Ozone loss in the lower stratosphere over Belgrano, Antarctica (78°S, 5° W) from 1999-2001 as obtained by ozonesondes: comparison with the SLIMCAT model.

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Abstract. The temporal evolution of ozone in the Antarctic lower stratosphere on selected isentropic surfaces obtained from ozonesounding at Belgrano station (78° S, 35° W) during the years 1999 - 2001 has been used to compute the rate of ozone loss during the austral spring. Results are compared with daily ozone profiles from the SLIMCAT 3-D chemical transport model, available for the nearby station of Halley (75°S - 34.5°W). Between 320 and 590 K chemical ozone depletion can be observed, but it is in the layer between 360 and 500 K where the ozone is completely destroyed. Observations show an almost steady depletion rate of 40-50 ppbv.day^{-1} between 420 and 500 K starting in early August and leading to a complete removal by the beginning of October. At lower levels the rate is smaller. The model is able to reproduce the observed seasonal evolution in the lowest levels of 335 to 420 K, but discrepancies exist at higher levels. Computed loss rates from the model at 506 K are around 35 ppbv.day^{-1} and at 557 K around 20 ppbv .day^{-1} compared to the observed 50 ppbv .day^{-1} and 30 ppbv .day^{-1}, respectively. As a result the model cannot account for the complete depletion in the layer 450-500 K during October. In this month SLIMCAT yields O_3 values above 1 ppmv when measurements are only 0.3 ppmv. In addition, the actual year-to-year variability in loss rates are larger than the modelled ones.

Introduction

Following the discovery of the "ozone hole" our knowledge and understanding of stratospheric ozone has vastly improved. However, there is still a controversial situation in the literature in that chemical models apparently fail to quantitatively reproduce the observed polar ozone loss. Consequently our ability to predict the future behaviour of the ozone layer in the next years is limited.

In 1999 an ozonesounding program at Belgrano station (continental Antarctica, 78°S, 35°W) was initiated by an agreement between INTA (Spain) and DNA/IAA (Argentina). The purpose of this work is to compare the ozone loss computed from sonde data at Belgrano with daily vertical profiles from SLIMCAT model at the nearly station of Halley Bay in order to assess how well the model reproduces the observations in the different layers between 335 K to 558 K.

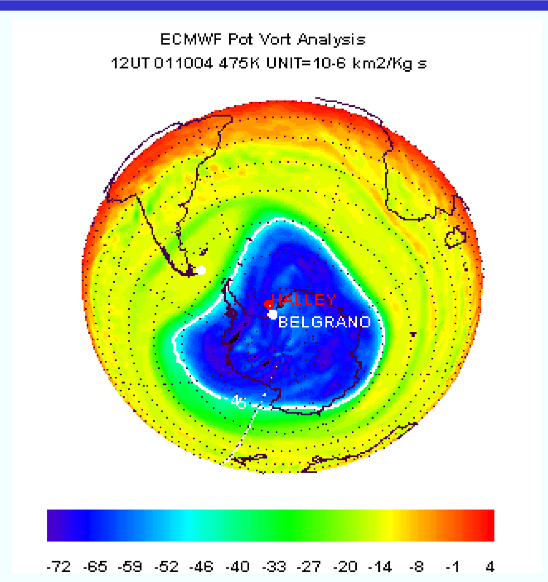

Figure 1. Location of the sites from which data are used in this study superimposed on potential vorticity distribution from ECMWF analysis data.

