

1. The Science behind Predictions of Climate Change

More than 100 years ago, a Swedish professor, Svante Arrhenius (1896), published the first paper pointing out that increases in carbon dioxide in the atmosphere might have effects on temperatures at ground level. He calculated—by hand—that if atmospheric concentrations of “carbonic acid,” that is, carbon dioxide, were to increase by 50 percent, temperatures in the areas between 30 and 40 degrees north latitude would rise by 4.1°C (7.4° Fahrenheit) and on the oceans by 3.3°C (5.9°F), figures that differ very little from those currently projected on the basis of elaborate computer models. He believed that this would prove beneficial to far-northern countries, such as his own (Cogan 1992, 82).

Does science support the proposition that manmade greenhouse gases are leading to a climate change? In fact, the evidence for the claim that the earth has grown warmer is shaky: the theory is weak and the models on which the conclusions are based cannot even replicate the current climate.

Notwithstanding the IPCC’s famous statement that “the balance of evidence suggests that there is a discernible human influence on global climate,” the evidence fails to support the warming hypothesis (IPCC 1995d). Federal government statistics show no rise in temperatures (NOAA 1996). British naval records find no significant change in temperatures at sea since the mid-1800s (*Technological Review* 1989). The reported worldwide increases in temperature of 0.5° to 1.0°F since the late 19th century occurred mainly before 1940—before the rapid rise in CO₂. Moreover, for reasons explained later, those numbers are far from reliable for much of the period.

Even if we accept the figures showing that the world has become 1°F warmer, the computer models predict a much greater climb in temperature over the past 100 years than currently measured (Lindzen 1994). Even the National Academy of Sciences is skeptical of the validity of the computer models and warns that the modeling of

clouds—a key climate factor—is inadequate and poorly understood (NRC 1991, 18). *Science* magazine has documented that the models need to be adjusted to replicate the current and past climates (Kerr 1994). Recently some researchers claim that by including aerosols the models fit the temperature records (Kerr 1995b). Patrick Michaels, a University of Virginia climatologist and a critic of global warming hysteria, has shown that the reported better fit resulted from using only a truncated portion of the record (Michaels 1997, 5–6). Even with aerosols in the model, the computer results fail to track temperatures over the last few years.

Generally Agreed On Facts

All climatologists agree that we live in a “greenhouse” world; the earth, were it not for the capture and retention of heat by components of the atmosphere, would be too cold to house most life forms, including humans. If the atmosphere did not trap heat, the earth’s temperature would be about 70°F colder, much too low to support life (Lamb 1972, 49, n. 1). Water vapor is the main heat-retaining agent; it contributes about 98 percent of the greenhouse effect. In addition, carbon dioxide (CO₂), methane (CH₄), and, in the modern world, chlorofluorocarbons (CFCs) add to the effect. Most of the concern, however, has focused on the increases in atmospheric levels of carbon dioxide, a product of combustion. As mankind has increasingly relied on fossil fuels for energy, CO₂ emissions have climbed. An increase in methane, arising mainly from rice paddies and from domesticated animals, has also contributed to potential warming.

As Table 1-1 shows, most carbon dioxide comes from natural processes and all of it is recycled out of the atmosphere (Justus and Morrissey 1995). The oceans absorb much of it, although all sinks of CO₂ are not well identified. Human activity contributes only about 4.5 percent of total carbon emissions. Methane emissions from rice paddies, trash dumps, and domesticated animals produce yearly the equivalent in warming of between 3.3 and 5 billion metric tons of CO₂. Thus carbon dioxide and methane are currently contributing about 86 percent of all the greenhouse gases being added to the atmosphere (NRC 1991). CFCs and N₂O (nitrous oxide) constitute the remaining manmade warming gases. All these gases, produced by humans, warm the atmosphere slightly, leading to more evaporation and hence more water vapor (H₂O being the major molecule

Table 1-1
GLOBAL SOURCES AND ABSORPTION OF GREENHOUSE GASES
(millions of metric tons annually)

Greenhouse Gas	Sources		Absorption	Annual Increase of Gas in Atmosphere
	Natural	Manmade		
CO ₂	555,000	26,300	570,000	11,470–12,950
Methane	110–210	300–450	460–660	35–40
Nitrous Oxide	6–12	4–8	13–20	3–5

