ENVIRONMENT

What matters is how the earth is warming, not just that it is.

The Way of Warming

By Patrick J. Michaels, Paul C. Knappenberger, and Robert E. Davis

Several lines of evidence now demonstrate that the way the planet has warmed is much more important than whether or not it warms. The patterns, seasonality, and timing of observed warming paint a rather benign, if not beneficial, picture of changes in the earth's climate.

The planetary average surface temperature is warmer than it was 100 years ago. But what does that warming mean? If that warming were in the coldest air of winter — rather than in the heat of summer — the effect might be beneficial. Most mathematical simulations of climate change predict an overall increase in precipitation, but is more precipitation really a bad thing? What if the increase in precipitation occurs through more gentle spring rains and less severe hurricanes?

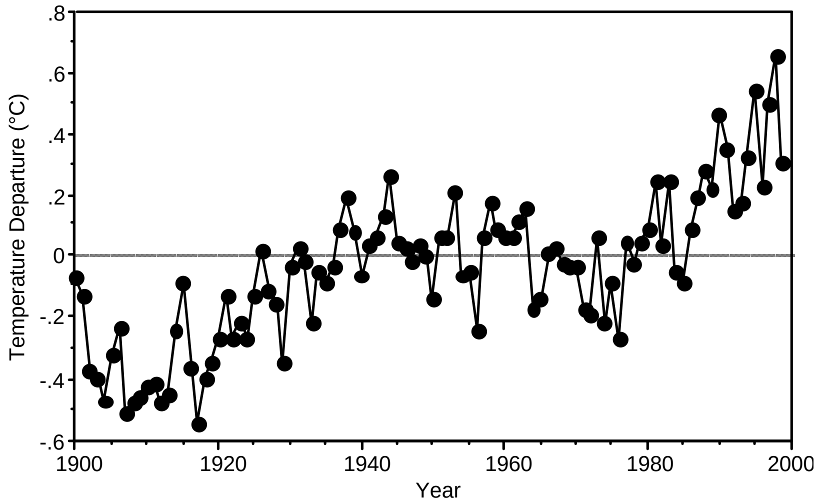
This paper examines the history of how climate changed over the twentieth century and what that change portends. At the outset, we believe it is going to be very difficult to demonstrate a large negative net effect of these changes, at least in free societies: Life span has doubled, crop yields have quintupled, and average wealth has increased to levels beyond the imagination of someone alive in 1900. All of those changes occurred as the planet warmed. Global warming may not have created those benefits (although there is some evidence for a positive agricultural impact), but it surely did not prevent them.

OVERALL HISTORY

As shown in Figure 1 below, two distinct warming trends occurred over the past century in the Northern Hemisphere. (We will not examine Southern Hemisphere warming records because of the paucity of coverage over the vast southern ocean and Antarctica.) The first Northern Hemisphere warming trend occurred from 1910 to 1940. It is highly unlikely that that warming resulted from changes in the earth's greenhouse effect because three-quarters of the greenhouse emissions are in the postwar era. NASA scientists Judith

This is a reformatted version of the article that originally appeared in *Regulation* Vol. 23, No. 3 (Fall 2000).

FIGURE 1



Northern Hemisphere annual temperature history, 1900 to 1999.

Lean and David Rind, along with Harvard astrophysicist Sallie Baliunas, have argued persuasively that this early warming is largely a result of solar changes.

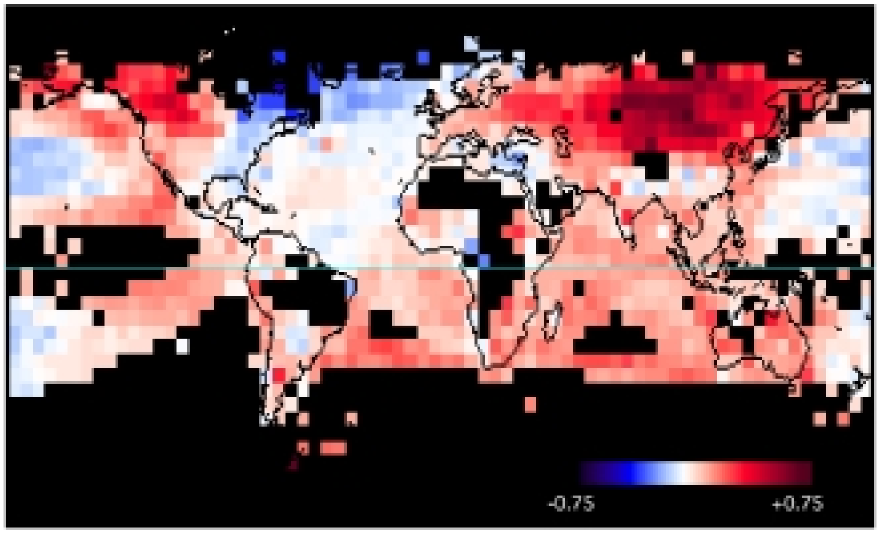
The second warming, which began about 30 years ago, is much more interesting because of the apparent effect it has had on the earth's coldest areas. Greenhouse-effect science indicates that increasing concentrations of carbon dioxide will warm very dry air much more than moist air. This is because the greenhouse effect of carbon dioxide is in many aspects similar to that of water vapor. Laboratory and theoretical considerations tell us that a given increment of greenhouse gas induces less warming as concentrations of the gas increase. So, if two greenhouse gases are similar in their absorption physics — as carbon dioxide and water are — then putting carbon dioxide into a moist atmosphere would create less warming than putting carbon dioxide into a dry atmosphere.

