Should We Worry About Ozone?

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Executive Summary

Synthetic chemicals known as chlorofluorocarbons (CFCs) have been widely used in air conditioners, refrigerators and cleaning compounds. CFCs are safe because they are nontoxic and nonflammable. Eventually, however, they diffuse upward into the stratosphere, where they are broken up by ultraviolet radiation and release reactive chlorine.

Scientists have shown that chlorine atoms can contribute to destruction of ozone. Although ozone near the earth is considered a harmful pollutant, ozone in the upper atmosphere blocks ultraviolet radiation, which can be dangerous to plant and animal life.

A theory held by some scientists is that the depletion of stratospheric ozone is substantial and will grow to alarming levels unless the use of CFCs and some related chemical compounds is eliminated. This theory led to an international treaty requiring that production of CFCs be rapidly phased out in developed countries. However, the theory of large-scale depletion caused by human use of these chemicals is not yet supported by solid scientific evidence.

It is not clear that stratospheric ozone is being significantly depleted worldwide, or that any depletion that may have occurred is permanent.

- Stratospheric ozone fluctuates so dramatically that it is almost impossible to define a long-term, statistically significant trend.
- The time period chosen for observation affects the conclusions; for example, ozone levels decreased from 1969 to 1985 but increased from 1962 to 1979.

If the ozone layer *is* being depleted, it is not clear that CFCs are the major cause or that reducing their use now will stop or even slow depletion.

- The general theory about ozone depletion and the role of CFCs has been revised many times, and continues to be neither proven nor refuted.
- The very close correlation between the variation in the earth's ozone level and the variation in seasonal sunspots suggests that sunspot cycles have more impact than CFCs in reducing global ozone.

It appears that the "ozone hole" above Antarctica (actually a dramatic thinning of the ozone in the lower stratosphere) is caused by unique conditions, and it is uncertain whether additional or reduced chlorine from CFCs would affect it.

- The large and unpredictable yearly fluctuations in the size of the hole argue against a simple theory of causation by CFC.
- The Antarctic polar vortex and stratospheric temperatures seem to have more impact than chlorine on the size of the hole, and chlorine may not be the limiting factor in ozone depletion.

Even if ozone depletion does occur, there is no reliable evidence that it will represent a grave threat to living things on earth.

- Some evidence indicates that the amount of ultraviolet radiation reaching the earth is down, not up, raising questions about the increased danger of skin cancer.
- Even if ultraviolet radiation is increasing, the harm to date is far less than the harm to which we routinely expose ourselves when we travel to higher altitudes or move a few miles closer to the equator.

The costs of eliminating CFCs for refrigeration and cooling are higher than most people realize, with estimates reaching nearly $100 billion over the next 10 years in the United States alone — an amount equal to almost $1,000 for every U. S. household.

- Some CFC alternatives are highly flammable and at least one causes tumors in rats.
- Lack of refrigeration is one of the most serious causes of health problems in the developing world — both because it leads to microbial food poisoning due to food spoilage and because life-saving vaccines deteriorate without refrigeration.

Much of the fear about ozone depletion has been generated by alarmist announcements during the 1980s and early 1990s by officials of the Environmental Protection Agency and the National Aeronautics and Space Administration. For example:

- EPA Administrator William Reilly claimed in 1991 that the northern midlatitudes (including the area over the northern United States) had been losing ozone so fast that an additional 200,000 deaths from skin cancer would occur over the next 50 years in the United States alone.
- NASA scientists claimed in 1992, while Congress was considering the NASA budget, that a hole could open in the ozone layer over the Arctic that would expose North America and northern Europe to higher levels of ultraviolet radiation.

Such scary scenarios may garner increased research support for scientists and their laboratories, but they do not hold up under scrutiny.

There is scientific support for concern, but not for panic. In our judgment, the Montreal Protocol banning CFCs should be changed to make the phase-out more gradual, and the costs (including such social costs as the loss of safety) of halting CFC production should be weighed against the small and uncertain benefits to the ozone.

Introduction

In 1992 a United Nations report predicted 1.6 million new cases of cataracts and 300,000 new cases of skin cancer each year.[1] Vice President Al Gore wrote that human immune defenses would weaken, implying that the AIDS epidemic might worsen.[2] *Time* warned of "horrendous long-term effects on human health, animal life, the plants that support the food chain and just about every other strand that makes up the delicate web of nature."[3]

Welcome to the ozone scare, the fear that the world's ozone layer is being eaten away by manmade chemicals known as chlorofluorocarbons (CFCs).

The theory behind the ozone scare is as follows: CFCs, which used to be in aerosol spray cans and are still around in air conditioners, refrigerators and some foam insulation, eventually will make their way into the upper atmosphere, where they may destroy a large part of the ozone layer. Although increased ozone on the ground is a harmful pollutant, ozone in the upper atmosphere blocks the ultraviolet radiation that can be dangerous for humans, other animals and plants.

"It is not clear that ozone is being significantly depleted globally."

Most scientists accept this theory. But it must be balanced against the following considerations:

- It is not clear that the ozone is being significantly depleted globally;
- If the ozone layer is being depleted, it is not clear that CFCs are the major cause or that reducing their use now will stop or even slow depletion;
- Some evidence indicates that the amount of ultraviolet radiation reaching the earth is down, not up;
- No reliable predictions indicate that if ozone depletion does occur, it will represent a grave threat to living things on earth; and
- The costs of eliminating CFCs are higher than most people realize, with estimates reaching nearly $100 billion over the next 10 years in the United States alone.

What Is Ozone?

Ozone is a gas found in both the atmosphere at sea level and in the stratosphere, the area from five to 31 miles above the earth.[4] Most ozone (roughly 95 percent) is found in the stratosphere in what is sometimes called "the ozone layer." The amount of ozone is very small (a few parts per million or less). If the entire stratospheric ozone layer were compressed to the same pressure as the air we breathe, the ozone would be about one-eighth of an inch thick.

The main reason ozone is important is that it absorbs a band of ultraviolet radiation (known as UV-B radiation) which comes from the sun.[5] If the amount of ozone declines, more UV-B rays could reach the earth. Although ultraviolet radiation is essential to life, in large doses it can cause harm. Sunburn and cornea irritation are the best-known effects of too much UV-B radiation. It also is believed to cause certain forms of skin cancer.

"Ozone is important because it absorbs UV-B radiation, which can cause harm in large doses."

Interestingly, ultraviolet rays are the reason why ozone exists in the first place — since ozone is formed when ultraviolet radiation breaks up oxygen molecules.[6] (The shorter wavelength rays that split up oxygen are known as UV-C rays.) Ultraviolet rays are also a source of ozone destruction.

