Remote sensing of trace constituents in the atmosphere by microwave radiometry and sun photometry from Jungfraujoch

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Introduction

The research team of the microwave department at the Institute of Applied Physics, IAP, of the University of Bern has a long reputation in the field of microwave remote sensing of atmospheric constituents. During the last years instruments for the detection of transition lines of atmospheric constituents have been developed and were successful in measuring spectra of O_3, H_2O, H_2O^{18}, ClO, HCl as well as CO. Radiometers are operated from the ground (Bern and Jungfraujoch), from aircraft and also have been flown on the Space Shuttle. The main focus of research in recent years was to obtain information on dynamical and chemical processes by investigating the temporal and where possible the geographical variability from the retrieved volume mixing profiles mainly from water vapor and ozone. Due to the high quality of our data, the ozone-radiometer has been selected as a complementary instrument of NDSC (Network for the Detection of Stratospheric Change) and regularly delivers data to the NDSC data bank.

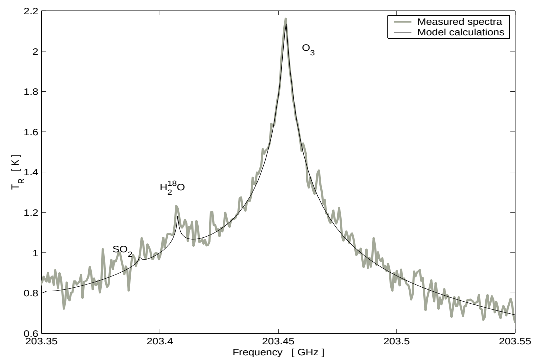
Microwave radiometry makes use of pressure broadened emission lines which allow to retrieve the altitude distribution of the molecules under investigation. Being a passive method, no background light sources are needed such as the sun or the moon for observations. For the detection of weak spectral features originating from the stratosphere a high transmission of the atmosphere is required. This is equivalent to a requirement for a low water vapor content of the atmosphere, a requirement that can be fulfilled at high altitude sites such as the Jungfraujoch. Therefore we operate instruments from the high Alpine site when necessary and complement them by other measurements e.g. of ozone performed from Bern whenever possible. For this reason our ozone instrument has been classified as a complementary NDSC instrument to Jungfraujoch.

The microwave methodology has been supplemented with sun photometry that provides information about the column density of ozone and water vapor as well as the optical depth and particle size distribution of aerosols. A sunphotometer has been operated from Jungfraujoch for an extended period.

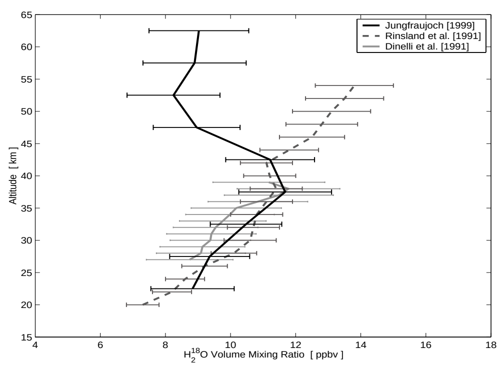
Our activities also contribute significantly to a number of national and international projects such as GAW-ozone, GAW-CHARM, both under the auspices of MeteoSwiss, to the EC-projects WAVE (Water Vapor Experiment), COSE (Compilation of atmospheric Observations in Support of satellite measurements over Europe) and EuroSOLVE, to COST action 712 (Microwave radiometry in Meteorology), just to mention the most important ones.

Water vapor

A main topic of our research is water vapor from the troposphere to the mesosphere. Investigations of water vapor in the stratosphere and mesosphere have been performed since several years from aircraft. The microwave instrument AMSOS (Airborne Millimeter and Submillimeter Observing System) is operated at 183 GHz to measure a water vapor transition. As the instrument was not otherwise used between flight campaigns we were looking for another application of the valuable equipment. The instrument has thus been operated from the high altitude observatory Jungfraujoch and it was possible to observe for the first time in Europe during very cold conditions this water line from the ground, allowing to retrieve a water vapor mixing profile in the middle atmosphere [1], [2]. In addition to these measurements at 183 GHz, a transition of the water vapor isotope H_2O^{18} at 203 GHz has been measured successfully with EMCOR, European Minor Constituent Radiometer, [3]. This very weak line was detectable due to the very low noise superconducting SIS receiver operating at Jungfraujoch, [4]. The isotopic composition of atmospheric water vapor resulting from the impact of various fractioning mechanisms is not fully understood. What is generally agreed upon is that water vapor entering the stratosphere from the troposphere is largely depleted in heavy isotopes D and O^{18} due to the vapor pressure isotopic effect which denotes that heavier isotopes have lower vapor pressure and are therefore more prevalent in the condensed phase. Measurements are extremely sparse and the data from EMCOR in conjunction with those of AMSOS for H_2O are extremely valuable. Due to high opacity at 183 GHz these measurements are only possible during very dry conditions from high altitudes. However it would be desirable to operate a system during all seasons from lower elevations. This is possible for the weaker line at 22 GHz. A corresponding system is presently under construction at IAP and will start operation in spring 2001. The mid atmospheric data as obtained by microwave radiometry could ideally be complemented with data of the troposphere obtained from the LIDAR system of the EPFL (Prof. B.Calpini).



Spectra of O_3 and H_2O^{18} measured with EMCOR from Jungfraujoch with corresponding synthetic spectrum based on the retrieved profile



Comparison of vmr for H_2O^{18} deduced from EMCOR with data from ATMOS, an IR solar occultation experiment, and data from a balloon borne Fourier transform instrument

A sun photometer has been used for measuring the columnar content of water vapor by solar transmittance measurements, [5]. The instrument was in operation for an extended period on Jungfraujoch and data have been compared to a microwave instrument and to the results obtained by Fourier Transform Spectroscopy, FTS, on Jungfraujoch as well as to radiosondes, [6]. The agreement of the collocated instruments on Jungfraujoch was within 9% of the water content. The same instrument also has been used to estimate the aerosol optical depth above Jungfraujoch, [7].

Ozone

The distribution of ozone from 15 km up to 75 km has been determined on a regular basis with the GROMOS instrument since 1994, [8]. GROMOS is part of the Network for the Detection of Stratospheric Change (NDSC) and our data are supplied to the NDSC data base that is open to the public. Based on these data large episodic perturbations of mid stratospheric ozone values as observed during winter have been analysed. Backward wave trajectory calculations show that the observed episodes are coincident with periods of enhanced meridional transport and thus the so-called ozone mini holes are related to planetary wave activity during winter and not to photochemical destruction, [9].

Outlook

The sucessful measurements of water vapour and one of its isotopes in parallel with microwave radiometry from Jungfraujoch shall be continued in order to obtain further information about chemical and transport processes in the middle atmosphere. Both instruments will be optimized in order to improve sensitivity.

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