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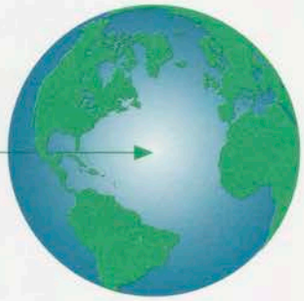
PROGRESS and the Planet



GLOBAL WARMING:

MESSY MODELS, DECENT DATA, POINTLESS POLICY

Dr. Robert C. Balling, Jr.

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by Dr. Robert C. Balling, Jr.

EXECUTIVE SUMMARY

The apocalyptic vision of the greenhouse effect has been presented to us all through a never-ending series of printed stories and editorials, scientific documentaries, and even several full-length films. However, sound scientific evidence argues against the existence of a greenhouse crisis, against the notion that realistic policies could achieve any meaningful climatic impact, and against the claim that we must act now in order to avert disaster.

Present day climatological predictive models that serve as the basis for the global warming catastrophe scenario fail to accurately simulate climate responses to greenhouse gas buildup. Scientists who work on these models are the first to point out that the models are far from perfect representations of reality, and that they are probably not advanced enough for direct use in policy implementation. Even the most sophisticated, modern-day models:

- do not accurately couple ocean and climate patterns;
- do not account for the effects of non-greenhouse gas buildup;
- fail to accurately represent the role of clouds in maintaining the earth's energy balance; and
- misrepresent the role of sea ice, snow caps, localized storms, and biological systems.

Greenhouse gas levels in the atmosphere have risen by 40 percent over the past 113 years. Computer models predicted that this atmospheric gas buildup would have produce a minimum 1°C warming. Temperature records indicate, however, that the earth has experienced a temperature increase of only 0.54°C; the models err by a factor of two.

Alternative explanations for the observed warming cast even more doubt on the ability of the models to accurately simulate changes in the climate. For example:

- Nearly 70 percent of the warming that has occurred this century took place prior to 1937.
- Satellite-based temperature measurements reveal no planetary warming since 1979, and even suggest a light cooling.
- Temperature records indicate that the Arctic region has cooled by 0.88°C over the past 50 years, while models predicted the Arctic would experience the greatest warming.

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The timing of any temperature change (day versus night) is critical in determining the severity of the greenhouse threat. A nighttime warming would lengthen growing seasons, and the lack of warming during the daytime would not force an increase in droughts. Indeed, potential benefits of a moderate warming have not been examined sufficiently.

Global warming is presented as a crisis that can be stopped or minimized with appropriate policy actions. However, the evidence suggests that realistic policies are likely to have a minimal climatic impact. Recent research also suggests that a delay in implementing policy responses will have little impact on the efficacy of global warming mitigation strategies.

It is absolutely imperative that the policies developed for the global warming issue be built on the best science available. Too often, policymakers appear to neglect the enormous evidence that argues against the greenhouse disaster, and freely accept and promote the scientific studies in favor of the crisis. The scientific evidence argues against the existence of a greenhouse crisis, against the notion that realistic policies could achieve any meaningful climatic impact, and against the claim that urgent action is necessary to reduce the greenhouse threat.

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Global Warming: Messy Models, Decent Data, Pointless Policy

by Dr. Robert C. Balling, Jr.

According to many environmentalists, politicians, and reporters, global warming represents a significant threat to the future of mankind and the planet. They believe that the continued buildup of greenhouse gases will cause the world to warm substantially, sea level will rise, ice caps will melt, droughts will become more frequent and more intense in the breadbaskets of the continents, severe storms will batter the coastlines with greater intensity, and wildfire activity will increase in our forests. The apocalyptic vision of the greenhouse effect has been presented to us all through a never-ending series of printed stories and editorials, scientific documentaries, and even several full-length films. The greenhouse advocates have been extremely effective in selling this message to the public, and as a result, the global warming issue continues to remain high in our environmental consciousness.

Three underlying and fundamental messages are heard over and over:

1. The continued buildup of greenhouse gases will produce substantial warming thereby generating a variety of undesirable outcomes.

2. Realistic policy options are available that can reduce or even eliminate the greenhouse threat.

3. We must act now — waiting for action is simply too dangerous given the severity of the global warming crisis.

From a climatological perspective (as opposed to social, economic, or political perspectives), I firmly believe that each of these three messages regarding the greenhouse effect is seriously flawed. The professional literature in climatology is full of articles that demonstrate the weaknesses in these three statements, and yet, this literature often is overlooked in presenting the greenhouse catastrophe to the public and policymakers. Anyone seriously interested in the greenhouse issue must become aware of the debate surrounding global warming projections, and they must come to understand that credible scientists are producing results that do not support the highly-popularized vision of a greenhouse disaster, and publishing these results in leading peer-reviewed professional journals.

Origins of the Greenhouse Scare

Nearly a century ago, Arrhenius[1] published an article in the *Philosophical Magazine* presenting calculations showing that a doubling of the atmospheric concentration of carbon dioxide (CO_2) would lead to a planetary

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temperature rise of 6°C. Arrhenius understood that certain gases, like CO_2, trap heat energy that otherwise would escape more quickly into space (the analogy is made to a greenhouse, and hence, gases with this radiative property have become known as greenhouse gases). Many of these greenhouse gases, including water vapor, are naturally occurring and help to maintain the "normal" temperature of the earth. However, due to a variety of human activities that involve fossil-fuel burning and deforestation, the atmospheric concentration of CO_2 has been increasing measurably since the beginning of the Industrial Revolution (Figure 1). Over the past two centuries, atmospheric concentrations of CO_2 have increased by 25 percent (from approximately 285 ppm to 356 ppm); virtually all of this increase has occurred in the past 100 years.

Credible scientists are producing results that do not support the highly-popularized vision of a greenhouse disaster.

During the same period of industrial development, many other gases have been added to the atmosphere that also have the potential to produce greenhouse warming. Methane (CH_4) concentrations were near 0.75 ppm in 1800; however, the recent measurements show methane levels to be near 1.70 ppm, and the increase is related largely to various agricultural activities, most notably, rice paddy agriculture. Nitrous oxide (N_2O) is another naturally-occurring greenhouse gas that has increased in atmospheric concentration due to deforestation, fossil fuel burning, and the use of some fertilizers. Atmospheric concentrations of N_2O have risen from about 285 parts per billion (ppb) for pre-Industrial Revolution levels to approximately 310 ppb in 1990.

