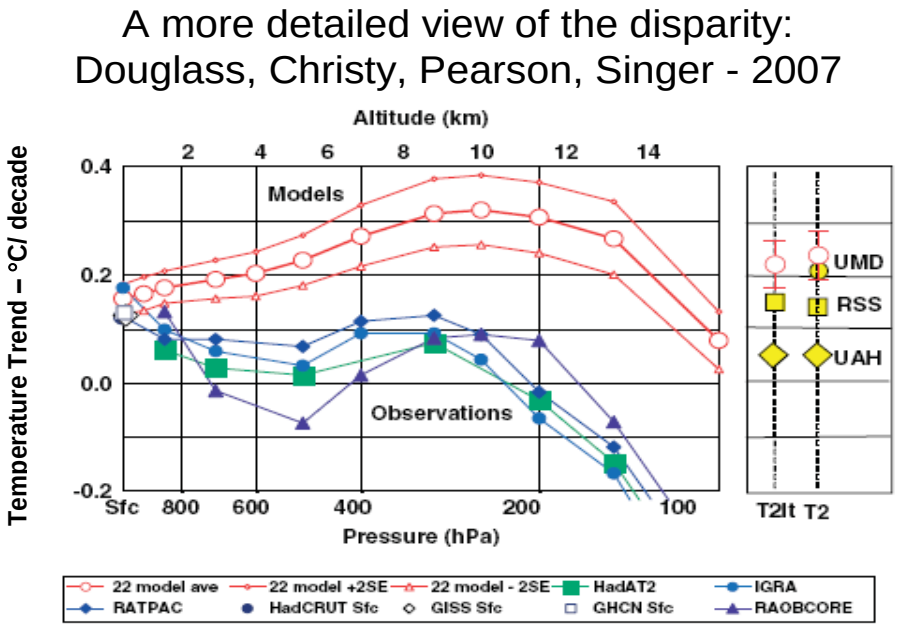
The MIT Club has sought balance in their choice of speakers. The first speaker this year was Antonio Busalacchi from the University of Maryland and the second was Peter Stone from MIT. Busalacchi argued *for* AGW, but Stone talked primarily about the difficulties and uncertainties of measurements.

The view opposing AGW was presented by the third speaker, S. Fred Singer, head of the *Science and Environmental Policy Project*, former Chief Scientist of the Department of Transportation, and first director of the National Weather Satellite Service. As such, Fred Singer has very detailed knowledge of how those satellite-born instruments make measurements, and he values the satellite measurements because they cover the *entire* earth, and are free from the urban-heat-island effect that afflicts most weather stations (at airports). The story told by the weather satellites is certainly different from the popular notions about temperature changes around the earth.

Although Fred Singer has been described as a "global warming skeptic" and variously ridiculed or denounced as a tool of big industry, in fact Singer has simply stuck very firmly to one scientific principle: *Data Trump Theory*. When a computer model

disagrees with observations, it is incorrect science to ignore the measurements; rather, the model obviously needs to be revised. That is the essential heart of what Fred Singer has been saying for over a decade. In a new book[14] about global warming, Singer and Dennis Avery argue strongly against accepting computer models.

At the MIT Club meeting on 11 December 2007, Fred Singer showed some data and compared it to modeling results, and then discussed the way it's being handled in the public square. His presentation was based on a paper[15] that accumulated a large number of modeling results, and then placed that on the same graph paper as the observations. The variables are: [trend of temperature change, °C/decade] and [altitude above the earth's surface]. The models indicate that the temperature in the tropics should be warmer in the *troposphere* (6 – 14 km) than at the surface, but the observations show the surface temperature is warmer – a major discrepancy between theory and data.



The concluding paragraph of this paper bears the customary scientific understatement: "The last 25 years constitute a period of more complete and accurate observations and more realistic modeling efforts. Yet the models are seen to disagree with the observations. We suggest, therefore, that projections of future climate based on these models be viewed with much caution."

At the 11 December MIT Club meeting, Singer also showed a plot of the band of

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[14] S. Fred Singer and Dennis T. Avery, *Unstoppable Global Warming: Every 1500 Years*, (© 2008 by Rowman & Littlefield)

[15] D.H. Douglass, J.R. Christy, B.D. Pearson & S.F. Singer, "A comparison of tropical temperature trends with model predictions," *International Journal of Climatology* (© 2007 by the Royal Meteorological Society).

