Profiles of Stratospheric Trace Gases Retrieved from Ground-Based Millimeter Wave Radiometry at Ny-Ålesund 1997 and Kiruna 1998

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During two subsequent polar winter measurement campaigns the ground-based millimeter wave radiometer MIRA2 has been operated from 12 March to 31 March 1997 at Ny-Ålesund (78.9°N, 11.9°E), Svalbard, and from 26 January to 3 April 1998 at Kiruna (67.8°N, 20.4°E), Sweden.

From the measurements at Ny-Ålesund a nearly continuous time series of 100 ClO vmr profiles could be retrieved and compared to calculations of the Karlsruhe Simulation Model of the Middle Atmosphere (KASIMA).

During the measurement campaign at Kiruna 1998 the weather conditions were not always favorable for ClO measurements. During the periods of bad weather conditions the radiometer was tuned for the detection of Ozone resulting in a time series starting from 26 January to 31 March, or for the detection of N_2O.

THE MEASUREMENT CAMPAIGN 1997 AT NY-ÅLESUND, SVALBARD

The measurement campaign at Ny-Ålesund from 12 March to 31 March 1997 was part of the international radiometer intercomparison of five ClO instruments. During the entire campaign this site was located inside the polar vortex. The system was fix tuned for the simultaneous detection of ClO and Ozone except for two days because of unfavorable weather conditions. A detailed description of the system is given in [1].

For inversion of the spectra an enhanced variant of the Optimal Estimation Method including the joint retrieval and the fit of standing waves within the inversion process [2] was used. Due to this direct inversion of spectra containing overlapping signatures of different constituents and standing waves there is no need to calculate day minus night difference spectra. This allows the separate processing for any timespan and so the achievable time resolution is only restricted by the noise temperature of the radiometer. According to simulations with synthetic data the errors caused by the joint retrieval, the fit of standing waves, errors in frequency calibration and Gaussian noise is estimated to be less than 0.5 ppbv for ClO. A vertical resolution of at least three independent layers between 17 and 55 km is achieved which was estimated by an analysis of the averaging kernels. Above and below this altitude range the profiles are determined by the a priori information.

At this campaign a nearly continuous series of 100 ClO vmr profiles could be retrieved. Fig. 1 shows a comparison of the period 12 March to 23 March with the Karlsruhe Simulation Model of the Middle Atmosphere (KASIMA) [3]. This is a combination of an off-line model using analyses of the European Center for Medium range Weather Forecast and a prognostic primitive equation model. The model includes a full atmospheric chemistry scheme. There is a good overall correspondence between the measurements and the calculated mixing ratios in the diurnal variation of the lower layer at about 20 km for the period under consideration. Differences occur in the upper stratosphere at about 40 km where the measurements show greater variability of the ClO mixing ratios than the model calculations. Also the modeled values are greater than the observed ones. In the lower stratosphere both, the measured and the modeled ClO mixing ratios show the same increase in the daytime peak mixing ratios during the first four days, a decrease in the following days and a last increase at around 20 March, which is shown in detail in Fig. 2.

These results are also in good agreement with values for the lower peak presented by Raffalski et al. [4].

In the end of March MIRA measurements show continuing chlorine activation whereas KASIMA calculates a deactivation of chlorine due to the release of NO_2 of HNO_3 and the subsequent formation of $ClONO_2$. The reason for this differences in the ClO distribution will be topic of further investigations.

THE MEASUREMENT CAMPAIGN 1998 AT KIRUNA, SWEDEN

For the measurement campaign at Kiruna from 26 January to 3 April 1998 some improvements at the system have been made, e.g. the replacement of the Martin-Puplett diplexer by a Fabry-Pérot diplexer and an improved thermal stabilization of the frontend by an acrylic glass cover.

During the periods of unfavorable weather conditions for ClO measurements the radiometer was tuned for the detection of the strong Ozone lines at 273.05 GHz or 274.48 GHz or for the detection of the N_2O signature at 276.33 GHz, respectively.

A complete time series of Ozone profiles has been retrieved covering the whole campaign (Fig. 4). There seems to be a weak anti-correlation between the mixing ratios at 27.3 km and the IPV at 550 K, which is plotted in the lower part of Fig. 4.