Carbon dioxide, methane, and nitrous oxide are greenhouse gases that occur naturally in the atmosphere. Unlike these other greenhouse gases, the pre-Industrial Revolution atmospheric concentrations of the chlorofluorocarbons (CFCs) were essentially zero. These CFCs are very powerful greenhouse gases, and despite having concentrations that are measured in parts per trillion, the CFCs add significantly to the overall greenhouse effect. These CFCs destroy some ozone in the stratosphere, and because ozone also operates as a greenhouse gas, the destruction of ozone by the CFCs may ultimately minimize the total greenhouse contribution of the CFC molecules.[3]

The overall radiative effects of these many greenhouse gases may be approximated by "equivalent carbon dioxide" values. The resultant value gives an indication of how much CO_2 would be required to produce the same greenhouse effect as other trace gases found in the atmosphere. Equivalent CO_2 levels were approximately 290 ppm at the beginning of the Industrial Revolution, 310 ppm in 1900, and nearly 440 ppm in 1994 (Figure 1). Since the beginning of the Industrial Revolution, equivalent CO_2 has increased by 50 percent, and in the last 100 years, the increase has been fully 40 percent.

The atmospheric concentration of CO_2 has been increasing measurably since the beginning of the Industrial Revolution.

There has been a tendency to believe that the trends in atmospheric concentrations in these gases would continue without any great surprises into the next century. However, in the late 1980s and early 1990s, the growth rate in the concentration of many greenhouse gases fell well below expected levels. Some greenhouse gases, such as methane and carbon monoxide, have levelled off or even declined.[4] Other gases, such as CO_2, have shown a substantial reduction in the rate of increase, that is, the atmospheric concentration is still increasing, but the rate of increase is far below previous levels. These findings have surprised many climatologists who are now groping for an explanation. An unusually long-lived El Niño/Southern Oscillation event, a reduction in biomass burning in tropical savannas, the eruption of Mount Pinatubo, enhanced growth in the biosphere, and even major repairs of large pipelines have all been suggested as possible causes of the trends in various greenhouse gases. Finally,

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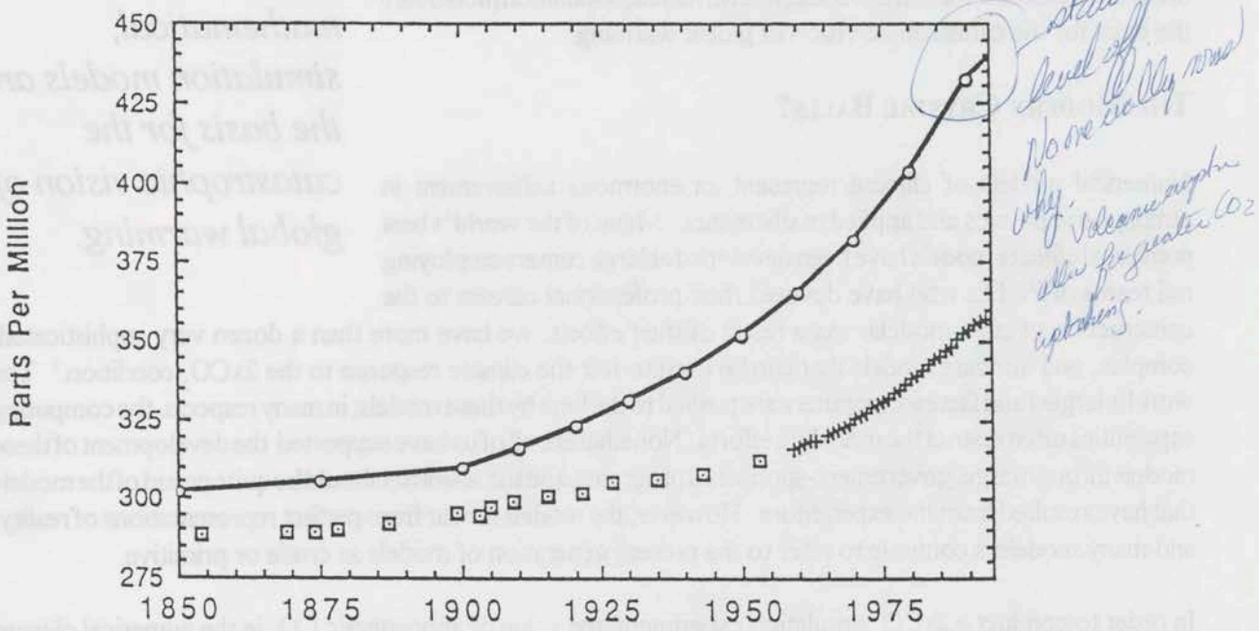
Figure 1.



Atmospheric CO_2 concentration derived from Siple Station, Antarctica ice cores (small squares) and Mauna Loa, Hawaii direct atmospheric measurements (plus signs), along with equivalent CO_2 concentrations of all other radiatively-active trace gases acting in concert with CO_2 (open circles). A description of these data is found in Balling[2].

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although the rate of increase has slowed in the most recent few years, many scientists continue to expect the equivalent CO_2 value to double by the middle of the next century, with respect to pre-Industrial Revolution values, and pass the 600 ppm level.

Given the observed and projected rise in the atmospheric concentration of these greenhouse gases, many scientists have re-addressed the calculations made by Arrhenius a century ago. But unlike Arrhenius, today's scientists have a battery of powerful tools for analyzing the sensitivity of climate to the buildup of greenhouse gases. The most powerful of these tools are enormous computer programs designed to simulate the physical principles that govern the earth-ocean-atmosphere system. These are the general circulation models, and these models have been independently designed throughout the world, and they have been used repeatedly to examine the warming that could be associated with a doubling of equivalent CO_2. The popularized projections for massive warming, sea level rise, glaciers melting, droughts, severe storms, and wildfires ultimately come from these numerical climate models. In essence, these theoretical, mathematical, simulation models are the basis for the catastrophic vision of global warming.

Theoretical, mathematical, simulation models are the basis for the catastrophic vision of global warming.

The Modern Crystal Balls?

