ICEBERG BREAKS OFF the San Rafael Glacier in Chile. Global disintegration of ice masses has the potential to raise sea level by several meters or more. The grim consequences of a rising sea level set a low threshold for how much the planet can warm without disrupting human society.

Global warming is real, and

Nevertheless, practical actions, which

Defusing the Global Warming TIME BOMB

BY JAMES HANSEN

the consequences are potentially disastrous.

would also yield a cleaner, healthier atmosphere, could slow, and eventually stop, the process

A paradox in the notion of human-made global warming became strikingly apparent to me one summer afternoon in 1976 on Jones Beach, Long Island. Arriving at midday, my wife, son and I found a spot near the water to avoid the scorching hot sand. As the sun sank in the late afternoon, a brisk wind from the ocean whipped up whitecaps. My son and I had goose bumps as we ran along the foamy shoreline and watched the churning waves.

That same summer Andy Lacis and I, along with other colleagues at the NASA Goddard Institute for Space Studies, had estimated the effects of greenhouse gases on climate. It was well known by then that human-made greenhouse gases, especially carbon dioxide and chlorofluorocarbons (CFCs), were accumulating in the atmosphere. These gases are a climate "forcing," a perturbation imposed on the energy budget of the planet. Like a blanket, they absorb infrared (heat) radiation that would otherwise escape from the earth's surface and atmosphere to space.

Our group had calculated that these human-made gases were heating the earth's surface at a rate of almost two watts per square meter. A miniature Christmas tree bulb dissipates about one watt, mostly in the form of heat. So it was as if humans had placed two of these tiny bulbs over every square meter of the earth's surface, burning night and day.

The paradox that this result presented was the contrast between the awesome forces of nature and the tiny lightbulbs. Surely their feeble heating could not command the wind and waves or smooth our goose bumps. Even their imperceptible heating of the ocean surface must be quickly dissipated to great depths, so it must take many years, perhaps centuries, for the ultimate surface warming to be achieved.

This seeming paradox has now been largely resolved through study of the history of the earth's climate, which reveals that small forces, maintained long enough, can cause large climate change. And, consistent with the historical evidence, the earth has begun to warm in recent decades at a rate predicted by climate models that take account of the atmospheric accumulation of human-made greenhouse gases. The warming is having noticeable impacts as glaciers are retreating worldwide, Arctic sea ice has thinned, and spring comes about one week earlier than when I grew up in the 1950s.

Yet many issues remain unresolved. How much will climate change in coming decades? What will be the practical consequences? What, if anything, should we do about it? The debate over these questions is highly charged because of the inherent economic stakes.

Objective analysis of global warming requires quantitative knowledge of three issues: the sensitivity of the climate system to forcings, the forcings that humans are introducing, and the time required for climate to respond. All these issues can be studied with global climate models, which are numerical simulations on computers. But our most accurate knowledge about climate sensitivity, at least so far, is based on empirical data from the earth's history.

Overview/*Global Warming*

- At present, our most accurate knowledge about climate sensitivity is based on data from the earth's history, and this evidence reveals that small forces, maintained long enough, can cause large climate change.
- Human-made forces, especially greenhouse gases, soot and other small particles, now exceed natural forces, and the world has begun to warm at a rate predicted by climate models.
- The stability of the great ice sheets on Greenland and Antarctica and the need to preserve global coastlines set a low limit on the global warming that will constitute "dangerous anthropogenic interference" with climate.
- Halting global warming requires urgent, unprecedented international cooperation, but the needed actions are feasible and have additional benefits for human health, agriculture and the environment.

The Lessons of History

OVER THE PAST few million years the earth's climate has swung repeatedly between ice ages and warm interglacial periods. A 400,000-year record of temperature is preserved in the Antarctic ice sheet, which, except for coastal fringes, escaped melting even in the warmest interglacial periods. This record [*see box on opposite page*] suggests that the present interglacial period (the Holocene), now about 12,000 years old, is already long of tooth.

