Are Human Activities Causing Global Warming?

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I. INTRODUCTION

Continuing controversy over the extent of human influence on climate change suggests that a review of the latest findings on global warming written for a general audience will contribute to a wider understanding of this critical issue. Previous analyses of the global warming problem by the Marshall Institute have concentrated on the validity of climate models, the climate record as revealed in temperature observations, and the lack of a greenhouse signal in the temperature record to date. This report summarizes some results discussed in earlier reports, but its focus is on new facts related to the global warming issue as it has been discussed over the last 12 months.

The study begins with a review of evidence relating to claims that 1995 was the warmest year on record, and that anthropogenic global warming has caused and will cause a greater frequency of severe storms and extreme weather events, including blizzards and hurricanes.

The remainder of the report concerns statements by the UN Intergovernmental Panel on Climate Change (IPCC) that for the first time it is now possible to discern in the temperature record a significant human influence on climate.

This most recent Marshall Institute review of scientific evidence on climate change confirms the earlier conclusion that predictions of an anthropogenic global warming have been greatly exaggerated, and that the human contribution to global warming over the course of the 21st century will be less than one degree Celsius and probably only a few tenths of a degree. Spread over a century, a temperature rise of this magnitude will be lost in the noise of natural climate fluctuations.

II. SIGNS OF GLOBAL WARMING CAUSED BY HUMAN ACTIVITIES

According to computer models of climate change, the average temperature of the earth's surface should have increased by approximately 1°C in the last 100 years, in response to the increased concentration of anthropogenic greenhouse gases in the atmosphere. A temperature rise of approximately one-half degree has been observed, but most of that rise occurred before 1940 while most of the greenhouse gases produced by human activities entered the atmosphere after 1940. (See Section V.) Thus, anthropogenic greenhouse gases can only account for a small part of the observed half-degree rise — at most a few tenths of a degree. This amount of global warming is considerably less than had been predicted to result from human activities. Recent work suggests that the cooling effect of atmospheric pollution can account for the apparent absence of global warming due to man-made greenhouse gases.[1] Section V discusses recent theoretical analyses leading to this conclusion.

An increase in the earth's average temperature would be the most direct manifestation of the climate impact of anthropogenic greenhouse gases. In view of the nonappearance of the predicted temperature increase, it has been suggested that signs of the climate impact of the anthropogenic greenhouse gases may be sought in other weather and climate phenomena, such as the occurrence of exceptionally hot years in the recent climate record, or an increase in the frequency of occurrence of hurricanes and other extreme weather events. Evidence bearing on these effects is discussed below.

1995: Warmest Year on Record?

On January 2, 1996, the British Meteorological Office (UKMO) and the University of East Anglia announced that 1995 had been the warmest year on record. The

1. Mitchell, J.F.B., T.C. Johns, J.M. Gregory and S.F.B. Tett, *Nature* **376**, 501-504 (1995).

global warming implications in this finding led to a considerable amount of press comment, e.g.,

> "'95 Is Hottest Year on Record As the Global Trend Resumes"
> — ***New York Times, 1/4/96***
>
> "Hottest year heralds global warming"
> — ***New Scientist, 23/30 December 1995***

According to the UKMO the global average surface temperature for 1995 was 0.04°C — 1/25 of a degree — warmer than the average temperature for the previous record-breaking year, 1990. However, a NASA team's analysis of global temperature observations finds 1995 to be *cooler* than 1990 by about 0.01°C. Moreover, throughout the 1980-1995 period, the NASA analysis differs from the UKMO results by an average of 0.1°C — substantially greater than the difference that is supposed to make 1995 the warmest year. The year-to-year fluctuations in each temperature analysis also average 0.1°C. These facts suggest that the temperature difference that forms the basis for the UKMO announcement is not significant. That conclusion is supported by the satellite temperature measurements, released later in January, which indicate that 1995 was only the eighth warmest year in the last 17 years (the period for which satellite measurements have been available). The temperature for 1995 is precisely in the middle of the temperature range for the last 17 years. Far from being unusually warm, 1995 was an ordinary year in the satellite record.

The Warm 1980s and 1990s

The 1980s and 1990s to date have been a warm 1 1/2 decades with a temperature increase of approximately 0.2 - 0.3°C from 1980 to the present. Over the last 17 years the temperature has been increasing at the rate of 0.17°C/decade according to surface measurements, and 0.09°C/decade according to satellite data.[2] Is this very recent warming trend caused by anthropogenic greenhouse gases?

Trends of the order of 0.1 - 0.2°C/decade are within the range of natural variability and occur frequently in the climate record. In themselves, they provide no indication of a human influence on climate. From 1890 to 1900, for example, the temperature rose at the rate of 0.2°C/decade — somewhat greater than the rate of temperature increase measured between 1980 and 1994. From 1900 to 1910 the temperature fell at the rate of 0.2°C/ decade. Between 1910 and 1940 the temperature rose approximately 0.15°C/decade for a total increase of nearly 0.5°C.

All these warming and cooling trends in the half century prior to 1940 must have been mainly the product of natural factors in the climate system, since no significant anthropogenic influence on climate existed in that early period. In particular, as noted earlier, the half-degree warming between 1910 and 1940 occurred too early for carbon dioxide and other anthropogenic greenhouse gases to have played any significant role. The 1990 *IPCC Scientific Assessment* concurs:[3] "The rather rapid changes in global temperature seen around 1920-1940 are very likely to have had a mainly natural origin." But if natural forces caused the half-degree temperature rise between 1910 and 1940, they could also have caused the temperature rise of 0.3°C observed in the 1980s and 1990s. Contrary to statements by some scientists that have been reported in the press, the recent temperature rise in the 1980s and 1990s provides no evidence of a global warming due to human activities.

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2. These values have been adjusted to include an estimate of the transient cooling caused by the eruption of the Mt. Pinatubo volcano in the Philippines. See Jones, P.D., *Geophys. Res. Ltrs*. **21**, 1149-1152 (1994).
3. *Climate Change: The IPCC Scientific Assessment*, Houghton, J.T., G.J. Jenkins and J.J. Ephraums, eds., p. 233, Cambridge University Press (1990).

III. EVIDENCE FROM THE RECORD OF ANCIENT CLIMATES

The geologic record reveals that major changes in the atmospheric concentration of carbon dioxide have occurred during the earth's history. A comparison with evidence for temperature changes occurring at the same time can yield information on the sensitivity of the earth's climate to CO_2 changes, and the planet's probable increase in carbon dioxide concentration expected in the next century. This empirically based determination of the temperature rise resulting from carbon dioxide increases could have greater validity than the theoretical estimates derived from computer models of the earth's climate, which are subject to major uncertainties because of difficulties in estimating cloud and water-vapor feedbacks.

Unfortunately for the usefulness of this approach to the global warming problem, the earth's climate record indicates that other significant factors in climate change frequently come into play simultaneously with the changes in CO_2 levels. These factors can add to the warming effect of an increase in CO_2, thus making the climate sensitivity to carbon dioxide changes seem greater than it really is; or they can subtract from the warming effect of the added CO_2, making the climate sensitivity to higher CO_2 levels seem smaller than it really is. Reliance on the paleoclimate record for clues to the magnitude of a future greenhouse effect may lead to seriously misleading results.

For example, in the Ordovician, 440 million years ago, the CO_2 concentration was as much as 10 times present levels. Using the IPCC's best estimate of a global warming of 2.5°C for the equilibrium response to a doubling of CO_2, the temperature in the Ordovician should have been approximately 8°C above today's levels. The lower limit of the range of IPCC estimates — a warming of 1.5°C for doubled CO_2 concentration — would have led to a warming of approximately 5°C in the Ordovician for this level of CO_2 concentration. However, the climate in the Ordovician did not agree with either of these estimates. The geologic record reveals that during the Ordovician the earth was in the grip of a major ice age, with temperatures 5 - 10°C *below* today's levels.[4]

Crowley and Baum have shown the low temperatures in the Ordovician ice age may be explained as a result of the proximity of the South Pole to the continental mass which is now a part of Africa.[5] Their analysis confirms that other factors — in this case, the altered geography in the Cretaceous — acting simultaneously with an increase in CO_2 can swamp the warming effect of the added CO_2. In general, these other factors are not fully understood; in some cases their existence may not be even be suspected. As a consequence, it may be impossible from the record alone to disentangle the temperature response to CO_2 changes.

In addition to episodes such as the Ordovician ice age — in which CO_2 increased but temperature did not — the climate record also reveals instances in which temperatures increased but CO_2 did not. An example is the warmest period of the current interglacial, in the mid-Holocene, ca. 4,000 BCE, when temperatures were 1 - 2° above today's levels,[6] and about the same as the warming predicted by climate models for the end of the 21st century. However, the concentration of CO_2 at that time was approximately equal to that of the preindustrial era, i.e., 25% *below* today's levels.[7]

These examples indicate that large errors in forecasting climate can result from the assumption that changes in CO_2 concentration are one of the main driving forces in climate change. It is not possible to assume that temperature changes in

4. Crowley, T.J. and S.K. Baum, *J. Geophys. Res.* **96**, 22,597-22,610 (1991).
5. Crowley, T.J. and S.K. Baum, *J. Geophys. Res.* **100**, 1093-1101 (1995).
6. Lamb, H.H., *Climate, history and the modern world,* Methuen, London and New York (1982).
7. Ref 3, p. 202.

the paleoclimate record have been caused largely or entirely by one factor — a change in the concentration of CO_2.

