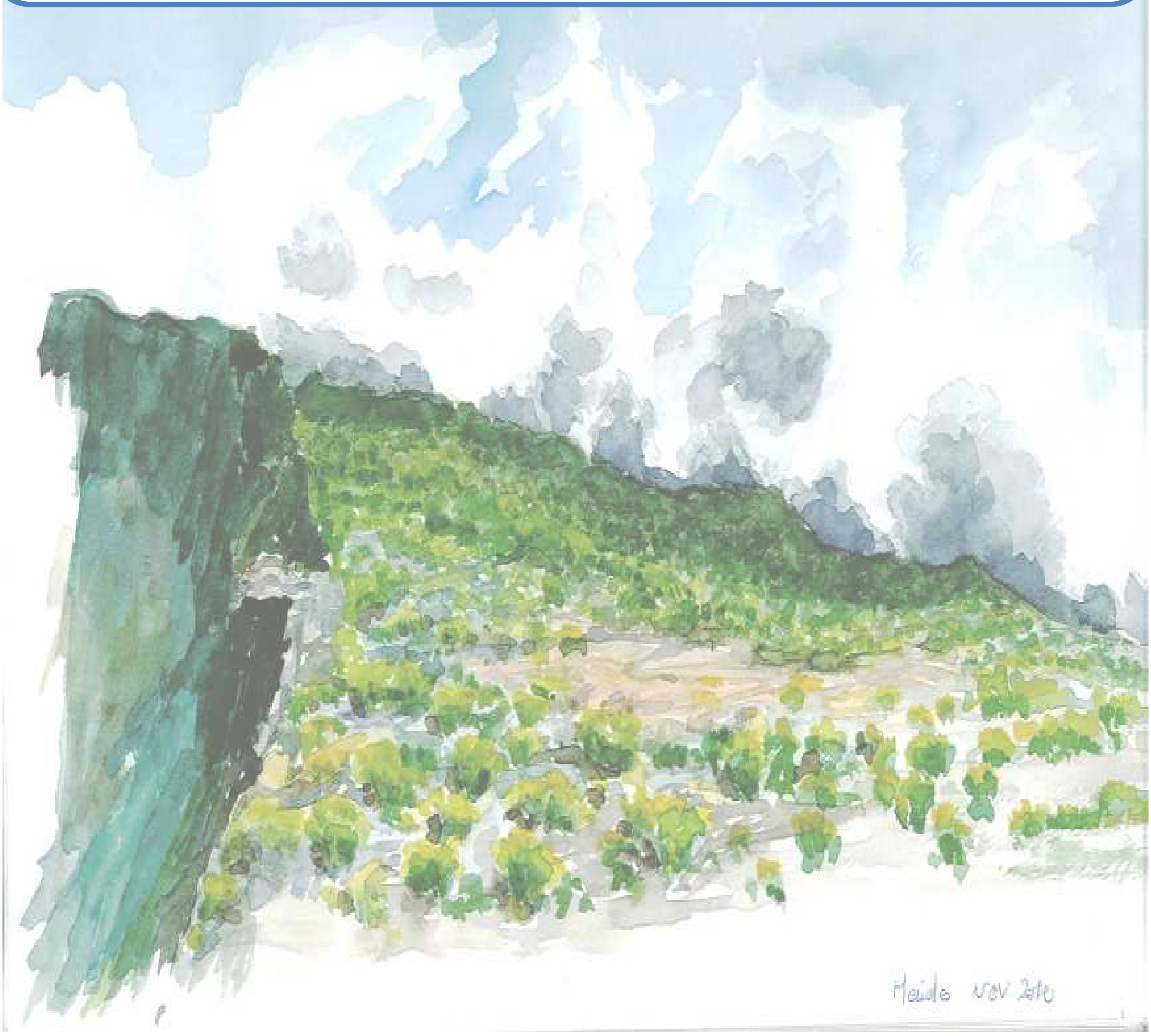
SESSION 4

WATER VAPOR



Oral Session

4-1 Temperature and Ozone Profiler Assessment at Lauder, New Zealand (TOPAL-2): First Results from the Intercomparison Campaign.

