Total Ozone Reduction in the Arctic Vortex during the Winters of 1995/96 and 1996/97

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INTRODUCTION

A method to derive the total ozone reduction in the Arctic winter has been suggested which consists to substract the dynamical contribution from total ozone and profile changes by the use of a 3D model where ozone is assumed chemically passive [1]. The total ozone measurements are those provided by the five Arctic SAOZ uv-visible spectrometers stations. The profiles are those of the balloon borne version of the instrument flown in the Arctic. The model is the 3D CTM model REPROBUS of Météo-France which could be run either in chemically passive or active mode, including in the last case chlorine and bromine activation on PSCs. Applied to the data collected during SESAME, the method was able to demonstrate that significant cumulative ozone depletion occurred in the Arctic vortex in 1994 (18% in total with a maximum reduction of concentration at about 50 hPa) as well, but of larger amplitude in 1995 (32% in total, but lower down at 60-80 hPa), partly captured by the chemical model only. Here, we report on a similar analysis, using the same instruments and model, but for 1996 and 1997.

MEASUREMENTS AND MODEL

The total ozone measurements are those of the five UV-visible SAOZ zenith sky spectrometers [2] stations at Ny-Alesund (Spitzbergen), Thule and Scoresbysund (Greenland), Sodankyla (Finland) and Zhigansk (Siberia), already used in the previous study [1], plus those of the new permanent uv-visible station of Harestua in Southern Norway operated by the Institut d'Aéronomie Spatiale de Belgique. The SAOZ sonde is the balloon-borne version of the instrument flown either from Andoya (Norway) or Esrange-Kiruna (Sweden) [3], two times in 1996 and six in 1997, but two times only in the vortex and in 1997 only. The model is the 3-D chemistry-transport model REPROBUS of CNRM Météo-France [4] initialised from UARS-MLS ozone fields of December 1, 1995 for the winter of 1996 and of December 18, 1996 for the one of 1997, that is immediately before the first PSC formed.

RESULTS

The total ozone measurements inside the vortex (PV > 42 PV Units) at the six stations are plotted altogether in figure 1a for 1996 (left panel) and 1997 (right panel). Note that, since the vortex remained centred over the pole in the polar night in January 1997, there is no data before

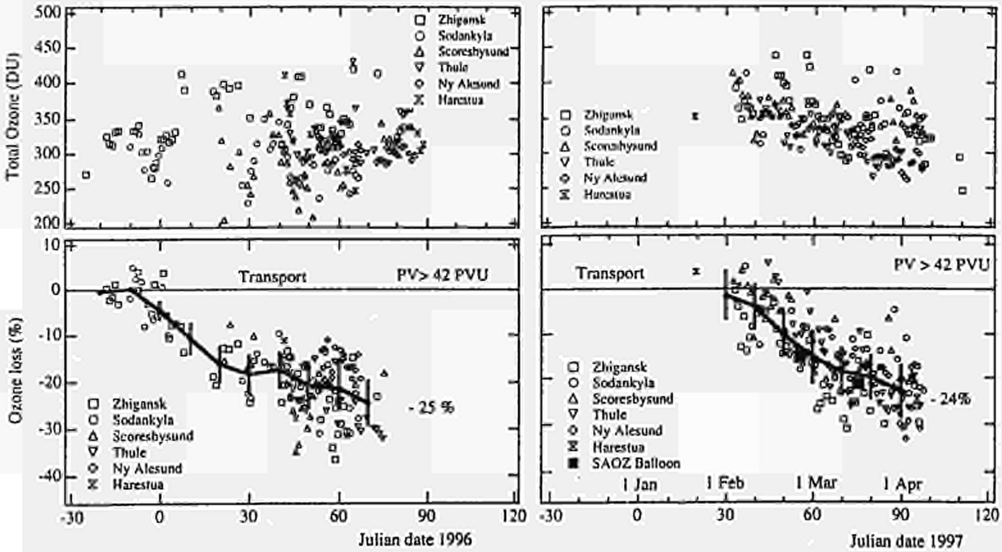

Figure 1. a) Total ozone over the six SAOZ stations and integrated balloon profiles inside the vortex (PV > 42 PV units); b) difference between measurements and simulations. Left panel: 1995/96. Right panel: 1996/97.