IV. SEVERE STORMS AND GLOBAL WARMING

"Blizzards, Floods & Hurricanes: Blame Global Warming."
— *Newsweek, 1/22/96*

It has been suggested that greenhouse warming will increase the frequency and severity of violent storms and extreme weather conditions. Both the recent climate record and the history of past climate changes going back a thousand years indicate that this suggestion has no foundation in fact. The climate history of the past millennium demonstrates that cold — and not warmth — is associated with greater storminess.

The warmest conditions in the last thousand years on both sides of the Atlantic occurred in the 10th - 12th centuries, when the temperature was approximately 0.5°C warmer than today[8] and comparable to the temperatures predicted by the climate models for the 2030 - 2050 period. Yet that was a period of benign climate in Europe and North America, when vineyards flourished in England and the southern regions of Greenland were free of ice and farmed by Norse settlers. Those relatively warm centuries are known as the Medieval Climatic Optimum.

In the 13th century the climate began to cool as the earth slid into a centuries-long cold period called the Little Ice Age. Temperatures in the depths of the Little Ice Age were 0.5 - 1°C cooler than today. The Little Ice Age lasted through the 17th and 18th centuries and into the 19th, when a recovery began and a climb to higher temperatures that appears to be still continuing. With the advent of colder weather

8. Lamb, H.H., *Climate: Present, Past, and Future,* Vol. 2, Methuen, London and New York (1972-1977).

in Europe starting in the 13th century, the severity and frequency of storms increased dramatically in the area around the North Sea. More than 100,000 people died in flooding of the North Sea by storms in 1421 and 1446; a storm in 1570 resulted in the deaths of over 400,000 people. The number of severe floods on the North Sea coast in the last 1000 years seems to have been greatest in the early 1400s and late 1600s; about three times as many disastrous floods occurred then as in the warmer 20th century.

Hurricanes and Tornadoes

A comparison of weather conditions in the Medieval Climatic Optimum and the Little Ice Age suggests that the general level of storminess will decrease, rather than increase, in a warmer climate. But can global warming cause an increase in the frequency and severity of the most violent storms — hurricanes and tornadoes? Meteorological records contain evidence bearing on this question. Figure 1 (p. 9) shows the dependence of the yearly number of hurricanes in the North Atlantic on the temperature of the Northern Hemisphere at the time each hurricane occurred.[9] There is no indication of a trend toward an increase in the number of hurricanes with increasing temperature. Figure 2 (p. 9) shows the relation between the yearly number of tornadoes in the U.S. and the U.S. average temperature, again with no indication of a positive trend.[10]

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9. *Hurricanes*: National Climatic Data Center, NOAA. *Temperature*: Jones, P.D., T.M.L. Wigley and K.R. Briffa, *Trends '93*, ORNL/CDIAC-65, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN, p. 603-608.

10. *Temperature*: Karl, T.R., D.R. Easterly, R.W. Knight and P.Y. Hughes, *Trends '93*, ORNL/CDIAC-65, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN, p. 689 and updates. *Tornadoes*: National Climatic Data Center, NOAA.

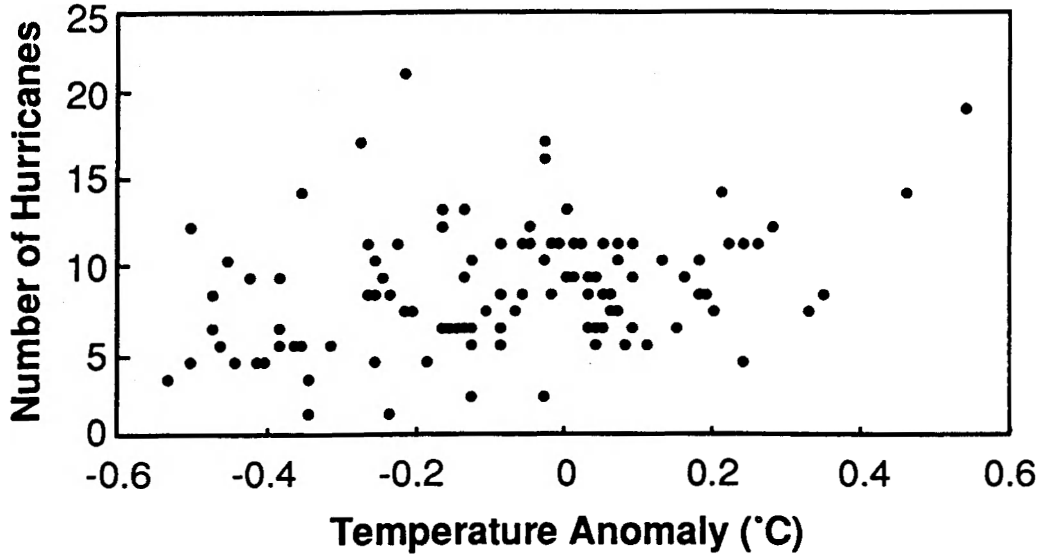

Fig. 1. Yearly number of North Atlantic hurricanes vs. Northern Hemisphere average temperature 1886 - 1995. (Source: ref. 9)

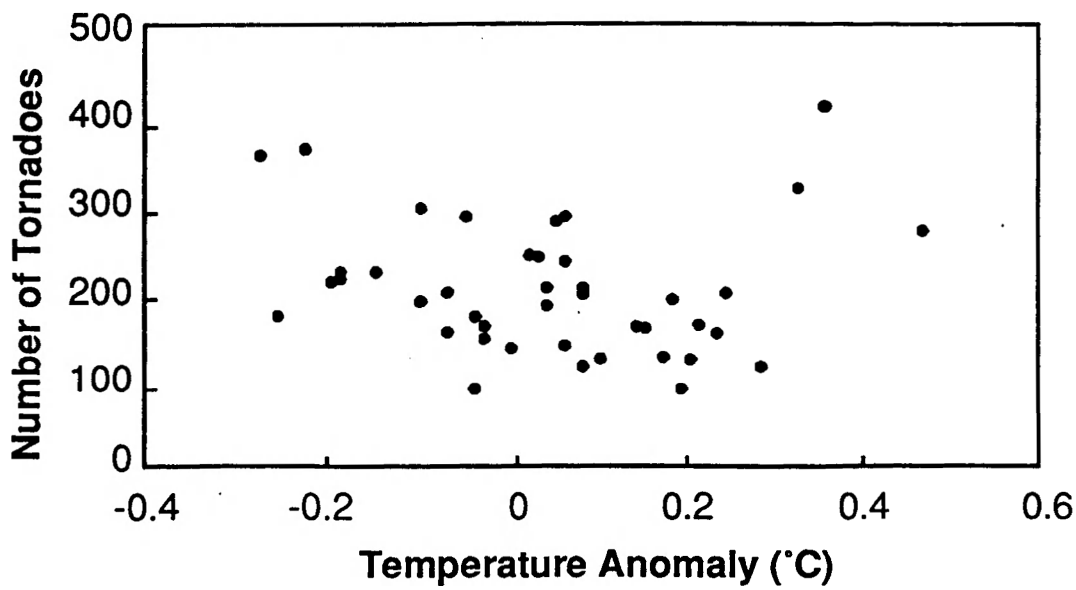

Fig. 2. Yearly number of tornadoes vs. U.S. average temperature 1953 - 1994. (Source: ref. 10)

Heavy Rains

The National Climatic Data Center has analyzed the number of heavy rains from 1910 to 1990. The records indicate that heavy rains, with accumulations greater than two inches over 24 hours, have increased in frequency over that period. The increase is modest: one additional heavy rain every two years.[11] Does this change constitute evidence for global warming due to human activity?

A change in the pattern of rainfall in the 1910-1990 period is not surprising, since there was a global warming of approximately one-half degree since 1910. A warmer earth means more evaporation and more condensation, and thus more and/or heavier rain. However, granting that global warming may change rainfall, the key question is: *Was the global warming caused by human activities?* Since, as noted earlier, most of the half-degree global warming occurred before 1940, while most of the CO_2 and other anthropogenic greenhouse gases entered the atmosphere after 1940, we can be certain that most of the half-degree warming was the product of natural factors and not the result of human activities. Therefore, these natural factors in climate change are the cause of heavier rainfall.

Severe Cold

It has been suggested that a global warming caused by human activities is responsible for the extremely cold weather that afflicted the eastern and southern U.S. in January 1996. However, the opposite is true; if the anthropogenic greenhouse effect has any appreciable impact on climate, it must be such as to make winters milder, not colder. The reason is that the warming effect of carbon dioxide and other greenhouse gases, as noted below in the discussion of Arctic temperature changes (Section VIII), is particularly effective at high latitudes; that is, the green-

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11. Karl, T.R., R.W. Knight and N. Plummer, *Nature* **377**, 217-220 (1995).

house effect warms the Arctic considerably more than the globe as a whole. When cold weather develops in the U.S., it is usually because cold polar air masses have moved southward. Because the warming due to the greenhouse effect is greatest at high latitudes, in and near the Arctic, these polar air masses are warmer than they would otherwise be, and the cold snap that develops over the U.S. is milder. If the warming caused by greenhouse gases has any significant impact on U.S. winters, the impact must be such as to make the winters milder.

