A Scientific Discussion of Climate Change - Comments on

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November 1, 1997

Preface

The extent of human impact on climate remains a highly complex scientific matter. As was made clear in the most recent report for the United Nations Intergovernmental Panel on Climate Change (IPCC), there are great uncertainties in understanding the impact of human actions, such as fossil fuel burning, on global climate. In that regard, we provide scientific background information and comments on recent statements by Dr. Michael MacCracken (Office of the United States Global Change Research Program), entitled "The Truth about Ten Leading Myths." We have used quotes from the literature in an effort to reach agreement on a body of accepted facts regarding climate change.

Dr. MacCracken implies that the human effect will dominate climate change in the next century. In addressing future climate change it is important to know its causes—both natural and anthropogenic. However, Dr. MacCracken's text omits quantitative specification of causes of climate change, which is the first step in a complete assessment. Without first understanding the causes of climate change it is not possible to make an accurate projection of future change.

The underlying theme of our discussion is that calculating the response of the climate to causes is extremely difficult because the climate is a nonlinear, coupled, dynamical system. It is essential to remember the distinction between calculating the input of energy to the climate system (through, e.g., an increase in greenhouse gases) and the much harder task of calculating its climatic response. The difficulty in calculating the climate response is reflected by the fact that current climate simulations fail to meet the criterion of validation. Only further research promises to allow the computer simulations to compare accurately human and natural causes of climate change.

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November 1997

Dr. MacCracken's statements are reproduced below and highlighted; portions on which we provide comments are repeated and shown in italics.

STATEMENT 1: Most climate scientists agree that the climate is changing and will change much more, causing a wide range of environmental and socio-economic consequences. The recent round of IPCC assessments has involved hundreds of authors and thousands of reviewers who have worked to develop an unbiased, measured, documented, and peer-reviewed result.

Most climate scientists agree that the climate is changing . . .

An important property of climate is variability. The issue is whether the human effect on climate is, or will shortly become, significant against the background of this natural variability.(1) Answering this question requires that the underlying natural variations in climate be understood, so that human impact may be distinguished quantitatively from natural variability.(2)

. . . and will change much more.

To the contrary, the most recent UN IPCC report (IPCC 1995) states, "Overall, there is no evidence that

extreme weather events, or climate variability has increased in a global sense, through the 20th century..."(3) This lack of increasing climate variability occurred during the period when greenhouse gases in the atmosphere are estimated to have increased by an amount equivalent to a 50% increase in carbon dioxide alone. In addition, the climate models do not give reliable predictions on the matter as evidenced by the fact that the models predict too little climate change on timescales of decades to centuries when compared with the actual change that has been observed.(4)

The recent round of IPCC assessments has involved hundreds of authors and thousands of reviewers.

Scientists affiliated with IPCC 1995 and others agree that the computer simulations are insufficient for the tasks of explaining current climate or projecting future climate. Some examples from the literature are:

Our ability to quantify the human influence on global climate is limited because the expected signal is still emerging from the noise of natural variability, and because there are uncertainties in key factors. These include the magnitude and patterns of long-term natural variability ... (5)

[The model results] cannot be considered as compelling evidence of a clear cause-and-effect link between anthropogenic forcing and changes in the earth surface temperature.(6)

We are far from anything resembling a 'theory' of climate, and cannot therefore expect a theoretical (necessarily computa-tional) approach, in isolation, to yield a totally convincing prediction of climate sensitivity in the near future. This becomes especially clear when attention is focused on the interactions between the large-scale flow and the various small-scale, moist-convective, cloud-determining processes …(7)

... [We] conclude that ... the GCM [General Circulation Model] considered cannot be used for any physical experiment devoted to studying real climate change, such as greenhouse warming, paleoclimate reconstructions, or El Niño prediction.(8)

... [It] is clear that using the GCM for investigation of the real climate variability ... has no scientific justification.(9)

… [I]t [is] hard to say, with confidence, that an anthropogenic climate signal has or has not been detected. (10)

STATEMENT 2: In the United States, average temperatures have remained high even in the presence of the increasing cooling influence of sulfate aerosols, and global average temperatures have warmed significantly. The rise in sea level, the melting of mountain glaciers, and other even more subtle climate changes all match the predictions.

In the U.S., average temperature have remained high even in the presence of the increasing cooling influence of sulfate aerosols . . .