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An intercomparison of ozone and temperature profiling instruments will be carried out at the Lauder, New Zealand, NDACC station in June/July 2011 (after the deadline for this abstract submission). The primary instruments being compared are the RIVM and GSFC differential absorption lidars and the UMass microwave radiometer. Other data will be included as available such as ECC sondes and satellite overpass measurements. This campaign builds on two similar previous campaigns: OPAL in 1995 and TOPAL in 2002. For these previous campaigns, agreement within 15% was found for single profiles and within 10% for the campaign average over the range from 20 to 40 km altitude. The campaign will follow the NDACC protocols for a blind intercomparison. An initial overview of the campaign and first results will be presented. We acknowledge the other members of the instrument teams and partial support by the National Aeronautics and Space Administration.

Oral Session

4-2 Long-Term Ground-based Microwave Measurements of Middle Atmospheric Water Vapor from NDACC sites

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Changes in atmospheric composition discerned from long-term NDACC measurements of stratospheric and mesospheric water vapor showed significant increases in the early 1990s, but since the mid-1990s no significant trend in water vapor has been observed. We present measurements from the Vapor Millimeter-wave Spectrometer (WVMS) instruments deployed at Network for the Detection of Atmospheric Composition Change (NDACC) sites at Lauder, New Zealand (45.0S, 169.7E) since 1993, and from Mauna Loa, Hawaii (19.5N, 204.4E) since 1996. These instruments have, and continue to, make measurements nearly continuously.

The data for long-term water vapor trend detection for the WVMS instruments is optimally in the lower and mid-mesosphere. These ground-based measurements are compared with coincident HALOE (1993-2005), ACE (2004-present), and Aura Microwave Limb Sounder (2004-present) measurements. Comparisons between the WVMS instruments and these instruments show similar interannual variations, and, in the case of HALOE, are of sufficient length to study the effect of the solar cycle in the mid and upper mesosphere [Nedoluha et al., JGR, 2009].

In the lower and mid-mesosphere most of the CH4 which has entered the middle atmosphere has been oxidized, hence changes in H2O can be caused by both changes in CH4 and changes in H2O entering the stratosphere. The global increase in surface CH4 since the mid-1990s has been <50 ppbv [Dlugokencky et al., GRL, 2009], and as this CH4 oxidizes it would cause an increase in H2O in the mid-mesosphere of <2% over ~15 years.

We also discuss the extension of the WVMS time series using a new generation of instruments which, among other improvements, can extend the lower limit of the retrieval range from ~40km down to ~26km [Nedoluha et al., JGR, 2011].

Oral Session

4-3 Water Vapor Measurements in the UTLS at 936 nm by stellar occultations with GOMOS/ENVISAT and comparison with NDACC data.

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The evolution of water vapor in the lower stratosphere is still a case for controversy; though its exact trend in response to climate change is important. Solomon et al. (2010) have argued that the observed decrease of about 10% after the year 2000 "acted to slow the rate of increase in global surface temperature… by about 25%... compared to that which would have occurred due to only CO2…". The GOMOS instrument on board ENVISAT (launched 2002 in a helio-synchronous polar orbit) contains a high resolution spectrometer for the measurement of O2 at 760 nm and H2O at 936 nm, with a resolution of ~0.05 nm per pixel. GOMOS is the first instrument measuring these species by the technique of stellar occultation, which is protected in principle from long term drift, an essential feature for long term monitoring of a possible trend. Nine stars are sufficiently bright to provide useful measurements for stratospheric H2O. However, the data retrieval has been plagued up to now by a severe pixel-to-pixel non-uniformity of the CCD detector giving a wet bias around 30 km, which is now corrected in the new reprocessing. Results of this reprocessing will be presented for the first time, in the altitude range 10-50 km with a vertical resolution 3-4 km. Comparisons with NDACC H2O instruments will be presented. At present only the microwave 22 GHz radiometer network data are publicly available (Haefele et al., 2009). Data obtained at 3 hPa (~ 40 km) can be compared to GOMOS measurements. It is proposed to perform a validation of the radiometer network with GOMOS, similar to the one performed with MLS/AURA (Haefele et al., 2009). The advantage to use a space borne instrument is to relate the various ground-based instruments to a common space-based reference. A comparison with the Lidar measurements (still in the validation process) will be also presented.