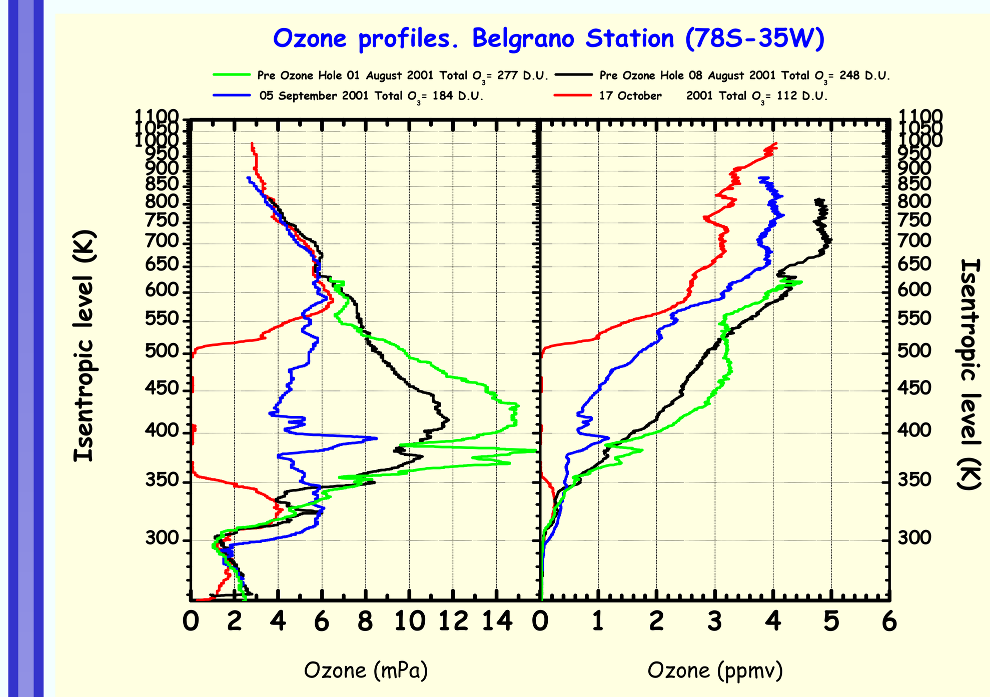

Figure 2. Ozone soundings for the period August 1 to October 17 at Belgrano station.

Vertical ozone profiles at Belgrano station for different days, before ozone destructions starts, (green line) until the day when total ozone reached its lowest value (red line) (figure 2). The red line shows that ozone has totally disappeared between 380 and 557 K. This study therefore focuses on this region.

Analogous profiles have been measured during this period in previous years.

Data and analysis

The vertical ozone profiles output from the SLIMCAT three-dimensional chemical model (CTM) at Halley station have been used to compare the ozone loss rates in the lower stratosphere obtained from the ozonosondes launched from Belgrano station. The SLIMCAT 3D CTM is described in detail by *Chipperfield [1999]*.

From the sonde data we extracted the ozone content at the same isentropic levels used in the model.

The time evolution of ozone at a fixed point in the space is estimated by continuity equation:

$$\frac{\partial [O_3]}{\partial t} = P - L - \vec{\nabla} \bullet (\vec{V}[O_3])$$

Where P is the photochemical production rate of ozone, L is the chemical loss rate and $\vec{V} \bullet (\vec{V}[O_3])$ is the net transport of ozone. During the period of study, P is approximately zero, so that, L is calculated as the sum of local change of O_3 and the net transport.

$$L = -\left(\frac{\partial [O_3]}{\partial t} + \vec{\nabla} \bullet (\vec{V}[O_3])\right)$$

As the Antarctic polar vortex is horizontally well isolated, horizontal transport of ozone is insignificant during the late winter [*Schoeberl et al.,1992*]. Furthermore, radiative heating calculations for this period show small values [*Rosenfield et al.,1994*], so, the vertical motion is also small. We considered as first approximation the transport of ozone to be negligible. Thus, the chemical loss rate of ozone is calculated as the derivative of the ozone abundance.

$$L = -\frac{\partial [O_3]}{\partial t}$$

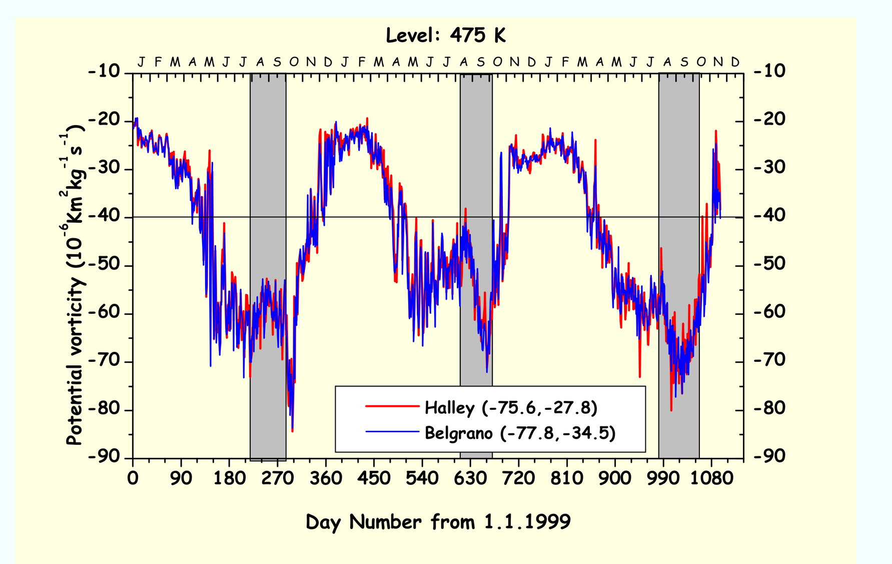

Figure 3. Time evolution of potential vorticity over Belgrano and Halley stations from 1999 to 2001 on the 475 K

