The Ozone Backlash

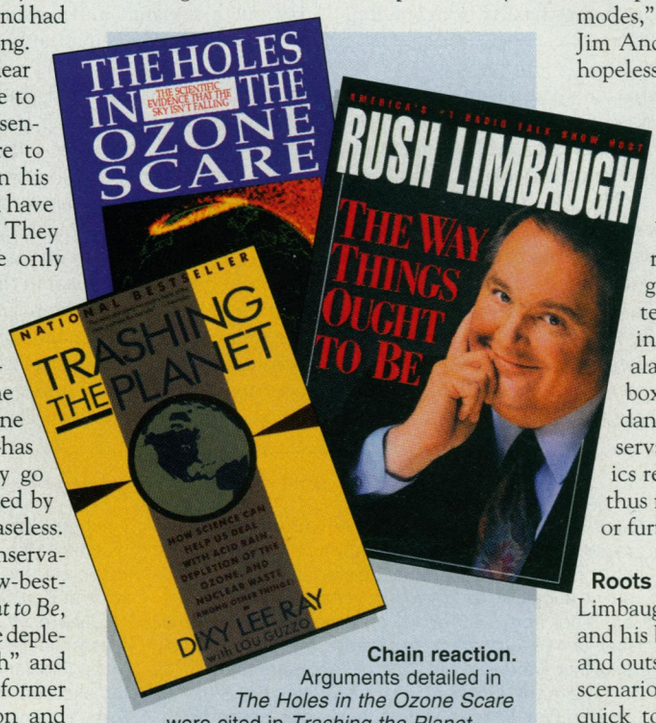
While evidence for the role of chlorofluorocarbons in ozone depletion grows stronger, researchers have recently been subjected to vocal public criticism of their theories—and their motives

Last June, Mario Molina, an atmospheric chemist at the Massachusetts Institute of Technology, was scheduled to give a 30-minute presentation on ozone depletion at a scientific forum preceding the environmental summit in Rio de Janeiro. Molina had been at the forefront of ozone research since 1973, when he and chemist Sherwood Rowland of the University of California, Irvine, first put forward the theory that chlorofluorocarbons (CFCs) would break down in the stratosphere, releasing chlorine that in turn would destroy ozone molecules. Nonetheless, Molina was less than prepared for the talk that preceded his. A Brazilian meteorologist explained to the assembled scientists that the ozone depletion theory is a sham. So much chlorine is getting into the stratosphere from sea salt, volcanoes, and burning biomass, he said, that CFCs couldn't possibly have a noticeable effect on the ozone layer.

Molina was stunned. The meteorologist's arguments had been debated over the years by the scientific community, he says, and had been tested and found simply to be wrong. Nonetheless, says Molina, "it became clear to me that I was not going to be able to teach the audience in a half-hour presentation enough about the atmosphere to rebut what this fellow was saying in his half-hour. Given enough time I could have carefully rebutted his objections. They sounded reasonable, but they were only pseudoscientific."

Molina's experience has become a familiar one recently to researchers working on ozone depletion. Their understanding of the mechanisms of ozone destruction—especially the annual ozone hole that appears in the Antarctic—has grown stronger, yet everywhere they go these days, they seem to be confronted by critics attacking their theories as baseless. For instance, Rush Limbaugh, the conservative political talk-show host and now-best-selling author of *The Way Things Ought to Be*, regularly insists that the theory of ozone depletion by CFCs is a hoax: "balderdash" and "poppycock." Zoologist Dixy Lee Ray, former governor of the state of Washington and former head of the Atomic Energy Commission, makes the same argument in her book, *Trashing the Planet*. *The Wall Street Journal* and *National Review* have run commentaries by S. Fred Singer, a former chief scientist for the Department of Transportation, purporting to shoot holes in the theory of ozone depletion. Even the June issue of *Omni*, a magazine with a circulation of more than 1 million that publishes a mixture of science and science fiction, printed a feature article claiming to expose ozone research as a politically motivated scam.