The temperature of the U.S., which has a relatively good surface record taken from many stations, has shown no significant warming trend over the last 100 years (see enclosed chart of annual surface temperatures, 1895-1996, from NOAA/National Climatic Data Center). The aerosol cooling effect referred to is extremely complex and difficult to quantify, but seems too small to reduce the projected warming trends.(11) The implication of that result is that the projections exaggerate the warming that should have already occurred from the increase in greenhouse gases to date. The sensitivity of the climate to the increased greenhouse gases is too large in the computer simulations, presumably due to the omission of other factors of climate change. Therefore, global warming projections for the future are likely to be unreliable.

. . . and global average temperatures have warmed significantly.

The globally averaged surface temperature record from IPCC 1995 shows an increase of about 0.5°C between 1910 and 1940, before most of the greenhouse gases from human activities entered the atmosphere. Therefore, most of the warming of the last 100 years has natural causes as its explanation.

Furthermore, in the last 18 years, the precise satellite data for the lower troposphere show no significant warming trend. The last two decades are important because the models project that in the lower troposphere, the region of the atmosphere measured by the satellites, an accelerating global warming trend should be occurring and readily detectable.(12) The fact that the global warming trend has not appeared in the satellite data is additional evidence that the climate simulations give exaggerated temperature projections.

The rise of sea level, the melting of mountain glaciers and other even more subtle

climate changes all match predictions.

Without significant and entirely ad hoc adjustments(13) of the energy in various components of the climate system, most models do not even get the average temperature of the earth correct. (14, 15) It is difficult to see how models that cannot predict even the basic properties of the climate system could correctly identify causes of subtle climate changes.

As stated in our preface, the scientific issue of cause and effect is important but not discussed by Dr. MacCracken. A temperature rise, no matter what the cause, should have warming-related effects. Thus, observing such phenomena is not a test of the validity of the models' ability to predict climatic responses as a result of increases in greenhouse gases. The observation of climatic responses per se says nothing about the causes of climate change and, in particular, says nothing about the consequences of greenhouse gas increases.

The issues of rising sea levels and melting glaciers are discussed in Statement 7.

STATEMENT 3: The Northern and Southern Hemisphere patterns of warming correlate well with the combined effects of increasing greenhouse gases and the increasing emissions of sulfate aerosols. In addition, the vertical and latitudinal patterns of temperature change reflect these influences and the additional influence of stratospheric ozone depletion—and these patterns are unlike those associated with natural variability.

[T]he vertical and latitudinal patterns of temperature change reflect these influences . . .

The statement refers to information in Chapter 8 of IPCC 1995. But the validity of the models used for this discussion has been refuted by temperature measurements of the upper atmosphere over the Southern Hemisphere ocean.16 The models predict incorrect patterns of vertical and spatial change, as shown by comparison to the observed temperatures.

. . . these patterns are unlike those associated with natural variability.

This assertion cannot be made without first defining "patterns of natural variability." Further, the pattern of natural variability must also be differentiated from that expected for increased greenhouse gases. It is critical to define the natural causes of climate change in order to be able to identify the signature of any human-caused effects.

STATEMENT 4: More carbon dioxide and other greenhouse gases create a warming influence, moderated somewhat by increasing sulfate aerosol concentrations. While feedbacks such as cloud-radiation interactions can moderate the magnitude of the change, there is no way they can change its sign —warming will be the overall response over the next century.

More carbon dioxide and other greenhouse gases create a warming influence, moderated somewhat by increasing sulfate aerosol concentrations.

This statement omits any mention of an important assumption about a strong, positive feedback by water vapor, discussed below. The sentence should read:

"In the absence of any feedback effect, more carbon dioxide and other minor greenhouse gases create a small warming influence ..."

See comments under Statement 2 on the evidence for the sulfate cooling effect being exaggerated in current models.

While feedbacks such as cloud-radiation interactions can moderate the magnitude of the change, there is no way they can change its sign—warming will be the overall response over the next century.

