Stratospheric ozone over Kiruna, Sweden, during Arctic winter/spring 2003/04

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Abstract. We have observed Arctic stratospheric ozone during the entire winter/spring period 2003/04. Measurements have been obtained by the millimeter wave radiometer at the Swedish Institute of Space Physics (IRF), Kiruna, Sweden, situated 67.8 N, 20.4 E, 400 m asl. Operation and retrieval of the measurements is a joint project of IRF and the Institute of Meteorology and Climate Research, Forschungszentrum und Universität Karlsruhe, Germany.

Introduction

The new millimeter wave radiometer at the Swedish Institute of Space Physics has started operation in January 2002. Since then nearly continuous stratospheric observations of ozone have been performed. The location of the radiometer at IRF above the polar circle is favourable for studying the evolution of the polar stratospheric winter chemistry both, inside and outside the polar vortex, and to investigate early ozone loss.

A continuous time series can be obtained due to the fact that millimeter wave observations are hardly impaired by changing weather conditions. Moreover, the Kiruna winter troposphere is usually very cold and dry leading to a high transparency of the troposphere.

Measurements

A thermal emission twin peak of ozone in the microwave region at 195 GHz is observed. In order to decrease instrumental interference the antenna/mixer unit together with the first HEMT-amplifier is cryogenically cooled to 30 K. Moreover baseline effects are reduced by using the internal balanced calibration method as suggested by Krupa [1998].

Data analysis

Measured spectra are integrated in order to improve the S/N ratio. Depending on the tropospheric water vapour content the integration time is typically about 0.5 – 2 hours for a single stratospheric ozone profile. The radiative transfer model includes data from HITRAN 96 [Rothman et al., 1998] and JPL [Pickett, et al. 1998], as delivered by the Bernese Atmospheric Multiple Catalog Access Tool (BEAMCAT) [Feist, 2003] and is described in Kopp [2001]. For the daily analysis NCEP pressure and temperature profiles together with ground temperature measured at IRF are used in the forward model. The vmr-profiles are retrieved from the measured spectra by a modified "Optimal Estimation Method" [Rodgers, 1976]. The retrieved profiles reach from 15 to 55 km with a vertical resolution of at best 7 km (at 25 km altitude). The instrument has a sensitivity of at least 75% over the entire altitude range [Raffalski, 2004].

Evolution of the Arctic stratosphere in winter 2003/2004

Meteorology The stratospheric ozone evolution is strongly connected to the development of the stratospheric conditions, i.e. the polar vortex. We calculated the vortex edge following the *Equivalent Latitude Method* [Nash, 1996] which enables to identify whether measurements have been taken inside or outside the Arctic vortex in order to estimate the ozone loss.

The polar vortex during Arctic winter/spring 2003/2004 has formed quite late in November in the middle stratosphere and even later in the lower stratosphere as can be seen in Figure 1. Compared to previous winters the vortex was unstable and weak. The late onset and the weakness of the vortex are depicted by the partly undefined vortex edge in November (higher altitudes) and well into December (lower altitudes).

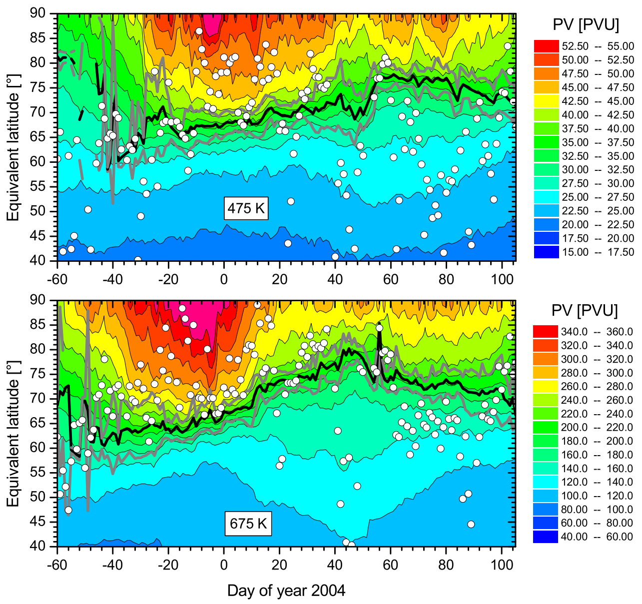

Figure 1. The evolution of the polar vortex in equivalent latitudes during winter/spring 2003/04 on two isentropic levels. The grey lines indicate the inner and outer edge of the vortex, respectively, while the black line describes the mean vortex edge, i.e. the strongest gradient in PV for the particular day. The colour coding shows the strength of the vortex in PVU. The open circles depict the PV over Kiruna and refer to the underlying PV colour coding, showing how far away of or how deep inside the vortex a measurements has been taken.