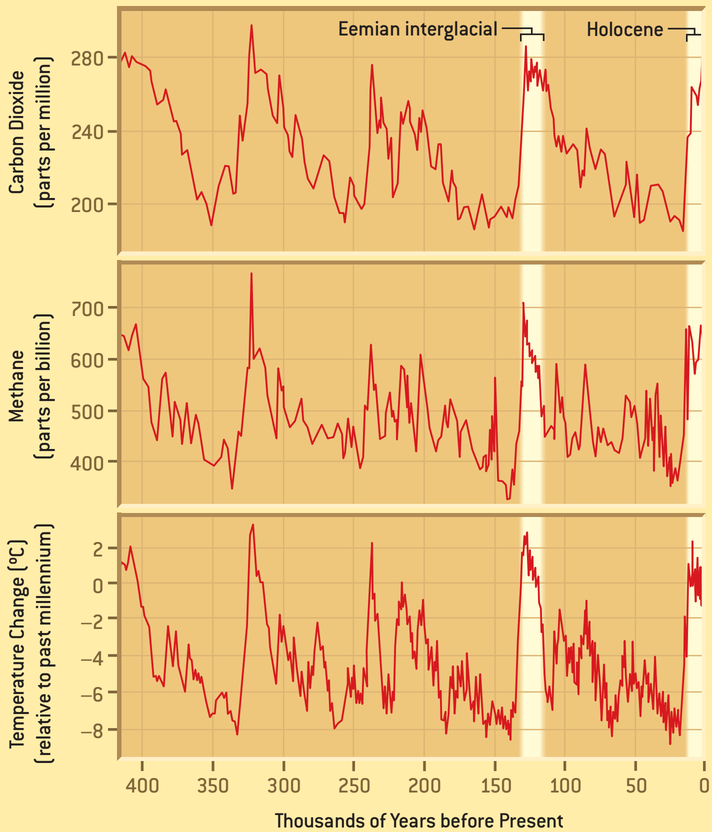
The natural millennial climate swings are associated with slow variations of the earth's orbit induced by the gravity of other planets, mainly Jupiter and Saturn (because they are so heavy) and Venus (because it comes so close). These perturbations hardly affect the annual mean solar energy striking the earth, but they alter the geographical and seasonal distribution of incoming solar energy, or insolation, as much as 20 percent. The insolation changes, over long periods, affect the building and melting of ice sheets.

Insolation and climate changes also affect uptake and release of carbon dioxide and methane by plants, soil and the ocean. Climatologists are still developing a quantitative understanding of the mechanisms by which the ocean and land release carbon dioxide and methane as the earth warms, but the paleoclimate data are already a gold mine of information. The most critical insight that the ice age climate swings provide is an empirical measure of climate sensitivity.

The composition of the ice age atmosphere is known precisely from air bubbles trapped as the Antarctic and Greenland ice sheets and numerous mountain glaciers built up from annual snowfall. Furthermore, the geographical distributions of the ice sheets, vegetation cover and coastlines during the ice age are well mapped. From these data we know that the change of

RIC ERGENBRIGHT *Corbis* (*preceding pages*)

400,000 YEARS OF CLIMATE CHANGE



ANTARCTIC ICE has preserved a 400,000-year record of temperature and of levels of carbon dioxide and methane in the atmosphere. Scientists study gases trapped in air bubbles in the ice—generally using ice cores (*photograph*) extracted from the ice sheet and transported to a laboratory. The historical record provides us with two critical measures: Comparison of the current interglacial period (the Holocene) with the most recent ice age (20,000 years ago) gives an accurate measure of climate sensitivity to forcings. The temperature in the previous interglacial period (the Eemian), when sea level was several meters higher than today, defines an estimate of the warming that today's civilization would consider to be dangerous anthropogenic interference with climate.

JEN CHRISTIANSEN; SOURCE: J. R. PETIT ET AL. IN *NATURE*, VOL. 399, PAGES 429–436; JUNE 3, 1999 (*graphs*); CSIRO/SIMON FRASER *Photo Researchers, Inc.* (*photograph*)

climate forcing between the ice age and today was about 6.5 watts per square meter. This forcing maintains a global temperature change of 5 degrees Celsius (9 degrees Fahrenheit), implying a climate sensitivity of 0.75 ± 0.25 degrees C per watt per square meter. Climate models yield a similar climate sensitivity. The empirical result is more precise and reliable, however, because it includes all the processes operating in the real world, even those we have not yet been smart enough to include in the models.