Blizzards and Snowstorms

> "Blame Global Warming for the Blizzard."
>
> — ***New York Times, 1/14/96***

The heavy snowfalls accompanying the cold weather of January 1996 have also been attributed to an anthropogenic global warming. This suggestion is based on the reasoning, again, that higher temperatures lead to more evaporation of water and a higher moisture content in the atmosphere, and thus to heavier snows when the warm, moist air encounters cold air masses moving southward from the polar regions.

However, observations indicate that the opposite is true, at least on the eastern seaboard, which was the site of much of the heavy snowfall in January 1996. Figure 3 (p. 12) shows, for the representative eastern seaboard state of Virginia, the number of inches of snow that fell in January and February for the years from 1927 to 1987, vs. the average temperature in January and February for the corresponding years.[12] The lines mark normal snowfall and temperature. Figure 3 demonstrates that, as intuition would suggest, heavy snowfalls occur when temperatures are low, and not when

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12. *Virginia Climate Advisory*, Vol. 11, No. 4, p. 13.

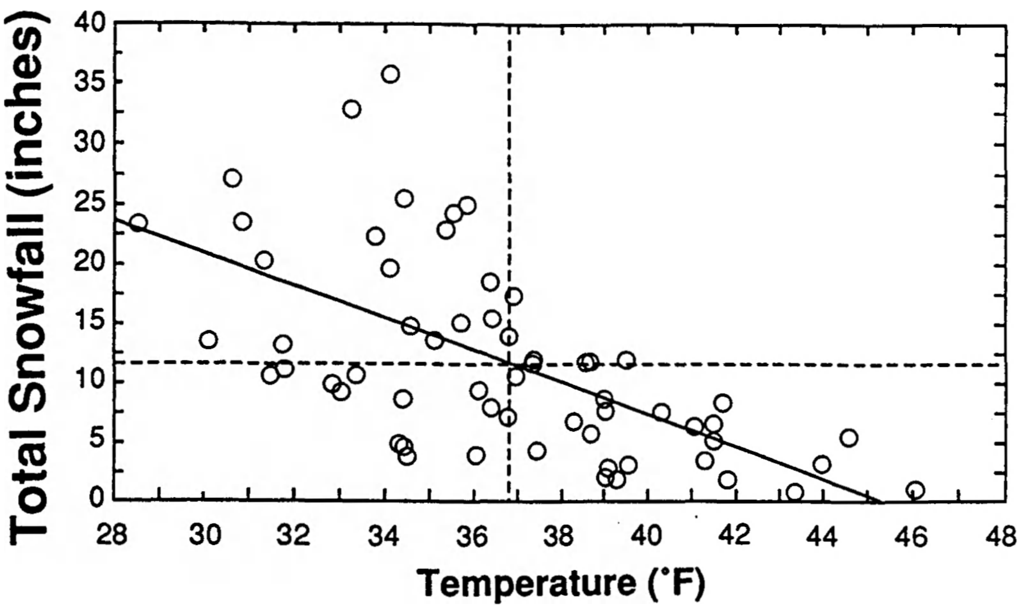

Fig. 3. Total snowfall in January and February vs. average January/February temperature for the period 1927 - 1987. The dotted lines indicate average snowfall and temperature in those months.

the weather is relatively warm. Note that the upper-right quadrant of the chart is empty: the heaviest snows *never* occur when the temperature is relatively high.

In sum: Both the recent climate record and the climate history of the last 1000 years demonstrate no connection between a warm global climate and an increased frequency and violence of storms. Storminess appears to be linked to cooler, rather than warmer temperatures. The most benign conditions have prevailed in times of elevated global temperatures.

V. CLIMATE IMPACT OF ATMOSPHERIC POLLUTION

As noted in Section II, it has been clear for some time that the earth is not warming as much as greenhouse theories had predicted. According to the climate model simulations of the greenhouse effect, carbon dioxide and other greenhouse gases added to the atmosphere in the last century should already have increased the average temperature of the earth's surface by about one degree Celsius.[13] The observations show an increase of approximately a half-degree over that period, suggesting, as noted earlier, that the calculations are exaggerating the greenhouse warming by a factor of two.

Exaggerated Estimates of Global Warming

The actual overestimate of man-made global warming must be considerably greater than a factor of two, because most of the half-degree rise occurred prior to 1940, whereas most of the CO_2 and other greenhouse gases entered the atmosphere after 1940.[14] Anthropogenic greenhouse gases cannot be the cause of a warming which occurred before these gases entered the atmosphere. It follows that the greenhouse effect can only be responsible for at most a few tenths of a degree out of the observed half-degree rise. The computer simulations of climate, which estimate a warming of approximately one degree due to the greenhouse effect in the last 100 years, apparently have overestimated the greenhouse warming to date by a factor of three or more.

Why does it matter whether the warming caused by the greenhouse effect over the ***last*** 100 years has been one degree, or one-half degree, or one-quarter degree? Isn't the important question how big the greenhouse effect will be in the ***next*** 100 years?

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13. Mitchell, J.F.B., R.A. Davis, W.J. Ingram and C.A. Senior, *J. Clim.* **8**, 2364-2386 (1995).
14. The concentration of CO_2 in the atmosphere has increased by 20 - 25% in the last hundred years, and increases in other greenhouse gases, such as methane, have increased by the equivalent of another 20 - 25% rise in CO_2. Overall, there has been a greenhouse gas increase equivalent to approximately a 40 - 50% rise in the concentration of CO_2 in the atmosphere in the last hundred years. Most of that increase has occurred in the last fifty years.

The reason these global warming overestimates for the last 100 years are important is that the same climate models which have exaggerated the warming in this century are the source of the predictions of a harmful global warming in the next century. When the global warming forecasts are corrected for the three-fold exaggeration, the predicted warming in the next century drops to a few tenths of a degree. Spread over a century, a temperature increase as small as this will be lost in the noise of natural climate fluctuations.

An Explanation for the Absence of Anthropogenic Global Warming

Why has the predicted global warming due to increasing CO_2 concentrations failed to appear? A plausible explanation is that the warming effect of the greenhouse gases is as large as the climate models estimate, but has been masked by the cooling effect of atmospheric pollution. The burning of fossil fuels — oil, coal and natural gas — releases sulphur compounds into the atmosphere, where these compounds form small particles called sulphate aerosols. The sulphate aerosols create a haze that partly screens the earth from incident sunlight and tends to cool the planet. Recent calculations with the climate models confirm that when the cooling effect of the aerosols is combined with the warming effect of carbon dioxide and other greenhouse gases, the predicted temperature rise comes closer to temperature changes actually observed in recent decades. (The report by the IPCC Working Group I notes, "This agreement does not, however, constitute identification of an anthropogenic effect on climate and may be serendipitous.")

An example of the improvement gained by adding the effect of aerosols is shown in Figure 4 (p. 15), adapted from a report by the British Meteorological Office (UKMO),[1] which compares the observed global average temperatures (solid curve) with temperatures computed assuming greenhouse warming only (dash-dot curve) or greenhouse warming plus aerosol cooling (dashed curve). The chart confirms that allowing for the cooling effect of aerosols improves the agreement between the observations and the computed global average temperatures for the last three decades.

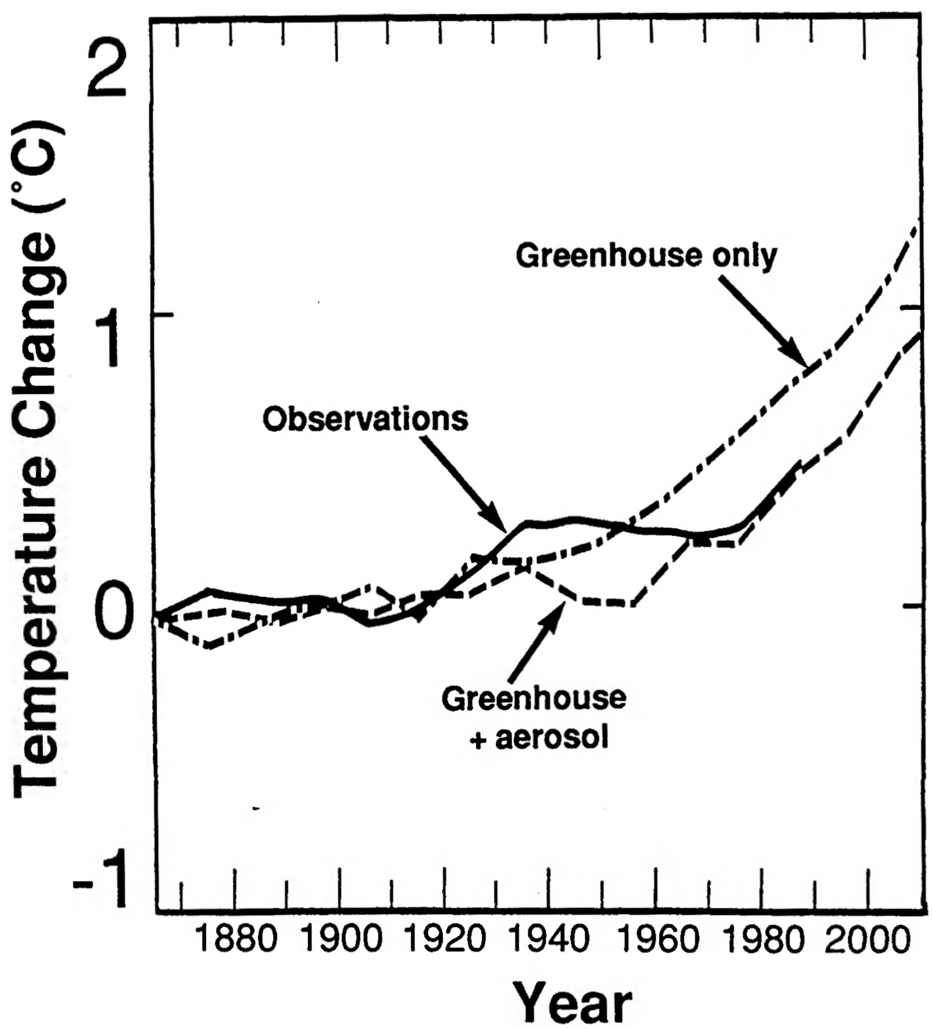

Fig. 4. Changes in global average temperature, computed from a climate model assuming greenhouse gases only (- — - —) and greenhouse gases plus aerosols (— — —), compared with observed temperatures (——). Adapted from Mitchell et al., ref. 1.

