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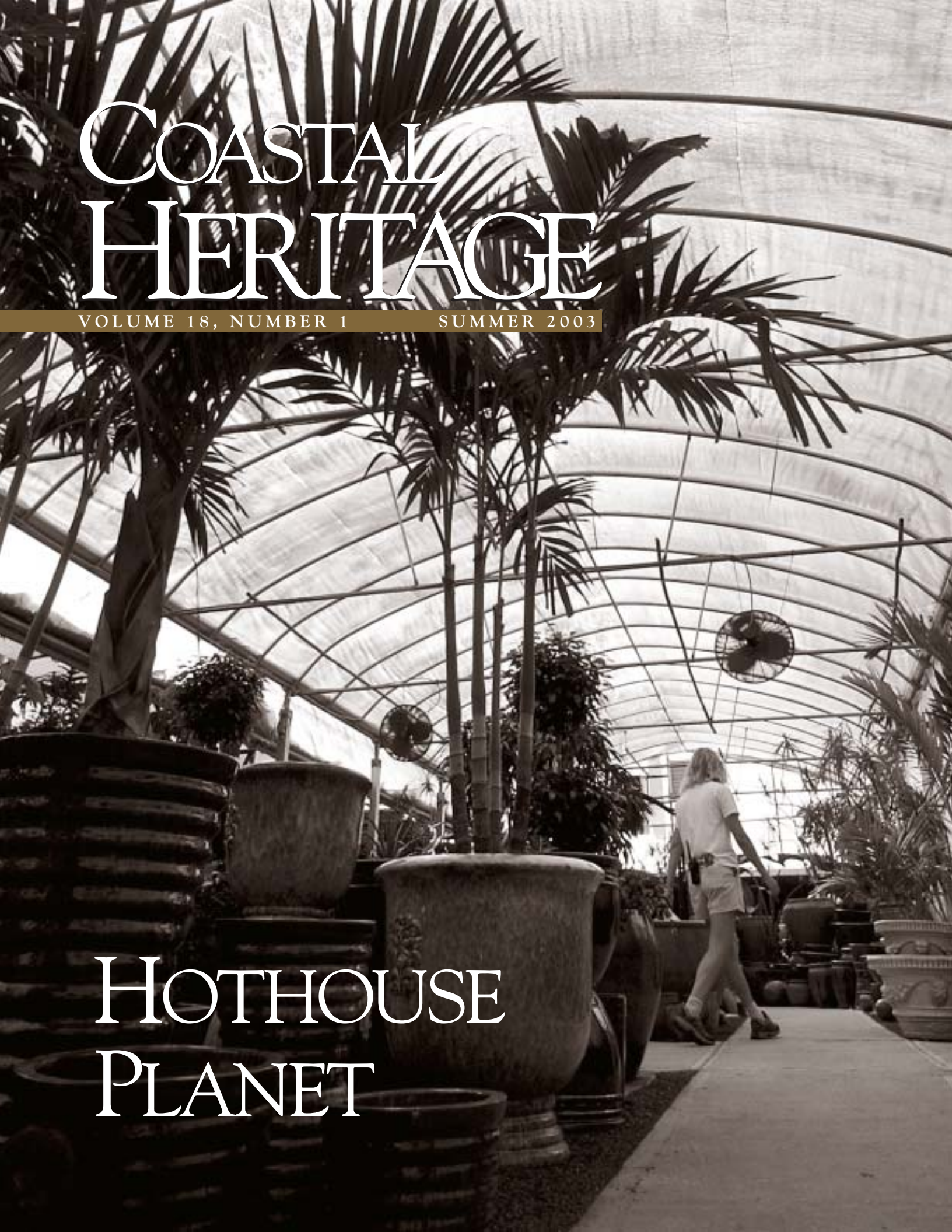

Hothouse Planet

CONTENTS

ON THE COVER

The Earth, fortunately, is a hothouse planet, benefiting from the greenhouse effect. Greenhouse gases naturally reflect a portion of the sun's solar radiation back to the Earth, warming the planet's surface and atmosphere like a greenhouse's windows contain heat. But now pollution, scientists say, is increasing the greenhouse effect, driving the planet's average temperature higher.
PHOTO/WADE SPEES

CLIMATE HISTORY. *Milt Brown, South Carolina state climatologist, leans on books of weather-station observations dating to the late nineteenth century. Brown worries that discrepancies in different generations of temperature instruments have caused variations in weather data during the past 30 years. "Different little things can affect the reliability of weather observations, and we need to get the best weather records we can."*
PHOTO/WADE SPEES

Sea Grant
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SPRING ARRIVES. *The tree swallow (*Tachycineta bicolor*) is among hundreds of wild species shifting behavior in response to climate change.*
PHOTO/PETER LaTOURETTE

HOTHOUSE PLANET

Which wild creatures can adapt to accelerating climate change?

By John H. Tibbetts

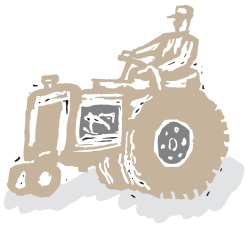
Signals of a warming planet can be read in the behavior of a common little bird. Only five inches long, the tree swallow (*Tachycineta bicolor)* is a migratory songbird with iridescent blue-green wings and a gleaming white belly. This small creature is a highly sensitive climate-change indicator across a band of temperate North America, from New England to the Pacific Northwest. By studying the tree swallow's nesting patterns, researchers have discovered that spring warming now arrives more than a week earlier in places like Massachusetts and Wisconsin because of global climate change.

Tree swallows, agile and swift, winter in places like coastal South Carolina, roosting in huge numbers in wax-myrtle trees and wheeling across the sky in pursuit of flying insects.