Oral Session

4-4 Temporal structures in middle atmospheric water vapor observed by an NDACC radiometer at northern mid-latitudes

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Water vapor plays a key role in the global climate system, impacts atmospheric dynamics by latent heating and inuences atmospheric chemistry by heterogeneous reactions, in particular in the region of the ozone layer. Long-term, continuous measurements of middle atmospheric water vapor are sparse, but are very sensitive to changes in the climate system. Due to the lack of direct wind measurements in the middle atmosphere, water vapor is often used as a passive tracer to study stratospheric and mesospheric dynamics. The MIddle Atmospheric WAter vapor RAdiometer (MIAWARA) at the University of Bern became part of NDACC in 2006. Since then, it is continuously measuring middle atmospheric water vapor from 30 to 80 km altitude with a temporal resolution of a few hours to days. The measurements also allow the retrieval of tropospheric water vapor and integrated water vapor at a high temporal resolution. In contrast to satellite obser vations, our ground-based instrument provides measurements during day and night time what allows us to study tides and diurnal variations in the middle atmosphere. The instrument location in the Alpine region is particularly interesting for the study of upward propagating gravity waves and planetary waves. In wintertime the location of the edge of the polar vortex is very often in the Alpine region what gives us the possibility to observe water vapor inside and outside of the vortex.
This presentation will give an overview of four years of middle atmospheric water vapor measurements in Bern and demonstrates the possibilities and potential of the data set. This includes studies about the seasonal and annual variations in di_erent altitude regions and diurnal variations and tides. Another topic is the study of planetary waves such as the quasi 2-day, 5-day and 8-day wave patterns, which are often observed in the middle atmosphere. Further we demonstrate the usability of water vapor as a tracer for atmospheric dynamics by case studies of sudden stratospheric warmings. These case studies are also examples of the dynamical coupling between the stratosphere, the troposphere and the mesosphere during extreme events.

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Network for the Detection of Atmospheric Composition Change

Poster Session

4P-1 Three years of measurements with the mobile ground based water vapor radiometer MIAWARA-C

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The 22 GHz water vapor spectro-radiometer MIAWARA-C has been specifically designed for profile measurement campaigns of the middle atmosphere. The instrument is of a compact design and has a simple set up procedure. It can be operated as a standalone instrument as it maintains its own weather station and a calibration scheme that does not rely on other instruments or the use of liquid nitrogen. \\ MIAWARA-C is operational since almost 3 years. As one motivation for the construction of MIAWARA-C was for it to serve as a traveling standard for the validation of NDACC water vapor radiometers its first three years of operation were mainly dedicated to fine tuning and the inter comparison with other instruments, e.g. ground based microwave radiometers and satellites.\\ The first campaign MIAWARA-C participated in was ARIS (Alpine Radiometer Inter comparison at the Schneefernerhaus) in winter 2009. During the 3 months at the Zugspitze MIAWARA-C was directly compared to two other new 22-GHz radiometers. ARIS was the first direct inter comparison of three new ground based microwave radiometers for middle atmospheric water vapor using different setups. For MIAWARA-C it pointed out room for instrumental and calibration improvements which were carried out gradually in the two years after ARIS. These changes reduced the integration time necessary for the profile retrieval from approximately 2 days to approximately 2 hours (starting December 2010).\\ The second campaign of MIAWARA-C was MOHAVE 2009 (Measurements of Humidity in the Atmosphere and Validation Experiments) where the goal was to compare to the Water Vapor Millimeter-wave Spectrometer at Table Mountain. \\ During the third campaign Lapbiat (Lapland Atmosphere-Biosphere Facility), which took place in winter 2010 in Sodankyl\"{a} (Finland), MIAWARA-C acquired a continuous 5 month time series of extremely variable middle atmospheric water vapor (time resolution between approximately 6 hours and 1 day depending on tropospheric conditions). This offered a good opportunity to compare to different satellite experiments. \\ The first inter comparison between MIAWARA-C and a NDACC instrument was carried out from summer 2010 to summer 2011 in Zimmerwald (Switzerland) where MIAWARA-C was operated in parallel with MIAWARA. Besides to MIAWARA MIAWARA-C was also compared to MLS during the time in Zimmerwald which means the inter comparison between MLS and MIAWARA-C could be extended from Arctic regions to mid latitudes.\\ Lapbiat was the first scientific campaign MIAWARA-C participated in with the goal to observe the water vapor distribution in and outside of the polar vortex. The time series acquired