The paleodata provide another important insight. Changes of the earth's orbit instigate climate change, but they operate by altering atmosphere and surface properties and thus the planetary energy balance. These atmosphere and surface properties are now influenced more by humans than by our planet's orbital variations.

Climate-Forcing Agents Today

THE LARGEST change of climate forcings in recent centuries is caused by human-made greenhouse gases. Greenhouse gases in the atmosphere absorb heat radiation rather than letting it escape into space. In effect, they make the proverbial blanket thicker, returning more heat toward the ground rather than letting it escape to space. The earth then is radiating less energy to space than it absorbs from the sun. This temporary planetary energy imbalance results in the earth's gradual warming.

Because of the large capacity of the oceans to absorb heat, it takes the earth about a century to approach a new balance—that is, for it to once again receive the same amount of energy from the sun that it radiates to space. And of course the balance is reset at a higher temperature. In the meantime, before it achieves this equilibrium, more forcings may be added.

The single most important human-made greenhouse gas is carbon dioxide, which comes mainly from burning fossil fuels (coal, oil and gas). Yet the combined effect of the other human-made gases is comparable. These other gases, especially tropospheric ozone and its precursors, including methane, are ingredients in smog that damage human health and agricultural productivity.

Aerosols (fine particles in the air) are the other main human-made climate forcing. Their effect is more complex. Some "white" aerosols, such as sulfates arising from sulfur in fossil fuels, are highly reflective and thus reduce solar heating of the earth; however, black carbon (soot), a product of incomplete combustion of fossil fuels, biofuels and outdoor biomass burning, absorbs sunlight and thus heats the atmosphere. This aerosol direct climate forcing is uncertain by at least 50 percent, in part because aerosol amounts are not well measured and in part because of their complexity.

small forces, maintained long enough, can cause large climate change

Aerosols also cause an indirect climate forcing by altering the properties of clouds. The resulting brighter, longer-lived clouds reduce the amount of sunlight absorbed by the earth, so the indirect effect of aerosols is a negative forcing that causes cooling.

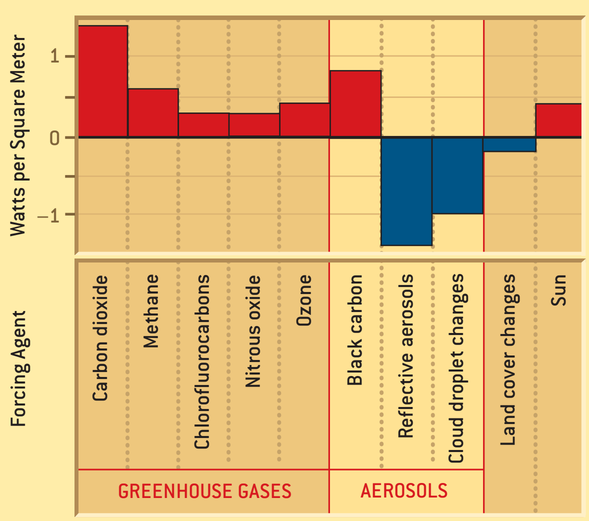
Other human-made climate forcings include replacement of forests by cropland. Forests are dark even with snow on the ground, so their removal reduces solar heating.

Natural forcings, such as volcanic eruptions and fluctuations of the sun's brightness, probably have little trend on a timescale of 1,000 years. But evidence of a small solar brightening over the past 150 years implies a climate forcing of a few tenths of a watt per square meter.

The net value of the forcings added since 1850 is 1.6 ± 1.0 watts per square meter. Despite the large uncertainties, there is evidence that this estimated net forcing is approximately correct. One piece of evidence is the close agreement of observed global temperature during the past several decades with climate models driven by these forcings. More fundamentally, the observed heat gain by the world ocean in the past 50 years is consistent with the estimated net climate forcing.