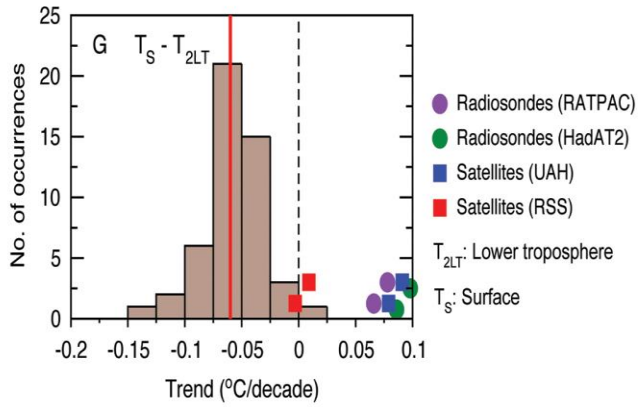
modeling results, with data superimposed; the data distinctly lay well outside the range of models. Below, the models are the pink band to the left; real data are the squares and dots. Although the IPCC text asserts there is agreement between theory and experiment, anyone who has ever heard the term *Gaussian Distribution* will recognize the obvious disagreement. You need an error band of 5 or 6 sigma to associate the two. The claim that this shows agreement can charitably be termed a "misunderstanding"; a more critical descriptor would be "misrepresentation."

Professor Ronald Prinn of MIT was the speaker on 15 January 2008, and he brought out a number of points in favor of taking action now to mitigate climate change. Prinn drew attention to the positive-feedback mechanisms that are present in some circumstances; for example, when arctic sea ice melts, the *albedo* of the open ocean is lower than the ice had been, and so absorption of sunlight will increase still more. Prinn stressed that if positive feedback loops continue, a runaway situation might occur. He conceded at once that no model is perfect and nothing is certain, so we must consider probabilities. He portrayed this as a roulette wheel with a small slice for "nothing happens" and a bigger slice for "catastrophe," and still larger slices for intermediate outcomes.

(a) CCSP 1.1 – Chapter 5, Figure 4G

(b) CCSP 1.1 - Executive Summary Figure 4G: Modeled and Observed Temperature Trends in the Tropics (20ºS-20ºN)

a.



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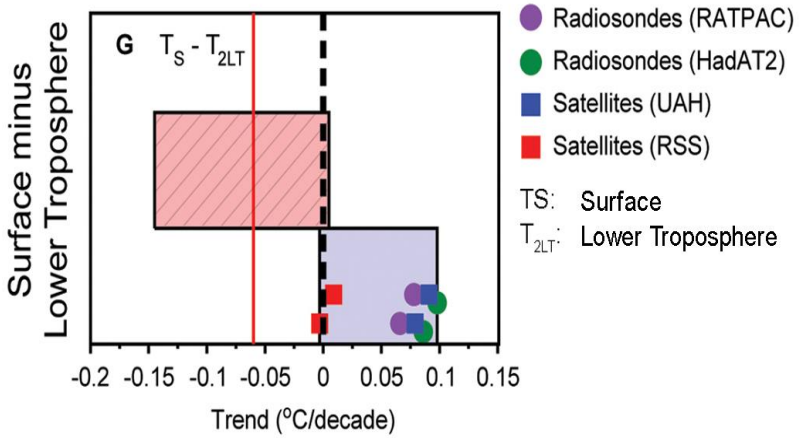

Ron Prinn's strongest argument was one familiar from the field of risk-analysis: if a possible event has low probability but enormous consequences, then it is wise to take appropriate action. Specifically, if AGW *might* cause polar ice melting and major sea level rise, then we should curtail CO_2 *now* in order to mitigate subsequent AGW.

The concern about possible future melting of north polar ice is worth examining. It is not hard to understand the perception, indeed the alarm, of those (especially in Europe) who focus on the arctic region. The exceptionally large amount of fossil fuels burned in the northern hemisphere says there is much more CO_2 injected into the northern atmosphere; the correlated observation of rising temperature enhances the AGW hypothesis. However, both the observations and the models must attend to the entire globe. Is northern-hemisphere warming compensated by southern-hemisphere cooling? Perhaps so, perhaps not; but either way, the question remains: is the changing climate natural or man-made? If warming is natural, not anthropogenic, then curtailing CO_2 will be ineffective.

