# Millimeter Wave Observations of Stratospheric Trace Gases at Kiruna during Spring 1996

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## INTRODUCTION

Spectral lines of several stratospheric trace gases resulting from rotational transitions can be found in the frequency range from 268 GHz to 281 GHz covered by tuning the millimeter wave radiometer of the Karlsruhe Research Center. The signatures of ClO, $O_3$, $N_2O$ and $HNO_3$ are strong enough to evaluate the pressure broadening of the lines. Using appropriate inversion techniques profiles of the volume mixing ratios of the corresponding constituents can be retrieved.

In 1996 a measurement campaign was performed from mid February to early April at Kiruna (67.84°N, 20.41°E, 425 m MSL), Sweden. Most of the time this site was inside the polar vortex.

## DATA EVALUATION

The measured spectra (Figure 1, 5, 6, 9, 13) show sinusoidal undulations caused by standing waves in the radiometer. While these standing waves are uncritical for the inversion of spectra with strong lines such as the signature of $O_3$ at 273.051 GHz, a careful fit of the baseline for the inversion of spectra including small signatures such as ClO at 278.631 GHz is essential. Furthermore the signature of ClO is superimposed by a neighbouring ozone line which makes it necessary to retrieve $O_3$ and ClO simultaneously. The same applies to the inversion of $N_2O$ and $HNO_3$ spectra.

For the inversion variants on the Tikhonov-Phillips-Regularization [4] and Optimal Estimation Method [5] were used, which have been extended by the fit of standing waves and the joint retrieval, as outlined by Kuntz [1, 3]. For the first guess the U.S. Standard Atmosphere (1976) for high latitudes was used. All error bars in the presented profiles refer to errors caused by thermal noise. No systematic errors or errors caused by the fit of standing waves are considered due to the difficult quantification. The width at half-maximum of the averaging kernels is considered as the altitude resolution of the retrieved profiles.

## CHLORINE MONOXIDE (ClO)

ClO has a small signature at 278.631 GHz. Figure 1 shows daytime and nighttime spectra measured on March 1-2. The sinusoidal undulations caused by standing waves can clearly be seen. The spectra corrected for the standing waves are presented in Figure 2 and the resulting profiles employing the Optimal Estimation Method in Figure 3. There are extremely high concentrations of ClO in the daytime measurement at 20 km. Furthermore the diurnal variation of the volume mixing ratio of ClO is obvious. The relatively high concentration of the nighttime profile in the lower stratosphere is a result of the long observation period extending after sunrise. At least three layers can be resolved as indicated in Figure 4.

