Validation Project

in response to the

Call for Proposals
Support to IASI/AIRS Calibration and Validation

in the framework of the EUMETSAT Polar System.

Title:

Ground-Truthing Center Zugspitze, Germany for AIRS/IASI Validation

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Phase I Report

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1. Introduction

This report describes the progress of our AIRS validation project according to the work plan and schedule of the project´s preparation phase given in our proposal. We report about our software/hardware developments and demonstration phase results as to 2) pTU-radio soundings, 3) GPS receivers and 4) solar FTIR for column water vapor retrievals. Section 5) presents the results of our combined analysis of all measurement data from the coincident operation of the different instrumentation from our demonstration phase measurements in March 2002. Section 6) gives information on complementary data (surface measurements, cloud/weather information, and lidar data), and Section 7) the conclusions. For a synopsis of the instrumentation of the newly established AIRS/IASI validation site, see Figure 1. Remark: Throughout the report we will refer to the data file name convention as used for the demonstration phase results delivered to EUMETSAT, and defined in the documentation file "documentation_3.txt" in the appendix of this report, which has also been transferred directly to the EUMETSAT server.

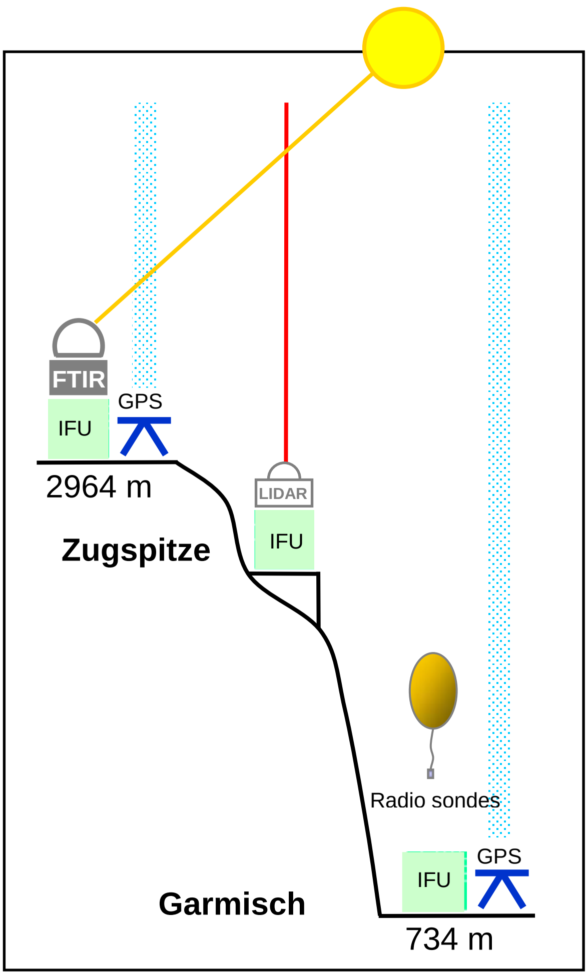

Figure 1: The AIRS/IASI validation site at Zugspitze (47.4 °N, 11.0 °E, 2964 m asl.)/Garmisch (47.5 °N 11.1 °E, 734 m asl.) for $VMR_{h2o}(z)$ and T(z).

2. Radio Sounding

Instrumentation. For the dedicated validation soundings on site, the Vaisala RS 80-30 G radio sondes are used including including 2-D GPS information for horizontal coordinates. TOTEX-800-g balloons are filled up with Helium to achieve a balloon ascent rate of approximately 5 m/s. Two different frequencies (404.57 and 404.85 MHz, respectively) are used for the sondes launched one hour and 5 minutes before satellite overpass, respectively. Note, that during the demonstration phase we used for simplicity only one receiver, i.e., the first sounding had to be terminated after about 45 minutes in order to allow receiving data of the second sonde data. Two receivers (operating on the two different frequencies in parallel) will be implemented for the main validation phase. We use the state-of-the-art Vaisala Digicora III (Marwin 21, SPS220G sounding processor, PTU/GPS) receiver. Note also that during the demonstration phase, for simplicity, we installed the receiver at the valley site Garmisch, whereas for the main validation campaign, the receivers will be placed on the mountain Wank, 1774 m asl. (and operated via remote control). This is in order to maintain good telemetry, even in case of strong westerly winds, where the line of sight between Garmisch and the sonde might be lost behind mountains, but will be guaranteed between the Wank and the sonde during the whole ascent.

Measurement results, Raw data and Data reduction. Our data reduction starts from the Digicora III output file "EDT.tsv" (see documentation_3.txt) which is produced for each ascent. This is slightly higher level so-called "edited" data provided by Vaisala automatically on a 2-s-time resolution including some smoothing and correction for erroneous data points (we have at hand a documentation for the automatic manipulations by the Vaisala Digicory III software with respect to the sonde raw data files "FRAWPTU.tsv"; this documentation is available from Vaisala upon request and requires signature of a confidentiality agreement). The EDT.tsv format files are the basis for all of our own further retrievals and reduced data. The data record (t, T, RH, height, p, ...) therein is explained in the header of each EDT.tsv file.

For the further reduction of q(z) and T(z) profiles we extract the EDT.tsv-file values of 7 primary quantities as a function of "time" (in sec, 2-s-equidistant scale, see above), i.e., absolute temperature ("T") in K, geopotential altitude ("height") in m, pressure ("P") in hPa, water vapor (mass) mixing ratio ("MR") in g/kg, and the horizontal coordinates of the balloon trajectory given in polar coordinates by "AZ" (in degrees, 0 deg is north, 90 deg is south) and "Range" in m from the launching site (Garmisch).

In a first step "MR" is converted to the (dimensionless) water vapor volume mixing ratio defined as

$$VMR = e / (P - e),$$

where e is the partial pressure of water vapor in hPa and P is the total atmospheric pressure in hPa, by using

$$VMR = MR*1000 / 0.62198,$$

where the constant 0.62198 is the ratio of molecular weight of water to that of dry air [General Eastern´s *Humidity Handbook*, 1993]. Furthermore, the balloon trajectory given in polar coordinates relative to the launching site (see above) is transferred to Cartesian (x(East)-y(North))-coordinates.

