Evidence from the Satellite Record

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In recent years, a great deal of scientific and political attention has been given to atmospheric problems such as acid rain, enhanced greenhouse warming and ozone pollution in urban areas. A common difficulty in dealing with these issues is the large, natural variability of the atmosphere, which on short time scales can either mask human impacts or make these impacts inconsequential. The problem of enhanced greenhouse warming due to the input of CO_2 generated by human activity into the atmosphere is a good example. Scientists have long hypothesized that increasing emissions of CO_2 from the burning of fossil fuel could cause the earth's temperature to rise. They postulated that increased levels of CO_2 would lead to an increase in the absorption of outgoing radiation and an increase in the re-emission of this radiant energy back to the surface. As a result, the total input of radiant energy to the earth's surface would rise, causing surface temperatures to rise as well. They have predicted that CO_2 emissions caused by human activity (with other greenhouse gases) could cause a doubling of the trace gas contribution to surface heating by the middle of the twenty-first century.

Modeling the enhanced greenhouse effect

Since the mid-1950s, atmospheric scientists have been developing mathematical computer models to simulate the behaviour and structure of the global atmosphere. By the mid-1980s, these models had developed to the point that scientists began to make "greenhouse experiments" in which they mimicked the effect of doubling CO_2 in the model atmosphere by contrived schemes that added about three watts to the rate at which energy arrives at the earth's surface. While different models produced quite different details in their doubled CO_2 experiments, all showed substantial warming of the mean global temperature (up to 6°C) with the greatest warming at polar latitudes (up to 18°C). These early results led to speculation that there could be major impact upon society—for example, severe droughts in major agricultural regions of the globe, including the central United States. Also, there were initial studies that indicated polar ice caps might melt and produce water that, when added to the thermal expansion of the oceans, could cause rises in the sea level large enough to inundate coastal cities.

Those inventing these atmospheric models—probably more than anyone else—recognized how primitive these early simulations were. They did not include coupled (or interactive) oceans, which are a major component of the earth's climate system. They only crudely represented cloud processes and so poorly captured hydrologic components that some models created summer deserts in the southeastern United States as the normal climate! Further, in their picture of the polar regions where projections of melting ice caps fueled much of the concern about global warming, the models of that era in some cases were inaccurate by 20°C to 30°C in simulating the current surface temperature. Because of the crudeness of the models and the glaring inconsistencies in the simulation of certain aspects of current climates, it should have been easy to disregard the more dire predictions about a world in which atmospheric CO_2 had been doubled. Some scientists argued, however, that there was no *a priori* reason that improvements in the models would lead to projections of less warming; in fact, they argued that better models might predict more warming. This unsettled situation generated such heated rhetoric about global warming that the subject has become the dominant global environmental issue of the 1990s.

Nevertheless, though improved models have not always predicted less warming, in the past 10 years improvements in models have in general reduced the magnitude of the projected warming in a world where concentrations of atmospheric CO_2 have doubled. Model simulations in the late 1980s, which were just beginning to include the effects of oceans, should have been understood not as predictions but as sensitivity experiments designed to determine only the impact on the global climate of increasing CO_2 concentrations. Thus, the question being examined was: how sensitive is the global climate to changes in the concentration of atmospheric CO_2 alone? These sensitivity experiments indicated that an idealized atmosphere would warm as much as 3°C by 2050, or warm at a rate of 0.2°C to 0.5°C per decade (IPCC 1990: 177ff). Unfortunately, these results were often interpreted as "predictions" rather than experimental tests of an idealized situation.

In the late 1990s, experiments are now being performed in which attempts are made to include many more factors affecting the global climate. For example, variations in the concentration of atmospheric ozone, sulfates, and aerosols are now included in simple formulations. In addition, the representation of the interaction of the ocean is becoming more complex, though representations of sea-ice processes are still extremely crude. Because many of these factors may counteract or delay warming caused by increased levels of atmospheric CO_2, estimates now predict global warming by 2100 (not 2050) to be between 1°C and 3.5°C, a warming rate of 0.1°C to 0.3°C per decade (IPCC I 1996: 289ff). Further, the present models still need substantial improvements and remaining discrepancies in the models' ability to reproduce some aspects of the current climate need to be resolved. For example, the most advanced climate models described by the IPCC (IPCC I 1996: 301) predicted that global temperatures should have risen 0.5°C between 1940 and 1995 but even this was not observed.

True coupling of atmospheric and ocean models is in its infancy and current experiments with coupled models require substantial adjustment to maintain a reasonable depiction of the present climate. It is also troubling that a substantial amount of the warming predicted by the present generation of models of doubled CO_2 concentrations is expected to occur at high latitudes where ice processes and deep ocean mixing are still very crudely handled.