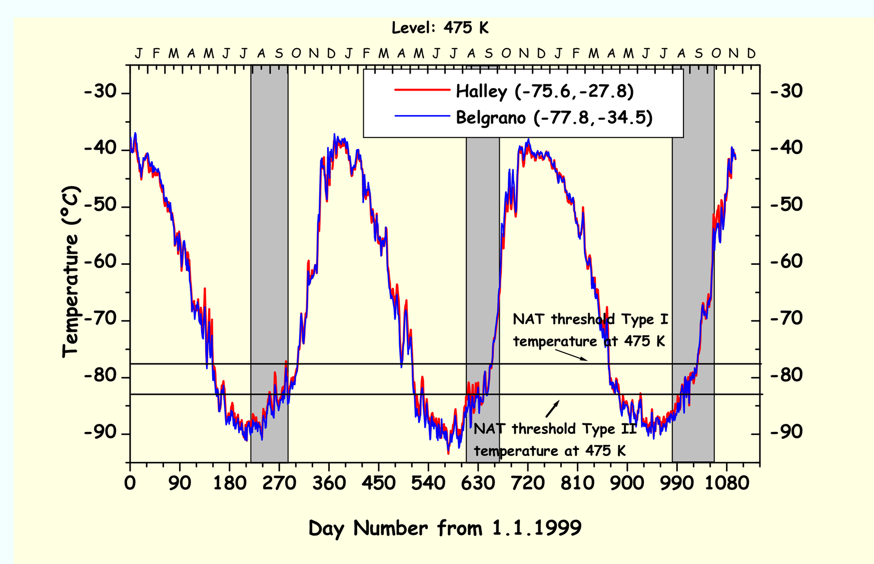

Figure 4. Time evolution of temperature over Belgrano and Halley stations from 1999 to 2001 on the 475 K.

The evolution of potential vorticity and temperature over the two stations (figures 3 and 4) shows clearly that Halley and Belgrano experience the same meteorological conditions. This fact, and the proximity of both stations, make our comparison valid. Every year from June to October in both stations the temperatures are low enough for type I and II PSC formation.

We defined PV values below -40×10^{-6} $Km^2kg^{-1}s^{1}$ on the 475 K to indicate that the station is inside the polar vortex. Using this criterion, it is evident that the two stations have been inside the vortex from June to mid October, therefore, our hypothesis that there is no transport of outside-vortex air over the stations is valid.