SOURCE: U.S. Energy Information Administration, *Emissions of Greenhouse Gases in the United States, 1995* (Washington: EIA, 1996). Cited in *Global Change* (electronic edition), March 1997; Pacific Institute for Studies in Development, Environment, and Security (<http://www.globalchange.org>).

that produces a warmer world). Scientists have estimated that concentrations of CO₂ and CH₄ are increasing about 0.5 percent (1.8 ppmv) and 0.9 percent (0.015 ppmv) annually (NRC 1991). About 40 percent of an increase in the emissions of carbon dioxide remains in the atmosphere for decades. The oceans promptly absorb but 15 percent; scientists are uncertain where the rest goes. It may be taken up as basic fertilizer by forests which, both in Europe and in the United States, have flourished in recent decades (Kauppi et al. 1992; Myneni et al. 1997). Climatologists estimate it would take between 50 and 200 years for a sudden injection of CO₂ into the atmosphere to be reabsorbed by the oceans and plants.

Methane and CFCs absorb more energy per molecule than does carbon dioxide and thus contribute more per molecule toward warming (see Table 1-2). Those emissions, however, constitute a smaller share of the total and thus add less to climate change. In fact, CFCs have been phased out in the industrial countries and are soon scheduled for complete abolition. CFCs also erode the ozone layer, a stratospheric phenomenon that contributes to a warmer climate. While CFCs absorb more energy, recent studies suggest that the added effect of this on climate change is roughly offset by their erosion of ozone (Justus and Morrissey 1995). On net, therefore, CFCs can be ignored: they are being phased out and they do not contribute much overall to climate change.

Table 1-2
DIRECT GLOBAL WARMING POTENTIAL FOR 100-YEAR
TIME HORIZON

Greenhouse Gas	Direct Global Warming	Indirect Component of Global Warming
Carbon Dioxide	1	none
Methane	11	positive
Nitrous Oxide	270	uncertain
CFC-11	3400	negative
CFC-12	7100	negative

SOURCE: IPCC 1992, 15, table 3.

Even though other gases retain more heat, most of the climatic effect of greenhouse gases comes from carbon dioxide. Of the direct heating of long-lived greenhouse gases, 64 percent comes from CO₂, while less than 20 percent comes from methane. According to the forecasts by the IPCC Working Group I, if carbon dioxide emissions remain at 1994 levels, atmospheric concentrations of that gas will reach about 500 parts per million of volume (ppmv) by the end of the next century, nearly twice the preindustrial level of 280 ppmv (IPCC 1995d).

In 1990, the National Academy of Sciences (NRC 1981) estimated that, if CO₂ emissions remained at current levels, the added warming would be about 1 watt per square meter (W/m²) of the earth. In comparison, the sun's radiation striking the upper atmosphere has an average over the year of about 340 W/m². During a year, the earth radiates all of this back into space. Initially about 25 percent is reflected from the top of the atmosphere; 45 percent is absorbed at the earth's surface; about 5 percent is reflected from the oceans and from the earth's surface (ice and snow reflect most of the radiation striking that frozen landscape). Through evaporation and heat transfers, the remaining energy radiates back into space. On net, long-lived greenhouse gases—carbon dioxide, methane, and nitrous oxide—contribute about 2.45 W/m² to climate change (IPCC 1995d).

At least in part, aerosols (small particles) produced by industry, volcanoes, and other sources can offset an increase in greenhouse gases (Kerr 1995a). Although the particles remain in the atmosphere

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a relatively short time, while there they do reflect solar energy back into space (IPCC 1995d). After the 1992 volcanic eruption of Mt. Pinatubo, which spewed huge amounts of sulfates into the atmosphere, the world cooled noticeably for several years. Researchers have attributed the failure of the world's temperature to rise as much as predicted to sulfates produced by industry. Aerosol concentrations can make clouds more reflective, thus increasing their cooling effect.

