

A New Zealand perspective on global ozone

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Abstract. Over the past two decades ozone has decreased over New Zealand at about 4-5% per decade during summer and winter, and with insignificant changes in autumn and spring. While the summer-time decreases are most likely the result of export of ozone depleted air from the Antarctic stratosphere following vortex break-up, the winter-time decreases remain unexplained. Furthermore, the decreases have not been monotonic and large decreases from 1984 to 1985 and the lack of any clear response in ozone to the Mt. Pinatubo volcanic eruption, remain unexplained. This paper discusses some of these issues in greater depth and examines the global role of New Zealand ozone research.

Past changes in ozone over New Zealand

An assimilated total column ozone time series has been created for Lauder (45.04°S, 169.68°E) by combining ground and satellite-based measurements in a manner similar to that described in Bodeker *et al.* [2001a]. Annual means of this time series are shown in Figure 1 and are

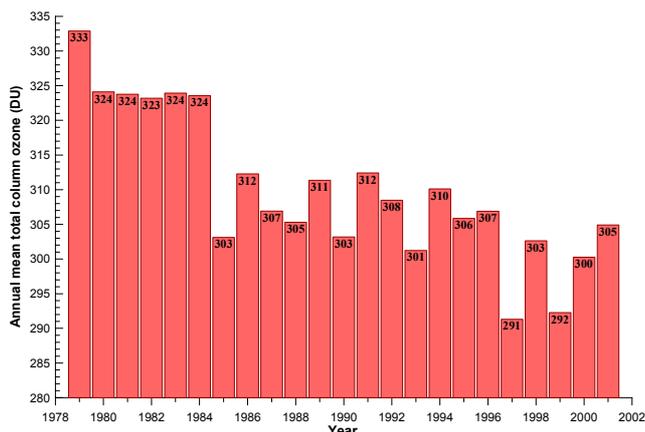


Figure 1: Annual mean total column ozone over Lauder.

representative for New Zealand. A clear downward step in total column ozone from 1984 to 1985 is visible while there appears to be no response to the Mt. Pinatubo eruption in June 1991.

An interhemispheric comparison of anomalies in mid-latitude ozone is shown in Figure 2 as daily time series of ozone mass anomalies between 30° and 60° latitude [Bode-

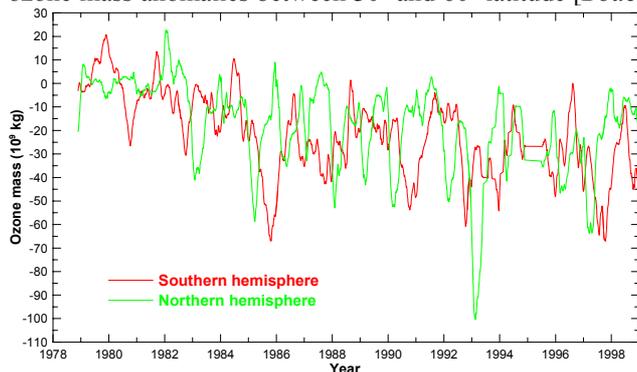


Figure 2: Mid-latitude ozone mass anomalies.

ker *et al.*, 2001b]. The mean annual cycle from 1978 to 1981 has been subtracted from each daily time series, which have then been smoothed. The decrease in southern midlatitude ozone in 1985 appears as a hemisphere wide phenomenon. However, unlike at Lauder, southern midlatitude ozone levels as a whole appear to recover after 1985. Note also in Figure 2 the pronounced decrease in northern hemisphere midlatitude ozone in 1992/1993, a result of the Mt. Pinatubo volcanic eruption in June 1991. In the southern hemisphere midlatitudes however, there is no clear response to the Mt. Pinatubo eruption.