The one prediction that has been exploited on several television programs (*e.g.*, *After the Warming*, a two-part series produced by James Burke and broadcast in 1990 by PBS) is the notion that the Midwestern United States will experience summer droughts and crop failures almost every year. One climate modeler reports that his results show that Dallas, Texas will see 90+°F (32+°C) temperatures almost every day in June, July and August (now it is one day in four) (McKibben 1993: 120, quoting climate modeler, James Hansen). Though American society readily adapts to systematic variations in temperature (corn grows from North Dakota at 48°N to Alabama at 31°N), if precipitation patterns were to change, the effect would be disastrous. The popular notion that because of global warming droughts in the nation's breadbasket will become more frequent and severe has never been verified. In fact, the only evidence for even a slight change in precipitation in the past 60 years is that indicating increasing amounts in the United States (IPCC I 1996: 152). This is only one example of the many inconsistencies between the popular notions of global climate change and actual observations.

The earth's temperature record

When the early models predicted a large impact on the earth's temperature by increased concentrations of atmospheric CO_2, scientists began to examine the record of measured temperatures to determine if a warming trend due to an "enhanced greenhouse effect" attributed to increasing CO_2 concentrations could be detected that would match what was predicted by the models. This, however, turned out to be a difficult task. While geographers and atmospheric scientists had previously attempted to piece together recorded temperatures to construct a global temperature record, the quality of the observations and the uneven distribution of thermometers around the globe made this record suspect for detecting the "greenhouse signal."

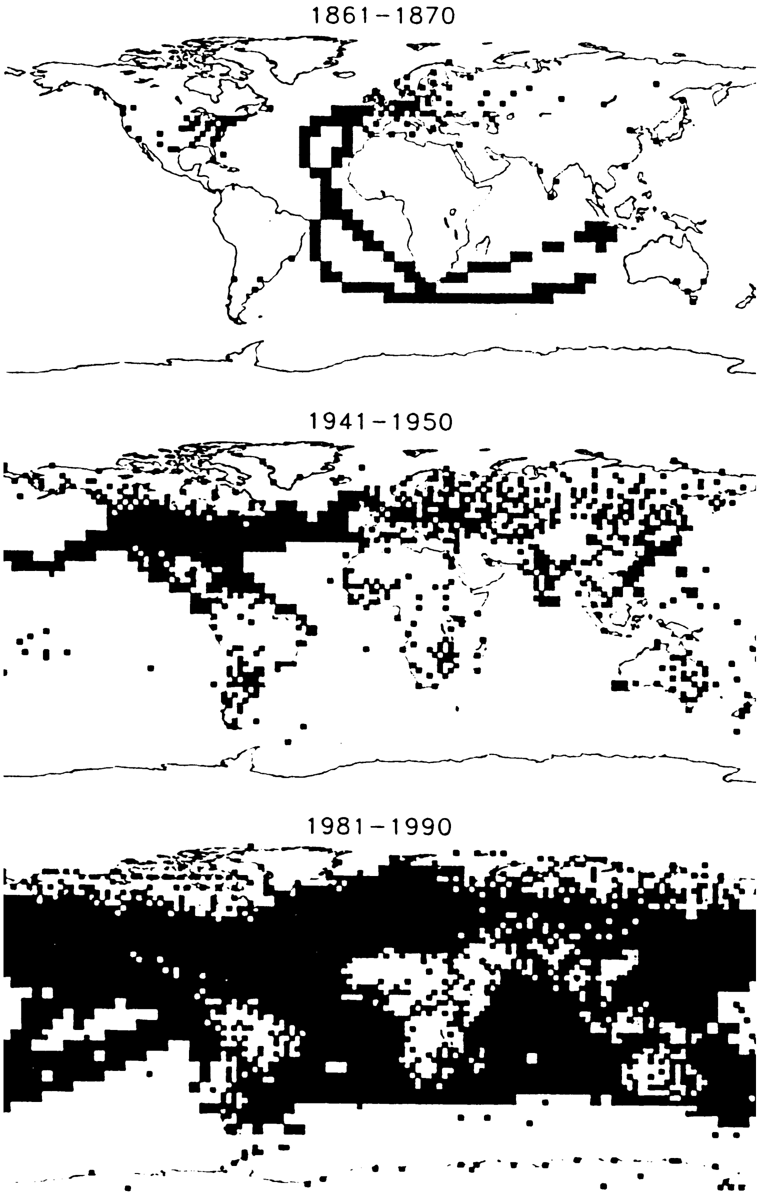
Figure 1 shows the global distribution of surface thermometer observations in three time periods and indicates the uneven global coverage and the sparseness of observations even in the present day. In the nineteenth century, there was only a small number of suitable stations. Attempts at filling in ocean areas by ship observations of sea-surface temperatures improved the global coverage, but the quality of the observations was suspect because of differing techniques for measuring water temperatures. Measurements were originally made using buckets and even the type of bucket used—wooden, canvas or metal—affected the observations. Additionally, the depth at which the observation was made was critical and, as more measurements came to be made in this century in sea water drawn in to cool ship engines, a bias developed in the temperature record. Considerable effort has been devoted to making adjustments to the observations to account for these inconsistencies, adjustments which sometimes are as large or larger than the resultant trend they purport to measure. Even with ship observations, there is no global coverage (figure 1) as observations from ships are concentrated in shipping lanes and leave large parts of the globe poorly sampled. Research has shown that the limited accuracy of the surface-water temperature data does not support claims for the veracity of the sea-water temperature trends (Trenberth *et al*. J. Climate, 1992).