In a second step we perform a data reduction from the vertical profiles of all these 7 quantities (i.e., time, T, ..., see above) given in 2-s-levels format to dedicated altitude levels spaced by 150 m and starting from the launching site altitude., i.e., for z-levels at 734 m, 900 m, 1050 m, 1200 m, ... altitude. This is performed by first applying a running mean of 150 m altitude width (i.e., running mean of 15 values of the “2-s data“ for a balloon ascent rate of 5

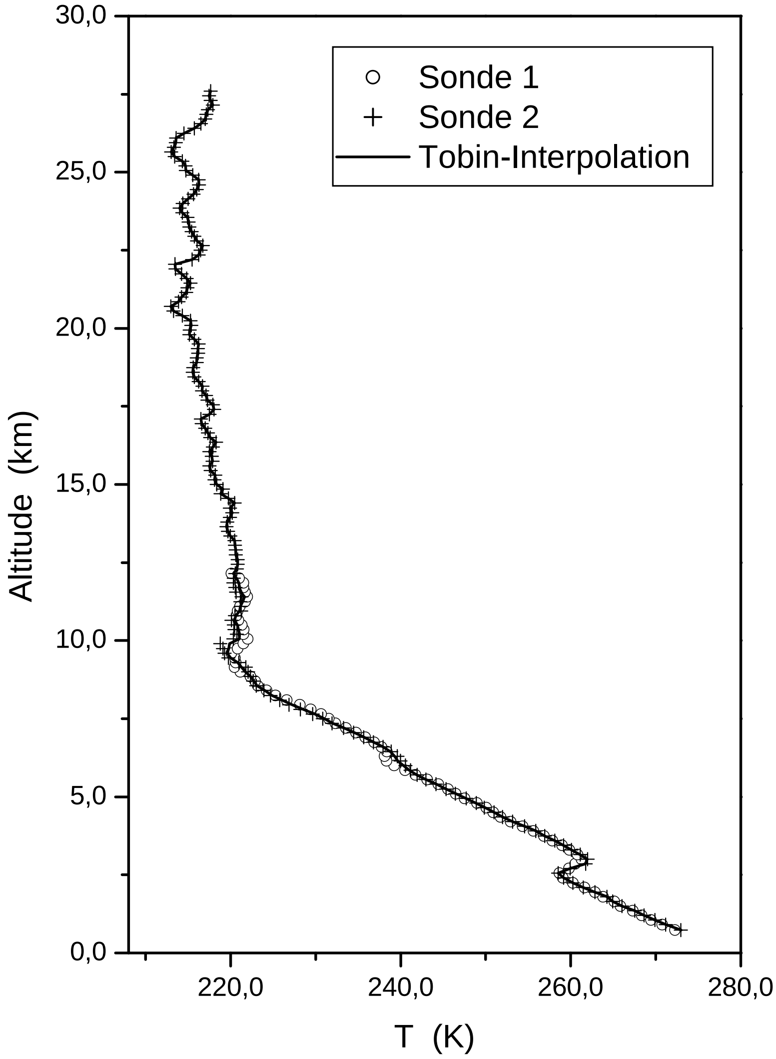

Figure 2: Radio sonde temperature profiles reduced to a equidistant scale of vertical levels spaced by 150 m. Data from the two soundings launched 1 hour and 5 min, respectively, before the 12:53:34 UTC NOAA-16 overpass on 25 March 2002 are displayed together with the Tobin interpolation to the overpass time.

m/s on the values of T(t), P(t), VMR(t), x(t), and y(t)), and subsequent linear interpolation of the closest neighbored values relative to the dedicated altitude levels. This results in two (slightly differing) profiles from the two subsequent soundings 1 and 2, i.e, $T_{1,2}(z,t)$, $P_{1,2}(z, t)$, $VMR_{1,2}(z, t)$, $x_{1,2}(z, t)$, and $y_{1,2}(z, t)$ on the (identical) dedicated z-levels scale.

Tobin interpolation. In a next step the two data sets of sonde 1 and sonde 2, respectively are interpolated to represent vertical profiles $T(z, t_{op})$, $P(z, t_{op})$, $VMR(z, t_{op})$, $x(z, t_{op})$, and $y(z, t_{op})$ at the time of the satellite overpass t_{op} using the formalism given by Tobin, e.g., for a parameter q

$$q_{Tobin}(z, t_{op}) = q_{sonde}(z, t_0) + (dq(z)/dt)\,(t_{op} - t_0),$$

where for t_0 one can either use the time of the sonde 1 or sonde 2 at a level z as a starting point, resulting in the same "Tobin-profile". The results are provided to EUMETSAT in a file named "dedicated_levels.prn". Figures 2 and 3 show plots of the vertical "Tobin-profiles" of $T(z, t_{op})$ and $VMR(z, t_{op})$

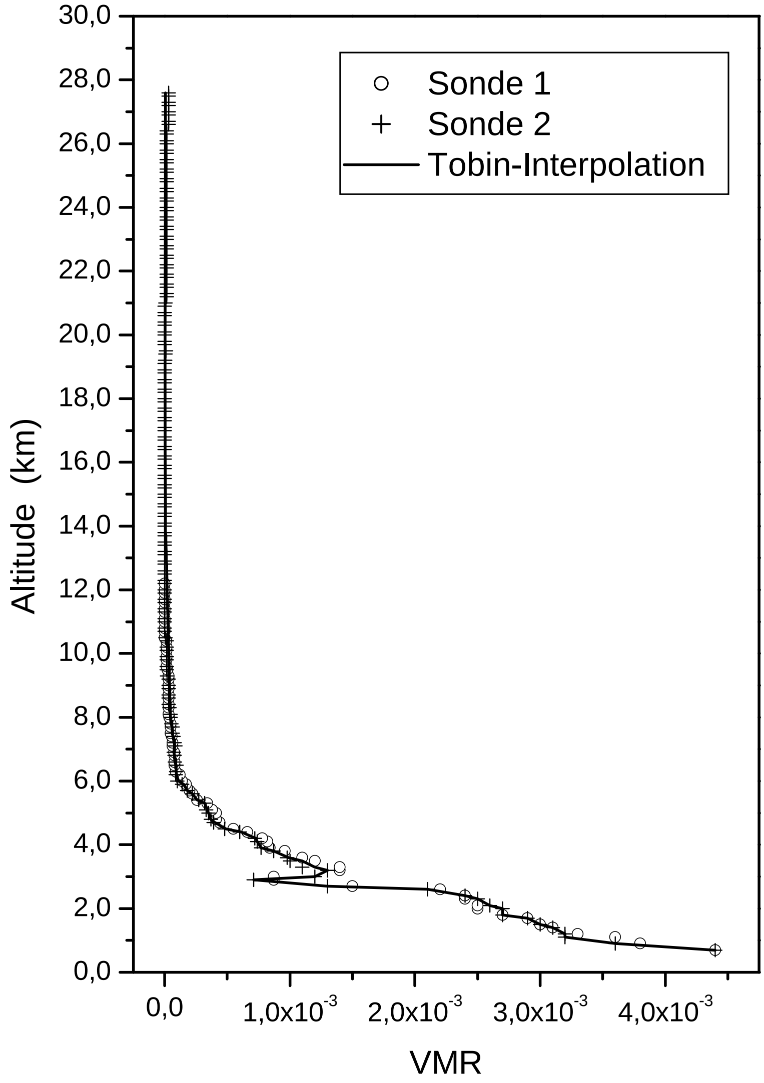

Figure 3: Radio sonde water vapor VMR profiles reduced to a equidistant scale of vertical levels spaced by 150 m. Data from the two soundings launched 1 hour and 5 min, respectively, before the 12:53:34 UTC NOAA-16 overpass on 25 March 2002 are displayed together with the Tobin interpolation to the overpass time.