CLIMATE FORCINGS

A CLIMATE FORCING is a mechanism that alters the global energy balance. A forcing can be natural—fluctuations in the earth's orbit, for example—or human-made, such as aerosols and greenhouse gases. Human-made climate forcings now dominate natural forcings. Carbon dioxide is the largest forcing, but air pollutants (black carbon, ozone, methane) together are comparable. (Aerosol effects are not known accurately.)



Global Warming

GLOBAL AVERAGE surface temperature has increased about 0.75 degree C during the period of extensive instrumental measurements, which began in the late 1800s. Most of the warming, about 0.5 degree C, occurred after 1950. The causes of observed warming can be investigated best for the past 50 years, because most climate forcings were observed then, especially since satellite measurements of the sun, stratospheric aerosols and ozone began in the 1970s. Furthermore, 70 percent of the anthropogenic increase of greenhouse gases occurred after 1950.

The most important quantity is the planetary energy imbalance [*see box on page 75*]. This imbalance is a consequence of the long time that it takes the ocean to warm. We conclude that the earth is now out of balance by something between 0.5 and one watt per square meter—that much more solar radiation is being absorbed by the earth than is being emitted as heat to space. Even if atmospheric composition does not change further, the earth's surface will therefore eventually warm another 0.4 to 0.7 degree C.

Most of the energy imbalance has been heat going into the ocean. Sydney Levitus of the National Oceanic and Atmospheric Administration has analyzed ocean temperature changes of the past 50 years, finding that the world ocean heat content increased about 10 watt-years per square meter in the past 50 years. He also finds that the rate of ocean heat storage in recent years is consistent with our estimate that the earth is now out of energy balance by 0.5 to one watt per square meter. Note that the amount of heat required to melt enough ice to raise sea level one meter is about 12 watt-years (averaged over the planet), energy that could be accumulated in 12 years if the planet is out of balance by one watt per square meter.

The agreement with observations, for both the modeled temperature change and ocean heat storage, leaves no doubt that observed global climate change is being driven by natural and anthropogenic forcings. The current rate of ocean heat storage is a critical planetary metric: it not only determines the amount of additional global warming already in the pipeline, but it also equals the reduction in climate forcings needed to stabilize the earth's present climate.

The Time Bomb

THE GOAL OF the United Nations Framework Convention on Climate Change, produced in Rio de Janeiro in 1989, is to stabilize atmospheric composition to "prevent dangerous anthropogenic interference with the climate system" and to

JEN CHRISTIANSEN; SOURCE: JAMES HANSEN

HUMAN-MADE climate forcings, mainly greenhouse gases, heat the earth's surface at a rate of about two watts per square meter—the equivalent of two tiny one-watt bulbs burning over every square meter of the planet. The full effect of the warming is slowed by the ocean, because it can absorb so much heat. The ocean's surface begins to warm, but before it can heat up much, the surface water is mixed down and replaced by colder water from below. Scientists now think it takes about a century for the ocean to approach its new temperature.

RANDY HARRIS

achieve that goal in ways that do not disrupt the global economy. Defining the level of warming that constitutes "dangerous anthropogenic interference" is thus a crucial but difficult part of the problem.

The U.N. established an Intergovernmental Panel on Climate Change (IPCC) with responsibility for analysis of global warming. The IPCC has defined climate-forcing scenarios, used these for simulations of 21st-century climate, and estimated the impact of temperature and precipitation changes on agriculture, natural ecosystems, wildlife and other matters. The IPCC estimates sea-level change as large as several tens of centimeters in 100 years, if global warming reaches several degrees Celsius. The group's calculated sea-level change is due mainly to thermal expansion of ocean water, with little change in ice-sheet volume.

These moderate climate effects, even with rapidly increasing greenhouse gases, leave the impression that we are not close to dangerous anthropogenic interference. I will argue, however, that we are much closer than is generally realized, and thus the emphasis should be on mitigating the changes rather than just adapting to them.

The dominant issue in global warming, in my opinion, is sea-level change and the question of how fast ice sheets can disintegrate. A large portion of the world's people live within a few meters of sea level, with trillions of dollars of infrastructure. The need to preserve global coastlines sets a low ceiling on the level of global warming that would constitute dangerous anthropogenic interference.