Comparison ozone evolution over isentropic levels: Sonde/model

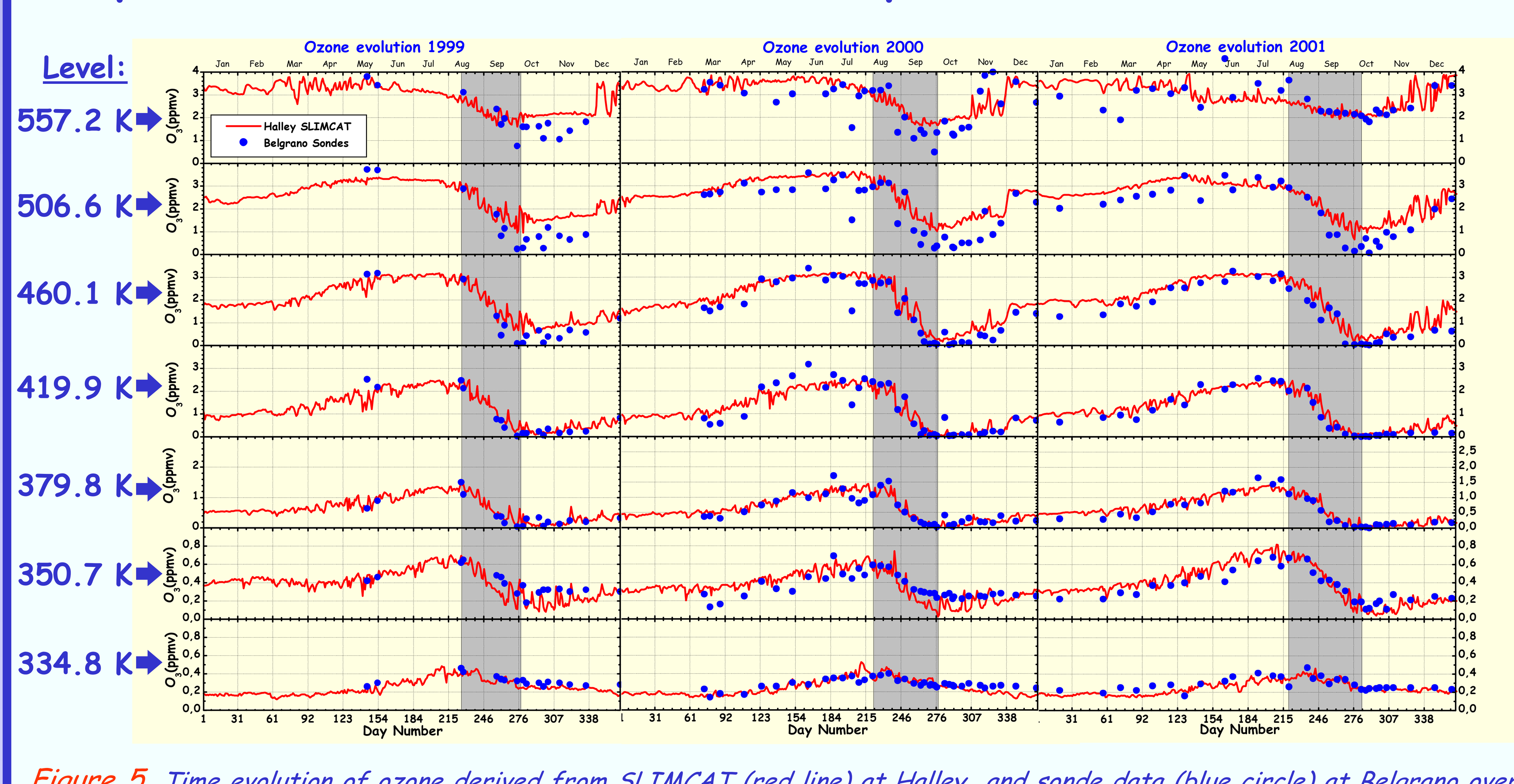

Figure 5. Time evolution of ozone derived from SLIMCAT (red line) at Halley and sonde data (blue circle) at Belgrano over isentropic levels from 334.5 K to 557.2 K during the years 1999, 2000 and 2001.

Time evolution of ozone on isentropic levels from 335 to 557 K are used to estimate the ozone loss in the lower stratosphere during the austral spring. We find good agreement in timing and magnitude at 380 and 420 K. However, large model/observation discrepancies occur at higher levels from the end of August to November every year. The model overestimate of the ozone content is likely due to too rapid deactivation of active chlorine at these levels, so that ozone loss stops too early.

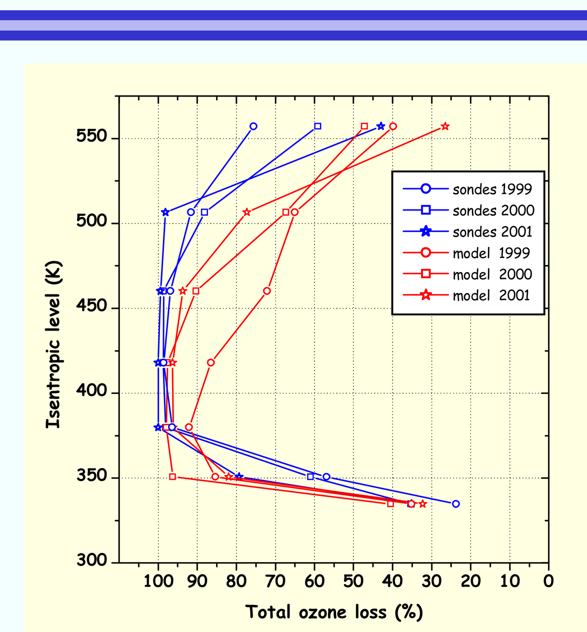

Figure 6. Total ozone loss calculated every year from sounding data and from the model for the shaded period showed in figure 5.

