Antarctic ozone depletion and its effect on New Zealand

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Abstract. This paper briefly describes the processes leading to the dramatic depletion of ozone that occurs each springtime over Antarctica, known as the Antarctic ozone hole. The temporal evolution of the size and severity of the ozone hole, and how it might change in the future, are analysed. In addition the ways in which the Antarctic ozone hole can affect southern mid-latitudes, including New Zealand, are discussed. Some of these effects cause isolated and transitory events, but the overall impact is a general dilution of ozone in mid-latitude air.

Introduction

It is now more than twenty years since the first scientific paper was published on enhanced depletion of ozone in the Antarctic (Farman *et al.*, 1985). Since then a huge research effort has brought a broad understanding of the mechanisms for this depletion, now known as the Antarctic ozone hole. This knowledge is summarised in quadrennial international assessments of ozone depletion (e.g. WMO 2003). Because of the relative proximity of New Zealand to Antarctica, there is understandably concern, not all of it well founded, that the ozone hole affects us in New Zealand.

The "recipe" for Antarctic ozone depletion

The principal contributor to ozone depletion is the elevated levels of anthropogenic chlorine and bromine in the atmosphere. However, the enhanced depletion of ozone over Antarctica that occurs each spring results from a combination of additional factors.

The story starts in winter with the formation of a polar vortex in the stratosphere around Antarctica. This is a band of strong westerly winds that acts as a barrier to the transport of air into and out of the Antarctic stratosphere. Inside this container, the lack of incoming solar radiation during winter means results in cooling of the stratosphere to global record lows.

Polar stratospheric clouds (PSCs) then form in the lower stratosphere at altitudes of 12-20 km, much higher than everyday clouds. The PSC particles can consist either mainly of hydrates of HNO_3 that form below 196K, or of water ice that form below 187K. The surfaces of these particles provide reaction sites for the chemical conversion of relatively stable forms of chlorine and bromine in the atmosphere more reactive forms.

The final step in that activation is a photolysis reaction that occurs as sunlight returns to the Antarctic stratosphere, resulting in highly reactive chlorine and bromine that destroys ozone through catalytic cycles. The result is a rapid removal of almost all the ozone during September at altitudes where PSCs form, reducing the total column of ozone by 60-70% and affecting an area of up to 30 million square kilometres (Figure 1).

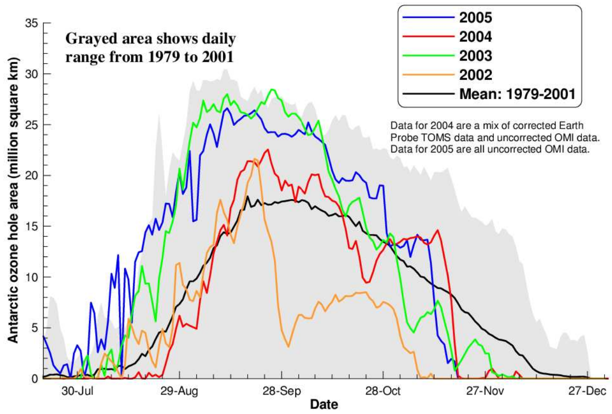

Figure 1. The area of the Antarctic ozone hole (total ozone < 220 DU) as a function of time for several years. The 2005 hole is shown by the blue line and 2002-2004 with lines of other colours. The range and mean size of earlier holes are also shown.

Once the Antarctic ozone hole has formed it remains largely contained within the vortex until the conditions that maintain the vortex weaken and it breaks up, usually in November or December (Figure1). During this period the vortex can get moved around by planetary-scale waves in the atmosphere, resulting in a sloshy, rotating motion. This means that a given site near the coast of Antarctica might have the ozone hole over it on one day and not on the next. For example, NIWA measurements of ozone at Arrival Heights (near Scott Base) during October 2005 varied wildly from 150 DU to 400 DU. It can also mean the hole is temporarily displaced to lower latitudes.

Is the Antarctic ozone hole getting bigger?

Figure 2 shows the daily average ozone mass deficit over Antarctica, averaged from late winter through to early summer. The ozone mass deficit, a measure of the severity of the Antarctic ozone hole, shows the mass of ozone that would need to be added to the stratosphere so that ozone no longer falls below 220 DU, the minimum ozone levels observed over Antarctic in the 1970s. Also plotted in Figure 2 is a measure of the amount of ozone depleting chemicals in the stratosphere, calculated from the concentrations of source gases in the lower atmosphere and lagged by 3 years to account for transport time to the stratosphere, scaled on the graph to show the best fit to the ozone hole sizes. During the 1980s and 1990s there was a general and rapid increase in the severity of the ozone hole, but with considerable year to year variability that sometimes appears to be a two-year oscillation. This rapid growth has now stopped and since 2000 the ozone hole has generally been less severe. This reduction is the severity of Antarctic ozone depletion in recent years results more from unusually warm stratospheric conditions in recent years (Hoppel et al., 2005), which reduced the coverage and frequency of PSCs, rather than a significant reduction in concentrations of ozone depleting substances. However, as concentrations of ozone depleting substances decline, continued reduction in ozone hole severity is expected but it will be several decades before there is no longer an Antarctic ozone hole.

