Comparison of AMSU-B humidity data with MOZAIC measurements and ECMWF fields

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Intruduction

UTH humidity is measured from space either by infrared instruments or by microwave instruments. The microwave measurements have the advantage of being much less affected by clouds than the infrared measurements. One of the microwave instruments is the Advanced Microwave Sounding Unit-B (AMSU-B).

This poster documents a study of comparing AMSU-B humiduty data to numerical forecast (European Centre for Medium Weather Forecast, ECMWF) and aircraft data (Measurement of OZone and water vapour by Airbus in-service airCraft, MOZAIC).

The basic idea of the study is to compare satellite data to aircraft's and model's data. However, the satellite measures radiances, not humidity directly. While obtaining radiances from given temperature and humidity profiles is straightforward, obtaining humidity concentrations from radiances is complicated and requires additional assumptions (a classical inverse problem; Rodgers, 2000). To avoid dealing with the inverse problem, the comparison is done in radiance space rather than state space: A radiative transfer (RT) model is used to generate simulated satellite measurements from the MOZAIC and ECMWF profiles, which can then be compared to the real satellite measurements. This approach has already been used by Buehler et al. (2004) for radiosonde data.

The Advanced Microwave Sounding Unit-B (AMSU-B) is a 5-channel microwave radiometer. It works in conjunction with the AMSU-A instruments to provide a 20-channel microwave radiometer. AMSU-B has been installed on NOAA 15, 16 and 17 satellites since 1998. The microwave characteristics of the atmosphere are provided in Fig. 1. AMSU-B covers channels 16 through 20. The highest channels: 18, 19 and 20, span the strongly opaque water vapor absorption line at 183 GHz (183.31 ± 1.00, 183.31 ± 3.00, and 183.31 ± 7.00 GHz). Channels 16 and 17, at 89 GHz and 150 GHz, respectively, enable deeper penetration through the atmosphere to the Earth's surface.