together with the individual sonde profiles of the two sonde ascents on 25 March 2002 dedicated to the NOAA-16 overpass at 12:53:34 UTC. Note, that for $VMR(z, t_{op})$ we only used sonde data up to 8 km altitude since a significant bias (too dry) is to be expected from the radio sondes [Ferrare et al., 1995]. Therefore, above 8 km altitude a linear interpolation to the 1976 U.S. STANDARD ATMOSPHERE (from ANDERSON ET AL.) is taken for water vapor. Figure 4 shows the trajectories together with the Tobin interpolation of the trajectories of the two sonde ascents dedicated to the NOAA-16 overpass at 12:53:34 UTC on 25 March 2002.

Calculation of layer averages. Vertical 0.5-km-thick layer averages of P and T and VMR between Garmisch and 30 km altitude are calculated from the level profile ("dedicated-levels.prn") by using the Curtis-Godsen approximation via the program package "FASCATM". The Curtis-Godsen approximation yields averages ā of quantity a in a layer Δz_i using

$$\bar{a}_i = \int_{\Delta z_i} \rho(z)a(z)dz \,/ \int \rho(z)dz \,,$$

where, ρ is the density of air. This yields the result for the unscaled sonde zPT-layer profile (file "fas.ptp") and the VMR-layer profile (file "fas.mix"). See Figures 5 and 6, for the sonde layer profiles of

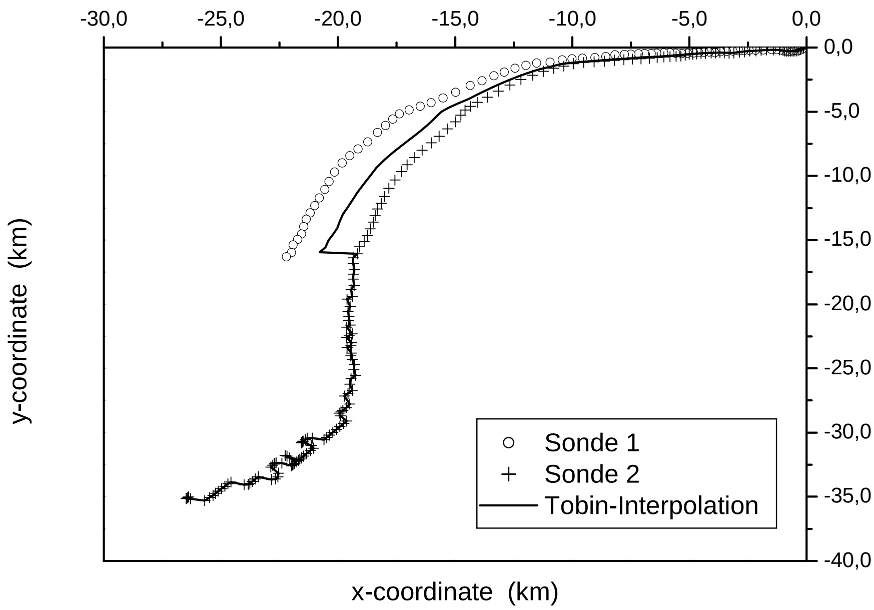

Figure 4: Horizontal projection of radio sonde trajectories relative to the launching site Garmisch. Data from the two soundings launched 1 hour and 5 min, respectively, before the 12:53:34 UTC NOAA-16 overpass on 25 March 2002 are displayed together with the Tobin interpolation to the overpass time.

T(z) and VMR(z), respectively from our soundings around the demonstration phase NOAA-16 overpass at 12:53:34 UTC on 25 March 2002.

Profile scaling. We have implemented a computer routine to scale the sonde water vapor VMR-layer profile ("fas.mix", see above) to a given column density (in mm or cm^{-2}; 1 mm = 3.345E+21 cm^{-2}) obtained from an independent column measurement like the Zugspitze FTIR or the GPS at Garmisch and/or Zugspitze, leading to a file named "scaled_fas.mix". For a determination of the scaling factor, the sonde water vapor VMR values are converted to number densities with a subsequent integration of the vertical number density profile in order to obtain the total column density of the radio sonde profile. Water vapor number density n (in $1/cm^3$) is calculated from water vapor VMR according to the relation

$$n = e * N_A * 1E{+}08 / (RT) \,,$$

$$\text{with } e = P * VMR / (1 + VMR),$$

where T is the absolute temperature, N_A = 6.022045E+23 mol^{-1} is the Avogadro constant and R = 8.31441 J $K^{-1}mol^{-1}$ is the Universal Gas constant.

In addition to the total water column, the program provides as a result numbers for the partial column betwen Garmisch and Zugspitze, as well as for the partial column above Zugspitze. This allows for direct comparison/scaling with respect to the Zugspitze FTIR and GPS and/or the Garmisch GPS.

3. GPS receivers

GPS receiver equipment for water sounding was installed according to the specifications of the currently established network within the German GPS Atmospheric Sounding Project (GASP, Reigber 1999-2002). This includes dual frequency GPS receivers (1.6- and 1.2-GHz

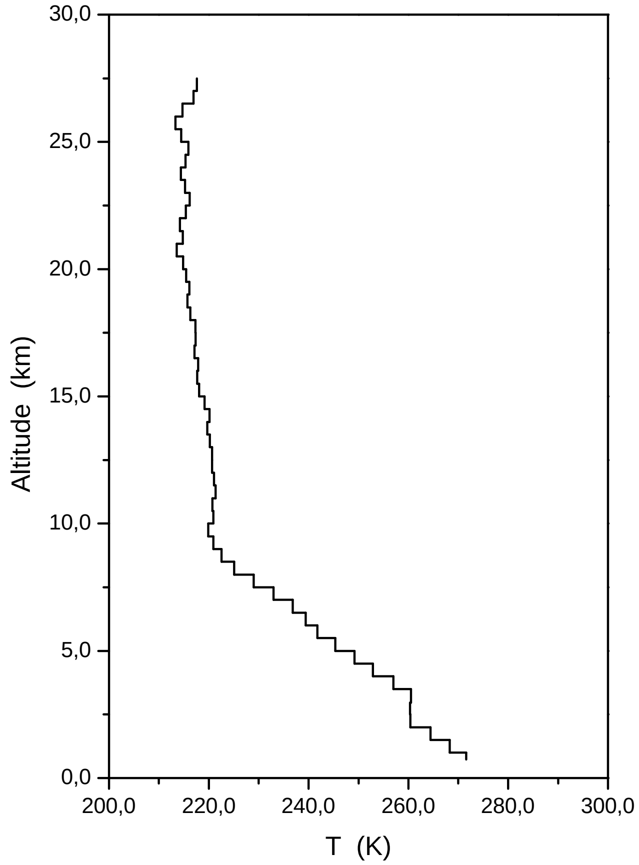

Figure 5: Radio sonde temperature profile presented as 0.5-km layer averages calculated from the Tobin interpolation of Figure 2.