Numerical models of climate represent an enormous achievement in atmospheric physics and applied mathematics. Many of the world's best numerical climate models have been developed at large centers employing full teams of Ph.D.s who have devoted their professional careers to the construction of such models. As a result of their efforts, we have more than a dozen very sophisticated, complex, and intricate models that can be used to test the climate response to the $2xCO_2$ condition.[5] The world's largest and fastest computers are pushed to the limit by these models; in many respects, the computing capabilities often restrict the modeling efforts. Nonetheless, all of us have supported the development of these models through large, government-sponsored programs, and the scientists should be quite proud of the models that have resulted from the expenditure. However, the models are far from perfect representations of reality, and many modelers continue to refer to the present generation of models as crude or primitive.

In order to conduct a $2xCO_2$ simulation experiment, the value of atmospheric CO_2 in the numerical climate model changes from 300 ppm to 600 ppm. In the equilibrium experiments, the model is run for 300 ppm, then run for 600 ppm, and the differences in the simulated climate are determined. In more difficult, but more realistic time-dependent experiments, the model's equivalent CO_2 levels are raised gradually and realistically from 300 ppm to the 600 ppm level, and the resultant climate is determined along the time continuum. These are somewhat different approaches to the problem, but in gross terms, they tend to produce similar results.

All climate models predict a global increase in annual average near-surface air temperatures as a doubling of equivalent CO_2 occurs. The range of projected global changes is from 1°C to 5°C, with a mean near 3.5°C. The tropics are predicted to warm the least, while the high latitudes are predicted to warm the most; more warming is predicted in winter than in summer. The models also predict an increase in globally-averaged precipitation due to an intensification of the hydrological cycle and the ability of the warmer atmosphere to hold more water. Irrespective of the changes in precipitation, the predicted warming should act to increase the rate at which water can be evaporated into the atmosphere. The rise in evaporation and transpiration is predicted to overwhelm any increases in precipitation, and soil moisture levels are expected to decrease over

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many continental areas. Climate predictions about wildfires, drought frequencies, or severe storm outbreaks are derived from the model results, but they are not direct outputs from these models.

Many people have argued that the best models in the world are basically all predicting something of a climate disaster for a doubling of the atmospheric concentration of greenhouse gases.[6] Given that these models represent the best tools for peering into our climate future, they argue that we should pay very close attention to the warning. They very fairly asked how we can neglect this warning, or they asked how will we ever explain to future generations that we knew about the coming disaster and we did nothing to stop it. If we place much faith in the models, then global warming must be viewed as a very real threat confronting mankind and the planet.

However, the same scientists who work on these models are among the first to point-out that the models are far from perfect representations of reality, and they are probably not advanced enough for direct use in policy implementation. Major weaknesses remain in the models, and in particular, the role of the ocean in absorbing CO_2 and storing and transporting heat is not adequately included in the existing models. Coupling the best ocean models to the best climate models is very tricky business computationally, but a necessary step in building more reliable forecast tools. Enormous strides are being made in coupling these models, and I suspect climate model outputs of the immediate future will look quite different from today's results as this critical coupling is achieved.

Cloud representations are particularly questionable in the present models. Yet clouds play a critical role in maintaining the energy balance of the earth.

Cloud representations are particularly questionable in the present models.[7] Yet clouds play a critical role in maintaining the energy balance of the earth. If the greenhouse enhancement acts to produce an increase in high clouds, the feedback could be positive and the warming could be accentuated. But if the greenhouse effect yields an increase in low clouds, the feedback could be negative, and the cloud increases could counter and even cancel the greenhouse warming.[8] These, and many other complexities regarding the clouds are not adequately handled in the models, and relatively small adjustments in the representation of these feedbacks can have a profound impact on the calculated climate response to a $2xCO_2$ condition.

Other widely acknowledged problems in the models are related to the representation and treatment of sea ice, snow cover, localized storms, and biological systems. Up to this point, we have totally neglected the fact that other non-greenhouse gases are being added to the atmosphere that can have strong local and regional cooling effects.[9] Sulfur dioxide emissions have increased at the global scale, and sulfur dioxide is known to have a cooling effect via the production of aerosols that reflect incoming sunlight, brighten clouds, and extend the lifetime of existing clouds. Simply doubling CO_2 in a model to represent future conditions is an interesting and valuable academic exercise, but in order to realistically simulate the future, changes in other gases, such as sulfur dioxide, must be considered in the modeling experiments.

As of today, we have very powerful and complex numerical models for testing the sensitivity of climate to various changes in atmospheric chemistry. But as we have seen, the models are crude and deficient in many of the critical representations of the climate system. The models are getting better all the time, and advances in computing technology, along with advances in the atmospheric sciences, will produce the next generation of models — their results may look quite different from the results of today's versions.

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These existing models may be viewed as crystal balls for peering into the climatic future, and we are free to believe in as much or as little of their predictions as we like. I firmly believe that as one learns more about the models, less confidence will be placed on their projections for the future. Many of the best modelers are ill-at-ease with any reference to their model outputs as forecasts or projections; they are far more comfortable using the phrase "sensitivity experiments" to describe their work. They understand most that the existing climate models are not very good crystal balls, but in contrast, there are many greenhouse proponents who place remarkable confidence in the model outputs, and demand policy changes based on their climatic crystal balls.

Lessons from the Recent Climatic Past

One obvious test of the models involves their ability to accurately simulate the observed climate changes that have occurred during the past century when equivalent CO_2 levels rose by 40 percent. Here, we begin to see the role of the observational climate record in the overall greenhouse question. When referring to the greenhouse "debate," one is often referring to the tension that exists between scientists who build and perfect the numerical models and the scientists who analyze the actual changes that have been observed in the climate system. Here, theoretical calculations meet empirical evidence, and the "heated debate" is at its best.

Much of the warming of the past century preceded the large increase in greenhouse gas concentrations.

Prior to approximately 1880, the temperature records from around the world are especially incomplete and unable to pass selected homogeneity tests commonly used in climatology.[10] If we begin with the mean annual temperature of the earth in 1881 and complete the record to the near present, we see that the thermometer network of the world shows a linear increase in temperature of 0.54°C (Figure 2). At first glance, there would seem to be empirical support for the greenhouse projections. The models are all predicting warming for an increase in greenhouse gases, and the earth appears to have warmed during the period of historical records. However, there is a lot more to this story, and the connection between the warming and the increase in greenhouse gases may not be so straightforward.

