

The hole truth

What's news (and what's not) about the ozone hole.

Susan Solomon

The discovery in 1985 of an unprecedented 'hole' in Antarctica's ozone layer heralded the beginning of one of the most influential environmental stories of the late twentieth century¹. The tale of the missing ozone at the bottom of the world was made all the more intriguing by its strong seasonal behaviour. Ozone levels decline rapidly each year in August and September (Antarctic spring), and the hole is typically at its deepest by late September to early October. It then largely fills in through mixing of surrounding ozone-rich air by late January, ready for the next year's cycle.

Each Antarctic spring in the late 1980s and early 1990s, enthusiastic scientists shared the news about the hole with a fascinated and equally enthusiastic public. Slowly, the mystery surrounding events in the Great White South evolved into understanding for both groups². The root cause of the hole was identified as a number of industrially produced chemicals. Policy-makers worldwide quickly agreed on the Montreal Protocol to phase out these chemicals, and by the late 1990s global production of these gases had dropped by more than 90% (see 'How can we tell if the Montreal Protocol is working?', overleaf). Like many scientists involved in this sea-change in scientific and public knowledge, I have been heartened by widespread interest in the issues, and encouraged by the ability of even school-children to understand the key elements of the story.

The ozone hole has been considered by many to be the success story of global environmental policy ever since the Montreal Protocol came into force. But in the past few years I have grown concerned about a public that seems to be more confused than intrigued by the news reports that greet the appearance of the hole each year. Despite the apparent success of the Montreal Protocol, the elimination of the ozone hole may seem to progress at a remarkably uneven rate. And as the hole changes in size and shape (Fig. 1, overleaf), communicating to the public what this means has become much harder.

I feel that this presents the scientific community with a new challenge. Given that global production of ozone-damaging compounds is now nearing zero, yet ozone depletion will continue for many years to come, how can scientists help to preserve the remarkable success in public understanding of the ozone hole? How can we best explain why this is so in language understandable to



The advent of a hole in the ozone layer over Antarctica brought the continent into the media spotlight.

students, teachers, scientific colleagues in other fields — indeed to everyone who shares our interest in a phenomenon that is not just scientific but also historic, not just technical but also sociological? How do we distinguish between what is news and what is not as the ozone hole moves into an expected period of very slow recovery? Are there any observable connections between the behaviour of the ozone hole and whether or not the Montreal Protocol is working? If not, how can we tell if the protocol is on or off track?

Cause and effect

Within five years of the ozone hole's discovery, the cause had been established. Direct observations of chemicals in the atmosphere showed that an increase in chlorine concentrations in the stratosphere was the key agent responsible³. This rise was mainly due to chlorofluorocarbons (CFCs) — long-lived chemicals produced by the chemical industry and used variously as, for example, coolants in refrigerators and air conditioners, foam-blowing agents and solvents.

The chemical reactions that destroy ozone can occur with unparalleled efficiency in Antarctica because of the very cold conditions in the polar stratosphere during the winter and spring months. These allow special high-altitude clouds to form as soon as temperatures dip below -85°C (ref. 4). Cold surfaces within these clouds serve as the sites for very rapid reactions that convert

inactive chlorine into its ozone-destroying forms. The hole appears during the Antarctic spring because the key ozone-destroying reactions are initiated by sunlight, a factor largely absent during winter months.

Why is there no Arctic hole? Ultracold temperatures are far more widespread and persistent in the Antarctic winter and spring atmosphere than in the Arctic, where the flow of air over the Himalayas and Rocky Mountains and land-sea temperature contrasts can generate very large 'atmospheric waves'. On the ground, we experience many of these waves as the passage of storms, and some travel upwards to the stratosphere, ultimately mixing warmer mid-latitude air with cold polar air. So the varied topography of the Northern Hemisphere gives it a greater number of atmospheric waves and a warmer polar stratosphere in the winter and spring on average than in the south⁵.

In brief, the ozone hole is driven by a blend of three factors: excess chlorine, which is why the ozone hole is a recent phenomenon; cold temperatures, which account for its occurrence in Antarctica; and sunlight, which explains why the hole opens up in spring, as light returns to the polar cap.