Besides the concerns about global coverage, scientists who attempted to build a time record of the earth's temperature had to deal with contamination of the record of temperatures over land by the effects of urban warming and other changes in land use. Scientists have long known that the asphalt, concrete and structures in cities can produce a local warming affect and many of the oldest temperature-monitoring stations around the globe are contaminated by this effect. Growth of cities around an observation location (usually at an airport) can produce a warming totally unrelated to the greenhouse warming signal that scientists are trying to detect. Scientists have worked diligently to remove the effect of urban warming from the temperature record but the methods for doing so are not universally accepted and have been a source of continuing controversies. Some of the data sets that have been used in recent years are thought by many scientists to be contaminated still by this and other non-climatic effects. It is unfortunate that some scientists continue to report their own measurements of global temperatures without removing any of the known urban-warming effect.

Temperature variability

Any temperature record shows interesting variations through time. Scientists are struggling to understand the causes for these variations and it is clear that fluctuations prior to this century occurring on time scales of years to thousands of years in length

Figure 1 Distribution of surface measurements of temperature for three different decades. Source: Karl *et al.* 1994.



are certainly natural in origin and unrelated to warming due to human-induced rises in the levels of CO_2 in the atmosphere.

For example, the top chart of figure 2 is the estimated global temperature over the past 1,000 years. The chart shows that large fluctuations are common to the climate system. A thousand years ago temperatures were apparently higher than today and it was during this period that the Vikings colonized Greenland. We note that the temperatures in the eighteenth and nineteenth centuries were unusually cool, for which we have anecdotal evidence in the common recreation of Londoners who ice-skated on the River Thames. Charles Dickens' novels speak of the winter snow and frozen landscape that were common in the first half of the nineteenth century. Unless natural temperature variability is taken into account, naïve comparisons between records from nineteenth and twentieth centuries will exaggerate the warming attributed to industrialization.

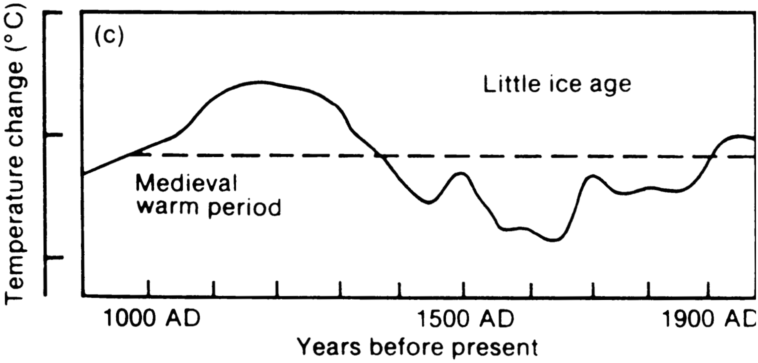
Information in both charts in figure 2 is accepted by most scientists as an accurate expression of general trends, though both lack true and consistent spatial coverage. While the temperature record prior to the 1800s is largely inferred rather than measured, scientists generally agree on the relative variations.

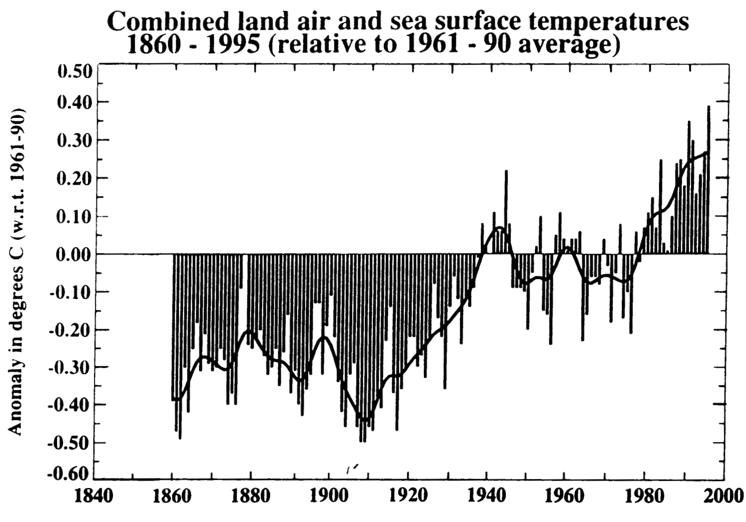
For the last several decades we have the record of surface thermometer measurements (figure 2). Before 1940, the build-up of atmospheric CO_2 was just beginning and should not have affected the global surface temperature to any measurable degree. Therefore, the much reported rise in surface air temperatures in the last 100 years (much of it concentrated in the period from 1917 to 1945 and which may be related to minimal volcanic activity) must in large part be due to natural variations or some urbanization effects.

