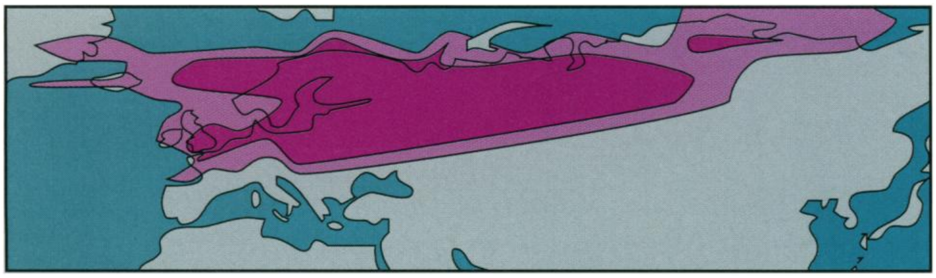

A sword hangs over Europe. *On 11 January the UARS satellite saw Antarctic-like levels of ozone-destroying chlorine monoxide over northern Europe.*

SOURCE: NASA ILLUSTRATION: D. DEFRANCESCO

New Assaults Seen on Earth's Ozone Shield

Observations from the Caribbean to the Arctic show that stratospheric ozone is poised for widespread destruction

"NONE OF THE NEWS IS GOOD," WARNED atmospheric chemist James Anderson as he laid out the disquieting results from the most detailed and far-ranging examination yet of the health of the stratospheric ozone shield. But how could the news possibly get worse? Chlorofluorocarbons (CFCs) and other manmade chemicals have already been found guilty of gnawing a hole in the ozone layer over Antarctica. CFCs have also been clearly implicated in limited ozone losses—but as yet no hole—over the Arctic. And ozone has been disappearing over the latitudes of the United States for more than a decade. Just the same, said Anderson and other researchers at a press conference last week, there's worse to come.

Don't be surprised to see a full-blown ozone hole over the Arctic, they said—perhaps within the next month—that might well slide south to affect densely populated areas of Europe. And expect ozone losses in other parts of the world to be more rapid than had been predicted, though researchers can't say just where. These grim forecasts reflect a newly proven systemic vulnerability in the upper atmosphere, Anderson said at the press conference, which was devoted to results from the ongoing Airborne Arctic Stratospheric Expedition and from NASA's Upper Atmosphere Research Satellite (UARS), launched in September. "The ability of the atmosphere to fend off [ozone-destroying] chlorine is weaker than we thought before," he said. "The system is breaking down in local regions; we don't know if it's going to be shredded on a larger scale."

The culprit is the stratosphere's haze of tiny particles. These set the stage for ozone destruction by catalyzing chemical reactions that, directly and indirectly, favor the conversion of the chlorine in CFCs into its ozone-destroying form, chlorine monoxide. Until now, only the stratospheric ice particles that form in polar regions had been definitively implicated in ozone destruction. But the new results show that particles elsewhere are fostering similar ozone-destroying chemistry worldwide. They include the natural aerosols of sulfuric acid in mid-latitudes—recently bolstered by the spreading cloud of debris from June's eruption of Mount Pinatubo—and perhaps ice particles in, of all places, the tropics.

The finding that particles are engaged in ozone destruction outside the polar regions doesn't come as a complete surprise to atmospheric chemists, who had suspected as much based on lab experiments, computer simulations, and ozone observations (*Science*, 1 November 1991, p. 645). But the efficiency with which chlorine monoxide has formed this winter in the mid-latitudes has startled them. With cold winter temperatures accelerating the chemistry, summertime levels of 0.025 parts per billion (ppb) had quadrupled to 0.100 ppb by December.