Then in early April they migrate north to claim and defend nesting sites in tree cavities and bird boxes. April truly is the cruelest month for these birds. Tree swallows must survive the last freezing weeks of northern winter until flying insects emerge during the first or second week of May. "They have some really lean times," says Cornell University ecologist and evolutionary biologist David W. Winkler.

The birds fatten up when insects start flying again. But tree swallows are patient family budgeters. Only when they can catch enough insects do they start laying eggs. Tree swallows time their breeding to the moment when insect populations explode in abundance, occurring during the first vigorous spurt of northern warming. Thus, if you study when these birds lay eggs, you'll know when spring arrives across the forested regions of the continent's northern tier.

Over a period of four decades, volunteer bird watchers tracked about 21,000 tree-swallow nests in the United States and Canada, sending data cards to Cornell University's Laboratory of Ornithology. With this information, Winkler and colleagues learned that tree swallows were laying eggs nine days earlier on average in 1991 than they had in 1959. The birds, Winkler says, are responding to global warming and earlier spring temperatures. This study, however, does not address nesting data throughout the 1990s, the warmest decade in recorded history.



Compounding problems

Climate change is not today's most important environmental crisis, some say. The potential consequences of global warming, they argue, are too far in the future to worry about. Instead, society should concentrate on overpopulation, suburban sprawl, excess nutrient pollution, invasive species, and water overexploitation.

The reality, however, is that global warming already worsens many challenging environmental problems. "It's the combination of population, resource use, and climate change that really makes the nasty brew," says James White, a climate scientist at the University of Colorado.

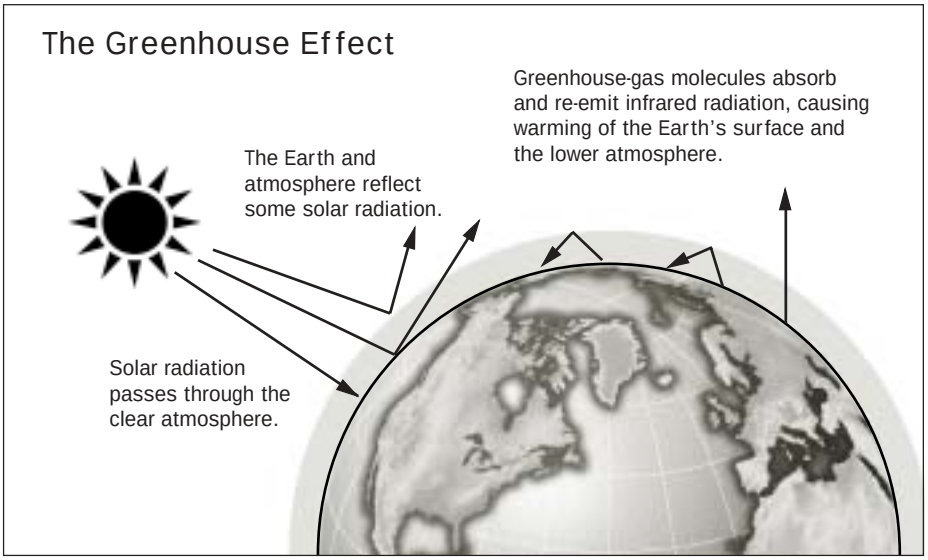
Rapidly growing populations and agriculture are using vast amounts of water, driving down reservoir levels and aquifers in some regions, even during times of average local rainfall. Society therefore often creates "human-demand droughts" in absence of meteorological droughts.

To compound this problem, global warming is apparently spawning increasing meteorological droughts in some regions, climate scientists say.

Starting in the late 1990s, an extremely intense warming in the western Pacific associated with the La Niña phenomenon pumped additional heat into the atmosphere and altered winds of the jet stream, changing precipitation patterns in a band stretching nearly around the world, including much of North America, from 1998 to 2002, reports Martin Hoerling of NOAA's Climate Diagnostics Center and Arun Kumar of NOAA's Climate Prediction Center in a recent *Science* journal article. The U.S. Southeast was one of the areas hardest hit by this drought.

The hot-temperature spike in the western Pacific was partly due to global warming consistent with increasing greenhouse gases, the researchers noted in their article.

Some meteorological droughts in the United States and elsewhere may have man's thumbprints all over them. "That human-contributed greenhouse gases could be causing widespread, persistent, and very damaging droughts raises the stakes considerably," says White.



Dozens of bird species with various life histories are similarly nesting earlier than before. And "a lot of bird species—from short-term to long-term migrants—are going north one to three weeks earlier than they did 20 years ago," says Jeff T. Price, director of Climate Change Impact Studies at the American Bird Conservancy, based in Boulder, Colorado. "Very few species are migrating later."

Plants are flowering sooner than they did a few decades ago in many regions. Some mammals are breaking hibernation earlier. Many species have shifted their ranges toward the poles.

The Earth has warmed by 1.1 degrees Fahrenheit since 1900, an unprecedented temperature rise over the past millennium. Two-thirds of this warming has occurred just within the past 30 years, including an abrupt temperature spike upward starting in the mid-1990s.

Over the past several decades, hundreds of research projects have documented wildlife species' responses to global warming. Working independently, two research teams analyzed many of these previously published papers, offering a startling picture of a changing climate's impacts on wild creatures.

Terry L. Root, a Stanford University ecologist, and colleagues used statistical tools to analyze 143 separate research studies involving a total of 1,473 species of plants and animals. Each original study examined a correlation between climate change and a biological response in plants or animals somewhere in the world.