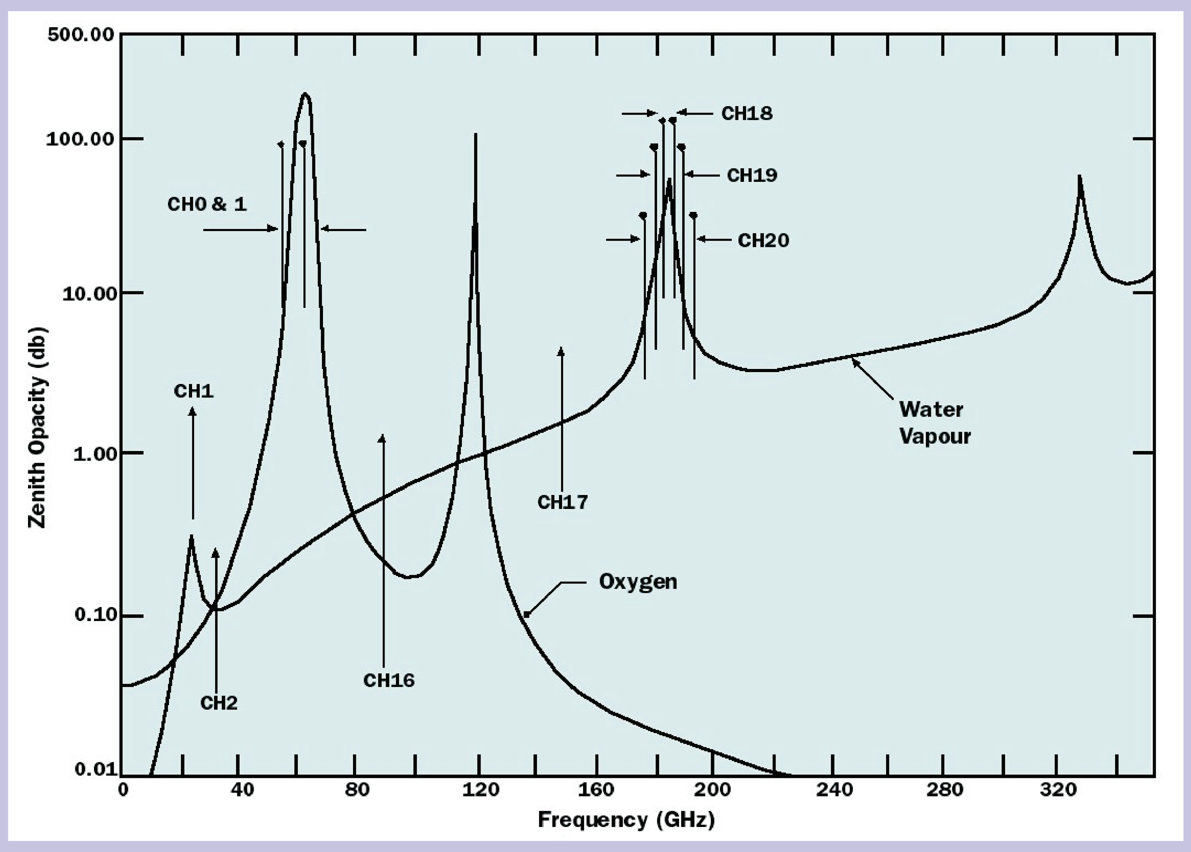

Fig.1. The region of electromagnetic spectrum covered by AMSU-B.

At each channel frequency, the antenna beamwidth is a constant 1.1 degrees. Ninety contiguous scene resolution cells are sampled in a continuous fashion, each scan covering approximately 1200 km on each side of the subsatellite path at 0.55° from nadir to 48.95° from nadir. These scan patterns and geometric resolution translate to a 20 × 16 km^2 cell for innermost positions and 64 × 52 km^2 cell for outermost positions, at a nominal altitude of 850 km. Figure 2 shows an example of AMSU data from channel 18.