Global ozone changes

A time series of global ozone mass [Bodeker *et al.*, 2001b] is shown in Figure 3. Note that global ozone mass levels are approximately 3×10^{12} kg. The timings of the El Chichon and Mt. Pinatubo volcanic eruptions are shown using orange arrows in the lower panel of Figure 3. There

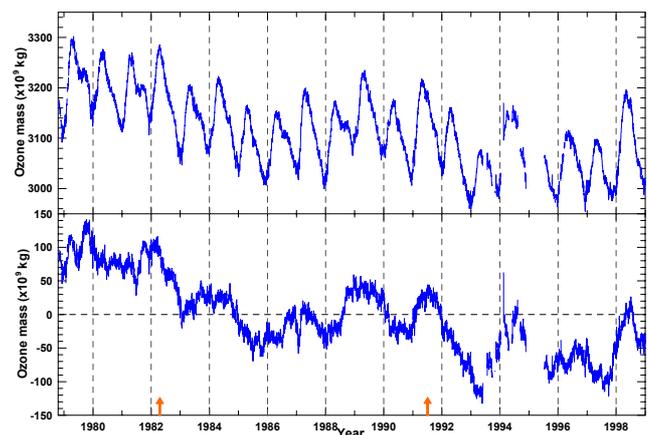


Figure 3: upper panel: daily global ozone mass; lower panel: daily global ozone mass with mean annual cycle removed

were strong decreases in global ozone levels following both volcanic eruptions.

To show more clearly the latitudinal structure and seasonality of long-term ozone changes, trends in total column ozone as a function of equivalent latitude and season are shown in Figure 4 [Bodeker *et al.*, 2001a]. The equivalent latitude is a coordinate system that is sensitive to the atmospheric dynamics (e.g. the center of the circumpolar vortex is at 90° equivalent latitude) and prevents zonal smoothing of ozone trends in the presence of steep ozone trend gradients. For the purposes of this discussion, the equivalent latitude approximates the true latitude.

The most pronounced feature is the Antarctic ozone hole where ozone trends exceed 26% per decade. There is also an indication of ozone decreases over the Arctic, though these are much smaller in magnitude compared to the Antarctic trends. Trends in the midlatitudes shown in Figure 4 indicate ozone decreases of a similar magnitude in both hemispheres. However, the strongest northern hemisphere decreases occur in February and March when solar elevations and UV levels are low. In contrast, the

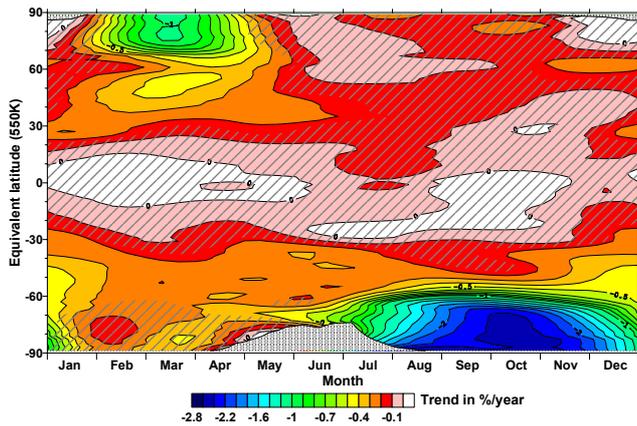


Figure 4: Trends in total column ozone from November 1978 to December 2000 as a function of equivalent latitude and month of the year. The hatched regions are where trends are not statistically different from zero at the 2σ level.

largest southern hemisphere trends occur in December and January when solar elevations and UV levels are high. This has resulted in strong summer-time increases in UV levels over New Zealand [McKenzie *et al.*, 1999].