As mentioned above Dr. MacCracken's statement on feedbacks omits an important assumption about the largest positive feedback in the models considered in IPCC 1995—that water vapor in the upper troposphere is assumed to amplify the warming from the minor greenhouse gases.(17) Both theoretical (18) and observational (19) research suggest that this assumption is flawed. Indeed, the feedback may be negative. (20) The assumption that the feedback of water vapor is positive may be the major reason why models produce too much warming in comparison to actual temperatures. Without the large positive feedback that is assumed for water vapor, the contribution of other positive feedback mechanisms would not produce a large temperature rise. The physics of water vapor is a critical uncertainty in the computer simulations of climate. (21)

STATEMENT 5: Climate models do well at representing large scale features of the present climate, and many aspects of past climates. The models indeed do less well at representing the fine scales which, due to computer resources and limitations in understanding, are harder to represent. That is why the projections are based on large-scale results and why research is needed and continuing to further improve the simulations. As it turns out, however, there is no other objective approach to making projections.

Climate models do well at representing large-scale features.

Regarding modeling large-scale climate features, several IPCC 1995 lead

authors state:

…[L]arge model-model differences in estimates of the spectrum of natural variability, both in terms of variance levels and large-scale spatial patterns, imply considerable uncertainties in our ability to specify the spectrum of natural variability and subsequently to detect any greenhouse warming signal—even if the space time evolution of such signal were perfectly known.(22)

The observations contradict the projections of the climate models, especially in the Arctic regions.(23) The Arctic is where greenhouse-gas warming, according to the models, should be substantially amplified both at the surface and in the lower troposphere, compared to the global average temperature.(24, 25, 26, 27)

In order to have an accurate model of climate change, all important factors on the relevant timescales must be considered simultaneously in the model.(28) However, all relevant factors are not known. See also comments under Statement 2.

The models indeed do less well at representing the fine scales.

We agree.(29)

there is no other objective approach to making projections.

Models have great value in studying climate change. However, validation of the models is requisite to having confidence in the projections. Since the models fail the test of validation against the actual climate records, the projections cannot reliably give even large-scale results.(30) Continuing research is necessary to improve the models. There is no other way to do science.

STATEMENT 6: Climate models simulations of the past century are showing good overall agreement with observations. Models are now starting to be able to simulate the effects of volcanic eruptions and to forecast the El Niño cycle on a seasonal to interannual basis. The latitudinal patterns of precipitation show quite reasonable agreement with observations, although local values differ significantly due to model resolution and the need to better treat cloud convection.

Climate model simulations of the past century are showing good overall agreement with observations.

As stated under Statements 2 and 5, models fail to simulate even the relevant large-scale properties of the climate system.(31)

Models are now starting to be able to simulate the effects of volcanic eruptions . . .

While it is reasonably well established that volcanic eruptions can have a measurable short-term effect on global and hemispheric climate and atmospheric circulation, the nature of volcano-climate interactions remains difficult to simulate.(32, 33)

. . .and to forecast the El Niño cycle on a seasonal to interannual basis.

It is important to realize that the underlying cause of El Niño - Southern Oscillation (ENSO) is not understood. (34)

STATEMENT 7: Melting of mountain glaciers, thermal expansion of the oceans, and other factors (probably the melting of Greenland and/or Antarctica) have caused sea level to rise 4-8 inches in the last hundred years. While melting sea ice has no effect, melting of Greenland and - further glacier melting and thermal expansion are likely to increase the rate of rise by a factor of two or more. Indeed, while some areas are melting it will likely, on average, snow more on the Antarctic continent, limiting the sea level rise from the other factors.

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(probably the melting of Greenland and/or Antarctica) have caused sea level to rise 4-8 inches in the last hundred years.

There are several important factors that contribute to the explanation of observed sea level rise over the last 100 years and they seem largely unre-lated to greenhouse gas increases.(35)

f*urther glacier melting and thermal expansion are likely to increase the rate of [sea level] rise by a factor of two or more.*

On the "likely" further acceleration of sea level rise, it is difficult to see the basis for the given quantitative prediction because past evidence shows no statistically significant acceleration over the last 100 years.(36) Some factors may cause sea level to drop with increased warming, and offset the rise from other factors.(37)

STATEMENT 8: Climate variability and extremes will change as climate patterns change. Models cannot yet predict the details of all the changes; however, overall warming and summer drying will intensify stress on crops, and more moisture in the air will mean more intensive rainstorms when they do occur. Also, reduced variability can be a significant concern – warmer nights will mean fewer frosts to kill off disease vectors.

Climate variability and extremes will change as climate patterns change.