signals), antenna, antenna mount, and a dedicated computer connected to the web to maintain real-time data flow via ftp. Installation of receivers both at the Zugspitze mountain site and the Garmisch ground-station allows to characterize also the partial water column between 734 - 2964 m asl. The Zugspitze GPS system was purchased for this project and consists of a RegAnt-1 Choke Ring Antenna and a Legacy-H GD L1+L2 receiver (Allsat Inc., Germany). The second system, installed at Garmisch, was provided by our partners at Geoforschungszentrum Potsdam, Germany and consists of a Ashtech Choke Ring Antenna and a TurboRogue SNR-800 receiver. A GPS receiver raw data file (sample rate 30 seconds) is stored and automatically transferred via ftp every full hour. Retrieval of water vapor vertical columns is performed automatically at Geoforschungszentrum Potsdam and provided as a file containing the two half hourly means of each hour with a delay of 45 minutes after the full hour. For online presentation of the Garmisch and Zugspitze water columns visit http://www.gfz-potsdam.de/pb1/pg1/gasp1/index_GASP1.html. See Figure 7, for the Zugspitze and Garmisch GPS half hourly water vapor column data retrieved around the time of the demonstration phase NOAA-16 overpass at 12:53:34 UTC on 25 March 2002.

Accuracy. We have received the following a priori information by our partners at Geoforschungszentrum Potsdam as to the accuracy/precision that should apply for the GPS measurements, see also Section 5, for our first own experiences. Note, that there is a difference between near real time data (NRT, available 45 minutes after the full hour) and off line processing (available after about two weeks). Comparisons to sondes or water vapor radiometers of partners showed differences between 1-2 mm. Scatter relative to a water vapor radiometer was found to be, e.g., about 0.8 mm, with a bias between –1 and +1 mm, which are also the limits of the radiometer. There is no significant bias between NRT and post

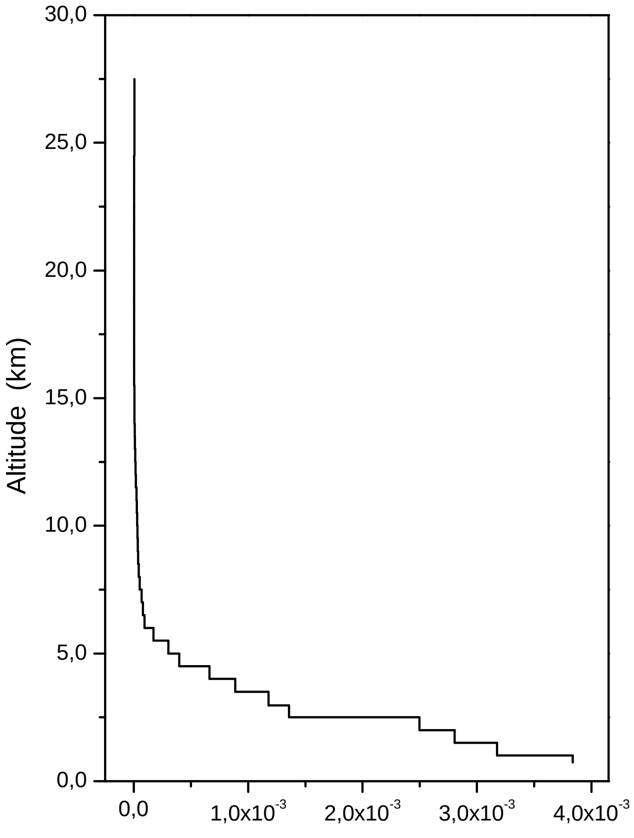

Figure 6: Radio sonde water vapor VMR profile presented as 0.5-km layer averages calculated from the Tobin interpolation of Figure 3.

processing, i.e., only a few 0.1 mm, in most cases even values close to zero. The scatter is approximately higher by 50 % for NRT as compared to post processing results.

4. Solar FTIR

Instrumentation and measurements. Correlative ground-based measurements are performed by the method of high resolution solar absorption FTIR-(Fourier Transform Infrared) spectrometry. The FTIR observatory at the Zugspitze summit is equipped with a state-of-the-art high-resolution (optical path difference 4.86 m) Bruker IFS 120 HR Fourier-

Transform spectrometer and a solar tracker for direct sun observations. This technique is established at various sites around the globe within the "Network for the Detection of Stratospheric Change" (NDSC), i.e., a group of so-called "primary" (i.e., quality controlled and operational) or "complementary" (i.e., quality controlled) sites; the Zugspitze is a NDSC primary-status instrument with full remote control from the institute´s ground station and operates typically on 80 measurement days a year. The standard NDSC-type high resolution measurements are covering the 750 – 4500 cm^{-1} spectral domain.

For the water vapor demonstration phase measurements of this project, measurements in the 750 – 1300 cm^{-1} spectral region were performed with a spectral resolution of 0.0036 cm^{-1}, i.e., an optical path difference of 250 cm (resolution defined as 0.9/optical path difference). The integration interval of a solar FTIR measurement is a trade off between a high signal to noise ratio achieved by averaging multiple interferograms, and, on the other hand, performing the measurement within a limited time span in order not to smear out the

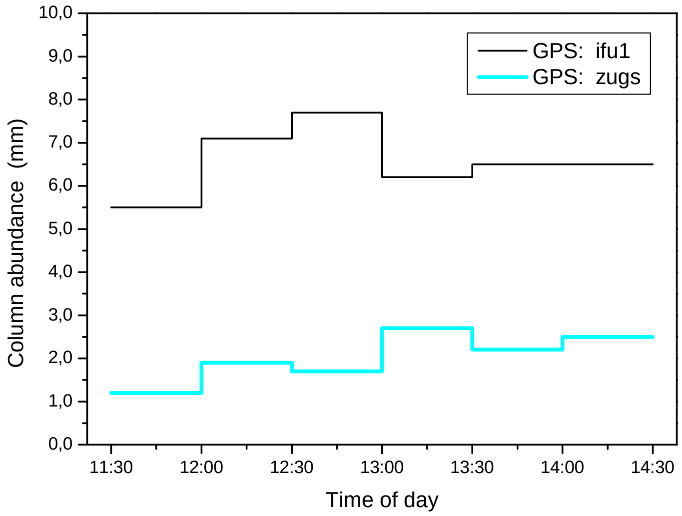

Figure 7: Water vapor total column half hourly mean values as a function of time (UTC) from the Garmisch GPS ("ifu1") and the Zugspitze GPS ("zugs"), respectively. Data are shown correlative to the 12:53:34 UTC NOAA-16 overpass on 25 March 2002.

spectra due to the changing solar zenith angle. We used as a compromise an integration time of 20 minutes which is a reasonable average of 8 individual scans and guarantees a change of the solar zenith angle below 1-2 degrees during the measurement.

