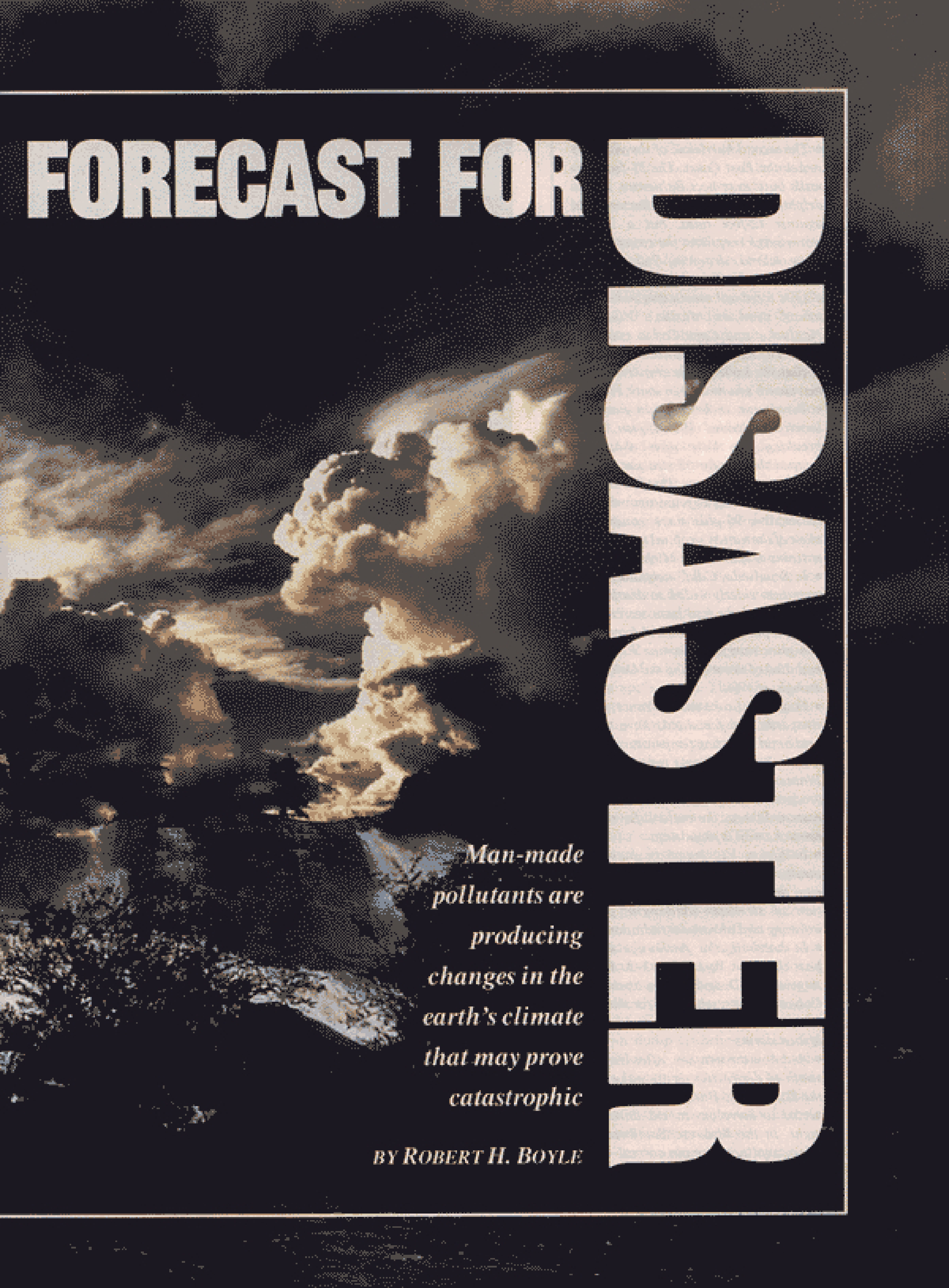
FORECAST FOR DISASTER

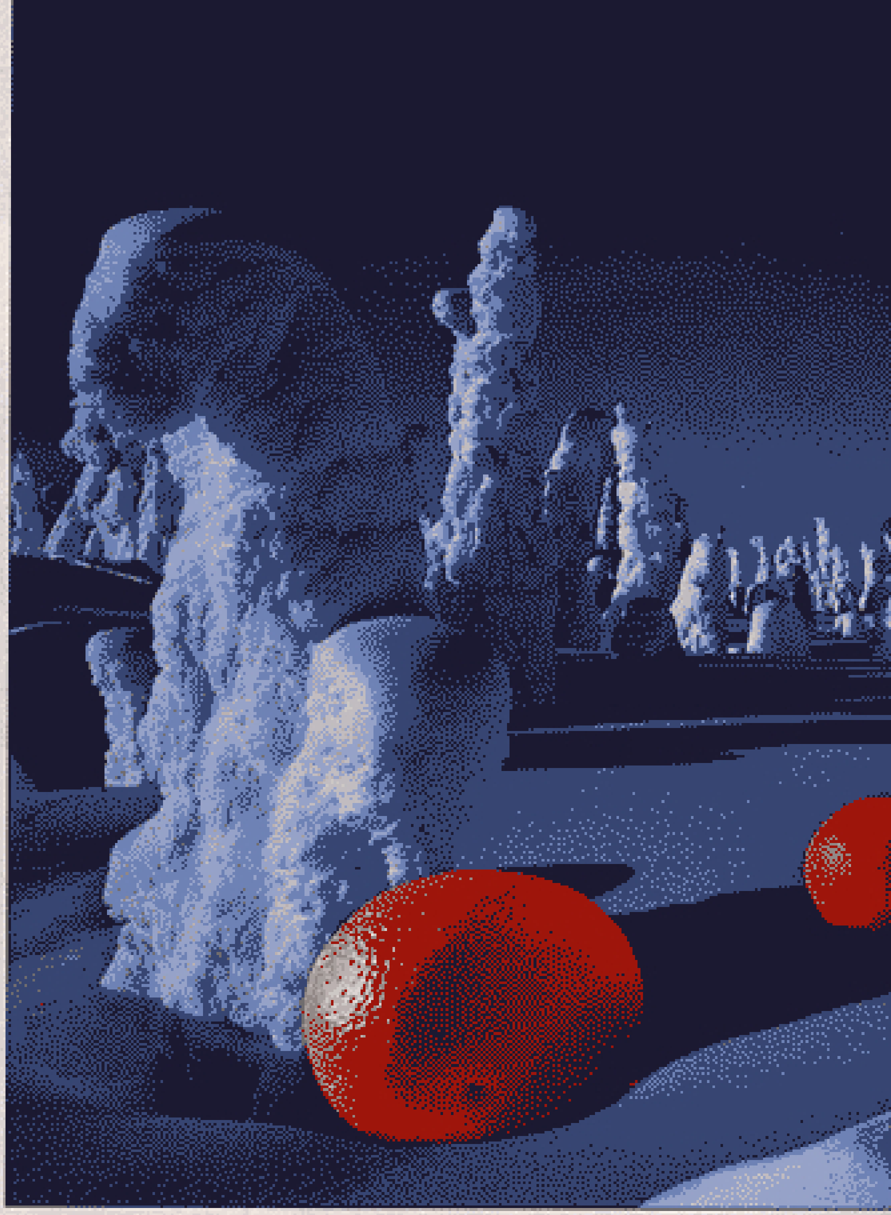


Man-made pollutants are producing changes in the earth's climate that may prove catastrophic

BY ROBERT H. BOYLE

And now the news for July 4, 2030:

- *The second hurricane of the year has struck the East Coast. The 15-foot seawalls built to protect Baltimore, Philadelphia, New York and Boston held against 12-foot tides, but a 25-foot storm surge swept over the eastern tip of Long Island, drowning 260 residents who had refused to leave their homes despite a federal evacuation order. The toll of dead on Martha's Vineyard, Nantucket and Cape Cod is estimated at 50. The 310 fatalities are still far fewer than the 5,600 people who drowned in last month's hurricane in south Florida.*
- *Twenty-two inches of rain from the hurricane flooded Washington, D.C., breaking the heat wave that had gripped the city for 62 straight days of 90°-plus temperatures. This fell short of the record set eight years ago when 72 consecutive 90-plus days caused the move of the nation's capital to the cooler environs of Marquette, Mich.*
- *In Sepulveda, Calif., neighbors hammered an elderly widow to death when they learned she had been secretly watering a pot of geraniums. A footnote to this grim story: The woman's husband had died of thirst during the California drought of 1998.*
- *Food riots broke out in France, where vineyards and farmlands have turned arid amid the rising temperatures.*
- *Dust bowl conditions continue in the Plains States of the U.S., but orange production is up in Saskatchewan. In eastern Siberia the outlook for a good cotton harvest is promising.*
- *In Stowe, Vt., botanists announced the death of the last red spruce. The species' demise is blamed on a combination of stresses—acid rain, global warming and ultraviolet radiation.*
- *In baseball, the Anchorage Braves beat the New York Mets 5–3. In Los Angeles, the Dodgers' game against the Calgary Giants, scheduled for the usual 5:30 a.m. start, was postponed because of dust storms.*
- *And now the weather. After leaving a swath of destruction in its wake along the East Coast, Hurricane Bruce is expected to move out to sea during the night. In the Midwest, Southwest and West, conditions remain normal—searing heat, drought and dangerous levels of ultraviolet radiation.*