Satellite temperature measurements

Because of the concerns about the surface-measured temperature record, NASA's Dr. Roy Spencer and I developed a data set of global temperatures based on satellite observations. These measurements report the temperature of deep atmospheric layers by using the fact that oxygen in the atmosphere emits microwave energy with an intensity that is proportional to its temperature. A series of identical instruments known as Microwave Sounding Units (MSUs) on board several weather satellites have measured these intensities since 1978. Thus, we are

Figure 2 Long-term anomalies in the mean global temperature: over the past 1,000 years (top) and over the past 140 years (bottom). Sources: (top) EarthQuest, Office of Interdisciplinary Earth Studies, Spring 1991, 5, 1; (bottom) IPCC 1996 from data generated by P.D. Jones (U. East Anglia) and D. Parker (UKMO).

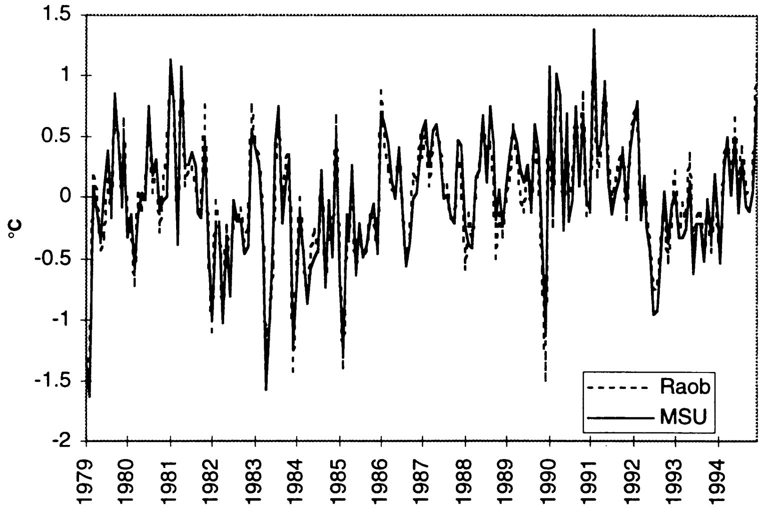




able to measure the temperature of the atmosphere, which is the same as that of oxygen for the entire globe every day.

The data set was first reported in *Science* in 1990 and has been described in several articles since then; all were subjected to rigorous peer review. Our method has been validated by a comparison of two completely independent systems, which has shown

Figure 3 Monthly variations of tropospheric temperature at 97 locations in the western northern hemisphere measured by balloons (dashed) and satellites (solid).



precision on monthly values of ±0.04°C (Spencer and Christy 1990; Spencer and Christy 1992; Christy 1995; Christy *et al.* 1997). Figure 3 shows a comparison between the tropospheric temperature measured at 97 balloon stations in the western northern hemisphere and collocated observations from the satellites. The agreement between the two independent systems is exceptionally close, giving confidence that both systems are reporting the actual temperature variations. The satellite temperature data set is the only one that is truly global and uses a completely homogeneous measurement (i.e., uses a single "thermometer" to view the entire planet and does not mix measurements of the temperature of sea water with measurements of air temperature). It also measures the part of the atmosphere (the troposphere) that, according to the models, should be experiencing the greatest warming due to the effects of increased concentrations of atmospheric CO_2.

For variations over the longer term, table 1 provides comparisons between large numbers of radiosondes and MSU tropospheric measurements. It is again clear that both systems are telling us the same story on atmospheric temperature variations since 1979. Note that none of the long-term trends differ by more than 0.03°C per decade.

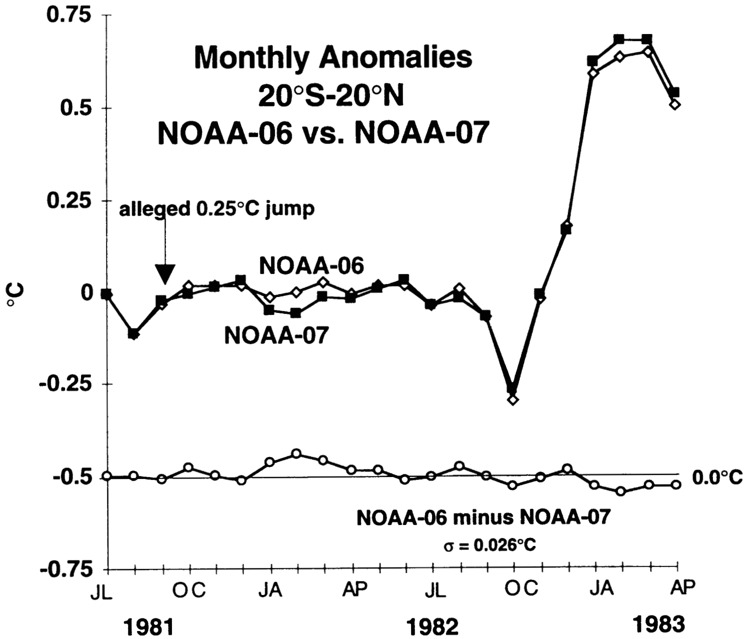
Table 1 Comparisons of trends since 1979 between data sets from Microwave Sounding Units (MSU) registering the lower troposphere versus data sets from various radiosonde-based (i.e. independent) tropospheric monitors that, except for the 850–300 hPa layer temperature, are weighted to match the MSU weighting function

	Number of stations used	Radiosonde trend °C/dec.	MSU trend °C/dec.	Difference (radiosonde minus MSU)	Years
Global (850-300 hPa)[A]	63	–0.06	–0.04	–0.02	1979–96
Global[B]	300+	–0.04	–0.04	0.00	1979–96
W. N. hemisphere[C]	97	+0.16	+0.14	+0.02	1979–94

[A] Angell 1988 and updates
[B] Parker et al. 1997
[C] Stations in an area roughly bounded by Truk, South Pacific to Pt. Barrow, AK to Keflavik, Iceland to Trinidad. This is a comparison of sondes with collocated MSU measurements.