Repairing the damage

As production of CFCs ceases, how long will it take for the reactions fuelling ozone loss to subside? The key is the atmospheric lifetime of the CFCs. Many air pollution problems, such as acid rain, are linked to

S. SOLOMON

chemicals that have short lifetimes in the atmosphere because they dissolve in rainwater within a few days, or are rapidly destroyed by chemical reactions. Likewise, most of the chlorine from natural sources, such as sea spray or volcanoes, dissolves quickly and effectively in rainwater, preventing much of it from reaching the stratosphere⁶. But the major CFCs have atmospheric lifetimes of 50–100 years, allowing them not only to reach the stratosphere in significant quantities but also to remain there long after emissions have stopped (see ‘How can we tell if the Montreal Protocol is working?’, opposite).

By 2001, global reporting of the production and emission of CFCs revealed a dramatic drop from peak values in the late 1980s and this trend was confirmed by air sampling studies^{7–12}. Nonetheless, the long lifetimes of the megatonnes of CFCs already in the atmosphere mean that clear and lasting improvements in the ozone hole can take place only slowly. Removal of the ozone-destroying chlorine and hence return of the Antarctic ozone layer to its natural state will take decades.

Variable pattern

But even in the relatively inactive Southern Hemisphere, with its less variable topography compared with the north, atmospheric waves and weather vary from one winter or spring to another. Just as a particularly warm spring can occur in, say, Wellington, New Zealand, one can also occur in the Antarctic stratosphere, resulting in less ozone depletion for that year. Satellite data confirm the distorting effects of atmospheric waves on the extent of the ozone hole from year to year (see Fig 1)⁵.

It is the annual reporting of these ups and downs in the ozone hole’s area (and occa-