RECORDS OF PREVIOUS CLIMATIC CHANGES SUGGEST THAT EVEN A SMALL

IF THIS READS LIKE A NEWSCAST from *Saturday Night Live*, it isn't. This report has been extrapolated from carefully considered forecasts for our planet by a wide variety of scientists as we spin toward the 21st century.

Pollutants are saturating our atmosphere. Acid rain, which already has had a devastating impact on parts of eastern North America, central Europe and southern Scandinavia, is one manifestation of this pollution, but its effects tend to be regional. Two similar and interrelated pollutant threats loom even larger, and they may soon affect life on a global scale. Both have the potential of wreaking catastrophic change on the earth's climate—and on life.

The first of these threats is the pollution caused by the release of chlorofluorocarbons into the atmosphere. These man-made chemical compounds—more commonly called CFCs—are used as refrigerants and coolants and in the manufacture of everything from pillows to polystyrene boxes for fast food. Ever since their invention not quite 60 years ago, CFCs have been rising into the stratosphere. When they hit the protective cover known as the ozone layer—10 to 20 miles up—they raise hell because their chlorine component devours the molecules that form the thin ozone shell. As that layer is depleted, stronger and stronger doses of ultraviolet (UV) radiation from the sun are able to penetrate to the earth's surface. Skin diseases and

RISE IN GLOBAL TEMPERATURES COULD HAVE ENORMOUS REPERCUSSIONS.

plant destruction are only the beginning of the troubles that excessive UV radiation can cause.

The other major threat is caused by the continuing buildup of carbon dioxide, nitrous oxide and trace gases, including CFCs, in the atmosphere. In the 150 or so years since the industrial revolution, man's activities have enormously increased the atmospheric concentrations of these gases. The rapidly expanding use of fossil fuels and the vast destruction of the earth's forests have combined to create a great effusion of these so-called greenhouse gases. They are given that name because when they rise into the atmosphere, they form a kind of blanket in the sky that lets in solar heat but prevents heat from escaping the earth's atmosphere—much like a giant greenhouse. The resulting rise in air temperatures could create havoc.

