Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft
Universität Bremen
Universität Karlsruhe (TH)
Universidad de los Andes Mérida-Venezuela

Microwave radiometry of the mesosphere

M. Palm[1], G. Kopp[2,3], S. H. W. Golchert[1], M. Sinnhuber[1], H. Küllmann[1], J. Notholt[1], G. Hochschild[2,3], P. Hoffmann[4], O. Schrems[5]

[1] IUP, Universität Bremen, [2] Universität Karlsruhe, [3] Forschungszentrum Karlsruhe, [4] Universidad de los Andes, Mérida, [5] AWI Bremerhaven

Introduction

Above the stratopause at 55 km altitude the sun gains increasing influence on chemical composition of the atmosphere. This influence manifests itself in photo dissociation by highly energetic radiation and particles descending into the atmosphere above the polar caps. The amount of available odd oxygen is governed by the Chapman cycle (Chapman, 1930) with its producing reactions

$$O_2 + h\nu \rightarrow O + O$$

$$O + O_2 + M \rightarrow O_3 + M$$

In altitudes near the stratopause (about 60 km) the lifetime of the O_x-family (odd oxygen: O, O_3) is about an hour.

Microwave radiometry provides a method to measure abundances of trace gases in altitudes up to 90 km from the ground. It is therefore particularly suited to investigate the sun-atmosphere interaction on its chemical branch.

Instrumentation

The Universität Bremen and the FZK Karlsruhe operate microwave radiometers in Ny-Ålesund (Spitsbergen, 79N) and on top of the Pico Espejo at Mérida (Venezuela, 8N).

Ny Ålesund

The OZORAM at Ny Ålesund measures the 142 GHz emission line of O_3. Since 9/2006 it operates two spectrometers in parallel, an AOS and a CTS. While the AOS has a large bandwidth of almost 1 GHz and a moderate resolution of 1.6 MHz, the CTS (bandwidth of 40 MHz, resolution of 12.5 kHz) provides highly resolved spectra of the line center (see fig. 1).

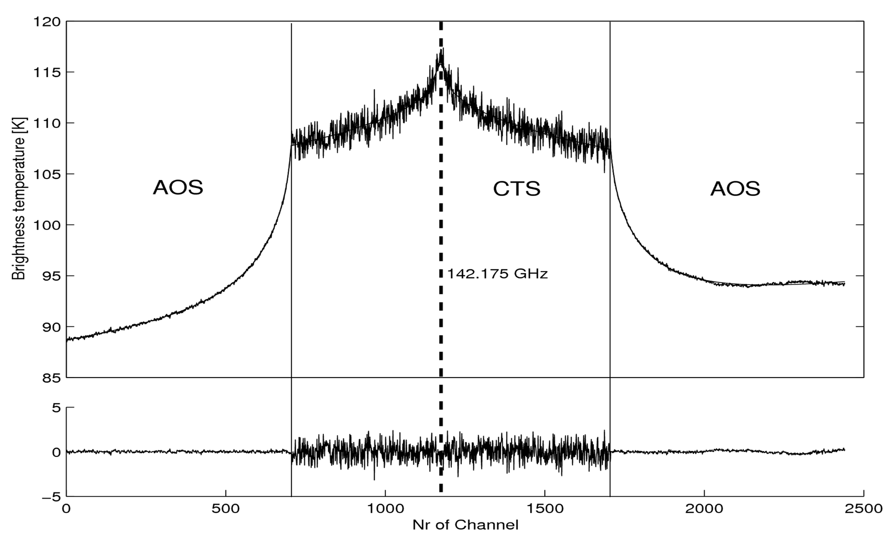

Fig. 1: Composite OZORAM spectrum example, atmospheric signal (upper panel) and residuum (measurement minus model fit). The center channels correspond to the CTS measurement with only 1% of the channel width of the AOS measurement.

Pico Espejo

The MIRA-2 on Pico Espejo is tunable over the range from 268-281 GHz. It measures the O_3 emission at 273 GHz. The spectrometer is an AOS with a bandwidth of 1 GHz and a resolution of 1.2 MHz (see fig. 2). The high altitude of the instrument's location provides a higher signal-to-noise ratio of middle atmospheric measurements.