Ozone loss calculated from the sondes on the layers between 380 and 557 K are almost 100% every year and are in good agreement with that derived from the model although at 506 and 557 K the loss are underestimated by nearly 25%.

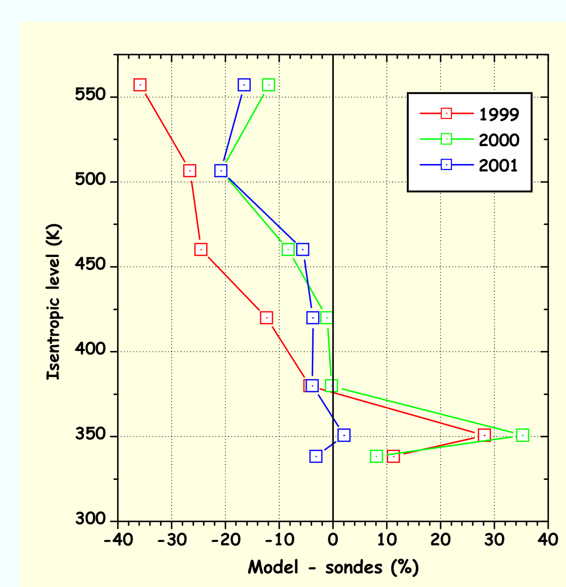

Figure 7. Bias between total vertical ozone loss calculated from sondes and model over the time period August to October for the three years.

The model overestimates total ozone loss at the lower levels. The observed and modelled O_3 loss between 380 and 460 K agree to within a few percent while at higher levels the differences are around 20%.

Total ozone

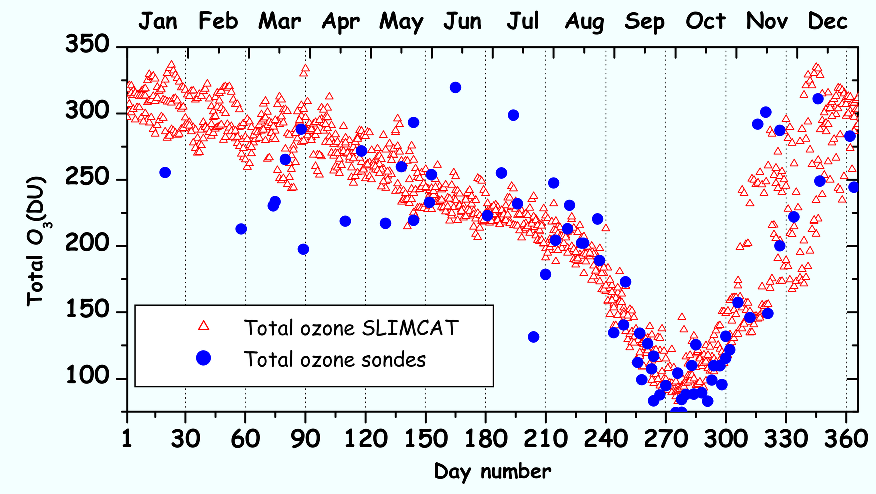

Figure 8. Partial ozone column between the upper and lower limits of SLIMCAT model derived from the model (red triangles) and sonde data (blue circles) at Belgrano during the years 1999, 2000 and 2001.

The model overestimates the integrated column in summer and underestimates it in mid-winter. The model column starts decreasing from June, while observation show the total column starts decreasing in August. Consequently, the model integrated column matches the observations from August to November.

Summary

- Comparison between measurements and the SLIMCAT model show that the model properly reproduces the vertical evolution of ozone between 379 K to 460 K especially for the period from August to mid-October, when the chemical ozone loss takes place.
- Ozone loss rates calculated from the model are in good agreement with the observations in the layers between 380 K to 460 K. At higher levels computed loss rates from the model at 506 K are about 35 ppbv.day^{-1} and at 557 K about 20 ppbv.day^{-1} compared to the observed 50 ppbv.day^{-1} and 30 ppbv.day^{-1}, respectively. The model cannot account for the complete depletion in the layer 450-500 K during October. For this month SLIMCAT yields O_3 values above 1 ppmv while measurements are only 0.3 ppmv.
- The time evolution of total ozone is not consistent with the measurement during the whole year. In summer the model overestimates the total column while from August to October the model values agree with the measurements.

Acknowledgments.

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