This is not the stuff of the far-off future, either. To the alarm of many scientists, a seasonal hole has begun to appear in the ozone layer above the Antarctic. When a significant drop in the ozone level was first recorded in 1978, the scientists who made the observations didn't pay much attention to their own data because no one had foreseen the possibility of such a thing. Unlike the ozone hole, the greenhouse effect was something scientists had anticipated, but it is developing faster than expected. In fact, Dr. James Hansen of the NASA Goddard Institute for Space Studies in New York flatly says that within 10 to 15 years the earth will be warmer than it has been in 100,000 years. Clearly, changes are under way. Whether they will be moderate or catastrophic depends on how man responds.

CFCs were invented in 1930 by the late Thomas Midgley, who left another dubious legacy, tetraethyl lead for gasoline. Midgley came up with CFCs when the Frigidaire division of General Motors asked him to find a safe replacement for the toxic ammonia then used in refrigerators. When Midgley's discovery was placed on the market, it was quickly hailed as a miracle compound, and similar substances were created and adapted for a wide variety of industrial applications. Besides serving as refrigerants, CFCs came to be used as foaming agents, blowing and cleaning agents and as propellants in aerosol sprays. Now they are literally all over the place. The major industry trade group, called the Alliance for Responsible CFC Policy, notes that chlorofluorocarbon refrigerants are used to cool 75% of the food consumed in the U.S., as well as for air conditioning in residential, industrial and automotive applications. They are used as solvents to clean microchips and printed circuit boards and are mixed with ethylene oxide to produce a nonflammable gas that sterilizes hospital and pharmaceutical equipment. The same gas blend is also used as a fumigant and pesticide in granaries, warehouses and ships' cargo holds. CFCs are used extensively in the production of plastic foams that insulate buildings, pipelines, storage tanks, railroad cars and trucks; likewise the foams in pillows, cushions, mattresses and the padded dashboards of cars; in egg cartons and in containers and cups for hot foods and beverages. When CFCs escape from discarded air conditioners and refrigerators, or when a bulldozer in the town dump crunches a discarded foam pillow or old mattress, the substances containing the CFCs are broken down, and the chlorofluorocarbons enter the atmosphere to do their dirty work in the ozone layer.

The most outspoken scientist on ozone depletion is a chemist named Sherwood Rowland. After receiving a

Ph.D. at the University of Chicago, Rowland, now 60, earned an international reputation in radiation chemistry. In 1964 he became chairman of the chemistry department at the University of California at Irvine. When he attended an Atomic Energy Commission meeting on atmospheric research in Fort Lauderdale in 1972, he was casting about for new fields to explore. At the AEC conference Rowland learned that James Lovelock, the unorthodox British scientist best known today as the father of the Gaia hypothesis—that all life on earth should be considered a single living entity—was going to report in the journal *Nature* that he had measured CFC levels in the lower atmosphere. In his paper, Lovelock suggested that CFCs might be used as atmospheric tracers, but he pronounced them "no conceivable hazard." Rowland was intrigued by the report; he had done research on fluorine, which is one of the components of chlorofluorocarbons, as well as in photochemistry (the action of light on chemicals), and he thought it might be interesting to study the eventual fate of CFCs in the atmosphere.

When Rowland began his investigation at UC Irvine in October 1973, the annual production of CFCs in the U.S. was on the order of 850 million pounds. DuPont, which sold them under the trade name Freon, was the major domestic manufacturer. Rowland did his initial research with Mario Molina, a postdoctoral student who had just received his Ph.D. from Berkeley. By December of that year the two scientists had completed their research, and in June 1974 they published a paper in *Nature*. The results of their research were startling, but as Rowland says, "There was no moment when I yelled 'Eureka!' I just came home one night and told my wife, 'The work is going very well, but it looks like the end of the world.' "

Briefly put, Rowland and Molina reported that CFCs were being added to the environment in steadily increasing amounts, that they aren't destroyed in the troposphere (the lower atmosphere) and that they survive for many decades, slowly drifting up into the stratosphere. Once CFCs reach the stratosphere, though, UV radiation decomposes them and releases chlorine atoms. This, in turn, triggers a catalytic chain reaction in which a single chlorine atom can destroy hundreds of thousands of molecules in the ozone layer before it eventually falls back to earth.

Ozone is constantly created by the action of sunlight on oxygen molecules, but over time chlorine atoms from relatively few decomposed CFCs can destroy more stratospheric ozone than the sun can create. The ozone layer is shifting and amorphous. It is thinnest and reaches its maximum altitude in the high stratosphere over the tropics, which is where most of the ozone is produced. The layer is at its lowest over the poles.

Rowland and Molina pointed out in their 1974 report that almost all the CFCs that had been released since the 1930s were still in the lower atmosphere, and thus the effect on the ozone layer could be expected to intensify in the future. Last May, Rowland told a joint hearing of the Senate Subcommittee on Environmental Pollution and the Senate Subcommittee on Hazardous Wastes and Toxic Substances that certain CFC compounds—notably CFC-11, CFC-12 and CFC-113—have lifetimes in the lower atmosphere that range from 75 to 120 years. "A 120-year average lifetime, without any intervening major changes in the atmosphere, means that . . . even without any further emission of [CFC-12]—and releases are occurring daily all over the world sufficient to average about 400 kilotons annual-

DEFORESTATION AND THE USE OF FOSSIL FUELS HAVE CAUSED A HUGE

ly—appreciable concentrations . . . will survive in the atmosphere for the next several centuries."

But the publication of the Rowland-Molina report was just the beginning of the battle against CFCs. The Governing Council of the United Nations Environment Programme convened a panel of experts to examine the problem in 1977. The following year, Canada, Sweden and the U.S. banned the use of CFCs in aerosol sprays (but only a few other countries have followed suit and CFCs from aerosol sprays still account for about 15% of the global total according to the Environmental Defense Fund). In March 1985, after eight years of continued UN-sponsored meetings, the U.S. and 20 other countries signed what is now known as the Vienna Convention for the Protection of the Ozone Layer. The convention called for international cooperation in research and monitoring. It also provided for the adoption of international protocols to limit the emission of ozone-depleting substances, should such measures be necessary. Richard Benedick, a career diplomat who was the American deputy assistant secretary of state for environment health and natural resources, signed the document for the U.S., calling it "a landmark event. It was the first time that the international community acted in concert on an environmental issue before there was substantial damage to the environment and health."