More than 80 percent of species had made a temperature-related shift in response to climate change, Root and co-authors discovered. Spring events—migrating, blooming, and nesting—had shifted earlier by an average of five days per decade over the past 30 years for temperate-zone species.

In another study, Camille Parmesan, a biologist at the University of Texas at Austin, collaborated with Wesleyan University economist Gary Yohe to analyze studies of 172 species of plants, birds, butterflies, and amphibians. Spring events had advanced by a mean of 2.3 days per decade over a time period of 16 to 132 years, with a median of 45 years.

Terrestrial ecosystems have experienced greater warming than deep oceans. But marine creatures are moving poleward too, particularly in intertidal areas and along continental shelves; shallow water is affected more by temperature than deeper ocean water. Around California's Monterey Bay, warmer water has changed community structure, driving many invertebrates northward and out of the bay, and allowing other species to replace them from the south.

In the North Atlantic Ocean, five of eight commercially important groundfish species have moved north in response to warming. Growing numbers of fish species common to Caribbean waters have been found at a reef off Beaufort, North Carolina, over the past 25 years. "The reef population here is much more tropical than it was," says R.O. Parker, a research fishery biologist with the NOAA National Marine Fisheries Service in Beaufort.

Just as wild creatures respond to a rapidly changing climate, so do row crops, forest plantations, and disease-carrying insects. Global warming is likely to affect many ecosystems on which we depend.

The Earth's average surface temperature will continue growing hotter over the next half-century at least. Natural variation has a part in this change. But human actions, scientists say, are mostly to blame. We are burning so much carbon once stored in the Earth—oil, natural gas, and coal—that we are altering the world's climate.

Since the industrial revolution began 200 years ago in Europe, people have burned fossil fuels, increasing the amount of carbon dioxide and other so-called "greenhouse" gases sent into the Earth's atmosphere.

The "greenhouse effect," of course, is a natural phenomenon. Greenhouse gases—carbon dioxide, methane, and nitrous oxide—naturally reflect a portion of the sun's solar radiation back to Earth and warm the planet. This entrapment sustains the global surface temperature. Without the greenhouse effect, the planet would be a ball of ice.

The problem is that our fossil-fuel burning *increases* the greenhouse effect, trapping more of the sun's energy and causing the Earth's temperature to rise.

"When we use the atmosphere as a sewer, something happens," says Stephen H. Schneider, a professor of geosciences at Stanford University.

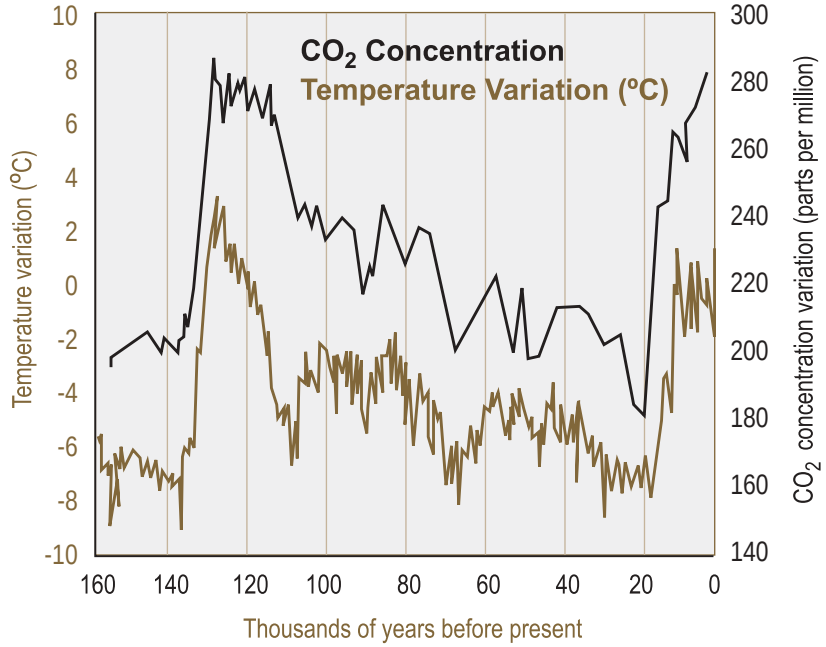
In 1988, the nations of the world appointed the Intergovernmental Panel on Climate Change (IPCC), comprising more than 2,000 leading experts to assess the science and economics of climate change. In 2001, the IPCC published its third major report, forecasting that the Earth could warm by 2.5 to 10.4 degrees Fahrenheit by 2100.

Global climate change generally affects higher latitudes (colder places closer to the poles) more than subtropical and tropical regions. In Alaska, for example, average temperatures have risen by about 3.6 degrees Fahrenheit over the past 30 years.

"There is not uniform warming" around the world, says James White, a climate scientist at the University of Colorado. "Europe and Asia are warming up quite a bit faster and quite a bit more (in degree) than North America." Indeed, the entire U.S. Southeast has actually cooled very slightly over the past century, though South Carolina has warmed by about 1 degree Fahrenheit.

The Arctic and Antarctic have experienced the most abrupt climate change. Since the 1950s, higher polar temperatures have diminished the extent of Arctic sea ice by 30 percent in spring and summer. Now floating masses of sea ice are splitting apart. The massive Greenland ice cap melted more last summer than in recorded history.

Unless nations support swift, substantial cuts in greenhouse-gas emissions, Arctic sea ice in summer time could diminish 60 percent by 2050, according to a 2001 assessment by the United Nations Environment Programme. Melting of polar ice and



SKETCHING THE PAST. *The upper curve shows atmospheric carbon dioxide over the past 160,000 years. The lower curve shows temperature variation over the same period. Data for these figures were taken from ice cores at Vostok, Antarctica. Data for this chart stop long before the industrial era began in 1750. Notice the correlation between carbon dioxide and temperature. Source: Wolfson, Richard and Stephen H. Schneider. "Understanding Climate Science." In* Climate Change Policy: A Survey. *Washington, DC: Island Press, 2002.*

WHAT YOU CAN DO

You can take steps to reduce energy consumption and fight global climate change.