What Are CFCs?

Chlorofluorocarbons (CFCs) are synthetic chemicals widely used in air conditioners, refrigerators and cleaning compounds. The federal government banned their use in aerosol spray cans in 1978, and they are now being phased out of all uses under an international treaty. Major CFC producers, including DuPont and ICI, have agreed to stop producing the chemicals by the end of 1995 and have been developing substitutes.[7]

CFCs are inert. They do not react with other chemicals. (That is one reason why they have been such a boon to humankind: They are nontoxic and nonflammable.) As a result, CFCs reside in the lower earth atmosphere for decades, eventually diffusing upward into the stratosphere. There, they are broken up by UV radiation, releasing reactive chlorine. There too, according to a theory proposed by scientists Mario Molina and Sherwood Rowland in 1974 and widely accepted today, the free chlorine atoms help to deplete ozone.[8]

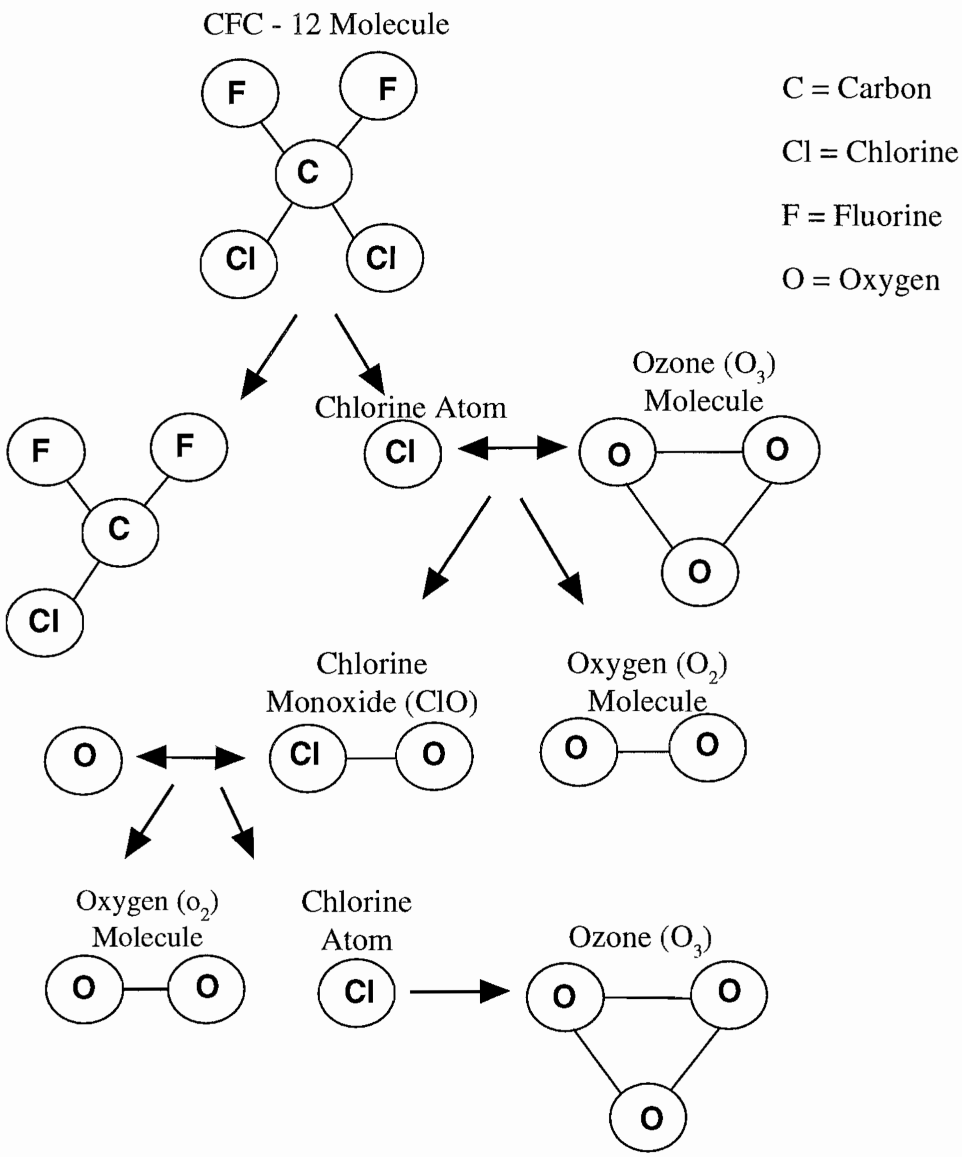
This complex process can be summarized as follows: Each chlorine atom reacts with an ozone molecule, producing chlorine monoxide and an oxygen molecule. Chlorine monoxide in turn reacts with an oxygen atom to produce a chlorine atom and another oxygen molecule, both of which react with other ozone molecules.[9] [See Figure I.] If the chemicals react in the stratosphere as scientists theorize, each chlorine atom may be capable of destroying as many as 100,000 ozone molecules before it is inactivated or returned to the lower atmosphere.[10]

Is the Ozone Being Depleted Worldwide?

That is unclear. If it has been depleted in recent years, the amount of depletion has been quite small. And there is no hard evidence that any depletion is permanent.

FIGURE I

How CFCs Destroy Ozone: The Elements of an Unproved Theory



Steps:

1. CFC-12, used in household refrigerators, has a very long life — approximately 110 years. Eventually it rises into the stratosphere.
2. At high altitudes, ultraviolet rays break down CFC-12 molecules into a free chlorine atoms and other molecules.
3. The single chlorine atom (Cl) combines with ozone (O_3) to form chlorine monoxide (ClO) and molecular oxygen (O_2).
4. The chlorine monoxide molecule is very reactive and quickly combines with atomic oxygen (O) to form another oxygen molecule (O_2) plus free chlorine.
5. This process may be repeated many times, so that a single chlorine atom may destroy hundreds of thousands of ozone molecules during its residence in the stratosphere.

What most Americans know about ozone they learn from the popular press. That has encouraged individuals whose reputations and research grants are at stake to focus on public relations, sometimes at the expense of traditional scientific verification. This prompted S. Fred Singer, who developed the satellite-based instrument that measures ozone, to complain about "scientists announcing momentous findings by press release ... with the normal peer review process unable to keep pace with policy decisions."