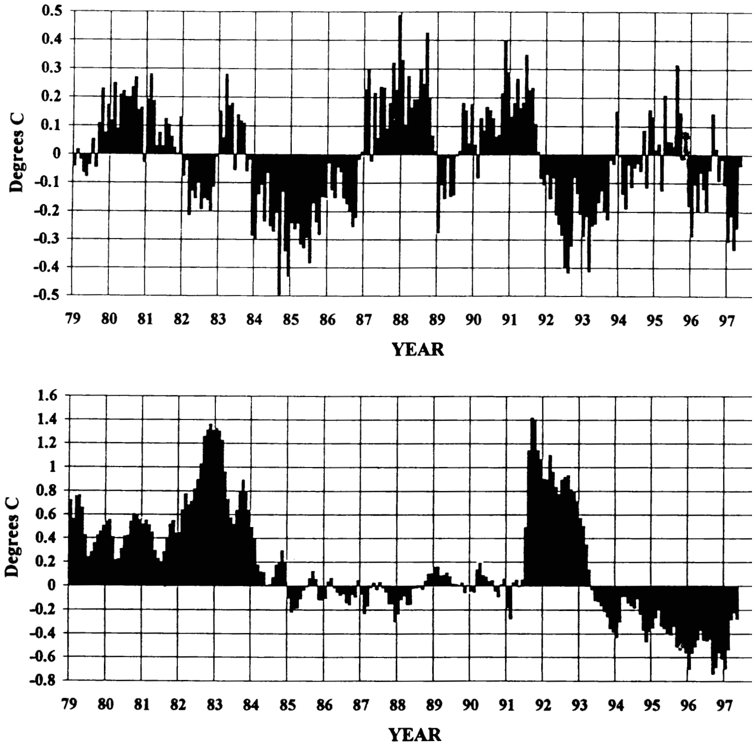
Recently, two colleagues have questioned the precision of the MSU data (Hurrell and Trenberth 1997). They believe the data have spurious jumps in 1981 and 1991 that caused the overall trend to be downward rather than upward as they believe it should be. Their allegations were based upon no observed data from the atmosphere and, since their allegations were made public, I have shown that the MSU data are indeed precise by comparison with independent and direct observations of the troposphere (i.e., real data). For example, in the most serious allegation, my two colleagues speculated that adding the data from one particular satellite, NOAA-7, caused a spurious jump of 0.25°C in the tropical time series for late 1981. I show in figure 4 the temperature anomalies of two satellites NOAA-6 and NOAA-7 for the tropics during that time. It is important to note that these were calculated completely independently of each other. One can readily see that whether NOAA-7 was included or not, the time series is still the same. Therefore, the addition of NOAA-7 into the data set did not cause a problem and the claim of my colleagues is clearly in error (Christy, Spencer, and Braswell 1997).

Figure 4 Monthly variations of tropospheric temperature for the tropics (20°S–20°N) from two independent satellites (NOAA–6 and –7). Claims that NOAA-7 caused an error of 0.25°C in the record are completely unfounded as shown in this diagram (Christy *et al.* 1997 Nature).



Our agenda in this project was to create a data set of sufficient scientific quality that we and other researches could discover something about why the climate varies as it does. In the discipline of atmospheric science, major advances have been made when new and reliable data sets of the atmosphere have become available. We did not know beforehand what the overall time series would show; what we found is shown in figure 5. The lower troposphere (from the earth's surface to an altitude of about 7km) reveals significant variability from year to year and a trend very close to zero for the past 18.5 years. The lower stratosphere (about 17km to 22km in altitude) shows a strong downward trend related, in part, to the influence of volcanic eruptions in 1982 and 1991 and ozone depletion (ozone naturally warms the stratosphere). These data sets provide a fascinating glimpse into the nature of atmospheric temperature variability.

