ARTS — A New Radiative Transfer Model for AMSU

V.O. John, M. Kuvatov, and S. Buehler

Institute of Environmental Physics, University of Bremen, Kufsteiner Straße, 28359 Bremen, Germany, vojohn@uni-bremen.de

1 Introduction

The **A**tmospheric **R**adiative **T**ransfer **S**ystem (**ARTS**) is a new radiative transfer model [1] which can handle any millimeter or sub-millimeter instrument in all viewing geometries: nadir, up, and limb. ARTS is now a one dimensional model and is limited to cases where scattering can be neglected. However, work is in progress to implement scattering, so that ARTS will be able to simulate radiances for a cloudy atmosphere. The main features of the program are modularity, extendibility, and generality. Besides producing spectra ARTS calculates weighting functions for temperature, trace gas concentrations, continuum absorption, ground emission, calibration and pointing off-sets. ARTS is publicly available on the website: http://www.sat.uni-bremen.de/arts/.

2 Study Setup

ARTS is a general purpose model with many options and free parameters. This section describes some of the choices made for the special case of simulating **A**dvanced **M**icrowave **S**ounding **U**nit (**AMSU**) measurements. The species considered are water vapour, oxygen, and nitrogen. The absorption coeffients are calculated according to Rosenkranz [5] for water vapour and Rozenkranz [4] for oxygen and nitrogen. Absorption coefficients are computed on a fixed pressure grid specified by the user. For this study we used 43, 100, and 200 pressure levels in logarithmic spacing. For the model intercomparison ground emissivity is taken as 0.6, 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 20 m. Cosmic backgroud radiance is set to a value corresponding to an equivalent brightness temperature of 2.735 K and the satellite altitude is taken as 833 km. Radiances 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 CIMSS-MWLBL is taken as the reference model. 42 atmospheric profiles are given for radiative transfer calculation in 43 pressure levels. The resolution of the ARTS internal pressure grid is changed to see its effect on bias and standard deviation of ARTS brightness temperature from CIMSS-MWLBL brightness temperature as illustrated in Table 1. Figure 1 illustrates that ARTS shows good agreement with the CIMSS-MWLBL.

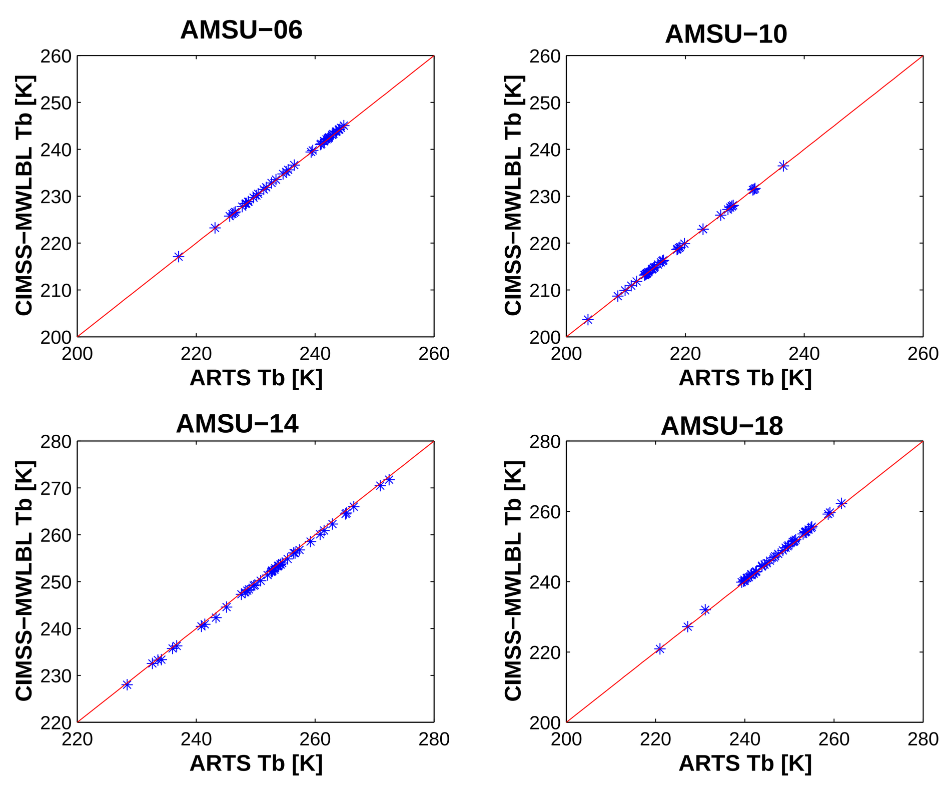

Figure 1: CIMSS-MWLBL brightness temperatures versus ARTS brightness temparatures for four AMSU channels using 100 pressure levels. The frequency of AMSU-06 is 54.4 GHz, AMSU-10 is 57.29±.217 GHz, AMSU-14 is 57.29±.3222±.0045 GHz, and AMSU-18 is 183.31±1 GHz.