The import of this statement is hard to ascertain because no scientific definitions are given for the terms climate variability and changing climate patterns. Nor are the causes of climate change, and the relative importance of natural and human causes, discussed in the necessary quantitative detail.(38) See also comments on Statement 1.

f*ewer frosts to kill off disease vectors*

The spread of infectious diseases like malaria is based on a complex set of variables, not just temperature. In the case of the mosquito vector of the malarial plasmodium, much of the U.S. has a suitable environment for its survival, at least some of the year. Malaria occurred significantly in the U.S. population until the mid-20th century when efforts to control the vector and the spread of the plasmodium succeeded. Malaria epidemics in the U.S. have been essentially eradicated because of its health and mosquito-control infrastructure.

Malaria currently causes nearly 3 million deaths annually, mostly in Africa, largely because of the lack of effective disease and vector controls.(39)

STATEMENT 9: Warming will occur in many locations and seasons, in each situation creating stresses not naturally there and thus overall exacerbating natural conditions. While sulfate aerosols will limit the warming in some locations, possibly over parts of North America, as the greenhouse gases continue to build-up, they will overwhelm the cooling influence. The warming influence of the greenhouse effect, coupled with the long distance for water to come from the oceans, will make the Great Plains drier and thereby hotter in summer.

Warming will occur in many locations and seasons . . .

Nearly all models discussed in IPCC 1995 predict strong surface warming in the winter in the Arctic region for increasing greenhouse gases.(40) However, the temperature records do not show the projected warming trends. See comments for Statements 2, 3 and 5.

. . .will make the Great Plains drier and thereby hotter in summer.

The computer simulations cannot make accurate projections on time scales of decades to centuries. For example, Dr. MacCracken notes in Statement 5, the model results have no credibility in predicting regional precipitation in a scientifically validated way. One reason is that most models that were used to project greenhouse warming effects do not even have the spatial resolution to see frontal systems, which are where storms occur.

STATEMENT10: While all bad weather is not evidence of global warming, all good weather is not evidence that warming and climatic change are not occurring. Because of natural climate fluctuations, the underlying changes from one year to the next cannot be distinguished, but as they accumulate over time, the changes will become significant. For the few years after the 1991 Mt. Pinatubo eruption, we enjoyed the shading effects of its aerosols. They are now gone, and the decadal average - temperature has started to rise again.

The underlying changes from one year to the next cannot be distinguished, but as they accumulate over time, the changes will become significant.

The increase in greenhouse gases is estimated to have gone halfway to an effective doubling of carbon dioxide. The models project that the warming trend should already be significant, yet it is not. Therefore, we agree with Dr. MacCracken's implication that the current climate projections are exaggerating the warming that should have already happened. That means that the projections of future warming are likely exaggerated as well. Whether or not the changes will become significant is a quantitative question. Such a statement would require validated climate simulations, which must include accurate modeling of all the relevant causes of climate change, anthropogenic and natural. Such simulations are presently unavailable.(41)

ENDNOTES

1. To avoid confusion we give the definition of natural variability we use: variations in the actual climate parameters, excluding anthropogenic causes. This is similar to "total natural variability" (p. 33) in Climate Change 1995: The Science of Climate Change: Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 1995), 1996, ed. J.T. Houghton et al. (Cambridge: Cambridge University Press), Summary for Policymakers, 572 pp.

2. For example: "Much of the unprecedented warmth of hemisphere-mean wintertime temperature during the past 20 years can be attributed to … natural causes" (J.M. Wallace and Y. Zhang, 1996, submitted to Journal of Climate). A similar result was found for northern hemisphere land temperatures whose variability "… is not - necessarily an integral part of the fingerprint of global warming" (J.M. Wallace, Y. Zhang, and J.A. Renwick, 1995, Science 270, 780-783).

3. IPCC 1995, Section 3.5.4, p. 173.

4. E.g., "The model data have lower variance than the paleodata at all time scales considered (2 years to >100 years), with the largest mismatches occurring on longer time-scales." [italics added] IPCC 1995, caption to Fig. 8.2, p. 421; see also text p. 421.

