Statement on Global Change

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Despite popular opinion to the contrary, the quantitative expectation of *substantial* global warming (more than 1ºC or so) arising in the next century because of man's production of minor greenhouse gases ($CO_2$, CFC's, methane, etc.) is without substantive scientific foundation. It is worth noting that the major greenhouse substance is water in the form of water vapor and layer clouds — which accounts for over 98% of the current greenhouse effect. It is sometimes noted that many minor greenhouse gases are directly related to man's activities, whereas water vapor and layer clouds are internally established by the atmosphere. However, it is obvious that models that do not properly deal with the major greenhouse substances will be inadequate for evaluating the response to minor greenhouse gases. As concerns catastrophic predictions (5ºC warming), it should be emphasized that we are not dealing with plausible consequences of a well established understanding, but rather with the consequences of identifiable model errors. Such consequences are, moreover, inconsistent with the history of the Earth's climate to date.

As concerns past climate, it is noted in the IPCC Scientific Assessment (Houghton, et al, 1990) that the observed warming over the past century (during which time we have increased minor greenhouse gases by about 50%) is most consistent with an increase in temperature, for a doubling of such gases, of about 1.2ºC (page 246). This estimate includes the delaying effect of the oceans and *assumes* that all observed warming over the past century (0.45ºC±0.15ºC) is due to increasing greenhouse gases. However as the IPCC Assessment notes (p. 254), "it is not possible to attribute all, or even a large part, of the observed global-mean warming to the enhanced greenhouse effect on the basis of the observational data currently available." The reason for this inability is simply that the global mean temperature naturally fluctuates by this amount over periods as short as 5 years.

It has been noted that the upper limit of the IPCC range of warming predictions for the end of the next century (5ºC) would leave the Earth warmer than it has been at any time in human history. This assertion is, in fact, modest. According to the distinguished paleoclimatologist, Rhodes Fairbridge of Columbia University and GISS, the average temperature of the Earth has been in the range 18ºC±5ºC for about 4 billion years — during much of which time the atmosphere contained many times the $CO_2$ projected for the next several centuries (Fairbridge, 1991). The model predictions exceed this range. Fairbridge also notes that equatorial sea surface temperatures have been in the range 30ºC±1ºC during this period. Virtually all models predicting large global warming predict 2-4ºC warming at the equator. Under any normal circumstances, one would conclude that the models are misbehaving — even allowing for some uncertainty in the data.

Beyond the *prima facie* evidence that model predictions are inconsistent with observations (and the inconsistency far transcends the above examples), are there other reasons for questioning model behavior? Indeed, there are many reasons; everyone has their favorite, and each is enough to swamp the effect of increasing $CO_2$ (recall that $CO_2$ contributes only about 1% to the greenhouse effect and model errors are far larger than this). Indeed, no current model can predict the mean temperature of today's Earth without what is euphemistically called `tuning'.

One issue I have been focussing on in the past few years has been the role of water vapor. This issue is summarized in the accompanying statement prepared at the invitation of the IPCC in connection with the preparation of an update to their 1990 document. (It is worth noting that the preparation of an update so soon after the original publication is indicative that the original document was hardly canonical.) The main points in the accompanying document are:

1. Water vapor and layer clouds account for over 98% of the greenhouse effect.

2. The ability of models to predict layer clouds depends on the ability of models to predict water vapor.

3. In the absence of positive feedbacks, the equilibrium response to a doubling of $CO_2$ is in the range 0.6ºC to 1.2ºC. Larger responses *require* positive feedbacks.

4. The largest positive feedback by far in current models is due to water vapor.

5. Without the positive water vapor feedback, no model would obtain an equilibrium warming due to doubling $CO_2$ as large as even 2ºC (assuming other feedbacks are positive — a matter of great doubt).

6. Water vapor is not equally important at all levels in the atmosphere. A molecule of water vapor at 12 km altitude is about 1000 times more important than a molecule at 2 km in its contribution to the greenhouse effect. The effect of molecules near the surface is almost nil. Thus, although most of the atmosphere's water vapor resides in the bottom 2 km of the atmosphere, it is the water that resides elsewhere that is crucial to the Earth's climate response[1].

7. Water vapor is not monitored above 6-9 km.

8. We do not understand the physical processes which determine water vapor above 2-3 km.

9. Due to numerical problems, models cannot currently deal with a substance like water vapor which varies so rapidly with altitude (it varies by 3-4 orders of magnitude between the ground and the tropopause). Current models commonly produce regions of negative water vapor, and the arbitrary `fixes' introduced to eliminate such impossibilities frequently play a major role in determining model water vapor.