FTIR retrieval. For retrieval of trace gas vertical column abundances and profiles from the ground-based spectra the code SFIT1 [*Rinsland et al*., 1984] and SFIT2 [*Pougatchev et al*., 1995] is operated by IMK-IFU, which is at the same time the standard code used within the NDSC. This code is based upon non-linear least squares spectral fitting and uses either a single iterative scaling factor for all layers of the a priori vertical profile used (in our case the radio sonde Tobin-Profile with a linear interpolation to the US Standard Atmosphere above 8 km) to get the total column – this is our standard approach for the campaign (SFIT1). The code allows also for a full inversion of the vertical profile (SFIT2) based upon the optimal estimation method [*Rodgers*, 1976], which we will use for case studies. While retrieval of a variety of atmospheric species is performed on a routine basis, in the case of water vapor the retrieval approach has still to be maturated to some extent, i.e., (i) the optimized spectral retrieval intervals for gaining quantitative tropospheric information need to be investigated, and (ii) some spectroscopic issues (line shape anomalies, line strengths, pressure broadening coefficients) have still to be accounted for, in order to achieve an accurate retrieval result – these are two major goals of this project.

Figure 8 shows a first result for the averaging kernels calculated for the FTIR retrieval of 2 partial layer columns. Columns between 3-7 km altitude and 7-100 km, respectively are displayed together with the total column averaging kernel obtained for one single water vapor absorption line at 841.9 cm^{-1} of the pure rotation band. Note that two independent pieces of altitude dependent information can be retrieved from this line.

See Figures 9-11, for the spectral micro-windows used for the FTIR water vapor retrievals. In Figures 9-11 in addition to the measured spectra, best fit simulations of the spectra are shown based on the HITRAN96 database. Several significant problems and inaccuracies in the spectroscopic parameters are obvious, i.e., errors in line positions, line strengths, pressure broadening parameters, as well as a interfering solar OH line at 839.695 cm^{-1} (Figure 9) not included in the database which is a perturbation within the wing of one of the water absorption lines (at 839.87 cm^{-1}) we are investigating.

In a first step, we included the spectroscopic water vapor data from the recent HITRAN2000 release into our line list files. This lead to the improved simulated spectra and best fit results shown in Figures 12-14. However, still the OH line problem was to be solved (Figure 12 shows a solar OH line quadruplet in the vicinity of the 839.9 H_2O line). In order to address this we implemented a subroutine within our retrieval batch code to automatically

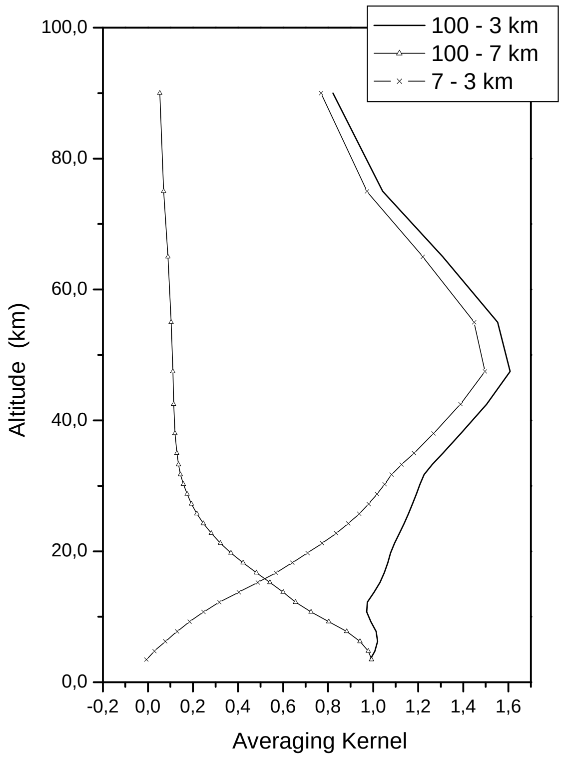

Figure 8: Averaging kernels calculated for solar FTIR retrieval of the total column (100-3 km), and the partial columns between 100-7 km and 7-3 km, respectively using one single absorption line.

remove the solar OH absorption at 839.695 cm^{-1} from each measured spectrum prior to the retrieval process. This is done by reading from each measured spectrum the spectral intensity data around the measured unblended solar OH feature (i.e., the OH line at 838.481 cm^{-1} within the same quadruplet, see Figure 12) as a template and adding this data (with inverted sign) to the 839.695cm^{-1} OH feature which is eliminated by this means. See Figure 15 for the final fitting result after this correction.

Column results and scaling of line strength. Figure 16 shows the total water vapor columns retrieved during the demonstration campaign on 25 March 2002. Direct retrieval results are shown from the 3 different micro windows around 840 cm^{-1} (Figure 15), around 849 cm^{-1} (Figure 13), and around 852 cm^{-1} (Figure 14). Retrieval results from the 840 cm^{-1} and the 552 cm^{-1} micro windows are highly consistent, while the columns retrieved from the 849 cm^{-1} micro window are slightly smaller, but still highly consistent as to relative changes. Therefore, we scaled the overall intensities/columns of all 3 micro windows to the mean value of the 840 cm^{-1} and 852 cm^{-1} results. For this scaling, the measurements time span for which the data appear most consistent was used, i.e., the columns from between 13:29 and 16:00 UTC of 25 March 2002 (Figure 16), i.e., we use FTIR measurements for 3 micro windows centered at 840 cm^{-1}, 849 cm^{-1}, and 852 cm^{-1}:

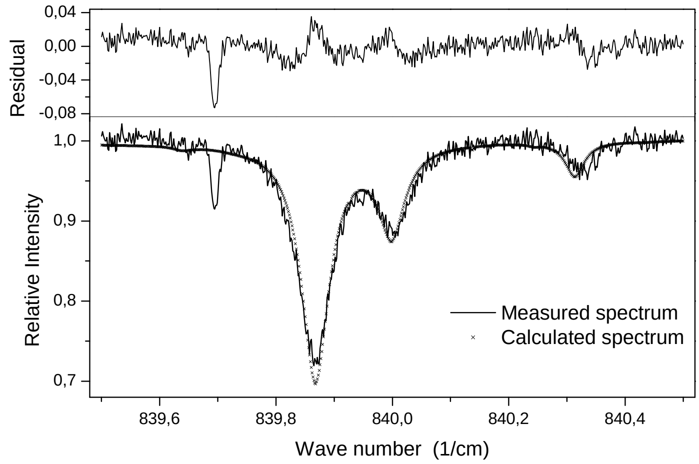

Figure 9: Zugspitze solar absorption FTIR spectrum of 25 March 2002 for water vapor retrieval referred to as "840 cm^{-1} micro window" throughout the text. The best fit calculated spectrum is based upon HITRAN96.