Your action: CO_2 reduction (pounds per year)

1. Use a push mower instead of a power mower: 80 (pounds per year)
2. Install low-flow showerheads to use less hot water: 300
3. Replace your washing machine with low-energy, lower-water-use machine: 440
4. Keep your hot-water thermostat no higher than 120° Fahrenheit: 500
5. Recycle all of your home's waste newsprint, cardboard, glass, and metal: 850
6. Caulk and weatherstrip around doors and windows to plug up leaks: 1,000
7. Leave your car at home two days a week (walk, bike, take public transit): 1,590
8. Insulate walls and ceilings: 2,000
9. Purchase a fuel-efficient car (rated at 32 mpg or more) to replace your most frequently used automobile: 5,600
10. When replacing windows, install energy-saving models: 10,000

Source: Environmental Protection Agency

permafrost pushes more freshwater into the Arctic Ocean, which could stimulate explosive shifts in ocean circulation and climate around the world.

How high could temperatures go, and how quickly?

"That increasing greenhouse gas concentrations *contributed* to (global) warming is not in serious dispute," notes a 2001 report by the George C. Marshall Institute, a nonprofit organization known for its criticism of mainstream climate-change research.

Skeptics argue that global warming is not cause for alarm. More warming has already brought some positive effects, they say. Since the 1960s, growing seasons have lengthened by one to four days per decade in the Northern Hemisphere, particularly in higher latitudes. Some cold-weather places now have more warm days to grow crops, and people have lower heating bills in winter. Most people in industrial nations, skeptics say, would simply adjust to a changing climate.

Patrick Michaels, a Virginia state climatologist and well-known global-warming contrarian, has argued that the planet will likely heat up by 2.8 degrees Fahrenheit by the year 2100. His forecast falls within the lower range of the IPCC assessment, yet it is almost triple the amount of last century's warming.

But even modest global warming could spell doom for creatures in certain vulnerable habitats. Within 50 years, some small oceanic islands could be drowned by large storms and rising sea levels. By 2050, coastal wetlands and mangroves in some regions could be permanently submerged. Many species in northern intertidal zones will face localized extinctions because of heat stress. Many coral reefs worldwide probably will be gone, killed by warming water and other impacts.

"Some ecosystems will find it virtually impossible to adapt to a fair amount of climate change, no matter how slowly it arrives," says Thomas E. Lovejoy, president of the Heinz Center for Science, Economics, and the Environment, based in Washington, D.C.

Mountaintop glaciers in warm-weather countries almost certainly will melt rapidly. High-altitude ice and snow in places like Tanzania have already receded so quickly that they will be gone in just 20 more years, says Lovejoy.

Go see them while you can: the famous snows of Kilimanjaro will soon be no more.

HISTORIC EVIDENCE AND MODELS

How do scientists really know that the Earth's surface is warming?

Beginning in the mid-1850s, governments established a network of instruments that have measured surface temperatures across land and marine regions of the Northern Hemisphere. As a result, researchers have continuous documentation of the hemisphere's climate over the past 140 years.

Two-thirds of recorded global surface warming has occurred since the end of the Vietnam War, and the decade of 1990s included nine of the 10 hottest years since the Civil War began. The warmest year was 1998; the third and fourth hottest were 1990 and 1995. The twenty-first century got off to a blazing start in 2001 and 2002; the latter was the second warmest year on record.

"We are reaching a fundamentally different level of temperature change on the planet," says White.

The Earth's biological and physical "archives" also contain clues to ancient temperatures. Bubbles of air trapped in Antarctic ice show that for the past 400,000 years carbon-dioxide levels in the atmosphere have closely

followed global temperatures as revealed in ice cores. It seems clear that carbon-dioxide levels and temperature generally move in long-term tandem.

By studying tree rings and ice cores, researchers have concluded that recent surface temperatures are probably higher than any comparable era since the Middle Ages. The period from 1970 to 2000 was likely the Northern Hemisphere's warmest three-decade period of the past thousand years, according to the Climatic Research Unit at the University of East Anglia in Great Britain.

Global average temperature will continue to rise because of heat-trapping pollution, climate scientists agree. Cars, factories, and power plants emit about 24 billion tons of carbon dioxide a year. Forests and the ocean, which help soak up heat-trapping gases, cannot absorb swiftly rising emissions levels. Instead, the atmosphere will have to take up more of the greenhouse-gas load.

Pollution from cars and factories does not affect climate immediately. It takes 10 to 20 years for today's pollution to begin showing in the temperature record. But some greenhouse gases have long lives. A century from now, our descendants will likely experience rising temperatures caused by current pollution.

WHAT'S THE CAUSE?

Could the recent spike in global surface temperature and Arctic meltdown be attributed to a natural, cyclical phenomenon?

Numerous forces affect global climate change, including solar variability that nudges Earth's temperatures up or down, volcanic explosions that spew dust into the air and cool the planet, and greenhouses gases that warm the Earth.

But only one phenomenon, most climate scientists say, can satisfactorily explain the sudden global temperature jump at the end of the twentieth century. "The recent warming, particularly over the past 20 years, cannot be attributed to anything but human involvement in greenhouse gases," says White.

Scientists use general-circulation computer models to estimate how the climate will respond to increasing greenhouse gases. These models—which Schneider calls "mathematical expressions of physical laws that we believe in"—are extraordinarily complex, with many built-in uncertainties.