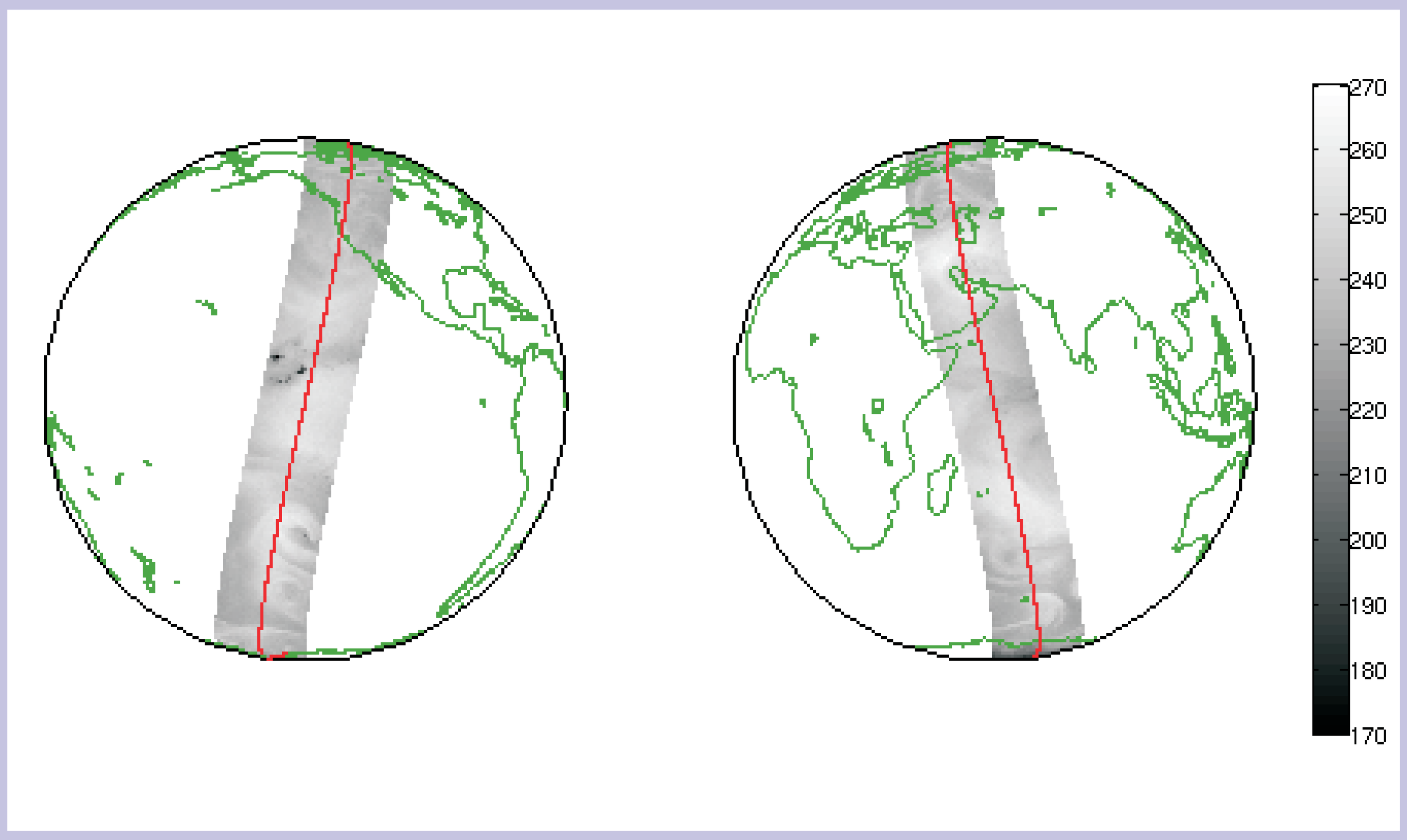

Fig. 2. Brightness temperature as seen by AMSU-B's channel 18 for example orbit.

The RT model Atmospheric Radiative Transfer Simulator (ARTS), described in an article by Buehler et al. (2004), was used to simulate AMSU radiances on the basis of ECMWF and MOZAIC profiles. Radiances were expressed as brightness temperatures in Kelvin, similar to the AMSU data. The program setup for this study was as follows: gaseous absorption was assumed to be only due to water vapor, oxygen, and nitrogen, Absorption models used were that of Rosenkranz (1998) for water vapor and oxygen and that of Rosenkranz (1993) for nitrogen. Required geophysical inputs of the model in this case are humidity and temperature profiles, the surface emissivity, and the surface skin temperature. Humidity and temperature profiles were taken from the aircraft data, the surface emissivity was assumed fix at 0.95, and the skin temperature was assumed to be equal to the lowest radiosonde temperature. The surface emissivity influences mainly window channels 16 and 17 and, under extremely dry conditions, also channel 20. Channels 18 and 19 are not influenced by the surface.

ECMWF

The ECMWF data are used: the results of the operational daily analysis. The data include among others the following atmospheric variables: geopotential, pressure, temperature and wind. All the information are available on a 1.5 x 1.5 degrees grid which is defined on the 60 model levels of the operational ECMWF-model. The approach is to compare the ECMWF data to the average AMSU radiance in a target area, described by a circle of radius 50 km centered in the grid points (see Figure 3) and closer than half an hour from ECMWF time (00, 06, 12 and 18 UT). In the circle can be up to 32 pixels but, due to the better statistics only the cases with number of pixels larger than 12 are chosen for the study.

There is one issue which should be addressed. It is possible contamination of the measurement by cirrus cloud scattering. In that case, measured radiances are colder than the simulated ones, because the cloud scatters radiation out of the line of sight of the instrument. The most sensitive channel for this effect is channel 20. The filter introduced by Hong et al. (2004) has been used in this study which chooses cases with brightness temperature for channel 18 colder than for channel 20.

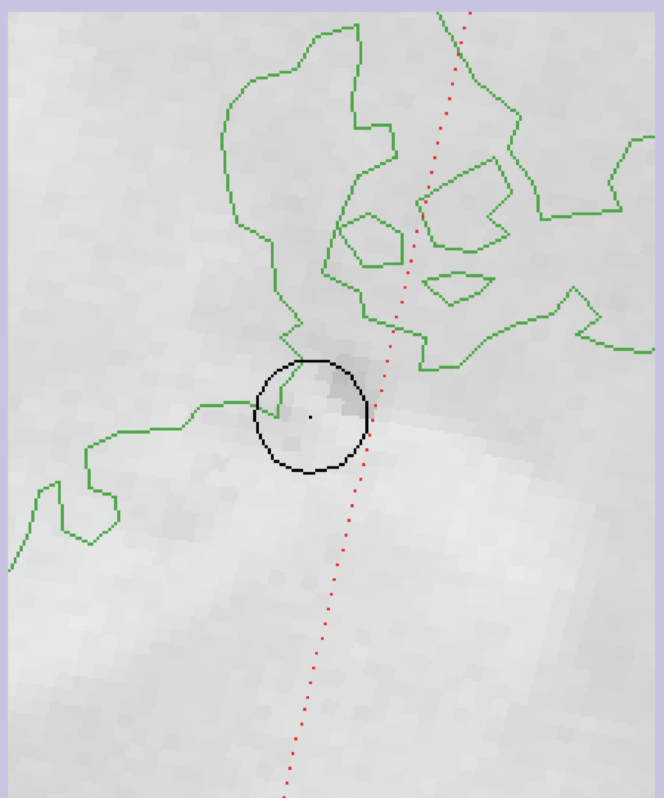

Fig.3. An Amsu overpass over one of ECMWF gridpoints.

