Has Stratospheric Ozone Started to Disappear?

Both the primary satellite monitor and ground-based instruments have recorded a large ozone decrease. Is it real?

RESEARCHERS monitoring the stratosphere from the ground and from an orbiting satellite are reporting a sharp decrease in the amount of protective ozone that began early this decade. These first widespread reports of an ozone decrease are controversial. Even the best ozone monitors have their imperfections, and the decrease—if it is the first detection of the predicted ozone destruction by man-made chemicals—is at least twice as great as theorists would expect.

But the new results of the past year are of such potentially great importance that the ozone community is working at a furious pace to confirm or deny the reported decrease by the end of the year. If the decline turns out to be real, it will take its place with the Antarctic ozone hole as a phenomenon that could be either a reflection of harmless, if poorly understood, natural variability of the atmosphere or the first sign that man's pollution of the stratosphere is destroying the ozone that protects life on the earth from damage by ultraviolet radiation.

The prime driving force behind the current data reevaluation is the Solar Backscatter Ultraviolet (SBUV) instrument aboard the Nimbus 7 satellite. Launched in late 1978, SBUV measures the amount of solar radiation scattered up from the atmosphere at different wavelengths—ozone absorbing the radiation to varying degrees at different wavelengths—and compares that measurement with the amount coming from the sun. Donald Heath and his colleagues at the Goddard Space Flight Center in Greenbelt, Maryland, are now reporting that the total amount of ozone around the globe as measured by the SBUV held steady after launch until 1982, but then plunged and recovered only partially before diving again in late 1984 and 1985.

Overall, total ozone fell about 4% over the 7-year period or about 0.5% per year. The known effects of everything from man-made chlorofluorocarbons to sunspots can account for only about half of that decrease, according to theorist Donald Wuebbles of the Lawrence Livermore National Laboratory. That alone leads some observers to suspect that this decline, if real, is not the ozone decrease predicted by models of atmospheric chemistry.

More suspicious to others is the way the decline occurred. It was not the gradual downward trend that models of ozone behavior predict. It was more like the ups and downs of natural but transient variations. In fact, the first step downward coincided with the April 1982 eruption of El Chichón, the most prolific eruption of the century in terms of stratospheric debris, as well as the 1982–83 El Niño, the strongest of the century. Those coincidences provide any number of likely causes for the 1982 ozone drop, from ozone destruction by volcanic chlorine to alteration of atmospheric circulation patterns. However, Heath points out, total global ozone never recovered after the El Niño was over and El Chichón's debris had fallen out of the atmosphere. And the next drop did not coincide with any event that could even speculatively be connected with it.

Uncertainties abound, but every indicator of ozone abundance seems to be heading down.

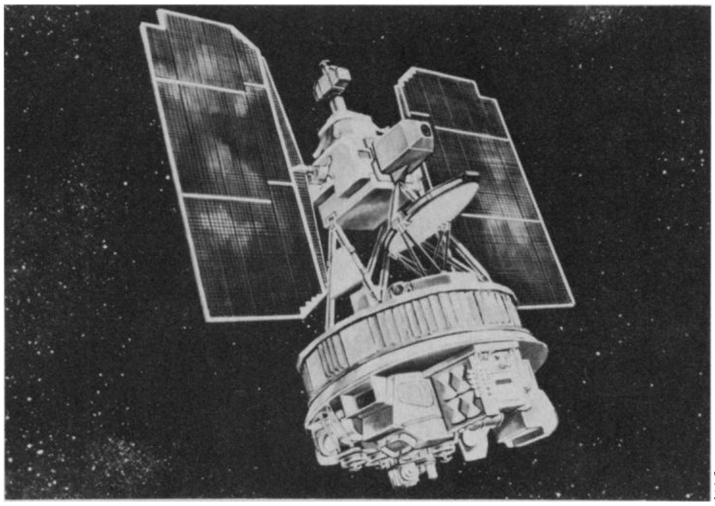
Putting difficult-to-prove suspicions aside, researchers are focusing on an obvious problem with the SBUV instrument, its inability to maintain a constant sensitivity to ozone. The problem's cause is the deterioration of the diffuser plate that directs sunlight into the instrument for comparison with the sunlight scattered from the atmosphere. Despite efforts to avoid the degradation seen on earlier instruments, including stowage of the diffuser for all but a few minutes a day, the SBUV diffuser now reflects as little as 50% of the solar ultraviolet that it did when launched. The team at Goddard processing the ozone data has allowed for this degradation by determining how its rate depends on the amount of time the diffuser has been exposed to sunlight. After 8 years of operation, the uncertainty in the amount of total ozone attributable to the diffuser degradation is less than 1% or about 0.1% per year, according to Richard Cebula of ST Systems Corporation of Hyattsville, Maryland, and Heath.

