Determining the impact of lower stratospheric ozone depletion on Southern Hemisphere climate

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Background

There has been strong stratospheric ozone depletion in the Southern Hemisphere since the 1980s. Ozone losses in the Southern Hemisphere occur from 250-20 hPa (12-24 km), with the maximum depletion at 70 hPa (18 km). The ozone loss is seasonally dependent and the maximum loss occurs during October.

In recent decades the surface temperature has been observed to cool over the Antarctic plateau and the warm over the Antarctic peninsula. There has also been an observed downward trend in the geopotential height over Antarctica in the spring and summer months. The stratospheric trends peak in November, whereas the tropospheric trends are largest in December and January (Thompson and Solomon, 2002).

Sonde measurements taken from different Antarctic stations have shown that the ozone loss occurs later at lower altitudes (Solomon et al., 2005). Surface temperatures are most sensitive to ozone loss near the tropopause (Forster and Shine, 1997).

Hypothesis

The tropospheric response to ozone depletion is forced mainly by ozone depletion near the tropopause (below 160 hPa).

Method

We model the climate response to changing ozone concentrations using HadSM3-L64. This model is the Hadley Centre atmosphere model with higher vertical resolution, 64 levels, coupled to a 50m slab ocean. The model is run for 50 years with a zonally varying ozone climatology which remains fixed for the model integration. The control climate (figure 1a) is without ozone depletion and is similar to the 1960s conditions. Two perturbed runs are carried out, one with ozone depletion throughout the depth of the stratosphere (figure 1c) and one with ozone depletion limited to the tropopause region (figure 1b).

Ozone Climatologies

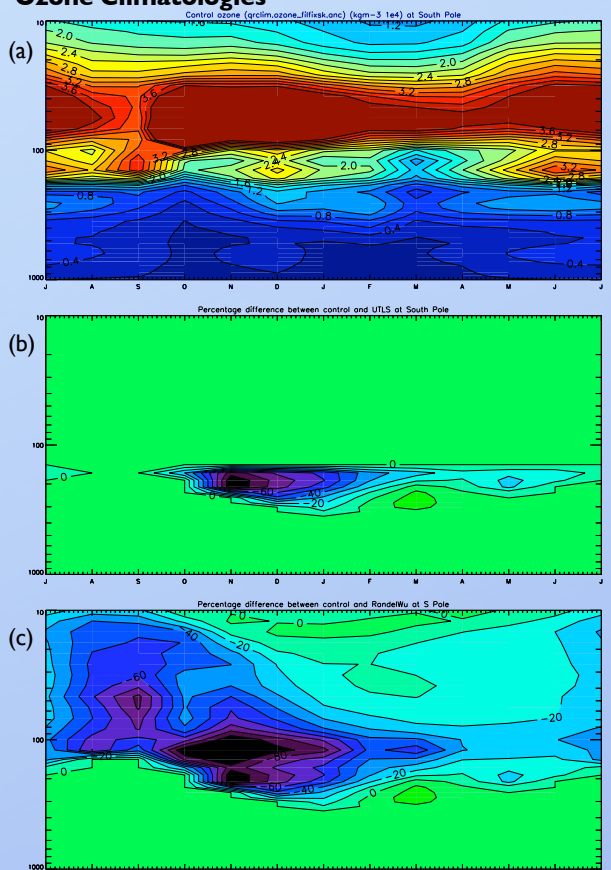

Figure 1: Ozone climatology for control run in kg/m^3(a), percentage change in ozone for the perturbed runs; tropopause region (b), whole stratosphere (c).

Results

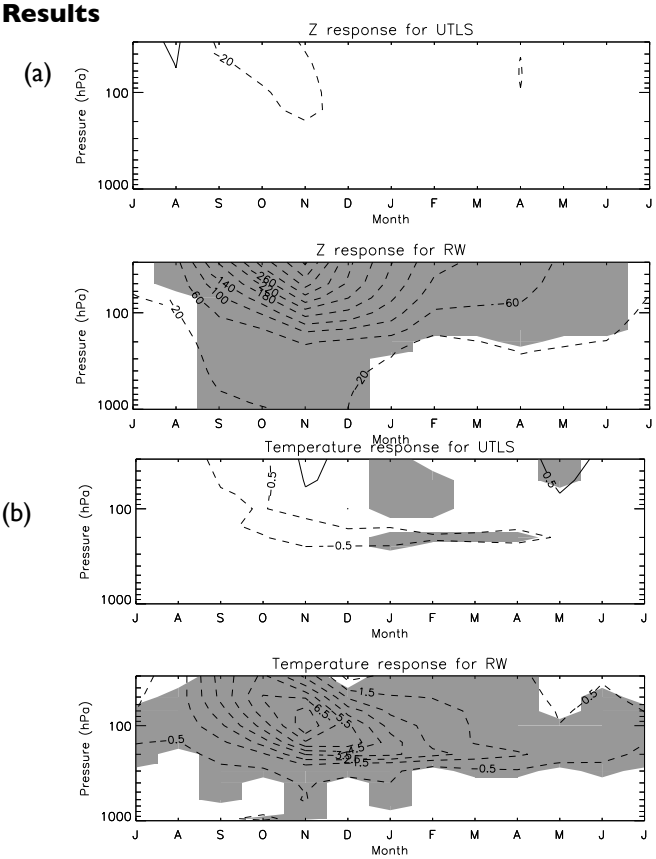

Figure 2: (a) Average Antarctic geopotential difference between control and perturbed run for the tropopause region depletion (upper panel) and whole stratosphere depletion (lower panel). (b) Average Antarctic temperature difference between control and perturbed run for the tropopause region depletion (upper panel) and whole stratosphere depletion (lower panel). Differences which are significant at the 95% level are shaded in grey.

Conclusions

When only the lower part of the stratosphere is subject to ozone depletion we do not see a strong response in the troposphere. This suggests that the tropospheric response is forced mainly by depletion in the mid-stratosphere.

References:

Solomon, S. Portmann, RW, Sasaki, T, Hofmann, DJ and Thompson, DWJ, Four decades of balloon measurements of ozone in Antarctica, *J. Geophys. Res.*, **110**, 2005.

Thompson, DWJ and Solomon, S, Interpretation of recent Southern Hemisphere climate change, *Science*, **296**, 895-899, 2002

Forster, PM, and Shine, KP, Radiative forcing and temperature trends from stratospheric ozone changes, *J. Geophys. Res.*, **102**, 10,841-10,857, 1997