Science by Press Release. During the 1980s and early 1990s, fear of ozone loss in the stratosphere was periodically reflected in the popular press. For example, in March 1988 NASA's Ozone Trends Panel held a press conference to announce it had found a 2 to 3 percent decrease in ozone between 1969 and 1986. Reporters never saw the actual scientific report, nor did anyone else who was not on the panel. In fact, the report was not made public until three years after the press conference and six months after the London conference that banned CFCs. The report did confirm the claims of the press release, but it also made clear that the panel had to go to heroic, subjective lengths to remove the "noise" in the data — noise ranging from sunspots to volcanic activity. The trend thus identified was very small, and the original unadjusted data were not published.[11]

In April 1991 Environmental Protection Agency Administrator William Reilly made a major announcement. He said that new information from NASA satellite ozone measurements showed the northern midlatitudes (including the area over the northern United States) to be losing ozone at a rate of 4 to 5 percent per decade — far more than previously thought.

"The EPA ignored data indicating that ozone decreased between 1979 and 1986, but then began to increase."

What the EPA ignored was that the data indicated that ozone had decreased between 1979 and 1986 and then had begun to *increase*. It also ignored the fact, recognized by NASA scientists, that 11.5 years of data aren't enough to distinguish a human-caused decline from the effects of the natural sunspot cycle. (Sunspots increase the production of ozone, and the sunspot cycle reached a minimum in 1986.)[12]

Extrapolating from this weak evidence and assuming that depletion would continue at the same rate for 50 years until it reached 25 percent, Reilly claimed that there would be an additional 200,000 deaths from skin cancer in the United States alone over that period[13] — a claim so extreme it is hard to imagine how he came up with it. He apparently assumed that all the additional cancers would be melanomas rather than the more common and more easily treated forms of skin cancer. In fact, the link between ultraviolet rays and melanoma is highly uncertain.

At another press conference on February 3, 1992, while Congress was considering NASA's budget, NASA scientists announced that high levels of chlorine monoxide in the Arctic could lead to an ozone hole large enough to expose the populated areas of North America and northern Europe to higher levels of ultraviolet radiation. *Time* magazine's cover story was entitled "The Ozone Vanishes," and *Time* warned: "A hole in earth's protective shield could soon open above Russia, Scandinavia, Germany, Britain, Canada and northern New England."[14] Other publications echoed similar fears.

Responding to a United Nations report concluding that "ultraviolet radiation leaking through the ozone layer by the turn of the century could cause 1.6 million additional cases of cataracts and 300,000 additional skin cancers a year worldwide,"[15] then-Senator Gore within days introduced a bill calling for a ban on CFCs by 1995. The bill passed unanimously. According to the *Washington Post,* the indications of ozone depletion were so "alarming" that NASA decided to release its findings before the data were analyzed. But a major northern ozone hole never materialized.

"The major northern ozone hole never materialized."

Most scientists believe that the high levels of chlorine monoxide measured in early 1992 were due to the 1991 volcanic explosion of Mount Pinatubo in the Philippines. The sulfur it emitted formed sulfuric acid droplets around the world. They temporarily prevented the normal chemical reactions that would have tied up chlorine, preventing it from depleting the ozone.[16] Strangely enough, many scientists suspected this effect long before NASA made its announcement.

Yet science by press release is increasingly acceptable to those who want to manipulate the political process. For example, Stephen Schneider, the former National Center for Atmospheric Research scientist who headed one of the leading climate modeling teams in the United States, told *Discover* magazine:[17]

> "We need to get some broad-based support, to capture the public's imagination. That, of course, entails getting loads of media coverage. So we have to offer up scary scenarios, make simplified, dramatic statements, and make little mention of any doubts we may have. . . . *Each of us has to decide what is the right balance between being effective and being honest.* I hope that means being both." [Emphasis added.]

Of course, scary scenarios enhance the likelihood of additional support for the research scientists and their laboratories.

Taking A Closer Look at the Evidence. It is extremely difficult to identify a trend in stratospheric ozone because it fluctuates dramatically.

- During 1980, for example, satellite measurements of ozone over Washington, D.C., varied by more than 25 percent from day to day during winter and spring.[18]
- During that period, ozone levels over Washington were sometimes 25 percent greater than those over Miami.[19]

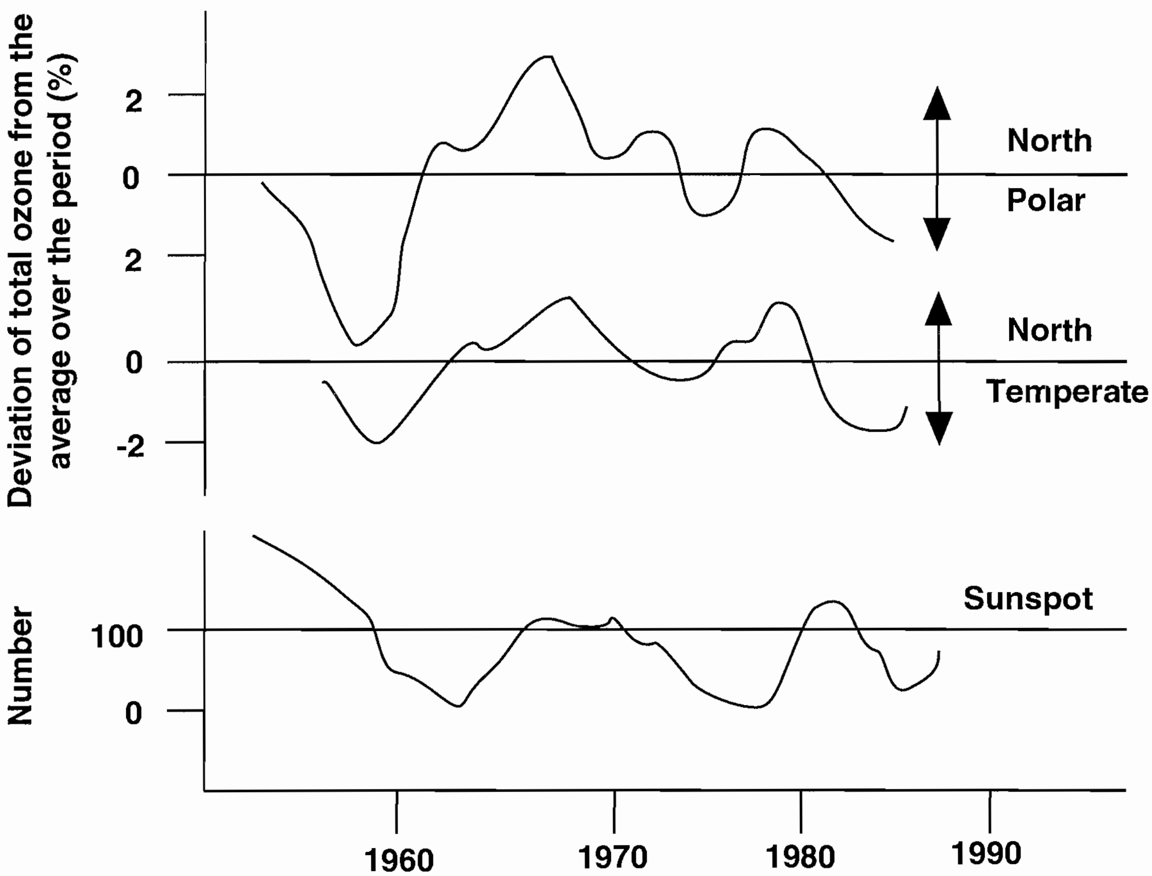
"It is almost impossible to find any long-term, statistically significant trend in stratospheric ozone."