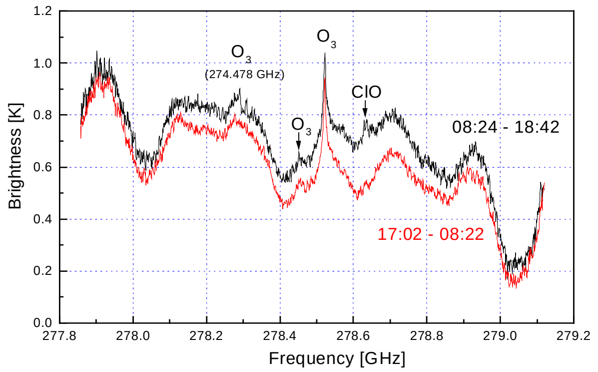

Figure 1: Raw daytime and nighttime ClO spectra measured on March 1-2

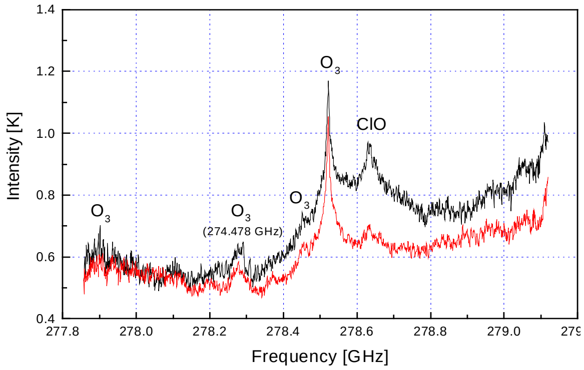

Figure 2: The same as Figure 1, but corrected for the standing waves

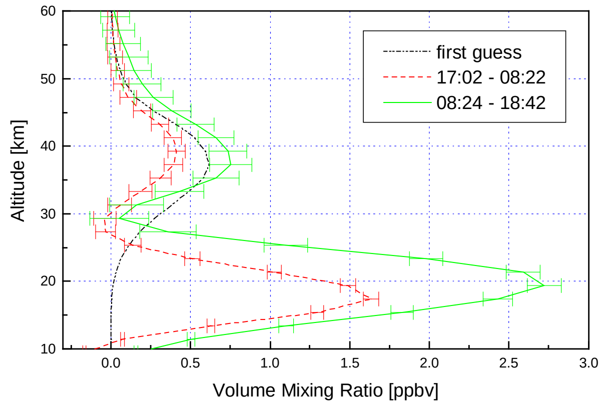

Figure 3: Retrieved volume mixing ratio profiles of ClO

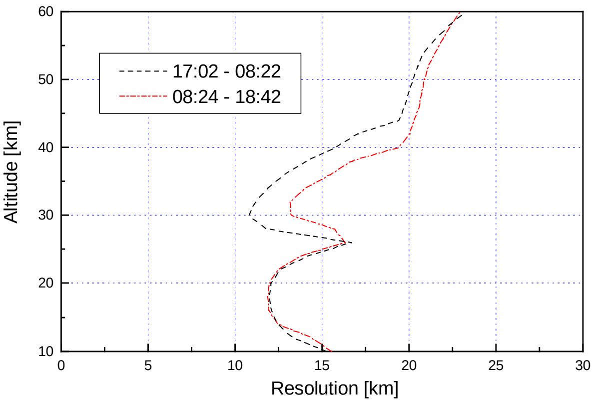

Figure 4: Vertical resolution of the profiles. The daytime profile has a better resolution due to the higher signal to noise ratio.

## OZONE ($O_3$)

The two ozone lines at 273.051 GHz and 274.478 GHz are the strongest in the frequency range covered by the radiometer. Due to the high signal to noise ratio of the measured spectra profiles with a very high resolution can be achieved (Figure 8).

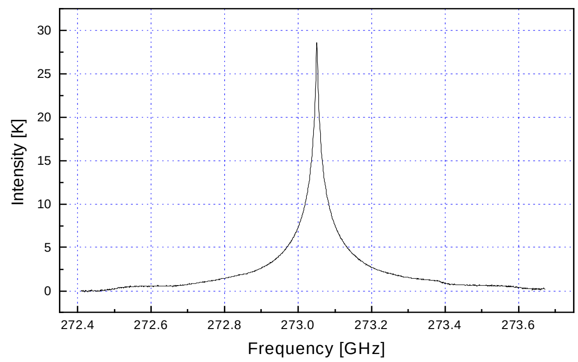

Figure 5: Raw spectrum of the 273.051 GHz ozone line, the strongest in the frequency range covered by the radiometer, measured on March 29