The propensity for greenhouse warming to heat dry air has enormous implications that have largely been ignored in the raucous debate about climate change. This is because a warming of dry air is largely a warming of very cold air. At -40º C, the amount of water in the atmosphere averages about .1 percent of what resides at +40º C (a range that encompasses the earth's natural temperature range), so the effect of adding carbon dioxide to cold air is to produce a tremendous warming.

The map shown in Figure 2 details the observed warming trends for the winter half-year in the last half of the twentieth century where adequate records are available. It is quite obvious that the lion's share of warming is taking place in Siberia and northwestern

North America. These two locations are home to the great Northern Hemisphere cold "anticyclones," or high-pressure regions. The high barometric pressure simply means that there is a more air present in these regions. Occasionally the jet stream kicks one of these air masses southeastward toward the eastern United States. In the Christmastime anticyclone in 1983, about 40 people perished from cold-related causes in South Carolina alone.

FIGURE 2



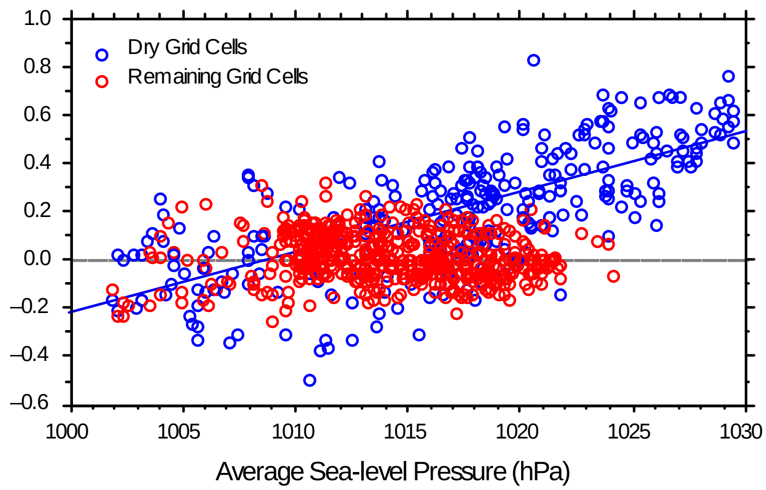
Surface temperature trends (°C per decade) during the cold half-year (October to March in the Northern Hemisphere, April to September in the Southern Hemisphere) from 1946–1995.

More Warming in Winter than Summer Summer half-year warming has been much less than in the cold half-year. In fact, less than one-third of the observed warming of the second half of the twentieth century occurs in the warm half-year, while two-thirds is in the cold half-year.

In our recent article "Observed Warming in Cold Anticyclones" published in *Climate Research* (Vol. 14), we observed that the amount of warming is indeed directly related to the amount of cold air available. In dry environments such as Siberia or Northwestern North America, warming increases significantly with barometric pressure. In other words, the more cold air there is, the more it warms. In wet environments, there is no relationship at all between the amount of air and warming, even in the winter. Below, Figure 3 illustrates this behavior.

The relative distribution of postwar warming is remarkably biased toward these very cold air masses. The overall warming trend (1945 to 1995, the period of this study) is .051º C per decade, but the breakdown between the winter and summer half-years is .070º C per decade during winter as compared to .032º C for summer. Within the cold half-year, the cold anticyclones occupy only 26 percent of the area that had data sufficient for analysis. But 78 percent of the winter half-year warming is within these air masses. Adjusting for the difference in area yields an average warming within the anticyclones of .214º C per decade and only .021º C per decade elsewhere.

FIGURE 3



In dry environments (blue circles), the amount of observed warming in the past 50 years increases with the air pressure. In the wetter environments (red circles), no relationship is present.