The history of the earth and the present human-made planetary energy imbalance together paint a disturbing picture about prospects for sea-level change. Data from the Antarctic temperature record show that the warming of the past 50 years has taken global temperature back to approximately the peak of the current interglacial (the Holocene). There is some additional warming in the pipeline that will take us about halfway to the highest global temperature level of the previous interglacial (the Eemian), which was warmer than the Holocene, with sea level estimated to have been five to six meters higher. One additional watt per square meter of forcing, over and above that today, will take global temperature approximately to the maximum level of the Eemian.

The main issue is: How fast will ice sheets respond to global warming? The IPCC calculates only a slight change in the ice sheets in 100 years; however, the IPCC calculations include only the gradual effects of changes in snowfall, evaporation and melting. In the real world, ice-sheet disintegration is driven by highly nonlinear processes and feedbacks. The peak rate of deglaciation following the last ice age was a sustained rate of melting of more than 14,000 cubic kilometers a year—about one meter of sea-level rise every 20 years, which was maintained for several centuries. This period of most rapid melt coincided, as well

THE AUTHOR

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ON A SLIPPERY SLOPE to disaster, a stream of snowmelt cascades down a moulin on the Greenland ice sheet during a recent summer. The moulin, a near-vertical shaft worn in the ice by surface water, carries water to the base of the ice sheet. There the water is a lubricating fluid that speeds motion and disintegration of the ice sheet. Ice sheet growth is a slow, dry process, inherently limited by the snowfall rate, but disintegration is a wet process, driven by positive feedbacks, and once well under way it can be explosively rapid.

as can be measured, with the time of most rapid warming.

Given the present unusual global warming rate on an already warm planet, we can anticipate that areas with summer melt and rain will expand over larger areas of Greenland and fringes of Antarctica. Rising sea level itself tends to lift marine ice shelves that buttress land ice, unhinging them from anchor points. As ice shelves break up, this accelerates movement of land ice to the ocean. Although building of glaciers is slow, once an ice sheet begins to collapse, its demise can be spectacularly rapid.

The human-induced planetary energy imbalance provides an ample supply of energy for melting ice. Furthermore, this energy source is supplemented by increased absorption of sunlight by ice sheets darkened by black-carbon aerosols, and the positive feedback process as meltwater darkens the ice surface.

These considerations do not mean that we should expect large sea-level change in the next few years. Preconditioning of ice sheets for accelerated breakup may require a long time, perhaps many centuries. (The satellite ICESat, recently launched by NASA, may be able to detect early signs of accelerating ice-sheet breakup.) Yet I suspect that significant sea-level rise could begin much sooner if the planetary energy imbalance continues

we are much closer to dangerous anthropogenic interference than is generally realized

to increase. It seems clear that global warming beyond some limit will make a large sea-level change inevitable for future generations. And once large-scale ice-sheet breakup is under way, it will be impractical to stop. Dikes may protect limited regions, such as Manhattan and the Netherlands, but most of the global coastlines will be inundated.

I argue that the level of dangerous anthropogenic influence is likely to be set by the global temperature and planetary radiation imbalance at which substantial deglaciation becomes practically impossible to avoid. Based on the paleoclimate evidence, I suggest that the highest prudent level of additional global warming is not more than about one degree C. This means that additional climate forcing should not exceed about one watt per square meter.

Climate-Forcing Scenarios

THE IPCC defines many climate-forcing scenarios for the 21st century based on multifarious "story lines" for population growth, economic development and energy sources. It estimates that added climate forcing in the next 50 years is one to three watts per square meter for carbon dioxide and two to four watts per square meter with other gases and aerosols included. Even the IPCC's minimum added forcing would cause dangerous anthropogenic interference with the climate system based on our criterion.

The IPCC scenarios may be unduly pessimistic, however. First, they ignore changes in emissions, some already under way, because of concerns about global warming. Second, they assume that true air pollution will continue to get worse, with ozone, methane and black carbon all greater in 2050 than in 2000. Third, they give short shrift to technology advances that can reduce emissions in the next 50 years.