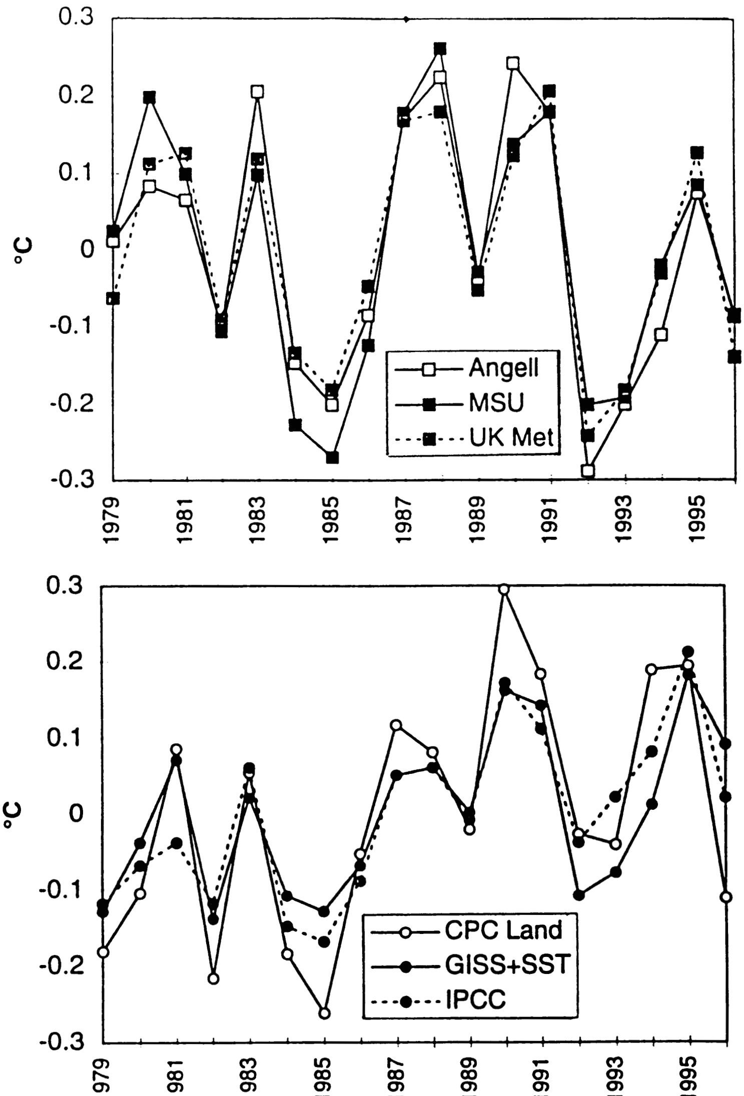
Figure 5 Monthly, global temperature variations for the lower troposphere (top) and the lower stratosphere (bottom) measured from Microwave Sounding Units on satellites.



Looking next at comparisons between the troposphere (measured by balloons and satellites independently) and the earth's surface, we see the temperatures apparently going in different directions over the past 18 years (figure 6). No climate model of which I am aware indicates that the troposphere should cool while the surface warms due to human-induced climate change over any 18-year period. We are at a loss for a clear explanation of these observations, which cover the period in which the greatest human effects should be evident, since the accumulated effects of CO_2 should be most apparent in the recent period.

Why is there a discrepancy between the models' estimate of global warming and what the MSU data have shown? One must remember that temperature is essentially a response parameter;

Figure 6 Annual variations in global temperatures for the troposphere for two balloon-based data sets and the satellite data set (top); trends: Angell –0.05, MSU –0.04, UK Met –0.04. Annual variations of "global" surface temperatures from three surface-based data sets (bottom); CPC Land +0.14, GISS+SST +0.09, IPCC +0.13.



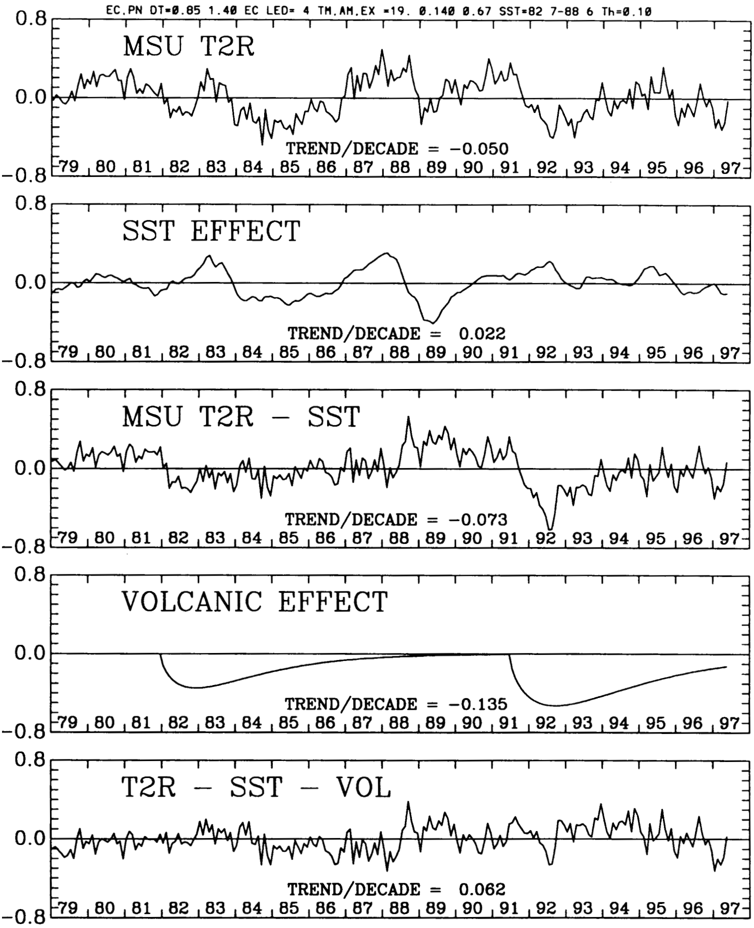
i.e. it reacts to changes in the way energy is distributed in the earth system. The temperature data in figures 5 and 6 show us what has been happening to the climate but not why. A key goal of efforts to study the planet from space is the provision of heretofore unmeasured data that can provide an understanding of why the earth and its atmosphere behave as they do.