Another adjustment to the SBUV data comes from a comparison with ozone measurements made with so-called Dobson instruments. Developed by Sir G. M. B. Dobson, these are, like SBUV, ultraviolet spectrometers that can be used to compare the absorption by ozone at different wavelengths. The first instrument in the present worldwide Dobson network began operation in 1931, not to monitor long-term trends of global ozone but to aid meteorologists in tracing air movements. Although individual sites have been operated by each host country to their own standards of maintenance and calibration, the Dobson network has the longest record of total ozone and is regarded as the best standard available for comparison with satellite data.

Since shortly after its launch, SBUV has detected less ozone than the Dobson network and this negative bias has been increasing more or less steadily at a rate of 0.38% ± 0.13% per year, according to Albert Fleig of Goddard. Groups outside Goddard have found the same bias. Fleig notes that this bias may result from increasing pollutant ozone near the surface or some drift in SBUV that remains uncorrected.

With all the adjustments being made to the amount of ozone measured by SBUV, the caution or plain skepticism being expressed by many researchers, most of whom have not yet had a close look at the data and their analysis, is understandable. And there are other problems. In addition to the correction for the diffuser degradation and the drift with respect to the Dobson network, there is also the natural drop in ozone as the sun's ultraviolet radiation, which generates ozone through photolysis, decreases from a peak at sunspot maximum. SBUV was launched just before sunspot maximum, and sunspot minimum seems to have occurred last year. The accompanying decrease in ultraviolet caused an ozone decrease of perhaps 0.2% per year, according to several estimates. That leaves an unexplained decrease of about 0.3% per year measured by SBUV compared to the 0.9% per year after correction for diffuser degradation but before adjustments for drift and solar activity. The chlorofluorocarbon-induced decrease might have been 0.1 or 0.2% per year at most according to the latest consensus, but it also could have been zero over that time.

While the uncertainties in the SBUV data are being determined to everyone's satisfaction, independent support for a recent de-



NASA

The Nimbus 7 satellite

The Solar Backscatter Ultraviolet (SBUV) spectrometer on Nimbus 7 has the best view of stratospheric ozone of any monitoring system.

crease of stratospheric ozone is coming from the latest analyses of the ground-based Dobson network. James Angell of the National Oceanic and Atmospheric Administration's Air Resources Laboratory in Silver Spring, Maryland, has found a 4% decrease in global ozone between 1980 and 1985, one quarter of which he tentatively attributes to the decrease of solar activity. "I don't think there's any doubt there has been a decrease of a few percent in the last 5 or 6 years," he says. "This is the first time I've ever considered that we're seeing something. What it means I don't know." Angell notes that although the recent two-step drop in ozone is unique in the Dobson record of the past 25 years, a less rapid increase of similar magnitude occurred during the 1960s and its cause remains a mystery.

Statisticians Gregory Reinsel of the University of Wisconsin, George Tiao of the University of Chicago, and their colleagues have also found a recent decrease in Dobson-measured ozone. Between November 1978 and December 1985, there was a decrease of 0.34% per year after allowing for the effect of the solar cycle. This drop is statistically significant, they say, having 95% confidence limits of ±0.28%. That uncertainty, unlike some others being offered, has been increased by consideration of the natural variability evident in the record. "The uncertainty is larger because of it," says Reinsel, "but much more realistic."

