Continuous Ground-Based Millimeter-Wave Observations of Ozone and HNO_3 in Winter/Spring 2000/2001 at Kiruna

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Overview

During Arctic winter 2000/2001, the ground-based millimeter-wave radiometer MIRA 2 of the Forschungszentrum Karlsruhe has been operated in the Istitutet för Rymdfysik (IRF, Swedish Institute of Space Physics) at Kiruna (67.8° N, 20.4° E, 425 m asl), Sweden. The instrument covers the frequency range 268–280 GHz and is capable to measure vertical profiles of ozone, HNO_3, ClO, and N_2O. A detailed description of this instrument can be found in [1]. For inversion a modified Optimal Estimation Method [5], including the fit of standing waves within the inversion process [3] and the simultaneous retrieval of several profiles [4], was used. The line data was taken from the HITRAN 96 database [6]. Nearly continuous time series of ozone and HNO_3 vmr-profiles in the altitude range 17–55 km were retrieved from the measurements. Using the full width at half maximum as criterion, a vertical resolution of at best 7 km for ozone and of at best 12 km for HNO_3 can be achieved [2].

Figure 1 shows the potential vorticity and the temperature in winter 2000/2001 at 550 K-level over Kiruna for all days, when measurements with MIRA 2 were performed (courtesy of the European Centre for Medium-Range Weather Forecasts, ECMWF). Although this Arctic winter was relatively warm in the lower stratosphere with a quite unstable vortex, temperatures over Kiruna dropped below PSC-type I formation temperatures in January and even below ice frost point for a short period around January 12. For some days in January and February, Kiruna was well inside the polar vortex. In mid February the vortex broke up in the final warming.

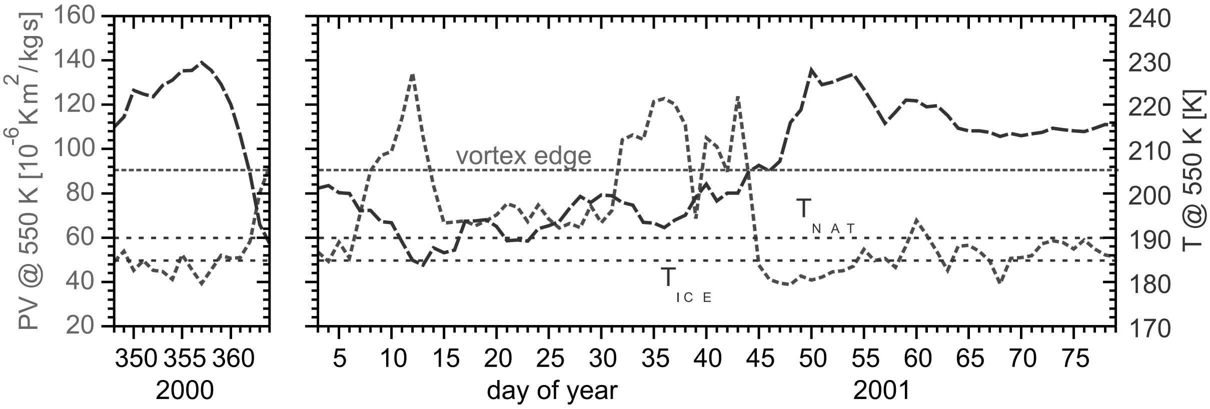

Figure 1: Potential vorticity and temperature at 550 K-level over Kiruna between December 13, 2000, and March 20, 2001 (ECMWF-data).

HNO_3

Figure 2 shows the time series of HNO_3-profiles between January 11 and March 19, 2001. On January 12, when Kiruna was well inside the vortex and temperature at 550 K-level dropped below the ice frost point (see Figure 1), maximum HNO_3 mixing ratios decreased drastically due to the uptake of HNO_3 into PSCs. After day 16, temperatures increased over NAT formation temperatures and the HNO_3 mixing ratios recover. Between day 32 and 43, Kiruna was again well inside the vortex for most of the time, but temperatures were too high for PSCs (see Figure 1). The maximum mixing ratios of HNO_3 show high values up to over 14 ppbv for most days which indicates that there was no significant vortex-wide denitrification. After day 45, Kiruna was outside the vortex for the rest of the time resulting in lower mixing ratios due to the the observation of mid-latitude air and the photolyzation of HNO_3 by the sunlight.