To begin, we can examine the timing of the warming over the last 113 years of record. While the amount of warming from 1881 to 1993 is 0.54°C, the warming during the first half of the record is 0.37°C. Nearly 70 percent of the warming of the entire time period occurred in the first half of the record; the bulk of the greenhouse gas buildup clearly occurred in the second half of the record. Much of the warming of the past century preceded the large increase in greenhouse gas concentrations.

Given the approximate 40 percent increase in atmospheric concentration of equivalent CO_2 over this 1881 to 1993 time period, the observed rise in temperature is low given numerical model predictions for a doubling of equivalent CO_2.[12] Given this buildup in equivalent CO_2, the models suggest that we should have observed at least 1.0°C of warming over the same period. Even if all of the 0.54°C can be ascribed to the effect of greenhouse gases, the models appear to be off by a factor of two. Noted climate modeler Stephen Schneider[13] acknowledged this point and concluded that "the twofold discrepancy . . . is still fairly small." However, alternative explanations for the observed warming, the timing of the warming, and/or the geography of the warming may increase the size of the discrepancy and cast even more doubt on the ability of the models to accurately simulate changes in climate.

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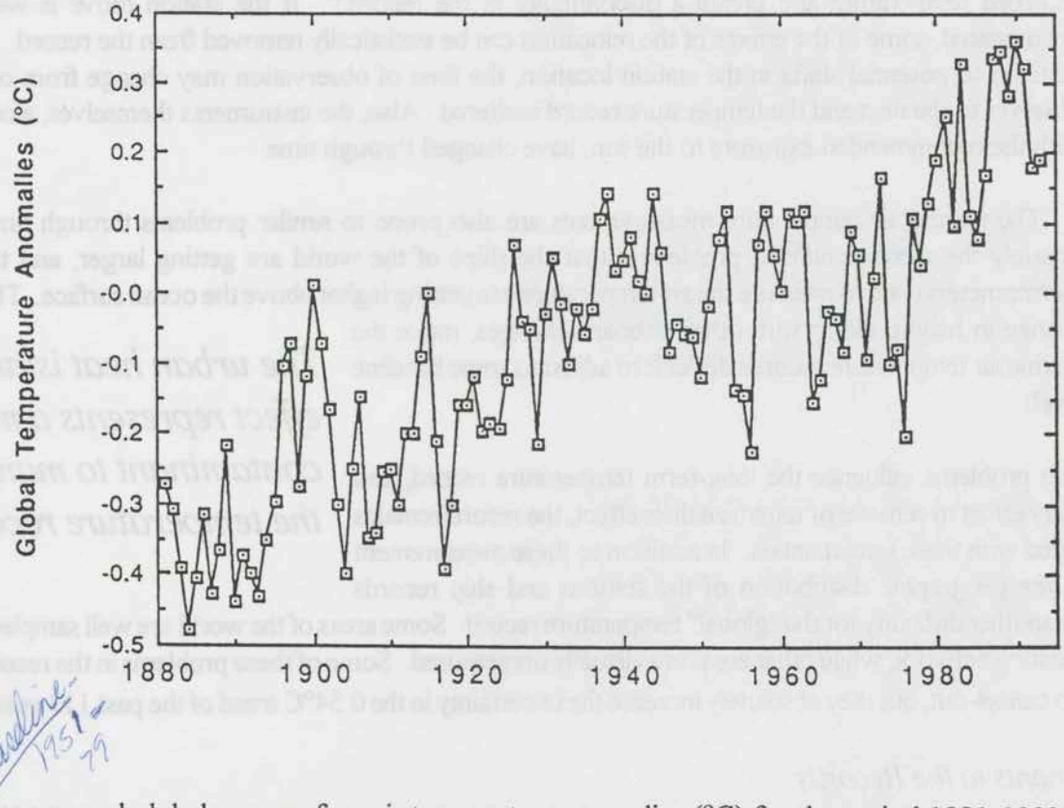
Figure 2.



Mean annual global near-surface air temperature anomalies (°C) for the period 1881-1993.[11]

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Reliability of the Measurements

The global near-surface air temperature data presented in Figure 2 were developed by the Climatic Research Unit at the University of East Anglia. These scientists screened the temperature data from land-based stations and ship records to eliminate as many non-climatic errors as possible (e.g., station moves, instrument changes). Efforts were made to avoid large cities where urban-induced climate changes could contaminate the record. As with the land-based records, extensive quality control analyses were performed on the ocean records. A 5° latitude by 10° longitude grid was established, and the station and ship data were then interpolated to the grid points. The most significant problems with the reliability of this global temperature record include the following:

1. Station relocations produce changes in exposure, elevation, and topography that can change the recorded temperature and create a discontinuity in the record.[14] If the station move is well-documented, some of the effects of the relocation can be statistically removed from the record. In addition to potential shifts in the station location, the time of observation may change from one observer to the next and the temperature record is altered. Also, the instruments themselves, along with the recommended exposure to the sun, have changed through time.

2. The marine air temperature measurements are also prone to similar problems through time. Possibly the most significant problem is that the ships of the world are getting larger, and the thermometers used to measure the air temperature are getting higher above the ocean surface. This change in height, along with other onboard changes, make the marine air temperature records difficult to adjust to some baseline level.

The urban heat island effect represents a major contaminant to many of the temperature records.

All of these problems influence the long-term temperature record, and despite every effort to remove or minimize their effect, the record remains contaminated with these uncertainties. In addition to these measurement problems, the geographic distribution of the stations and ship records creates yet another difficulty for the "global" temperature record. Some areas of the world are well sampled with the existing network, while other areas are virtually unmeasured. Some of these problems in the record will tend to cancel-out, but they absolutely increase the uncertainty in the 0.54°C trend of the past 113 years.

Contaminants to the Records

While each of the problems described above cannot be overlooked in the search for any greenhouse signal, the potential impact on the temperature record caused by the urban heat island effect represents a major contaminant to many of the temperature records. Recognizing that cities tend to warm their local environments, a number of scientists have attempted to explicitly quantify the urban heat island effect in the historical land-based temperature records of the globe.[15] A variety of schemes have been used in these analyses, and from this research, it would appear that the global temperature data set has a global urban warming bias somewhere between 0.01°C and 0.10°C per century, with the most likely value near 0.05°C.[16]

The urban effect creates a localized warming signal that is not representative of the surrounding area. Recently, it has been discovered that overgrazing and desertification may be producing a large-scale warming signal that is clearly not related to the greenhouse gases. The role of desertification in changing the regional temperature

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was strongly debated following a landmark article by Charney[17] who suggested that overgrazing in arid and semi-arid lands would increase the albedo (reflectivity) by removing the dark-colored vegetation. The increased albedo would reflect more of the sun's energy, less solar energy would be absorbed by the surface, and surface and air temperatures would drop. Soon after the introduction of the Charney hypothesis, Jackson and Idso[18] and others argued that removal of vegetation would reduce evapotranspiration rates, less solar energy would be consumed in evaporating and transpiring water, leaving more solar energy to warm the surface and the air. Most empirical data[19] and recent theoretical findings[20] support the notion that overgrazing and desertification would act to warm, not cool, the surface and air temperatures.