These jabs may not have been sufficient to knock the world's leading atmospheric researchers off balance. But they have recently been hit with a flurry of new blows, as the critics have seized upon revisionist articles in the mainstream press to contend that the scientific community is retreating on the CFC-ozone connection. A recent *Washington Post* front-page article, for example, noted that, with the Montreal Protocol limiting global production of CFCs, "the problem appears to be heading toward solution before [researchers] can find any solid evidence that serious harm was or is being done." The otherwise balanced article played this point of view against what *Post* reporter Boyce Rensberger called "a decade of headlines and hand-wringing about erosion of the Earth's protective ozone layer." That was enough for *The Washington Times*, a conservative newspaper owned by Sun Myung Moon, to declare that the *Post*, *Science*, and other leading publications had joined "a growing chorus dismissing alarmist cries of ozone depletion."



Chain reaction. Arguments detailed in *The Holes in the Ozone Scare* were cited in *Trashing the Planet*, which in turn formed the basis for Rush Limbaugh's attacks on ozone orthodoxy. The same arguments were also cited in a petition circulated around the scientific community.

Welcome back to the ozone wars, which many scientists believed were long settled. The backlash now being encountered by atmospheric researchers graphically demonstrates the problems of doing research on a politically charged issue when there are still many scientific uncertainties. The gap between the present danger of ozone depletion—little or none that can be attributed to rising ultraviolet radiation at Earth's surface—and the possible danger in the future, had not the Montreal Protocol been passed, provides plenty of room for a wide range of opinions as to how much concern is warranted. "The public tends to operate in one of two modes," says Harvard atmospheric chemist Jim Anderson, "either there's ozone loss, a hopeless disaster, and we panic and become dysfunctional, or it's no problem at all because there's no massive ozone loss. The truth, of course, is somewhere in between."

Atmospheric researchers have been forced to walk a political tightrope: On the one hand are the dangers of reporting the situation as potentially disastrous and being called, in Limbaugh's words, "dunderhead alarmists and prophets of doom" (see box on p. 1581). On the other are the dangers of presenting scientifically conservative scenarios and having their critics respond that there's no problem, and thus no reason for either further concern or further research.

Roots of the backlash

Limbaugh, by virtue of his various talk-shows and his best-selling book, is the most visible and outspoken critic of the ozone depletion scenarios and the research community. He is quick to blame the ozone "scam" on self-interested scientists out to procure funding for their unnecessary research. "They always want more funding," he writes, "and today that means government funding. What could be more natural than for the National Aeronautics and Space Administration (NASA),

A Fateful Prediction

To critics of ozone-depletion science, researchers and their allies in the press and government showed their true colors at a 3 February 1992 press conference. These critics were already convinced that the scientific consensus, which holds that manmade chlorofluorocarbons (CFCs) are eroding the ozone layer, was based more on politics than science (see main text). The failure of the dire predictions aired at the press conference only sealed their conviction that atmospheric researchers are pursuing their own hidden agendas. For the researchers themselves, however, the event and its aftermath simply reflect the difficulties of making public pronouncements in areas where the science is uncertain.

The press conference was held by members of the Airborne Arctic Stratospheric Expedition and researchers working with the National Aeronautics and Space Administration's (NASA) Upper Atmosphere Research Satellite (UARS), which had been launched the previous September. Together, the high-altitude airplane flights of the arctic expedition and the instruments aboard UARS had detected unprecedented levels of chlorine and aerosols, two prerequisites for ozone depletion, in the stratosphere of the Northern Hemisphere. As a result, Harvard atmospheric chemist Jim Anderson told reporters, "the probability of significant ozone loss taking place in any given year is higher than we believed before." Worse, NASA officials added, this was no longer the remote Antarctic, but the atmosphere over "very populated regions."

The news conference sparked *New York Times* and *Washington Post* editorials calling for accelerated phase-out of CFCs. Then-Senator Al Gore made his memorable speech in Congress on the "ozone hole over Kennebunkport." The cover of *Time* declared "Vanishing Ozone: The Danger Moves Closer to Home." The Senate quickly voted unanimously to accelerate the CFC phase-out mandated by the Montreal Protocol, and the White House just as quickly went along with the speed-up.

The predictions of drastic ozone loss did not pan out, however. In April, NASA reported that the extreme cold in the Arctic required for ozone depletion didn't last; a sudden warming spell hit the Arctic in late January, causing ozone depletion to bottom out at only 10%.

