

# Validation of AMSR-E and AMSU/HSB level 1 brightness temperatures and level 2 cloud and precipitation parameters

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Ralf Bennartz (PI), Grant Petty (Co-I), University of Wisconsin  
 Daniel B. Michelson (Co-I), Swedish Meteorological and Hydrological Institute

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## 1. Overview

The report is divided in two parts. In the first part we describe briefly the scientific results achieved so far. In the second part we discuss the dedicated validation observations that have been taken coincident with AQUA data, the scientific publications that arose from the project, and our future scientific plans. To provide a short overview, Table 1 lists the proposed activities and their current status.

Table 1: Project goals and their current status

Objective	Status	Comment
Pointing accuracy of AMSU, HSB, AMSR-E	Ok	Scientific results see section 2
AMSR-E/AMSU/HSB Level 1 $T_B$ comparison	Postponed due to calibration issues	
AMSR-E level 2A assessment	Postponed due to calibration issues	
Provide HSB convolution to AMSU resolution	Ok	Scientific results see section 2
Validation of AMSR-E cloud liquid water algorithm	Ongoing. Used TRMM data while AMSR was not available	Scientific results see section 2
Validation of AMSR-E rainfall at high latitudes	Ongoing. Used NOAA-XX and SSM/I data while AMSR/AMSU /HSB was not available. Performed simulation studies. Ongoing validation data collection	Scientific results see section 2
Validation of AMSU/HSB rainfall at high latitudes		Dedicated validation datasets see section 3

Since AQUA microwave data has only become available recently, after calibration issues have been solved, a considerable effort has been undertaken within this project, to establish validation strategies for similar instruments that provide similar level 2 products as the AQUA instruments (TRMM for cloud liquid water and rainfall, AMSU-

A/AMSU-B on the NOAA satellites for rainfall from AMSU/HSB). In addition, theoretical studies have been performed on issues with relevance to AQUA precipitation retrievals at high latitudes but also with relevance to future NASA efforts on global precipitation measurements. Due to the unique combination of microwave sensors AQUA can be used as a testbed for future sensors.

## 2. Scientific results

### 2.1. Validation of Level 1 products

#### Assessment of AMSR-E beamwidth, IFOVS, and EFOVs

The validation of the retrieval of spatially highly variable environmental parameters (such as rainfall) makes it necessary to account for the actual spatial sensitivity of the sensor. We found some slight inconsistencies in the tabulated values of the 3dB footprint sizes on NASA's and NASDA's AMSR websites so we reassessed the representation of the instantaneous field of view (IFOV) and effective field of view (EFOV) of AMSR-E. The term IFOV refers to the projection of the 3dB points of the antenna gain function onto the Earth's surface. The term EFOV is used for the 3dB width of the actual field of view of the sensor, which includes effects due to the rotation of the main reflector. Measured antenna gain functions were available from NASDA.

Table 2: Beamwidth, IFOVs, and EFOVs of AMSR-E as derived from the measured antenna gain functions. The first three rows give the values publicly available from NASA's and NASDA's websites. The last three rows give the values we obtained from NASDA's measured antenna gain functions.

	6 GHz	10 GHz	18 GHz	23 GHz	36 GHz	89 GHz A	89 GHz B
Beamwidth published (NASDA)	2.2	1.4	0.8	0.9	0.4	0.18	
IFOV published (NASA)	75x43	51x29	27x16	32x18	14x8	6x4	
EFOV based on published beamwidth (NASDA)	75x44	48x28	27x17	31x19	14x11	6x9	
<b>Beamwidth according to NASDA antenna pattern (h+v)/2</b>	<b>2.05</b>	<b>1.36</b>	<b>0.76</b>	<b>0.84</b>	<b>0.40</b>	<b>0.16</b>	<b>0.17</b>
<b>According IFOV</b>	<b>70x40</b>	<b>46x27</b>	<b>26x15</b>	<b>29x16</b>	<b>14x8</b>	<b>5x3</b>	<b>6x3</b>
<b>According EFOV</b>	<b>70x41</b>	<b>46x28</b>	<b>26x17</b>	<b>29x18</b>	<b>14x11</b>	<b>5x9</b>	<b>6x9</b>

**Results:** The differences between the reassessed and the published IFOVs and EFOVs are small and can be neglected without any problems for almost all applications. Only at 6 GHz and 10 GHz the small deviation between the published and newly calculated EFOVs might become important for some applications.