Highly accurate satellite-based global temperature measurements show no warming.

Because the overgrazing, resultant desertification, and landscape degradation occurs over decades, it is reasonable to expect a relative warming trend for the areas of the earth that have experienced substantial desertification. Warming signals have been found in the global temperature records that appear to be related to this non-greenhouse forcing; the desertification warming signal in the global temperature record, like the urban heat island effect, accounts for between 0.01·C and 0.10·C of the global warming trend of the past century.[21]

The Role of Volcanic Dust

We have seen an upward trend in the surface air temperature data, but in addition to the buildup of the greenhouse gases, many other phenomena could be causing the increase. There remains the strong possibility that some of the trend shown in Figure 2 could be explained by some external forcing of the climate system.

Many climatologists believe that volcanic dust in the stratosphere can act to cool the earth, particularly when the eruption emits large amounts of sulfur.[22] The resultant dust and sulfuric acid particles in the stratosphere may increase the reflection of incoming radiation and ultimately act to cool the planet. So the question remains—is some of the trend in the global temperatures of the past century related to volcanic dust in the stratosphere?

To answer this question, one needs to examine a long-term record of dust measurements in the stratosphere. Fortunately, a data set has been produced that can be used in this regard.[23] The statistical relation between the stratospheric dust index and global temperatures is relatively easy to establish and when the effect of stratospheric dust is removed from the global temperatures, fully 0.18·C of the total trend is eliminated. Nearly one-third of the global temperature trend of the past 113 years disappears when the stratospheric dust index is considered.

Effects of a Variable Sun

Obviously, the total energy output of the sun could play a major role in governing the planetary temperature. For many years, some scientists have argued strongly in favor of this mechanism as a primary control of planetary temperature[24] while others have rejected the idea that small variations in solar output can explain much of the trend of the past century.[25] Recently, two researchers have found that the length of the solar sunspot cycle is related strongly to the fluctuations in temperatures on the earth.[26] Although the physical mechanism responsible for the linkage remains elusive, it is noteworthy that over 75 percent of the observed global warming in this century can be statistically explained by the variations in the length of the solar sunspot cycle.

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Global Temperatures from Satellites

Satellite-based lower-tropospheric atmospheric temperature measurements are available for 2.5° latitude by 2.5° longitude grid cells on the monthly basis for the period 1979 to the present.[27] These temperature measurements are made by a passive microwave sensor system on the 53.74 GHz channel that detects thermal emission of molecular oxygen in the middle and lower troposphere. The measurement is not particularly affected by changes in water vapor, cloud variations, or changes at the surface. In addition, the temperature changes occurring in the stratosphere do not significantly affect the microwave data.[28] When averaged for the world as a whole, the resultant global temperature is accurate to within ±0.01°C at the monthly time scale.

The diurnal temperature range has declined significantly over the past half century in many locations around the world.

A plot of the satellite-based monthly temperatures from January 1979 to April 1994 is presented in Figure 3. These data reveal a statistically significant *cooling* of 0.13°C over the 184-month period! Despite all the talk about global warming during the 1980s, despite the buildup of greenhouse gases during the 1979 to 1994 time period, and despite the anticipated 0.3°C decade warming, the highly accurate satellite-based global temperature measurements not only show no warming, but they show very real cooling. The eruption of Mount Pinatubo in June 1991 undoubtedly contributed to this cooling pattern; however, Christy and McNider[30] controlled for such volcanic eruptions as well as El Niño/Southern Oscillation events, and they also found no warming in the satellite-based global temperature measurements.

Geography of the Warming

Based on the previous discussion, it should be clear that the amount of warming at the global scale over the past decade or century is not particularly supportive of the apocalyptic global warming projections. Although the regional predictions made by the models are typically viewed with considerable skepticism, it is noteworthy that all of the models predict the greatest warming to occur in the Arctic region of the Northern Hemisphere.[31] Given this prediction of warming in the high latitudes of the Northern Hemisphere, many scientists have attempted to determine the temperature trends in this part of the world.

Figure 4 presents updated Arctic-area annual near-surface air temperature anomalies over the past century. The amount of linear warming over the past century in the Arctic is 1.03°C, and at first glance, this warming in the Arctic would appear to be supportive of the projections from the models. However, over the most recent 50 years of the record, and during the time of the greatest greenhouse gas increase, Arctic temperatures have actually *cooled* by 0.88°C. Virtually all of the Arctic warming of this century occurred in and around the 1920s. Furthermore, the satellite-based temperature measurements show Arctic cooling of 0.21°C during the 1979 to 1993 period. Additionally, others found no warming over the past 40 years in near-surface air temperatures as measured from balloons launched daily throughout the Arctic.[34] The high latitudes of the Northern Hemisphere should be warming quickly according to the $2xCO_2$ model projections, and yet, the best regional datasets available show no warming, or even cooling, in this part of the earth.