Natural variability

We have seen that the global temperature of the atmosphere has experienced sudden warmings and coolings over the last several hundred years. We actually understand very little about the reasons for these fluctuations, whose size is often larger and whose occurrence more rapid than that predicted for warming induced by higher concentrations of atmospheric CO_2 (Stager and Mayewski 1997). Large fluctuations also occur in the satellite data set but the overall trend is essentially zero. Some of these relatively rapid (interseasonal) changes in global temperature within the past 18.5 years are of the same magnitude as the total warming that the models have predicted will take place over the next 50 years due to the enhanced greenhouse effect.

The year-to-year fluctuations due to volcanoes and ocean temperatures affect the tropospheric temperature, making it difficult to judge whether a warming trend is evident in the satellite data. Dr. Richard McNider (also of the University of Alabama in Huntsville) and I calculated and removed varying oceanic and volcanic influences to see if there would be a trend over the longer term (Christy and McNider 1994). The key results are shown in figure 7. The top graph re-displays the global temperature as shown in figure 5. The second graph in figure 7 shows the reason for about half of the variability, tropical Sea-Surface Temperatures (SSTs) connected with a phenomenon known as El Niño —Southern Oscillation (ENSO). ENSOs result from a complex series of atmospheric and oceanic events not yet fully understood that lead to a warming of the SSTs in the central and eastern tropical Pacific Ocean. This additional oceanic warmth is transferred to the atmosphere on such a large scale that the global temperature is affected in the lowest 7km of atmosphere. ENSO events occur every few years and can heat or cool the global atmosphere by up to 0.5°C in just a few months (notice, for example, 1983 and 1987). Impacts of warm ENSO events frequently include flooding in California and Peru, hurricanes in the central Pacific Islands and droughts in

Figure 7 Anomalies in the global temperature for the period from January 1979 to May 1997 (top) as derived from satellite measurements; (2nd) as affected Sea Surface Temperatures; (3rd) measurements minus the SST effect; (4th) as affected by the eruptions of El Chichon and Mt. Pinatubo; (5th) as adjusted by subtracting the SST effect from, and adding the volcano effect to, the satellite results. (Christy and McNider 1994, updated).



Australia and Indonesia. Such catastrophes are the result of naturally induced variations in the climatic system.

The fourth temperature graph of figure 7 shows the temperature effect that is induced by volcanoes. There have been two major eruptions since 1979 (1982, El Chichon; 1991, Mt. Pinatubo). When aerosols from such volcanoes enter and remain in the stratosphere, they are able to scatter some of the incoming sunlight back to space, which, in effect, slightly shades the earth for a year or more. The loss of sunlight cools the lower atmosphere and surface; see the fourth graph where first El Chichon's (with Nyamuragira in December, 1981) and then Mt. Pinatubo's effects are estimated. The global cooling caused by Mt. Pinatubo of about 0.7°C represents a tremendous loss of global heat energy and was probably a contributing factor to the severe winter in the Middle East (1991/92) and very cool summer of 1992 in North America and the northern hemisphere. The southern hemisphere also experienced its coolest winter and summer of the satellite record following the Mt. Pinatubo eruption.

By subtracting the SST effect (second graph) from the temperatures displayed in the first graph, then adding in the lost heating due to the volcanoes (fourth graph), we have a chart of the estimated (some would say contrived) global temperature without these influences. It shows that the trend over the last 18.5 years is about +0.06°C per decade (±0.04°C)—a magnitude considerably less than the average projections of the present climate models. The projected warming trend for this period from several models is +0.08 to +0.30°C per decade (IPCC I 1996: 438). The residual satellite warming trend is small enough to be placed easily within the bounds of natural variability though we cannot be certain about that: humans could very well be having a slight impact on the global tropospheric temperature. Even so, no one can say whether this small trend is due to increasing concentrations of CO_2 in the atmosphere because variations on time scales longer than a decade (due to the North Atlantic Ocean circulation, for example) are possibly affecting these results.

We are just now beginning to acquire the necessary knowledge and skill to investigate the natural fluctuations that are sure to continue and that are sure to cause major economic loss as time goes on. At present, atmospheric scientists know relatively little about the factors that control the longer natural fluctuations and have little skill in predicting them (*e.g.* Barnett *et al.* 1996). Our current ability to forecast global variations due to ENSOs is very weak and, of course, we have no idea when the next major volcano will erupt. At a time when there are calls for increased—and increasingly costly—regulation to control projected global warming, it must be pointed out that the cost to society of dealing with these natural fluctuations, which are manifested as droughts, floods, heat spells or cold winters, is at least as great (and probably several times greater) than the cost of possible global warming over the next century.