Professor Henry Jacoby of MIT spoke about global warming and economic issues on 12 February 2008. A close colleague of Prinn's, Jacoby also used the roulette wheel to argue for urgent action. Jacoby added that more recent calculations indicate increased probability of very adverse effects. He explained the impossibility of stabilizing CO_2 at current levels, suggesting that 550 ppm is the best we can hope for. At MIT, they have run many scenarios of cap & trade proposals, and the effects upon the economy of the world, usually focusing on 2050. They examined what would change if there were more nuclear power, more biomass, carbon capture & storage, etc. Their risk-management approach says that even a modest amount of mitigation makes sense.

During the question & answer portion, which ranged over topics of mitigation vs. adaptation, Jacoby said that a change in attitude (nationwide) could make nuclear power the best choice overnight.

The speaker on March 11 was *New York Times* reporter Andrew Revkin; he described the dynamics of the journalism business, where stories that are factual and restrained wind up buried in the back, and only flamboyant assertions make it onto page 1. Revkin's personal testimony from "in the trenches" was very helpful in understanding how the coverage of global warming became so distorted toward favoring the notion of human-caused massive sea-level rise, droughts, floods, hurricanes and so forth.

MODELING ISSUES

When trying to predict the future, you're necessarily in the business of modeling. People in business, economics, politics, etc., all do this every day, using models of various levels of sophistication. The models used for climate change calculations are the very best models we have, but are they good enough? To those who emphasize the disagreement between observations and models, it is fair to inquire "what do you think is wrong with the models?"

The *Global Circulation Models* (GCMs) are getting better, and as they do so, the plausible range of predicted future temperatures has diminished. That is definitely encouraging progress. But they still face many severe hurdles. To grasp the size of the problem, note that if one grid square is 5^o longitude by 5^o latitude, there will be 2,592 grid boxes in all. To anchor a model in observations, data is needed from each of these. Today about 600 grid boxes (< ¼) are covered, and those are predominantly in populated areas (especially the temperate zone of the northern hemisphere).

Despite many improvements over the years, the GCMs still do not account quantitatively for the influence of clouds.[16] Some clouds reflect away sunlight toward outer space, while others trap heat radiation emitted by the earth. Clouds are extremely important: changes in cloud density have an order-of-magnitude greater effect on radiative forcing than all the other GHGs combined. A basic problem is that the computational grid size is many kilometers, often larger than the size of clouds. Local and regional variations do not show up in such models. This limitation stands as a caution against trusting numerical models too much.

Feedback loops, either positive or negative, involve clouds. It is plausible to argue that if CO_2 makes the ocean surface warmer, more H_2O will evaporate into the air, and that causes more infrared absorption, hence more warming – a positive feedback loop. But it is equally plausible to note that more evaporated H_2O forms more clouds, and reflects more sunlight away into space – a negative feedback loop. With models unable to calculate clouds accurately, this argument remains totally open.

Yet another problem is the unknown influence of aerosols. Previous reports[17] have essentially said "The large heating predicted by the models *would have* come true if it hadn't been for the aerosols, which reflect away sunlight." While there is an element of plausibility to that assertion, it's merely hand-waving to excuse modeling deficiencies this way. That isn't how science is done.

When a model is inaccurate, it is proper to strive to improve it, but still the inaccuracies cannot be glossed over. *Data Trumps Theory*. A model that cannot predict the past is not good enough to trust about the future. Here is what Earth's actual temperature looks like over the near and distant past: Box A includes the last ice age; Box B shows the "*Holocene*" period; Box C is the last 2000 years.