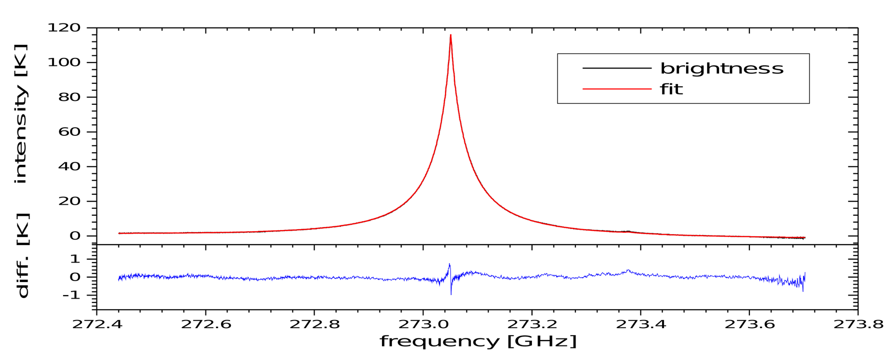

Fig. 2: An example of a spectrum and residuum taken by the MIRA-2 radiometer.

Retrieval

The spectra of both instruments are inverted using the Optimal Estimation Method (Rodgers, 2000). The altitude resolution is about 10 km FWHM (Full width at half maximum of a Gaussian resolution function). The different baseline level is due to different calibration algorithms.

References
Guy Brasseur , Susan Solomon; Aeronomy of the Middle Atmosphere, Reidel, 1986
Clive D. Rodgers, Inverse Methods for Atmospheric Sounding, World Scientific, 2000
Chapman, S, Ferraro, C.A.F., A new theory of magnetic storms, Nature, 126, 129-130, 1930

Acknowledgements
This work has been funded by the DLR, project CAWSES-SACOSAT 404/5-1 and national financial support by the virtual institute PEP (Polar-Equator-Polar) within the Helmholtz Association. We also thank the Alfred-Wegener-Institute for support on the research base AWIPEV in Ny Ålesund, Spitsbergen.

Day and night

In polar regions, true day and night exist only in short periods around spring and autumn equinox. Because of the high latitude the solar zenith angle (SZA) varies only about 20° on one day. The night terminator is slowly traversed which enables the study of the dependency of the amount of O_3 on the SZA. The partitioning among the O_3, O and O_2 is governed by the following swift reactions (Brasseur and Solomon, 1986):

$$O_3 + h\nu \rightarrow O(^1D) + O_2$$

$$O(^1D) + O_2 \rightarrow O + O_2(^1\Sigma_g)$$

$$O + O_2 * M \rightarrow O_3 + M$$

Because the O_3 lifetime in this altitude is about 2 min, the atmosphere can be regarded in equilibrium within the time of each measurement (about 20 min).
In the tropics well defined day and night cycles and only little variation of the night terminator are found.

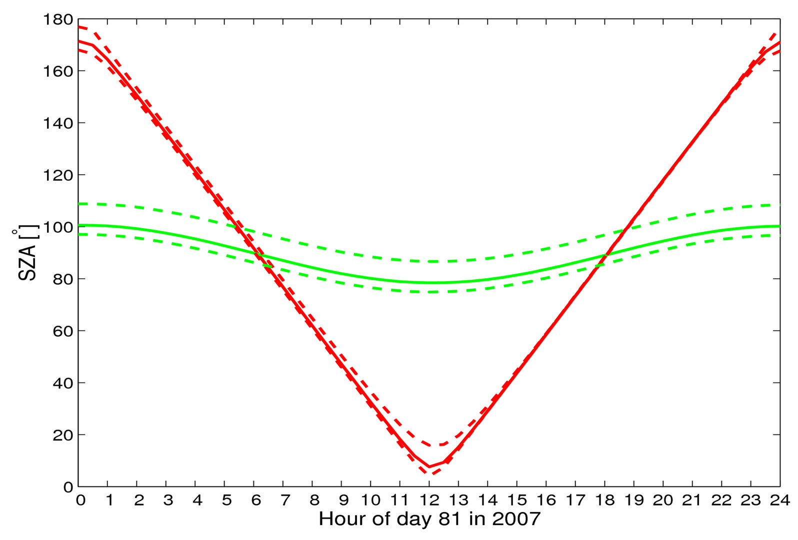

Fig. 3: Solar zenith angle (SZA) versus hour of day on the spring equinox 2007. The green line is the course of the sun above Ny-Ålesund (green line) and above Mérida (red line). The dotted lines denote the course of the sun at the 1st and the 31st of March.

Results

The measurements clearly show the expected diurnal variation of O_3 at high latitude and at 65 km altitude (see fig. 4).