5. IPCC 1995, Summary for Policymakers, p. 5.

6. IPCC 1995, Summary for Chapter 8, p. 411.

7. I.M. Held, 1993, Bulletin of the American Meteorological Society 74, 228-241.

8. I. Polyak and G. North, 1997, Journal of Geophysical Research 102, 1921-1929.

9. I. Polyak and G. North, 1997, Journal of Geophysical Research 102, 6799-6812.

10. T.P. Barnett, B.D. Santer, P.D. Jones, R.S. Bradley, and K.R. Briffa, 1996, Holocene 6, 255-263.

11. There are two assumed aerosol effects: direct and indirect. The climate impact of the direct effect seems small: "Our specific conclusion regarding anthropogenic aerosols is that their net 'direct' impact on global surface temperature .. is probably small and even its sign is uncertain" (J. Hansen, M. Sato, and R. Ruedy, 1997, Journal of Geophysical Research 102, 6831-6854). On the - indirect aerosol effect, IPCC 1995 states that it "… remains very difficult to quantify, more so than the direct effect" (p. 72), and, "Our quantitative understanding is so limited at present that no mid-range estimate is given" (p. 115). For example, Pan et al. (1997) estimate that the modeled uncertainty of the direct aerosol effect is between –0.1 and –4.2 Watts m-2 (i.e., unknown by a factor of 42); this should be compared to the global mean radiative forcing by the increased gases since 1880 of 2.5 Watts m-2 (W. Pan et al., 1997, Journal of Geophysical Research 102, 12,915-12,924).

12. In addition to the satellite measurements, balloon radiosonde records of the lower troposphere extend

back nearly 40 years and provide another test of predictions by climate simulations. In that regard, T.N. Palmer states, "Let us conclude … by asking why the IPCC GCM simulations have not replicated the Angell [balloon-radiosonde] observations? It is possible that large-scale dynamics of many GCMs is still inadequate, and that the simulated warming in the 300-100 hPa region is a manifestation of this inadequacy." T.N. Palmer, 1996, in Decadal Climate Variability Dynamics and Predictability, NATO ASI Series, Vol. I 44, ed. D.L.T. Anderson and J. Willebrand (Berlin-Heidelberg: Springer-Verlag), 84-155. Incidentally, the satellite records are consistent with the balloon-based records where they overlap.

13. "…[T]he [flux] adjustments do prevent the rapid drift of the model state from the realistic initial conditions, which could seriously distort the results of a numerical experiment … the adjustments do not eliminate the shortcomings of the model physics …" S. Manabe and R.J. Stouffer, 1997, Bulletin of the American Meteorological Society 78, 1177-1185. "There is, however, always the possibility … that the true climate will shift to a new 'equilibrium' under changing conditions while the climate model with its flux correction may fail to predict this change. It is obvious, however, that a removal of flux adjustments is not a remedy at least at the moment. If this is done the climate will drift but the model errors remain. Predictions of climate change without flux - corrected models are hardly more reliable." J. Egger, 1997, Climate Dynamics, 13, 285-292.

14. M. Nakamura, P. Stone, and J. Marotzke, 1994, Journal of Climate 7, 1870-1882; J.D. Neelin and H.A. Dijkstra, 1995, Journal of Climate 8, 1325-1342; E.K. Schneider, 1996, Annales Geophysicae 14, 336-341; W. Cai and P.C. Chu, 1997, Annales Geophysicae 15, 1067-1075.

15. Without parameter adjustment, models do not correctly predict the temperature difference between the equatorial and polar regions, where a significant flow of energy occurs in the climate system. "… [W]ithout knowing the dynamical heat fluxes, it is clear that one cannot even calculate the mean - temperature of the earth" (R.S. Lindzen, 1997, Proceedings of the National Academy of Science, USA 94, 8335-8342).

16. P.J. Michaels and P.C. Knappenberger, 1996, Nature 384, 522-523; G.R. Weber, 1996, Nature 384, 523-524. In addition, the statistical methods used to claim detection of the human-caused climate change signal may be biased and inap-propriate (D.R. Legates and R. E. Davis, 1997, Geophysical Research Letters, 24, 2319-2322).

17. IPCC 1995 assumes a positive water-vapor feedback: "The processes determining the distribution of upper tropospheric water vapour are still poorly understood … [but] the preponderance of evidence also points to [water vapor feedback] being positive in the upper troposphere" (p. 197). However, IPCC 1995 also states: "Much of the current debate has been addressing feedback from the tropical upper troposphere, where the feedback appears likely to positive. However, this is not yet convincingly established; much further - evaluation of climate models with regard to observed processes is needed" (p. 201).

18. D.-Z. Sun and R. Lindzen, 1993, Annales Geophysicae 11, 204-215; D.-Z. Sun and R.S. Lindzen, 1993, Journal of Atmospheric Sciences 50, 1643-1660.

