Upper Tropospheric Humidity and Ice from Meteorological Operational Sensors (UTH-MOS)

Stefan A. Bühler

Introduction
Upper tropospheric humidity (UTH) is a crucial parameter for the atmosphere's energy balance [Buehler, von Engeln, Brocard et al., 2004], but difficult to measure [Buehler and Courcoux, 2003]. The objective of the UTH-MOS project is to develop and interpret an upper tropospheric humidity climatology product from microwave data collected by the polar orbiting operational meteorological sensors of the AMSU-B type. Figure 1 shows an example of AMSU data and the derived UTH. For the correct interpretation of these data, the impact of cirrus clouds on the measurement in the microwave channels has to be well understood and taken into account in the retrieval. An auxiliary objective is to explore the potential of these data for deriving information on cloud ice particles. The research work in UTH-MOS is split between the modelling of the radiative transfer in the presence of cirrus clouds on one hand, and the actual data analysis and atmospheric research applications on the other hand.

The project will run until the end of 2005. Work so far has concentrated on radiative transfer modelling, developing the methods for the data evaluation, understanding the data properties, and validating the data by comparing to other satellite sensors and in-situ measurements.

Radiative transfer model development
The Atmospheric Radiative Transfer Simulator ARTS is an open source radiative transfer (RT) code developed jointly by the Institute of Environmental Physics, Bremen and the Department of Radio and Space Science, Chalmers University of Technology, Gothenburg. The code with documentation is freely available at: http://www.sat.uni-bremen.de/arts/. It can simulate radiances for up, limb, and down looking instruments for a wide frequency range. An overview of the clear-sky version of ARTS is given by Buehler, Eriksson, Kuhn et al. [2004].

Particular attention was paid to ensure that the model correctly represents the absolute value of atmospheric absorption, not just the component that varies quickly with frequency. This requires the addition of absorption continua for water vapour, oxygen, and nitrogen [Kuhn et al., 2002].

As part of the UTH-MOS project, ARTS has been extended to include the effect of ice particles in cirrus clouds, which mainly interact with the radiation by scattering. The version with scattering is described by Emde et al. [2003], Emde et al. [2004], and Srereekha et al. [2002]. The algorithm solving the radiative transfer problem uses a successive order of scattering approach in discrete ordinates. It can handle all four components of the Stokes vector in a 1D, 2D, or 3D spherical atmosphere.
Figure 1: Top: Radiance from channel 18 of the AMSU-B instrument on the NOAA-16 satellite (June 6, 2004). The unit is brightness temperature (BT) in Kelvin. This channel is most sensitive to the water vapor concentration at altitudes between 500 hPa (mid-latitude) and 350 hPa (tropics). Bottom: The retrieved upper tropospheric humidity (UTH) product. The unit is relative humidity with respect to ice. On this particular day a dry air extrusion ranged from the subtropics across Europe. (Figure by O. Lemke and V. Commen.)

Model – data comparison

A necessary condition for accurate retrieval is that the forward model, in this case the RT model ARTS, accurately predicts the measurement from a given atmospheric state, and that all errors in RT model and measurement are well understood. One way to gain confidence in the RT model is to do comparisons to other RT models, as described by Melsheimer et al. [2004]. Another way is to compare directly AMSU measurements to simulated ones, if some in-situ data are available. Such a comparison, based on radiosondes, is described by Buehler, Kuvatov, John et al. [2004]. Figure 2 shows a comparison of different German radiosonde stations performed by the same method. The general level of agreement is very satisfactory, but there are small differences between the different radiosonde stations, pointing to potential problems in the humidity data of some stations. In the context of COST Action 723 these data are currently used for a systematic European radiosonde site intercomparison.
Upper tropospheric humidity retrieval

Although there is a straightforward relationship between atmospheric humidity content and temperature on the one hand, and top-of-the-atmosphere radiances, on the other hand, the task to invert this relationship and obtain humidity values from measured radiances is far from trivial. In principle, two approaches are possible, a variational profile retrieval [Eriksson, Jimenez, and Buehler, 2004], or a simpler statistical regression approach [Buehler and John, 2004; Jimenez et al., 2004].

The second approach is computationally cheap and thus allows the analysis of large amounts of satellite data. It requires a set of atmospheric states and matching radiances, which could in principle be obtained by collecting in-situ measurement and correlated satellite measurements. However, it is in practice difficult to get enough global data this way. Another possibility is to use a collection of atmospheric states covering the atmospheric variability, and use the radiative transfer model to generate matching radiances. This is the approach followed by us.

To give a flavour of the method’s capability, one can apply the method to an arbitrary AMSU overpass. Figure 1 shows AMSU radiances and derived UTH for a pass over Europe on June 6, 2004. The top plot shows the original radiances, displayed as brightness temperatures in Kelvin, the bottom plot shows the derived UTH in relative humidity with respect to ice.

Conclusions and Outlook

Microwave data from polar orbiting meteorological sensors are well suited to study upper tropospheric humidity in climate applications. By the developed advanced radiative transfer algorithms, retrieval schemes, and validation efforts, the UTH-MOS project has paved the way for a wider use of these data. The remaining project time until the end of 2005 is planned to be used for applying the developed algorithms to the available data and for climatological studies with the derived datasets.

Below is a list of references. For those papers still in the review process or in press, preprints can be found at http://www.sat.uni-bremen.de/publications/.
References (Articles)


References (Theses)


KUVATOV, M., Comparison of simulated radiances from radiosonde data and microwave sounding data for the validation of the forward model for water vapor retrieval, Thesis, Postgraduate program Environmental Physics (PEP), University of Bremen, 2002.