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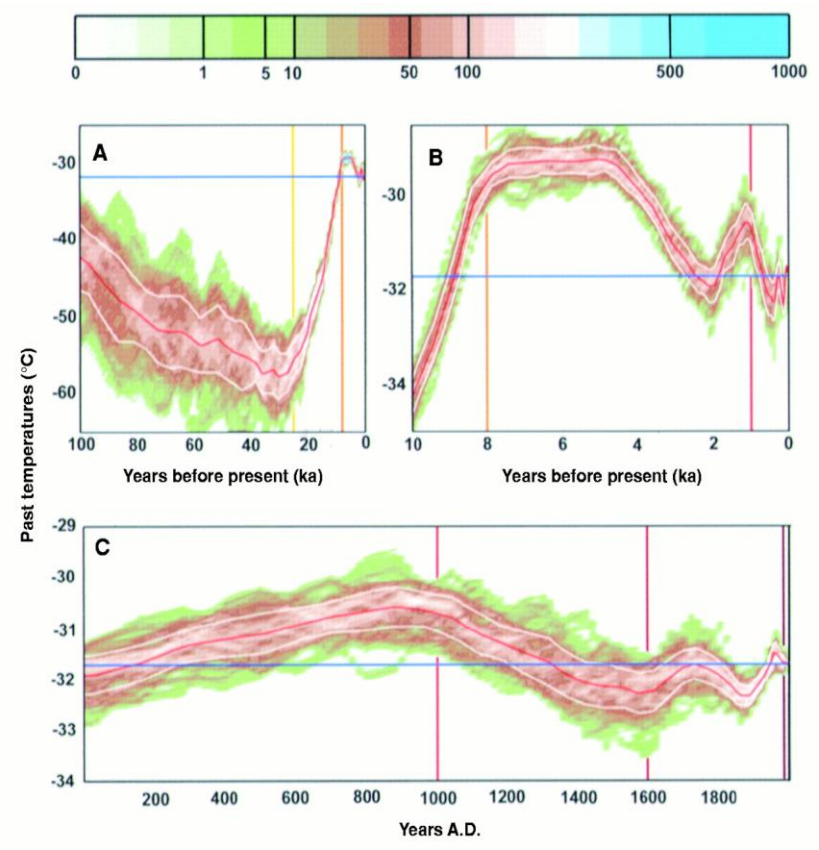
16 R. Davies "Science Goals: Study of Clouds" (NASA: May 2004)

17 IPCC, *Second Assessment Report* (1996)



Sometimes there are anomalies in the way models are constructed that escape attention. In 1998 a graph of temperature over many centuries was made,[18] and it showed a long flat period followed by a sharp upward trend in temperature since 1910 -- it looked like a hockey stick lying down. Dubbed the "hockey stick" for that reason, it soon gained the status of the "smoking gun" to display the influence of mankind. This strongly reinforced the already-prevailing public perception, and made the IPCC consensus even stronger. The graph was featured in an important government document[19] in 2000.

However, a few years later, a statistical analysis of that graph was performed,[20] and it was shown to be invalid. The critics uncovered a flaw in the statistical methodology that was producing the result; a very opaque computer code had concealed

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[18] Michael E. Mann *et al*, "Global-Scale Temperature Patterns and Climate Forcing over the Past Six Centuries," *Nature* 392, 779 (1998) and *Nature* 430, 105 (2004)

[19] *U.S. National Assessment of the Potential Consequences of Climate Variability and Change*, (2000)

[20] Stephen McIntyre and Ross McKitrick, "Correction to the Mann *et al* Proxy Data Base and Northern Hemisphere Average Temperature Series, 1998", *Energy & Environment* 14, 751 (2003)

that flaw. Close examination of underlying original data[21] confirmed that the "hockey stick" graph was meaningless. The use of totally *random* input temperature data *still* gave a hockey-stick shape. It does not resemble the proxy data of the last 1000 years shown in plot (C) just above. Unfortunately, by that time the "hockey stick" graph had been widely circulated in the media, where it was accepted outright. The counter-argument had to do with statistical techniques, and was too boring to be a good story for the media. The "hockey stick" still has considerable appeal today, outside of scientific circles.

Additional examples abound. Anyone who has actually written a model knows that you have to cut it off somewhere or else you'll be tinkering with details forever. The whole point of writing a model is to *leave out* unimportant things and concentrate on the essentials. A *good* model is one where wise judgments have been made about what to include.

Unfortunately, one reality of very large models is that sometimes a key factor is missing, but the model's complexity obscures the problem, not just from the public but from the modelers themselves. *Wishing* for a hypothesis to be confirmed is a very powerful influence, and can easily mislead. The antidote is to have the model examined and run by someone *else* who wishes for the opposite conclusion. Regrettably, with regard to climate change calculations, the cadre of such cautionary voices is small.

FEEDBACK IN MODELING

Within any computer model, there are always embedded assumptions and algorithms that do not rise to the level of attention of the audience. One need not explain how a standard deviation is computed, nor that an integral is being truncated when only tiny values remain. In the same way, while there certainly may be disagreements about details of physical feedback mechanism, the basic equations describing feedback are taken for granted. Doing so may have caused an oversight of an important variable.