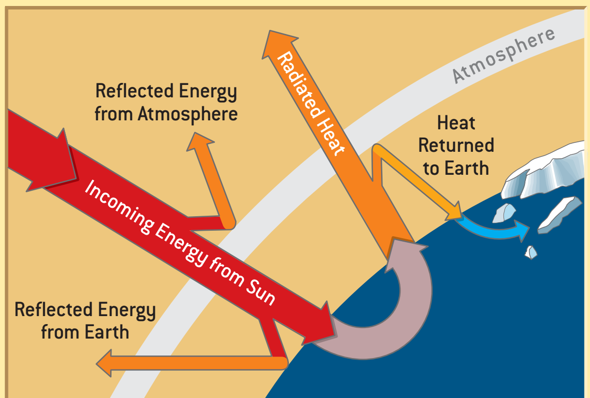
An alternative way to define scenarios is to examine current trends of climate-forcing agents, to ask why they are changing as observed, and to try to understand whether reasonable actions could encourage further changes in the growth rates.

The growth rate of the greenhouse-gas climate forcing peaked in the early 1980s at almost 0.5 watt per square meter per decade but declined by the 1990s to about 0.3 watt per square meter per decade. The primary reason for the decline was reduced emissions of chlorofluorocarbons, whose production was phased out because of their destructive effect on stratospheric ozone.

The two most important greenhouse gases, with chlorofluorocarbons on the decline, are carbon dioxide and methane. The growth rate of carbon dioxide surged after World War II, flattened out from the mid-1970s to the mid-1990s, and rose moderately in recent years to the current growth rate of about two parts per million per year. The methane growth rate has declined dramatically in the past 20 years, by at least two thirds.

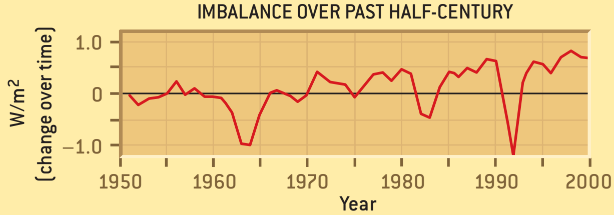
EARTH'S ENERGY IMBALANCE

THE EARTH'S ENERGY is balanced when the outgoing heat from the earth equals the incoming energy from the sun. At present the energy budget is not balanced (*diagram* and *table*). Human-made aerosols have increased reflection of sunlight by the earth, but this reflection is more than offset by the trapping of heat radiation by greenhouse gases. The excess energy—about one watt per square meter—warms the ocean and melts ice. The simulated planetary energy imbalance (*graph*) is confirmed by measurements of heat stored in the oceans. The planetary energy imbalance is a critical metric, in that it measures the net climate forcing and foretells future global warming already in the pipeline.



TOTAL INCOMING SOLAR ENERGY	340 W/m²
TOTAL OUTGOING ENERGY	339 W/m²
REFLECTED ENERGY (from atmosphere and surface) 100 W/m² because of natural processes 1 W/m² because of human-made aerosols	101 W/m²
RADIATED HEAT (from land and ocean sinks) 240 W/m² because of natural processes –2 W/m² because of human-made greenhouse gases, which return heat to the surface	238 W/m²
NET RESULT	1 W/m²
1 W/m² of excess energy, which warms the oceans and melts glaciers and ice sheets	

IMBALANCE OVER PAST HALF-CENTURY



JEN CHRISTIANSEN; SOURCE: JAMES HANSEN

the emphasis should be on mitigating the changes rather than just adapting to them

These growth rates are related to the rate of global fossil-fuel use. Fossil-fuel emissions increased by more than 4 percent a year from the end of World War II until 1975 but subsequently by only about 1 percent a year. The change in fossil-fuel growth rate occurred after the oil embargo and price increases of the 1970s, with subsequent emphasis on energy efficiency. Methane growth has also been affected by other factors, including changes in rice farming and increased efforts to capture methane at landfills and in mining operations.