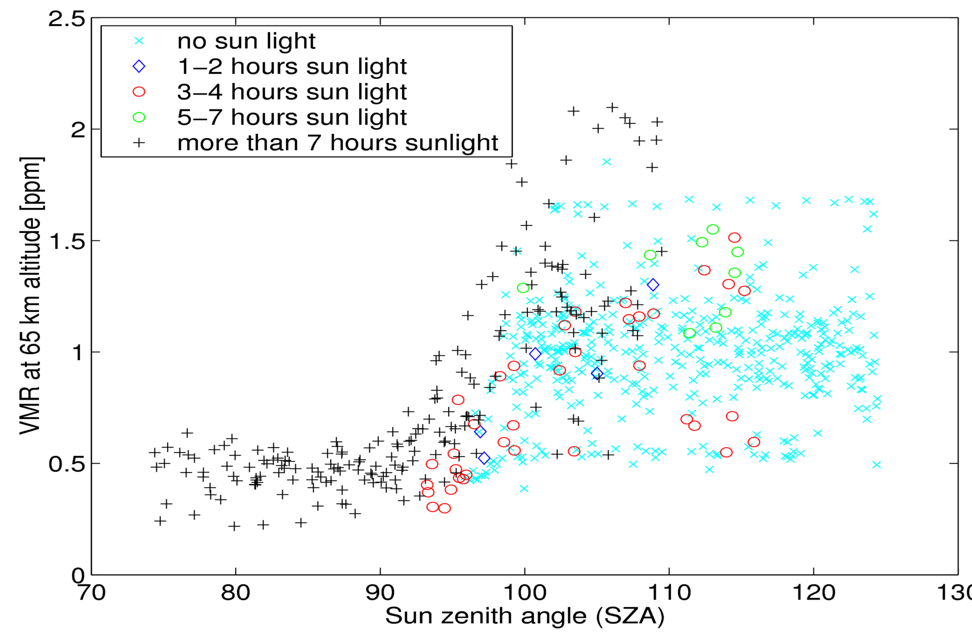

Fig. 4: O_3 abundance derived from Ny-Ålesund measurements. Color denotes the duration of the sunshine on the day of measurements. Sun light is assumend if SZA < 95°.
The measurement error is 0.2 ppm.

The high variation during the night is probably caused by dynamics. Long illuminated periods cause sometimes very high O_3 abundances during the night. This can be attributed to the high energy input. Influences besides sunlight, i.e. dynamics and chemical composition, are not yet quantified.

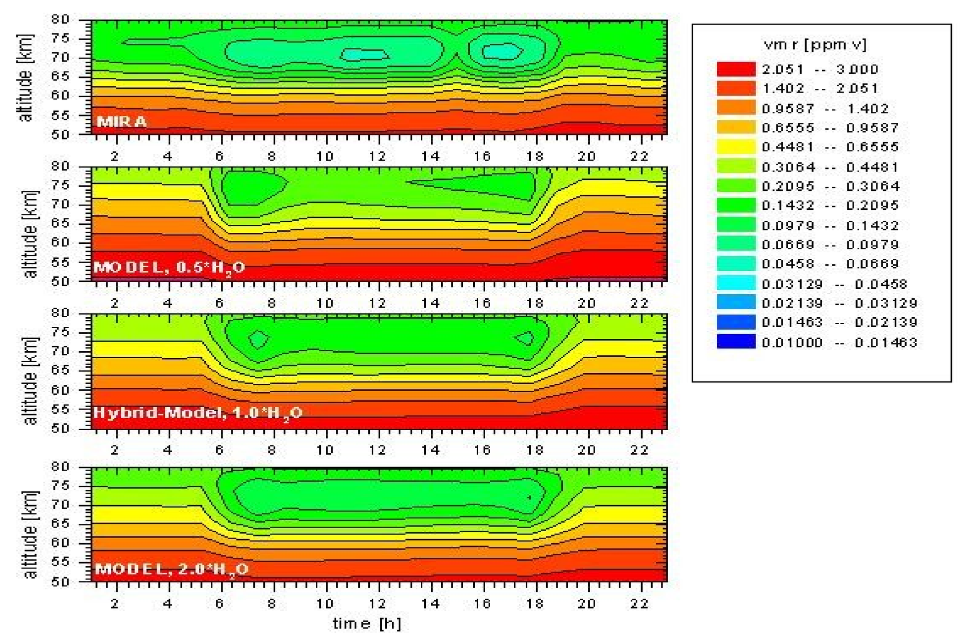

Fig. 5: The diurnal variation of O3 above Mérida integrated from 1st to the 31st of March 2006. Three model runs (lower 3 panels) using different input of H_2O are compared to the measured variation (1st panel).

The daily course of O_3 (fig. 5) above Mèrida is swiftly changing between illuminated sky and night. The three model runs below use different amounts of water vapour. While the runs look qualitatively similar, the dynamical range is only matched if the model uses unlikely high water vapor VMRs.