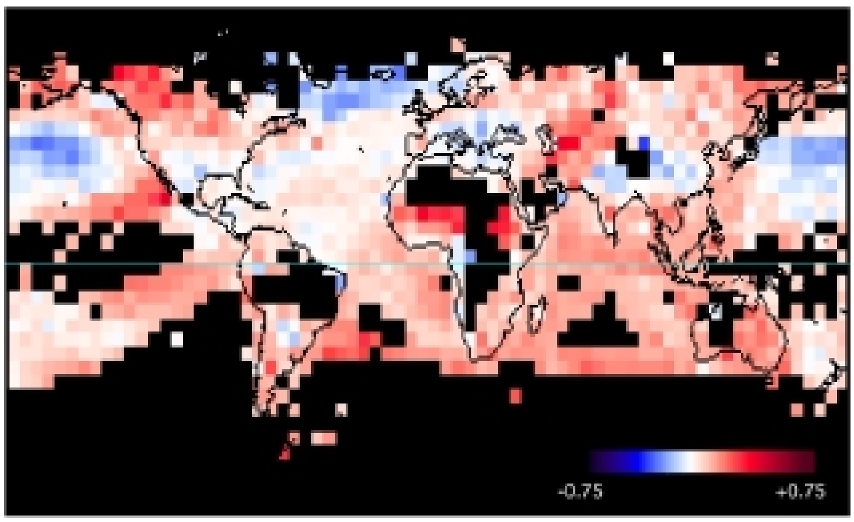
An individual living in Siberia or northwestern North America has, for the last fifty years, experienced a winter half-year warming of nearly 1.1º C. When one factors in the phenomenon that cold anticyclones are not very prevalent in the “transitional” months between summer and winter, one discovers that the average warming of the coldest months approaches 2º C in those two areas. An individual living anywhere else (in the remaining 74 percent of the region) where sufficient data exist for analysis experiences virtually no winter warming.

Longer Growing Season The cold anticyclones are usually responsible for the last freeze in the spring and the first freeze in the fall. Reducing their inherent coldness should therefore lengthen the growing season, which is defined by the length of the freeze-free period in the warm portion of the year. There are several lines of evidence indicating that this pattern of warming is occurring. A study by David Thompson of Bell Laboratories, published in *Science* in 1995, found that the spring warm-up is occurring about three days earlier in our latitude. In 1997, another group of researchers led by R.B. Myneni released satellite data showing that the high (peri-polar) latitudes were "greening up" a week earlier in the 1990s than they were in the 1980s. In a commentary in *Nature*, one of those scientists — NASA's Compton Tucker — noted that "we're talking about a 10 percent increase in [green matter accumulation] by plants." This rather large change in greenness for only an additional week in the growing season obtains because of the very short nature of the freeze-free period at high latitude.

Deserts Warm Most In Summer In comparison with the data from the winter months, temperature data from the summers show much less warming. A general inspection of Figure 4 reveals the average color to be much less "red" (warm) than the winter map in Figure 2.

However, the theory about accelerated warming in dry air is evident in the summer map. The greatest warmings take place around the Sahara Desert, which is the driest region available for analysis in the summer half of the year. Unfortunately, the black grid cells do not have sufficient data; if they did, we hypothesize that we would find a warming of the central Sahara in the summer that is similar in magnitude to what is observed in Siberia in the winter.

FIGURE 4



Surface temperature trends (°C per decade) during the warm half-year (April–September in the Northern Hemisphere, October–March in the Southern Hemisphere) from 1946 to 1995.

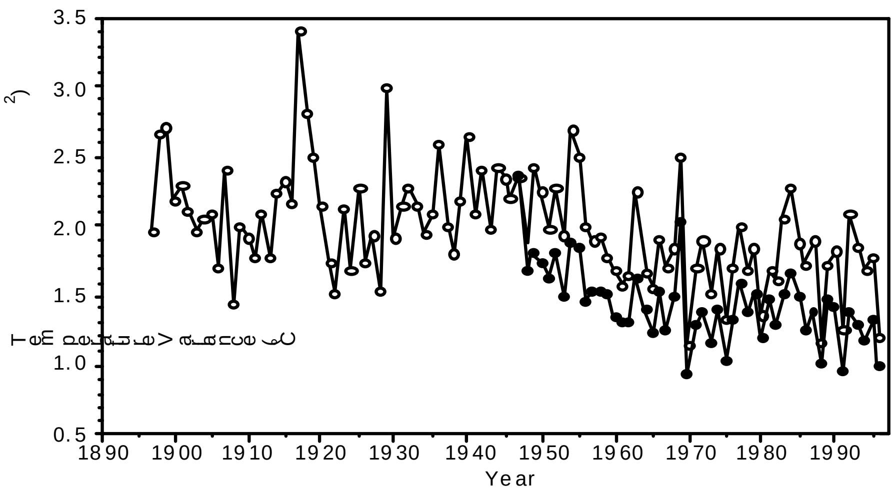
WARMING AND TEMPERATURE VARIABILITY

Economic and ecologic systems are adapted both to the average conditions and expected variation. The likelihood that the variance of weather and climate elements will change can be as important as simple changes in average value. We examined this proposition in our 1998 article “Analysis of Trends in the Variability of Daily and Monthly Historical Temperature Measurements” (*Climate Research*, Vol. 10) and found that the changes that are occurring are likely to be beneficial rather than deleterious.