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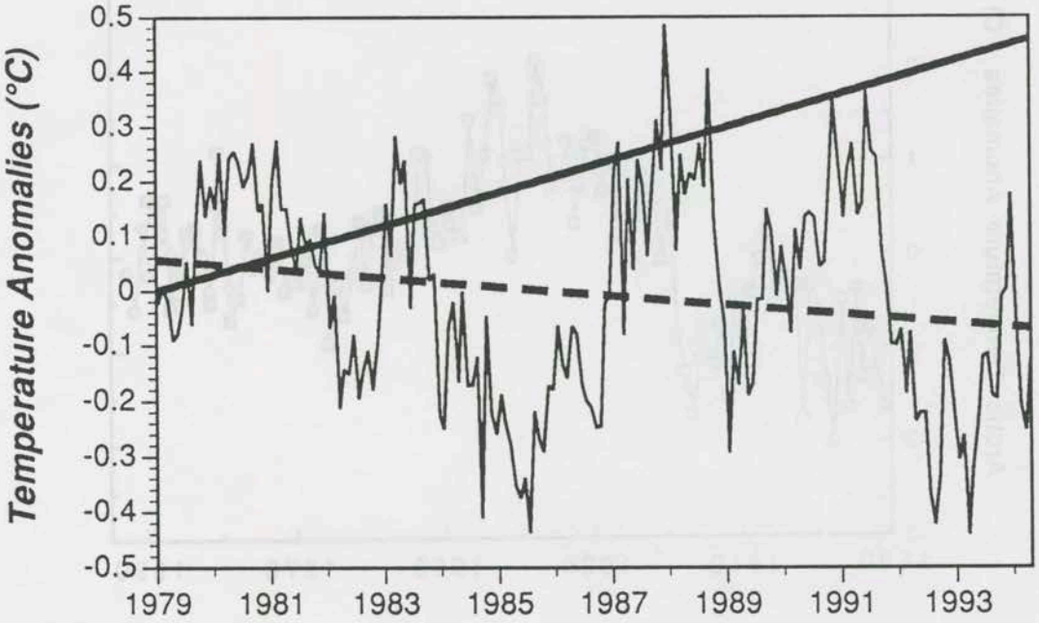
Figure 3.



Satellite-based monthly global temperatures for the period January, 1979 to April, 1994 (thin solid trace).[29] The thick dashed line shows the linear cooling observed during this time period while the thick solid line shows the 0.30°C decade^{-1} of expected greenhouse warming.

shows cooling
not used for that reason.
June 91 Nt Pinatubo eruption

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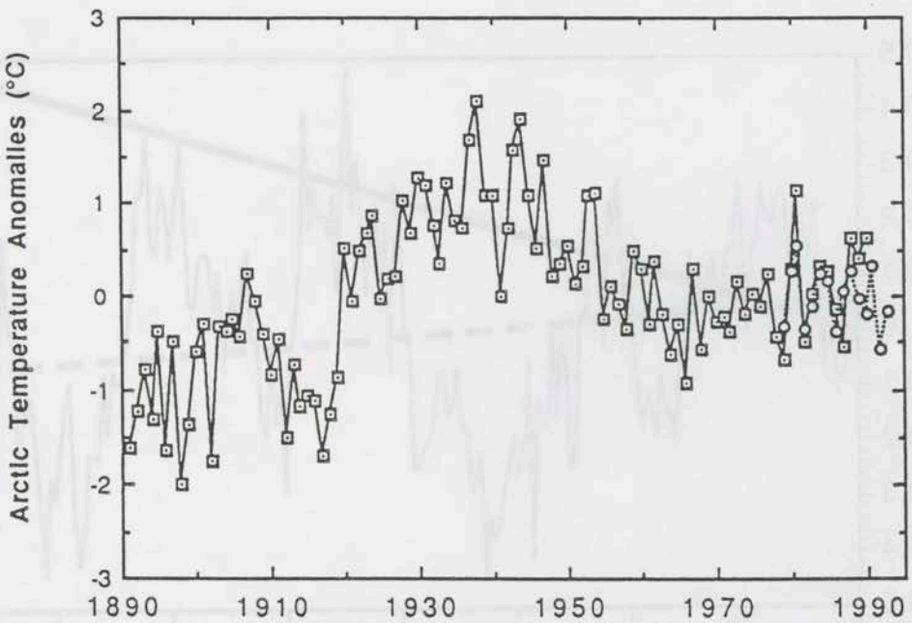
Figure 4.



Arctic-area annual near-surface air temperature anomalies for the period 1891 to 1990[32] and anomalies based on the satellite-based Arctic-area measurements[33] for the period 1979 to 1993.

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Day Verses Night Warming

Detailed studies of the climate record have uncovered a particularly interesting and important pattern in the temperature data — the diurnal temperature range (the difference between the daily maximum and minimum temperatures) has declined significantly over the past half century in many locations around the world.[35] The decline in the diurnal temperature range has been well documented in North America using a variety of datasets and analytical procedures.[36] Similar decreases in the diurnal temperature range have been identified in Europe, Australia, Asia, and Africa.[37] In contrast, no evidence is found for a decrease in the diurnal temperature range in New Zealand and surrounding islands[38] and an increase in the diurnal temperature range has occurred in India.[39] In order to explain the observed trends in the diurnal temperature range, investigators have proposed many interrelated mechanisms including changes in cloud cover, precipitation, snow cover, atmospheric sulfate levels, and greenhouse gas concentrations.

It is noteworthy that a decrease in the diurnal temperature range has been reported from several $2xCO_2$ numerical climate model experiments.[40] However, the Intergovernmental Panel on Climate Change (IPCC)[41] concluded that "There is no compelling evidence for a general reduction in the amplitude of the diurnal cycle." Several years later, IPCC[42] further concluded that although a decrease in diurnal temperature range was observed over 25 percent of the global land area, "the reasons for this change, which is largely a result of an increase in minimum temperatures, are not yet clear."

The timing of any temperature change (day versus night) is critical in assessing the impact of the change on other elements of the ecosystem.

As noted by Michaels and Stooksbury[43] among others, the trend in the diurnal temperature range is critical in determining the severity of the greenhouse threat. A lower diurnal temperature range would not allow daytime evaporation rates to climb, thereby generating the predicted increases in droughts, growing seasons would be longer, plants would experience less thermal stress, and polar melting would be reduced. In many respects, the decrease in the diurnal temperature range could be beneficial to a substantial portion of the global ecosystem. It should be clear that the timing of any temperature change (day verses night) is critical in assessing the impact of the change on other elements of the ecosystem.

Clouds and Precipitation

All of the discussion in the previous sections centered on temperature measurements compared against temperature predictions from the $2xCO_2$ numerical experiments. But just as all of the models are predicting an increase in temperature for the buildup of greenhouse gases, they also predict increases in cloud cover and precipitation across the globe. Not surprisingly, scientists have been assembling data on these variables and examining trends over the period of historical records.

The global precipitation index (available from the World Meteorological Organization) has been established for over 5,000 stations around the world. The index shows departures from the average based on a 1951 to 1970 "normal" period. As seen in Figure 5, the global precipitation index reveals an upward trend of 16.55 mm over the period 1882 to 1990. In the most broad terms, this general increase in precipitation is consistent with predictions from the $2xCO_2$ numerical climate experiments.