Unresolved Discrepancies

However, while aerosols improve the agreement with observation in recent decades for the *globally* averaged temperature, in some regions of the globe the inclusion of aerosols worsens the agreement. These regions include the heavily industrialized and densely populated areas of the U.S. and Europe, which are intense sources of aerosols and consequently are cooled by them to a greater degree than the globe as a whole. Figures 5 (a) and (b), also adapted from the UKMO report, show that in North America and Europe the agreement between the observed and calculated temperatures, which was fairly satisfactory without the aerosols, is poor when they are included in the climate computations because these regions are now too cool.

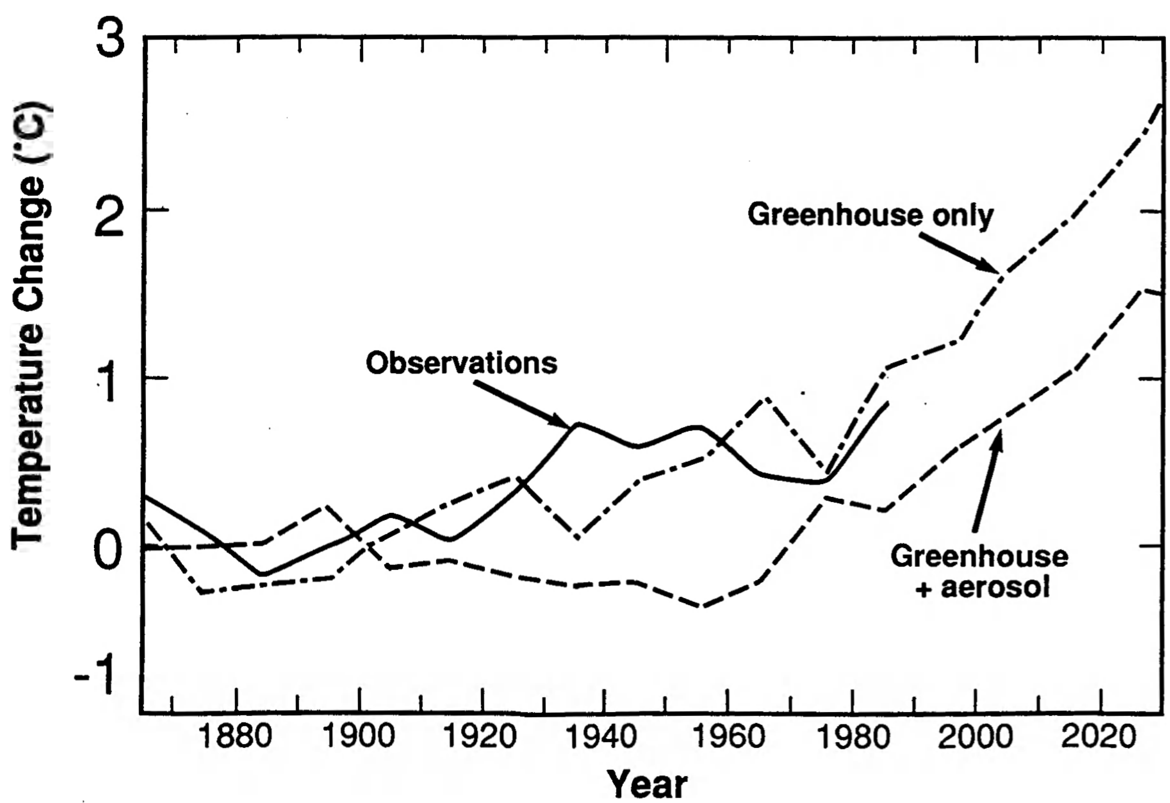

Fig. 5(a). Same as Fig. 4, for North America.

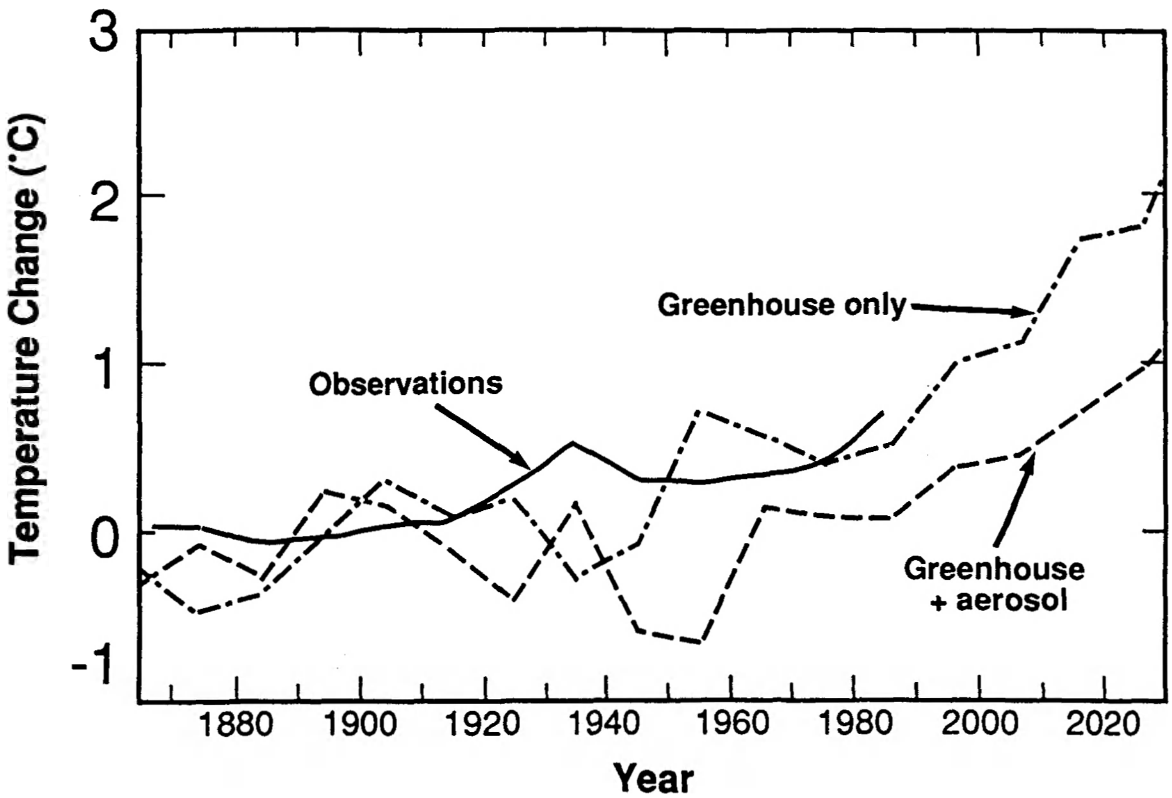

Fig. 5(b). Same as Fig. 1, for Europe.

VI. RECENT RESULTS ON REGIONAL PATTERNS OF TEMPERATURE CHANGE

Globally averaged temperatures are a relatively crude measure of climate change and do not reveal much information regarding the separate impact of the greenhouse gases and the aerosols. While it is useful to supplement the study of the global averages by looking at a few particular regions of interest, such as North America and Europe, a still more sensitive test of the climate impact of the greenhouse gases and aerosols results from a study of the comparison of the compiled and observed temperatures for every region on the entire globe. Since the greenhouse gases and the aerosols each place their own fingerprints on the climate in the form of a distinctive pattern of regional temperature changes, a comparison between the observed and computed patterns of regional change may also enable us to estimate their separate contributions.

Analysis of Regional Temperature Patterns

Mitchell et al.[1] have undertaken an analysis of the regional patterns of temperature change produced by greenhouse gases and aerosols. The initial year chosen for the analysis is 1860. The surface of the earth is first divided into blocks of area 15 degrees on a side (approximately 1500 kilometers at the equator). The first in the series of numerical experiments is a control run in which the average temperature is computed in each block, assuming no change in greenhouse gases and no aerosol cooling.

In the next experiment, the calculations are carried out from 1860 to the present, assuming the appropriate changes in the concentration of greenhouse gases but still no aerosol cooling. They are repeated again with constant greenhouse gas concentrations, but with aerosol concentrations increasing with time according to observation.