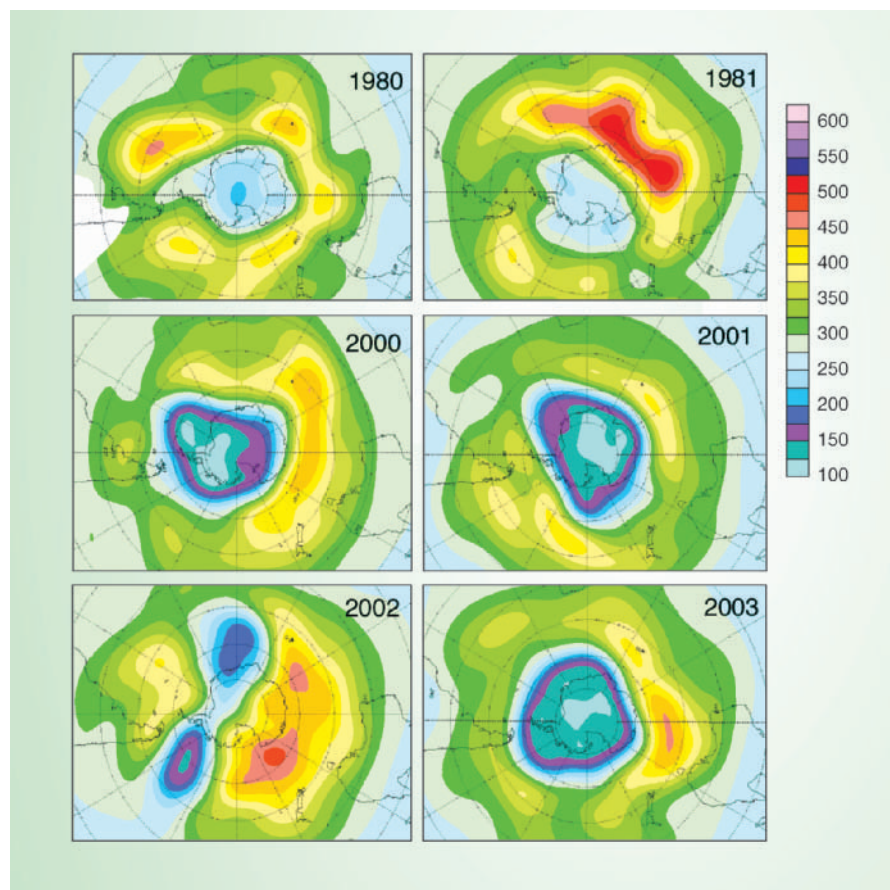


Figure 1 Satellite maps of total ozone over Antarctica on 24 September, when the ozone hole is near its annual peak, in 1980, 1981, 2000, 2001, 2002 and 2003. The colour scale shows the amount of ozone in Dobson units, indicating the depth of the hole. The images are based on multiple satellite records and analyses and are available from many sources, including the World Ozone and Ultraviolet Radiation Data Centre in Toronto, Canada, <http://woudc.ec.gc.ca/cgi-bin/selectMap>.

sionally depth) that seems to be causing general confusion. For example, the ozone hole in 2000 was large, leading much of the media — including respected institutions such as the BBC¹³ — to speculate that recovery might take longer than had been expected. Other news sources suggested that it was a sign of a reversal in recovery, or a problem with the Montreal Protocol.

In contrast, the 2002 ozone hole was much smaller and split in two, an unprecedented event. A massive Antarctic wave led to stratospheric temperatures in September that were higher than observed in the previous 50 years, affecting both the area and depth of the hole¹¹. Whether this was a rare but random event dictated by the intrinsic chaos of atmospheric dynamics (as for the ‘storm of the century’) or the beginning of a more systematic shift is currently unknown. It certainly did not signal that the protocol was working even faster than expected, although numerous reports that I saw on local and national television suggested exactly that. It was also interpreted that way by some industrial representatives according to a report in the *New York Times*¹⁴.

For us to know whether the Montreal Protocol’s future will match its past success will require continued observations of global changes in CFC levels (see ‘How can we tell if the Montreal Protocol is working?’, opposite). These measurements should therefore be highlighted whenever the protocol’s status is being discussed by scientists or journalists. In contrast, linking fluctuations in hole size with the protocol’s effectiveness should be discouraged. Public understanding is likely to be best served if scientists stress that year-to-year changes in ozone-hole area (or depth) are more likely to reflect changes in stratospheric ‘weather’ conditions that influence ozone loss over the short term, rather than long-term issues such as whether the protocol is working or not.

Future scientific questions that might be linked to the fate of the ozone hole include whether global warming will begin to affect ozone depletion (either through effects on waves or on temperature); whether the Arctic stratosphere will change to be more like the Antarctic in coming centuries; and how possible changes in the atmospheric concentration of methane or nitrous oxide might affect ozone-hole chemistry. Insights on

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Monitoring the levels of CFCs in air samples is key to assessing the success of mitigation efforts.

these issues obtained by monitoring the ozone hole will surely be of interest to the public, but will not arise from observations from a single year, or even over a few years, underscoring the need for care when discussing them.

Are annual reports on the development and size of the ozone hole still newsworthy in view of these considerations? One might imagine that the time has passed for annual press statements on a phenomenon that is so well known and understood, but like many issues in science, this one has a range of devoted and rightfully interested parties. People throughout the Southern Hemisphere reasonably want to know as early as possible what is happening above Antarctica, because severely ozone-depleted air can occasionally be transported to populated areas of South America, New Zealand and even as far north as Australia. But the ozone hole belongs not just to the people of the Southern Hemisphere nor to interested scientific audiences, but to a wider world whose curiosity has been aroused. In their annual announcements and reports, both scientists and journalists will best serve the public by taking that into account.

Because there are several sources of information on the ozone hole, there has been a rush in previous years to be the first to announce the appearance of the hole. Taking more time on the part of scientists to make clear just what the story is and to ensure that the analyses are complete would foster greater public understanding. Taking more care on the part of journalists to avoid leaps to unfounded policy inferences would bolster the probity that is the hallmark of quality science reporting. Scientists and journalists will be best placed to communicate with each other and with the public if together they ensure that any routine announcements on the ozone hole not only describe what is occurring each year but also what that does and does not mean.

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How can we tell if the Montreal Protocol is working?

The ozone hole grew during the 1980s as emissions of chlorofluorocarbons and other gases built up in Earth's atmosphere and ozone-depleting chemistry took place at ever-faster rates. By the late 1990s, enough nations had signed the Montreal Protocol to drastically reduce global emissions of most of the key gases. How can we be confident that these actions are working?

