ARTS — A New Radiative Transfer Model for AMSU
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1 Introduction
The Atmospheric Radiative Transfer System (ARTS) is a new radiative transfer model [1] which can handle any millimeter or sub-millimeter instrumentation in all viewing geometries. Its main features are modularity, extensibility, and generality. Inside, the algorithms ARTS calculates weighting functions for temperature, water vapor, water vapor, and angle of scattering. ARTS is publicly available on the web site http://www.zas-unibremen.de/arts/.

2 Study Setup
ARTS is a general purpose model with many options and free parameters. This section describes some of the features made for the current case of simulating Advanced Microwave Sounding Unit (AMSU) measurements. The species considered are water vapor, oxygen, and nitrogen. The absorption coefficients are calculated according to Beisinghoff [2] for water vapor and Beisinghoff [2] for oxygen and nitrogen. Absorption coefficients are computed as a fixed pressure grid specified by the user. For this study we used 41, 100, and 200 pressure levels in logarithmic spacing. For the model intercomparison, ground emissivity is taken as 0.04, ground temperature is set to the temperature of the lowermost grid point of each profile, and calculations are done for nadir looking. The step length along the line of sight for the radiative transfer integration is 30 km, Cosmic background radiation is set to a value corresponding to an equivalent brightness temperature of 200 K and the satellite altitude is taken as 550 km. Radioclines are calculated and converted to Planck brightness temperatures.

3 Intercomparison with Other RT Models
As an initiative of the International TOVS Working Group (ITWG), a model intercomparison has been done for infrared and microwave radiative transfer models [3]. Since this intercomparison was done before ARTS appeared, it did not participate in the comparison. However, the intercomparison input data and results of the other models are still available, so that ARTS calculations can be compared with the other models in the intercomparison. In the microwave case, CEMUS-search (EMUS) is taken as the reference model. In the microwaves, the CEMUS profile is given for the intercomparison in logarithmic pressure levels. The solution of the ARTS internal pressure grid is chosen to see its effect on bias and standard deviation of ARTS brightness temperature compared to CEMUS/MIRW [4]. As shown in Table 1, the CEMUS/MIRW has more agreement with the CEMUS-search.

![Figure 1: CEMUS/MIRW brightness temperatures vs. ARTS brightness temperatures for four AMSU channels with 100 pressure levels. The frequency of AMSU-A6 is 50.4 GHz, AMSU-A10 is 57.75, 217 GHz, AMSU-A14 is 57.75, 222 GHz, and AMSU-A18 is 182.8 GHz.](image1)

![Figure 2: As retrieval accuracy of AMSU brightness temperatures, the data are compared with the CEMUS-search.](image2)

4 Comparison of Simulated Brightness Temperature from Radiosonde Data to AMSU Data
In this study, high resolution radiosonde profiles of temperature and water vapour for Lindenberg(52.37°N, 14.27°E) are used. Lindenberg is the reference radiosonde station of the German Weather Service, DWD. Brightness temperatures are simulated using the profiles and compared with AMSU data. The study has been done to see some possible bias in the forward model. The volume mixing ratios for oxygen and nitrogen are taken as constants, 0.009 and 0.782 respectively. Calculated and observed data have been found and filtered according to the following criteria:
- the center of the pixel should be within 15 km for AMSU-A10 and 30 km for AMSU-A14,
- the satellite pass should be within 90 minutes before or after the radiosonde launch,
- profiles with relative humidity greater than 90% above 2 km are neglected as a rough filter against cloud contamination,
- the simulations are done for the same looking angle as the pixel to account for the limb darkening effect.

Three months of data (January-March, 2001) are used for this study. The surface emissivity is taken as 0.9. The result of this comparison is shown in Figure 2.

5 Jacobian
The Jacobian is the partial derivative of the spectrum vector with respect to any of the variables used by the forward model. The Jacobian of the forward model is given by the steady state and standard deviations of the ARTS brightness temperature calculations from CEMUS/MIRW as illustrated in Table 1. The figure shows good agreement between the CEMUS/MIRW and the ARTS.

![Figure 3: ARTS brightness temperatures vs. CEMUS/MIRW brightness temperatures for four AMSU channels with 100 pressure levels. The frequency of AMSU-A6 is 50.4 GHz, AMSU-A10 is 57.75, 217 GHz, AMSU-A14 is 57.75, 222 GHz, and AMSU-A18 is 182.8 GHz.](image3)

6 Summary and Future Work
Radiative transfer calculations by ARTS have been validated in two different ways:
- by comparing with models — according to the ITWG intercomparison criteria, the simulation of AMSU-A6 and AMSU-A10 is excellent and that of AMSU-A14 and AMSU-A18 is very good,
- optimum pressure levels is 100,
- by comparing with AMSU data — the RMS of the simulated brightness temperature and the measured brightness temperature is remarkably close to the mean equivalent temperature of the channels, but somewhat large, which can be explained with sampling error. Note that channels 6 and 20, which have the highest RMS, are most likely to see some influence from the ground,
- there is some bias and scaling factors. Further, further analysis and more data are required before making any conclusions in this regard,
- it is planned to use ARTS for the retrieval of temperature and upper tropospheric humidity.

References