In a July 2008 publication,[22] Christopher Monckton looked deep into the IPCC models and re-examined the way feedback is handled. He discovered that a very simple feedback-multiplier factor (f) was causing a large exaggeration of the *climate-sensitivity* factor (that is, the temperature change ΔT due to doubling atmospheric CO_2). The equation for f was taken from a classic text[23] on feedback in vacuum-tube amplifiers:

$$f = 1 / (1 - b\,\kappa)$$

where b is the sum of all climate-relevant temperature feedbacks (both plus and minus), and κ is the "no feedback" climate sensitivity parameter. Numerically, $2 < b < 3$ W/m^2K

[21] D.A. Graybill & S.B. Idso, "Detecting the Aerial Fertilization Effect of Atmospheric CO_2 Enrichment in Tree Ring Chronologies," *Global Biogeochemical Cycles* 7, 81 (1993).

[22] C. Monckton, "Climate Sensitivity Reconsidered," Physics & Society 37, # 3 pp. 6-19 (July 2008)

[23] H. W. Bode, Network Analysis and Feedback Amplifier Design (Van Nostrand: 1945)

while κ is about 1/4 m^2K/W. Monckton gave great scrutiny to their exact values, because of the strong influence on f and hence on the prediction of ΔT. (Clearly, if κ → 1/3 while b → 3, the factor f blows up and the calculation of ΔT diverges.) Monckton found a best value of 0.24 for κ, while by 2007 the IPCC number[24] had crept up to 0.313 m^2K/W. Meanwhile, a good value for the feedback-sum b is 2.16 W/m^2K, although this too can be debated. Defining the "climate sensitivity parameter" λ = κ f = κ/(1-bκ), the 30% upward drift in κ (from 0.240 to 0.313) increased λ by 93%. Consequently, the ΔT predicted by IPCC (for a doubling of CO_2) nearly doubled.

This extreme sensitivity to the choice of one numerical value within a buried equation illustrates just how severely unreliable computer models really are. The fact that this totally escaped the attention of ~ 2500 signers of the IPCC report is hardly a surprise, since virtually no one scrutinized the inputs as carefully as Monckton did. But the implications are huge: where IPCC predicted a 3°C warming, a more careful choice of the feedback parameter would predict 1.5°C. From a single numerical adjustment of 0.313 back to 0.240, the notorious worries about Greenland melting and cities flooding completely vanish.

MITIGATION REQUIRED ?

The IPCC has called the climate influence by mankind "discernable," but skeptics think it is negligible, swamped by natural variability. The situation today is one in which the consensus view is being challenged, because the models are not reliable enough, and because new studies are coming out that support the "natural" hypothesis. National leaders don't yet have adequate knowledge, and are wondering what to do.

If AGW is real, it is presumed to be due to man-made emissions of greenhouse gases (GHG), principally CO_2. Hence the path to mitigating AGW is to curtail CO_2 emissions. The perceived sense of urgency to do that is widely variable:

a) One school of thought calls for prompt action, and already a significant industry has sprung up around this strategy, including the formation of a market to trade CO_2 credits. Bills have been introduced into Congress to formalize cap & trade programs.
b) Another school of thought, made up mainly of developing countries in Asia, feels entitled to emit GHGs comparable to what the western countries have already done. In early 2008 this was stated emphatically by a government Minister from India, who rejected CO_2 mitigation efforts but pledged that India's *per capita* emissions would never be as large as western countries. The inability to *demand* compliance from sovereign nations is inconvenient, to say the least.
c) Yet a third school says "wait and see," but that is rejected as too dangerous by AGW proponents. To do nothing would be irresponsible, and might allow various catastrophes to occur downstream. (That is the theme of Al Gore's book and movie.)

[24] S. Bony *et al*, "How well do we understand and evaluate climate change feedback processes?", Journal of Climate 19, 3445-3482 ((2006)

d) A fourth position urges more rapid research. The technology of *Carbon Capture and Sequestration* (CCS) is being explored, although with very limited success so far. It is probable that the leading advocates in the media for this approach do not understand how difficult this research task is.

e) A fifth position asserts that taking action now has no downside consequences, since if we're wrong we haven't *hurt* the earth, but merely reduced greenhouse gases. The only "downside" is that money going into mitigation might have been spent elsewhere. Whatever that cost might be, it is assumed to be much less than the catastrophe it averts. This is the essence of Prinn/Jacoby's risk-aversion approach.

