Ground-Based Millimeter Wave Observations of Stratospheric Ozone at the Alpine Station Zugspitze in 2003

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Abstract. From February to July 2003 the ground-based millimeter wave radiometer MIRA2 was operated at the Environmental Research Station Schneefernerhaus (Umwelt Forschungsstation Schneefernerhaus, UFS), situated on the south slope of the Zugspitze summit (47.4°N, 11°E, 2650 m a.s.l.). This high altitude site was chosen because of its low tropospheric opacity during long seasonal periods. From the measurements a nearly continuous time series of ozone profiles in the vertical range 15-55 km was retrieved. The location was well outside the polar vortex for most of the period, except around March 20 when this site was in the vortex edge region. The result was a decrease of the maximum mixing ratios of ozone. No significant growth in the stratospheric columns has been observed during this event which might be due to some ozone loss in the vortex edge region. From winter to summer an increasing altitude of the isopleths in the lower stratosphere due to the upwelling and decreasing stratospheric columns were observed.

Introduction

The ground-based millimeter wave radiometer MIRA2 was developed by the Forschungszentrum Karlsruhe and is designed to measure ozone, ClO, N2O, and HNO3 in the frequency range 268-281 GHz. A detailed description of the system is given in Berg et al. [1998]. For data analysis a modified Optimal Estimation Method [Rodgers, 1976] is used to retrieve vmr profiles of the stratospheric constituents in the vertical range 15-55 km. The vertical resolution of the retrieved ozone profiles is at best 7 km and for the minor constituents the vertical resolution is at best between 10-12 km [Kopp et al., 2002].

From 12 February to 28 July 2003 the radiometer MIRA2 was operated at the Environmental Research Station Schneefernerhaus (Umwelt Forschungsstation Schneefernerhaus, UFS) on the Zugspitze (47.4°N, 11°E, 2650 m a.s.l.). Because of its altitude this site has a high tropospheric transmission and is therefore well suited for ground-based microwave observations. At the end of February the tropospheric transmission reached maximum values of more than 90%. From the measured spectra nearly continuous time series of the stratospheric constituents were retrieved.

Results

The results of the measurements for ozone and N2O are presented in Figure 1. For comparison the potential vorticity and temperature at 475 K isentropic level over the Zugspitze (ECMWF data) are shown in the lower panel of the same figure. The inner, outer, and mean vortex edge were calculated using the equivalent latitudes as suggested by Nash et al., [1996]. The mean vortex edge is given by the steepest gradient of the PV plotlet against the equivalent latitude, and the inner and outer edge by the strongest curvature.

As can be seen in this graph the Zugspitze was outside the polar vortex for most of the time. But around March 20 the Zugspitze was in the vortex edge region resulting in increasing PV values and decreasing temperatures.

Ozone The topmost panel of Figure 1 shows the time series of ozone vmr profiles from 18 February to 16 July. During some periods no measurements were taken due to technical problems. Single days of missing data were interpolated for this graph. The second panel shows the corresponding ozone columns above an altitude of 10 km.

During the first two weeks the vertical ozone distribution over the Zugspitze stayed nearly unchanged. Then the maximum mixing ratios decreased significantly when this site was in the vortex edge region. The ozone columns show no significant increase as one would expect if no ozone depletion took place inside the polar vortex. Therefore the nearly constant stratospheric columns during this event are an evidence of chemical ozone depletion inside the vortex and the vortex edge region. This corresponds to the results of Odin measurements [Urban et al., 2004] and to measurements in Kiruna (67.8°N, 20.4°E, 425 m a.s.l.) using a radiometer system similar to MIRA2 [Raffalski et al., 2004].

In the course of spring to summer the time series of ozone profiles shows increasing altitudes of the isopleths as a result of the buoyancy in the atmosphere. During the same time span the ozone columns decrease due to the buoyancy in the atmosphere and the breakdown of the Brewer-Dobson circulation which transports ozone rich air from the tropics to higher latitudes during winter.

N2O The third panel of Figure 1 shows the time series of N2O vmr profiles between 15 March and 16 July. As for the ozone time series single days of missing data were interpolated for this graph. N2O is widely used as a long-lived tracer to investigate dynamical effects in the stratosphere.

During the time span in March when the Zugspitze was in the vortex edge region the N2O isopleths show decreasing altitudes. This is the result of the diabatic subsidence inside the polar vortex. Close inspection reveals that the diabatic subsidence increases with altitude. The altitude difference between the vortex edge values and the N2O profiles outside the vortex amounts to over 6 km for the 0.05 ppmv isopleth.

From spring to summer the isopleths show increasing altitudes due to the buoyancy in the stratosphere. The difference in altitude between spring and summer amounts to about 6 km for the isopleths between 0.05 and 0.3 ppmv N2O.
Figure 1. Ozone and N₂O as measured by the microwave radiometer MIRA2 on the Zugspitze in 2003 and the corresponding PV and temperature at 475 K isentropic level (ECMWF data).

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