Two months later, in May 1985, *Nature* published alarming new information about CFCs. This paper was written by Dr. Joe Farman, an atmospheric scientist with the British Antarctic Survey, which had been routinely measuring the ozone layer above the Antarctic since 1957. He and others examined the data and saw that in recent years the ozone levels in September and October (the Antarctic spring) had fallen considerably.

The British measurements came from ground-based observations, and the wary Farman wondered if NASA satellites had recorded the phenomenon from space. At first it appeared that they had not. However, further checks of NASA computer data revealed that the hole in the ozone layer was apparent as early as October 1978—the first year in which such satellite comparisons could be made—and had reappeared each year at roughly the same time. The Farman paper suggested that the ozone drop might be tied to CFCs. But other scientists thought the unique weather dynamics above Antarctica were a more important factor. In August 1986, Dr. Susan Solomon, an atmospheric chemist with the National Oceanic and Atmospheric Administration, led a team of scientists to the Antarctic to study the hole. At its maximum, it was the size of the U.S. The scientists also noticed that some ozone depletion extended as far north as Tierra del Fuego and Patagonia. This past August four more teams traveled to Antarctica to make further observations. Although scientists are still going over their data, there now seems to be general agreement that the ozone hole is caused primarily by chlorine from CFCs.

Depletion of the ozone layer increases the amount of ultraviolet radiation reaching the earth, and the potential effects on human health are considerable. First, there's skin cancer. It is the most common form of cancer in this country, with an estimated 500,000 cases discovered each year. A study published by the Environmental Defense Fund projects that by 2025 there will be an additional 1.4 million incidences of skin cancer over the present rate if nothing is done to control ozone depletion.

Cataracts are another threat posed by elevated UV levels. So is alteration of the immune system. Research on

NCREASE OF CARBON DIOXIDE, PROMOTING THE GREENHOUSE EFFECT.

the effects of UV radiation on the immune system has been done using mice as subjects. According to congressional testimony by Dr. Margaret L. Kripke, chairman of the department of immunology at the University of Texas, "There is considerable evidence that the UV rays damage a type of immune cell found in the skin, the Langerhans cell, and that this damage leads to activation of suppressor lymphocytes, instead of the appropriate immune response. Thus, although the initial damage is localized to the area of skin exposed to the UV radiation, the resulting immunological suppression is systemic, because the suppressor cells circulate throughout the body."

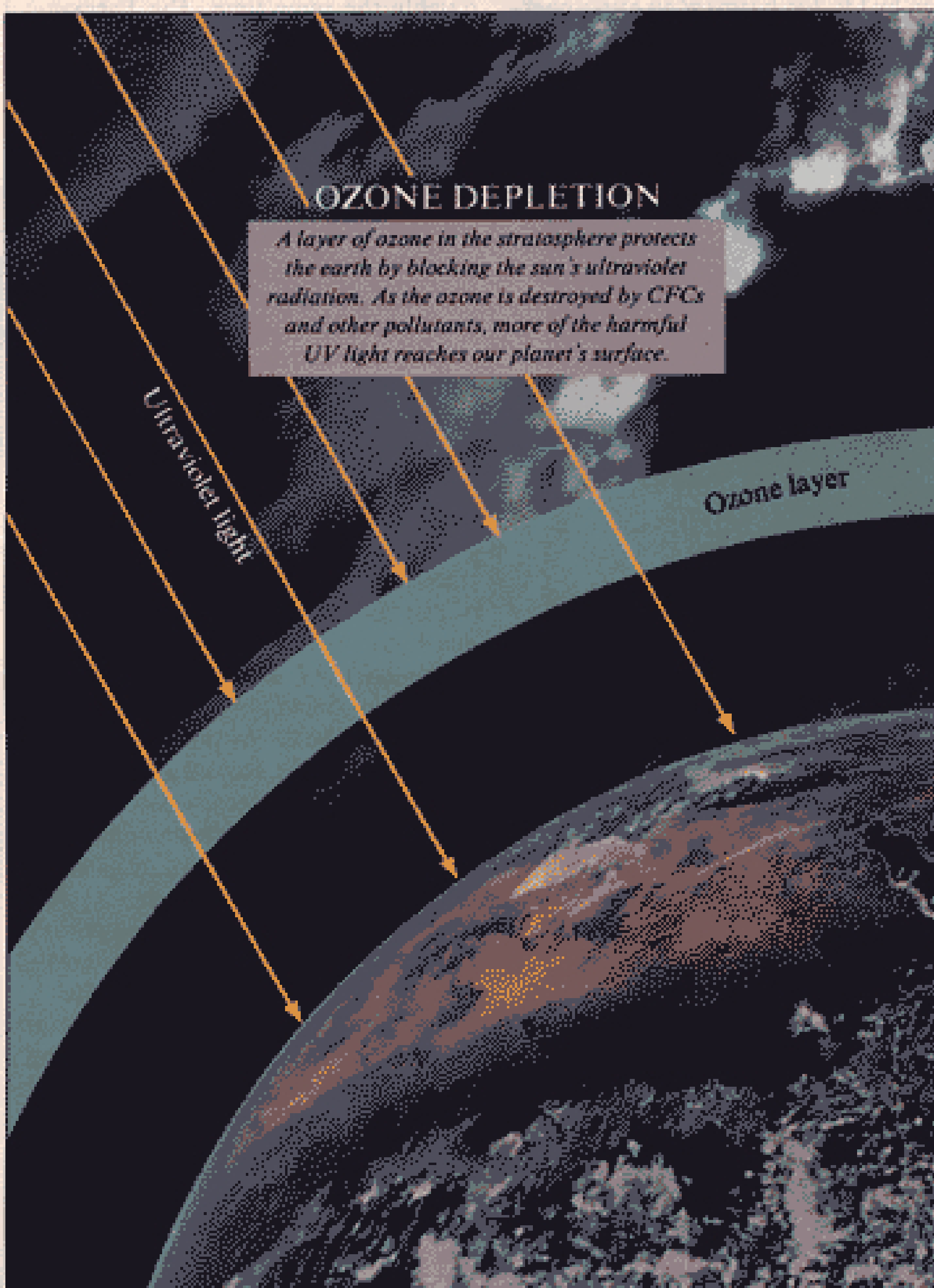
Not only mankind is at risk. Experiments with marine organisms have shown that UV radiation can damage animals in the marine food chain. The potential for damage to vegetation is also high. Dr. Alan Teramura, a professor of physiological ecology at the University of Maryland, reports that although some plants may adapt to UV radiation, many are adversely affected by increased levels. In tests, higher levels of UV radiation caused plant stunting, reduction in leaf area and reduced physiological vigor—the latter rendering them more vulnerable to pests and disease. In a six-year study of soybeans, UV radiation was increased to simulate a 25% reduction in the ozone layer; the result was a 20 to 25% loss in yields.