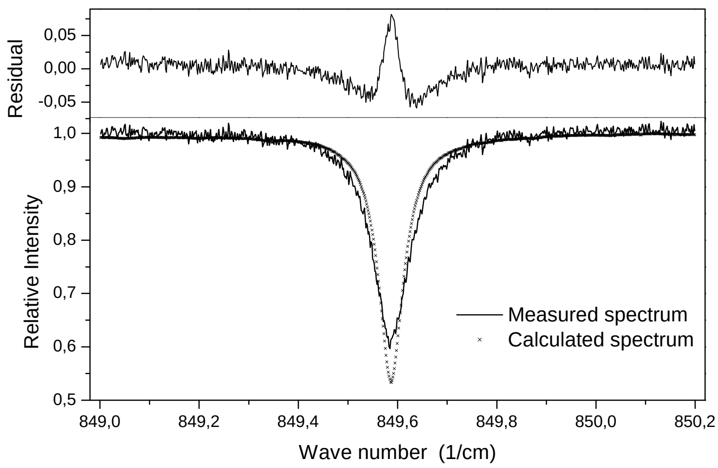

Figure 10: Zugspitze solar absorption FTIR spectrum of 25 March 2002 for water vapor retrieval referred to as "849 cm^{-1} micro window" throughout the text. The best fit calculated spectrum is based upon HITRAN96.

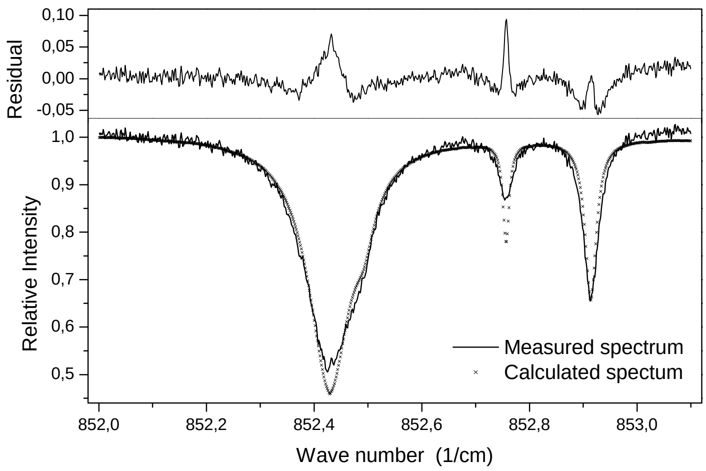

Figure 11: Zugspitze solar absorption FTIR spectrum of 25 March 2002 for water vapor retrieval referred to as "852 cm^{-1} micro window" throughout the text. The best fit calculated spectrum is based upon HITRAN96.

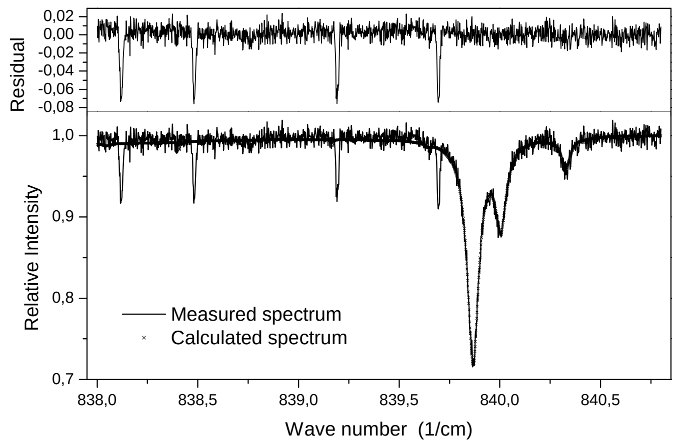

Figure 12: Zugspitze solar absorption FTIR spectrum of 25 March 2002 for water vapor retrieval referred to as "840 cm^{-1} micro window" throughout the text. Note the improvement compared to Figure 9, i.e., the best fit calculated spectrum is based upon HITRAN2000. Still the solar OH lines have not been removed.

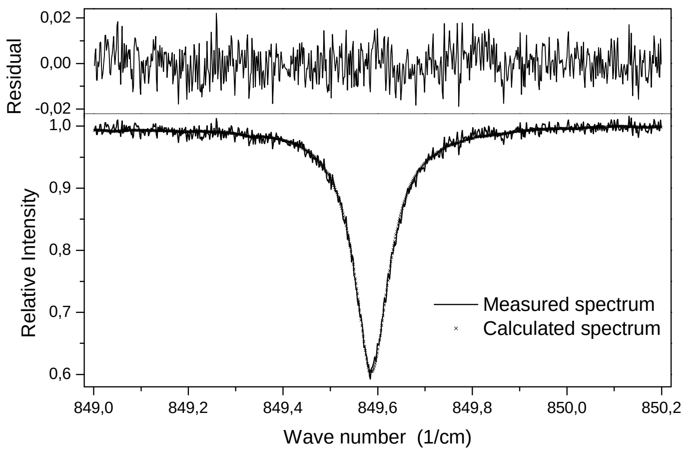

Figure 13: Zugspitze solar absorption FTIR spectrum of 25 March 2002 for water vapor retrieval referred to as "849 cm^{-1} micro window" throughout the text. Note the improvement compared to Figure 10, i.e., the best fit calculated spectrum is based upon HITRAN2000.

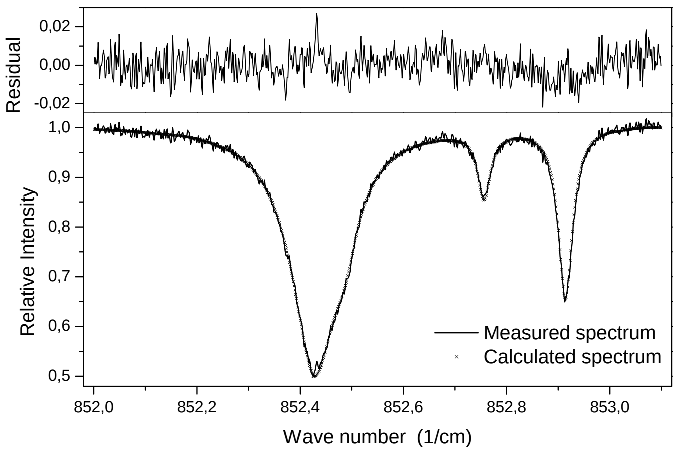

Figure 14: Zugspitze solar absorption FTIR spectrum of 25 March 2002 for water vapor retrieval referred to as "852 cm^{-1} micro window" throughout the text. Note the improvement compared to Figure 9, i.e., the best fit calculated spectrum is based upon HITRAN2000.