The result was a slew of editorials and articles questioning the motives of the researchers, NASA officials, politicians, and the press. "Money, in part, may explain NASA's rush to get the 'evidence' of a likely ozone hole out 2 months before the arctic research project closed," said *The Washington Times*, for example. Talk-show host Rush Limbaugh called the press conference a "scam."

Anderson, for one, is convinced that NASA and the researchers took the right course. "The discovery of the extremely high chlorine monoxide levels over the Arctic was, from a scientific point of view, a very serious one. We felt it was a straightforward matter of releasing the information and discussing what we had seen," he said later.

Although researchers had pointed out at the press conference that drastic ozone loss was by no means certain, these caveats didn't always come across in the press that followed, which is often the case with reporting of complicated scientific issues. "At the time of the press conference," says Richard Stolarski of NASA, "they qualified everything properly. But the tone that came across was that this was an unmitigated disaster and we're all going to die, which in a sense just gives fuel to the Limbaughs, who think it's all hogwash."

–G.T.

with the space program winding down, to say that because we have this unusual amount of chlorine in the atmosphere we need funding? Obviously, we have to research this. But first we have to 'inform' the public."

Limbaugh gets his facts, he says in his book, from Ray's *Trashing the Planet*, which he calls "the most footnoted, documented book" he has ever read. Ray cites two other authors for most of her information on ozone depletion: Fred Singer and Rogelio Maduro. Maduro has a bachelor of science degree in geology and is an associate editor of *21st Century Science & Technology*, a magazine published by supporters of Lyndon LaRouche, an extremist politician currently serving 15 years in jail for conspiracy to evade taxes. Maduro is also co-author with Ralf Schauerhammer, a German writer, of *The Holes in the Ozone Scare: The Scientific Evidence That the Sky Isn't Falling*, which is also published by *21st Century*.

Maduro and Schauerhammer discuss at great length the source of chlorine in the stratosphere, arguing that natural sources dwarf any contributions from CFCs. As Limbaugh translates their case, the argument against the ozone depletion scenarios is simple: In one eruption, he says, Mount Pinatubo spewed forth "more than a thousand times the amount of ozone-depleting chemicals...than all the fluorocarbons manufactured by wicked, diabolical, and insensitive corporations in history." And the result was at best a minor depletion of ozone. Meanwhile, volcanoes have been spewing chlorine for billions of years, and yet the ozone is still there "in sufficient quantities to protect Democrats and environmentalist wackos alike from skin cancer." Atmospheric scientists counter that these claims have been intensively studied and found wanting (see sidebar on page 1582).

Although it's not common for a LaRouche publication to have an impact in mainstream thought, Maduro's arguments have not only percolated from Ray to Limbaugh, but are also the basis of much of the information in the *Omni* article, its author, novelist Jim Hogan, told *Science*. In addition, *21st Century* has circulated a petition around the scientific community citing Maduro's arguments and calling for the repeal of the Montreal Protocol. Among the dozen American researchers who have signed it are Derek Barton, a Nobel Prize–winning chemist at Texas A&M, and Petr Beckmann, a professor emeritus at the University of Colorado. Barton told *Science* that he signed because he's "one of these people who are opposed to getting scared about imaginary problems. I think the ozone hole and global heating are nonsense." Beckmann, who edits a newsletter called *Access to Energy*, told *Science* that he also got much of his information from Maduro's writings, describing them as "some very good material published, unfortunately, by not very reliable people."

Many of the atmospheric researchers interviewed by *Science* have read parts of *Holes in the Ozone Scare*. They often say they can see how readers who are not experts in the field might find the arguments compelling. "Part of the strategy in this backlash," says Anderson, "is to try to entrain apparently responsible scientists who clearly don't understand the problem and have not gone over the data before they've commented." And indeed, one National Science Foundation official commented, "I read that book, and found it made a lot of sense."

Those who are directly involved in the research, on the other hand, describe the work as based on a selective use of out-of-date scientific papers, and an equally discretionary choice of scientific results, often taken out of context. The end result may seem commonsensical, these researchers say, but along the way it loses touch with science. Retiring AAAS President Sherwood Rowland, who

Stratospheric Chlorine: Blaming It on Nature

Much of the bitter public debate over ozone depletion has centered on the claim that chlorofluorocarbons (CFCs) pale into insignificance alongside natural sources of chlorine in the stratosphere. If so, goes the argument, chlorine could not be depleting ozone as atmospheric scientists claim, because the natural sources have been around since time immemorial, and the ozone layer is still there.