Reinsel and Tiao's similar treatment of the SBUV data had yielded a downward but nonsignificant trend until a few months ago when they included the 1985 data. With records covering the same period from late 1978 to late 1985, both the Dobson and corrected SBUV observations show the same significant decline of 0.34% per year, they report. Reinsel cautions that although there may have been less ozone in 1985 than in 1978, it is still difficult to say whether there is a downward trend as opposed to a series of fluctuations: the significances are borderline, the records are short, and the fluctuations are a complicating factor in determining any trend, he says.

Some support for the reality of the decline and its relation to chlorofluorocarbons comes from a special application of the Dobson instruments. At about a dozen sites, the instrument follows the sun as it crosses the sky so that variations in the ozone signal with the sun's height in the sky can be used to map ozone variations with altitude. Researchers are particularly interested in using this Umkehr (meaning "reversal" in German) technique to probe the upper stratosphere near an altitude of 40 kilometers, where all chemical models predict large decreases in ozone as chlorofluorocarbons accumulate.

In this particularly responsive layer of the upper stratosphere between 34 and 43 kilometers, Reinsel and Tiao found a downward trend in ozone of 0.30 ± 0.17% per year from 1970 to 1981. This decrease falls within the predictions of chemical models. In addition, David Silberstein of ST Systems Corporation, Fleig, and their colleagues reported recently that SBUV tracks the Umkehr record well in the upper stratosphere.

As usual, there are caveats in the supporting Umkehr data. There are far fewer Umkehr sites than standard Dobson sites and they are far more unevenly distributed around the world. There is also a correction to the observations, this time for the effect of volcanic aerosols. The inability so far to correct for the huge surge of aerosols from El Chichón eliminates at least 2 years of data from consideration. An unresolved conflict also remains between data from SBUV and the Solar Mesosphere Explorer (SME) satellite at an altitude of 53 kilometers, where their ozone measurements overlap on the upper fringe of the predicted depletion zone. SBUV found a sharp decrease there beginning in 1982 whereas SME found no change or even an increase.

SBUV has detected a second layer of ozone depletion in the lower stratosphere below 25 kilometers, where the highest concentrations of ozone are found. This is a controversial claim in that SBUV's profiling of ozone abundance with altitude becomes increasingly difficult as the instrument probes through more of the atmosphere to altitudes below 20 kilometers. But here again there is qualified support for the satellite trend. Tiao and Reinsel recently found a decrease in ozone of 0.5% per year from 1970 to 1982 in the layer between 15 and 21 kilometers. This statistically significant trend is generally consistent with model predictions.

The decrease in the lower stratosphere was measured by ozonesondes, which are electrochemical ozone analyzers lofted into the stratosphere by balloons. The usual problem of poor global coverage applies—the 13 ozonesonde stations are mainly in the mid-latitudes of the Northern Hemisphere. In addition, there are uncertainties about the behavior of the analyzer itself.

Uncertainties abound in the search for trends in ozone, but every indicator of ozone abundance seems to be heading down. Heath believes that it all fits together. "We're seeing changes [in SBUV measurements of total ozone] that we can't explain by instrument degradation that are in excess of 0.5% per year," he noted at a meeting this spring. "Regional and global [ground-based] observations are consistent with what we're seeing with the satellite data. Everything appears as if we're dealing with a photochemical loss process. I'm not saying it's the chlorofluorocarbon chemistry; it could be something else. I think there's a fairly consistent picture emerging. Unfortunately, we can't explain it."

The community of stratospheric ozone researchers would like to know if Heath is right, and, if so, what it means. Only last year researchers from around the world completed an exhaustive evaluation of what is happening and what might happen in the stratosphere. The SBUV data and Heath's interpretation of them have prompted a follow-on study by an internationally sponsored Ozone Trends Panel that includes nearly 100 participants. The panel is chaired by Robert Watson of the National Aeronautics and Space Administration. The panel will complete its peer-reviewed report by the end of the year, about the time that the early results from the second National Ozone Expedition may be clarifying the nature of the Antarctic ozone hole. ■

RICHARD A. KERR