"Unlike drought or other geographically restricted stresses, increases in UV would affect all areas of the world simultaneously," Teramura says. "Even small reductions in crop yield on a global basis could lead to considerable economic consequences." Almost all knowledge of the effects of UV on plants comes from studies of cultivated crops, but these account for less than 10% of the world's vegetation. We have little or no information on the effects on the other 90%—the forests, grasslands and shrub lands. In fact, there is much we don't now know about the extent of the damage that may be done by CFCs rising into the sky, because nothing like it has ever happened before. But when it comes to massive changes in climate, there are some precedents that may give us signs of what to expect.

Over the last 2,000 years, the earth has undergone two major changes in climate. The first was a warm period known to scientists as the medieval warm epoch; it occurred between the years 800 and 1250, when average global temperatures were about the same as they are now. Certain areas, however, were distinctly warmer. During that time barley and oats were grown in Iceland and vineyards flourished in England, where sea levels were gradually rising. In Belgium the rising sea made Bruges, now some 15 miles inland, a seaport.

Around 985, the Vikings began to colonize Greenland, which had been discovered by Eric the Red. But by the end of the 13th century Arctic sea ice had spread through Greenland's waters and had become such a navigational hazard that the colonies died out.

The medieval warm epoch was soon followed by the Little Ice Age, which lasted from



OZONE DEPLETION

A layer of ozone in the stratosphere protects the earth by blocking the sun's ultraviolet radiation. As the ozone is destroyed by CFCs and other pollutants, more of the harmful UV light reaches our planet's surface.

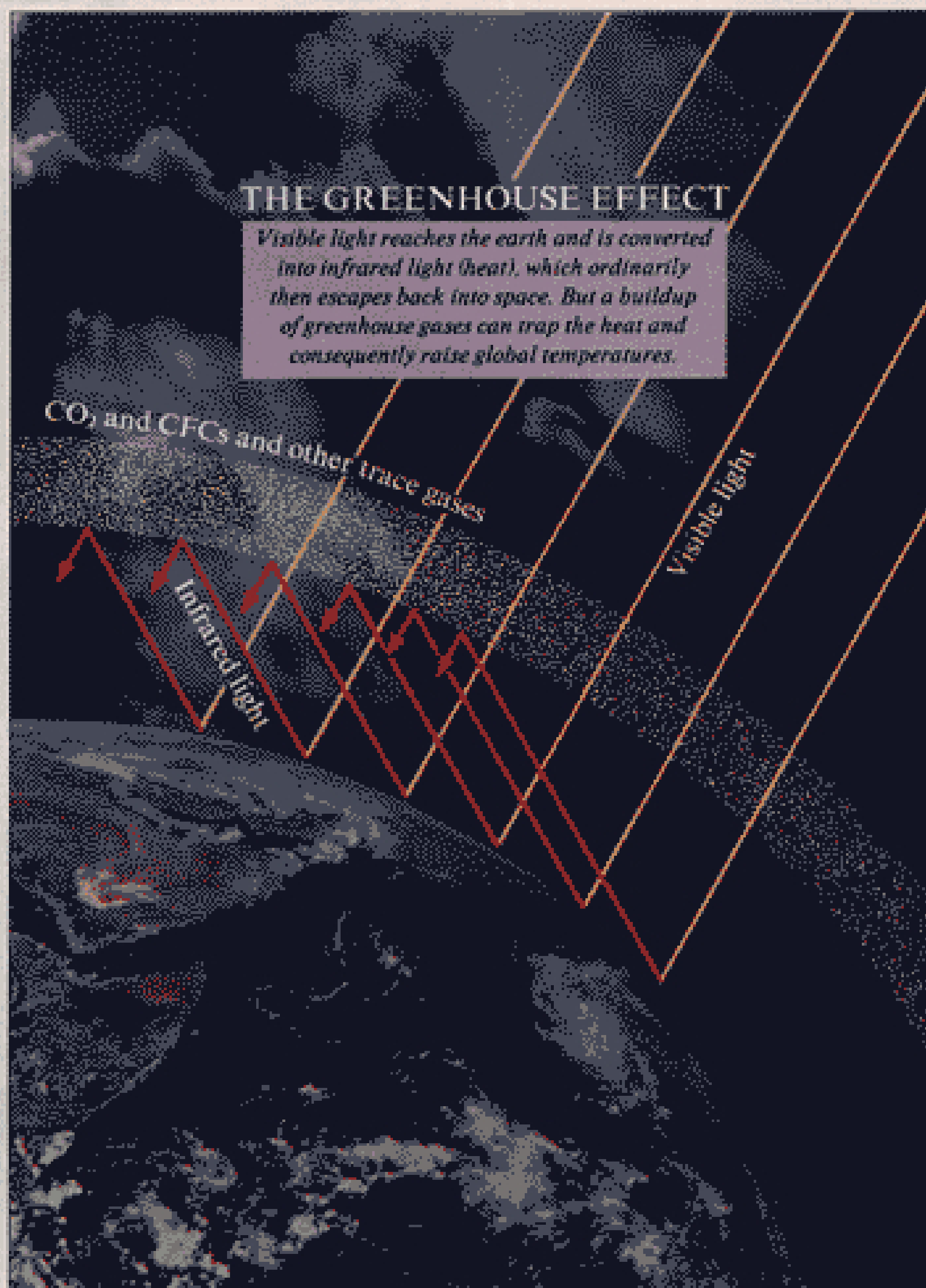
about 1550 to 1850, during which the global climate was generally about 1°C (2°F) cooler than now. In India, the monsoons often failed to arrive, prompting the abandonment in 1588 of the great city of Fatehpur Sikri because of lack of water. The Thames froze over several times in the late 1500s. Year-round snow, now absent, covered the high mountains of Ethiopia. The vineyards of northern France died off.