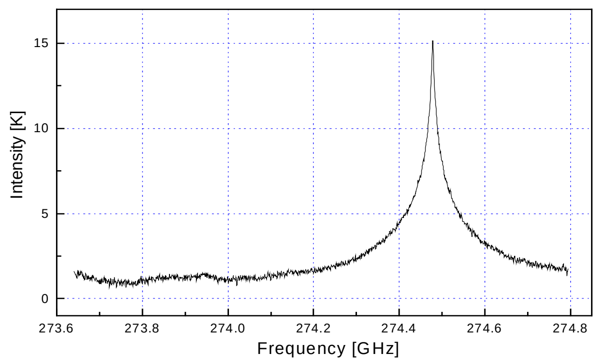

Figure 6: Raw spectrum of the 274.478 GHz ozone line, measured on February 19

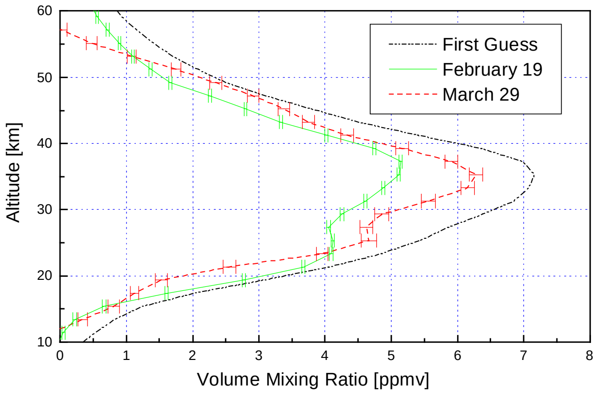


Figure 7: Resulting profiles of the VMR

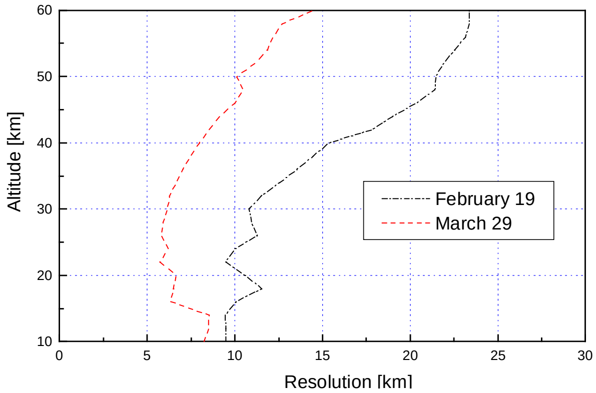


Figure 8: Vertical resolution of the profiles

NITROUS OXIDE ($N_2O$)

The $N_2O$ line at 276.328 GHz is difficult to detect because the maximum of the volume mixing ratio of $N_2O$ is below 20 km. This results in a weak, heavily pressure broadened signature. The spectrum presented here was measured on March 31. In the raw spectrum the extremely broad line of $N_2O$ can hardly be distinguished from the sinusoidal undulations caused by standing waves. Only in the corrected spectrum the signature of $N_2O$ is discernible (Figure 9). The Figures 10 and 11 show the simultaneously retrieved volume mixing ratios of $N_2O$ and ozone, respectively, using Tikhonov-Phillips-Regularization. In comparison to the first guess there is less $N_2O$ in the middle stratosphere. The high concentrations of $N_2O$ in the lower stratosphere are artifacts. In this region the resolution decreases since there is no information in the spectrum about the lowest atmospheric layers due to the limited bandwidth of the radiometer and the standing waves. Thus the profile in this altitude range is strongly influenced by the a priori information, which is in the case of Tikhonov-Phillips-Regularization the smoothness of the profile.

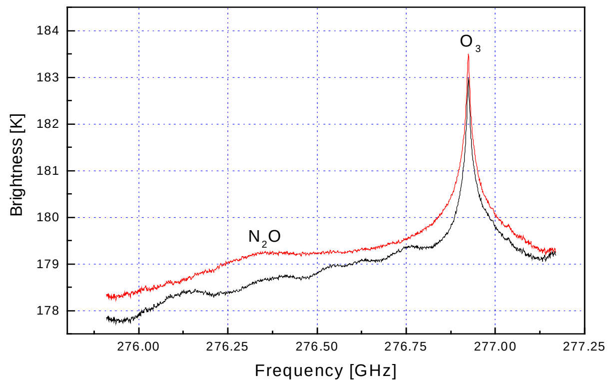


Figure 9: Raw (upper) and corrected (lower) spectrum of $N_2O$ and Ozone, measured on March 31