Contentious Issues

Virtually all climatologists agree that an increase in greenhouse gases will affect climate, although they are unsure as to how and to what degree. The theoretical predictions of temperature change have continuously been slashed as more information and better models have been developed. A decade or more ago, researchers forecast sea levels rising 18 feet by the middle of the 21st century; current predictions are more in the range of six inches to three feet in the next 100 years (IPCC 1995d). The 1990 IPCC *Scientific Assessment* forecast global warming at 6° to 14°F by 2050; the 1996 *Assessment* estimated warming of 2° to 6°F by 2100, a cut of more than 50 percent over a period twice as long. In other words, if climate change occurs, it will come at only about one-quarter of the speed of earlier predictions. The IPCC Working Group I concluded (1995d) that the current "best estimate" of temperature warming at the end of the next century would be only 3.6° Fahrenheit, about one-third lower than their prediction five years earlier of 4.5°F warmer for the year 2050.

The speed as well as magnitude of any climate change will determine its effect on the globe. Although many environmentalists have contended that the rate of change in temperature will exceed any that has occurred since the last Ice Age, it now appears that any warming will occur more slowly. Moreover, researchers have now determined that climate variability has been greater over the last 10,000 years than experienced during the last century and a half (Overpeck 1996). The IPCC, however, asserts that over the next century "the average rate of warming would probably be greater than any seen in the last 10,000 years" (1995d). Given that temperatures so far have failed to keep up with model predictions, one can remain skeptical about the future speed of climate change.

An Unknowable Future

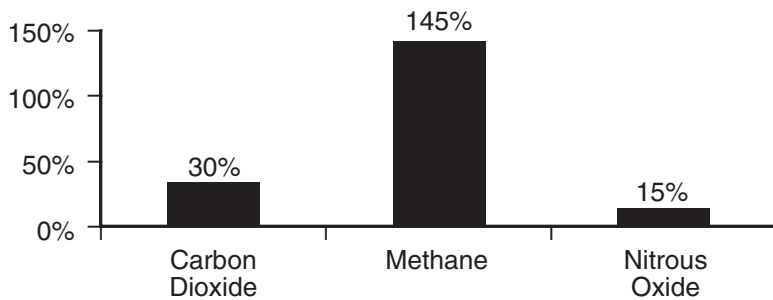
Some believe that the warming will be very modest while predicting that a buildup of greenhouse gases will result in increased evaporation and cloud cover. In that scenario, climate change will affect temperature marginally but will have greater impact on rainfall. If that view of warming is correct, any rise in sea levels will be small; the levels may even drop. Accordingly, even though the oceans may warm marginally and thus expand, increased precipitation and especially snowfall in Antarctica will add to the amount of water trapped in glaciers and perhaps lead to a net fall in water levels.

On the other hand, scary news articles have intimated that global warming might melt the polar ice caps and lead to a huge rise in sea levels. Most of the Arctic is covered by ocean with floating ice, which if it melted would not have any effect on water levels. The only large bodies of frozen water that if melted would measurably increase the height of the oceans are located in Greenland and Antarctica. The glaciers in Greenland are surrounded by mountains that block them from sliding suddenly into the sea with potentially large effects. Melting of the Greenland glaciers would take centuries.

The Antarctic is covered with glaciers thousands of feet thick. The West Antarctic ice sheet is open to the sea and thus could potentially be discharged into the sea. Such a development might raise ocean levels by 16 to 20 feet within a hundred years (Bentley 1997). Such a rise would clearly be extraordinarily costly. Fortunately, the experts believe that it is also extremely unlikely. Professor Charles Bentley of the Geophysical and Polar Research Center at the University of Wisconsin writes: "In light of the evidence for recent stability, it is difficult to see how climate warming . . . could trigger a collapse of the WAIS [West Antarctic Ice Sheet] in the next century or two. Ice sheets take thousands of years to respond to changes in surface temperature" (Bentley 1997, 1078).

Not only are we uncertain about the direction of sea levels, but the future growth in greenhouse gas emissions is far from clear. There is little doubt that the concentration of CO₂ in the atmosphere has been rising for well over a hundred years. In 1990, the concentration of carbon dioxide in the atmosphere was measured at 353 parts per million by volume, a rise of 25 percent from the pre-Industrial Revolution figure of 280 parts per million (NRC 1991). Human activity, especially the burning of fossil fuels, has contributed to this

Figure 1-1
GROWTH IN GREENHOUSE GASES SINCE THE
INDUSTRIAL REVOLUTION



SOURCE: IPCC 1995d.

change (see Figure 1-1). What is uncertain is the future. Will humans continue to depend for energy primarily on coal, oil, and the burning of wood? Certainly for the next few decades the world will derive its main source of energy from carbon-based fuels.