As the temperature warms, do annual and seasonal temperature swings become more erratic? In the last century, some years have been warm and some cold. This natural variability allows us to examine whether the seasonal and monthly variability embedded in those years are different from those with near-mean temperatures.

The monthly variation in temperature in the last 100 years is shown in Figure 5. Prior to 1940 (which includes the warming trend from 1910 to 1940) the variation exhibits little change. In the last third of the twentieth century, the variation declines. In other words, as the extremely cold air of Siberia and northwestern North America has warmed, the within-year variation in temperature has dropped. A plot of variance versus temperature anomaly (Figure 6, below) also shows a statistically significant relationship, with warm years being less variable than cold ones.

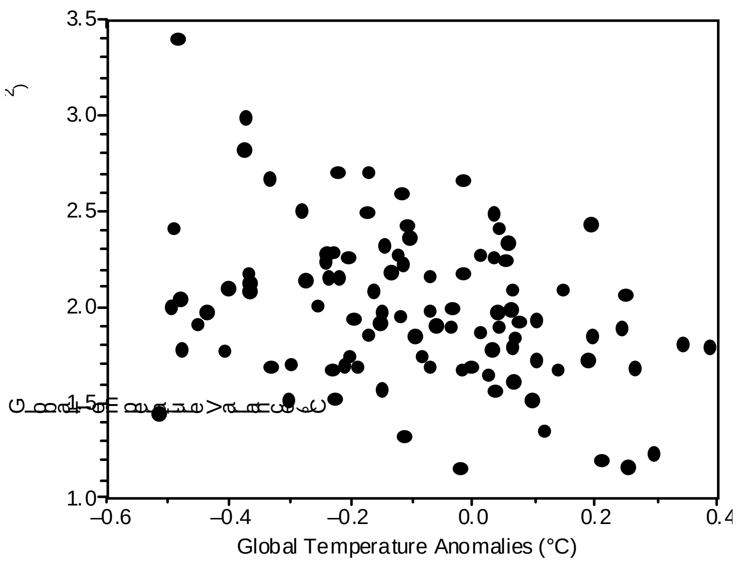
FIGURE 5



Time series of intra-annual global temperature variability. The data incorporate 393 valid 5° latitude by 5° longitude grid cells beginning in 1897 (open circles) and 1,041 cells beginning in 1947 (filled circles). Temperature variability has been declining over time.

That seems intuitive. If a large part of human-induced warming takes place in winter's coldest air, then it is likely that variance will drop on all scales. In the winter, day-to-day temperature changes are much larger than they are in the summer. Warming the coldest temperatures in winter also reduces the annual temperature range.

FIGURE 6



Intra-annual temperature variability vs. global surface temperature anomalies from 1897 to 1997. The warmer the global temperature, the lower the temperature variability.

We examined the year-to-year temperature variability within decadal subsamples of the United Nations' global temperature history and found that this variability has not changed during the past 100 years. In short, there is no evidence that the fluctuations in the earth's temperatures are greater now than they were at the beginning of the twentieth century. And most evidence suggests that temperature has become less variable.

PRECIPITATION, DROUGHTS, AND FLOODS

The 1996 report of the United Nations Intergovernmental Panel on Climate Change (IPCC) was somewhat ambiguous concerning changes in rainfall extremes. It stated:

> Warmer temperatures will lead to a more vigorous hydrological cycle, with prospects for more severe droughts and/or floods in some places and less severe droughts and/or floods in others.

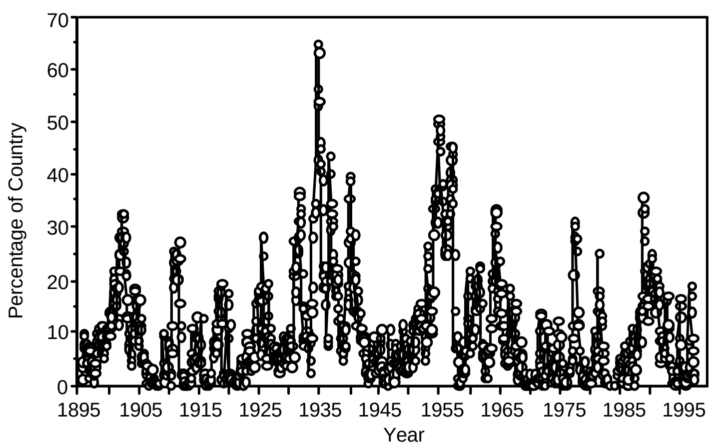
There is little doubt that, strictly speaking, this statement covers every imaginable moisture anomaly.