Early models could not begin to approximate the climate system's intricacy. But newer models incorporate more of the hydrological, geological, and biological factors that influence climate: dust and soot, volcanoes, tree cover, ocean currents, among many others.

Yet even the best models cannot address factors that will dramatically affect the pace of future warming, such as the behavior of water vapor, clouds, and atmospheric particles. These "feedback" mechanisms could significantly increase warming or damp it down.

The problem is that nearly all feedback mechanisms in current models are positive, skeptics say. Computer models show that as the Earth grows warmer, the atmosphere increasingly traps energy from the sun. As a result, the Earth's atmosphere becomes moister, which exacerbates surface warming, which makes the atmosphere even moister.

Nevertheless, the Earth's climate probably doesn't work like that, says John Christy, an Alabama state climatologist and an IPCC report lead author. As human society increases greenhouse-gas emissions, larger-than-expected amounts of energy apparently leak into space from the Earth's surface, therefore slowing global warming.

"There is increasing evidence that energy escapes (from the Earth's

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surface into space) through clear, dry areas of the planet," says Christy. "Those areas become drier and larger as (atmospheric) carbon dioxide increases."

This process, he says, is part of the planet's self-regulating mechanism, in which climate tends to return to the long-term mean after temporarily becoming colder or warmer. Christy also argues that greenhouse-gas emissions can be blamed for only a small fraction of global warming over the past century.

But only a tiny minority of knowledgeable scientists—just a handful in number—holds Christy's view that human society is not primarily responsible. The overwhelming majority of climate scientists argue that humankind is largely to blame for rising temperatures.

Even so, climate scientists acknowledge their lack of an airtight case: they cannot prove beyond any doubt that increasing greenhouse gases from human activities have warmed the Earth and will continue to do so.

Researchers, however, do have "multiple lines of evidence and fingerprints" that the planet has warmed primarily because of greenhouse-gas emissions, Schneider says. Climate scientists have gathered detailed circumstantial evidence that human activities are mostly to blame for the rising average global surface temperature.

Scientists are especially confident that they understand the workings of carbon dioxide, the most influential heat-trapping greenhouse gas. Before 1750, global carbon-dioxide load in the atmosphere was 280 parts per million. Due to increased pollution, the atmospheric load has risen to 370 parts per million, one-third above pre-industrial levels.

The Earth's atmosphere, according to climate-computer models, is likely to contain double the pre-industrial levels of heat-trapping gases within the next 50 years, causing a rise of two to four degrees Fahrenheit in global average

NIGHT LIFE. *This is a composite image of hundreds of pictures made by orbiting defense satellites, illustrating what the Earth looks like at night. Urbanization has spread to nearly every habitable corner of the world. "There's nothing on the planet that people don't monkey with," says climate scientist James White of the University of Colorado-Boulder.*
PHOTO CREDIT/C. MAYHEW & R. SIMMON (NASA/ GSFC), NOAA/ NGDC, DMSP Digital Archive

surface temperature. Unless the global community establishes policies to control greenhouse gases, the atmospheric load could rise to 1,000 parts per million by the end of the next century, causing potentially explosive climate changes.

Climate scientists have assumed that increased economic development, particularly in developing countries, would cause sharply rising greenhouse-gas emissions. New, cleaner technologies cannot quickly replace polluting energy sources such as coal-fired electric plants and the internal-combustion engine.

But that assumption is wrong, says Michaels. Instead, developing countries will soon bypass older, dirty technologies and employ technologies that reduce heat-trapping emissions. "Very clean technologies are being developed by affluent countries," says Michaels, "and these technologies are going to be sold to developing countries."

Still, an important question remains: should governments wait to act until researchers have complete scientific certainty before taking steps to control greenhouse-gas pollutants? No, climate scientists say. By the time researchers have "smoking-gun" evidence, it could be too late to prevent environmental, social, and economic catastrophes in some regions.

BIOLOGICAL IMPACTS

Animals have always responded to temperature fluctuations throughout their evolutionary history. Couldn't most creatures adjust to climate change? Isn't that what natural selection is all about?

Climate change hasn't harmed the tree swallow, which nests earlier without ill effects. The tree swallow still thrives by eating flying insects. And it could probably adapt to climate change over the next century. "Tree swallows should do pretty well," says Winkler, because flying insects would still provide a consistent food source in a hotter era.

But other species might not be so fortunate.

Plant and animal species thrive only within certain temperature ranges. They must relocate to a new habitat when a particular location gets too hot or too cold for them. When the climate cools, species generally move in the direction of the Equator and down mountainsides. When the climate warms, most species head toward the North Pole in the Northern Hemisphere and the South Pole in the Southern Hemisphere, or they move up mountainsides.

In the future, some species could relocate to habitat many miles away, though their food sources might not follow as far. Meaning that an animal species might relocate to a different place than its prey does. "We could see

a tearing apart of natural communities," separating animals from their food sources, says Root.

Some animals with narrow foraging requirements might not survive in a rapidly warming world. A bird, for example, that relies exclusively on a particular species of insect or worm could starve or fail to reproduce. The bird's climate-induced migration could be out of synchrony with its prey's migration; predator and prey could go to different places.

"Those species with any kind of specialized relationship with prey organisms could really get into trouble," says Winkler.

Moreover, cities, farms, ranches, plantation forests, and other intensively managed landscapes could block many climate-induced wildlife migrations. Species could get squeezed between rising temperatures behind them and development in front of them. Thus, rapid climate change could cause numerous extinctions.