In the face of so much natural variability, it is almost impossible to find any long-term, statistically significant trend. So far, researchers have failed to find such a trend. As Fred Singer has pointed out:[20]

- At some of the Ozone Trends Panel measuring stations, natural variations were as large as 50 percent over a few months, while the long-term decrease was asserted to be 0.2 percent per year.
- This means that "the natural variations are a hundred times larger than the alleged steady change."

FIGURE II

Ozone Levels and Sunspots



Source: Dr. James Angell, *Journal of Climate,* 1989. S. Fred Singer, "The Science Behind Global Environmental Scares," *Consumers' Research*, October 1991, p. 18.

Note: These lines show that average ozone levels closely correspond to changes in the number of sunspots on the sun (a number that reflects the "sunspot cycle"). More sunspot activity means that more ozone is produced, and less activity means that less ozone is produced. This naturally occurring correlation may be more important than any other, such as the presence of CFCs in the stratosphere, in determining the ozone level.

Another problem is the behavior of the sun. As Figure II shows, the correlation between the variation in the earth's ozone level and the variation in seasonal sunspots is very high. This correlation undermines much of the evidence for ozone depletion:

- Kevin Trenberth of the National Center for Atmospheric Research in Boulder, Colo., concluded that most of the decrease in ozone in the northern hemisphere can be explained by the 11-year sunspot cycle.[21]
- Another study in the *Journal of Geophysical Research* concluded that 73 percent of the global decline in ozone between 1979 and 1985 was due to solar variability.[22]

"Depending on the dates chosen for the measurements, ozone levels could have shown an increase instead of a decrease."

A final problem is the time period chosen. The Ozone Trends Panel looked at changes in ozone levels over the 17-year period between 1969 and 1985. But as Fred Singer and other scientists have pointed out, this arbitrary choice of starting and ending dates may have led to spurious conclusions. Had they chosen the 17-year period beginning in 1962 and ending in 1979, the panel would have observed an *increase* in ozone.[23] If the measurements had begun in 1985, they would also have observed an increase.[24]

Measurement of ozone is a complex business and has not been going on long enough to assure accuracy. Two scientists from the Belgian Meteorological Service, writing in the *Journal of Geophysical Research*, reported in 1992 on their studies of ozone data measured from the ground for over seven years. They contend that atmospheric sulfur dioxide is contaminating ozone measurement, and they consider widespread reports of depletion based on ground-level measurements to be unreliable.[25]

Long-Term Trends. As Figure II shows, viewing the data over a period of 30 years gives a much different picture than viewing them over 17 selected years. For example, in 1962 CFCs were not in widespread use and could not have been blamed for ozone depletion. Yet in 1990, atmospheric scientist Hugh Ellseasser stated that there was more ozone then than there was in 1962.[26]

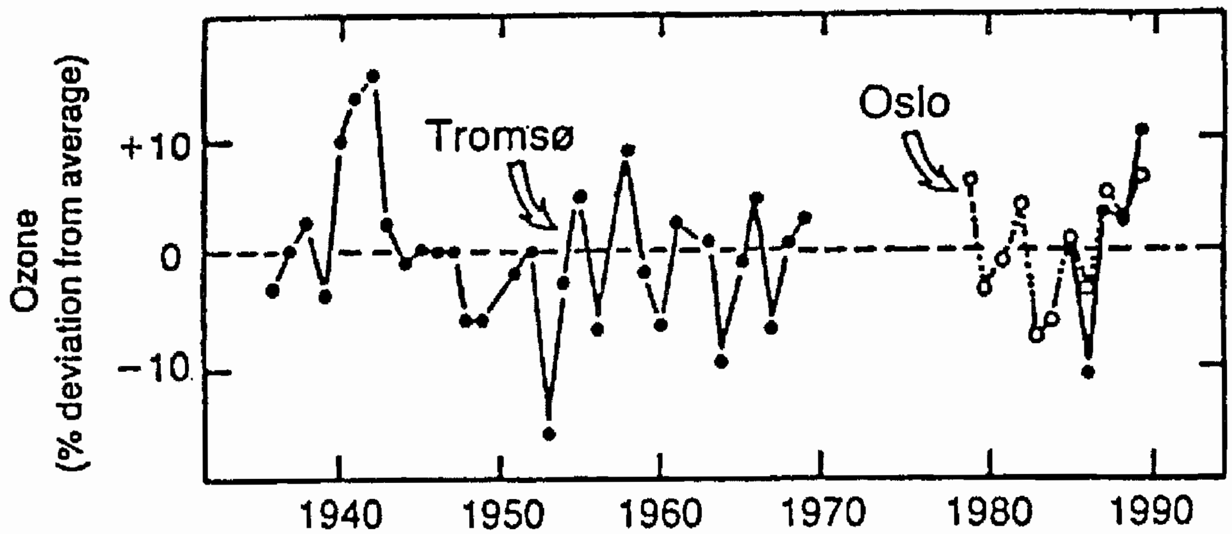
Data over an even longer period were produced by a study of ozone levels over Scandinavia. The study found no evidence of long-term ozone depletion over the Arctic region since 1935.[27] [See Figure III.]

Is Stratospheric Ozone Depletion Caused by CFCs?

The chemistry of the ozone depletion theory is widely accepted, even though scientists do not try to estimate the quantitative effect of additional CFCs. Some atmospheric scientists concede that the data are not all in on the chemistry itself, but they have not mounted a major challenge the way they

FIGURE III

Ozone Measurements in the Arctic



The average spring values of ozone (February, March and April) for the Norwegian stations at Tromso at latitude 70 N (filled circles) and Oslo (open circles). This is the period when ozone depletion occurs in Antarctica (August, September and October). These values show wide fluctuations and no sign of a trend toward ozone depletion.