February, 1 in 1997. The lower panels show the same data after subtraction of the transport component simulated by the 3D model : individual measurements at each station indicated by symbols, 10 day average and dispersion represented by full line and error bars, integrated balloon profiles shown by large squares.

Significant total ozone reduction occurred again in 1996 (25%) as well as in 1997 (24%) but following a totally different timing. In 1995/96, the ozone dropped by 18 % between December 20 and January 20 at an average rate of 0.6 % per day, then it remained constant until February 10 when it dropped again by 7% at an average rate of 0.3 % until March 10 at the end of the simulation. In 1996/97, the ozone loss started later in the season. The ozone dropped by 20 % between February 1 and March 10 at an average rate of 0.5 %, then stays almost constant during ten days and dropped again by 4% at an average rate of 0.2 % until April 10.

METEOROLOGY AND PHOTOCHEMICAL SIMULATIONS

The upper panels of figure 2 show the geographical extent of type I (shaded area) and type II (triangles) PSCs at 380K, 475K and 550K derived from ECMWF temperature fields on both years and the lower panels the results of chemical simulations (small dots specific of each station) compared to the 10 day average (full line and error bars) derived from the measurements already shown in fig. 1. The periods of observed ozone loss correlate very well with the presence of PSC. In 1995/96 the first NAT PSC formed as early as in mid-December, the largest surface area being at 550 and 475K but vanished completely in early March after the warming of the stratosphere. In contrast in 1996/97, the first NAT PSCs appeared in mid-January only but the ozone loss process did not start since the vortex remained in the polar night until the end of the month. The largest depletion occurred during the second half of February and the first third of March, when temperature was low enough at 475 and 380K.

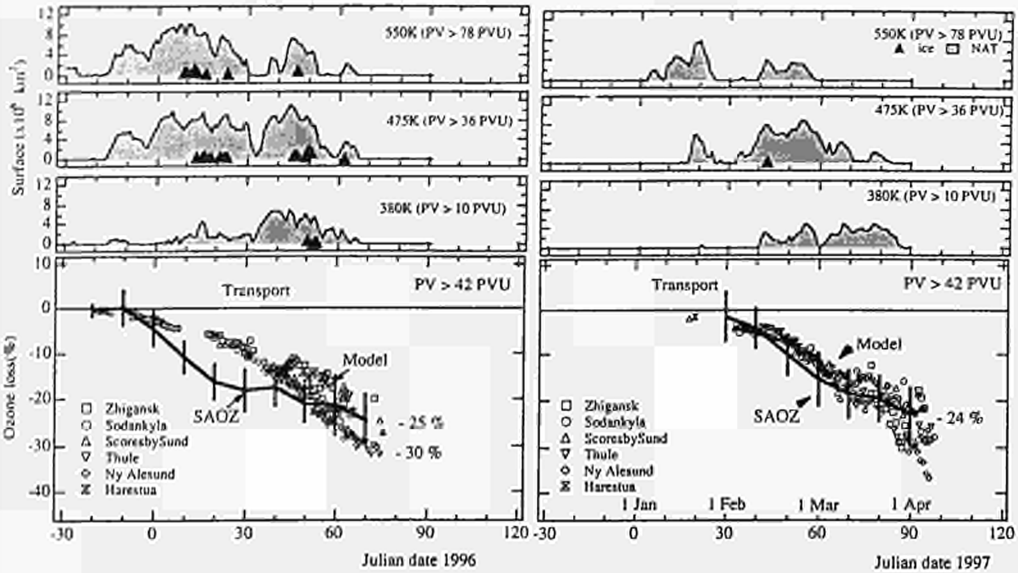

Figure 2. PSC geographical extent in the vortex at 550K (22.5 km), 475K (20 km) and 380K (14.8 km). Total ozone reduction observed by the SAOZ network (10 day average and standard deviation: thick line as on figure 1b) and simulated over each station by the Chemical Transport Model (dots specific to each station) during the winter of 1995/96 on the left panel and of 1996/97 on the right panel.