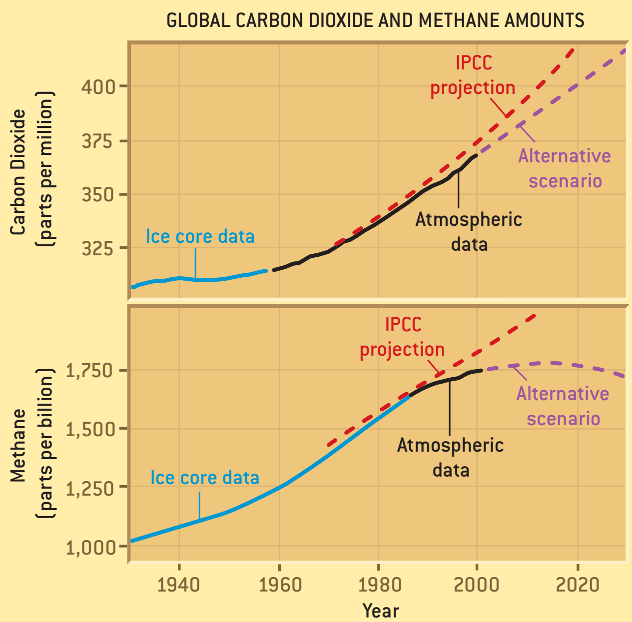
If recent growth rates of these greenhouse gases continued, the added climate forcing in the next 50 years would be about 1.5 watts per square meter. To this must be added the change caused by other forcings, such as atmospheric ozone and aerosols. These forcings are not well monitored globally, but it is known that they are increasing in some countries while decreasing in others. Their net effect should be small, but it could add as much as 0.5 watt per square meter. Thus, if there is no slowing of emission rates, the human-made climate forcing could increase by two watts per square meter in the next 50 years.

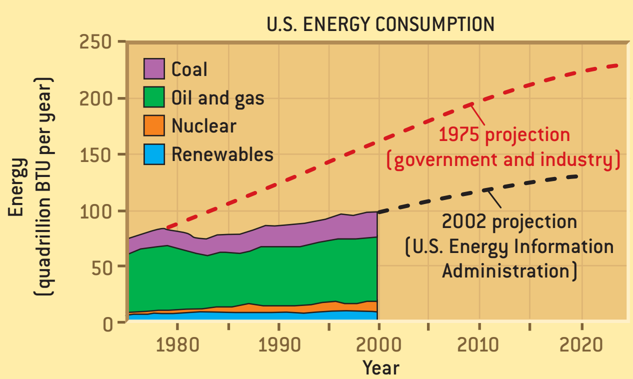
This "current trends" growth rate of climate forcings is at the low end of the IPCC range of two to four watts per square meter. The IPCC four watts per square meter scenario requires 4 percent a year exponential growth of carbon dioxide emissions maintained for 50 years and large growth of air pollution; it is implausible.

Nevertheless, the "current trends" scenario is larger than the one watt per square meter level that I suggested as our current best estimate for the level of dangerous anthropogenic in-

REDUCING EMISSIONS

OBSERVED AMOUNTS of carbon dioxide and methane (*top two graphs*) fall below IPCC estimates, which have proved consistently pessimistic. Although the author's alternative scenario agrees better with observations, continuation on that path requires a gradual slowdown in carbon dioxide and methane emissions. Improvements in energy efficiency (*bottom graph*) have allowed energy use in the U.S. to fall below projections in recent decades, but more rapid efficiency gains are needed to achieve the carbon dioxide emissions of the alternative scenario, unless nuclear power and renewable energies grow substantially.





JEN CHRISTIANSEN; SOURCE: JAMES HANSEN (*graphs*); MARK BOULTON *Photo Researchers, Inc.* (*photograph*) fluence. This raises the question of whether there is a feasible scenario with still lower climate forcing.

A Brighter Future

I HAVE DEVELOPED a specific alternative scenario that keeps added climate forcing in the next 50 years at about one watt per square meter. It has two components: first, halt or reverse growth of air pollutants, specifically soot, atmospheric ozone and methane; second, keep average fossil-fuel carbon dioxide emissions in the next 50 years about the same as today. The carbon dioxide and non–carbon dioxide portions of the scenario are equally important. I argue that they are feasible and at the same time protect human health and increase agricultural productivity.