proved to be of particular value as a sudden stratospheric warming transporting mid latitude air to arctic regions took place during that time. The measurements of MIAWARA-C are used together with measurements from another water vapor radiometer operated from Andenes (Norway) and from two meteor radars to investigate the temporal development of winds, temperatures and water vapor variations during the SSW 2010 with a special focus on coupling processes, tides and waves in the mesosphere/mesopause region.\\ In early summer 2011 MIAWARA-C was taken to Sodankyl\"{a} again with the goal to measure variations in the arctic upper stratosphere and mesosphere. The improved time resolution of two hours allows to investigate tides and planetary waves. In addition the comparison to satellites will be continued. Plans exist to operate MIAWARA-C from Ma\"{\i}do Observatory on La R\'{e}union island in a future campaign.\\ This presentation will give an overview of the first three years of the microwave radiometer MIAWARA-C with a focus on the results of the inter comparisons to other ground based radiometers and satellites. We show that the instrument can serve as a campaign instrument for NDACC in the future. In addition we will present the potential of MIAWARA-C's dataset for studies of middle atmosphere dynamics.

Poster Session

4P-2 TROPOSPHERIC TEMPERATURE AND WATER VAPOUR OBSERVED BY THE 60- AND 183-GHZ RADIOMETER HAMSTRAD AT DOME C, ANTARCTICA

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Water vapour (H2O) plays a key role in the Earth climate system since it is the main greenhouse gas emitting and absorbing in the infrared domain. The HAMSTRAD (H2O Antarctica Microwave Stratospheric and Tropospheric Radiometers) programme aims to develop a ground-based microwave radiometer to sound tropospheric H2O and temperature above the Dome C (Concordia Station), Antarctica (75°06'S, 123°21'E, 3233 m asm l) over a long time period. The HAMSTRAD instrument is a state-of-the-art microwave radiometer for measuring tropospheric H2O at 169-197 GHz (G-band, strong water vapor line, centered at 183.3 GHz), together with tropospheric temperature from the oxygen line (51-59 GHz, V-band, lower frequency wing of the oxygen line). The altitude of the Dome C site associated with a weak amount of water vapour in the troposphere and very low temperatures encountered in the lowermost altitude layers (one of the driest and coldest site around the world) favours the setting up of microwave radiometers at high frequency and with a much better sensitivity (weak integration time) with respect to sites located at sea level. The present paper focuses on the description of the HAMSTRAD fully automated instrument dedicated to sound tropospheric H2O and temperature over Dome C. A successful validation campaign has been performed at the Pic du Midi (PdM, 42°56'N, 0°08'E, 2877 m asml, France) in the Pyrenees Mountains during the period February-June 2008. The instrument has then been installed at Dome C in January 2009, and operated outdoors, for 12 days. It has been placed indoors into a dedicated shelter in January 2010 and is successfully running since then. We will show comparisons of the HAMSTRAD H2O and temperature profiles against daily radiosondes, measurements from the nadir-viewing IR space-borne Infrared Atmospheric Sounding Interferometer (IASI) instrument aboard the MetOp platform, the Atmospheric Infrared Sensor (AIRS) instrument aboard the AQUA platform, in situ sensors along a 45-m high tower, and the outputs from the European Centre for Medium-Range Weather Forecasts (ECMWF). A particular attention will be given to the diurnal variations of temperature and humidity in the Planetary Boundary Layer (PBL), and to the assessment of the quality of temperature and H2O fields in the Upper Troposphere and Lower Stratosphere (UTLS) during the year 2010.

