Enhanced Chlorine Monoxide above Spitsbergen in spring 1997 measured by the Ground-based mm-Wave Radiometer RAM

U. Raffalski, B. Franke, U. Klein, K. F. Künzi, J. Langer, B.-M. Sinnhuber, R. Tuckermann

Institute of Environmental Physics, University of Bremen, PO Box 33 04 40, D-28334 Bremen, Germany

Abstract

Observations of chlorine monoxide (ClO) have been performed at Spitsbergen throughout the winter and spring 1997 with the millimeter wave Radiometer for Atmospheric Measurements (RAM) by the University of Bremen. Spitsbergen was located well inside the polar vortex with periods of very low stratospheric temperatures over Ny-Ålesund (78.9°N/11.9°E). Low stratospheric temperatures are a neccessary condition for polar stratospheric clouds (PSC) to occur, which can entail chlorine activation. The ClO measurements require low tropospheric water vapor. The rather poor weather conditions limited the successful observing periods to approximately 8 days. Data from these periods show enhanced lower stratospheric ClO mixing ratios of up to 1.9 ppbv during daytime.

Polar vortex

Chlorine activation is caused by heterogeniuous chemical processes on polar stratospheric clouds and subsequent denitrification and/or dehydration inside the polar vortex. Once Nitrogen compounds disappeared ClO and the dimer Cl_2O_2 exist as long as temperatures inside the vortex are sufficiently low. The potential vorticity at the 475 K niveau presented in fig. 3 shows that Ny-Alesund was located well inside the polar vortex almost all the time from February to mid April with temperatures low enough to form PSC in March. Higher temperatures at mid April indicate the vortex slightly moving away from Ny-Ålesund.

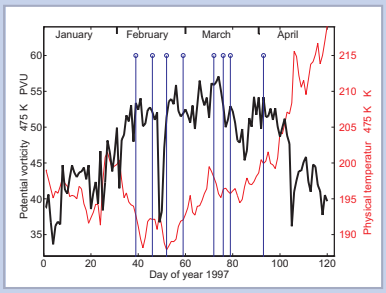

Figure 1: Potential vorticity in PVU and temperature in Kelvin at 475 K isentropic above Ny- Ålesund. Data from ECMWF. The circles indicate days with RAM measurements that were processed with the scaling factor method.

Measurements

The measurements performed by the mm-wave radiometer RAM are limited by the strong influence of tropospheric water vapor. Using the beam switch method minimizes instrumental effects. Differencing of day and night spectra decreases baseline effects assuming just a small amount of ClO remaining in the lower stratosphere around 23 km during the night. The difference spectrum therefore gives the slightly decreased ClO signal of the daytime measurement.

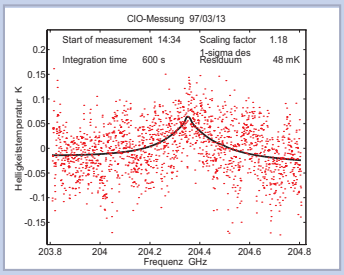

Figure 2: A typical daytime minus nighttime difference spectrum of the ClO mesasurements of March 13. The integration time is appr. 600 s. The solid line shows a fit of a model spectrum to the measure- ment.

Retrieval method

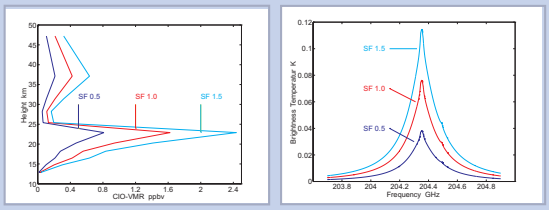

Figure 3: Left: the model profile (red) and two examples of scaled profils. Right: the corresponding spectra due to radiative transfer calculations.

In a situation of disturbed stratospheric chemistry most of the ClO content is concentrated in a layer around an altitude of 23 km (fig. 2) From this profile a synthetic spectrum can be calculated with an intensity proportional to the peak VMR at 23 km. We scaled this synthetic spectrum to approximate the measured day-night difference spectra by a least-squares-fit. The scaling factors obtained with this method can be used to estimate the ClO VMR at 23 km of altitude.

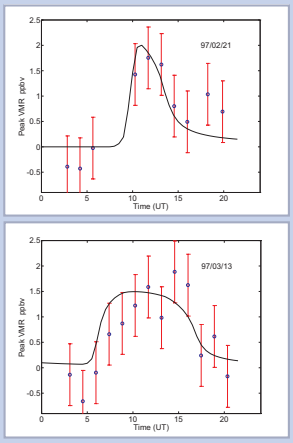

Fig. 4: Two sets of measurements from February 21 and March 13, showing diurnal variation of the ClO VMR calculated with the method des- cribed above.

Results

The evolution of the ClO VMR for two days obtained by the scaling factor method is shown in fig. 4. Together with the ClO measurements a modeled photochemically induced diurnal cycle of ClO is presented in the figure. The error due to noise and baseline effects is ~10% in the calculated scaling factors. The ClO VMR retrieved from the measurements clearly show a diurnal variation following sunrise and sun- set in the stratosphere. The vortex during winter 1997 being cold and stable above Ny-Ålesund has experienced a chlorine activation with a maximum ClO value of around 1.9 ppbv. ClO VMR retrieved from simultaneous measurements performed by other microwave instruments (see posters of Klein et al., Hochschild et al., de Zafra et al.) are in very good agreement with the RAM results. The high values de- tected at eight days throughout the winter that are shown in fig. 5 (with calculated column densities) indicate a rather strong chemical deple- tion of lower stratospheric ozone above Ny-Ålesund. This is confirmed by the ozone evolution observed by the RAM presenting a decrease of about 35% at the 475 K isentropic level (see poster of Langer et al.) throughout the winter. The decrease started mid February when ClO values were high and the sun turned back into the lower stratosphere.

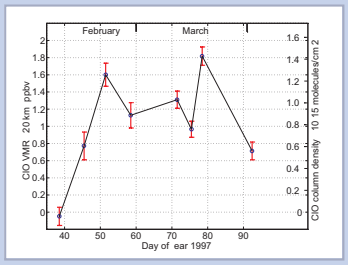

Figure 5: Midday ClO VMR obtained with the scaling factor method. At the right side of the figure column densities are labeled.

Acknowlegdements

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