Some scientists who have studied the earth's climatic cycles believe that around 1700, when the Little Ice Age began its gradual decline, the earth swung into a period of 1,000 years of natural warming. This forecast, however, does not take into account the effect of *unnatural* agents, such as the increasing concentrations of carbon dioxide, nitrous oxide and other greenhouse gases in the atmosphere.

What's happening is this. Light from the sun passes through these transparent gases to the earth, where the shortwave radiation (light) becomes long-wave radiation (heat). The heat rises from the earth and ordinarily would escape into space. However, greenhouse gases absorb the long-wave radiation. Thus, the more these gases accumulate in the atmosphere, the more heat they absorb, and the warmer the earth becomes. In time, the planet will come to be like a greenhouse—or a car parked with its windows up on a sunny day.

The theory that increasing levels of carbon dioxide could cause this greenhouse effect was first advanced in 1896 by a Swedish physicist and chemist named Svante Arrhenius. However, the idea took on startling new significance in 1958 when Charles D. Keeling, a chemist and professor of oceanography at the Scripps Institution of Oceanography, began measuring atmospheric carbon dioxide on Mauna Loa in Hawaii. Since Keeling's measurements began, the concentration of the gas has increased every year. It jumped from 315 parts per million (ppm) in 1958 to 349 in 1987—a 25% increase from the levels that are thought to have been present before the industrial age. The increase is attributable to a combination of the burning of fossil fuels and the destruction of forests, which serve as reservoirs of carbon. A forest stores about 100 tons of carbon per acre, and in the last 40 years it is estimated that as much as half the world's forests have been destroyed. Given current emission levels, the atmospheric concentration of carbon dioxide is expected to reach about 420 ppm by the year 2030.

Two other greenhouse gases, CFCs and nitrous oxide, are double whammies: They are involved in the depletion of the ozone layer (in the case of nitrous oxide this is true only when the gas mixes in the atmosphere with CFCs or carbon dioxide) and they absorb heat. Measured in the range of parts per trillion, CFC concentrations



might seem insignificant, but they are extraordinarily effective heat absorbers. One molecule of CFC-11 or CFC-12 can trap as much heat as 10,000 molecules of carbon dioxide. And CFC levels are increasing at the rate of 5 to 7% per year.

Ground-level ozone also qualifies as a greenhouse gas. It is formed by the action of sunlight on nitrogen oxide and hydrocarbon pollutants emitted primarily by cars and trucks. We call it smog. Ozone has a split personality. Stratospheric ozone protects life by shielding the earth from harmful UV radiation; ground-level ozone is toxic. In the U.S. alone, according to a study made by the Environmental Defense Fund, ozone pollution is responsible for annual losses of as much as $2 billion in wheat, corn, soybeans and cotton. Ozone produced on earth cannot be used to replenish the ozone layer in the stratosphere because it has a limited life span before combining into other chemical substances. Therefore it doesn't last long enough to accumulate in amounts significant enough to replace what's being lost in the stratosphere.

In the last 100 years, the global mean temperature has gone up by about 0.5°C. Even if all emissions of greenhouse gases were cut off today, past emissions already make another 0.5°C increase likely by 2050. According to computer model estimates done by Dr. Veerabhadran Ramanathan, an atmospheric scientist at the University of Chicago, the global average surface temperature could increase by a total of as much as 4.5°C in the next 40 years, based on current levels of greenhouse gas emissions. That would make the earth almost as hot as it was during the Cretaceous period, the age of the dinosaurs, 100 million years ago. Mind you, that is the global average. The greatest increase in temperatures will occur from the mid-latitudes to the poles, where wintertime averages could be 10°C higher than now.

Hansen, of NASA's Goddard Center, uses a climate model that predicts a temperature increase averaging 1° to 2°C in the U.S. by the middle of the 21st century. He also has created a computer model that predicts temperature increases for a number of U.S. cities. By around 2050—give or take a couple of decades because the role of the oceans is not yet predictable and could delay the warming effect—Washington, D.C., which according to Hansen's model has about 36 days a year when the temperature exceeds 90°F, will have 87 such days; Omaha, with 37 days over 90° now, will have 86; New York, with 15 now, will have 48; Chicago, with 16 now, will have 56; Denver, with 33, will have 86; Los Angeles, with 5, will have 27; Memphis, with 65, will have 145; Dallas, which has 100, will have 162. Hansen's model similarly shows an increase in 100°F days: Washington goes from 1 a year to 12; Omaha from 3 to 21; New York from 0 to 4; Chicago from 0 to 6; Denver from 0 to 16; Los Angeles from 1 to 4; Memphis from 4 to 42; and Dallas from 19 to 78.