Higher temperatures would likely spawn faster rates of evaporation and precipitation, so that some regions would have shorter and more intense rainy seasons. Other regions would have longer droughts, endangering some crops and causing a drop in global food production, though most U.S. agricultural sectors could adapt to a warmer climate. Longer droughts would also diminish water supplies in many areas, exacerbating existing shortages.

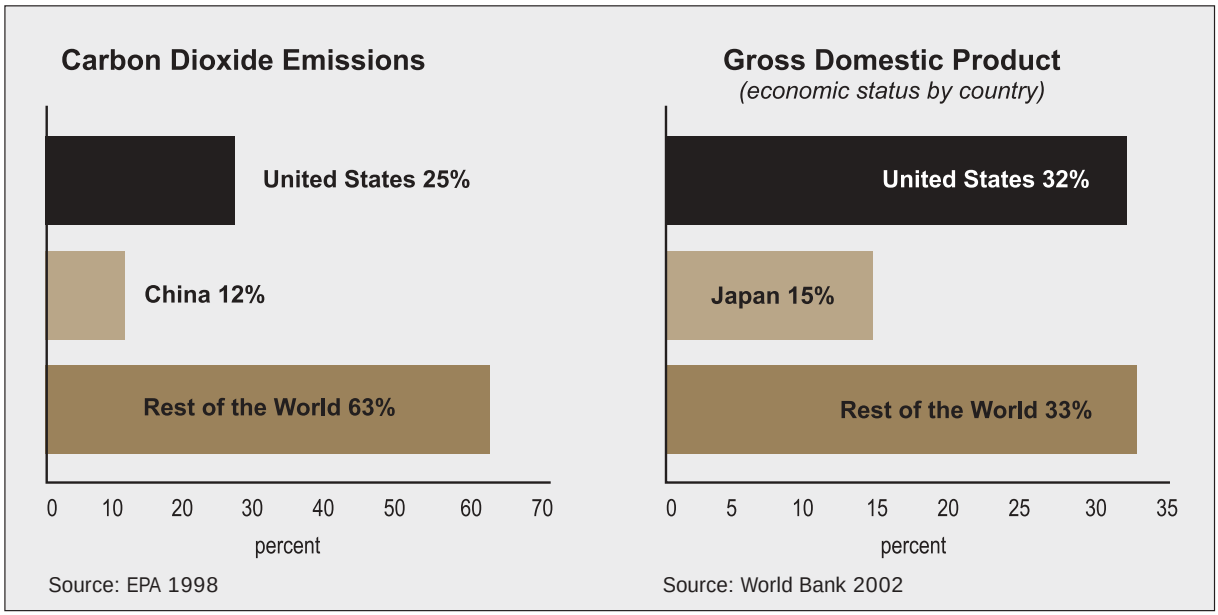
Mosquitoes and many other disease carriers will probably increase their range due to warmer and wetter weather. Illnesses such as malaria and dengue fever will probably become even more prevalent in some developing nations. "A warmer world would be a sicker world," says Andrew P. Dobson, an epidemiologist and ecologist at Princeton University.

PLANETARY MONKEYING

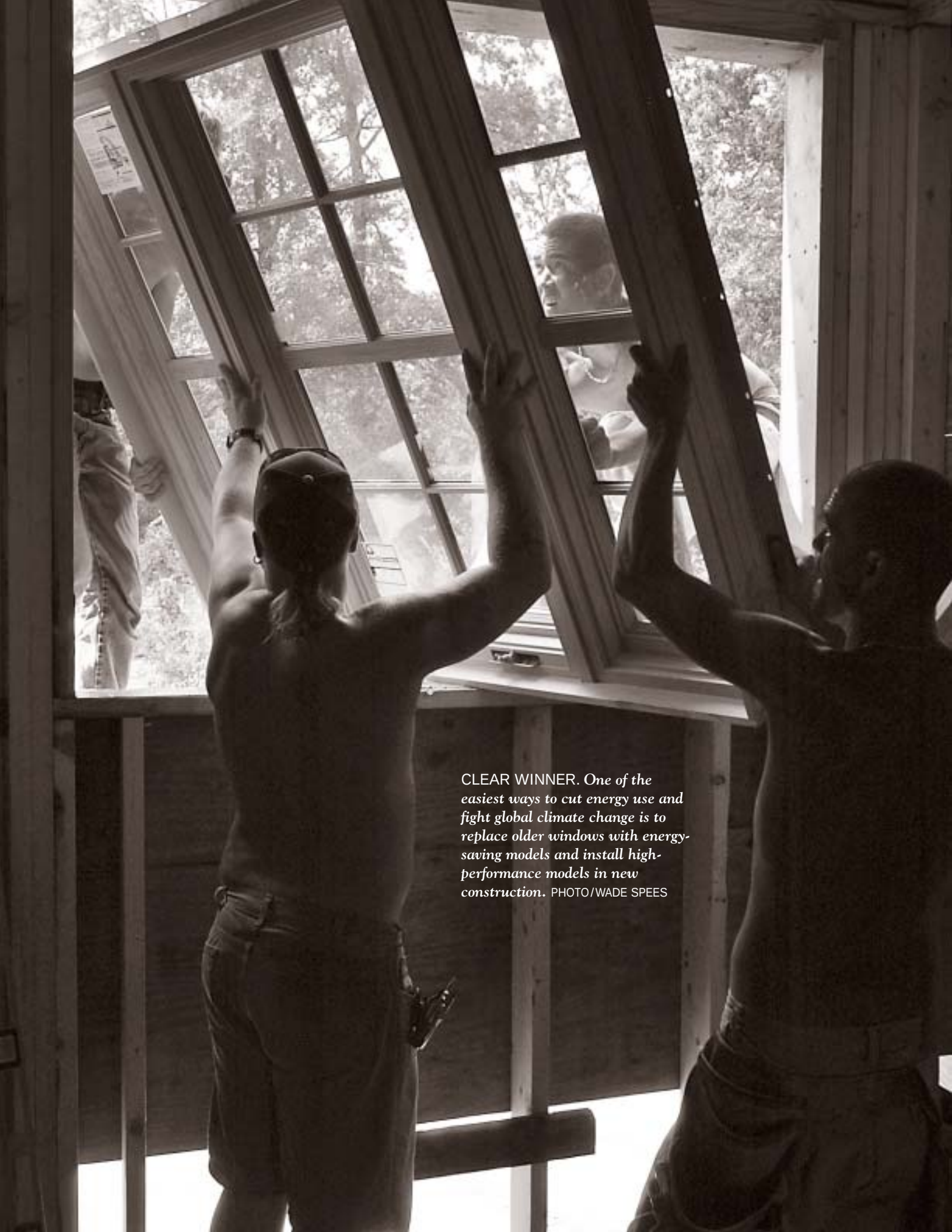
Some experts had hoped that the Kyoto Protocol of 1997 would be the answer to global climate change. It is an international treaty that seeks to control greenhouse-gas emissions to below 1990 levels by 2012, applying mandatory standards on advanced industrial nations that ratified it. The problem is that the Kyoto's provisions would only amount to a two to five percent cut in greenhouse-gas emissions. "Kyoto really does little to materially affect the climate," says Roger A. Pielke, Jr., a University of Colorado political scientist. The Kyoto treaty is far too little, too late, he says.