Climate change: an uncertain phenomenon

Our current ability to model the earth's climate accurately, therefore, is still in a developmental stage. As we have seen, recent models project warming rates that are more modest than those projected a decade ago. Further, a careful analysis of the precise satellite data shows that even the more modest rates of warming are not being manifested in the actual atmosphere. These two facts appear to take away some of the urgency for immediate action for CO_2 reductions, though sensible measures such as conservation and increased efficiencies are always warranted. In other words, the world is not threatened with immediate catastrophe from climate changes since they are apparently quite small in magnitude. Unfortunately, the rhetoric on global warming has been less than scientific and is based in many instances on scientific information that is 10 years old and now known to be largely erroneous.

We have witnessed many "environmentalists" condemn CO_2 as an air pollutant. There is nothing toxic about CO_2 at levels even 5 times that of the current amount in the atmosphere. Plant life flourishes with increased CO_2 (up to 3 times the present concentrations), and the entire biosphere is invigorated with CO_2 in greater concentrations. It was in such an atmosphere enriched with CO_2 to concentrations at least three times today's levels that most of our present biosphere evolved. This unfortunate choice of slogan—"CO_2 is a pollutant"—can reduce the perception of danger that we actually do face from gases and other materials that are indeed toxic and threaten our supplies of air and water.

Global warming has also been connected with the destruction of the world's tropical rainforests. There are many real reasons—from reducing soil erosion to preserving species diversity—to save the world's forest system. The connection made between global warming and the destruction of the rainforests—which has, at best, uncertain justification—may actually dampen enthusiasm for saving the forests when it is shown that the alleged warming is of little consequence to the forests.

Climate variability

Both the long-term and short-term records indicate that variability is a real and important aspect of the earth's climatic system. Given the occurrence of such variability, "global warming" may not be important or even detectable. A failure to account for natural variability in the climate system also creates other problems. For example, the drought of 1988 in southeast United States cost the agricultural community hundreds of millions of dollars in direct losses due to crop failures. During the drought, the extremely high ozone levels in the eastern United States set into motion regulatory programs and controls that will cost the nation hundred of millions of dollars. Yet, no one truly understands the natural variability of near-surface ozone resulting from special meteorological conditions such as occurred during the 1988 drought. Thus, legislative actions may be both economically damaging and environmentally ineffective because the real cause of the variations is natural, not human. For example, no one attributed the drought of 1988 to global warming caused by human activity (worse droughts occurred in the 1930s), yet it reminded the eastern United States how vulnerable our present economy is to the natural variations of the climate system.

If we had regular weather measurements for the past 5000 years, we would see centuries in which the temperature rose, others when it fell. There would be observations of far more devastating floods, droughts, blizzards and so on than have been seen in the last 100 years. Simply put, the natural climate system is not a stationary system. Focusing on just the last 18.5 years with satellites or 100 years with thermometers does not give one a good idea of the proper context in which to judge the variations of the twentieth century. If we look into the somewhat murky world of proxy data—tree rings, ice and sea cores, corals and such—most records do not show this century as remarkably different from others in the past. Our present weather woes (woes, that is, relative to humanly defined comfort) have always been part of the planet's history.

Conclusion

Given the limited current state of knowledge about enhanced greenhouse warming and the limited ability that we have to predict and detect it, the imposition of severe measures for its mitigation (limitations on emissions of CO_2) would be premature at present. We do know, however, that variations in the world's climate are real and have significant economic impact. Even if the greenhouse climate change hypothesis turns out to be true, the real concern is that climate variability might change; that is, the climate of an atmosphere with twice the present concentration of CO_2 might include an increased number of El Niños, hurricanes, regional droughts, floods, and so on.

We are still woefully ignorant of how the earth's climate system works yet we are totally dependent upon it for food production and, in the end, for our quality of life. Further, our vulnerability to climatic variation, whether natural or the result of human activity, is increasing as we exploit marginal geographic regions less able to supply human requirements. Whether or not global warming is significant, we need to learn to predict and respond to climate variability in order to reduce the human suffering it produces. The recent eruption of Mt. Pinatubo and its impact on the global temperature show how vulnerable we might be if a series of eruptions altered the climate for several successive years. A colder climate is potentially far more disruptive than a warmer climate. Stephen Schneider, in his book *Genesis Strategy* (1976) was correct in his foresight that society should develop means for coping with climate variability, whether it be colder or warmer.

In summary, climate variations must always be placed in proper perspective. Until fundamental research reports with improving confidence on causes for these variations, we will be vulnerable to calls for remedies to combat what is perceived as "climate change." It is extremely frustrating as a scientist to see in the media that every weather woe is now being blamed on "climate change" when, in fact, these events are part of the natural variability of the climate system. The severe "remedies" that we are being urged to impose are likely to turn out to be misdirected, ineffective, unproductive and economically damaging. As we have seen in this chapter, the current rate of global warming is relatively so small compared with natural variability (and with estimates from previous models) that there is time to develop solutions to CO_2 production more economically viable than severe legislative controls.

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