The claim, put forward in a book by Rogelio Maduro and Ralf Schauerhammer, has since been touted by former Atomic Energy Commissioner Dixy Lee Ray and talk-show host Rush Limbaugh, and it forms the basis of much of the backlash now being felt by atmospheric scientists (see main text). The argument is simple: Maduro and Schauerhammer calculate that 600 million tons of chlorine enters the atmosphere annually from seawater, 36 million tons from volcanoes, 8.4 million tons from biomass burning, and 5 million tons from ocean biota. In contrast, CFCs account for a mere 750,000 tons of atmospheric chlorine a year. Besides disputing the numbers, scientists have both theoretical and observational bases for doubting that much of this chlorine is getting into the stratosphere, where it could affect the ozone layer.

Linwood Callis of the National Aeronautics and Space Administration's (NASA) Langley Research Center points out one crucial problem with the argument: Chlorine from natural sources is soluble, and so it gets rained out of the lower atmosphere. CFCs, in contrast, are insoluble and inert and thus make it to the stratosphere to release their chlorine. What's more, observations of stratospheric chemistry don't support the idea that natural sources are contributing much to the chlorine there.

If sea salt were making it up to the stratosphere, argues Richard Turco, an atmospheric chemist at the University of California, Los Angeles, then there should be evidence of sodium from the salt in the lower stratosphere. "It's just not there," says Turco. Chlorine from biomass burning should also have a distinctive signature: the chlorine-containing compound methylchloride. Maduro and Schauerhammer quote a 1979 *Nature* article by atmospheric chemist Paul Crutzen and his colleagues, estimating that biomass burning releases at least 420,000 metric tons of chlorine a year in the form of methylchloride; then they multiply that figure by 20 based on much higher estimates of biomass burning than Crutzen used. But that chlorine isn't making it to the stratosphere, Crutzen says; satellite data reveal that only 20% of the chlorine in the stratosphere is bound up in methylchloride. What's more, says Jurgen Lobert of the National Oceanic and Atmospheric Administration, who has worked with Crutzen, the most accurate estimates of global biomass burning today suggest that this source can account for only one-fourth of the total methylchloride in the stratosphere, or 5% of the total chlorine budget. "Very significant," Lobert says, but not as significant as chlorine from CFCs.

Even if seawater and biomass don't hold up as major sources of stratospheric chlorine, Limbaugh, Ray, Maduro, and Schauerhammer point to a source that they believe is sufficient on its own to render CFCs irrelevant: volcanoes in general, and Mount Erebus—a volcano in Antarctica that has been erupting constantly since 1973—in particular.

The volcano theory begins with a 1980 *Science* paper by the late David Johnston, a volcanologist with the U.S. Geological Survey. Johnston estimated the chlorine emitted by a 1976 eruption of Mount Augustine in Alaska, and concluded that it pumped 175,000 tons of hydrogen chloride (HCl) into the stratosphere. Johnston then suggested that the "eruption of the Bishop Tuff from Long Valley Caldera, California, 700,000 years ago...may have injected 289 million tons of HCl into the stratosphere, equivalent to about 570 times the 1975 world industrial production of chlorine in fluorocarbons."

In her book *Trashing the Planet*, Ray takes this speculation and incorrectly attributes Johnston's numbers for the gargantuan Bishop Tuff volcano to the 1976 Mount St. Augustine eruption, and Limbaugh picks up on Ray's misstatement and goes further, applying similar numbers to the eruption of Mt. Pinatubo.

As for Mt. Erebus, Maduro and Schauerhammer cite a 1985 *Nature* paper by William Rose of Michigan Technological University and his colleagues estimating that Erebus emits more than 1000 tons of chlorine a day. "In short," write Maduro and Schauerhammer, "the chlorine measured in Antarctica should be no mystery. Mt. Erebus is constantly blowing out a huge cloud of chlorine and other volcanic gases."