In the industrialized West, however, carbon dioxide production relative to national income has been declining (Ausubel 1994). As our economy becomes more information-based and less oriented toward heavy industry, we also become less dependent on coal and petroleum. Predictions about what kind of energy might be used 100 years hence have little validity. Some forecast that, long before then, mankind will have run out of oil and natural gas. Coal supplies appear to be plentiful for several hundred years, but coal has other drawbacks beyond those related to CO₂ emissions. Coal mining is dangerous; burning coal produces sulfur oxides that contribute to acid rain; coal burning also produces particulates that may be hazardous to human health.

The wide range of emission forecasts reflects the uncertainty about future economic growth rates for the world, the availability of cheap fossil fuels, population expansion, and the willingness of countries to pay the costs of cutting emissions. If China were to continue to grow rapidly and to rely on its existing huge stocks of coal, carbon dioxide emissions would continue to grow regardless of whatever

Table 1-3
IPCC ASSUMPTIONS

Scenario	Population in 2100	Period	Economic Growth	Energy Supplies
IS92a,b	11.3 Bil.	1990–2025 1990–2100	2.9% 2.3%	12,000 EJ Oil; 13,000 EJ Gas Solar costs \$0.075/ kWh
IS92c	6.4 Bil.	1990–2025 1990–2100	2.0% 1.2%	8,000 EJ Oil; 7,300 EJ Gas; Nuclear costs fall 0.4% yearly.
IS92d	6.4 Bil.	1990–2025 1990–2100	2.7% 2.0%	8,000 EJ Oil; 7,300 EJ Gas; Solar costs \$0.065/ kWh; bio available at \$50/barrel
IS92e	11.3 Bil.	1990–2025 1990–2100	3.5% 3.0%	18,400 EJ Oil; 13,000 EJ Gas Nuclear phase out by 2075
IS92f	17.6 Bil.	1990–2025 1990–2100	2.9% 2.3%	18,400 EJ Oil; 13,000 EJ Gas Solar costs \$0.083/ kWh; nuclear costs \$0.09/kWh

SOURCE: IPCC 1992, 11, table 1.

the rest of the world were to do. On the other hand, if there were to be a significant technological breakthrough that reduced the need for reliance on fossil fuels, emissions might even decline. The best guess, however, is that the future path will reflect current rates of economic expansion and current uses of energy sources, and that, while the rate of population growth will be slowing, the number of humans worldwide will still be rising throughout most of the century. The IPCC has established six scenarios, shown in Table 1-3, reflecting differing rates of economic growth, population (projections in billions), and energy supplies in the next century.

Historical Records

The models that employ the various scenarios are poor at replicating past climate and even current weather conditions. Temperature data for the world, measured over the last hundred years, show an increase of about 1°F or less. Partisans point to this as evidence of warming, but much of that boost in worldwide temperatures occurred before 1940 and a good portion took place around 1920, prior to widespread industrialization (Ausubel 1991, 215). From 1940 to the mid-1970s, global temperatures declined a little, setting off speculation about global cooling. Then, starting in the second half of the 1970s, the world became warmer. Overall for this century, temperatures have risen most at night and during the winter with a fall in summer daytime readings (IPCC 1992, 152, table C2).

Within the United States, which has the best records, thermometers have registered no significant gain for the 101 years between 1895 and 1996 (NOAA 1996). Temperatures in 1896 were actually slightly warmer than in 1996! Nor has precipitation varied over the same century. The general circulation models that have been predicting warming forecast that the polar regions should warm the most. Over the last 55 years, no significant warming has been measured at either pole (*World Climate Report 1995*, vol. 1, no. 8). American researchers at the South Pole, who have been keeping records for 40 years, recorded the coldest month ever in July 1997 (Browne 1997, B11).

Moreover, there are real problems with the measurements used to calculate temperature trends worldwide. Those data are based on ground measurements, taken mainly in cities. Most of the world, especially the Southern Hemisphere, is water and there are no figures for much of this area. Mountainous regions also sport few thermometers. Poor and primitive areas are underrepresented in the data since most of the gauges are located in the more economically advanced parts of the world.

Another major problem with the data is that, as cities grow and pave more of their area with asphalt and cement, heat is trapped, thus raising local readings. In other words, the data collected from urban sites are subject to the "heat island" effect. Although climatologists claim to have adjusted for this bias, questions remain about whether the record can accurately portray world temperature changes.