10. It has been asserted that the observational analysis of Raval and Ramanathan (1989) proved that the water vapor feedback is positive[2]. That result is demonstrably due to a faulty assumption in their analysis — namely, that the shape of temperature profiles are independent of surface temperature.

In view of the above alone, it is clear that models are presently incapable of calculating the response to enhanced $CO_2$. The situation hardly improves when we consider the uncertainties in clouds (barely touched in the above discussion), the uncertainties in ocean transport, and even the uncertainties in the behavior of $CO_2$ itself. There is simply no basis for saying that the range 1.5ºC-5.0ºC is `likely' — especially since all these values are excessive according to the behavior of the climate over the past century.

Where then does this leave us. At the least, it leaves us with a self-evident need to understand our climate, and, more generally, our environment. It seems entirely reasonable for wealthy, scientifically and technologically advanced societies to set themselves the goal of understanding the

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[1] The reason for this is that, counter to the popular picture of the greenhouse, the Earth's surface does not cool primarily by infrared emission. Rather, heat (in various forms) is bodily carried from the surface by air currents to regions of much reduced greenhouse potential (at higher altitudes and latitudes), and from these regions, the heat is radiated to space. Thus, it is greenhouse gas concentrations in those regions of the atmosphere where motions deposit heat that are most important in determining the surface temperature. (The situation is schematically illustrated in the first accompanying figure.) It follows that models that do not accurately depict transports by air currents, cannot accurately predict the temperature of the Earth. Current models do, in fact, have severe problems with transport.

[2] A recent study by Sun and myself suggests, on the basis of paleoclimatic data from the last major glaciation, that the water vapor feedback may, in fact, be strongly negative.

physical environment they reside in. Such an understanding would be among the greatest gifts we could leave to our successors on this planet. Such an understanding would not only enable us to anticipate currently unexpected dangers, but would also help us avoid being exploited by dangerous hysteria based on ignorance. In emphasizing understanding, I must point out that although understanding benefits from large observational programs and supercomputers, it is primarily an activity of the intellect. The development of a sound conceptual framework is essential to the planning and evaluation of large programs. Such development is monetarily cheap but difficult, and large programs can tend to deemphasize such theoretical efforts — not only because they are cheap but also because it would be embarrassing to admit that the conceptual foundations for large efforts might sometimes be absent. As a theoretician, it is clear that my concern about conceptual foundations is self-serving; I believe the concern is also well founded.

Turning more specifically to the problem of global climate change, we must certainly develop an adequate understanding of the behavior of water vapor in the atmosphere. Monitoring must be extended to the upper troposphere. Much work needs to be done to improve our understanding of the microphysics of deep convective clouds in order to know how these clouds determine the balance between the water and ice they pump into the environment and the precipitation that falls to the surface. We need to determine what role the oceans may play in tranporting heat and material. We also need to understand what determines the transport of heat, momentum, and material by the large scale circulation of the atmosphere. We are still in a position where we do not quantitatively know what determines the equator to pole temperature difference. Yet, over the history of the Earth, climate variations have been far more associated with changes in the equator to pole temperature difference than with changes in the global average temperature. Improved data for both the atmosphere and the ocean is certainly essential. However, observations must be based on well determined needs rather than available instruments and platforms. The behavior of $CO_2$ remains rich in puzzles. It is essential that we understand the sources and sinks of $CO_2$ over land and sea, and that we understand why $CO_2$ has varied in the past without human intervention. Indeed, although we cannot obtain data for the future, the past, in varying degrees, is accessible. Every effort should be made to collect, assemble, analyze and organize data for the past so as to be able to reconstruct as accurately as possible the climate of the last decade, the last century, the last millennium, the last million years, and even the last several billion years. Such reconstructions will provide the best opportunity for us to test our understanding of climate. The fact that no current model can simulate the cycles of glaciation over the past 2 million years (which we currently believe, on the basis of observations, to be forced by the Earth's orbital variations) hardly lends confidence to our predictions for the future.

**References**

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Houghton, J.T., G.J. Jenkins, and J.J. Ephraums, editors, 1990: **Climate Change, The IPCC Scientific Assessment**, Cambridge University Press, Cambridge, 365 pp.