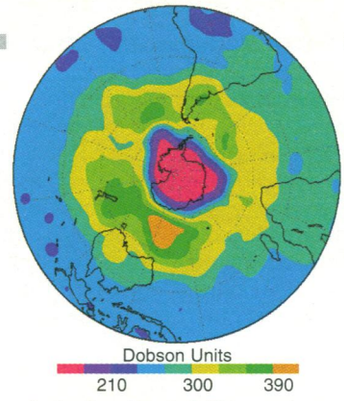
ENVIRONMENT

Ozone Hole Won't Worsen?



NOAA

As bad as it gets? This year's ozone hole, as charted by TOVS.

The timing was fitting. Last week, the chemistry Nobel Prize went to the researchers who first linked chlorine-containing pollutants with stratospheric ozone loss (see page 381). And last week brought the climax in the annual drama of Antarctic ozone destruction, which begins when the spring sun triggers the ozone-depleting reactions.

No one was quite sure what to expect from this year's ozone hole. Would 1995 finally show just a bit of healing, after several years when debris spewed by the 1991 eruption of Mount Pinatubo probably worsened ozone depletion? Or would the hole continue deepening year by year, as humanmade ozone-destroying chemicals continue building up in the stratosphere?

As of last week, the news was mixed. Satellite and balloon observations showed that the hole is about as deep and wide as ever. But new computer modeling of hole formation suggests a modestly upbeat conclusion: Future holes will be no larger. All else being equal, the model says, they should hold steady until early in the next century, when restrictions on the emission of ozone-destroying chemicals start to bring down their concentration in the stratosphere, allowing a 50-year-long recovery to begin.

Orbiting above the hole, the TIROS Operational Vertical Sounder (TOVS) gauged its area last week at about 21 million square kilometers, according to Arthur Neuendorffer of the National Oceanic and Atmospheric Administration (NOAA) in Silver Spring, Maryland. Although the hole may have had a little more growth left in it, Neuendorffer said, it probably would not exceed the 22 to 23 million square kilometers seen in recent years. Meanwhile, balloon-borne instruments flying into the hole from the South Pole found that total ozone had dropped from normal amounts of 280 Dobson units to as low as 98 Dobson units, say David Hofmann and his NOAA colleagues in Boulder. That equals the lowest ozone minima seen in recent years.

Expect about the same in the next few years, says atmospheric physicist Mark Schoeberl of the Goddard Space Flight Center in Greenbelt, Maryland. He and his colleagues have built a computer model of the swirling vortex of winds over Antarctica that forms the reaction chamber for the destruction of ozone. The model reproduces the year-to-year deepening and widening of the hole from 1980 to the early 1990s as ozone-depleting chemicals increased, Schoeberl says. As concentrations increase further in the next few years, however, the model predicts that Antarctic ozone "will go down faster each year, but [the hole] won't get deeper or wider."

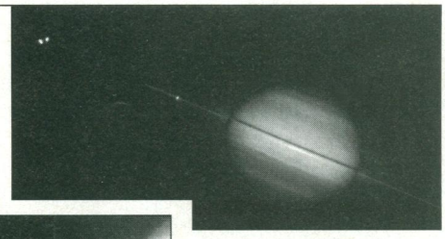
The reason, Schoeberl explains, is that in the thin stratospheric layer where temperatures are frigid enough for the ozone-destroying reactions, depletion is practically complete already. The model predicts that factors such as the loss of ozone, which chills the stratosphere, will not enlarge the layer. The next few holes should tell whether the model's optimism is justified.

–Richard A. Kerr

Summaries of the status of the ozone hole are available at URL **http://www.wmo.ch/web/arep/ozobull.html**

PLANETARY SCIENCE

Hubbub at Saturn's Rings Revealed



NICHOLSON/NASA

BOSH/NASA

Ring turmoil. One of HST's finds *(at left, right spot)* orbits near the F ring.

Saturn's rings may look serene from a distance. But ever since the two Voyager spacecraft sailed by the planet in 1980 and 1981, planetary scientists have known that there's plenty of upheaval in the wispy F ring, which lies just beyond the main ring system. The F ring looks kinked, braided, and clumpy; what order there is seemed to be the work of two small "shepherd" moons, Prometheus and Pandora, that gravitationally herd the particles of the ring into line. Now a combination of new technology—the Hubble Space Telescope (HST)—and a rare opportunity to see past the glare of the other rings is revealing more players and deeper turmoil in the F-ring region.

Astronomers announced their first new F-ring discoveries at the end of July after Saturn's rings turned edge-on to Earth in May, momentarily reducing their blinding glare (*Science*, 4 August, p. 639). Using HST, Amanda Bosh and Andrew Rivkin of Lowell Observatory in Flagstaff, Arizona, detected a host of objects that did not fall where any known moons should have been. Now astronomers are starting to make sense of how the interlopers got there and what they are.

One of the summer's discoveries, temporarily designated S/1995 S4, is now clearly a previously unknown satellite orbiting just 6000 kilometers outside the F ring. But two others are actually Prometheus and a third nearby moon, Atlas, ranging far from their predicted positions. In Atlas's case, astronomers' uncertainty about its orbit might explain the straying, Bosh says, but Prometheus is another matter. "I'm inclined to think something has happened to Prometheus to shift its orbit," says Philip Nicholson of Cornell University.

And Nicholson may have found that something. During August's second ring-plane crossing by Earth, he and his colleagues pointed HST at the F ring and discovered another new satellite, named S7, whose orbit appears to coincide with that of Prometheus. If the coincidence is real, 100-kilometer Prometheus may have a "sheep dog" companion about one-third its size that could explain its unexpected position. Like the so-called coorbital Saturnian satellites Janus and Epimetheus, Prometheus and S7 would revolve around Saturn along paths perhaps 50 kilometers apart, the innermost and faster one slowly gaining on the slower until they approached each other. Then every few years, in a gravitational pas de deux, they would switch orbits, the pursued becoming the pursuer.

Alternatively, if the orbital coincidence is more apparent than real, says Nicholson, Prometheus's orbit may have shifted when it suffered a collision or near-miss with one of the largest unseen bodies thought to be embedded in the F ring itself. Dynamicists calculate that Prometheus's orbit did take it briefly inside the F ring in 1993. Such collisions might help explain the F ring's kinks and braids—as could the sustained gravitational tug from S7, from the shepherds, and from the moons embedded in the ring itself.

Astronomers will have one more chance to sort out the turmoil when the rings go edge-on to the sun on 21 November. Then it will be another 15 years before the next time Saturn's rings obligingly wink out of sight.

–Richard A. Kerr

The Saturn Ring Plane Crossing home page (URL **http://newproducts.jpl.nasa.gov/saturn/**) has the latest news and images.