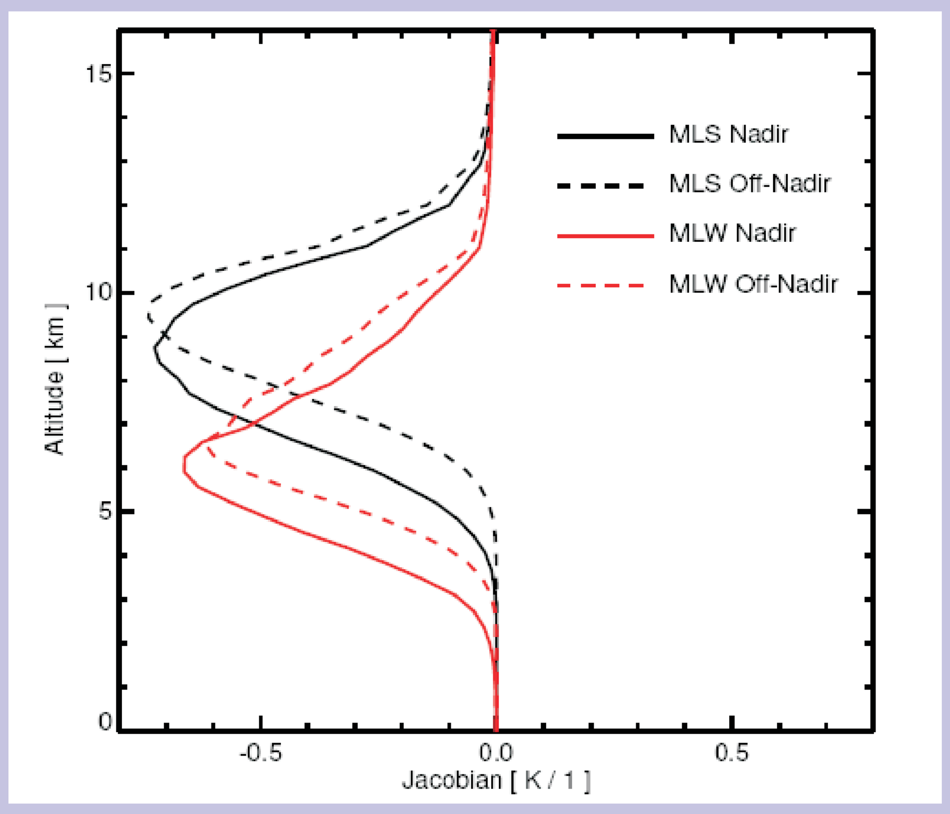

Fig. 4. Water vapor jacobians of AMSU-B channel 18 for a midlatitude summer and a midlatitude winter scenarios for nadir and maximum off nadir viewing angles.