Finally, the calculations are repeated assuming increasing concentrations of both greenhouse gases and aerosols. The gradually evolving patterns of regional temperature change relative to the control run are then compared with the observed patterns of temperature change for each of the three experiments — greenhouse only, aerosols only, and greenhouse + aerosols.

Figure 6 shows the results for the calculated regional patterns of temperature change for the case of aerosols and greenhouse gases combined, compared with temperature observations going back to 1860. The comparison is expressed in terms of the spatial correlation, R, which indicates the extent to which warm and cool regions in the observations are matched by similarly warm and cool regions in the computations. R is defined to equal 1 if the correspondence between the observed and computed temperature patterns is perfect. A value of R close to zero signifies no similarity between the two patterns of regional temperature change.

From 1860 until approximately 1960, R fluctuates around zero — i.e., there is essentially no correlation between the observed and computed regional patterns of temperature change. Between the 1960s and 1980s, R increases to a peak value of 0.3.

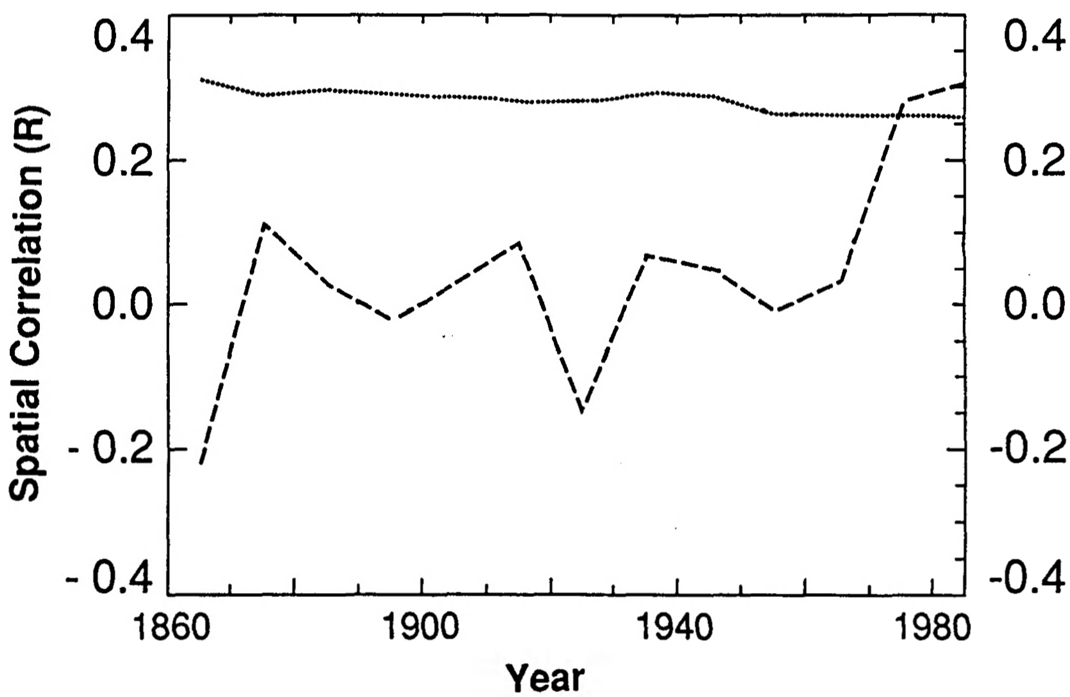

Fig. 6. Regional correlation between computed and observed decadal patterns of temperature change relative to the 1860-1990 mean, for the case of greenhouse gases + aerosols (adapted from ref. 1). The dotted line is the 10% (one-tailed) level of significance, based on climate model estimates of the natural variability of climate.

The increase in R since 1960 has been interpreted by Mitchell et al.[1] to be a combined greenhouse and aerosol signal gradually rising out of the background of natural climate variations in recent decades, as both the greenhouse gases and the aerosols increase in concentration and climate impact.

Similar results have been obtained by Santer et al.[15] In their analysis, R begins to increase in the 1950s and rises to values in the neighborhood of 0.3 in the 1980s. Figure 7, adapted from reference 15, shows the correlation coefficients for the fall season, which display the increase in R clearly. The average value of R from Fig. 7 for the period 1953 - 1993 is 0.17. The upward trend in R is 0.006/yr for the interval 1942 - 1993. On the basis of climate model estimates of natural climate variability, Santer et al. estimate a probability of less than 5% that this upward trend is the result of natural climate fluctuations.

Santer et al. give no estimate of the statistical significance of the R values themselves in Figure 7. Assuming the values of R are significant, Figure 7 also suggests the gradual emergence of a combined greenhouse/aerosol signal in the temperature record.

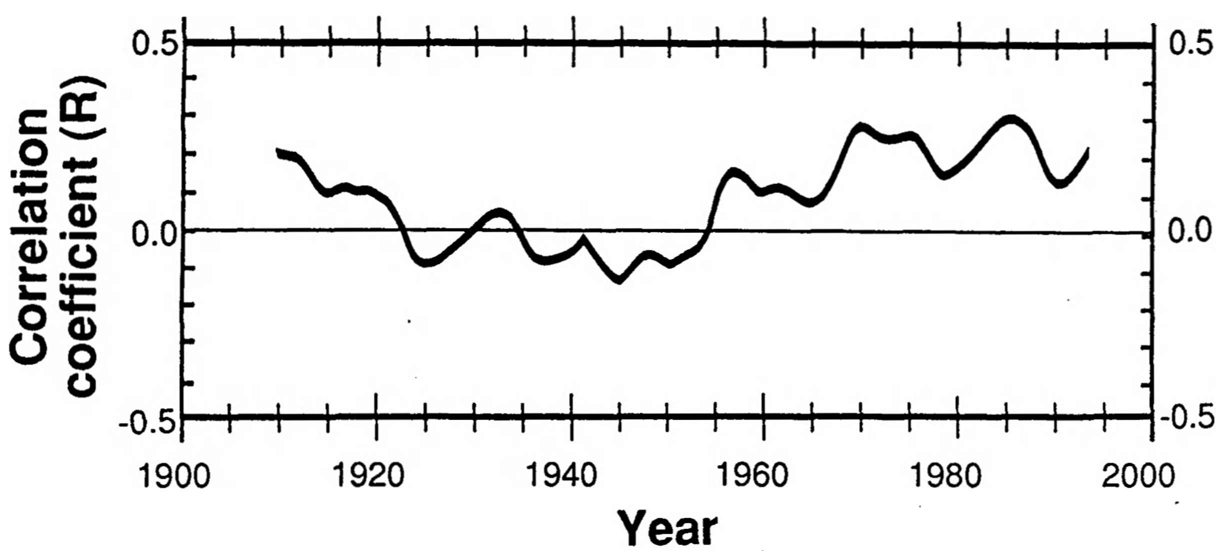

Fig. 7. Correlation coefficients between observed and computed regional patterns of temperature change, for greenhouse gases plus aerosols, and for the fall season (September/October/November) (adapted from reference 15).

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15. Santer, B.D., K.E. Taylor, T.M.L. Wigley, J.E. Penner, P.D. Jones and U. Cubasch, *Clim. Dyn.* **12**, 77-100 (1995).

Similar results are obtained for the summer season, although not for the winter and spring months.

The increasing correspondence in recent decades between the observed and computed patterns of regional temperature change is cited in IPCC reports as a significant part of the evidence for a detectable human influence on climate.[16]

VII. CLIMATE IMPACT OF GREENHOUSE GASES AND AEROSOLS

Which mechanism — greenhouse gases or aerosols — is primarily responsible for the improvement in the agreement between observed and computed regional temperature patterns?

Figure 8 shows the regional pattern correlation for the computation with aerosols alone and no greenhouse gas increase, again adapted from reference 15. As in the case of the aerosols and greenhouse gases combined, Fig. 8 also indicates an

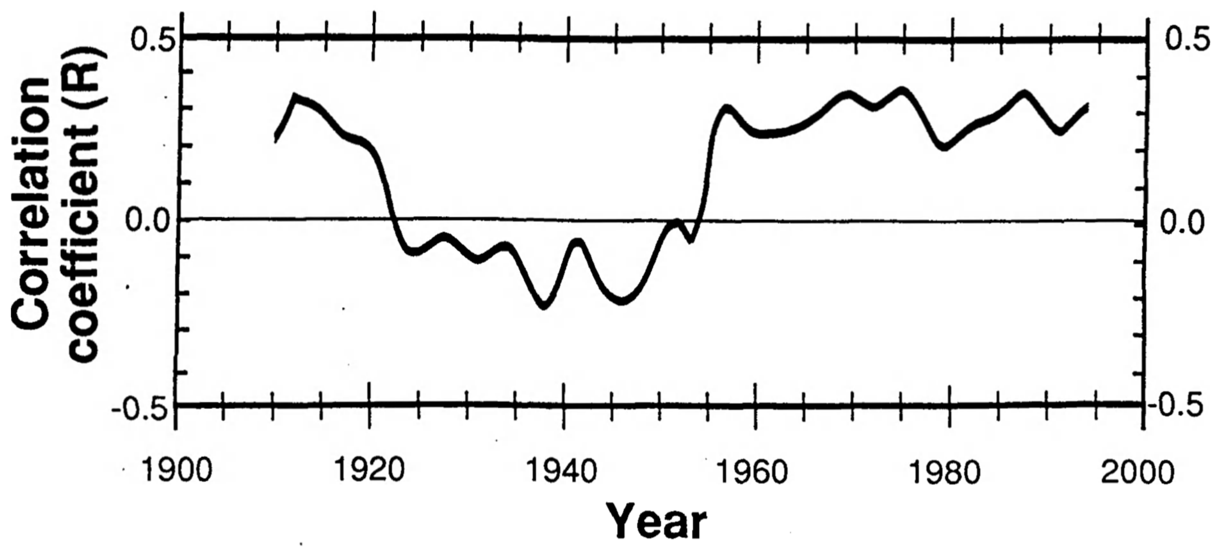

Fig. 8. As in Figure 7, for aerosols only.