Droughts The standard measure of drought is known as the Palmer Drought Severity Index. It is a statistical measure that is based upon the departure from average moisture conditions for a region rather than absolute wetness or dryness. So, according to the

Palmer Index, regions such as Death Valley — where the annual average rainfall is only 1.89 inches — are not in a "drought" unless there is even less precipitation than that.

The Palmer Index attempts to account for all the variables that create local hydrological variations. Consequently, it uses temperature and latitude in combination with precipitation to estimate evaporation, deep and shallow moisture storage, and other related variables. When the Palmer Index is one standard deviation below its average value for a region (which occurs approximately one-sixth of the time), the Palmer Index indicates "moderate drought." A Palmer Index one and a half standard deviations below its mean is considered "severe drought." And a Palmer Index that is two standard deviations below the mean officially designates an "extreme drought." In other words, about one-sixth of the nation experiences moderate drought at any time. Whether or not this is meaningful is highly debatable, as both humans and natural vegetation are clearly adapted to conditions that should be expected 17 percent of the time.

FIGURE 7



The percentage of the United States experiencing severe or extreme drought conditions fluctuates from year to year but shows no long-term trend.

Figure 7 shows the percentage of the U.S. lower 48 states experiencing severe Palmer Drought from the beginning of the record in 1895. Clearly, there is no overall trend and the drought periods in the 1930s and 1950s dwarf anything we saw in the last quarter of the 20th century.

Floods What about intense rainfall? On Earth Day 1995, Vice President Al Gore, speaking at George Washington University, said: "Torrential rains have increased in the summer in agricultural regions." He was referring to a then-unpublished paper by climatologist Tom Karl. Karl's paper examined U.S. precipitation records and found that the percentage of annual rain falling from extremely heavy storms (defined as two- to three inches in 24 hours) had increased. Indeed, recent decades showed 11 percent of all rain now coming from these storms, compared with nine percent at the beginning of the twentieth century. But Karl's study, which was published in *Nature* several months after Gore's speech, also showed that a similar change in precipitation took place between 1935 and 1950, before much of the greenhouse alterations had occurred.

An alternative method of measuring precipitation extremes examines streamflow data in undammed catchment basins. In 1999, U.S. Geological Survey scientist Harry Lins published a paper showing *no* increase in the frequency of flooding streamflow, but a decrease in the frequency of the lowest (drought) flow categories. That is to say, streamflow records indicate decreased drought and no change in floods.

HEAT-RELATED DEATHS

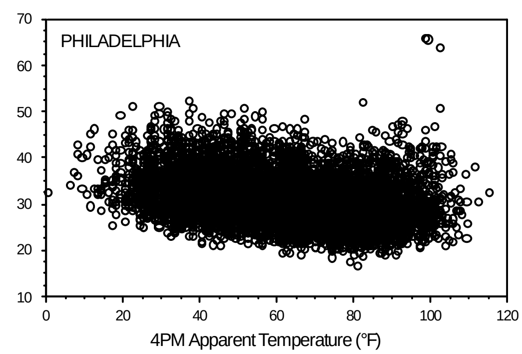
The popular perception is that heat-related deaths will increase with global warming. As evidence of this perception, consider these two quotations from recent publications"

> On a warmer planet, intense heat waves alone are by 2050 likely to result in increases in death by cardiac and respiratory ills of several thousand a year — especially in urban areas and among the elderly and very young…. (*Wall Street Journal*, October 19, 1999)

> [Based upon data from several North American cities], the annual number of heat-related deaths would approximately double by 2020 and would increase several fold by 2050. (IPCC, 1996)

Our research shows that this perception is dead wrong. After standardizing U.S. mortality data for age distribution, we first plotted death rates against "effective temperature" — a combination of temperature and humidity that accounts for the multiplicative impact of moisture on heat stress at a given temperature. In general, heat-related deaths *decline* with effective temperature, although there are a few days that show