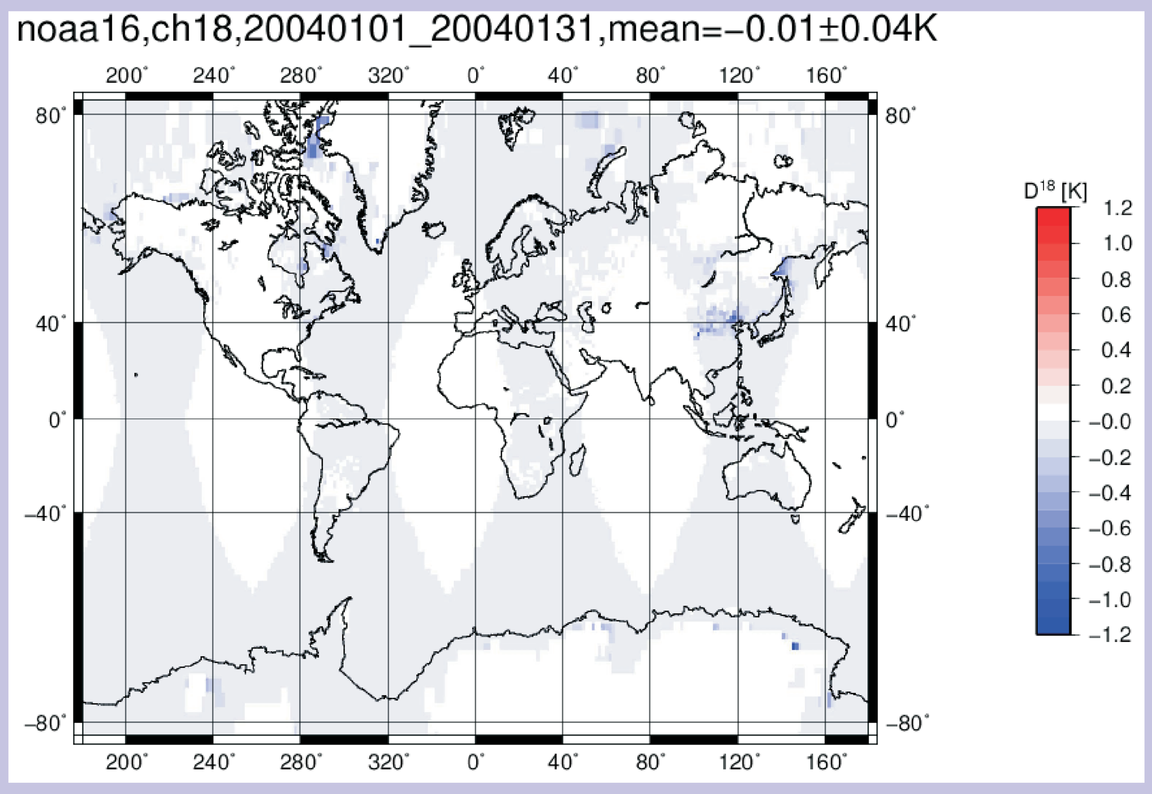

Fig. 5. Differences between ARTS calculations with emmisivity equal to 0.6 and 0.95 for channel 18 (NOAA-16), January 2004.

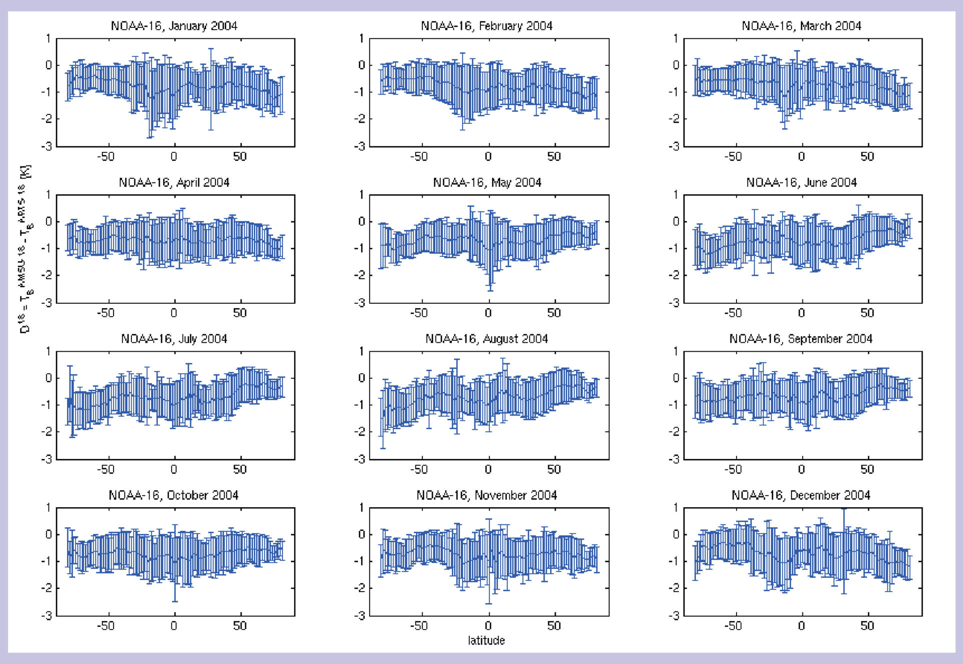

Fig. 6. The latitudional dependence of the differencies with standard deviations between AMSU and ECMWF for NOAA-16, for individual months of 2004.