In addressing air pollution, we should emphasize the constituents that contribute most to global warming. Methane offers a great opportunity. If human sources of methane are reduced, it may even be possible to get the atmospheric methane amount to decline, thus providing a cooling that would partially offset the carbon dioxide increase. Reductions of black-carbon aerosols would help counter the warming effect of reductions in sulfate aerosols. Atmospheric ozone precursors, besides methane, especially nitrogen oxides and volatile organic compounds, must be reduced to decrease low-level atmospheric ozone, the prime component of smog.

Actions needed to reduce methane, such as methane capture at landfills and at waste management facilities and during the mining of fossil fuels, have economic benefits that partially offset the costs. In some cases, methane's value as a fuel entirely pays for the cost of capture. Reducing black carbon would also have economic benefits, both in the decreased loss of life and work-years (minuscule soot particles carry toxic organic compounds and metals deep into lungs) and in increased agricultural productivity in certain parts of the world. Prime sources of black carbon are diesel fuels and biofuels (wood and cow dung, for example). These sources need to be dealt with for health reasons. Diesel could be burned more cleanly with improved technologies; however, there may be even better solutions, such as hydrogen fuel, which would eliminate ozone precursors as well as soot.

Improved energy efficiency and increased use of renewable energies might level carbon dioxide emissions in the near term. Long-term reduction of carbon dioxide emissions is a greater challenge, as energy use will continue to rise. Progress is needed across the board: continued efficiency improvements, more renewable energy, and new technologies that produce little or no carbon dioxide or that capture and sequester it. Next-generation nuclear power, if acceptable to the public, could be an important contributor. There may be new technologies before 2050 that we have not imagined.

Observed global carbon dioxide and methane trends [*see box on opposite page*] for the past several years show that the real world is falling below all IPCC scenarios. It remains to be proved whether the smaller observed growth rates are a fluke, soon to return to IPCC rates, or are a meaningful difference. In contrast, the projections of my alternative scenario and the observed growth rates are in agreement. This is not surprising, because that scenario was defined with observations in mind. And in the three years since the alternative scenario was defined, observations have continued on that path. I am not suggesting, however, that the alternative scenario can be achieved without concerted efforts to reduce anthropogenic climate forcings.

How can I be optimistic if climate is closer to the level of dangerous anthropogenic interference than has been realized? If we compare the situation today with that 10 to 15 years ago, we note that the main elements required to halt climate change have come into being with remarkable rapidity. I realize that it will not be easy to stabilize greenhouse-gas concentrations, but I am optimistic because I expect that empirical evidence for climate change and its impacts will continue to accumulate and that this will influence the public, public-interest groups, industry and governments at various levels. The question is: Will we act soon enough? SA

For an expanded version of this article, including more data and additional sources, see www.sciam.com/ontheweb

BUT WHAT ABOUT . . .

"Last winter was so cold! I don't notice any global warming!"
Global warming is ubiquitous, but its magnitude so far is only about one degree Fahrenheit. Day-to-day weather fluctuations are roughly 10 degrees F. Even averaged over a season this natural year-to-year variability is about two degrees F, so global warming does not make every season warmer than a few decades ago. But global warming already makes the probability of a warmer than "normal" season about 60 percent, rather than the 30 percent that prevailed from 1950 to 1980.

"The warming of the past century is just a natural rebound from the little ice age."
Any rebound from the European little ice age, which peaked in 1650–1750, would have been largely complete by the 20th century. Indeed, the natural long-term climate trend today would be toward a colder climate were it not for human activities.

"Isn't human-made global warming saving us from the next ice age?"
Yes, but the gases that we have added to the atmosphere are already far more than needed for that purpose.

"The surface warming is mainly urban 'heat island' effects near weather stations."
Not so. As predicted, the greatest warming is found in remote regions such as central Asia and Alaska. The largest areas of surface warming are over the ocean, far from urban locations [see maps at www.giss.nasa.gov/data/update/gistemp]. Temperature profiles in the solid earth, at hundreds of boreholes around the world, imply a warming of the continental surfaces between 0.5 and one degree C in the past century.

JAMES HANSEN