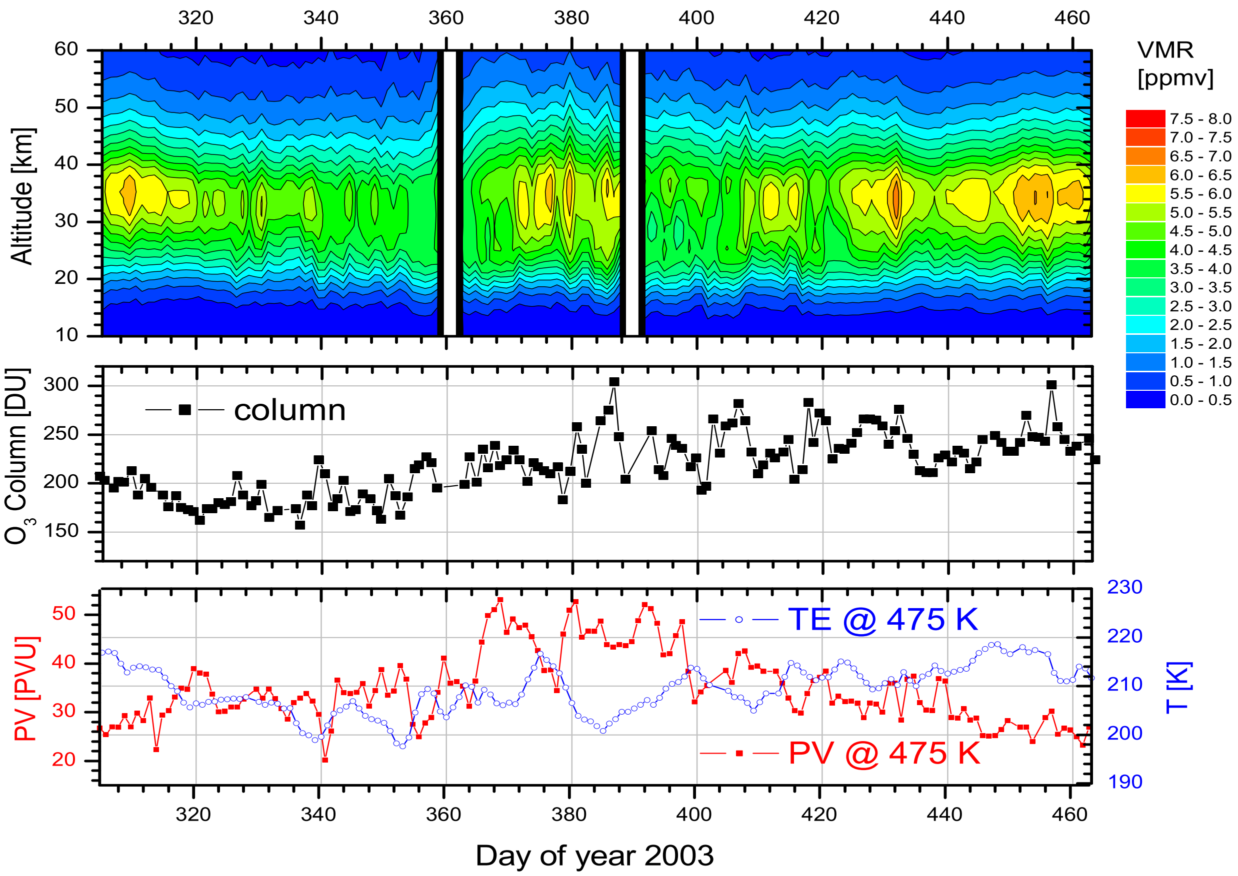

Figure 2. The evolution of ozone during 2003 and 2004. The upper panel shows the time series of ozone vmr profiles. Longer periods with no data due to technical problems have been kept blank. The middle panel shows the stratospheric ozone column above an altitude of 10 km. The lower panel shows the potential vorticity (red squares) and temperature (blue circles) on the 475 K isentropic level (ECMWF-data).

Ozone Ground-based measurements over a longer time span like a week observe a substantial part of the inside vortex air mass, they provide some kind of vortex averaged data. Along with the weak vortex the temperature stayed relatively high (> 197 K) during the entire winter/spring season as shown in Figure 2. Furthermore the vortex was substantially weakened by a warming at higher altitudes in mid/end January which in mid February has reached the lower altitudes. Mixing with low latitude ozone-rich air can be assumed under these conditions. Under these circumstances and without the use of a dynamical tracer (e.g. N_2O) any chemical ozone depletion is masked in our measurements during the winter/spring period 2003/2004. However, given the evolution of the polar vortex temperature during this winter, a substantial chemical ozone depletion is rather unlikely.

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