ALTERNATE THEORIES

The concluding line by Douglass *et al*[15] "…projections of future climate based on these models be viewed with much caution" should not be seen as a variant of the third position, but is actually distinct from any of them. Douglas *et al* and like-minded scientists essentially argue that the models are wrong, and CO_2 is not "the culprit" after all. They consider the increased CO_2 content of the atmosphere harmless; after all, CO_2 *is* plant food.

Anyone who wishes to challenge the "conventional wisdom" has got to propose an alternate theory, of comparable or greater plausibility to the prevailing theory. Opponents of AGW have taken that requirement seriously.

First, opponents of AGW point out that over the last 3 ice-age cycles, other long-term proxy measurements indicate that temperature increases have *preceded* CO_2 increases by hundreds of years[25]. This is a very important case of data/theory mismatch, because it has exactly the opposite sequence (and causality) from that predicted by the AGW hypothesis. It argues strongly *against* the notion that CO_2 changes cause temperature changes.

In the early 1980s, mile-long ice cores were extracted from Greenland, and they provided sufficient data to discern[26] not only the ice ages, but a temperature cycle of about 1500 ($\pm$ 500) years. Singer's book[14] provides many details about this phenomenon.

In his MIT-club talk, Fred Singer also drew attention to some important observation stretching far back in time: an examination of a stalagmite from a cave provided very long-term measurements of C^{14} and O^{18} isotopes. C^{14} is a proxy for solar activity, and O^{18} is a proxy for temperature. The two correlate extremely well[27] – which indicates that solar activity determines temperature variations.

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[25] H. Fischer et al, *Science* 283, 1712 (1999)

[26] W. Dansgaard et al, "North Atlantic Climatic Oscillations Revealed by Deep Greenland Ice Cores," in *Climate processes and Climate Sensitivity*, ed. J.E. Hansen & T. Takahashi, Geophysical Monograph 29, 288 (© Amer. Geophysical Union:1984)

[27] U. Neff *et al*, "Strong coherence between solar variability and the monsoon in Oman between 9 and 6 kyr ago," *Nature* 411, 290 (2001).

The sun's output is variable (direct *solar forcing*), and that bears consideration. Sunspots have been considered influential towards climate for over 200 years, but the change in observed energy is insufficient to explain the changing temperatures. However, there are other subtleties, and one argument goes as follows: cosmic rays approach the earth all the time, but are mostly diverted away by the earth's *magnetosphere*, which gets stronger or weaker with variations in the sun's output. Therefore the number of cosmic rays reaching the lower atmosphere likewise varies, often dramatically. Next, cosmic rays provide nucleation sites for water droplets to form, and thus affect the formation of clouds.[28] That mechanism had not been understood previously. The effect of clouds upon temperature is called *cloud forcing*. Therefore there is an additional link (other than just solar intensity) between solar activity and global temperature.

This plausible cosmic-ray mechanism has been duplicated in the laboratory,[29] but further experiments and observations are warranted to refine our understanding. It is important to do so, because at present, Svensmark's hypothesis is the only experimentally verified hypothesis that explains the changes in temperatures for the past 100 years, 1000 years, and 10,000 years.

Others have drawn attention to climate shifts caused by variability of *El Nino*, and argue that what we are experiencing is merely the occasional synchronization of four natural ocean cycles[30]. The authors[31] constructed a model that explains *past* data, which enhances its credibility.

Recalling Ron Prinn's caution about hypothetical positive feedback loops, it is reasonable to ask for a means by which the earth does *not* heat up when CO_2 increases. That is, to someone who doubts a proffered positive feedback loop: show us a counteracting negative feedback loop.

The "thermostat" in the western Pacific Ocean proposed by Lindzen *et al*[32] is exactly such a negative-feedback mechanism. On this showing, when the sea surface temperature exceeds 28^{o}C, evaporating water creates more low, wet clouds, and less high cirrus clouds. This creates downdrafts of air that cool the sea surface. Basically, what happens is that a vent hole opens naturally, regulating temperature. This is not just one

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[28] H. Svensmark, "Influence of cosmic r4ays on Earth's climate," Physical Review Letters 81, 5027 (1998)

[29] H. Svensmark, "Cosmoclimatology: a new theory emerges" Astronomy & Geophysics 48, 1.18 – 1.24 (2007)

[30] El Nino Southern Oscillation (ENSO), North Atlantic Oscillation (NAO), North Pacific Oscillation (NPO), and Pacific Decadal Oscillation (PDO).