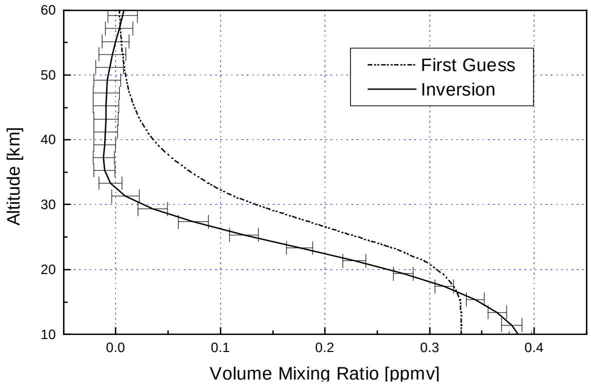


Figure 10: Retrieved $N_2O$ profile

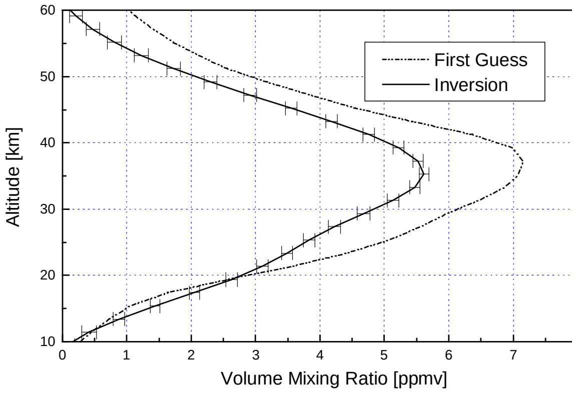


Figure 11: Retrieved ozone profile

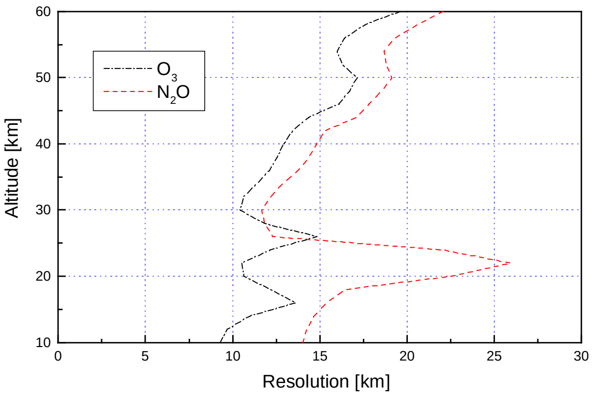


Figure 12: Vertical resolution of the profiles

## NITRIC ACID ($HNO_3$)

Caused by the pressure broadening the numerous $HNO_3$ lines at about 269.4 GHz merge to a single wide signature. The spectrum presented here was measured on March 20 (Figure 13). For the inversion the Optimal Estimation Method was used to calculate the profiles of the volume mixing ratios of $HNO_3$ and ozone (Figures 14 and 15). The volume mixing ratio of $HNO_3$ reaches its maximum at lower altitudes in comparison to the a priori profile (first guess).

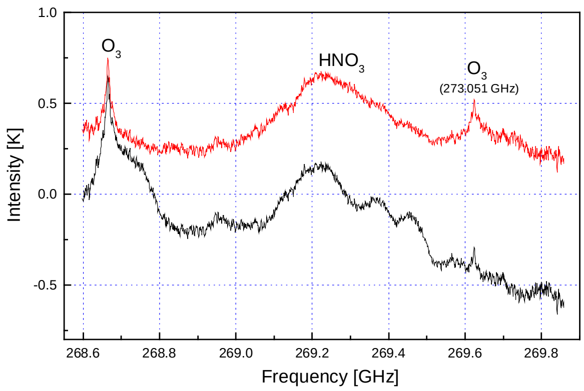


Figure 13: Raw (upper) and corrected (lower) spectrum of $HNO_3$ and Ozone, measured on March 20

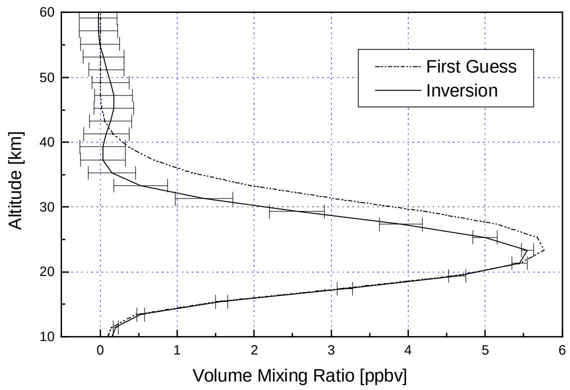


Figure 14: Retrieved $HNO_3$ profile

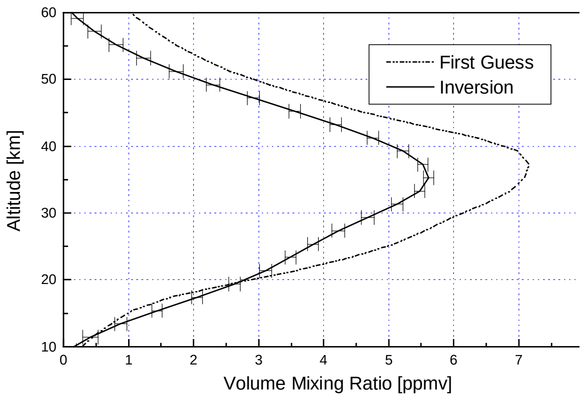


Figure 15: Inverted ozone profile

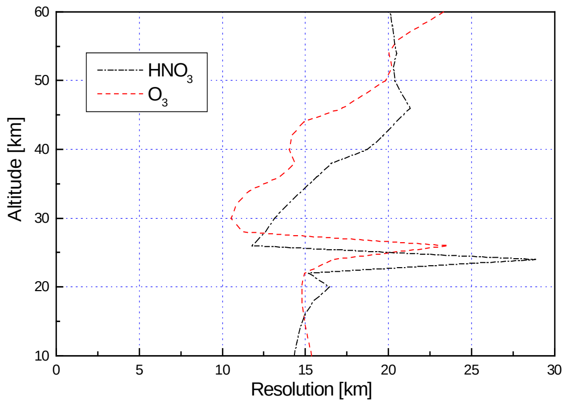


Figure 16: Vertical resolution of the profiles

## REFERENCES


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