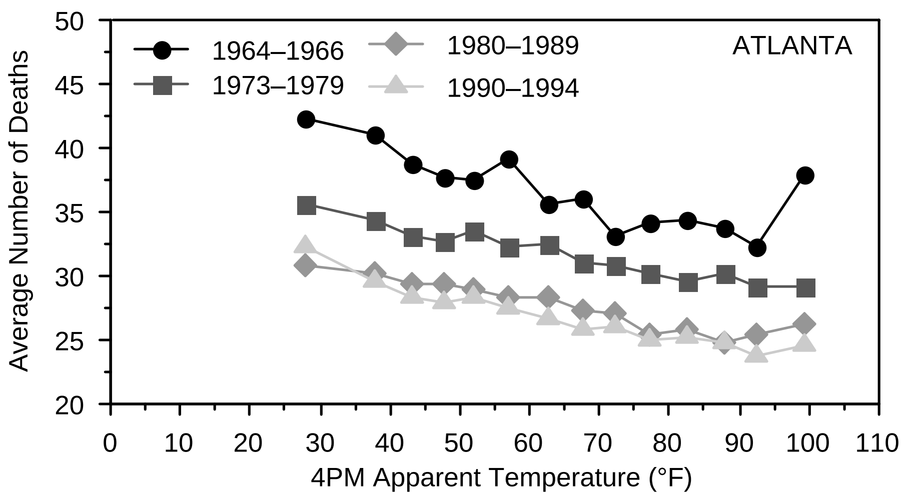
FIGURE 8



In Philadelphia, typical of most American cities, the daily mortality generally decreases with temperature, with the exception of the very hottest days.

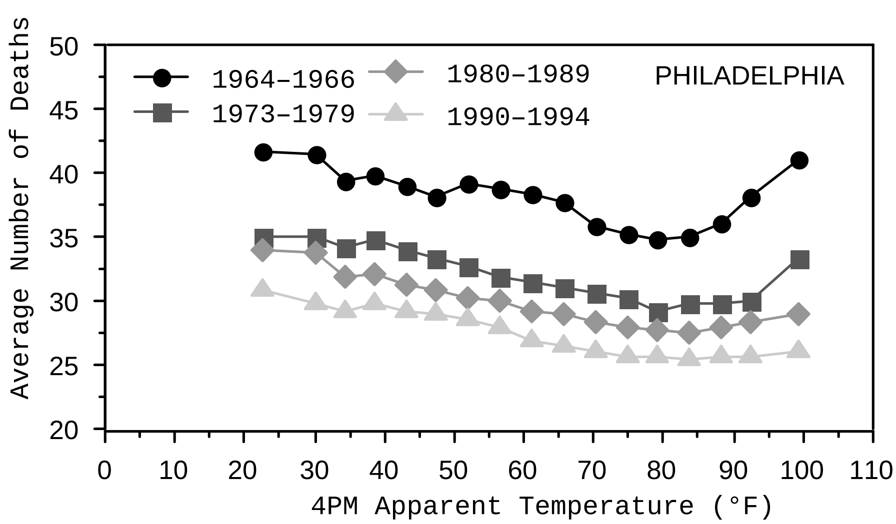
remarkable death excursions at high temperature (Figure 8). There are no excessive heat deaths in cities in the southern United States (Figure 9), which means that people adapt to their climatic expectations. Perhaps more interesting is that deaths at high effective temperatures have been declining in northern cities such as Philadelphia to the point that they are now near zero (Figure 10).

FIGURE 9



In a southern city like Atlanta, there is little mortality response to extremely high temperatures. Here, the population has adapted to the expected climate.

FIGURE 10



In a more northern city, such as Philadelphia, where extremely hot conditions occur less frequently than in the South, the population exhibits a higher mortality rate on hot days. However, over time, the population of Philadelphia's sensitivity to high temperatures has been declining.

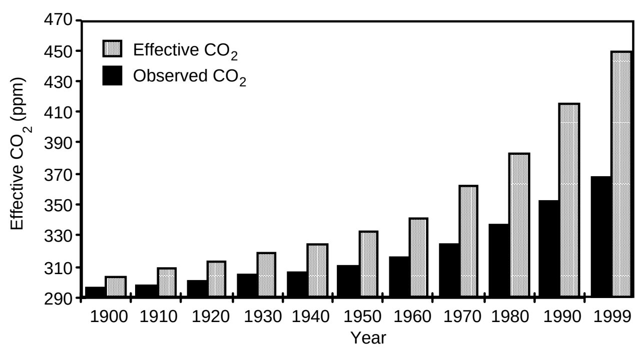
WHAT DOES THE FUTURE HOLD?

By now, climate modelers have run dozens of different computer simulations to estimate future warming. How do you decide which, if any, of these models is likely to be correct?