Compared to this, the photochemical model captures very well the amplitude and the timing of the ozone loss in 1996/97, including the increased dispersion at the end of the winter indicative of a large inhomogeneity in the vortex, but not in 1995/96 for which it largely underestimates the loss rate at low sun in January, but in contrast, overestimates that occurring later at high sun in March.

The ozone profiles measured (thick line) in 1997 by the SAOZ sonde in the vortex (there is no balloon flight in the vortex in 1996) and simulated by the model (passive mode in thin line and full chemistry dotted), are displayed in figure 3. The model captures very well the loss starting at about 50 hPa in mid-February and extending later lower down around 80-90 hPa in mid-March in consistency with the lower altitude of the PSC (fig. 2). Compared to that simulated in passive mode, the reduction of concentration at this altitude would have been of 31%.

COMPARISON TO PREVIOUS WINTERS

The observed and simulated cumulative total ozone reduction during the last four years, is summarised in table 1.

Significant ozone reduction took place in the Arctic vortex during the last four winters, the large being that of 1994/95. But the period during which it occurs varies largely from one year to the other. It could start as early as December 20 as in 1993/94 and 1995/96 when the cold vortex was displaced toward mid-latitude and extend as late as April as in 1996/97 when a late winter record low temperature has been reported.

Compared to this, the photochemical model does capture also a significant loss, but the timing and the rate of reduction is not always consistent with the observations. The fast loss at

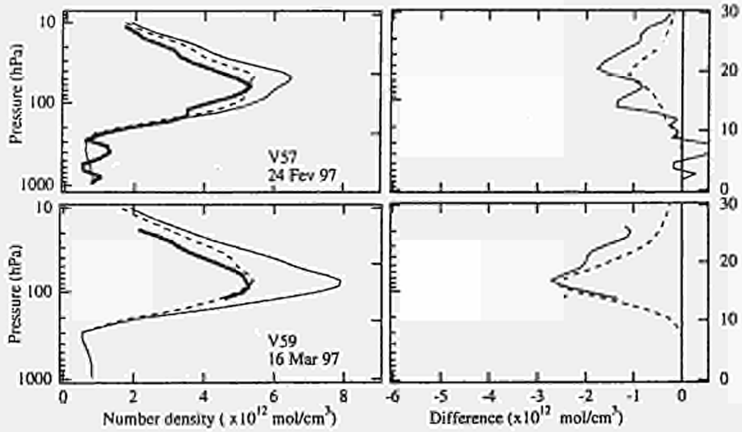

Figure 3. Left : ozone profiles in the vortex on Feb. 24, and Mar 16, 1997 measured by a SAOZ balloon sonde (thick line) and simulated by the 3D model (passive mode in thin line; full chemistry in dotted line. Right : observed (thin line) and simulated (dotted line) chemical loss by comparison with passive mode simulation.

Winters	Measured (%)	Simulated (%)	Periods
1993/94	18	22	Dec. 20 to 30 and March 1- 10
1994/95	32	22	Jan. to Feb. 10 and Feb. 20 - March 20
1995/96	25	30	Dec. 20 - Jan. 30 and Feb. 10 - March 10
1996/97	24	25	Feb. 1- March 10 and March 20 - April 10

Table 1: Total ozone reduction measured and simulated during the four last winters.

low sun in January in 1994/95 and 1995/96, is underestimated while the late reduction which occurred in early march in 1995/96 is overestimated. This could indicate that some particular processes are not well described, rather than a more fundamental general problem.

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