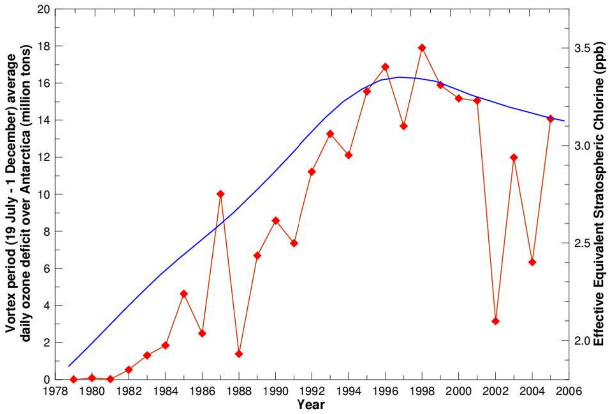

Figure 2. A measure of Antarctic ozone hole severity, the average mass of depleted ozone from July to December, diamond symbols, left axis) and an estimate of the amount of chlorine and bromine in the stratosphere, effective equivalent stratospheric chlorine (smooth curve, right axis).

The effect on mid-latitudes

When the ozone hole is at its maximum extent, in late September and October, there is no direct effect on mid-latitudes because the ozone hole is well contained by the polar vortex. During this period, a ridge of ozone rich air builds up at the equatorward edge of the vortex and New Zealand experiences its annual maximum in ozone. For example, at the start of October 2005, when the ozone hole was close to its maximum size, the ozone over New Zealand was relatively high at 370 Dobson Units (DU) and the peak clear sky UV index (UVI) would have been 5 in the South and 6 in the North .

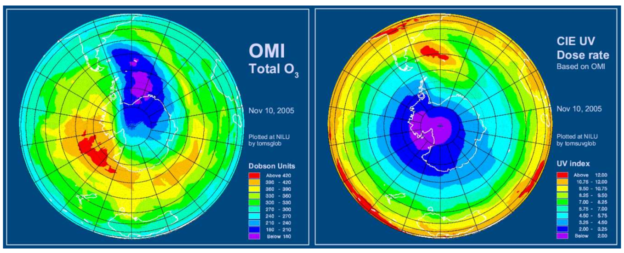

Figure 3. Total ozone measured by satellite on November 10, 2005 (left panel) showing the ozone hole displaced towards the South Atlantic, and estimated peak surface UVI calculated from the same measurements (right panel).

However three distinct effects can occur which do affect mid-latitudes later in the season. The first of these are events where the ozone hole is displaced to lower latitudes before it breaks up. For example on 10th November 2005 (Figure 3) the ozone hole was displaced towards the Atlantic Ocean resulting in the region around South Georgia getting a UVI of 12, compared to the expected 3-4 for that latitude and season. This occurs less frequently on the New Zealand or Pacific side of Antarctica compared to other longitudes, which is confirmed in Figure 4 of Liley and McKenzie (2006).

The second type of event occurs when the ozone hole breaks up and remnants or filaments of ozone-depleted air pass over sites in mid-latitudes. There was such an event observed over New Zealand in 1998 (Ajtic *et al.*, 2003), and another more recently in December 2005. The effect of this later event peaked on 17th December, when ozone dropped to 250 DU and the peak measured UVI was 14 at Lauder, compared to 12 a few days either side of the event. The later in the year these events occur, i.e. the closer to the summer solstice, the bigger the effect on UV, because of the dominant effect of sun angle in determining UV at the ground.

The two types of event described so far are transitory, but the third and final effect is more significant. After the vortex breaks up, the mass of ozone-poor air that was the Antarctic ozone hole dilutes ozone concentrations in southern mid-latitudes as it mixes. This effect cannot be directly measured, but efforts to quantify it are based on either model simulations, in which ozone concentration are compared with and without the chemical processing on PSC particles included in the model (e.g. Ajtic *et al.*, 2004), or by examining the correlation between springtime ozone in the Antarctic with summertime ozone at mid-latitudes (e.g., Figure 4 of Connor *et al.*, 2006). The range of estimates from these studies indicate that 40-70% of the change in ozone since 1980 at southern mid-latitudes in summer months is attributable to the dilution from the Antarctic ozone hole. This is clearly a significant effect.

Acknowledgements

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