16. Summary for Policymakers of the Contribution of Working Group I to the IPCC Second Assessment Report 1995.

increase in R, beginning in this case in the 1940s. For this case, the average value of R for the period 1953 - 1993 is 0.29. The upward trend in R for the 1942-1993 period is 0.009/yr.

Comparison between these results for the case of aerosols only, and the corresponding mean values of R and trend in R for the case of aerosols combined with greenhouse gases, leads to a significant result. Inclusion of the greenhouse effect in the temperature calculations makes the agreement with the observed regional temperature patterns somewhat poorer than in the case of the aerosols alone. Thus aerosols, and not the greenhouse effect, are the cause of the improved agreement between observed and computed regional temperature patterns in recent decades.

Again, assuming that the values of R and the changes in R are significant, the IPCC conclusion that "geographical patterns of temperature change provide important evidence for a discernible human influence on climate" is an accurate assessment of the evidence. However, the human influence in question is almost entirely that of the aerosols.*

The IPCC conclusion was widely misunderstood to imply observational confirmation of a global warming caused by human activity, e.g.,

> "Experts Confirm Human Role in Global Warming"
> *New York Times,* **9/10/95**

> "Global warming 'jury' delivers guilty verdict"
> *New Scientist,* **12/9/95**

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* The climate models also predict a cooling of the stratosphere as a result of the increased concentration of atmospheric CO_2. This prediction is confirmed by radiosonde and satellite observations and has been cited as an additional item of evidence for the climate impact of anthropogenic CO_2. However, stratospheric cooling may be understood simply as a consequence of the fact that CO_2 is an efficient radiator in the infrared. It conveys no direct information regarding the amount of warming of the surface and lower atmosphere that would result from the addition of CO_2 to the atmosphere.

"Climate panel confirms human role in warming"
Nature, 12/7/95

However, examination of the regional pattern studies which were factored into the IPCC analysis leads to the contrary conclusion: the studies prove that the anthropogenic global warming produced by an increase in the concentration of greenhouse gases has been too small to have a detectable impact on temperatures.

The conclusions to be drawn from the studies of regional patterns of temperature change are the same as those derived earlier from the analysis of globally averaged temperature changes: (1) the greenhouse effect has had a negligible impact on global climate, and (2) the warming effect of the greenhouse gases is substantially smaller than the climate models have predicted.

VIII. ARCTIC TEMPERATURE CHANGES

The accuracy of the climate models can be further tested by examining their predictions at high latitudes in the Arctic zone. All climate models predict that the warming caused by the greenhouse effect will be particularly intense in the Arctic. This prediction of a large Arctic warming makes Arctic temperature measurements a particularly sensitive test of the accuracy of the greenhouse predictions.

Predictions of Arctic Warming Compared with Observations

The climate models predict that the Arctic should have become 1 - 2°C warmer in the last 50 years.[17] However, surface temperature measurements in the Arctic for the last 40 years show that temperatures in the Arctic *decreased* by

17. Manabe, S., R.J. Stouffer, M.J. Spelman and K. Bryan, *J. Clim.* 4, 785-818 (1991).

approximately 1.5°C in that period.[18] Satellite data for the last 17 years also show a cooling in the Arctic. (Figure 9) [19]

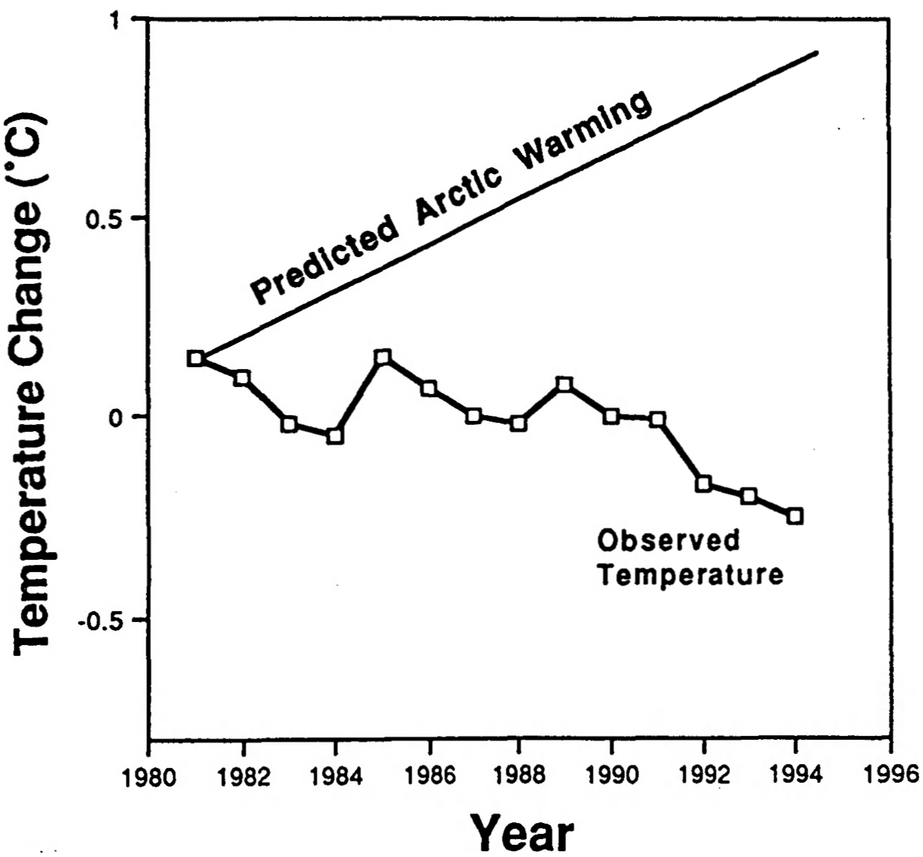

Fig. 9. Satellite measurements of annual average Arctic temperature for the latitude band 67.5N - 82.5N vs. greenhouse predictions. (Source: ref. 19)

Cooling by aerosols cannot explain this very large error in the predictions, since the concentration of aerosols in the Arctic is roughly 10 times smaller than at lower latitudes.[1]

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18. Kahl, J.D., D.J. Charlevoix, N.A. Zartseva, R.C. Schnell and M.C. Serreze, *Nature* 361, 335-337 (1993).
19. *Satellite observations*: Earth Science System Laboratory, University of Alabama at Huntsville; *predicted warming*: Stouffer, R.J., S. Manabe and K. Bryan, *Nature* 342, 660 (1989).

It was concluded above, on the basis of the comparison with globally averaged temperature data, that theoretical estimates of the greenhouse effect must be decreased by at least a factor of three to bring them into better agreement with global averages. A three-fold reduction in the computed Arctic warming would reduce the predicted Arctic temperature rise in the next century from 1 - 2°C to roughly 0.3 - 0.7°C. This range of Arctic temperature increases is still considerably greater than the measured values, which indicate that the Arctic has not warmed at all. It appears that a three-fold reduction in climate model predictions is not adequate to bring the computed Arctic values into line with observation, and a further reduction in the predicted warming is required.

This result implies that the temperature increase produced in the next century by anthropogenic greenhouse gases will be less than one degree, and probably no more than a few tenths of a degree.

IX. PENALTY FOR DELAY ON LIMITING CO_2 EMISSIONS

As the previous discussion indicates, significant new results on global warming are still accumulating. The general trend over the past five years has been toward a reduction in the magnitude of the global warming predictions. In view of the potential importance of the global warming phenomenon, it may be prudent to allow the process of collecting evidence on global warming to continue for some time before policy decisions are reached on CO_2 emission limits and possible mitigation measures.

A recent analysis by Wigley, Richels and Edmonds [20] estimates the additional global warming that would result from a delay of as much as 25 years before action is

20. Wigley, T.M.L., R. Richels and J.A. Edmonds, *Nature* **379**, 240-243 (1996).

taken to limit worldwide CO_2 emissions. Wigley et al. take the goal of such action to be a stabilization of CO_2 concentration in the atmosphere at approximately twice the preindustrial CO_2 concentration, or 550 parts per million by volume (ppmv). They conclude that there is little difference between immediate (1995) emission cuts and initiation of cuts in 2020. Peak emissions are approximately 9 billion tons/year (GT/yr) for the case of immediate cuts, vs. 12 GT/yr for a business-as-usual policy — i.e., no cuts in CO_2 emissions — to 2020 and heavy cuts thereafter. Both scenarios lead to the same stabilized CO_2 concentration of approximately 550 ppmv. The penalty for a 25-year delay in action is an additional global temperature rise of 0.2°C in 2100. A 0.2°C rise distributed over a century would be insignificant.