The downward step in ozone over Lauder from 1984 to 1985

Annual mean ozone maps for the southern hemisphere have been calculated using Total Ozone Mapping Spectrometer (TOMS) daily ozone fields. To show the hemisphere wide structure of the downward step in ozone from 1984 to 1985, the annual mean ozone distribution for 1985 has been subtracted from that for 1984 and is shown in Figure 5. Locations where ozone was higher in 1985 than 1984 are shown in red and yellow, while locations with lower 1985 ozone levels than in 1984 are shown in green

Annual mean TOMS anomaly for 1985

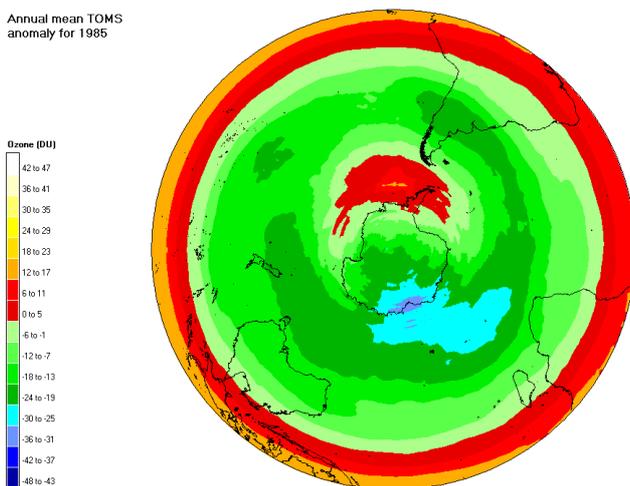


Figure 5: Annual mean 1984 TOMS distribution minus the 1985 annual mean TOMS distribution.

and blue. There are two main features in Figure 5:

1. A zonally symmetric anomaly where ozone levels are higher in 1985 than 1984 in a zone equatorward of $\sim 15^\circ\text{S}$. This is most likely the result of the Quasi-biennial Oscillation (QBO) which affects ozone levels in a see-saw pattern with a node at $\sim 15^\circ\text{S}$.
2. A wave 1 pattern where lowest ozone anomalies are observed over the southern ocean in the eastern hemi-

sphere, and positive anomalies are observed over the southern ocean in the western hemisphere.

The wave 1 pattern in the anomalies suggests a dynamical origin. To investigate this possibility further, annual mean 100hPa geopotential height fields have been calculated and subtracted in the same way as the total column ozone fields. The results are shown in Figure 6. The large wave 1 pattern in the lower stratosphere geopotential heights supports a dynamical cause for the observed ozone changes. The cause of the wave pattern in the geopotential height field remains unresolved.

Annual mean 100 hPa geopotential height anomaly for 1985

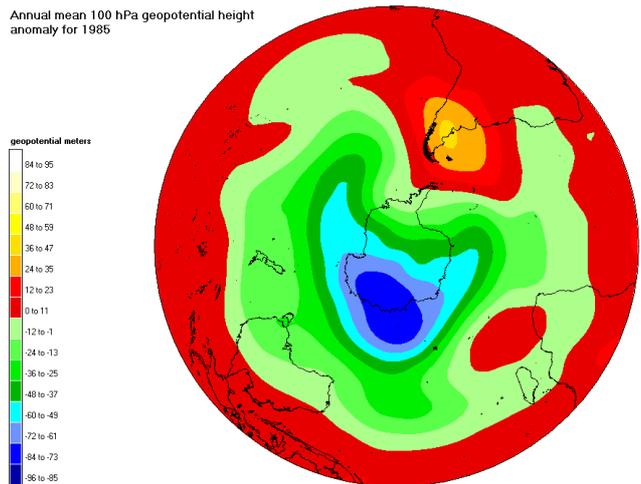


Figure 6: Annual mean 1984 100 hPa geopotential height field minus the 1985 annual mean 100 hPa geopotential height field.

New Zealand's role in global ozone research

New Zealand has been identified as one of the best locations in the world to detect the expected recovery of the ozone layer [Weatherhead *et al.*, 2000]. Through a comprehensive programme measuring total column ozone, vertical ozone profiles and the atmospheric constituents affecting ozone, at Lauder and Arrival heights (both charter sites in the Network for Detection of Stratospheric Change (NDSC)), we will play a key role in international research to gauge whether ozone is responding to Montreal Protocol regulations, as predicted by state-of-the-art atmospheric models.

References

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