One cause for the jump in chlorine monoxide is obvious in data from the high-flying ER-2, a converted U-2 spy plane that measured stratospheric composition over North America as part of the airborne expedition. One of the compounds studied, nitrogen oxide, can protect ozone by tying up chlorine in a harmless form. Researchers already suspected that a reaction catalyzed by sulfuric acid aerosols immobilizes the nitrogen oxide, blocking its protective role. Still, they were taken aback when David Fahey of the National Oceanic and Atmospheric Administration's (NOAA) Aeronomy Laboratory in Boulder reported that the aerosols had locked up as much as three-quarters of the protective compound. And that loss was even greater when the ER-2 flew through Pinatubo's debris cloud.

The aerosols are also weakening another crucial component of the ozone defenses, a reaction between methane and chlorine that forms hydrogen chloride. That reaction locks up chlorine that might otherwise form destructive chlorine monoxide. Not this year, though: A second new instrument on the ER-2, operated by Christopher Webster of the Jet Propulsion Laboratory (JPL), revealed far less hydrogen chloride than aerosol-free air should produce.

The aerosol mischief might have been expected, but the finding of a potential new hotbed of ozone-depleting chemistry in the tropics came as a complete surprise. Flying south out of Bangor, Maine, the ER-2 encountered thin sheets of air particularly rich in chlorine monoxide as far south as the latitude of Cuba. "That is totally unexpected and extremely disquieting," says atmospheric chemist Steven Wofsy of Harvard. The sheets might have spun off the chlorine-monoxide-rich vortex of swirling winds over the Arctic, says Anderson. But it is more likely, he says, that the sheets originated in the tropics. They do not resemble the layers seen shearing off polar vortexes, he notes, and the most dramatic example was found near the Caribbean, not near the Arctic vortex.

If Anderson's guess is right, it would mean that, like the polar regions, the tropics can be a center for intensified production of chlorine monoxide. The crucial factor, as at the poles, might be the presence of ice crystals. That isn't so far-fetched, notes Anderson, when you consider that because of the cooling effect of the exceptionally strong updrafts in the tropics, the lower stratosphere there is the second coldest region on Earth (the coldest being the stratosphere over the poles). The detection of chlorine monoxide-rich gases near the tropics "may be the tip of an iceberg," says Anderson. "It could be an early warning" of more troubles to come.

Even in the more familiar territory of the polar stratosphere, the new results held some surprises. Within the part of the vortex over eastern Canada and northern New England, the ER-2 found the highest concentrations of chlorine monoxide it had ever encountered, even in flights into the Antarctic ozone hole. This suggests that the Arctic vortex is unleashing the compound even more efficiently than researchers had suspected. Perhaps more alarming, UARS revealed that the blob of high chlorine monoxide slipped off the pole for several weeks in January and hung over northern Europe from London to Moscow. "It's somewhat disconcerting to see [chlorine monoxide] in such large quantities over such extensive areas," said UARS principal investigator Joe Waters of JPL.

All that's needed now for some serious ozone destruction at northern latitudes is more sunlight, which turns on the catalytic destruction of ozone by chlorine monoxide. The Airborne Expedition team estimates that the chlorine monoxide present in the vortex at the end of January could destroy ozone at a rate of 1% to 2% per day when the spring sun hits it—more than twice as fast as the rate of springtime ozone destruction calculated during a 1989 study of the Arctic stratosphere. The total ozone loss depends on how long the polar vortex—which normally breaks up in March or April—confines the brew of chemically altered air. "If the vortex persists," says Anderson, "we can expect large ozone losses," on the order of 30% to 40%. Losses in the Antarctic hole exceed 50%, but it does not get pushed off the pole and over large population centers, the way the Arctic vortex does.

If things look bad now, researchers say, just wait a few years. Pinatubo's extra contribution to ozone destruction will fade away during the next couple of years, but the atmospheric concentrations of manmade chlorine are increasing apace. The abundance of stratospheric chlorine is now about 3.4 ppb, according to a United Nations analysis, but chlorine will peak at the turn of the century at about 4.1 ppb even if all nations adhere to the Montreal Protocol by eliminating CFCs by 2000.