It seems clear that even if fears of anthropogenic global warming were realized — a concern which finds no support in the scientific data — there is no significant penalty for waiting at least two decades before taking corrective action to reduce global CO_2 emissions.

APPENDIX. ACCURACY OF SATELLITE TEMPERATURE MEASUREMENTS

Because of their nearly complete coverage, the temperature data acquired by satellites add important information to the database of surface temperature measurements used in estimating the size of the greenhouse effect. The surface temperature measurements are sparse over the three-quarters of the earth's surface covered by oceans, and provide essentially no coverage of the polar regions. Coverage of the southern oceans is particularly poor. The satellite measurements provide coverage of all oceans as good as their coverage of land areas. They also survey the polar regions to within 4° of the Poles. The complete satellite global temperature survey includes 99% of the earth's surface and is repeated every four days.

The satellite data agree extremely well with ground-based temperature readings wherever the ground-based coverage is good. In Europe and North America, where surface temperature measurements are numerous and reliable, the correlation coefficient between satellite and surface measurements for the last 17 years is 0.95 — close to perfect agreement.[21] Figure 10 (p. 28) shows the close agreement between the satellite and surface measurements with respect to year-to-year changes in globally averaged temperature.

The correlation coefficients noted above are not sensitive to long-term trends in the globally averaged data. However, fairly good agreement is also found between the satellite data and other sources of temperature measurement in respect to long-term trends. For the period 1979 - 1993, after adjustment for the transient cooling caused by the volcanic eruption of Mount Pinatubo in the Philippines, the satellite value for the global temperature trend is 0.09°C/decade, compared to

21. Christy, J.R, R.S. Spencer and R.T. McNider, *J. Clim.* **8**, 888-896 (1995).

0.10°C/decade from the radiosonde balloon measurements and 0.17°C/decade from the surface temperatures.[2]

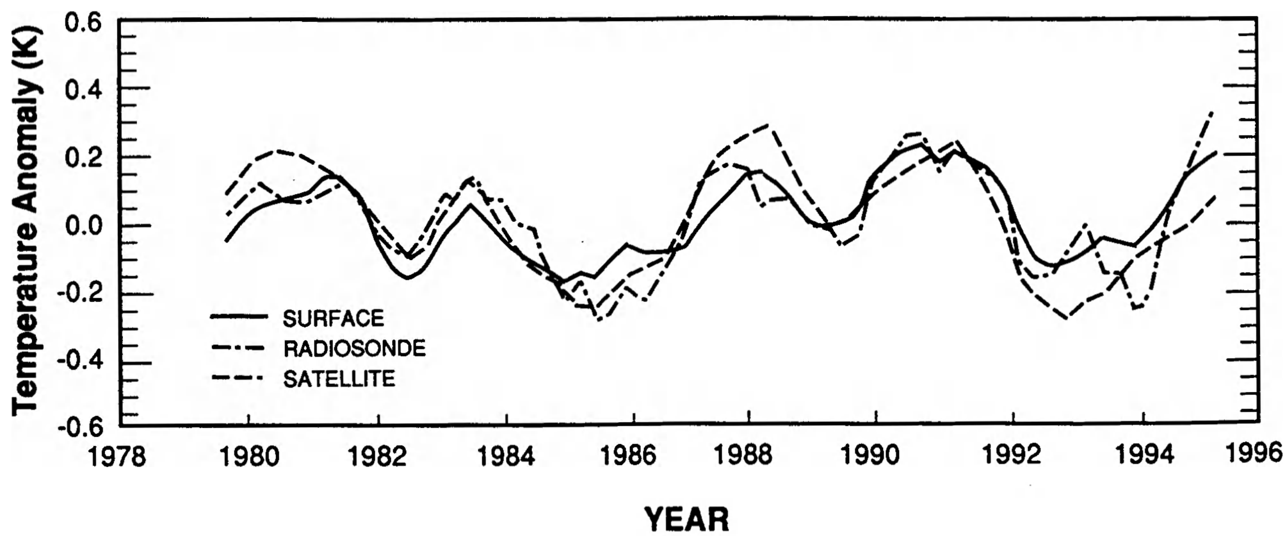

Fig. 10. Comparison of globally averaged temperatures from satellites (— — —), radiosonde balloons (— · — · —) and surface stations (——), courtesy A. Arking. Surface: Hansen, J. and S. Lebedeff, *Geophys. Res. Ltrs.* 15, 323-326 (1988). Radiosonde: Angell, J.K., *J. Clim.* 1, 1296-1313 (1988) plus updates. Satellite: J.F. Christy, Earth and Planetary Science Laboratory, University of Alabama at Huntsville.

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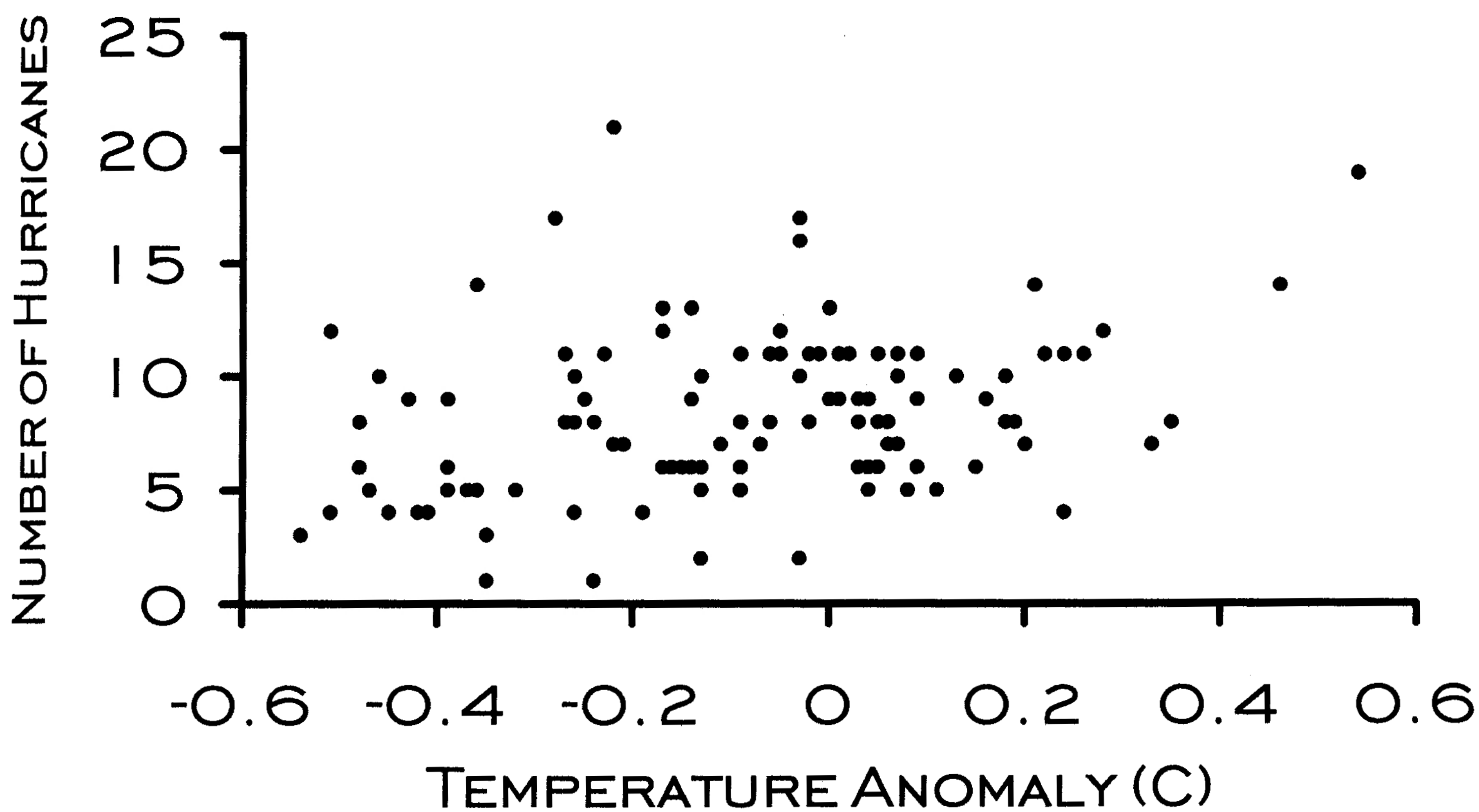
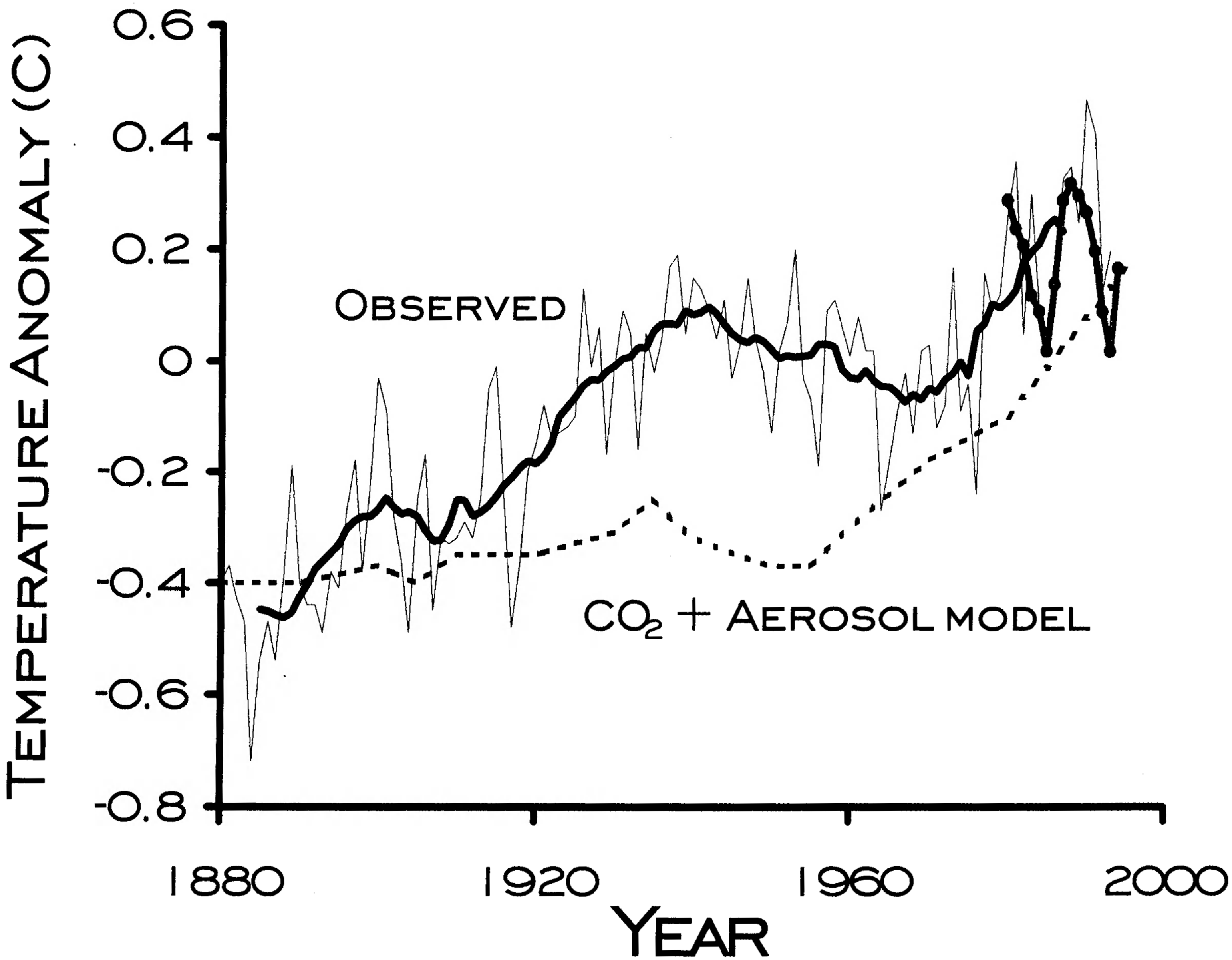
ATLANTIC HURRICANES