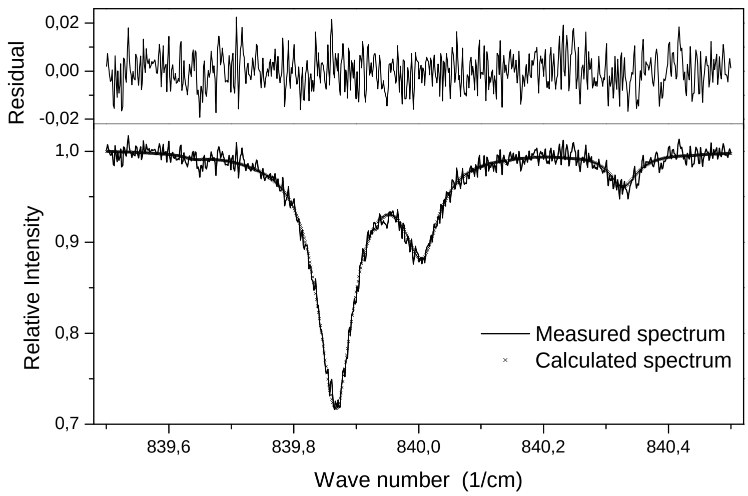

Figure 15: Zugspitze solar absorption FTIR spectrum of 25 March 2002 for water vapor retrieval referred to as "840 cm^{-1} micro window" throughout the text. Note the improvement compared to Figures 12 and 9, i.e., the interfering solar OH line at 839.695 cm^{-1} has been removed.

Date	Time (UTC)	vca_840	vca_849 (columns in cm^{-2})	vca_852	Average 840/852
25.3.02	13:29	3.53E+21	3.48E+21	3.56E+21	3.55E+21
25.3.02	13:51	3.47E+21	3.36E+21	3.44E+21	3.46E+21
25.3.02	14:12	3.47E+21	3.41E+21	3.50E+21	3.49E+21
25.3.02	14:34	3.45E+21	3.38E+21	3.46E+21	3.45E+21
25.3.02	14:55	3.39E+21	3.30E+21	3.39E+21	3.39E+21
25.3.02	15:17	3.35E+21	3.29E+21	3.37E+21	3.36E+21
25.3.02	15:38	3.47E+21	3.41E+21	3.50E+21	3.48E+21
25.3.02	16:00	3.60E+21	3.52E+21	3.61E+21	3.60E+21.

The scaling factors relative to the average 840/852 are determined,

Scaling factors	840/Av	849/Av	852/Av
25.3.02 14:29	9.94E-01	9.81E-01	1.01E+00
25.3.02 14:51	1.00E+00	9.73E-01	9.97E-01
25.3.02 14:12	9.97E-01	9.80E-01	1.00E+00
25.3.02 14:34	9.97E-01	9.77E-01	1.00E+00
25.3.02 14:55	1.00E+00	9.74E-01	1.00E+00
25.3.02 15:17	9.98E-01	9.79E-01	1.00E+00
25.3.02 15:38	9.96E-01	9.79E-01	1.00E+00
25.3.02 16:00	9.99E-01	9.78E-01	1.00E+00

leading to the final average scaling factors,

Average scaling	9.98E-01	9.78E-01	1.00E+00.

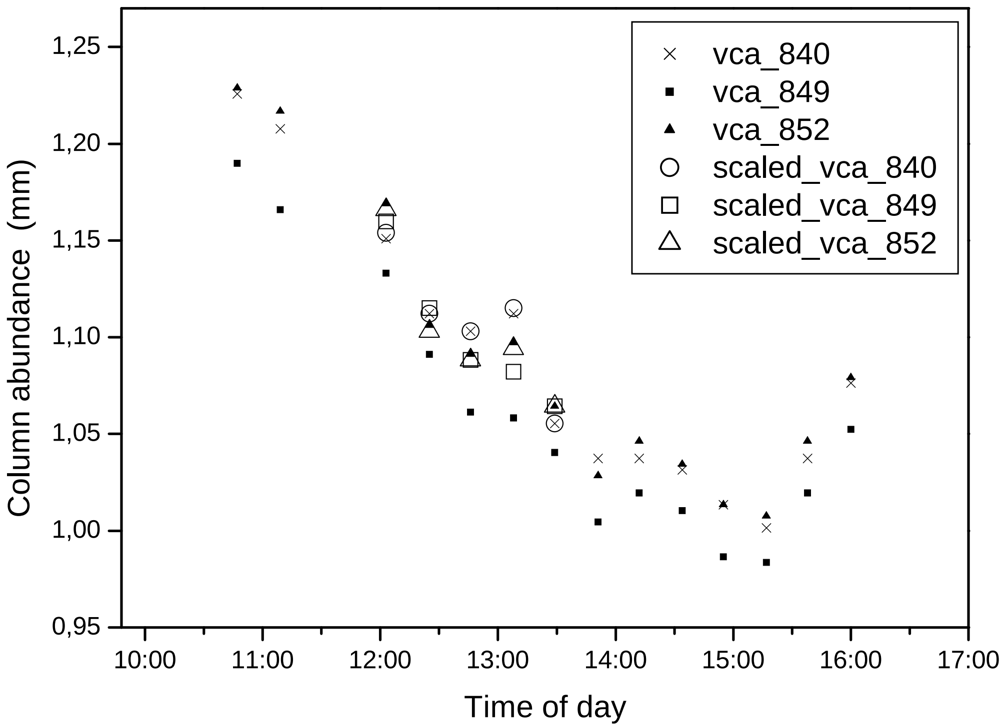

Figure 16: Water vapor total columns from Zugspitze solar absorption FTIR measurements as a function of time (UTC). Data are shown correlative to the 12:53:34 UTC NOAA-16 overpass on 25 March 2002. For details, see text.

This means in particular, that the columns retrieved from the 849 cm^{-1} micro window have to be increased by a factor of 1/9.78E-01 or, in other words, the line strength for the water line at 849.6 cm^{-1} has to decreased by a factor of 9.78E-01.