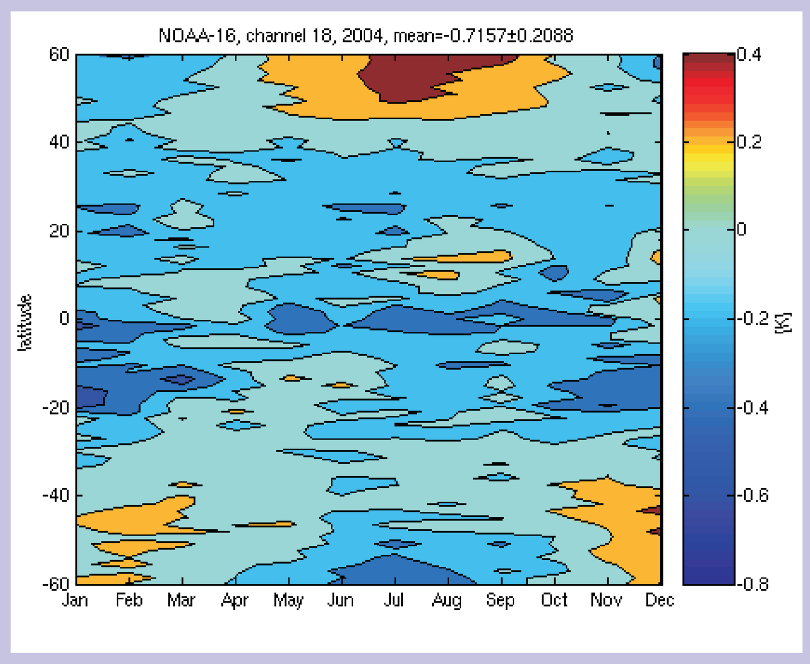

Fig. 7. Deviations from the mean value of the difference between AMSU and ECMWF (indicated on the plot) for NOAA-16, 2004.

MOZAIC

The MOZAIC program (Measurement of OZone and water vapour by AIrbus in-service airCraft) was initiated in 1993 by European scientists, aircraft manufacturers and airlines to collect experimental data. MOZAIC consists of automatic and regular measurements of ozone and water vapour by five long range passenger airliners flying all over the world. For water vapor, a special airborne humidity sensing device (AD-FS2), developed by Aerodata (Braunschweig, Germany) and based on the humidity and temperature transmitter HMP 230 of Vaisala (Helsinki, Finland), is used for measuring relative humidity and temperature of the atmosphere. The sensing element itself is a combination of a capacitive relative humidity sensor (Humicap-H, Vaisala) and a Pt100-temperature sensor. Since the beginning of operational flights in August 1994, more than 20 000 flights have been performed by the five MOZAIC A340 (status : August 2003). Four Airlines have been involved in the MOZAIC Program: Air France, Lufthansa, Austrian and Sabena. The figure 8 shows the airports visited by the program. The case study will be performed for data from ascents and descents from Frankfurt airport which has most data available. Figure 9 shows example profiles from the aircraft. The profiles extend only to about 12 km. Missing data for radiative calculations will be taken from climatology. AMSU-B pixels will be averaged along the aircraft track from the ground to begin/end of the cruise part of the flight.