Source: Frederick Seitz, *Global Warming and Ozone Hole Controversies: A Challenge to Scientific Judgment* (Washington, DC: George C. Marshall Institute, 1994), p. 18.

"There is no evidence of long-term ozone depletion over the Arctic region since 1935."

have with global warming. Also, few discuss the actual consequences of the anticipated ozone loss over the next century, even though, as we shall see, the consequences are probably more benign than the general public believes.

One reason the issue seems settled is that the theory has been around a long time, and no clear or convincing refutation has emerged. But that does not mean the theory is correct. It has been revised again and again as new information has emerged. Along with these revisions have come fluctuations in the projected impact of CFCs on the atmosphere:[28]

- In 1979 the National Research Council predicted an 18 to 20 percent depletion of stratospheric ozone by the mid-21st century.
- In 1982, the prediction was 9 percent and by 1984 it was 3 percent.
- Many are reluctant to make predictions today because no one knows whether stratospheric reactions mirror those in the laboratory.

The interactions are complex, and the needed projections of chemical constituents, temperatures and reaction rates cannot be made with available knowledge.

In addition to these fluctuations in the general theory about ozone depletion, scientist Fred Singer has noted the many "wild gyrations" in particular theories of catastrophe. Take the theory that airplane exhaust from supersonic transports (SSTs) would destroy the ozone:[29]

- In 1970 some scientists predicted that 70 percent of the ozone would be destroyed by the SST fleet.
- The prediction soon fell to 10 percent depletion, and by 1978 scientists began asserting that SST exhaust would *add* to the ozone layer.
- By 1980 the predictions had switched and the effects of SSTs were again supposed to be slightly negative.

The Ozone Hole Over Antarctica

"A dramatic thinning of the ozone in the lower stratosphere above Antarctica begins in August, but ozone-rich air from lower latitudes later reverses the trend."

The "ozone hole" is a very large seasonal thinning of the ozone layer in the lower stratosphere above Antarctica.[30] British scientists reported in *Nature* in 1985 that the 1984 springtime measurements of the vertical column of total ozone over the Antarctic, measurements taken from August to October, were more than 40 percent below those taken in 1977. Actually, seasonal thinning had been recorded by satellite instruments since 1974 but had not reached high levels until the mid-1980s.

This severe loss of ozone is not really a "hole" but rather a dramatic thinning of the ozone in the lower stratosphere (roughly from eight to 15 miles up). It begins in August (the end of winter in the Southern Hemisphere), reaches a maximum sometime in October (spring in the Southern Hemisphere) and then reverses itself when ozone-rich air flows in from lower latitudes. This inflow occurs when the polar vortex, an isolated air mass that circulates around the South Pole much of the year, breaks up as temperatures warm.

The average total amount of ozone in a vertical column during this August to October period had been between 275 and 300 Dobson units in the 1960s and early 1970s, but it fell to about 180 units in 1984. (A Dobson unit is a measure representing an extremely small amount of ozone.) The drop to 180 units of total ozone overhead gives rise to the claim that a hole opens in the stratospheric layer of ozone. The so-called hole has recurred each year. In 1987, ozone reduction reached a historic maximum, with as much as 50 percent depletion of total ozone. The hole was much smaller in 1988, but approached the maximum in subsequent years.

"The Antarctic ozone hole was a complete surprise to scientists."

The Antarctic ozone hole was a complete surprise to scientists. The conditions leading to the hole are unique, and the chlorine chemistry proposed by Molina and Rowland did not explain the steep seasonal ozone decline. The mathematical models used at the time to forecast future global ozone depletion due to CFCs predicted a global decline of at most 5 percent sometime during the 21st century, not the severe but localized losses of this magnitude.[31] In addition, the models predicted that the most significant ozone depletion would occur in the upper stratosphere and in the midlatitudes (between the poles and the equator), but the "hole" occurred mostly in the lower stratosphere and over the South Pole.[32]

Scientists and the media leaped on the discovery of the hole as a sign that the problem of ozone depletion had been drastically underestimated. They expressed fear that the ozone hole would eventually bulge over more of the Antarctic Ocean, pushing toward population centers of the Southern Hemisphere.[33] However, the refinements in ozone science following the discovery of the hole also indicated the unique role of the Antarctic polar vortex. The ozone-destroying conditions in the vortex simply do not exist elsewhere. The experience also showed that the theory of ozone depletion was incomplete, since it failed to predict the event in the first place. The theory continues to develop, but remains incomplete.

Scientists were quick to organize information-collecting missions and to theorize about the newly discovered hole. Within a few years, scientists generally settled on the view that peculiar conditions in the Antarctic—in particular, extremely cold polar stratospheric clouds—trigger the depletion in two ways. In the presence of these clouds, reactions apparently take place in which chlorine nitrate and hydrogen chloride (which otherwise would inhibit the reaction of chlorine and ozone) are converted into a far more reactive form of chlorine, Cl_2. This subsequently dissociates when spring begins, forming atomic chlorine. In addition, the cold may convert the nitrogen oxides to nitric acid, which freezes or liquefies and then is removed by precipitation. (Otherwise, the nitrogen oxides would react with chlorine to form chlorine nitrate.) When the sunlight returns, ozone is rapidly depleted.[34]

The large and unpredictable yearly fluctuations in the size of the ozone hole argue against a simple theory of CFC causation. Chlorine has been increasing gradually in the stratosphere for many years, but the ozone hole shows great variability. Mark Schoeberl and Dennis Hartmann stated in *Science* that the strength of the Antarctic vortex and stratospheric temperatures seem to have more impact than chlorine on the size of the hole.[35] Japanese researchers Hiroshi Kanazawa and Sadao Kawaguchi argued in 1988 that "warming and ozone transport by dynamical process can deeply affect the depth and area of the Antarctic ozone hole."[36]

Clearly, factors other than CFCs are at work. In 1988 a sudden warming in the stratosphere over Antarctica in winter and spring was accompanied by a much smaller ozone hole than that observed in 1987. One suggestion is that unusually low stratospheric temperatures may be causing the ice crystals to form.[37] If so, scientists do not know why this is happening.