#### Geolocation/navigation of AMSR and AMSU/HSB

The absolute geo-referencing of AMSU and AMSR-E has been studied. A high-resolution land/sea-mask has been convolved to the spatial resolution of the sensors taking into account the two-dimensional antenna pattern functions for AMSU, HSB and

AMSR-E. In coastal regions, the strong contrast in emissivity between land and water surfaces and the resulting strong gradients in observed brightness temperatures, results in a strong correlation between the convolved land/sea-mask and the measurements. By varying the navigation around the initial navigation and correlating the land/sea-mask to the observed window frequency brightness temperatures a matrix of correlation coefficients is obtained. The maximum correlation gives the position of the shift in navigation that best fits the observed scene. Since in principle the navigation of the data could vary with each scan line, the results might differ slightly for different overpasses. The accuracy of this method depends on several factors that have been discussed in Bennartz (1999) for the similar case of the Special Sensor Microwave/Imager (SSM/I). In summary it allows to estimate the navigation accuracy to within  $\pm 0.1$  FOVs, which for the HSB would correspond to approximately  $\pm 0.1$  degrees (AMSU-A:  $\pm 0.3$  degrees) in cross-track direction and  $\pm 0.1$  scan-line at nadir in along-track direction. For the AMSR-E navigation data for all different channels was available from NASDA. The different channels have a slightly different boresight position depending on the position of the feedhorns on the instrument.

**Results:** The navigation accuracy of all three instruments is to within the accuracy of the method accurate. Figure 1 shows as an example results for the AMSR-E 18 GHz channel. In this particular case the best agreement is found at a shift of zero in along-scan direction and a shift of 0.2 scan lines in along-track direction, which is well within the accuracy limit of the method. Similar results have been found for AMSU and HSB.

### **Mapping of HSB to AMSU resolution**

The intention of this method is to provide users with a tool to exactly map HSB onto the spatial resolution of AMSU-A so that for example combined temperature and moisture profiles are based on observations of the same scene. A similar algorithm is currently used at NESDIS for all three AMSU-As/AMSU-Bs on the operational NOAA satellites.

**Results:** The existing AMSU-A/AMSU-B algorithm has been adapted to AMSU-A/HSB. First results have been presented on the AIRS science team meeting at the end of February 2003 in Washington. The algorithm will be distributed to the AIRS science team and AIRS validation team by the end of March 2003, after final quality controls have been made.

## **2.2. Validation of Level 2 products**

### **Cloud liquid water from AMSR**

Another objective of the project is to validate the level-2 retrieved cloud liquid water (CLW) from AMSR, which is based on the algorithm of Frank Wentz (see Ocean Products ATBD). Because AMSR-E data got available only recently (February 2003), we focused initially on validation of the Wentz-derived CLW for the TRMM Microwave Imager (TMI), which a similar physical model and retrieval strategy, but with slight adjustments for the channel frequencies and incidence angle.

The sensitivity of microwave radiances to variations in CLW is well understood and not believed to be a large source of error in microwave retrievals of CLW. Far more important are biases in modeled background brightness temperature which can swamp the relatively small signal of the cloud water itself and give rise to large systematic errors in absolute CLW. Our validation strategy lies in examining the error characteristics of the CLW product in known cloud-free regions, for which the true CLW value is very close to zero. Observed random and systematic errors in CLW in the cloud-free case represent lower bounds on the errors to be expected in cloudy cases as well, for which direct validation is virtually impossible.

We developed two methods for identifying cloud-free TMI scenes over ocean. The first, and most direct, is based on the visible albedo observed by the Visible and Infrared Scanner (VIRS) carried on the same satellite. We required that the albedo of all VIRS pixels within a 30 km radius of the corresponding TMI-derived CLW pixel be less than 4%. The second method is based on the relative variance of TMI 85 GHz polarization within a 30~km radius --- low variance was confirmed to occur only in scenes lacking significant cloudiness. We verified that the second method, which can be easily applied to future AMSR-E data without the need for voluminous high-resolution MODIS data, yields the same CLW validation results as the visible albedo-based method. Figure 2 shows the distribution of retrieved CLW for several months in 1998, using the two methods for identifying cloud free scenes.

**Results:** Preliminary results indicate that the Wentz CLW retrievals are biased positive by about  $0.03 \text{ kg/m}^2$ , with a standard deviation of about  $0.015 \text{ kg/m}^2$ . No significant systematic dependence on water vapor, SST, or wind speed was noted.

### **2.3. Rainfall validation**

Collection of validation datasets has been established and is ongoing, for details see section 3.1. In addition to the ongoing data collection effort we have carried out simulation studies to optimize high latitude rain- and snowfall retrievals. These studies entered into NASA's Technical report on the 'Scientific Assessment of High Frequency Channels on GPM Core Satellite for Warm and Light Rain plus Snow Measurements.' (Liu et al., 2001) and in a separate publication by Bennartz and Bauer (2003). Details about the scientific results can be found in those studies. In addition we have compared NESDIS operational products for AMSU and SSM/I with radar data over land and are currently in the process of evaluating results together with R. Ferraro at NOAA. The algorithm used at NESDIS is conceptually identical with the AMSR-E land algorithm which is also provided by NESDIS.