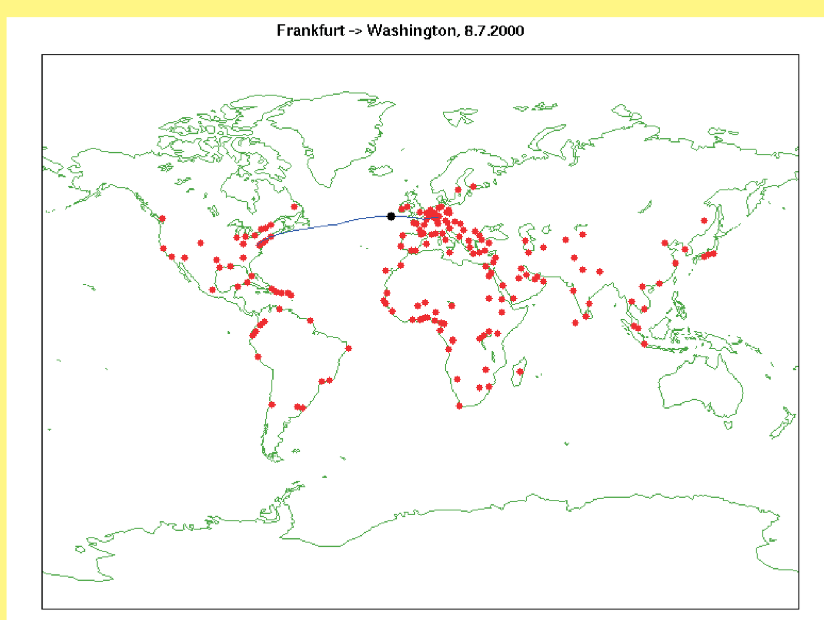

Fig.8. Red dots indicate cities visited by the MOZAIC program. Blue line is an example aircraft's track. The black dot shows the start of cruise part of the flight and maximum altitude of the profiles on the right.

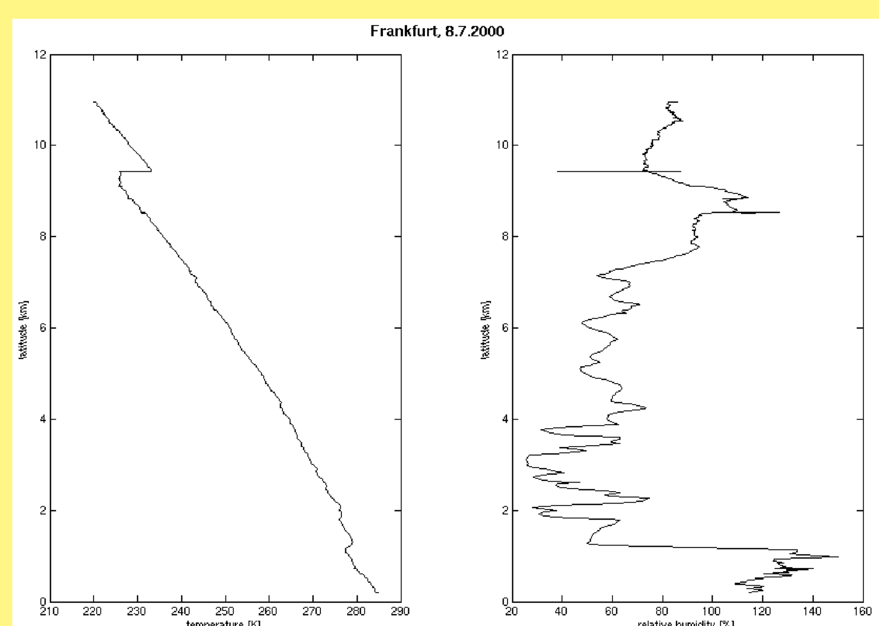

Fig.9. The example humidity and temperature profiles from an ascent from Frankfurt airport.

References

Buehler, S. A., M. Kuvatov, V. O. John, U. Leiterer and H. Dier (2004), *Comparison of Microwave Satellite Humidity Data and Radiosonde Profiles: A Case Study*, J. Geophys. Res., 109, D13103.
Hong, G., G. Heygster, J. Miao and K. Kunzi (in press, 2004), *Potential to estimate the canting angle of tilted structure in clouds from microwave radiances around 183 Ghz*, IEEE T. Geosci. Remote Sens. Lett.
John, V. O. and S. A. Buehler (2005), *Comparison of microwave satellite humidity data and radiosonde profiles: A Survey of European stations*, Atmos. Chem. Phys., 5, 1843-1853
Rodgers, C. D. (2000), *Inverse Methods for Atmospheric Sounding: Theory and Practise*, 1st ed., World Sci., River Edge, N. J.
Rosenkranz, P.W. (1993), *Absorption of microwaves by atmospheric gases, in Atmospheric Remote Sensing by Microwave Radiometry*, edited by M. A. Janssen, pp. 37– 90, John Wiley, Hoboken, N. J.
Rosenkranz, P. W. (1998), *Water vapor microwave continuum absorption: A comparison of measurements and models*, Radio Sci., 33(4), 919–928. (Correction, Radio Sci., 34, 1025, 1999.

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