Furthermore, since 1979, satellites circling the earth have measured temperatures around the globe, including much of the world where no one can regularly take temperatures. Those data fail to show an increase in global temperatures over the period 1979 to 1997, even though the models predict and earth-based thermometers show a slight rise. Although the satellite figures are controversial, they are highly correlated with the readings from weather balloons, taken twice a day around the planet (*World Climate Report 1997*, vol. 2, no. 13). Critics of the satellite figures point out that they reflect the average temperature between the earth's surface and 15,000 feet. On the other hand, not only do the data from space cover the planet, but they are free from the heat-island effect and are accurate to within plus or minus 0.02 degrees.

Model Uncertainties

Forecasts of future warming rely not only on the surface temperature data but also on multiequation models run on supercomputers. Using those elaborate models, climatologists have calculated the effect of increases in greenhouse gas emissions on the world's climate. The computer simulations are so big that they require supercomputers to solve the multiple equations. Many factors must simply be assumed. Various parameters are imposed to make the models fit reality. Because of the number of variables involved, weather variables are averaged for very large regions so that they cannot include data on weather fronts, rainfall patterns, or other regional effects (*World Climate Report 1995*, vol. 1, no. 8).

The models replicate current conditions imperfectly. In fact, researchers have had to *adjust* the results to match the models to current weather. As *Science* (Kerr 1994) put it: "In climate modeling, nearly everybody cheats a little." Nevertheless, most of the researchers have concluded that increases in greenhouse emissions will lead to warming of the climate. To nonclimatologists like myself, the predictions may sound reasonable—a buildup of CO₂ and methane will lead to increased retention of heat in the atmosphere. Potential feedbacks, however, might either augment warming or offset it. Professor Richard Lindzen (1994) of the Center for Meteorology and Physical Oceanography at MIT, for example, suggests that negative feedbacks may largely offset the effect of a growth in greenhouse gases. He points out that the standard view assumes a positive

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feedback effect from water vapor to achieve significant climate change.

Probably the most contentious issue is the effect of clouds on climate. As noted, clouds reflect heat back into space and absorb infrared radiation reflected from the earth's surface. Recent research shows that clouds absorb heat directly from the sun with an unknown effect on climate (*World Climate Report* 1995, vol. 1, no. 7).

In addition the models are singularly poor at predicting regional climate. Until very recently, they also did a poor job of tracking the globe's climate over the last 100 years. They cannot explain, for example, the temperature decline from 1940 to the mid-1970s. Moreover, they predicted that, on the basis of the known buildup of greenhouse gases, the earth's climate should have warmed significantly more than it has.

New modeling has incorporated sulfate aerosols produced by human activity. Those particles reflect solar energy back into space, thus cooling the planet. The significant effect of the sulfate particles was confirmed by the 1991 Mount Pinatubo eruption, which, as noted, threw vast amounts of particles into the upper atmosphere, leading to a measurable cooling of the earth for the next two years. Sulfate aerosols not only reflect energy directly away from the globe but act to condense water vapor into clouds, which also reflect incoming solar radiation away from the earth. The net effect is to reduce the amount of warming from manmade sources. Incorporating the effects of aerosols into the models has led to better predictions of past temperature changes; more important, it has reduced significantly the forecast temperatures and sea level rises resulting from climate changes.

Even when sulfates are included, the computer models fail to track the temperatures in the lower atmosphere (*World Climate Report* 1996, vol. 2, no. 8). Moreover, those portions of the globe with the highest concentration of industry that spews sulfates—Western Europe, Eastern United States, and East Asia—have experienced warming over the last decade and a half, while the rest of the earth has cooled (*World Climate Report* 1996, vol. 1, no. 9). The theory would predict the opposite: the Northern Hemisphere, with most of the world's factories, transportation, oil refineries, and economic activity, should have experienced the least warming rather than the most.

Table 1-4
IPCC SUMMARY

Stabilization Level (CO ₂ ppmv)	450	550	650	750
Equivalent CO ₂ , ppmv	560-760	800-980	920-1160	1140-1340
Cumulative CO ₂ Emissions, GtC*	450-620	660-810	760-960	930-1090
Global Mean Temp Change at Equilibrium	2° to 6°	3° to 8°	3° to 10°	4° to 11°

SOURCE: IPCC 1992.