Poster Session

4P-3 The development of a new 22 GHz microwave spectrometer for monitoring middle atmospheric water vapour at polar latitudes

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Water vapour is a crucial element of the climate system, as it affects radiative, chemical and thermodynamic processes in each layer of the atmosphere. Recent studies showed that changes in lower stratospheric humidity could have had a substantial impact on global surface temperature trends in the last decades. Accurate observations of stratospheric water vapour profiles are therefore particularly needed in the equatorial belt, where most water vapour crosses the tropopause, and in polar regions, that are most affected by climate change. Ground-based observatories, albeit limited in spatial coverage and vertical resolution, can provide the reliability and long-term stability needed for climate change monitoring as well as satellite validation and intercomparison on decadal time scales. For this reason, we started developing a new ground-based microwave spectrometer (the water Vapour Emission SPectrometer for Antarctica at 22 GHz, or VESPA 22) for the observation of the H2O spectral line at 22.235 GHz using the balanced beam-switching technique. VESPA 22 is the first microwave spectrometer for stratospheric remote sensing developed in Italy.We based its design on our experience at millimeter-waves and on the experience of the NDACC microwave working group. VESPA 22 was designed to operate year-round on a long-term basis with limited supervision at an established high-altitude or polar observatory. Among these, Thule Air Base (Greenland) and Concordia Station (Antarctica) are proposed as locations where to observe changes in the polar regions and Mount Chacaltaya (Bolivia) is considered for observing the tropical tropopause. Extended operation time will be achieved by using the established noise-diode online calibration technique, thus limiting the reliance on scarce supplies of liquid nitrogen at these remote stations. This contribution presents the current state of development and testing on the main components of VESPA 22, the front-end receiver with its antenna and the back-end spectrometer. The receiver antenna has a rotating parabolic off-set mirror and a choked Gaussian horn, for an overall directivity of 35.3 dB. The parabolic antenna has been fully characterised with indoor and outdoor measurements in a 2-GHz frequency interval, resulting in a half-power beam width (HPBW) of 3.5° and a side lobe level 40 dB below the main lobe. The heterodyne front-end receiver employs an uncooled GaAsFET low-noise amplifier with a noise temperature of 125 K as first stage amplifier, and the total gain of the receiver is 105 dB. The estimated signal-to-noise ratio allows several measurements each day, in order to observe diurnal changes in the lower stratosphere. The back-end system is an Agilent U1080A FFT spectrometer with a 1 GHz bandwidth and a 63 kHz resolution which, given the pressure broadening coefficient of the H2O line, allows the retrieval of concentration profiles from about 20 to 80 km altitude. During winter 2011, the FFT back-end performance has been assessed using the Ground-Based Microwave Spectrometer (GBMS) front-end in an intercomparison campaign involving both the FFT and the AOS back-ends. The FFT has shown similar performance to the existing AOS spectrometer regarding spectral noise and frequency stability.

Poster Session

4P-4 Preliminary Water Vapor Lidar Measurements at Lauder, NZ during the TOPOL-2 Campaign

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Laurence Twigg SSAI

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In June, 2011 the GSFC STROZ lidar will participate in a validation campaign with the RIVM ozone lidar, according to the NDACC Validation Protocols. During this time an official, blind temperature intercomparison will take place between the lidar instruments and other ancillary measurements. Although not part of the official intercomparison, the STROZ lidar will make measurements of water vapor profiles over the Lauder site from approximately 1 – 12 km ASL. The STROZ lidar has recently added the capability for retrieving water vapor, and participated in the MOHAVE 2009 campaign. These measurements will be presented and discussed.