[31] A. A. Tsonis et al, "A new dynamical mechanism for major climate shifts," Geophysical Research Letters **34**, L13705 (2007)

[32] R. Lindzen *et al*, "Does the Earth Have an Adaptive Infrared Iris?" *Bull. Amer. Meteorological Soc.* 82, 417 (2001)

man's promotional idea, but has been verified by other independent observations.[33, 34] These additional papers argue that the amount of heat emitted during recent decades was equivalent to what modelers predict if the atmospheric CO_2 instantly doubled.

Does this end the reign of the AGW hypothesis? Hardly. There are still plenty of significant correlates between the growth of CO_2 and the observed global warming. However, what it does show is that this is still very much an open question, scientifically. The easy answers are quite evidently inadequate, and it is entirely respectable to be on either side of the controversy. The assembly of global warming alarmists has forgotten how *real* science works.

WEIGHING THE COSTS

There are many uncertainties and contradictions associated with the total assembly of observations and experiments, and the computer models fail when tested against historic data. A rigorous, empirically-tested hypothesis (either for or against AGW) is still a long ways away. Nevertheless, many respected scientists and organizations insist that mankind is the cause of the current warming.

Based on the precautionary principle, there are widespread calls to take action toward mitigating CO_2 emissions. Recognizing the very long residence times of CO_2 in the atmosphere, even very prompt action now to curtail CO_2 will take effect only slowly, and the CO_2 content of the atmosphere probably cannot be stabilized at less than 500 ppm. The mitigation argument asserts that the cost of doing so is worth it to avoid a catastrophe.

On the other hand, if climate variation is not anthropogenic but natural, as the skeptics argue, it follows that it would be futile to engage in a world-wide program to reduce CO_2. In particular, both trading of CO_2 credits as well as *Carbon Capture and Sequestration* (CCS) are without merit under this interpretation.

A lot of thought has gone into CO_2-mitigation options, and every one of them is expensive. CCS is in the research stage, and if successful, will likely increase the price of electricity by factors estimated in the 40 – 80% range. Shifting to renewables or carbon-neutral biomass-derived fuels can't match the numbers for fossil fuels. Switching away from fossil fuels can only even be contemplated in already-developed countries, and that still leaves the CO_2 burden emitted by China, India and others as they develop – in which case there would be no benefit gained for the expenditures. Separately, one study[35] asserted that warming would cause a slight net gain in American GDP, although there would be ups and downs among sectors of the economy.

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[33] J. Chen et al, "Evidence for Strengthening of the Tropical General Circulation in the 1990s," *Science* 295, 838 (2002)

[34] B. A. Wielicki et al, "Evidence for Large Decadal Variability in the Tropical Mean Radiative Energy Budget," *Science* 295, 841 (2002)

[35] R. Mendelsohn and J. Neumann, *The Impact of Climate Change on the U.S. Economy* (© Cambridge Univ. Press: 1999)

At this time, there is *no* means, either known or forecast, to mitigate CO_2 sufficiently.

ADAPTATION VS. MITIGATION

There is one area of agreement between opponents in all of this. Regardless of *why* the climate is changing, people need to be prepared for it.

On 11 February 2008, as part of the *Energy Conversation* series of the Department of Defense, John Marburger, President Bush's Science Advisor, spoke on the topic "Energy Security and Climate Change."[36] Marburger accepts the technical reports prepared by *Working Group 2* associated with the fourth IPCC report as the best authority, and consequently has confidence that CO_2 is causing global warming. Again, a very noteworthy scientist who accepts the argument for Anthropogenic Global Warming. Marburger agreed that mitigation is very difficult, and that adaptation must be undertaken.

Marburger was not happy with the media treatment of the topic, saying that "the complexity of the issue outruns the capability of the media." He added that many scientists have gone along with the media in the interest of simplicity, but they shouldn't. (I didn't get a chance to ask him what he thought about Rush Holt's review[13] of *An Inconvenient Truth*.) While the *Summary for Policymakers* gets all the publicity, the technical summaries are accessible via the web, and Marburger strongly urged his listeners to read them.