*Gigatons (billions of tons) of carbon.

Table 1-5
IPCC PREDICTED WARMING FOR 2100

Date of Prediction	Best Estimate of Warming
Published in 1990	5.8°F
Published in 1992	4.5°F
Published in 1995	3.6°F

SOURCE: IPCC 1990; IPCC 1995d.

Although the computer models have come up with a range of predictions for increased warming, the current consensus estimates that a doubling of greenhouse gases will boost world temperatures somewhere between 2° and 7°F with a best guess, made in 1992 by the IPCC, a 4.5°F increase. Table 1-4 gives the IPCC's summary of atmospheric concentrations, the total manmade emissions of CO₂, and the predicted mean temperature change.

As noted, the forecasts of climate change have shrunk in recent years as a result of the incorporation of the role of aerosols into the models (see Table 1-5). With somewhat lower temperatures predicted, forecasts of rising sea levels have also fallen. Since climate change is likely to produce more precipitation worldwide, it is likely to contribute to the buildup of ice in Antarctica, which, by itself, should lower sea levels. The warmer oceans will, however, expand. The net result could be either a small fall in the oceans or a rise of perhaps one to three feet by the end of the next century (Schneider 1997). Seashores are rising in some places and falling in others,

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making it difficult to measure sea level changes accurately; but satellite measurements have failed to find any significant change (Nerem 1997).

Weather Effects of Climate Change

The global warming models predict that the circumpolar vortex, also known as the jet stream, should move toward higher latitudes. The jet stream divides the Northern Hemisphere between the cold polar air and the warmer tropical areas. The winds, driven by differences in temperature, are the major force creating storms and driving precipitation, clouds, and weather fronts. Although a northern movement of the jet stream, especially during the winter, has been expected and would bring warmer weather to much of the hemisphere, the records since 1947 show that the opposite has occurred. The circumpolar vortex has moved farther south, not north as global warming would lead us to expect (Davis and Benkovic 1994).

Many alarmists have suggested that global warming will lead to an increase in the number and severity of storms. Much of the weather that Americans experience is driven by the difference in temperatures between the North Pole and the equatorial region. Since climate change is expected to boost high latitude temperatures more than those near the equator, that temperature differential will be reduced, cutting the differences in atmospheric pressure and thus the severity of most storms. On the other hand, it is true that tropical hurricanes get their strength from warm ocean waters. If global warming occurs, it will expand the area of sea warm enough to generate more hurricanes and perhaps boost the surface temperature of the water itself, possibly making the storms more severe and extending the tropical storm season.

As the next chapter reports, however, warmer periods in the past have experienced less violent storms than colder eras. So far the data for the Atlantic show that violent hurricanes were more common in earlier decades than recently (Landsea et al. 1996). For that region, the number of tropical storms has averaged 9.1 annually since 1960, while the number of such storms in the western Pacific has been 27.5 per year. In that region, no trend is detectable (*World Climate Report 1996*, vol. 1, no. 13). At the same time, the average maximum velocity of sustained winds in Atlantic storms has actually declined since the mid-1940s.

CLIMATE OF FEAR

The record of storms over recent decades simply fails to support the proposition that weather is becoming more violent. In the Atlantic basin, the number of intense hurricanes, those scaled between 3 and 5 (5 being the most violent), actually declined during the 1970s and 1980s (Landsea 1993). The four years from 1991 to 1994 enjoyed the fewest hurricanes of any four years over the last half century (Landsea et al. 1996). Researchers have found that the average number of tropical storms and hurricanes has not changed over the past 52 years, while there has been a major *decrease* in the number of intense hurricanes. For the Pacific around Australia, other researchers have found that the number of tropical cyclones has *decreased* sharply since the mid-1980s (Nicholls 1992). Of the 10 deadliest hurricanes to strike the continental United States, all raged before 1960, notwithstanding the huge expansion of population in coastal areas vulnerable to such storms (Landsea 1993).

Environmentalists have viewed climate change as a catastrophe necessitating immediate and major steps to head off or mitigate. Whether global warming will occur is uncertain. Although temperature data until now could reflect a warming planet, they are also consistent with normal fluctuations in weather. From a scientific viewpoint the evidence for global warming must be “not proven.”