Monitoring these gases in our atmosphere provides direct proof. The great bulk of industrial chemicals that contribute to changes in the ozone layer are remarkably inert and so survive in the atmosphere for decades or even centuries. The mix of factors that controls the build-up and decline of such gases — production, emission and lifetime — can be illustrated by data for one major chlorofluorocarbon, CFC-11 (see inset).

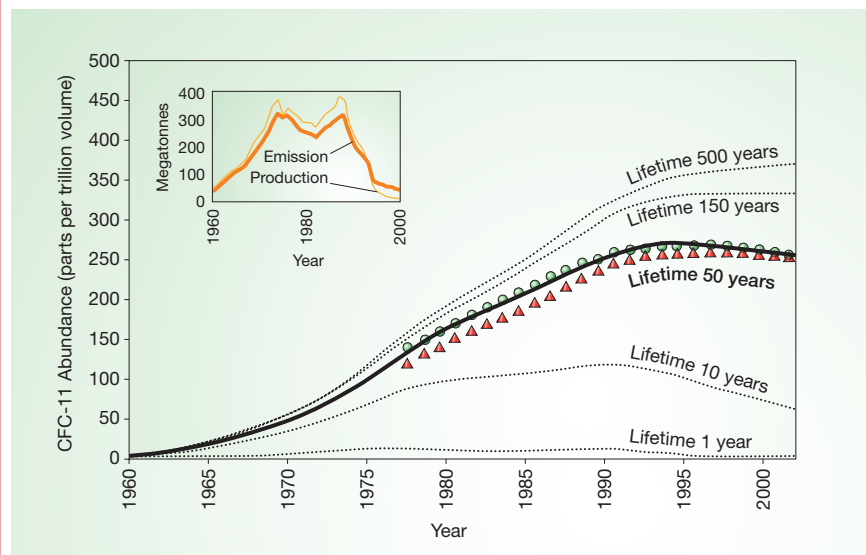
Global production and emission for CFC-11 (see inset and refs 7,12) are based upon industrial estimates, and are thought to be accurate to about 15%. Production is not necessarily the same as emission in a given year because of delayed release from existing materials, such as thermal foam insulation in older buildings or refrigerators⁷. Consumers and policy-makers who wish to accelerate the recovery of the ozone should consider responsible recovery of such materials, as is done when the materials in discarded refrigerators are recycled rather than shredded.

The third factor, lifetime, is reflected in the comparison of the observed and calculated abundances of CFC-11. Observations from

both hemispheres^{8–10} (data points) are shown alongside the calculated abundances based on global emission estimates (curves) and adopting atmospheric lifetimes of 1, 10, 50, 150 or 500 years. These show that the atmospheric lifetime of CFC-11 is about 50 years. If it were much shorter, the gas's abundance could never have built up to its present value and would have dropped more steeply by now; much longer and the concentrations would have peaked at higher values and would be continuing to increase slowly today despite the greatly reduced emissions of recent years.

The slow decline in abundances now being observed by scientists worldwide supports, within data uncertainties, the true 50-year lifetime of CFC-11 and illustrates the success of the Montreal Protocol. More evidence that the protocol is working comes from the gradual closing of the gap between Northern and Southern Hemisphere abundances measured over the past decade. During the build-up of emissions in the 1970s and 1980s there were far larger releases of CFC-11 in the more heavily populated Northern Hemisphere, but as emissions declined after 1990, atmospheric mixing acted to even out the global distribution. Similar behaviour has been documented for many other chlorofluorocarbons. These data show that the Montreal Protocol is working, while emphasizing the need for patience as we seek signs of genuine recovery in the ozone layer over future decades.

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CFC-11 in the atmosphere. The curves represent predicted abundance of CFC-11 for different atmospheric lifetimes. Actual data for Northern (circles) and Southern (triangles) Hemispheres show that CFC-11's atmospheric lifetime is about 50 years. Data points compiled from refs 8 and 9; data from ref. 8 have been adjusted by 2% to align calibrations within uncertainties; curves adjusted upward by 10% within uncertainties.