Microwave Radiometry of Water Vapour

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1. INTRODUCTION

Water vapour plays a key role in the earth's radiative budget as well in chemical (formation of polar stratospheric clouds, ozone depletion) and dynamical processes in the atmosphere. In the upper troposphere water vapour is one of the main greenhouse gases absorbing longwave terrestrial radiation. Due to its long chemical lifetime, water vapour is also a valuable tracer for atmospheric motion.

There exist two main sources of middle atmospheric water vapour. Water vapour can enter the stratosphere by vertical transport in the tropical tropopause with the air being freeze dried by the low tropopause temperature. This water vapour spreads to middle latitudes with a certain phase lag. The other main source of stratospheric water vapour is the oxidation of methane. The sink of middle atmospheric water vapour is photolysis. While methane oxidation is a well understood process, the understanding of the troposphere−stratosphere exchange mechanisms is poor. The saturation vapour pressure of water isotopes depends heavily on temperature, measurements of the isotopic content of water entering the tropical stratosphere could therefore lead to a better understanding of these vertical transport processes.

The large gradient of the water vapour mixing ratio around the tropopause and the stratospheric mixing ratios of a few ppmv on one side and the moist tropospheric air masses on the other side require an enormous technical effort to measure water vapour in the upper troposphere and in the stratosphere. The spatial and temporal variability of stratospheric water vapour is relatively small, this means that changes of a few tenths of 1 ppmv need to be detected with a similar accuracy of the measurement. Microwave radiometry is a well suited technique for remote sensing of water vapour in the atmosphere.

2. MICROWAVE RADIOMETRY

Microwave radiometry is a passive remote sensing technique detecting the emission lines of atmospheric constituents. The spectral analysis of the pressure broadened lines allows to retrieve the altitude profiles of the species under investigation from 20 − 70 kilometers typically. This altitude range covers the atmosphere from the lower stratosphere to the mesopause. The direct detection of the spectral features is not possible in the microwave region, except for frequencies below 20 GHz, therefore microwave radiometers are operated in the so−called heterodyne mode. In this mode the incoming high frequency atmospheric signal is superposed with a highly stable signal form a local oscillator in a non linear element thus transformed to an intermediate frequency where sufficient amplification and spectral analysis is possible. The spectral analysis is achieved by either an acousto optical spectrometer or by a chirptransform spectrometer.

The Microwave Group at the Institute of Applied Physics (IAP), University of Bern, has developed and operated various instruments for the detection of transition lines of atmospheric constituents such as: O_3, H_2O, $H_2{}^{18}O$, ClO, HCl and CO.

3. RESULTS

For several years, our institute has provided measurements of water vapour in the middle atmosphere with an airborne microwave radiometer called AMSOS (Airborne millimeter and submillimeter spectrometer). This instruments measures the strong water vapour emission line at 183 GHz which is ideal for airborne measurements. The typical campaign covers almost all of the northern latitudes from the subtropics to the arctic. The campaign in spring 2000 led up to the north pole and allowed to measure the water vapour distribution at the north pole for the first time.

The analysis of the flights from different seasons indicate that the state of the atmosphere changes dramatically between these periods, especially at high latitudes. Measurements in winter and spring show a completely different picture than those taken during summer. Summer profiles show an almost climatological distribution of water vapour, while winter and spring profiles show a stronger maximum at much lower altitudes in polar regions, typically with very low water vapour values above it. Figure 1 shows the results of the year 2000 campaign. The flights have taken place in March 2000.

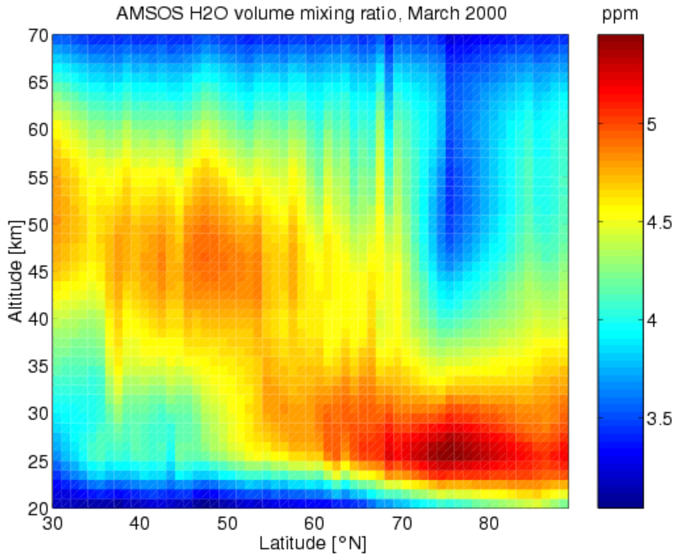

Figure 1 Latitudinal distribution of water vapour. Measurements from AMSOS flight campaign 2000.

Besides the flights the AMSOS instrument was placed on the high Alpine research station Jungfraujoch during winter season when the atmosphere was sufficiently dry to perform for the first time ground−based water vapour at midlatitudes using this frequency. At the research station Jungfraujoch AMSOS was operated besides the EMCOR (European Minor Constituents Radiometer) that measures the $H_2{}^{18}O$ transition at 203 GHz. The data from both radiometer were combined to determine the isotopic ratio of $H_2{}^{18}O$ to $H_2{}^{16}O$. The isotopic composition of water vapour can be used to deduce information about the species chemical and physical history. The obtained data has been validated with profiles from the PAOM satellite instrument.

The water vapour transition at 22 GHz is a favorable transition for ground−based measurements. The tropospheric opacity at this frequency is sufficiently weak to allow measurements of middle atmospheric water vapour from low altitude stations. To provide long−term measurements of middle atmospheric water vapour we newly built a radiometer called MIAWARA (Middle Atmospheric Water Vapour Radiometer) . It has started operation in fall 2001 and is currently placed at Bern.

4. CONCLUSION

Microwave remote sensing provides en excellent tool to study processes in the atmosphere related to water vapour. Due to the spectral features it is possible to obtain water vapour profiles of the atmosphere from the lower stratosphere to the mesopause. The operation of a microwave radiometer onboard a plane allows the investigation of latitudinal variations of middle atmospheric water vapour. The measurement of the isotopic composition of stratospheric water vapour might give insight in the place of origin of water in the middle atmosphere.

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