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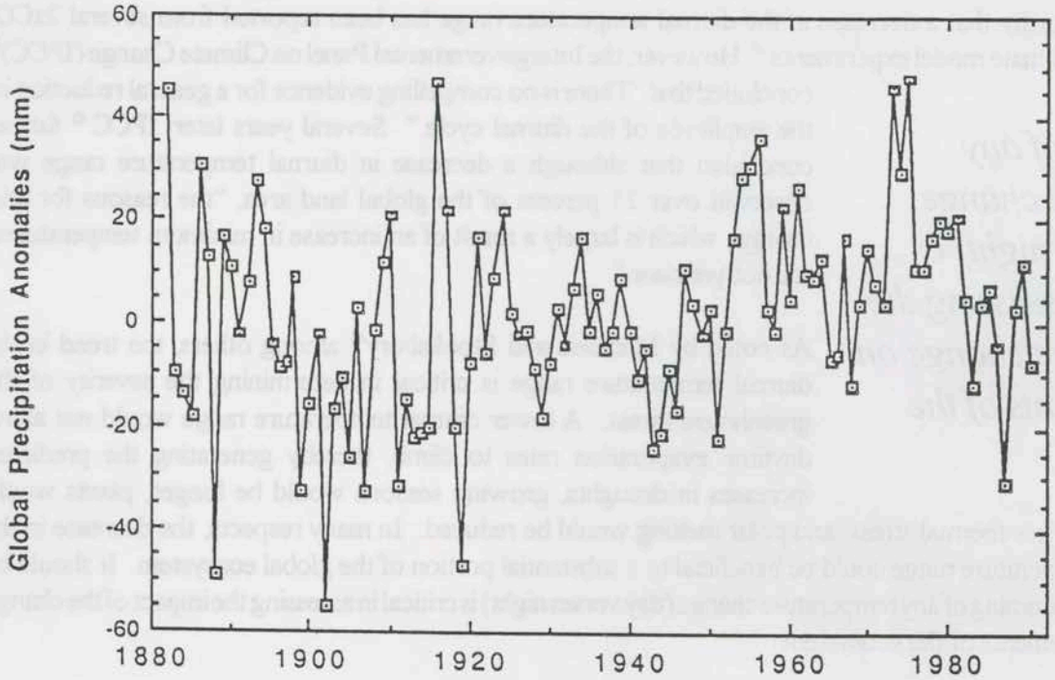
Figure 5.



Plot of global precipitation anomalies (mm) from 1882 to 1990; data are available from the World Meteorological Organization.

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Given the observed increase in precipitation, one would expect an increase in cloudiness over the past century, and in fact, such an increase has been observed. Results by many scientists suggest that global cloudiness has increased between 5 and 10 percent over the past century over land areas; data presented by others also show a total cloud cover increase over the oceans during the past 50 years.[44]

From a straight climatological perspective, the evidence suggests that realistic policies are likely to have a minimal climatic impact.

A Benign Greenhouse Effect?

What emerges from this discussion is a greenhouse effect of slightly higher temperatures, a reduction in the diurnal temperature range, and an increase in cloudiness and precipitation. This view of the greenhouse effect is consistent with the observational record of the past century and it is reasonably consistent with the model simulation studies, particularly when the climate effects of aerosol sulfates are included in the modeling experiments. However, this view of the greenhouse effect is not consistent with the popularized vision of a global warming catastrophe. Although we rarely hear about greenhouse benefits, it is clear that nighttime warming would lengthen growing seasons, and the lack of warming during the daytime would not force upward potential evaporation rates that could cause an increase in droughts. More clouds and more rain should generally increase soil moisture levels and alleviate moisture stress to plants. No one would argue that all greenhouse effects are bound to be beneficial, but in an environment of thinking only of greenhouse costs, potential benefits must be examined.

Stopping the Crisis?

As discussed earlier, global warming is almost always presented as an environmental crisis that can be stopped or minimized with appropriate policy actions. Policymakers can debate the impact and the cost-effectiveness of their policies forever, but from a straight climatological perspective, the evidence suggests that realistic policies are likely to have a minimal climatic impact.

For example, Figure 6 was derived directly from the 1990 Intergovernmental Panel on Climate Change (IPCC) report. The uppermost line represents the IPCC "Business-as-usual" trend in global temperature to the year 2100. According to that scenario, the earth will warm by approximately 4°C over the natural, background planetary temperature by the end of the next century. If that were to occur, many elements of the greenhouse disaster would become reality. If we adopt IPCC "Scenario B" scenario, which includes (a) moving to lower carbon-based fuels, (b) achieving large efficiency increases, (c) controlling carbon monoxide, (d) reversing deforestation, and (e) implementing the Montreal Protocol (dealing with chlorofluorocarbon controls) with full participation, the IPCC projects that the earth would warm according to the line at the bottom of the cross-hatched area. The earth stills warms by nearly 3°C of warming if we adopt the suggested policy. The IPCC "Scenario B" policy spares the earth very little warming (the cross-hatched area) over the entire century; by the year 2050, the policies of this IPCC scenario have spared the earth only 0.3°C of warming. These policies do not stop global warming at all. Indeed, they barely even slow it.

The evidence argues that there is no need for urgent action.

Furthermore, the climatic impact of any policy is directly dependent on the amount of warming predicted over the next century. Figure 6 also shows the impact of the IPCC scenario assuming a business-as-usual 1°C