Two measurements of N_2O are shown in Fig. 5. On 6 February Kiruna was situated outside and on 22 February 1998 inside the polar vortex. The mixing ratios in the middle stratosphere inside the polar vortex are lower in comparison to outside due to the sinking inside the vortex.

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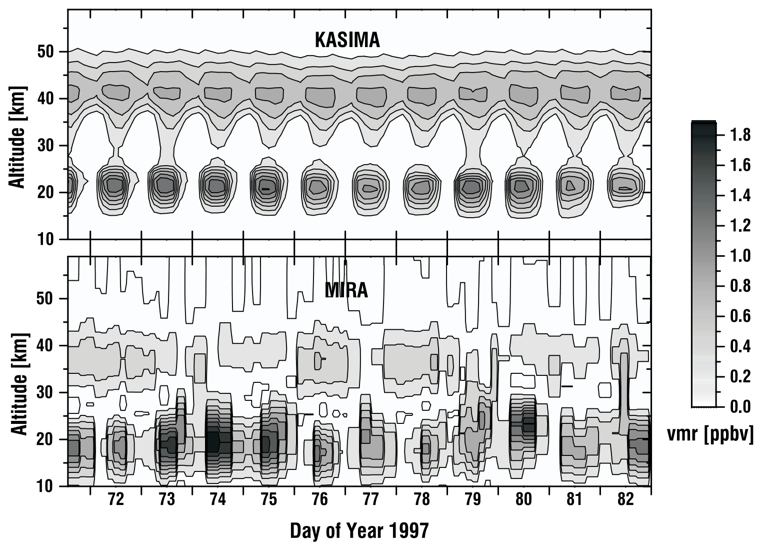

Fig. 1: Volume mixing ratios of ClO from 12 March to 26 March 1997 at Ny- Ålesund. Calculations of KASIMA (upper graph) and measurements of MIRA (lower graph)