No. of Levels	AMSU-06		AMSU-10		AMSU-14		AMSU-18	
	std	bias	std	bias	std	bias	std	bias
43 levels	0.08	-0.18	0.09	0.12	0.34	0.94	0.17	-0.37
100 levels	0.06	-0.14	0.02	0.00	0.15	0.52	0.17	-0.37
200 levels	0.06	-0.13	0.02	-0.02	0.15	0.51	0.16	-0.37

Table 1: Standard deviation and bias of ARTS brightness temperature compared to CIMSS-MWLBL brightness temparature for the four AMSU channels.

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(52.21^0N, 14.12^0E) 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 [2]. The volume mixing ratios for oxygen and nitrogen are taken as constants, 0.209 and 0.782 respectively. Collocated AMSU data has been found out and filtered according to the following crieteria:

- the centre of the pixel should be within 15 km for AMSU-B and 50 km for AMSU-A.
- 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.

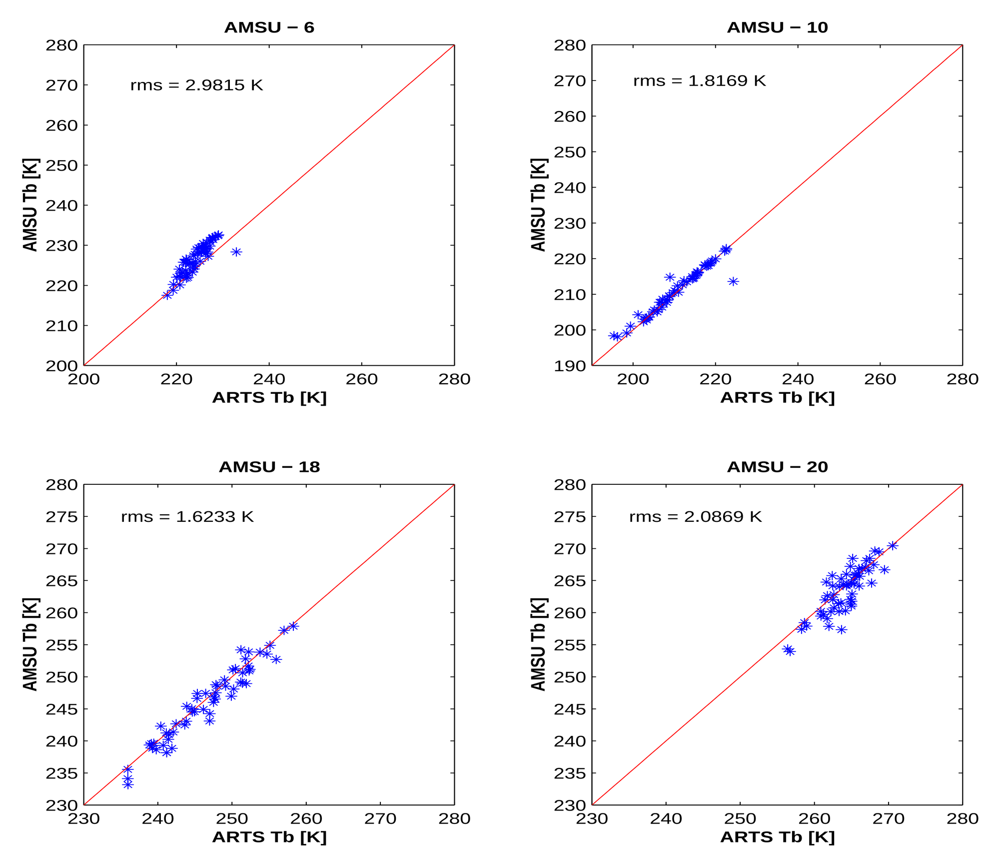

Figure 2: AMSU measured brightness temperatures versus ARTS brightness temparatures for four AMSU channels. The frequency of AMSU-06 is 54.4 GHz, AMSU-10 is 57.29±.217 GHz, AMSU-18 is 183.31±1 GHz, and AMSU-20 is 183.31±7 GHz. The noise equivalent temperatures of these channels are 0.25 K, 0.40 K, 1.06 K, and 0.60 K respectively.

5 Jacobian

The Jacobian is the partial derivative of the spectrum vector **y** with respect to any of the variables used by the forward model. ARTS calculates Jacobians analytically for species concentrations and semi-analytically for temperature(if hydrostatic equilibrium is neglected). Temperature Jacobians for three AMSU-A channels and water vapour Jacobians for three AMSU-B channels are shown in Figure 3. The unit of the temperature Jacobian is K/K, so the peak value of 0.05 means that the simulated brightness temperature will change by 0.05 K if the atmospheric temperature is changed by 1 K at one grid point. The water vapour Jacobian is in fractional units (K/1), so the curves correspond to the change in brightness temperature for a doubling of the mixing ratio at one grid point.