Poster Session

4P-5 On the Way to Combined DIAL and Raman Lidar Sounding of Water Vapour at Zugspitze

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The primary greenhouse gas water vapour has moved into the focus of lidar sounding within the Network for the Detection of Atmospheric Composition Change (NDACC). Lidar systems with an operating range reaching at least the tropopause region are asked for, with some hope of future extension into the stratosphere. As a first step, we installed in 2003 a powerful differential-absorption lidar (DIAL) at the Schneefernerhaus high-altitude research station 300 m below the Zugspitze summit (Garmisch-Partenkirchen, Germany) [1]. This lidar system, located at 2675 m a.s.l., provides water-vapour profiles in the entire free troposphere above 3 km with high vertical resolution and an accuracy of about 5 % up to 8 km without observable bias [2,3]. Most importantly, due to the high sensitivity of the DIAL technique this wide operating range is also achieved during daytime and under dry conditions. We present examples from the routine measurements of this lidar system during the past four years, in part carried out simultaneous to ozone lidar measurements. A range extension of the DIAL measurements into the stratosphere would require a research platform located at an unrealistic altitude of about 7.5 km [1]. Here, the stronger absorption band of H2O around 935 nm could be used. Due to the very low stratospheric water-vapour mixing ratio of about 5 ppm lidar sounding of H2O in the stratosphere is a highly demanding task for all lidar methods. On the other hand the lack of sufficiently accurate routine measurements with other instrumentation (such as radiosondes or microwave radiometers) between roughly 10 and 20 km is a strong motivation for the lidar community. Our solution is a particularly big Raman lidar system, which is currently under development at the Schneefernerhaus. By using a 350-W xenon-chloride laser system (308 nm) and a 1.5-m-diameter receiver we hope to extend for the first time accurate humidity measurements to almost 30 km. At the same time the sensitivity for water vapour around the tropopause will be enhanced. The big XeCl laser (308 nm) is normally used for industrial production and not fully suitable for the application in a scientific system. By using an intra-cavity Fabry-Perot etalon and a thin-film polarizer stable single-line operation with about 99.5 % spectral purity and a linear polarization of 99.4 % have been achieved. A fraction of the radiation will be wavelength shifted by stimulated rotational Raman scattering in hydrogen. This emission will serve as a reference for retrieving the ozone density profile, which is necessary for correcting the absorption losses during the upward propagation of the 308-nm beam. It will also be used for the stratospheric and mesospheric temperature measurements that are based on the atmospheric density determined by Rayleigh scattering. In the lower atmosphere temperature measurement will be based on rotational Raman shifting. The calibration of the Raman lidar will be ensured by simultaneous measurements with the DIAL system. [1] H. Vogelmann, T. Trickl, Wide-range sounding of free-tropospheric water vapor with a differential-absorption lidar (DIAL) at a high-altitude station, Appl. Opt. 47 (2008), 2116-2132 [2] Wirth M., et al., Intercomparison of Airborne Water Vapour DIAL Measurements with Ground Based Remote Sensing and Radiosondes within the Framework of LUAMI 2008 Contribution S07-P01-1, 3 pp. in: Proc. 8th International Symposium on Tropospheric Profiling, A. Apituley, H. W. J. Russchenberg, W. A. A. Monna, Eds., http://cerberus.rivm.nl/ISTP/pages/index.htm, ISBN 978-90-6960-233-2. [3] H. Vogelmann, R. Sussmann, T. Trickl, T. Borsdorff, Intercomparison of atmospheric water vapor soundings from the differential absorption lidar (DIAL) and the solar FTIR system on Mt. Zugspitze, Atmos. Meas. Technol. 3 (2011), 835–841