How Much Have CO_2 Concentrations Increased? From the end of the glacial stage 10,800 years ago, to the Industrial Revolution, the concentration of atmospheric carbon dioxide — the main greenhouse emission resulting from human activity — varied between 260 and 320 parts per million (ppm) The average value during that period was near the low end of that range, about 280 ppm. The current concentration is 365 ppm, about a 30-percent increase.

The effect of other greenhouse gases is usually described in terms of its carbon dioxide equivalent. Methane emissions, for example, contribute an increase of another 20 percent to carbon dioxide's natural greenhouse effect. About 15 percent of the total enhancement to date comes from chlorofluorocarbons, refrigerants whose atmospheric concentrations have yet to decline much despite the Montreal Protocol against their manufacture. A host of other anthropogenic emissions contribute much smaller additional increments. But when all is said and done, the emissions produce a total "carbon dioxide equivalent" concentration of around 450 ppm, or 60 percent above the 280 ppm average background. The temporal history of this change appears in Figure 11.

FIGURE 11



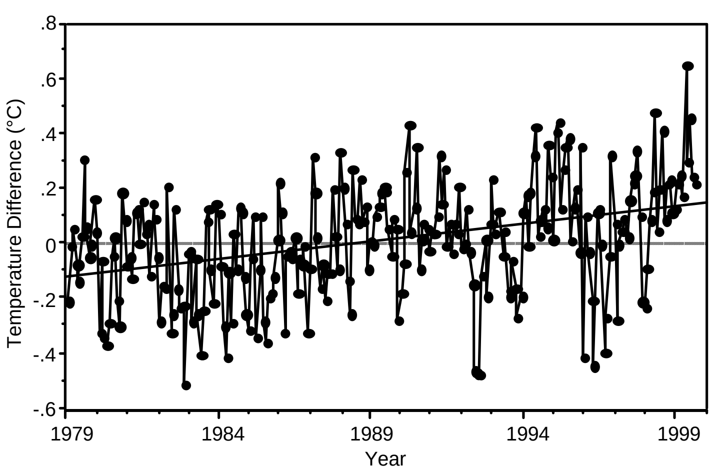
The change in CO_2 and other greenhouse gases concentrations from 1900 to 1999.

How Much Warming Is From CO_2? Nearly 20 years ago, a few climate scientists noted that the planet had not warmed as much as would be expected from early computer simulations of greenhouse warming. By 1996, IPCC acknowledged that most scientists now agreed that observed warming was less than models had predicted. Although it has been fashionable to try to “explain” the lack of warming with sulfate aerosols — a product of combustion that was thought to cool the surface — that explanation has never withstood the simplest of atmospheric tests.

Ironically, it was the same “few” scientists who initially questioned the amount of overall warming who have denounced the validity of the sulfate hypothesis. And now, many researchers who were instrumental in igniting the greenhouse concern, among them NASA’s James Hansen, have conceded — in published papers no less — that the sulfate explanation is gravely lacking in substance.

The simplest illustration of the sulfate hypothesis failure appears in Figure 12. Sulfates are largely produced in the Northern Hemisphere, and because they typically remain in the atmosphere for less than a week, the southern half of the planet is largely sulfate-free. If sulfates were so powerful that they could drastically influence greenhouse warming, then the Southern Hemisphere should be warming more rapidly than the Northern Hemisphere. But monthly satellite data (our only true *global* temperature history), shows without a doubt that the opposite is occurring, as is shown in Figure 12.

FIGURE 12

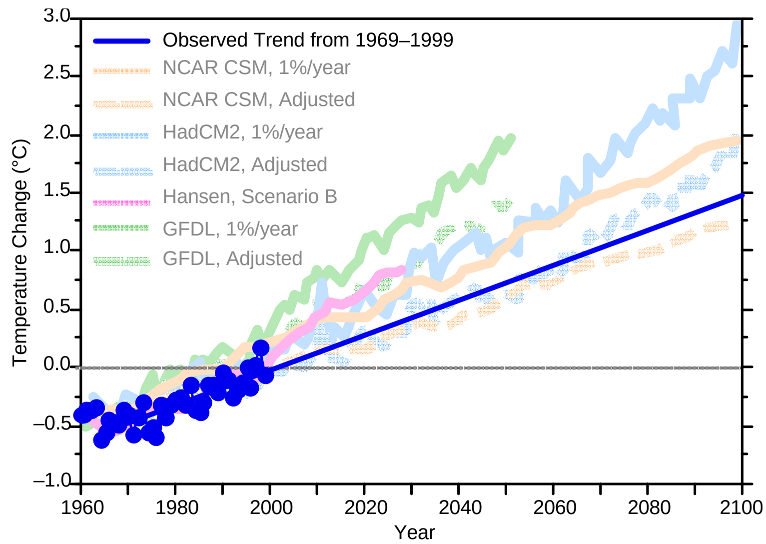


If the sulfate hypothesis were correct, then a negative slope should result from a graph showing the difference when Southern (sulfate-free) Hemisphere temperatures are subtracted from Northern (sulfate-rich) Hemisphere temperatures. Empirical observations show that the opposite is happening.