"Other discussions of the practical impacts of greenhouse warming have focused on possible indirect effects such as changes of sea level, storm frequency and drought," Hansen says. "We believe that the temperature changes themselves will substantially modify the environment and have a major impact on the quality of life in some regions. . . . However, the greenhouse issue is not likely to receive the full attention it deserves until the global temperature rises above the level of the present natural climate variability. If our model is approximately correct, that time may be soon—within the next decade."

Dr. Wallace Broecker, a geochemist at the Lamont-Doherty Geological Observatory of Columbia University, thinks the situation may be even worse than indicated by models, with their supposition of a gradual warming over a considerable period of time. "The earth's climate doesn't respond in a smooth and gradual way," he says. "Rather, it responds in sharp jumps. These jumps appear to involve large-scale reorganizations of earth systems. If this reading of the natural record is correct, then we must consider the possibility that the major responses of the earth system to our greenhouse provocation will also occur in jumps whose timing and magnitude are uneven and unpredictable. Coping with this type of change is clearly a far more serious matter than coping with a gradual, steady warming."

These models are far from perfect—none of them was able to predict the ozone hole over the Antarctic, for example—but, for now, they're our best source of information about changes we can expect to see by the year 2050. The view is not pretty.

Climate modeling done by Dr. Syukuro Manabe, an atmospheric scientist at the National Oceanic and Atmospheric Administration Geophysical Fluid Dynamics Laboratory in Princeton, N.J., led him to testify before a congressional committee in 1985 that "winters in Siberia and Canada will be less severe. Because of the penetration of warm, moisture-rich air into the high latitudes, a doubling of atmospheric carbon dioxide or the equivalent might increase the rate of river runoff in northern Canada and Siberia by 20 to 40 percent. Our climate model also indicates that in response to the increased greenhouse gases, summer drought will become more frequent over the middle continental regions of North America and the Eurasian continent. For example, the model-produced summer drought is characterized by dry soil, reduced cloud cover and higher surface temperature, which resemble the situation during the dust bowl of the 1930s."

A study by the National Academy of Sciences suggests that water volume in northern California rivers and in the Colorado River will decline by as much as 60%. This would leave much of the West without water. Southern California would run dry and be subjected to an increased incidence of fire, as would forests throughout much of the West and upper Midwest.

Within the past 100 years, tide gauges on the Atlantic Coast of the U.S. have documented a 30-centimeter, or one-foot, rise in sea level. Globally, the average is about five inches. Models predict that the level will have risen by another foot in low-lying coastal regions of the U.S. in 2030, and by as much as three feet in 2100. According to Dr. Steven P. Leatherman, director of the Laboratory for Coastal

Research at the University of Maryland, at least part of the present sea-level rise on the East Coast is caused by the natural compacting and subsidence of coastal sediment. But at least 4.5 inches of the rise has been caused by the expansion of warmer ocean surface waters and the melting of mountain glaciers, triggered in part by the 0.5°C increase in global temperature registered during the last century.

"Sea-level rise will promote increased coastal erosion," Leatherman says. "Already approximately 80 percent of our sandy coastlines is eroding. . . . Artificial nourishment is being used to restore beaches, but the costs are high." According to one study that will soon be published, the cost of maintaining East and Gulf Coast beaches will run anywhere from $10 to $100 billion. A series of aerial photographs taken since 1938, for instance, shows that the Blackwater National Wildlife Refuge on the eastern shore of the Chesapeake Bay, one of the most important East Coast waterfowl sanctuaries, is in a state of disintegration because of rising sea level. Human activity can hasten such destruction.

UV RADIATION CAUSES SKIN CANCER AND MAY SUPPRESS THE IMMUNE SYSTEM.

Some of the other threats posed by a one- to three-foot rise in sea level include increased salinity of drinking water; saline intrusion into river deltas and estuaries, which would imperil fisheries; the inundation of wetlands, cypress swamps and adjacent lowlands; increased flooding in populated areas, which would necessitate the building of costly flood protection systems, such as sea walls; the disappearance of beaches all over the world.

Then there are these further dire possibilities:

- Studies by meteorologist Kerry Emanuel at MIT indicate that more severe hurricanes are likely because of warmer oceans. Such storms could increase in ferocity by as much as 60% over current maximums.
- Radical change in the Antarctic ice sheet could have severe consequences. Antarctica has 91% of the world's ice (only 1% is locked up in mountain glaciers). If the Antarctic ice sheets were to melt completely, the global sea level would rise 15 to 20 feet. No one expects that to happen. At currently projected rates, the greenhouse effect and global warming are not expected to have a major impact on the Antarctic ice sheet for several centuries. But no one predicted holes in the ozone layer, and as Dr. Stanley S. Jacobs, a senior staff associate at Lamont-Doherty, said in a recent article in *Oceanus* magazine: "Antarctica may be a wild card in the deck, but who can say the deck is not stacked, with Nature setting up the sting?"

Couple all the greenhouse effects with increased ultraviolet radiation, and we have written the prescription for disaster—ecological, economical and political.

It is ludicrous to assume that we could rapidly adapt to such changes. "Infrastructures of society, such as water supplies, transportation networks, and land use patterns have evolved over centuries in response to prevailing climate," says Dr. Gordon J. MacDonald, a former professor of geophysics at Dartmouth who's now vice-president and chief scientist of the Mitre Corporation, a nonprofit research organization. "Significant changes in climate over decades will exert profound disruptive forces on the balance of infrastructures."

MacDonald is talking about infrastructures that are already in place. But corporations and governments throughout the world are now making big decisions about long-term projects that involve coastal development, massive land use, irrigation, hydroelectric power, oil exploration, natural

RISING SEA LEVELS COULD ADVERSELY AFFECT PORTS LIKE LONDON.

gas, etc. Nearly all of these decisions are being based on the notion that the climate of the recent past will continue into the future. This is no longer a safe assumption. In October 1985 the World Meteorological Organization, the International Council of Scientific Unions and the United Nations Environment Programme convened a conference in Villach, Austria, at which more than 80 scientists from 16 countries assessed the climatic changes that could be brought about by the accumulation of greenhouse gases. The scientists concluded that using the climate of the recent past to plan for the future "is no longer a good assumption since the increasing concentrations of greenhouse gases are expected to cause a significant warming of the global climate in the next century. It is a matter of urgency to refine estimates of the future climate conditions to improve these decisions."