Atmospheric researchers counter that Erebus, although 14,000 feet high, is still several kilometers below the base of the stratosphere in Antarctica. And Erebus does not erupt explo-

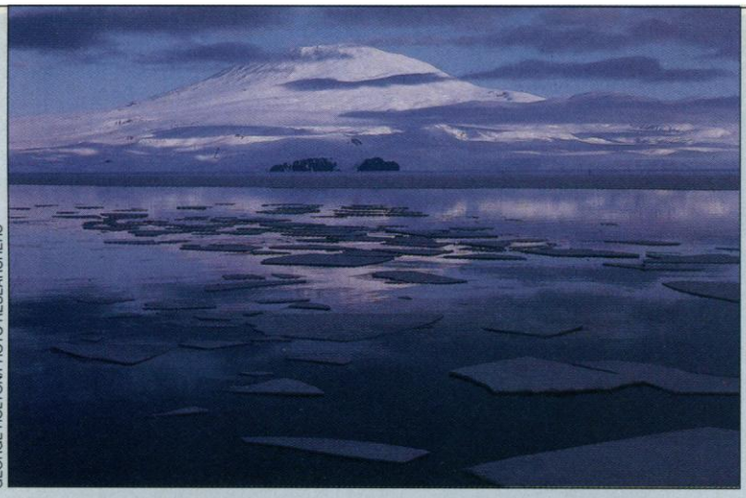
devoted part of his address to the AAAS annual meeting to the ozone backlash (see page 1571), for instance, calls the book "a good job of collecting all of the bad papers [in the field] in one place." Maduro responds that scientists like Rowland and his colleagues "have systematically ignored all the massive research which debunks elements of their theory."

Even Fred Singer, whose writings are cited by Ray, takes issue with Maduro and Schauerhammer's arguments about natural sources of chlorine, calling them "red herrings and completely false." Singer believes that the overall ozone depletion theory is still riddled with uncertainty but he describes himself as "somewhere in the middle" in the controversy. Many of the atmospheric researchers interviewed by *Science* say that he makes an effort to understand the data and speak to the scientists involved. Singer says he, too, once believed that natural sources of stratospheric chlorine overwhelm any man-made contribition, but the data have convinced him that CFCs are the major source.

Nevertheless, researchers who try to debate the critics quickly find themselves in a no-win situation. The reason: Maduro and Limbaugh say the researchers are part of what is in essence a massive conspiracy to ignore or bury any findings at odds with the accepted theory. In their book, Maduro and Schauerhammer, for example, accuse the proponents of the ozone depletion theory of having "deliberately obfuscated the facts about ozone research" and add that these researchers are now "in top posts with command power over scientific journals and associations and, ultimately, public opinion." That the great majority of atmospheric researchers agree on the basic findings of ozone depletion by CFCs is only considered evidence of how widespread is the conspiracy. Says Maduro: "What I am most concerned with is that scientists who have been presenting an opposing view have a public forum, the ability to present their work to the public."

The remaining questions

In such a polarized and political environment, researchers say it is difficult at best to do science and make sensible public policy recommendations. Stephen Schneider, an atmospheric modeler at Stanford University, describes the problem as being "caught between the exaggerations of the advocates, the exploitations of political interests, the media's penchant to turn everything into a boxing match, and your own colleagues saying we should be above this dirty business and stick to the bench."



GEORGE HOLTON/PHOTO RESEARCHERS

Blowing smoke? Mount Erebus has been blamed as the source of chlorine for the Antarctic ozone hole; atmospheric scientists say the claim is groundless.

sively, which is a necessary condition to lift chlorine from volcanoes into the stratosphere. "The highest they've ever seen the plume rise [from Erebus]," says NASA's Rich Stolarski, "is half a kilometer above the mountain. Most of the time it doesn't even make it that far, it's usually oozing over the side." What's more, Philip Kyle, a co-author of the 1985 *Nature* paper, now reports that Erebus emits only 15,000 metric tons of chlorine per *year*, only $\frac{1}{24}$ what was originally reported.

Even Fred Singer, whose own skepticism about some aspects of the ozone depletion theory has been cited by the critics to bolster their case, refers to the argument over volcanoes as "polemics." The volcano issue, he says, "has to be decided on the basis of data." And so far, expeditions that have brought back direct experimental data on volcanic emissions into the stratosphere suggest that volcanoes play a relatively minor role.