All that chlorine, the latest findings suggest, will do more damage than was assumed only a few months ago. Just last October, a study sponsored by the United Nations and the World Meteorological Organization had concluded that "the additional ozone losses during the 1990s are expected to be comparable to those already observed for the 1980s." But Michael Kurylo, NASA's upper atmosphere program manager, now thinks that assessment "is probably an underestimate because the atmosphere's ability to keep ozone losses in check is less than we thought."

This realization is adding to the momentum, even within the heretofore reluctant Bush Administration, for another acceleration of the CFC withdrawal schedule and stiffer controls on other dangerous compounds. But even an accelerated phase-out would reduce peak chlorine concentrations by only a few tenths of a part per billion. That would mean, notes Kurylo, that ozone loss will be "our legacy for much of the next century." ■ RICHARD A. KERR

Swimming Against The PCB Tide

A group of marine biologists and toxicologists is out to rejuvenate the bad reputation of organohalogens

ONCE CONSIDERED SO DANGEROUS THAT Congress banned their manufacture in 1976, the family of chemicals known as the polychlorinated biphenyls (PCBs) has come in for some revisionist thinking in recent years. Many of the toxicity problems attributed to the PCBs can instead be traced to other chemicals with which PCBs were contaminated, this thinking goes. But now, PCB revisionism may itself need some revising, if a group of marine biologists and toxicologists—call them the counterrevisionists—is right.

Although no PCBs have been manufactured in the United States and other industrialized countries for years, the chemicals are still very much with us: Like DDT, they are extremely long-lived. They are still found today, for example, in older electrical transformers, where they are used as coolants. And only about 1% of the total PCBs produced have reached the oceans so far, estimates marine biologist Peter J.H. Reijnders of the Research Institute for Nature Management in The Netherlands. It's the PCBs' longevity and the lingering threat of more PCBs being released into the environment that worries the counterrevisionists.

They maintain that the PCBs and related organohalogens that have entered the oceans are making their way through the food chain into marine animals. As a result, they claim, the animals are becoming more prone to a variety of ailments, including reproductive abnormalities and immune suppression that makes them more susceptible to disease. "The oceans may be suffering from a condition similar to AIDS," is the eye-catching way that marine biologist Roger Payne, president of the Whale and Dolphin Conservation Society, puts it. Unless something is done to prevent further contamination by organohalogens such as PCB, many species of ocean mammals might become extinct and some species of fish inedible, he predicts.

Earlier this week, Payne and several colleagues officially launched a campaign to solicit funds for a 3-year research project aimed at determining just how serious PCB and other organohalogen problems are in the oceans. The idea is to look for correlations between organohalogen exposures and illness in two populations of animals in the Northern Hemisphere: beluga whales and albatross. "We want to wake up the world to the fact that these chemicals have pervaded ecosystems globally," says zoologist Theo Colborn, a senior fellow at the W. Alton Jones Foundation, a nonprofit organization that funds environmental policy research.

Payne's group has started to approach foundations and federal agencies for funding for their study, which they say could begin as early as this summer. And they've already had some success: The Dutch government tentatively has agreed to participate in some of the immunological work, Colborn says.


THE DISCOVERY CHANNEL

PCB danger? *Marine biologist Payne says yea, but others say nay.*

But some of the researchers who are most familiar with PCBs' track record are giving Payne's proposal a chilly reception. "I think the [PCB] problem is under control," says Stephen Safe, a Texas A&M toxicologist who has been studying the chemicals for 20 years. And another leading PCB researcher, Alf Fischbein of the Mount Sinai School of Medicine in New York City, says: "It's a situation where we don't have evidence of health risk. One has to raise the question about whether this concern is warranted."

Floating in the gulf that separates the two schools of thinking is a hot issue in toxicology generally: how to pin down the risks posed by low-level exposures to toxic substances such as PCBs, especially when exposures are rarely limited to just one potentially toxic chemical. Indeed, risk assessment related to low-level exposure of toxic chemicals will be a major topic at this year's meeting of the Society of Toxicologists,