Dr. Michael Oppenheimer, a former Harvard astrophysicist who is now senior atmospheric scientist with the Environmental Defense Fund, puts it this way: "We're flying blind into a highly uncertain future. These changes are going to affect every human being and every ecosystem on the face of the earth, and we only have a glimmer of what these changes will be. The atmosphere is supposed to do two things for us: maintain a constant chemical climate of oxygen, nitrogen and water vapor, and help maintain the radiation balance—for example, by keeping out excess UV. The unthinkable is that we're distorting this atmospheric balance. We're shifting the chemical balance so that we have more poisons in the atmosphere—ozone and acid rain on ground level—while we're also changing the thermal climate of the earth through the greenhouse effect and—get this—simultaneously causing destruction of our primary filter of ultraviolet light. It's incredible. Talk about the national-debt crisis—we're piling up debts in the atmosphere, and the piper will want to be paid."

The fate of the earth rests on political decisions, which doesn't necessarily make it hopeless. Until recently, the Reagan Administration has done little to deal with the crisis of atmospheric pollution. When the issue has been addressed, it has been largely at the prodding of individual legislators: in the Senate by Republicans John Chafee of Rhode Island, Robert Stafford of Vermont and Dave Durenberger of Minnesota, and Democrats Max Baucus of Montana and George Mitchell of Maine, all members of the Environment and Public Works Committee.

Albert Gore, the Tennessee Democrat who's now a senator, led hearings on the greenhouse effect while he was in the House in 1981, and he's the first current presidential candidate to raise the issue. Indeed, Gore's willingness to discuss this politically unpopular subject prompted columnist George Will to chide him for "a consuming interest in issues that are, in the eyes of the electorate, not even peripheral." But as Chafee says, "This is not a matter of Chicken Little telling us the sky is falling. The scientific evidence is telling us we have a problem, a serious problem."

Fortunately, it's still possible to ameliorate the damage. Here's what we must do:

• *Reduce production of CFCs by 95% worldwide within the next six to eight years.* Chafee and Baucus have introduced bills calling for such a reduction. Last winter Chafee told CFC manufacturers, "If the six- to eight-year phase-out in our bills is unrealistic, tell us how much time you need and show us how you will use that time. We are

SOME PREDICTED CHANGES: WARMING IN SIBERIA AND DROUGHT IN CALIFORNIA.

open to suggestions, but the burden is on you to justify a longer time frame. . . . Undoubtedly there will be testimony that we cannot ratchet down on production of CFCs too swiftly. It is well to recall that the ban on aerosols in the U.S. caused production of CFCs for aerosols to drop . . . to less than 25 million pounds . . . six years later. And our country survived. I am not convinced that American or any other producers have a constitutional right to continue to produce products that cause permanent harm to our world, to our citizens."

In September the U.S. and 23 other countries signed a treaty calling for a 50% cut in CFC production by mid-1999, but the new findings from the Antarctic demonstrate that the cut is neither big enough nor fast enough. "We've got to beat the clock," says Rafe Pomerance, a policy analyst who has been following the ozone problem for the World Resources Institute in Washington, D.C., for the past two years. "If the data from the Antarctic continues to build over the next few months, we may have to reconvene and strengthen the treaty."

• *Reduce dependence on fossil fuels.* "We should focus on incremental steps that limit our dependence on coal and oil," Oppenheimer says. "Let's focus on the doable. No. 1, conservation. The U.S. still uses twice as much energy per capita as the European nations. We're wasting money, we're wasting energy, and we're producing too much carbon dioxide because of our overdependence on fossil fuels."

Reliance on these fuels can also be reduced through greater use of nonpolluting alternative sources of energy. Solar power is a prime example, but the U.S. seems to have given up leadership in photovoltaic research, and the Japanese are now forging ahead. Photovoltaic technology promises to deliver energy at a reasonable price without producing carbon dioxide.

• *Halt deforestation.* "You have to do two things," says Dr. George M. Woodwell, former president of the Ecological Society of America and now director of the Woods Hole (Mass.) Research Center. "First, you have to stop deforestation around the world, not just in the tropics, and you have to do it on the basis of an international protocol. Second, you have to have an equally intensive and imaginative protocol that calls for reforestation so as to store one billion tons of carbon annually. A million square kilometers is 600 miles by 600 miles, and we will probably have to reforest on the order of four million square kilometers per year over good land to do the job."

• *Establish a national institute devoted to basic environmental research.* Says Oppenheimer: "We need a national commitment comparable to the Manhattan Project, not only so we can understand what the consequences of global change are for man, but so that we can be in the forefront of the development of alternative energy sources that will help limit this problem. I envision a multibillion dollar scientific effort. It's as important as national defense. It *is* the national defense. If we do nothing waiting for the atmosphere to change and for unpleasant consequences to occur, it will be too late for us to avoid disruptive and devastating changes."

• *Discontinue basic environmental research by or funded by EPA and the Department of Energy.* These agencies are unreliable because they are heavily influenced by political pressures. Last January, Broecker bluntly told the Senate Subcommittee on Environmental Protection, "I believe that most scientists would agree with me that the handling of research on greenhouse gases by DOE [the Department of Energy] and on acid rain by EPA has been a disaster."

Will the world act in time? As Rowland, who won eight varsity letters in basketball and baseball at Ohio Wesleyan and the University of Chicago, puts it, "The key thing about baseball is, there is always next year, another season. The question for the earth now is, will there be a next year?" ■