Moreover, Marburger also drew attention to the importance of local effects, which are very hard to model. Things like *El Nino* affect precipitation all over the globe, but we have no model that can say how *El Nino* is changed. The effects on cloud cover and aerosols are even worse understood, and these affect water resources and agriculture. Every international program for sustainability is relevant to climate change.

There are important decisions to be made regarding *adaptation* vs. *mitigation*. Marburger said that reducing CO_2 will occur too slowly to save the vulnerable. He recited statistics about American and global use of fossil fuels, and raised questions like "Can we build 136 new 1-GW nukes to replace coal, or 270,000 1-MW wind turbines?" His point was that mitigation is for the long term. Social returns are much higher for spending on adaptation.

Marburger also underlined the global nature of the issue: People everywhere desire to improve their lives, and that will not be denied. If we are going to make any progress on mitigation, we've got to break the link between economic development and fossil fuels. That linkage is via technology. Our aim should be to reduce the *energy intensity* of the global economy, promoting conservation and making sustainable

[36] This talk was not part of the MIT Club series.

technology attractive to developing countries. Reducing the cost of low-carbon-emission technologies is the key to success.

On the other hand, dictating a limit on CO_2 is a fruitless enterprise unless we give the developing countries an option. CO_2 has to be reduced in *all* major economies. But what options are available? The *only* sufficiently mature technology that can compete with coal is nuclear fission. Research is needed to overcome problems like waste and proliferation. For coal, research is needed on carbon capture and storage (CCS).

John Marburger very clearly established the relationship between climate change and energy security. He reminded the audience that the Bush Administration began in 2001 trying to recruit developing countries into a partnership, and recognized that this would take a century.

Here is a genuine scientific consensus: in the short and intermediate term, *adaptation* must be the response to climate change, whether or not mankind is causing it.

CONCLUSION

The purpose of this paper is to explain that there is *not* a monolithic body of opinion, a consensus, that mankind is causing global warming. The large and growing number of eminent scientists on the opposite side cannot be ignored any longer.

Much of my discussion above emphasizes the "other side" of the AGW debate, because that side has hardly been heard, certainly not in the media, but even by scientific journals and professional societies. The "wisdom" got accepted much too fast. The steady stream of contrary data appearing in this decade meets the criteria for publishable science, and needs to be given equal consideration with data that supports AGW.

I do not assert that the AGW hypothesis is false; rather, that it is still wide open for debate. I hope I have successfully explained the unreliability of computer models. Having public policy driven by the predictions of computer models is very tenuous to begin with, and when those models don't match the data, it becomes a major mistake.

Certain things can and should be done:

First, more observational data is needed in many areas. When a model makes a prediction, there should be a way to test it, and that should be done. (Some predictions are about the *past*, and are subject to verification.) Everyone involved should agree on the scientific canon that *Data Trumps Theory*.

Second, clouds have to be taken into account correctly. This weakness of the models would be embarrassing to modelers were it not for the glib acceptance of very adverse predictions that is routinely extended by the media.

Third, alternative hypotheses should be modeled at the same level of intensity (and funding) as the models that focus on CO_2.

Fourth, professional societies and information forums should strive to hear both sides of the debate, as the MIT Club of Washington has done. The American Physical Society would do well to re-examine its official statement (box on p. 4 above).

Certain other practices should be discontinued at once:

First, the unrelenting *ad hominem* attacks on skeptics are beginning to backfire, as growing numbers of scientists suspect that those making the attacks are unable to back up their own positions with solid science. I will testify that my own interest in this field was generated more by concern over unscientific and unethical attacks than by any other factor. The scientific method simply does **not** include *ad hominem* arguments.

Second, scientists who stand to benefit by global warming alarmism should avoid falling into an ethical trap. It is tempting to say "keep your mouth shut, keep out of the crossfire, take the money, and let the politicians do the fighting." That's wrong. It will eventually accrue ill to scientists in general to allow this important area of national policy to proceed forward without honorable scientific input. Reasoned debate has been the ideal of science for centuries, and it is needed now more than ever. The fact that media-driven alarmism has dominated the public perception on this issue so far should not be an excuse for complacency or inattention.