19. R.W. Spencer and W.D. Braswell, 1997, Bulletin of the American Meteorological Society 78, 1097-1106.

20. R.S. Lindzen, 1996, in Climate Sensitivity to Radiative Perturbations: Physical Mechanisms and Their Validation, NATO ASI Series, Vol. I 34, ed. H. Le Treut (Berlin-Heidelberg: Springer-Verlag), 51-66.

21. E.g., "The cumulus convection schemes currently in use in GCMs bypass the microphysical processes by making arbitrary moistening assumptions. We suggest that they are inadequate for climate change studies" (N.O. Rennó, K.A. Emanuel, and P.H. Stone, 1994, Journal of Geophysical Research 99, 14, 429-14, 441).

22. Barnett et al. (1996), p. 257 [italics added].

23. "Some of the results from the present study are relevant to most—if not all—

of the present general circulation models in use today to study natural climate variability and the climate change associated with increasing greenhouse gases; they suggest that the variability in the arctic climate is probably much more energetic than is being simulated in these general circulation (climate) models … [O]ur results suggest that the treatment of sea ice in the climate models that are presently used to address the detection problem seriously jeopardizes the veracity of the simulated arctic climate variability...this raises serious questions concerning the viability of the predicted climate change using these models" (D.S. Battisti, C.M. Bitz, and R.E. Moritz, 1996, Journal of Climate 10, 1909-1920).

24. "…[G]reenhouse-induce warming is not detectable in the Arctic troposphere

for the 1958-1986 period" (J.D.W. Kahl et al., 1993, Journal of Geophysical Research 98, 12,825-12,838).

25. The satellite MSU data (1979-1997) and the balloon radiosonde data (1958-1995) show no net warming in the high (60-90°N) Northern latitudes (J. Christy, 1997, personal communication).

26. An indication that the Arctic region is warming would be that the winter weather system, the polar vortex, is shrinking. However: "… the January circumpolar vortex has expanded over the past two decades … contrary to - general circulation model forecasts that predict a decrease in the meridional temperature gradient of the Northern Hemisphere as trace-gas concentrations increase" (R.E. Davis and S.R. Benkovic, 1994, International Journal of Climatology 14, 415-428).

27. The U.K. Meteorological Office's monthly surface temperature observations for the Northern Hemisphere, which comprise the temperature record widely used by the climate community and the IPCC, were analyzed by I. Polyak and G. North. They found that there is no significant warming trend at high northern latitudes since 1946, and that the earlier portion of the record is too unreliable for determining a trend (I. Polyak and G. North, 1997, Journal of Geophysical Research 102, 1921-1929).

28. S.H. Schneider, 1994, Science 263, 341-347; D. Rind, 1996, in Climatic Variations and Forcing Mechanisms of the last 2000 years, NATO ASI Series, Vol. I 41, ed. P.D. Jones, R.S. Bradley, and J. Jouzel, (Berlin-Heidelberg: Springer-Verlag), 563-581.

29. "At present the predicted regional changes in surface climatic variables cannot be regarded as reliable either in forced or coupled GCMs, since the agreement between different models is lower than the agreement between alterna-tive observed climatologies, especially for quantities associated with the hydrological cycle. At current resolution, GCMs are limited to their - ability to investigate regional - climate change" (B. Timbal et al., 1997, Journal of Climate 10, 1463-1469).

30. R.S. Lindzen, 1994, Annual Review of Fluid Mechanics 26, 353-378. See also - comments on Statements 1 and 2.

31. ". . . [T]he 100-year runs of the GCM without variability validation cannot produce observed climate and . . . any speculations about climate change, based on the utilization of the results of these runs, cannot be credited with any level of confidence." Polyak and North, 1997, p. 6799.

32. "It has been emphasized that the results of numerical modeling aimed at the assessment of climate change due to eruptions are controversial. It has been shown that it is difficult to identify VCS (Volcanic Climate Signal) because of the coupling between various climate-forcing processes (the El Niño/Southern Oscillation phenomenon, and the Quasi-Biennal Oscillation in the stratosphere being of special significance)."

K. Ya. Kondratyev, 1996, in The Mount Pinatubo Eruptions Effects on the Atmosphere and Climate, NATO ASI Series, Vol. I 42, ed. G. Fiocco, D. Fua, and G. Visconti, (Berlin-Heidelberg: Springer-Verlag), 273-287.