So while it appears likely that chlorine chemistry (with the chlorine probably coming from CFCs) causes the ozone hole, the reaction may well be triggered by a mechanism such as unusually cold stratospheric temperatures. If so, the hole may be, as Fred Singer stated, "not very sensitive to the amount of chlorine in the stratosphere, or to the amount of CFCs in the lower atmosphere." Additional chlorine from CFCs may not affect the ozone hole and stopping their addition may not reduce it.[38]

Is More Ultraviolet Radiation Reaching the Earth's Surface?

A great irony is that in spite of the concern about ozone depletion, the presumed effect — increased levels of ultraviolet radiation in most of the world — does not appear to have occurred. A major study of UV-B radiation levels was conducted in the United States from 1974 to 1985. A network of eight ground-level monitoring stations measured UV-B radiation. These measurements not only showed no increase in ultraviolet radiation but, in fact, showed signs of decrease. The findings covered a period during which the Ozone Trends Panel and NASA determined that there was a decrease in stratospheric ozone.[39] Of course, the experience of eight monitoring stations is far from definitive.[40]

"In spite of the concern about ozone depletion, increased levels of ultraviolet radiation do not seem to have occurred."

There have been some findings that do show increases in UV-B Radiation. A study conducted in the Alps found increases,[41] as did studies in the Antarctic during the time of the ozone hole.

In 1993 two scientists reported that they had measured increases of more than 5 percent per year between 1989 and 1993 in ultraviolet radiation above Toronto, Canada.[42] The media proclaimed the findings to be evidence that ozone depletion could be causing an increase in UV radiation, but three University of Virginia scientists challenged the findings. They pointed out, among other things, that the supposed upward trend was based on four measurements in March 1993, a time at the "extreme end" of the measurement record, and one "associated with unusual meteorological conditions."[43]

There has been no systematic study of UV-B radiation reaching the Earth, with observations over a wide area and a long time period. The few existing studies offer fragmentary and conflicting results. Thus, there is no convincing evidence that human exposure to UV-B radiation is increasing.

Why Should We Care?

Whether human behavior causes it or not, if the depletion of ozone increases the ultraviolet radiation that reaches the earth, should we be deeply worried? The alarmists say yes and point to potential dangers to all living things. Let's examine their arguments.

"EPA Administrator William Reilly predicted that ozone depletion could cause 200,000 extra cancer deaths in the United States during the next 50 years."

Skin Cancer. As we saw earlier, concern about skin cancer soared in April 1991, when EPA Administrator William Reilly predicted that ozone depletion could nearly double the skin cancer rate during the next 50 years, causing as many as 200,000 extra deaths in the United States alone. Reilly's prediction was quite wrong.[44] However, ozone depletion could lead to some additional cancer deaths.

Clinical and animal studies suggest a cause-and-effect relationship between sunlight exposure and basal cell and squamous cell skin cancers. In addition, epidemiological evidence suggests that in areas closer to the equator, where the angle of the sun is more direct and exposure to ultraviolet light is greater, people are more likely to get skin cancer.[45] Thus a decrease in the ozone level could increase cancer deaths by the following reasoning:

- In 1981 a National Cancer Institute study estimated that every 1 percent increase in annual UV-B radiation would result in a 2.5 percent increase in the incidence of skin cancer.[46]
- Since a 1 percent decrease in ozone is believed to cause a 0.8 percent increase in ultraviolet radiation, these findings led to the conclusion that a 1 percent decrease in ozone corresponds to about a 2 percent increase in the number of skin cancers.[47]
- Given that there are approximately 200,000 skin cancers per year in the United States, a 5 percent decrease in ozone could increase the number of skin cancers by 10 percent or 20,000 per year in the U.S.
- Reilly claimed that these additional cancers would lead to deaths, but less than 1 percent of these kinds of cancers are fatal.

One way to put this scenario into perspective is to consider the degree to which people voluntarily change their exposure to ultraviolet light. In 1975 the National Academy of Science estimated that a person's risk of skin cancer doubles with every 600 miles proximity to the equator.[48] Thus every increase of six miles increases one's risk by 1 percent.

- Moving from Chicago to Nashville increases your risk of skin cancer by about 67 percent.
- Moving from Kansas City to Dallas raises your risk by about 75 percent.

The increase in exposure to ultraviolet light increases with altitude, too.

- There is about a 1 percent increase in UV-B exposure for each 150-foot increase in elevation.[49]
- So moving from Kansas City to Denver increases your exposure to UV-B radiation by about 30 percent because you move up 4,500 feet, and your risk of cancer goes up 75 percent.
- If the estimates of a 4 to 5 percent ozone loss above the United States during the 1980s are correct, they have increased your cancer risk by 8 to 10 percent, about the same as you would if you moved about 60 miles south — say, from Seattle to Tacoma or New York to Philadelphia.

"If estimates of ozone loss are correct, the increased cancer risk is about the same as that incurred by moving from New York to Philadelphia."

Such facts led a research group headed by Arne Dahlback in Norway to conclude that even worst-case predictions of ozone depletion — depletions of 15 to 20 percent — would have a "rather small effect on life on earth."[50] And a report by the National Research Council pointed out that even modest protection such as limiting one's time in the sun can reduce UV-B exposure "by factors that are much greater than the least conservative factors estimated from ozone-related increases in UV."[51]

Melanomas. While UV-B is clearly linked to some skin cancers, a link between the much more dangerous melanoma skin cancer and UV-B intensity is less certain. Melanoma, a cancer of the pigment cells, is fatal in about one-third of the cases. Melanoma rates have been rising 4 percent a year since the 1970s, but they began increasing well before CFCs were widely used. The incidence of melanomas appears to depend on latitude, but there are inconsistencies. For example, melanomas can occur on parts of the body not exposed to the sun and occupational studies fail to show a difference in melanoma incidence between indoor and outdoor workers. Equally puzzling is the fact that Scandinavian populations have unusually high rates of melanoma, even though they live in the higher latitudes where ultraviolet exposures are lower.[52]

In July 1993 a group headed by Richard Setlow of Brookhaven National Laboratory concluded that 90 to 95 percent of the effect of light in inducing melanoma came from visible light or the UV-A part of the spectrum, not the UV-B wavelength affected by ozone.[53] (Although ozone blocks UV-B rays, it has very little effect on UV-A rays.)[54]

Cataracts. In 1991 a United Nations environment program updated its findings on the ozone issue and predicted that the world might experience 1.6 million new cataract cases because of the increase in ultraviolet radiation from loss of ozone. But here again the suspicious rays are UV-A, not UV-B radiation. After concluding in its 1982 report that the ozone level has virtually no effect on cataracts, the National Research Council omitted discussion of the issue in its report the following year.