President George W. Bush announced in 2001 that the United States would not ratify the Kyoto treaty two years after the U.S. Senate declared it dead. The U.S. government saw Kyoto as unfeasible, because most of its costs would have fallen on the shoulders of American companies. Instead, the Bush Administration has sought voluntary commitments from companies to reduce emissions, arguing that the science addressing climate change is uncertain and that human factors are not clearly contributing to global warming.

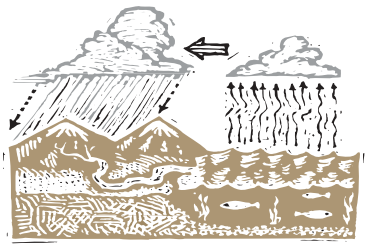
This stance sparked international criticism from U.S. economic partners that point out that the United States produces about 25 percent of the world's carbon-dioxide emissions. Japan and Australia together produce about 6 percent; all of Western Europe produces 16 percent.



LEADER OF THE PACK. *The United States is blessed with the largest economy on Earth, but it is also the largest contributor to worldwide greenhouse-gas emissions. China produces the second-largest amount of greenhouse-gas emmissions, while Japan has the second-largest economy.*



CLEAR WINNER. *One of the easiest ways to cut energy use and fight global climate change is to replace older windows with energy-saving models and install high-performance models in new construction.* PHOTO/WADE SPEES



Sea levels

Could climate change interact with a natural cycle in sea level to damage coastal resources?

During the past century, sea levels have risen by an average of one foot on Gulf and Atlantic beaches primarily because of seawater's thermal expansion. When the global surface temperature becomes hotter, seawater expands, and sea levels rise.

Shorelines have migrated landward at an average rate of one or two feet per year over the past century, though local conditions vary greatly. In some areas, the annual erosion rate is more than 20 feet annually. Other areas are stable or growing.

Sea levels are expected to rise by an average of 19 inches worldwide between 1990 and 2100, affecting low-lying countries and some coastal cities and habitats, according to the World Water Council, an international water agency.

Sea level also naturally fluctuates during cycles on the order of every 20 years, says James T. Morris, a marine biologist at the University of South Carolina. For a single 20-year period, sea level rises overall, though there are ups and downs within the larger cycle. Then for the next 20-year cycle, sea level falls overall, though with smaller ups and downs. "The 20-year cycles are regular and very predictable, but they are not caused by any astronomical force that we know of, such as the motion of the planets, moon, and sun." These cycles remain a mystery, says Morris.

Today, sea levels have neared the very top of a natural cycle. "Sea level has risen very rapidly over the last 10 to 15 years, and we are now due for a decline in sea level over the next decade, provided past cycles repeat themselves. The fact that we do not understand their cause means that we cannot forecast with confidence."

How much of recent sea level rise is driven by the 20-year cycle and how much is driven by global climate change? That's impossible to say.

The ascending side of the 20-year cycle could end soon. Sea level is likely to fall over the next two decades, reducing global warming's impacts on coastlines. But in the future, an ascending swing of the 20-year cycle could combine with thermal expansion of seawater to swamp coastal habitats around the world.

Many traditional U.S. allies have argued for strong steps to control greenhouse gases. Prime Minister Tony Blair of Great Britain recently laid out ambitious plans to cut greenhouse emissions by 60 percent in the next five decades.

Senators John McCain (R-Arizona) and Joseph I. Lieberman (D-Connecticut) have joined in proposing legislation that would require mandatory though small reductions in greenhouse emissions by 2010 and sharper ones by 2016.

More than any other nation, the United States has the potential to disrupt the world's climate. Yet this country could adapt better than most. Americans have the scientific skills, financial resources, technology, and social and political structures to adjust to all but the most extreme scenarios over the next century.

American agriculture, for example, probably would not be harmed overall by climate change; in fact, warming could even help farmers in some regions. In the Southeast U.S., however, climate change could spell trouble for many farmers and foresters. Agriculture is already a marginal activity in this region, and farmers would face increased water shortages for irrigation, potentially driving them out of business. Forests would likely endure greater numbers of destructive pests and slower growth because heat stress could weaken trees, says Milt Brown, South Carolina state climatologist.