So we are left to conclude that the warming we have seen in the last third of the twentieth century is largely from greenhouse changes. It is very linear (constant in rate) at about .15º C per decade at the surface. A small part of the increase in temperature (calculated to be around .02º C per decade) stems from an increase in solar intensity. That leaves us with about .13º as a greenhouse signal.

Warming as a Linear Trend Figure 13 shows the warming since 1970 as well as output from a large suite of climate forecast models. All the models (with one exception) predict that as greenhouse gases increase exponentially in concentration, warming will increase linearly, although they differ in the slope of their projected warming because of internal model dynamics and assumptions. The linear prediction occurs because of an experimentally verified characteristic of greenhouse gases: the warming caused by a specific greenhouse gas decreases logarithmically as concentration of the gas increases. The combination of a logarithmic decreased response and exponential increase in concentration results in a linear net effect.

FIGURE 13



Observed warming of the last three decades superimposed on typical climate model projections. The observed linear trend is near the lowest value that the climate models predict and considerably below the mean projected warming.

In our view, a likely course for the future is a linear projection of the warming experience of the last three decades. By the middle of the twenty-first century, we will have an additional surface warming of .65° C to .75º C, with .75° C to .85º C in the winter half-year and .60° C to .65º C in the summer. Interestingly, these 50-year figures are quite similar to the warming that occurred during the twentieth century.

CONCLUSION

The relative distribution of postwar warming is remarkably biased toward the cold winter air masses of Canada and Siberia. While the overall warming trend from 1945 to 1995 is .051º C per decade, the warming within the cold air masses is of .214º C per decade and the warming outside them is only .021º C per decade.

This is a reformatted version of the article that originally appeared in *Regulation* Vol. 23, No. 3 (Fall 2000).

The effects of this warming have been benign or beneficial. The growing season has lengthened by about three days at U.S. latitudes and a week at more northern locations. Warming the coldest winter air masses has also reduced the annual temperature range. Streamflow records indicate decreased drought and no change in floods. And heat-related deaths *declined* with effective temperature.

No known mechanism can stop global warming in the near term. International agreements such as the Kyoto Protocol would have no detectable effect on average temperature within any reasonable policy time frame of 50 years or so — even with full compliance. Beyond 50 years, we have little, if any, idea what the energy infrastructure of our society will be. To highlight the folly of any such projection, compare the energy-related concerns of 1900, when pundits cautioned that major U.S. cities would be knee-deep in horse "emissions" by 1930 unless we saw fit to "act now," with those of 2000. We simply cannot predict our future. Rather, the more serious question provoked by the facts on global warming is this one: Is the way the planet warms something that we should even try to stop?

READINGS

R.C. Balling Jr., P.J. Michaels, and P.C. Knappenberger. "Analysis of Winter and Summer Warming Rates in Gridded Temperature Time Series." *Climate Research*, 9 (1998).

R.E. Davis et al. "Decadal Changes in Summer Mortality in the United States." *Proceedings of the 12th Conference on Applied Climatology*. Asheville, N.C., 2000.

J.E. Hansen et al. "A Common-Sense Climate Index: Is Our Climate Changing Noticeably? *Proceeding of the National Academy of Sciences*, 95 (1998).

T.R. Karl, R.W. Knight, and N. Plummer. "Trends in High-Frequency Climate Variability in the Twentieth Century." *Nature*, 377 (1995).

J. Lean and D. Rind. "Climate Forcing by Changing Solar Radiation." *Journal of Climate*, 11 (1998).

H.F. Lins and J.R. Slack. "Streamflow Trends in the United States." *Geophysical Research Letters*, 26 (1999).

P.J. Michaels et al. "Analysis of Trends in the Variability of Daily and Monthly Historical Temperature Measurements." *Climate Research*, 10 (1998).

P.J. Michaels et al. "Observed Warming in Cold Anticyclones." *Climate Research*, 14 (2000).

R.B. Myneni et al. "Increased Plant Growth in the Northern High Latitudes, from 1981 to 1991." *Nature*, 386 (1997).

D.J. Thompson. "The Seasons, Global Temperature, and Precession." *Science*, 268 (1995).

S.H. Wittwer. *Food, Climate, and Carbon Dioxide*. Boca Raton, Fla.: CRC Press, 1995.

This is a reformatted version of the article that originally appeared in *Regulation* Vol. 23, No. 3 (Fall 2000).