## **3.Validation datasets, publications, and future plans**

### **3.1. Dedicated validation datasets**

Since August 2002 we have continuously taken collocated radar observations at the radar site of Gotland (57.24 N, 18.39 E). The site is equipped with a C-band Doppler radar. The observation strategy is to obtain as much information as possible about the vertical and horizontal structure of precipitation to validate the AMSR and AMSU/HSB rainfall algorithms at a high latitude site. The radar has therefore been set up to scan for

precipitation at different elevations (between 0.5 and 30 degrees elevation angle), so that a three-dimensional volume of radar reflectivities can be retrieved for each overpass.

The data collection effort is quasi-operational and ongoing for the remainder of the project so that a long-term observational dataset of collocated AMSR-E/AMSU/HSB and radar data for about two years will be available at the end of project. In addition to validating AQUA rainfall estimates this dataset might serve as a precursor dataset for future satellite missions with emphasis on high latitude precipitation. In **Table 3** we list the number of collocated observations taken every month since August 2002.

The data are taken by the Swedish Meteorological and Hydrological Institute (SMHI) being processed, quality controlled and integrated at the UW-Madison. The final validation product consists of a ncdf-file that holds gage adjusted radar surface rain rate composites, a frontal/convective classification, and the volume scans for each AQUA overpass. The data will be distributed to the AIRS validation archive (JPL) as well as to the AMSR validation archive (CSU, NSIDC).

Table 3: List of radar observations taken by the Gotland radar timed according to AQUA overpasses.

Aug 02	Sep 02	Oct 02	Nov 02	Dec 02	Jan 03	Feb 03
59	44	60	57	60	58	52

### 3.2. Peer-reviewed publications and technical reports

The following peer-reviewed papers and reports have been published with full or partial support by this project:

- Bennartz, R. and P. Bauer, 2003: Sensitivity of microwave radiances at 85-183 GHz to precipitating ice particles. In press *Radio Science*.
- Fetzer, E., L. McMillin, M. Goldberg, S. Zhou, H. Ding, D. Tobin, D. Whiteman, J. Barnes, J. Yoe, M. Newchurch, D. Hagan, M. Hofstadter, P. Minnett, R. Bennartz, W. McMillan, R. Atlas, F. Schmidlin, H. Vomel, V. Walden, and H. Revercomb, "AIRS/AMSU/HSB validation," *IEEE Trans. Geosci. Remote Sensing*. In press
- Michelson, D. B., J. Koistinen, R. Bennartz, C. Fortelius, and A. Thoss, 2003: BALTEX Radar Achievements at the End of the Main Experiment. In press *Proceedings of The Second European Conference on Radar Meteorology (ERAD)*. Peer-reviewed conference proceeding.
- Lothar Schueller, Ralf Bennartz, and Jean-Louis Brenguier, 2003: A MODIS algorithm for the retrieval of droplet number concentrations and geometrical thicknesses of marine boundary layer clouds. Submitted to *Journal of Applied Meteorology*.
- Liu, G. et al. 2001: Scientific Assessment of High Frequency Channels on GPM Core Satellite for Warm and Light Rain plus Snow Measurements. NASA Technical report. See NASA's GPM-homepage.

### **3.3. Future plans**

With AMSR-E and AIRS/AMSU/HSB data now becoming available, the project will in the future concentrate on evaluating the AQUA level 2 products using the validation datasets that have been collected. In particular we will:

- Concentrate on the validation of AMSR-E rainfall estimates using the already available and growing database of collocated passive microwave and ground based radar data. We will in particular evaluate the performance of the AMSU/HSB and AMSR rainfall algorithms with respect to different types of precipitation events (stratiform/convective). These efforts are carried out in cooperation with the algorithm developers (Kummerow (CSU), Ferraro (NESDIS), Staelin (MIT))
- Carry out forward simulations and sensitivity studies to gain insight into the response of observed brightness temperatures to different types of precipitation and help define possible refinements of the retrieval algorithms
- We will evaluate the AMSR-E cloud liquid water algorithms using collocated MODIS and AMSR-E data.
- Continue monitoring level 1 georeferencing for the different instruments and implement the convolution of HSB to AMSU-A

These search terms have been highlighted: **scientific assessment of high frequency channels on gpm core**

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