AND NORTHERN HEMISPHERE TEMPERATURE

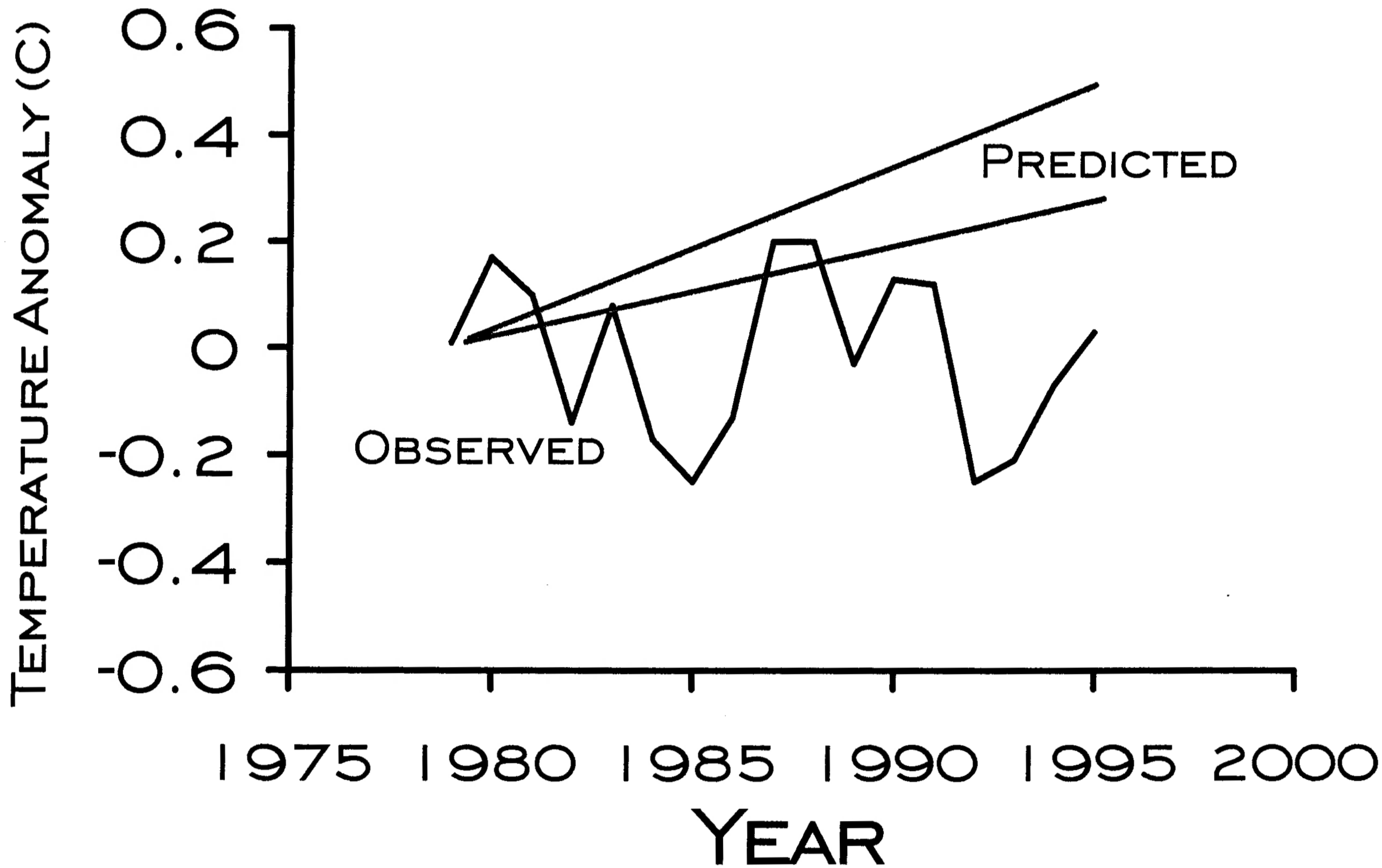
(1886-1995)



Global Temperature



Global Satellite Temperature



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SUMMARY OF PRINCIPAL FINDINGS

ARE HUMAN ACTIVITIES CAUSING GLOBAL WARMING?

In the preparation of this report the Marshall Institute asked two questions on matters that have received considerable press coverage over the last year:

1. Have there been more tornadoes, hurricanes or other severe weather events as a result of global warming?

2. Have CO_2 and other greenhouse gas emissions had a discernible influence on climate?

Principal findings follow:

Hurricanes and Tornadoes. Do highly destructive storms occur more often because of global warming? Data on the frequency of hurricanes and tornadoes over the last 50-100 years show no increase in frequency despite increasing temperature and the equivalent of a 50% buildup in CO_2. (See Report pp. 7-10)

Global Warming and Cold Winters. Is human-made global warming the cause of recent cold winters in the U.S.? Cold winters occur when cold polar air masses move southward over the U.S. from higher latitudes. According to the climate models, the warming caused by the greenhouse gases is particularly intense in the polar regions. Consequently, the polar air masses should be less cold because of global warming. Greenhouse warming should make U.S. winters milder, not colder. (See Report pp. 10-12)

Was 1995 the Warmest Year in the Record? British reports claim that 1995 was warmer than 1990 -- the previous record holder. But, NASA says 1995 was cooler than 1990. Satellite data show that 1995 was only the eighth warmest year in the last 17 and an ordinary year, in the middle of the range. (See Report pp. 2-3)

Will Human Activities Cause a Serious Global Warming in the Next 100 Years? An increase in greenhouse gases equivalent to a 50% rise in carbon dioxide has already occurred in the last 100 years. According to the climate models, this increase should have produced a temperature rise of about 1°C. But the actual increase is 0.5°C, only half the rise predicted by the models.

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PRESS ADVISORY
Contact: Fred Lindeberg
at Ruder Finn
Telephone: 202/466-7800

Human Activity Not Causing Global Warming

Extreme Weather Fears Unfounded

The George C. Marshall Institute is holding a press conference to release its most recent review of technical literature on climate science, particularly the controversial, soon to be published, IPCC Scientific Assessment.

What: A press conference to release the Marshall Institute study "Are Human Activities Causing Global Warming?"

Who: Dr. Sallie Baliunas, Harvard astrophysicist and Chair of the Marshall Institute Science Advisory Board
Jeffrey Salmon, Executive Director of the Marshall Institute

When: Wednesday, April 10, 1996, 9:30am to 10:30am.

Where: National Press Club, Lisagor Room.

*** Electronic media should contact Fred Lindeberg for special instructions***