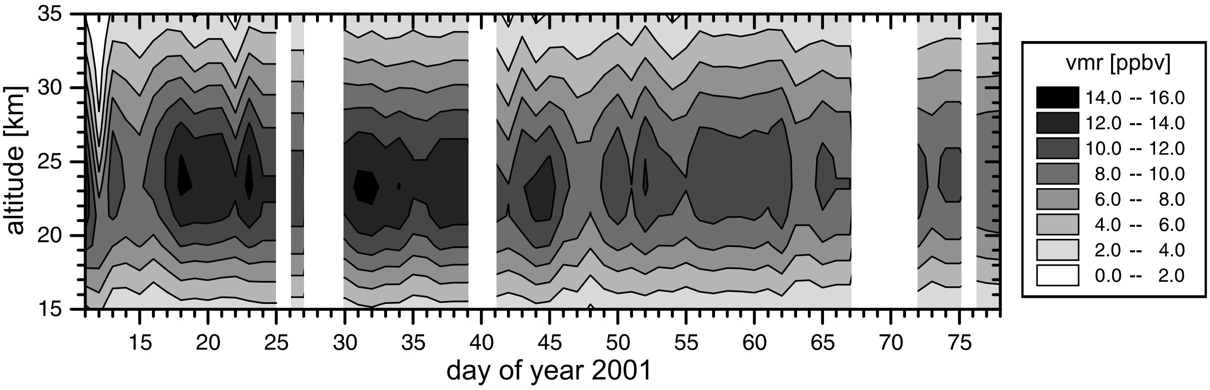

Figure 2: Time series of HNO_3-profiles over Kiruna from January 11 to March 19, 2001. Note the strong decrease of HNO_3 mixing ratios on January 12 due to the uptake of HNO_3 into PSCs.

To estimate the uptake of HNO_3 into the PSCs of January 12, the difference profile of January 11, when Kiruna was also well inside the polar vortex (see Figure 1) but no significant HNO_3 uptake was observed, and January 12 was calculated. The result is shown in Figure 3. A maximum uptake of 8 ppbv can be found at an altitude of about 26 km, but since the retrieved MIRA 2-profiles are smoothed due to regularization, this estimate is a lower limit for the real HNO_3-uptake at this altitude. In total columns, the uptake of HNO_3 amounts to $2.2 \cdot 10^{19}$ molecules/m^2, which is smaller than the value found during the strong PSC-events over Kiruna in January 2000 of about $5 \cdot 10^{19}$ molecules/m^2 [2]. The reason is, that the latter were found at lower altitudes and therefore had a stronger impact on the total column.

Ozone

The measurements of ozone between December 13, 2000, and March 20, 2001, are shown in Figure 4. It is obvious, that on days, when Kiruna was well inside the polar vortex, the retrieved profiles show reduced volume mixing ratios in the lower stratosphere. Since the vortex was quite unstable in winter 2000/2001, it has to be analyzed, whether this is a result of dynamic processes or chemical depletion.

Anthropogenic ozone loss in mid January seems to be quite unlikely due to the lack of sunlight. To investigate possible ozone loss between January and February, mean values of the partial columns above 15 km on days in January and February, when Kiruna was

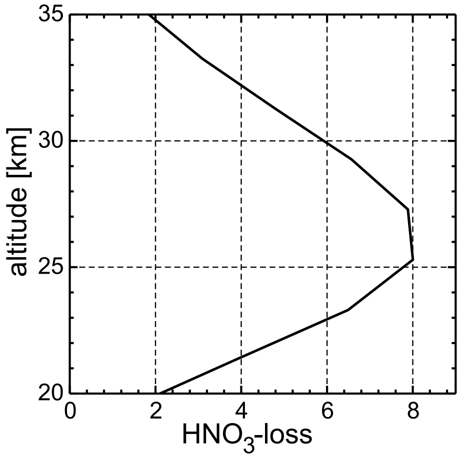

Figure 3: HNO_3-loss due to the uptake of HNO_3 into PSCs on January 12, 2001.

well inside the polar vortex, were calculated. The comparison of these mean values yields an increase of 29 DU ± 22 DU (only statistical errors are regarded) between January and February. Even if some ozone loss is covered by the increase of column values due to ozone rich air entering the top of the vortex (e.g. see[1]), the measured increase makes a strong ozone depletion between January and February unlikely. These results suggest, that the low ozone mixing ratios in the lower stratosphere inside the polar vortex are most likely a dynamic feature.

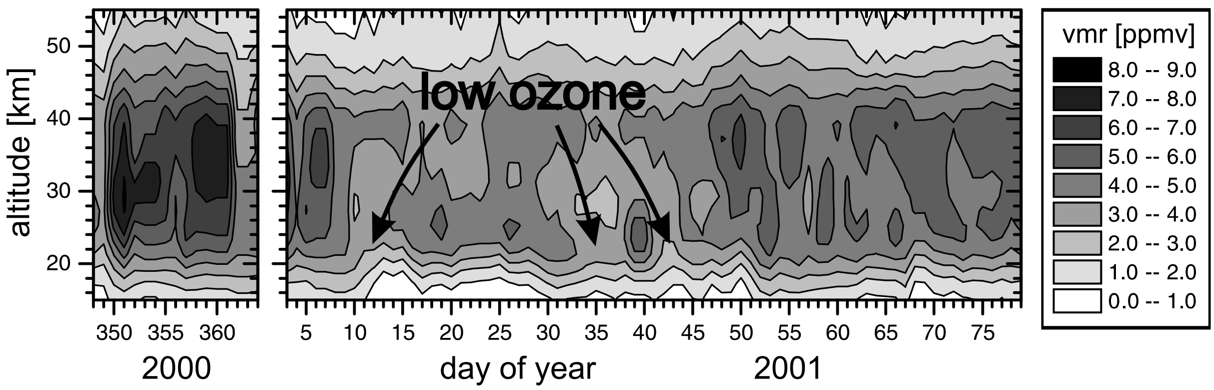

Figure 4: Time series of ozone over Kiruna from December 13, 2000, to March 20, 2001. Note the low ozone values in the lower stratosphere on days, when Kiruna was well inside the polar vortex.

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