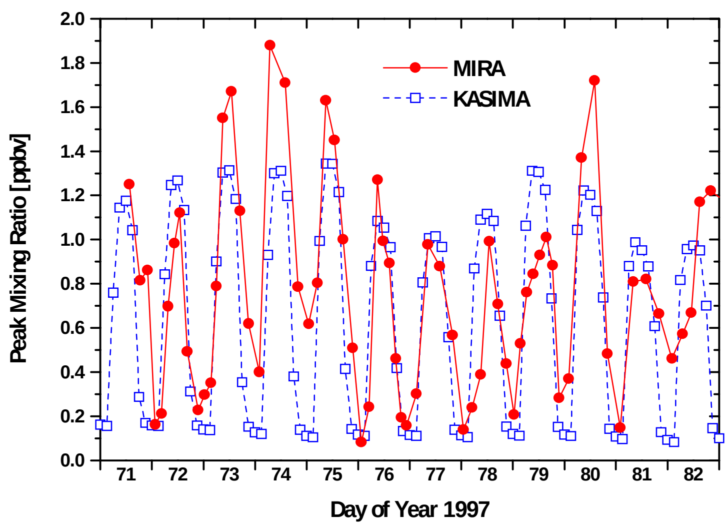

Fig 2: Variation of the lower ClO layer from 12 March to 26 March 1997

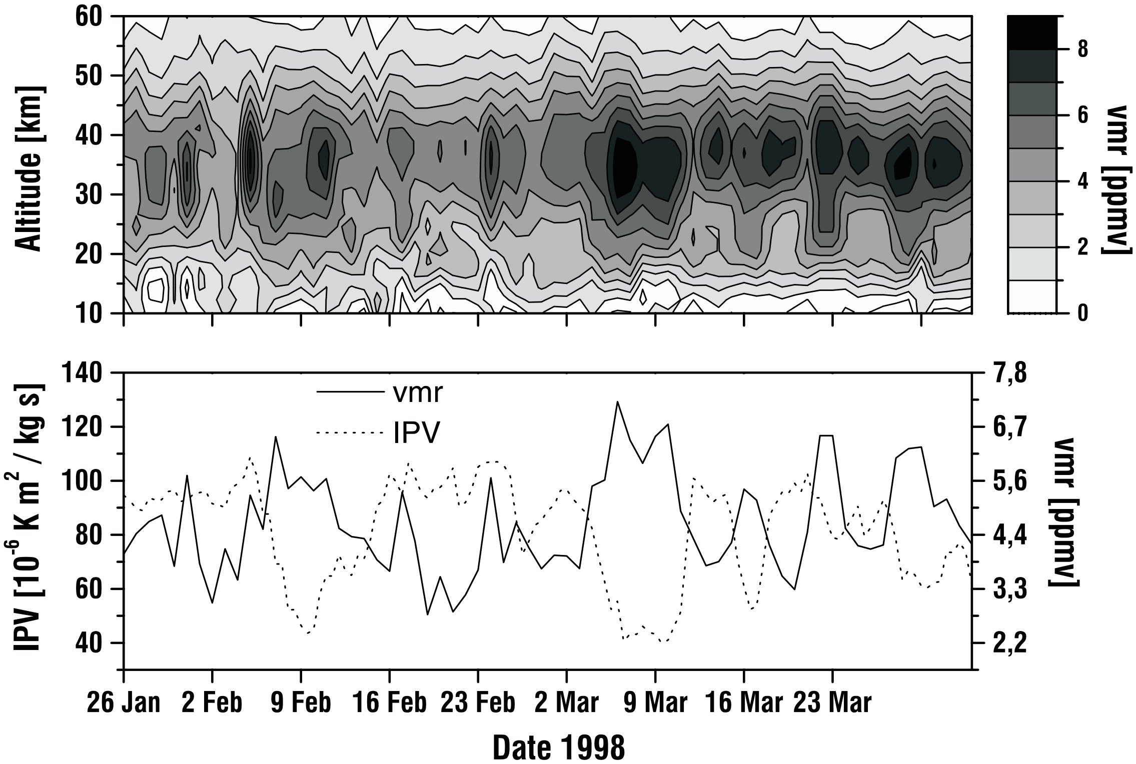

Fig. 4, upper graph: Volume mixing ratios of Ozone from 26 January to 3 April 1998. Lower graph: Volume mixing ratios in an altitude of 27.3 km in comparison to the IPV at 550 K (ECMWF data)

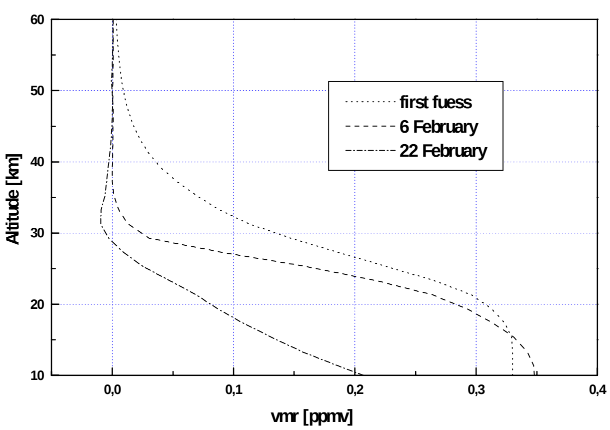

Fig. 5: Volume mixing ratios of N_2O outside (6 February) and inside (22 February) the polar vortex

REFERENCES

[1] H. Berg, R. Krupa, G. Hochschild, G. Kopp, M. Kuntz, "Millimeter wave radiometer with adjustable internal calibration load for high resolution measurements of stratospheric constituents", Proceedings of 2nd ESA Workshop on Millimetre Wave Technology and Applications: Antennas, Circuits and Systems; pp. 372-377; Espoo, May 1998

[2] M. Kuntz, "Bestimmung der Höhenverteilung stratosphärischer Spurengase aus Emissionsspektren eines bodengebundenen Millimeterwellen-Radiometers", Rep. 5719, Forschungszentrum Karlsruhe GmbH, Karlsruhe, Germany, 1996

[3] W. Kouker, "The Karlsruhe simulation model of the middle atmosphere (KASIMA)", Wissenschaftliche Berichte 5635, Forschungszentrum Karlsruhe GmbH, Karlsruhe, Germany, 1995

[4] U. Raffalski et al., "Ground based millimeter-wave observations of Arctic chlorine activation during winter and spring 1996/1997", Geophys. Res. Lett., 25, 3331-3334, 1998