Effects on the Ocean's Food Chain. Much concern has focused on the effects of ultraviolet radiation on living organisms because high levels of the radiation may reduce photosynthesis. The discovery of the ozone hole over the Antarctic led to fears that higher levels of UV-B might kill phytoplankton, the simple organisms that lie at the bottom of the food chain. The creatures that depend on phytoplankton could starve and their deaths could reduce the food for the next level of creatures, causing massive starvation at ever-higher levels of the food chain.

Investigators are divided on whether the increases in ultraviolet light in the Antarctic are or could be harmful to the microscopic phytoplankton. Early studies claiming to demonstrate such harm have been discredited.[55] The latest research by a team led by Osmund Holm-Hansen of the Scripps Institute of Oceanography suggests that a "well-developed ozone hole" may decrease phytoplankton production, but the reduction would be less than 4 percent while the hole is overhead. Since the ozone hole is seasonal, it probably reduces total production throughout the year by only two-tenths of a percent or less. These results, report the researchers, "indicate considerable resiliency by the primary producers in the Antarctic food web ... and suggest that the magnitude of loss in primary production caused by ozone depletion over the Southern Ocean will be relatively small."[56] A 1994 report in *Nature* concluded that the ozone hole "has had little effect" on the phytoplankton.[57]

"Discussions of ozone depletion almost always ignore the fact that ultraviolet light is essential to life."

The Beneficial Effects of Ultraviolet Light. Discussions of ozone depletion almost always ignore the fact that ultraviolet light is essential to life. Ultraviolet light converts oils in the skin to vitamin D, which is essential for the assimilation of calcium into skeletal bones. Hugh Ellsaesser, a scientist with the Lawrence Livermore Laboratory, notes that 20 million Americans suffer from osteomalacia, a weakening of the bones that stems from insufficient vitamin D. He considers it likely that slightly higher levels of ultraviolet light would help prevent some osteomalacia in the future.[58]

What About the CFC Substitutes?

In 1987, 31 countries signed the Montreal Protocol, agreeing to phase out production of chlorofluorocarbons. As concerns have increased, that agreement has been revised to speed up the phase-out so that production of CFCs will cease in the industrial world by December 31, 1995. Developing countries have a longer time to phase out CFC production — in most cases till the year 2010.

Yet the implications of these decisions are dramatic. The nations signing the Montreal Protocol agreed to give up nontoxic substances used in millions of automobiles and refrigerators without offering satisfactory substi-

"Alternatives to CFCs are more costly, more corrosive to cooling systems — and may be less safe."

tutes. American industry is coming up with alternatives, but they are more costly, more corrosive to cooling systems, less dependable and less manageable. Some even appear to be less safe.

One of the substitutes, HCFC 123, caused tumors in rats. The tumors were benign, but at least one industrial refrigeration company has rejected the substance.[59]

A bigger worry may be fire. In 1992 *Consumers' Research* magazine reported on a conflict between the Environmental Protection Agency and the DuPont Company over whether another refrigerant, R-152a, was safe enough to be used in refrigerators. DuPont claimed that under some circumstances a refrigerator with leaky R-152a fluid could explode and rejected the coolant. The EPA, concerned that there might not be substitutes when the deadline arrived, wanted DuPont to continue working on it.[60]

DuPont was ready to stop making CFCs earlier than the 1995 deadline but the Clinton administration, increasingly worried about shortages, asked DuPont to keep making CFCs until the end of 1995.

In April 1995, the *New York Times* reported that a widely distributed substitute known as H-12a is highly flammable, according to the Mobile Air Conditioning Society, a trade association. The Environmental Protection Agency is investigating it, the *Times* said.[61]

For many Americans, maintaining car air conditioners is going to be much more difficult in the future. As CFCs are being phased out, the price of Freon (the CFC used in air conditioners) is rising, both because of the impending shortage and because of the government's high tax. Freon and its generic equivalents now cost about $15 per pound, compared with $1 in 1989.[62] The only substitute considered safe, HFC-134a, is less efficient than Freon. Auto air conditioners may have to be retrofitted to use the substitute. Experts hope to develop a retrofit system that will cost only about $220. But that's in addition to the current cost of maintenance, which averages $216.[63] The cost of retrofitting some cars could be $1,000, and the trade-in value of cars with the old Freon system will go down.[64]

Early in 1995 some household air-conditioning coolant was illegally sold to Phoenix auto repair shops as Freon for car air conditioners. It caused explosions in several cars, reported *Automobile* magazine, and one man was severely burned. The rising price of Freon is likely to spur more substitutions. It is already causing CFCs to be illegally smuggled into the U.S. to avoid the government's high tax, according to *Global Environmental Change Report*.[65] As long as developing countries are allowed to produce CFCs, this smuggling will continue.

"Law enforcement officials say the refrigerant has become the most lucrative contraband after illicit drugs," reported the *New York Times*. A Florida woman was indicted in April for smuggling over 3,000 tons of Freon over a period of a year. The market value was $52 million.[66]

The Competitive Enterprise Institute (CEI) has estimated that, for refrigeration and home cooling alone, the cost to Americans of switching to substitutes will be $45 billion to $99 billion over the next 10 years.[67] As many Americans experience the high costs of retrofitting their auto air conditioners and finding Freon, many other costs will be hidden. For example, food may be more expensive as supermarkets are forced to redesign their equipment to use the substitutes, and more energy may be required for air conditioning and refrigeration because the substitutes are less efficient. People may never realize that replacing CFCs was the cause of such price increases. Had the date of phase-out not been moved ahead from 2000 to 1995, CEI estimated that the cost would have been much lower — about one-quarter of what we will now have to bear.

"Smuggling of CFCs will continue as long as developing countries are allowed to produce them."

For countries such as China and the rest of the developing world, the opportunity for cheap refrigeration will be lost if CFCs are not available. Lack of refrigeration is one of the most serious health problems in those countries, both because of microbial food poisoning due to food spoilage and because lifesaving vaccines deteriorate without refrigeration. Writing in *Scientific American*, Tim Beardsley reported that "the challenge [of preserving vaccines] can be daunting in regions where temperatures may reach more than 40 degrees Celsius and where the kerosene fuel for portable refrigerators is of varying quality and availability."[68] Beardsley noted that infectious diseases kill more than 13 million people every year, mostly infants.[69]

Conclusion

Scientists have been working on the ozone depletion issue for two decades and the theory that chlorine reacts with ozone in the stratosphere and that much of the chlorine comes from CFCs is widely accepted by the scientific community, although the precise role of CFCs in the stratosphere is unclear. For many years, well-funded industries that produce and use CFCs have had opportunities to offer countervailing evidence and theories. What has happened is that the theory has continually been revised but no alternative has taken its place.