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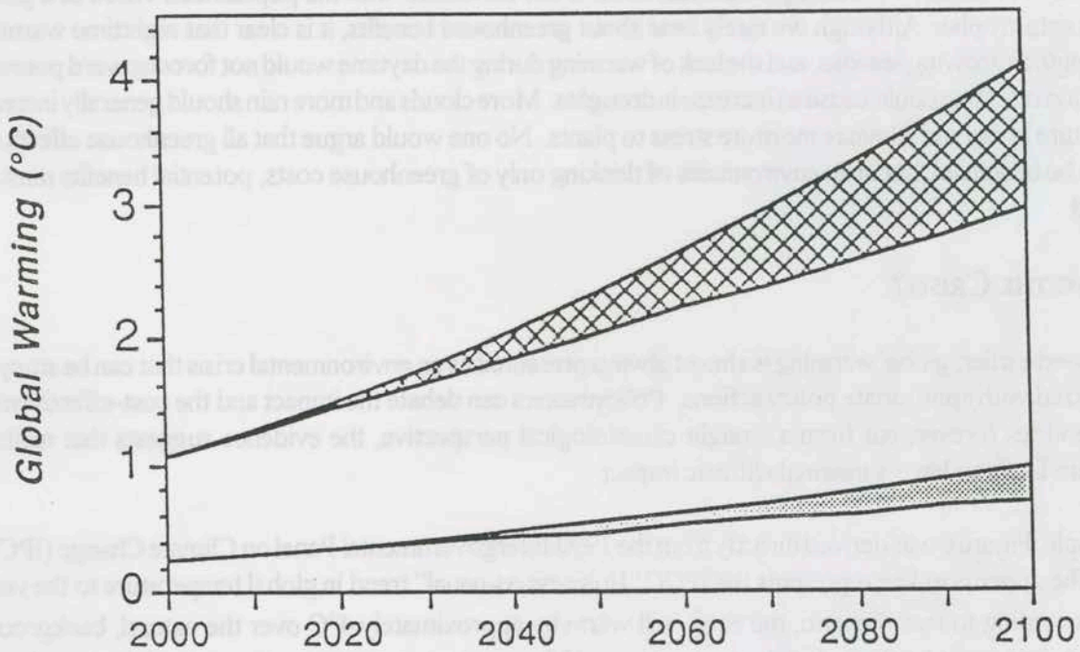
Figure 6.



IPCC "Business-as-usual" projected warming (upper boundary of cross-hatched area) and IPCC "Scenario B" projected warming (lower boundary of cross-hatched area) for the coming century.[45] The lower set of lines (defining the stippled area) are the proportionally reduced "Business-as-usual" and "Scenario B" estimates.

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temperature increase (this would be much more consistent with the historical record). As seen at the bottom section of that figure, the IPCC "Scenario B" policies spare the planet less than 0.3 °C by the year 2100, and by 2050, they would have spared the earth something near 0.07°C. As scientists lower their estimate of temperature rise for the next century, they also reduce the potential climate impact of any corrective policies. In a very recent and important study, scientists[46] performed a numerical modeling study and concluded that it will take 70 to 100 years to detect any climatic difference between the business-as-usual scenario and the most draconian scenario proposed by the IPCC.

Must We Act Now?

Despite all the material presented to this point, many scientists and policymakers continue to argue that we must act immediately to avoid a greenhouse disaster. Waiting is simply seen as too dangerous given the threat. Fortunately, several scientists have seriously evaluated the climate difference between acting immediately and waiting a decade or more to implement selected policies. Schlesinger and Jiang[47] used a numerical model to simulate the impact of realistic policies hypothetically adopted in 1990, and they calculated the global temperature for the middle of the next century. They then simulated the impact of waiting a decade to implement the same policies, and they found that the temperature of the earth by the middle of the next century was not affected by the delay. Their results obviously generated a tremendous debate in the scientific and policy arenas, but fundamentally, their results continue to support the unpopular view that we simply do not need to rush into policy regarding the greenhouse issue.

It is absolutely imperative that the policies developed for the global warming issue be built on the best science available.

Nonetheless, many nations seem impatient with the progress made on meeting the many commitments signed at the 1990 Earth Summit in Rio de Janeiro. Accordingly, some nations, including the United States, may be pressured into adopting stronger measures to control greenhouse gas emissions. These measures may increase the costs to the nation, but they seem doomed to failure. As described above, the evidence argues that there is no need for urgent action, and the suggested measures will probably have only a trivial effect on the global greenhouse gas concentrations.

Concluding Remarks

From the viewpoint of a scientist, it is obvious that the greenhouse debate will be with us for many years to come. The climate models are getting better all the time, and their predictions for a doubling of atmospheric CO_2 will continue to capture the interest of a significant number of climatologists. As the climate effects of other gases are included in the model simulations (e.g., sulfur dioxide), the projected temperature rise will likely be lowered, and the threat of global warming will weaken further. Equally important, climate data bases on a variety of variables will continue to be expanded in both time and space. As I have attempted to demonstrate, the state-of-the-art satellite-based planetary temperature measurements continue to show no warming at all. As the satellite database grows, I suspect global warming will be even more difficulat to prove on empirical grounds. Within the coming decades of better models and better climate databases, there is little doubt that the scientists will develop an even better understanding of how the climate system will respond to future changes in atmospheric chemistry.

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It seems equally obvious that the greenhouse issue will continue to be a major force in the policy arena. Government agencies from the United Nations to the regional scale have developed to deal with the policy concerns raised by the greenhouse issue. Many of these government groups have expanded in recent years, and the very fate of these agencies is tied to the perception that global warming represents a significant threat to the planet. The bureaucratic inertia virtually guarantees that the greenhouse question will remain high on the list of environmental policy priorities. Despite the evidence reviewed in this chapter, the upcoming versions of the various IPCC reports will continue to trumpet the threat of global warming. Press releases will probably emphasize the risks of the greenhouse effect and make little mention of potential benefits of the greenhouse world.

I have become increasingly concerned that a wide gap has opened between many of the policy-oriented groups and the science-oriented groups. Too often, policymakers appear to neglect the enormous evidence that argues against the greenhouse disaster, and freely accept and promote the scientific evidence in favor of the crisis. It is absolutely imperative that the policies developed for the global warming issue be built on the best science available, and not on the extreme viewpoints that seem to satisfy and justify the policymakers. In my opinion, the scientific evidence argues against the existence of a greenhouse crisis, against the notion that realistic policies could achieve any meaningful climatic impact, and against the claim that we must act now if we are to reduce the greenhouse threat.

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About the Author

Dr. Robert C. Balling, Jr. is director of the Office of Climatology and associate professor of geography at Arizona State University. He is the author of *The Heated Debate: Greenhouse Predictions Versus Climate Reality* (Pacific Research Institute, 1992) and co-author (with Martin Williams) of *Interactions of Desertification and Climate* (UNEP/WMO, forthcoming). An active participant in the greenhouse debate, Dr. Balling has published over 70 articles in the professional scientific literature. Dr. Balling is presently serving as a climate consultant to the United Nations, the World Meteorological Organization, and the Intergovernmental Panel on Climate Change. He received an M.A. from Bowling Green State University and a Ph.D. from the University of Oklahoma.

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