33. "Global cooling of the Earth's surface has been observed following the largest volcanic eruptions of the past century, although the average cooling is perhaps less than expected from simple energy balance considerations … Climate models which incorporate the effects of continents and oceans and treat the ocean heat capacity in ways neglecting dynamical feedbacks typically yield a maximum global cooling of about 0.5°C … It is noteworthy that none of these - models realistically portrays the interactions of surface climate with either ocean dynamics or stratospheric dynamics … Overall, we conclude that the connection of volcanoes and climate change has remained substantially anecdotal and much less quantitative than desired (Self and Rampino 1988; Robock 1991), in part because of the difficulty of identifying volcanic effects in the presence of large natural climate variability." J. Hansen et al., 1996, in The Mount Pinatubo Eruptions Effects on the Atmosphere and Climate, NATO ASI Series, Vol. I 42, ed. G. Fiocco, D. Fua, and G. Visconti, (Berlin-Heidelberg: Springer-Verlag), 233-272.

34. J.D. Neelin, D.S. Battisti, A.C. Hirst, F.-F. Jin, Y. Wakata, T. Yamagata, and S. Zebiak, 1997 (in press), Journal of Geophysical Research.

35. "Ice accumulation at high latitudes, ocean thermal expansion and changes of circulation, melting of small glaciers, and water storage in large and small artificial reservoirs can offset one another to a greater or lesser extent. One must also account for the relative stability of sea level for the several millennia prior to 19th century, and the subsequent sudden (in historic terms) increased rate of rise beginning well before there was a significant increase of anthropogenic atmospheric greenhouse gases. Finally, the strongly-held and not totally implausible view that global sea level rise value reported by recent authors is only an artifact resulting from coastal subsidence or poor data distribution, must be addressed" (B.C. Douglas, 1995, U.S. National Report to International Union of Geodesy and Geophysics 1991-1994: Reviews of Geophysics, Supplement, 1425-1432).

36. "For the 80-year period of 1905-1985, 23 essentially complete tide gauge records in 10 geographical groups are available for analysis. These yielded the apparent global acceleration –0.011 (± 0.012) mm yr-2. A larger, less uniform set of 37 records in the same 10 groups with 92 years average length covering the 141 years from 1850 to 1991 gave for acceleration 0.001 (± 0.008) mm yr2. Thus there is no evidence for an apparent acceleration in the past 100+ years that is significant either statistically, or in comparison to values associated with global warming"

(B. C. Douglas, 1992, Journal of Geophysical Research 97, 12, 699-12, 706).

37. H. Ye and J.R. Mather, 1997, International Journal of Climatology 17, 155-162. In the case of the Antarctic ice shelf: "For the present mode of oceanographic circulation, the implication is that warmer winters (a climate warming[)], leading to lower rates of sea-ice formation, would cause a reduction in the flux of HSSW [High Salinity Shelf Water] beneath the ice shelf. The resultant cooling in the sub-ice cavity would lead, in turn, to a reduction in the total melting at the ice shelf's base. A moderate warming of the climate could thus lead to a basal thickening of the Fichner-Ronne Ice Shelf, perhaps increase its longevity" (K.W. Nicholls, 1997, Nature 388, 460-462).

38. In summarizing the section on projections of Changes in Extreme Events, IPCC 1995 concluded that "Current climate models lack the accuracy at smaller scales and the integration are often too short to permit analysis of local weather extremes. Except maybe for precipitation, there is little agreement between models on changes in extreme events." (p. 336) Regarding extreme wind events: "Clearly, there is little agreement between models on changes in storminess that might occur in a warmer world. Conclusions regarding extreme storm events are obviously even more uncertain." (p. 334) As for tropical cyclones: " … [I]t is not possible to say whether the frequency, area of occurrence, time of occurrence, mean intensity or maximum intensity of

tropical cyclones will change." (p. 334)

39. C.J.L. Murray and D. Lopez, 1996, in The Global Burden of Disease Study, Global Burden of Injury Series (Boston: Harvard University Press), 975 pp.

40. See for example IPCC1995 Figure 6.10 on p. 307.

41. "Our ability to quantify the magnitude of [the human influence] is currently - limited by uncertainties in key factors, including the magnitude and patterns of longer-term natural variability and the time-evolving patterns of forcing by (and response to) greenhouse gases and aerosols" (IPCC 1995, p. 439).