As sea levels rise, U.S. coastal cities could retreat or build seawalls, though that would be expensive. Public-health resources could be mobilized to fight emerging and re-emerging diseases spawned by a warmer climate.

Poor people in some developing nations, however, could face calamities if the climate continues to warm rapidly. "What's not dangerous in the U.S. might be dangerous somewhere else," says Tom Wigley, a senior scientist at the National Center for Atmospheric Research, based in Boulder, Colorado. Residents of flood- or drought-prone regions—such as coastal Bangladesh, the African desert Sahel region, and small oceanic islands—would likely have to relocate. "In some cases . . . we've probably gone beyond the state of adaptation (to global climate change)," Rajendra Pachauri, chairman of the IPCC, has said.

Now the Earth's climate system is undergoing changes exacerbated by pollution, experts say. Nevertheless, many Americans believe that we could not disrupt something as vast as the Earth's climate, and that natural variability must be solely to blame.

"The average person," says White, "does not have a good grasp of just how important human beings are—not only in the climate system but in all phases of the planet's systems. There's nothing on this planet that people don't monkey with."

Web sites

Intergovernmental Panel on Climate Change: www.ipcc.ch

World Meteorological Association: www.wmo.ch/indexflash.html

EPA Global Warming site:
yosemite.epa.gov/oar/globalwarming.nsf/content/index.html

Grist Magazine "Heat Beat":
www.gristmagazine.com/heatbeat/thisjustin013103.asp

Momentum change

Since the early 1990s, the momentum has shifted in scientific debates about global climate change. A decade ago, many researchers argued that global warming could be attributed exclusively to natural variation. Some doubted that the planet was warming at all. But the Earth's surface is undoubtedly growing hotter, especially near the poles. Moreover, a growing body of circumstantial evidence indicates that humans have a strong hand in this change.

Experts are now more certain in answering one fundamental question over the past 12 years: are people contributing to global warming?

In 1990, the First Assessment Report of the Intergovernmental Panel of Climate Change (IPCC) reported: "The unequivocal detection of the enhanced greenhouse effect from observations is not likely for a decade or more."

In 2001, the IPCC Third Assessment offered a firmer stand: "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities."

At the behest of President George W. Bush, the National Academy of Sciences studied global-climate research and in 2001 issued a report that said: "Greenhouse gases are accumulating in the Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise. . . . Human-induced warming and associated sea level rises are expected to continue through the 21st century."

FILL 'ER UP. *Transportation—particularly cars, trucks, and jet fuel—accounted for about one-third of U.S. greenhouse-gas emissions in 2001.* PHOTO/WADE SPEES

Meanwhile, the two most influential science journals in the English-speaking world, *Science* and *Nature*, have published dozens of studies detailing the causes and impacts of climate change.

"The scientific evidence on global warming is now beyond doubt," Donald Kennedy, editor-in-chief of the journal *Science*, wrote in a recent editorial. "Readers of these pages during the past couple of years have seen one careful study after another documenting the role of anthropogenic sources of carbon dioxide and other greenhouse gases in global warming; describing the impact of past and present climate change on marine and terrestrial ecosystems; and measuring rates of glacial melting in the Arctic, the Antarctic, and on the tops of low-latitude mountains."

STONE MOUNTAIN. *A mountain of coal to be fired in a South Carolina power plant. Electric power accounted for 39 percent of U.S. greenhouse-gas emissions in 2001.* PHOTO/WADE SPEES

The United States, Kennedy argues, must take action on global climate change. "In this case, the stakes are well beyond national interest, because the nonparticipation of the United States in the global effort on climate change is more than a national embarrassment. It's dangerous."

To some skeptics, however, the editors of *Science* and *Nature* have been blinded by political considerations. These journals "are agenda-driven magazines," says John R. Christy, the Alabama state climatologist and an IPCC report lead author. "They have decided that climate change is a threat; therefore it must be dealt with by centrally planned solutions, taking access to energy away from people, passing regulations from a government mandate, saying you must reduce your energy consumption."

EBBS & FLOWS

American Fisheries Society 133rd Annual Meeting

Quebec City, Quebec
Aug. 10-14, 2003

"Worldwide decline of fish populations" is the theme for the 2003 meeting, which will include symposia, a trade show, student activities, poster sessions, and guided tours. The meeting will run for four full days, with up to 20 concurrent technical sessions. For more information, contact Stephanie Lachance (418) 521-3955 or stephanie.lachance@fapaq.gouv.qc.ca

Oyster Summit Meeting

Annapolis, Maryland
Sept. 8-9, 2003

A conference, "Oyster Research and Restoration in U.S. Coastal Waters: Strategies for the Future," is scheduled for Sept. 8-9. Speakers at this meeting will summarize the status of oyster fisheries in the United States, share recent developments in oyster-disease research, and synthesize developments for management and restoration of oyster populations. For more information, see http://www.mdsg.umd.edu/oysters/meeting

15th Annual Beach Sweep/River Sweep

South Carolina
Sept. 20, 2003

Each year thousands of people participate in Beach Sweep/River Sweep, South Carolina's largest one-day litter cleanup of beaches and waterways. The S.C. Sea Grant Consortium and S.C. Department of Natural Resources organize the event, and anyone can participate—individuals, families, schools, civic clubs, or businesses.

Last year volunteers collected over 59 tons of debris, but there is still more to be done. To find out how you can help, call Susan Ferris, coastal coordinator, at (843) 727-2078 or Bobbie Adams, inland coordinator, at (803) 734-9108. For more information, visit http://scseagrant.org/education/education_bsrs.htm

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