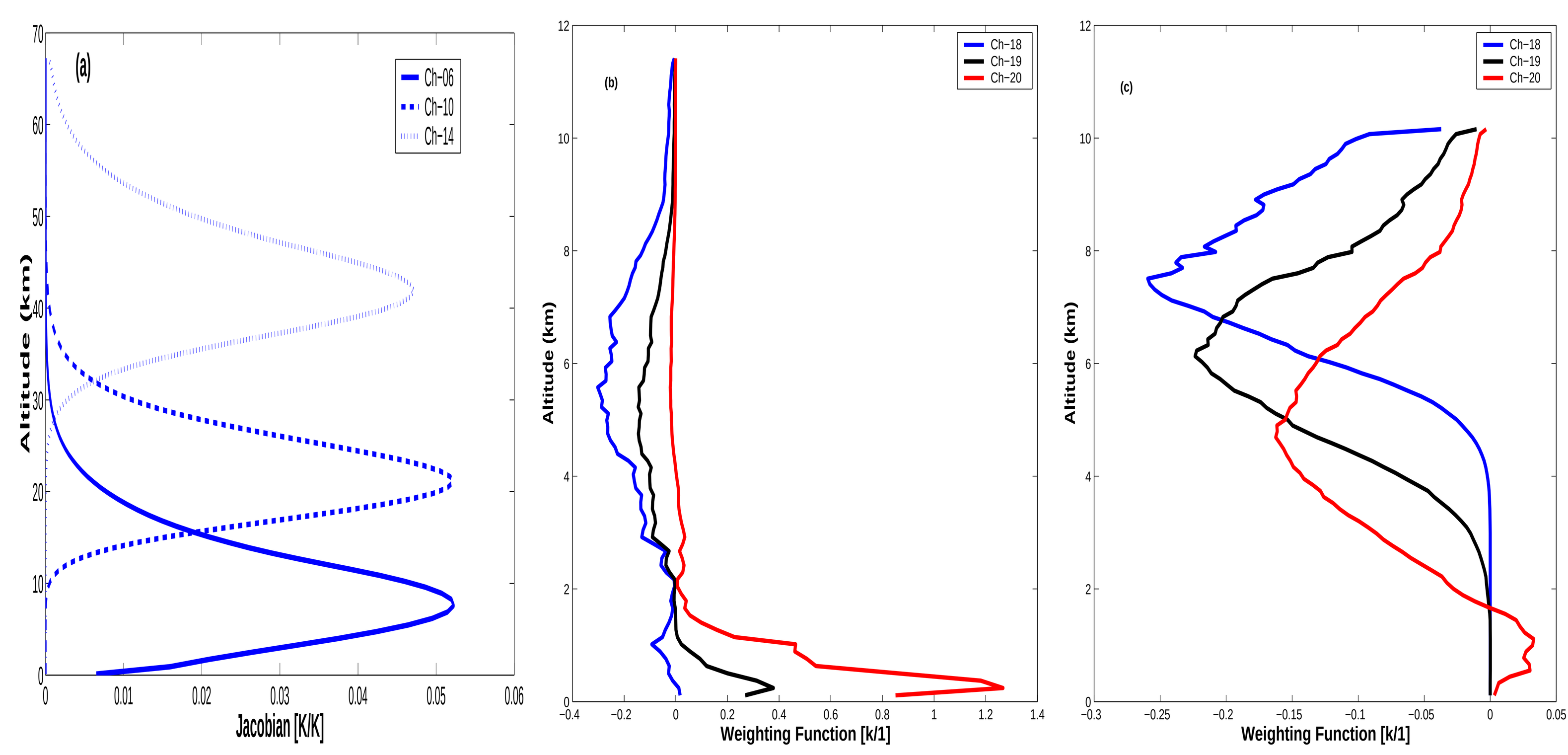

Figure 3: Jacobians calculated by ARTS: (a) temperature for midlatitude winter scenario, (b) water vapour for a dry atmosphere, and (c) water vapour for a humid atmosphere. These two cases correspond to the driest and the most humid radiosonde profile. The column integrated water vapour upto 10 km is 1.71 kg/m^2 and 11.61 kg/m^2, respectively. Note that the Jacobians differ significantly in dry and humid conditions.

6 Summary and Future Work

Radiative tranfer calulations by ARTS have been validated in two different ways:

- by comparing with models
  - according to the ITWG intercomparison criteria, the simulation of AMSU-06 and AMSU-10 is excellent and that of AMSU-14 and AMSU-18 is very good.
  - optimum number of 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 noise equivalent temperature of the channels, but somewhat larger, which can be explained with sampling error. Note that channels 6 and 20, which have the highest RMS, are also most likely to have some influence from the ground.
  - there are hints of small biases and scaling factors. However, 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

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