Bill Mankin and Michael Coffey, both of the National Center for Atmospheric Research, sampled emissions from El Chichón after its 1982 eruption. According to Mankin, they saw a "significant increase in HCl [in the stratospheric cloud], roughly 40% above the background level." This represented a 10% increase in global stratospheric chlorine at a time when the stratospheric HCl budget was increasing by 5% each year. Thus, says Mankin, El Chichón seems to have advanced chlorine buildup in the stratosphere by just 2 years. Similar measurements were attempted after Mount Pinatubo erupted in April 1991, but according to Mankin, the nature of the cloud from Pinatubo made the measurements more difficult than those from El Chichón . Nonetheless, he says, Pinatubo appeared to have emitted an amount of HCl, "perhaps less than, perhaps comparable to, El Chichón."

For the global picture, atmospheric researchers point to measurements from the ATMOS instrument, which flew on the space shuttle in 1985. The instrument precisely determined the total chlorine budget in the stratosphere by making measurements of 30 molecular signatures, including the major CFCs, as well as their sinks and sources. According to Curtis Rinsland of NASA Langley, the measurements showed that chlorine is bound up in CFCs at lower levels of the stratosphere and in the predicted by-products of CFC breakdown, HCl and hydrogen fluoride (HF), at higher levels—just as the ozone theory predicts.

Further studies done from the Kitt Peak Observatory, by Rinsland and his colleagues, and from a base in the Swiss Alps by Rodolphe Zander, an atmospheric physicist with the University of Liège, and his colleagues, document the rise in HCl and HF over the past 20 years for Kitt Peak, and 40 years for the Swiss station. Both show a steady atmospheric increase of the two molecules, with HF rising at a consistently higher rate than HCl. Whereas HCl does have some natural sources, HF is produced almost entirely by photo-disassociation of CFCs. "When you monitor the increase," says Zander, "and see the ratio of HF and HCl have a kind of constancy, you can say that HCl and fluorine in the stratosphere are coming from the same source, namely the [CFCs]."

Singer agrees now that Zander, Rinsland, and colleagues have done "a very careful job of tracing the amount of chlorine and fluorine in the stratosphere." He adds that this seems to settle at least one point: "I'm now reasonably convinced," Singer told *Science*, "that CFCs make the major contribution to stratospheric chlorine, and what has convinced me is the published data." And that leaves the critics with little basis for claiming that the ozone layer has long withstood high levels of chlorine without harm.

–G.T.

What is perhaps most ironic, or frustrating, to the research community is that their most vocal critics focus on the least uncertain aspect of ozone depletion science. It is well established, they note, that levels of CFCs are increasing in the stratosphere and that chlorine levels are rising in tandem. And the evidence that the Antarctic ozone hole is caused by chemical reactions, in which chlorine plays a key role, is equally robust.

Yet atmospheric scientists freely admit that, as a January 1993 review of the Department of Energy's (DOE) Atmospheric Chemistry Program's Ozone Project put it, current understanding of global ozone behavior is "fraught with uncertainty." Among these uncertainties are whether ozone depletion in the Northern Hemisphere is due to natural variation and changes in atmospheric circulation, chlorine from CFCs, or some combination of both. Another crucial unknown is whether ozone depletion has led to a measurable increase in the flux of ultraviolet light at Earth's surface. The only existing study, by Joseph Scotto, then of the National Cancer Institute, published in *Science* in 1988, showed no increase in ultraviolet light in eight locations in the United States, and perhaps a slight decrease. Scotto, however, used data obtained from instruments that were not built for measuring yearly trends.

What everyone seems to agree on is that more research is needed. For now, what to do is a question of scientific politics: What constitutes enough certainty to require action and regulation? The dilemma was aptly described in the DOE's Ozone Project review: "On the one hand, recent evaluations of stratospheric and global tropospheric ozone trends indicate substantial anthropogenic impacts that, if allowed to continue, could result in widespread and unacceptable damage. On the other hand, current and proposed remediation efforts have resulted and will result in severe and potentially unacceptable, socioeconomic impacts."

From there, opinions will naturally vary on what action is necessary. Singer, for instance, argues that the Montreal Protocol was passed prematurely, while the state of the science was still far too uncertain and the possible deleterious effects of ozone depletion unknown as well. Ari Patrinos, director of the DOE program, like many of the researchers *Science* spoke to, argues the opposite—for the necessity of taking action. "There's only one atmosphere," says Patrinos, "and sometimes we have to be very conservative in the actions we take."

–Gary Taubes