Ozone falls as the winds weaken

The ozone content of the stratosphere above Australia seems to have decreased slightly over the past few years. But the evidence doesn't point to supersonic jet exhausts, spray-can gases, or any other pollutants as the cause. The decrease appears to be due to a reduction—probably temporary—in high-altitude wind strengths.

Ecos has referred many times to the ozone layer, its vital role in filtering out dangerous ultraviolet radiation from the sun, and man-made threats to it. Scientists have recently suggested another possible threat—nitrogen oxide gases given off when bacteria in the soil break down nitrogen fertilizers. But, as with other nitrogen and chlorine compounds that are now finding their way into the stratosphere and could destroy ozone, there is no evidence yet that these gases are having any impact.

Trends in ozone concentrations are hard to identify, because of large natural fluctuations. Maximum concentrations, recorded in spring, can be half as high again as autumn minimums. Also, big fluctuations occur from year to year and over longer periods. Measurements between 1926 and 1971 at Arosa, Switzerland, show trends over 10-year periods ranging from falls of 9% to rises of 6%. But no significant trend emerges from the whole 45 years of records.

The 1960s seem, in general, to have been years of rising concentrations. The increase averaged about 7·5% in the Northern Hemisphere and in the Southern Hemisphere about 2·5%. Now, at least above Australia, the trend seems to be downward.

From 1960 to 1970, scientists from the CSIRO Division of Atmospheric Physics found statistically significant increases in ozone at Darwin and Brisbane. They also recorded increases, but not statistically significant ones, at Macquarie Island in the Southern Ocean and Aspendale, Melbourne.

The period 1963–74, however, saw a statistically significant downward trend at Aspendale—about a 4% fall. The measurements also show falls over this period at Brisbane and Macquarie Island, but these weren't statistically significant. Neither was a small rise recorded at Darwin.

The two sets of figures, taken together, suggest that concentrations have been falling at least since 1970.

To further complicate the picture, different trends in ozone concentrations occur at different levels in the stratosphere. At Aspendale, for example, measurements by Dr Barrie Pittock show that ozone concentrations decreased between 1965 and 1974 up to an altitude of about 25 km and increased above that height. And the trends vary with season.

Dr R. N. Kulkarni of the

Changes between 1963 and 1974

above	temperature fall 16 km up (degrees C)	predicted ozone change (m.atm.cm)	measured ozone change (m.atm.cm)
Darwin	1·6 ± 0·4	−3	+1 ± 4
Brisbane	1·5 ± 0·7	−7	−4 ± 4
Aspendale	1·1 ± 0·7	−10	−13 ± 4
Macquarie Island	1·5 ± 1·0	−9	−7 ± 8

Division of Atmospheric Physics worked out the concentration trends for 1963–74. Then, searching for the reasons for the changes, he looked at variations that had occurred in stratospheric temperatures and winds, which are known to be related to ozone concentrations.

Scientists have found a link between the air temperature at an altitude of 16 km and ozone concentrations. As the amount of ozone increases, so does this temperature. The CSIRO observations show that a 1°C change corresponds to a change in atmospheric ozone content ranging from about 2 units over Darwin to 9 over Aspendale. The units are milli atmospheric centimetres (m.atm.cm.); ozone levels in the air range between about 250 and 400 m.atm.cm.

The temperature 16 km above Australia varies from about -60°C to -70°C. Dr Kulkarni looked at the records and found that the average had fallen between 1963 and 1974 over all four ozone-measuring stations, by between 1·1°C and 1·6°C.

The ozone decreases predicted from these temperature drops agree well with the measured changes (see the table). Dr Kulkarni concludes that there is therefore no need to look to possible effects of chemicals added to the stratosphere to explain the ozone trend.

Why have the temperatures fallen? The explanation seems to be that air is taking longer to spread outwards from the tropical regions where ozone is formed. Ozone forms high in the stratosphere when ultraviolet radiation shines on oxygen molecules. It is then carried towards the poles by the winds, and towards the ground as the air mass subsides.

If the winds in the lower stratosphere weaken, ozone and the air travelling with it take longer to reach middle-latitude locations such as Australia. There is less movement towards the ground and hence less warming of that part of the stratosphere.

Dr Kulkarni sought to confirm that the stratospheric circulation had slowed during the period of falling temperatures and ozone concentrations. He found that wind measurements at a height of 18–19 km over the Laverton Air Force Base near Melbourne showed a weakening of the southerly component. This is consistent with a slowing circulation in the lower stratosphere.

Another piece of evidence is the fact that winter concentrations of ozone have declined over Aspendale and Brisbane while summer concentrations have risen. Less ozone could be expected to arrive from equatorial regions in winter if the lower stratospheric circulation was weaker. And in summer, less could be expected to move out of the stratosphere into the lower atmosphere where it is converted back to ordinary oxygen.

This leads to the question: why has the circulation slowed? The answer isn't known.

Dr Kulkarni thinks stratospheric wind speeds, and hence ozone concentrations, may turn out to be linked to the activity cycle of the sun. Every 11 years the sun reaches a peak of activity, erupting with stronger and more-frequent solar flares and geomagnetic storms than in the years between. A low point in activity comes half way through this cycle.

A trough occurred in 1974, and 1969 was a peak year. This fits in with the observations suggesting rising ozone concentrations to about 1970 and then a fall. But whether a link exists, and if so how it operates, remain unknown.

Ozone is continuously formed and destroyed in the stratosphere, and one of the gases that destroys it is nitrogen dioxide. This is one of the compounds that scientists fear may weaken the ozone barrier if human activities produce increased concentrations. But it occurs naturally in small quantities.

Measuring atmospheric ozone from the ground . . .

. . . and by balloon.

Knowledge of how these quantities vary around the earth and with season is obviously important if the causes of rises and falls in ozone concentrations are to be fully understood. But so far very little information exists on nitrogen dioxide levels, mainly because they have been difficult and expensive to measure.

Dr Kulkarni has now worked out a way to use the spectrographic instruments monitoring ozone to measure nitrogen dioxide as well. The measurements are not very precise, but they are good enough at least to show major fluctuations. And they can be easily made at the 120 or so ozone-monitoring stations now operating around the world.

An interesting finding that has already showed up at Aspendale is that nitrogen dioxide and ozone concentrations rise and fall together with season. Both have their maximums in early spring and minimums in autumn.

This suggests that similar processes are responsible for the fluctuations of both gases. It also shows that, at least from season to season, a build-up of nitrogen dioxide is not necessarily accompanied by a reduction in ozone concentrations.

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