Today, we are confident that CFCs are a source of chlorine in the atmosphere because scientists measured the byproducts of the breakdown of CFCs in the stratosphere.[70] But we are not certain that the addition of CFCs to the atmosphere is causing the ozone hole over Antarctica or significantly reducing ozone elsewhere. Reductions in ozone in the world's atmosphere are small and may be completely natural fluctuations, and the earth's organisms apparently can adapt to some loss of ozone. Even if ozone levels have been declining, the increases in exposure to ultraviolet light that people fear have not been reliably reported or verified.

Nevertheless, the potential remains that inert, chlorine-containing chemicals could cause them to build up sufficiently in the stratosphere to eventually cause serious reductions in ozone. Given that concern, what should policymakers do?

Acting out of panic is not necessary and will likely have harmful consequences. Our government should allow behavior to adjust gradually as scientific knowledge evolves. We recommend the following:

"Acting out of panic is not necessary and will likely have harmful consequences."

1. Stop treating ozone as a crisis; costly emergency actions are not needed.

2. Change the Montreal Protocol, making the CFC phase-out more gradual.

3. Weigh the costs (including such social costs as safety) of halting CFC production against the small and uncertain benefits of protecting the ozone.

4. Avoid panic over the next environmental "crisis" that demands "immediate" action.

NOTE: Nothing written here should be construed as necessarily reflecting the views of the National Center for Policy Analysis or as an attempt to aid or hinder the passage of any bill before Congress.

Notes

*The authors would like to thank Donald R. Leal for doing substantial background research for this study.

1 Michael Weisskopf, "Scientists Find Growing Evidence of Ozone-Loss Peril Over Northern Hemisphere," *Washington Post*, February 4, 1992.

2 Al Gore, *Earth in the Balance: Ecology and the Human Spirit* (New York: Houghton Mifflin Company, 1992), p. 86.

3 *Time,* February 17, 1992, p. 60.

4 Between 10 and 31 miles at low latitudes and between five and 31 miles at high latitudes.

5 This is energy that comes in very short wavelengths (between 290 and 310 nanometers or billionths of a meter). It is not visible to the human eye. Ozone blocks most of this UV-B radiation. (UV-A radiation consists of somewhat longer rays, but ozone has little effect on them.)

6 UV radiation breaks up oxygen molecules (0_2) into oxygen atoms (0), each of which recombines with another oxygen molecule (0_2) to form ozone (0_3).

7 Some of the substitute products will be illegal after the year 2030 — banned because they too contain chlorine, the component of CFCs that is said to destroy ozone.

8 M. J. Molina and F. S. Rowland, "Stratospheric Sink for Chlorofluoromethanes: Chlorine Atom Catalyzed Destruction of Ozone," *Nature,* June 28, 1974, p. 810.

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23 See S. Fred Singer, "The Science Behind Global Environmental Scares," *Consumers' Research*, October 1991, pp. 17-21.

[24] Sallie Baliunas, "The Ozone Crisis," speech to Washington Roundtable on Science and Public Policy, George C. Marshall Institute, May 17, 1994.

[25] D. DeMuer and H. DeBacker, "Revision of 20 Years Dobson Total Ozone Data at UCCLE (Belgium): Fictitious Dobson Total Ozone Trends Induced by Sulfur Dioxide Trends," *Journal of Geophysical Research,* April 15, 1992.

[26] Hugh Ellsaesser, talk given to the Conference of the Atmospheric and Geophysical Sciences Division of Lawrence Livermore National Laboratory, August 1990.

[27] Soren H. Larsen and Thormod Henriksen, "Persistent Arctic Ozone Layer," *Nature,* January 11, 1990, p. 124.

[28] National Research Council, *Stratospheric Ozone Depletion by Halocarbons: Chemistry and Transport* (Washington, DC: National Academy Press, 1979); National Research Council, *Causes and Effects of Stratospheric Ozone Reduction: An Update* (Washington, DC: National Academy Press, 1982) [hereinafter called the *1982 Ozone Reduction Update*]; National Research Council, *Causes and Effects of Changes in Stratospheric Ozone: Update 1983* (Washington, DC: National Academy Press, 1984) [hereinafter called the *1983 Ozone Depletion Update*]; and S. Fred Singer, "Stratospheric Ozone: Science & Policy," in S. Fred Singer, ed., *Global Climate Change: Human and Natural Influences* (New York: Paragon House, 1989), p. 158.

[29] Singer, "My Adventures in the Ozone Layer." The culprits blamed for ozone depletion were initially water vapor from the burning of the SSTs' fuel and later nitrogen oxides.

[30] J. C. Farman et al., "Large Losses of Total Ozone Reveal Seasonal ClO_X/NO_X Interaction," *Nature,* Vol. 315, 1985, pp. 207-10.

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[32] Susan Solomon, "Progress Towards a Quantitative Understanding of Antarctic Ozone Depletion," *Nature*, Vol. 347, September 27, 1990, pp. 347-54, on p. 347.

[33] Richard Kerr, "Another Deep Antarctic Ozone Hole," *Science,* Vol. 250, October 19, 1990, p. 370.

[34] Solomon, "Progress Towards a Quantitative Understanding of Antarctic Ozone Depletion," pp. 348-49.

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[36] Hiroshi Kanazawa and Sadao Kawaguchi, "Large Stratospheric Sudden Warming in Antarctic Late Winter and Shallow Ozone Hole in 1988," *Geophysical Research Letters*, Vol. 17, January 1990, p. 80 ff.

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[42] J. B. Kerr and C. T. McElroy, "Evidence for Large Upward Trends of Ultraviolet-B Radiation Linked to Ozone Depletion," *Science*, November 12, 1993, p. 1032.

[43] Patrick J. Michaels, S. Fred Singer and Paul C. Knappenberger, "Analyzing Ultraviolet-B Radiation: Is There a Trend?" *Science*, May 27, 1994, p. 1341.

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47 National Research Council, *1982 Ozone Reduction Update*, p. 98.

48 National Academy of Sciences, *Environmental Impact of Stratospheric Flight* (Washington, DC: National Academy of Sciences, 1975).

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50 Arne Dahlback et al., "Biological UV-Doses and the Effect of an Ozone Depletion," *Photochemistry and Photobiology,* Vol. 49, 1989, p. 624.

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