Antarctic ozone reaches lowest levels

Returning from a six-week-long experiment, atmospheric scientists last week had a dramatic message for the world about the Antarctic ozone hole. "The amount of ozone in August and September in the Antarctic region has hit an all-time low since we've been making satellite measurements," said Robert Watson of NASA.

The ozone concentration in the stratosphere above Antarctica has dropped to half of its normal levels and will most likely stay there until it begins to rise at the end of October. This cycle of ozone loss and reappearance has repeated itself each year for the last decade, worrying scientists and spurring most industrialized nations to sign an unprecedented ozone-protecting treaty (SN: 9/26/87, p.196).

While this year's cycle runs its course, the returning scientists are sifting through reams of data that will help explain why Antarctic ozone disappears and that may eventually indicate whether this process can occur over more populated regions of the world. The observations are also isolating key aspects of the ozone phenomenon that are poorly understood and will require further investigation, say the researchers.

Although the scientists who participated in this NASA-coordinated experiment could not offer any final answers about the causes and implications of the ozone hole, they did announce the preliminary results of the study, which was based at the southern tip of South America. Using two airplanes that flew into and under the areas of greatest ozone loss, the scientists garnered the first direct measurements of the air from inside the hole.

Of major importance is their conclusion that both chemical and meteorologic processes are contributing to the ozone loss. Since scientists recognized this phenomenon two years ago, they have debated whether chemical reactions are destroying ozone, or whether air patterns are transporting ozone away from the Antarctic stratosphere. Last year, a ground-based experiment in Antarctica found abnormally high levels of chlorine chemicals coincident with the areas of ozone depletion, indicating that chlorine — mostly coming from human-made chlorofluorocarbons — was active in chemically destroying ozone (SN: 9/19/87, p.182).

While the airborne experiment confirmed the role of chlorine chemicals in ozone destruction, it also found signs that meteorologic processes must be active as well. As evidence of this, the researchers cite a period from Sept. 4 through Sept. 6, when ozone levels dropped by 10 percent over an area of 3 million square kilometers. "With that sort of rapid change, it's difficult to believe it's chemical," says Watson, a program manager for the ozone experiment. In this case, he says, "it's air motions that are moving ozone around."

Moreover, the researchers believe that meteorology contributes to the Antarctic ozone loss in a much more general manner as well, by setting up a kind of self-contained "reaction vessel" in which chlorine chemicals can break down ozone. During the long, dark periods of the Antarctic winter and spring, a vortex of air over the continent seals off the atmosphere above and prevents it from mixing with air from more northerly latitudes.

As a result of this isolation, stratospheric temperatures plummet to a point where water vapor condenses and creates cloud particles. On these particles, inactive chlorine chemicals readily assume an active form that participates in an ozone-destroying chain reaction. The reaction begins with the springtime return of sunlight to the bottom of the world. Later in the spring, influxes of northern air break the vortex apart and return the Antarctic stratosphere to more normal conditions.

a.) $Cl + O_3 \rightarrow ClO + O_2$

b.) $ClO + ClO \rightarrow Cl_2O_2$

c.) $Cl_2O_2 + \text{light} \rightarrow Cl + \begin{cases} ClO_2 \\ \text{or} \\ OClO \end{cases}$

Steps a through c detail how chlorine can break down ozone (O_3). Scientists are unsure how often Cl_2O_2 breaks into the inactive, symmetric form (OClO).

According to Watson, the extreme weather conditions are crucial to the special chemistry that is active in the Antarctic. In other areas of the world, chlorine is also destroying ozone; but these reactions occur at much higher altitudes and at drastically slower rates. Still, some scientists say that certain types of special chemistry similar to that of the Antarctic might possibly become active in warmer latitudes. For now, though, Watson cautions that "we do not fully understand the cause or causes of the Antarctic ozone hole; therefore, we believe it is *extremely* premature to speculate on the global ramifications."

In particular, he says, scientists are baffled by a new finding concerning the size of the chemical "reaction vessel." Researchers who believed that chemistry was the driving force behind the ozone hole had originally assumed that unusual chemical conditions would extend throughout the entire Antarctic vortex. However, says Watson, the aircraft observations revealed that "the area of perturbed chemistry is actually smaller than the area of the classical meteorologic vortex."

What is remarkable about this observation, he says, is that ozone concentrations were low inside the entire meteorologic vortex, even in regions where the chlorine levels were normal. "That is one of the real puzzles, as to why there was not good mixing or there was not a more homogeneous atmosphere within the meteorologic vortex," he says.

Mark R. Schoeberl, an atmospheric scientist with NASA, also notes that chlorine monoxide (ClO) — a principal chemical active in the ozone destruction — was not always present at altitudes that would account for the low ozone levels. While the ozone-depleted layer extended from 23 km above the surface down to 14 km, ClO appeared to be concentrated above 18 km.

Schoeberl and most other atmospheric scientists think these discrepancies between ClO and ozone signal the activity of some complicated meteorologic processes. But Schoeberl is also quick to admit that chlorine is undoubtedly contributing to ozone destruction in the atmosphere above Antarctica. The question that no one yet can answer is: How *much* of the ozone problem results from chlorine chemistry?

In theory, computer models of the stratosphere can provide an answer. By plugging in the observed levels of ClO and other chemicals, researchers can use a model to calculate the ozone loss that would result from that distribution of chemicals. But the airborne experiment has isolated one key unknown in the chlorine chain reaction.

Atmospheric chemists believe that one step in the chlorine cycle produces a chemical that can be shaped in two distinct forms. If the reaction produces the asymmetric form of the chemical (ClO_2), then the ozone-depleting cycle continues to speed ahead, and one chlorine atom can destroy almost 1 million ozone molecules per second, says N. Dak Sze from Atmospheric and Environmental Research, Inc., in Cambridge, Mass. However, the reaction can also produce a symmetric version of this molecule (OClO). When chlorine is shunted into this form, it enters a null cycle that does not destroy ozone.

Scientists are unsure how often the chlorine reactions produce the symmetric, innocuous molecule, but they have observed it in the Antarctic stratosphere. Because modelers do not know the ratio of symmetric OClO to asymmetric ClO_2, they cannot accurately assess how much damage the observed chlorine is causing. If, says Sze, the reaction always formed OClO, "that would mean the high [observed] ClO values have nothing to do with the ozone reduction." He adds, "In terms of chemistry, I think everyone agrees that this is probably the number-one question."

— R. Monastersky