Applying the average scaling factors to the FTIR measurements performed around the NOAA-16 overpass at 12:53:34 UTC on 25 March 2002 leads to the scaled values,

Scaled values	sca_840	sca_849	sca_852
25.3.02 12:03	3.86E+21	3.88E+21	3.90E+21

25.3.02 12:25	3.72E+21	3.73E+21	3.69E+21
25.3.02 12:46	3.69E+21	3.64E+21	3.64E+21
25.3.02 13:08	3.73E+21	3.62E+21	3.66E+21
25.3.02 13:29	3.53E+21	3.56E+21	3.56E+21.

These final column results are also displayed in Figure 16 in addition to the unscaled columns.

Finally the grand average of all these column values is calculated

Grand average

25.3.02 12:03	3.86E+21	840
25.3.02 12:25	3.72E+21	840
25.3.02 12:46	3.69E+21	840
25.3.02 13:08	3.73E+21	840
25.3.02 13:29	3.53E+21	840
25.3.02 12:03	3.88E+21	849
25.3.02 12:25	3.73E+21	849
25.3.02 12:46	3.64E+21	849
25.3.02 13:08	3.62E+21	849
25.3.02 13:29	3.56E+21	849
25.3.02 12:03	3.90E+21	852
25.3.02 12:25	3.69E+21	852
25.3.02 12:46	3.64E+21	852
25.3.02 13:08	3.66E+21	852
25.3.02 13:29	3.56E+21	852

Grand average	3.69E+21 cm^{-2}	n=15 individual values,
stdv	1.14E+20	standard deviation of individual values,
3stdv/sqrt(n)	8.86E+19	standard deviation of the mean value,

which is the column value retrieved from the FTIR measurements above Zugspitze, that is to be compared to the satellite data of the (NOAA-16) overpass at 12:53:34 UTC on 25 March 2002.

5. Comparison of Sondes, FTIR, and GPS

We performed demonstration phase measurements correlative to three NOAA-16 overpasses, i.e., the afternoon overpasses of 22 March, 24 March, and 25 March 2002. March 25 was the only clear sky day allowing also for solar FTIR measurements. The resulting column data are summarized as follows:

Columns above Garmisch (in mm):

Date	Sonde	GPS (“ifu1”)	GPS/Sonde
22 March	10.36	11.06	1.07
24 March	6.04	6.65	1.10
25 March	5.07	6.90	1.36

Columns above Zugspitze (in mm):

Date	Sonde	GPS (“zugs”)	GPS/Sonde	FTIR	FTIR/Sonde
22 March	3.28	4.72	1.44	-	-
24 March	1.40	3.55	2.54	-	-
25 March	1.065	2.10	1.97	1.103	1.04

In summary, while the FTIR gives a perfect agreement with the sonde integral (within 3.6 % on 25 March), we have an indication for a significant over-estimation of the water column above Zugspitze by the Zugspitze GPS (“zugs”) of up to a factor of 2.54. Also the Garmisch GPS shows a (moderate) over-estimation of the columns relative to the sonde integral by a factor of 1.07 (on 22 March), and 1.1 (on 24 March). There seems to be an indication that in case of low total columns (above Zugspitze in general, and above Garmisch for dry days) the GPS technique yields a significant wet bias.

6. Complementary data

Surface measurements. Are performed both at Garmisch and Zugspitze round the clock by state of the art in-situ instrumentation. We provide to the EUMETSAT server a file named "ifu1met.prn" within the subdirectory "ground_meteorology". It contains the in-situ ground data (p, T, U, wind, in minutely averages) of the Garmisch site. File contents are:

First column is the date
Second column is the time in MEZ = GMT + 1 h = UTC + 1 (this will be changed to UTC for the Phase II campaign)
Third column is temperature in deg Celsius
Fourth column is the local pressure in hPa
Fifth column is rel. humidity with respect to water surface (%)
Sixth column wind velocity in m/s
Seventh column is wind direction in deg (0 deg is North, and 90 deg is East)

Furthermore, we provide a file "zugsmet.prn". File contents are analogous to "ifu1met.prn" but for the Zugspitze site, and there is no wind information contained for Zugspitze.

Cloud/weather observations. Were obtained for the Zugspitze site from the German Weather Service. We provided to the EUMETSAT server a file named "weather.prn" within the subdirectory "ground_meteorology". It contains hourly weather information from the Zugspitze in the following format:

First column is the date
Second column is observation time in MEZ = GMT + 1 h = UTC + 1 h (this will be changed to UTC for the Phase II campaign)
Third column is weather information
Fourth column is cloud fraction in units 1/8 and altitude of the cloud bottom

Furthermore, we provided a file "clouds.prn". It contains detailed 6-hourly cloud information from the Zugspitze:

First column is the date
Second column is observation time in MEZ = GMT + 1 h = UTC + 1 h (this will be changed to UTC for the Phase II campaign)
Third column is level of bottom of cloud
Fourth column is total cloud cover

Fifth column is cloud cover of low altitude clouds
Sixth column is type of cloud of low altitude clouds
Seventh column is type of cloud of medium altitude clouds
Eighth column is type of cloud of high altitude clouds
Nineth column is a comment, e.g., "no further information due fog"

Remark: As agreed upon during the mid-term review, we will provide cloud information also for the Garmisch site during the Phase II campaign.

Lidar data. The possibility to utilize a water vapor differential absorption lidar was proposed for this project. This lidar development at IMK-IFU, however, is not part of this project. It is a project funded by the Bavarian Ministery for Economy. Due to different reasons (change of our institute´s affiliation from Fraunhofer Society to Helmholtz Community, difficulties in finding a PhD student in time, late delivery of laser components) there has been a delay of this project. The current status is, that the lidar system is in the test phase at Garmisch and will be installed at the Zugspitze probably during July 2002. So there is still a chance that first lidar measurements can be performed within Phase II of this project (Aug-Oct 2002).

7. Conclusions and Outlook

We demonstrated full operationality of all instrumentation and retrieval software as to surface measurements and cloud/weather observations, radio sounding, GPS and solar FTIR measurements at the newly established AIRS/IASI validation site Garmisch/Zugspitze. The data transfer from and to the ftp server of EUMETSAT worked well without any problems. Further work, before the AIRS main validation campaign envisaged for August 2002, will include investigations as to a possible wet bias of the GPS technique. Therefore, e.g., the Zugspitze and Garmisch GPS receivers shall be exchanged for a limited time period during a stable weather situation for intercomparison. Furthermore, we will complete the systematic search for the optimum micro windows for FTIR retrieval, improve the spectroscopic data base where required, and optimize the retrieval strategy as to gaining optimum information content on the vertical water vapor VMR distribution. In preparation of the main validation campaign our software for retrievals and formatting will be further automated.

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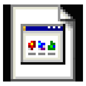
10. Appendix:



documentation_3.txt