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

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1. Overview

The report is divided in two parts. In the first 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. In the second part we describe briefly the scientific results achieved. 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	AMSU OK, AMSR-E open	Scientific results see section 3
AMSR-E/AMSU/HSB Level 1 T_B comparison	OK, bias monitoring ongoing	See section 3
AMSR-E level 2A assessment	OK, bias monitoring ongoing	See section 3
Provide HSB convolution to AMSU resolution	Finished	See previous report
Validation of AMSR-E cloud liquid water algorithm	Finished	Scientific results see section 3
Validation of AMSR-E rainfall at high latitudes	Performed simulation studies. Ongoing validation data collection. Scientific studies ongoing. Data used by precipitation PIs for validation.	Scientific results see section 3
Validation of AMSU/HSB rainfall at high latitudes		Dedicated validation datasets see section 2

2. Publications, future plans, and Validation datasets

a) Peer-reviewed publications and technical reports

The following peer-reviewed papers and reports have been published with full or partial support by this project (reprints/preprints can be provided as needed):

Bennartz, R., 2004: Passive microwave precipitation measurements at mid- and high latitudes. Book chapter, V. Levizianni, P. Bauer, J. Turk Eds. in press.

Bennartz, R., 2004: Identification of snowfall at the surface from AMSR-E observations. In preparation.

Greenwald, T, A. Heidinger, R. Bennartz, and C. O'Dell, 2004: A fast successive order of interaction radiative transfer model for use in radiaince assimilation schemes. In preparation. To be submitted to J. Atmos. Oceanic Technology.

Bennartz, R. and P. Bauer, 2003: Sensitivity of microwave radiances at 85-183 GHz to precipitating ice particles. Radio Science, 38, 4, 8075, doi: 10.1029/2002RS002626

Bennartz, R. and D. B. Michelson, 2003: Correlation of precipitation estimates from spaceborne passive microwave sensors and weather radar imagery for BALTEX PIDCAP. Int. J. Remote Sensing, 24, 4, 723-739/

Fetzer, E.; McMillin, L.M.; Tobin, D.; Aumann, H.H.; Gunson, M.R.; McMillan, W.W.; Hagan, D.E.; Hofstadter, M.D.; Yoe, J.; Whiteman, D.N.; Barnes, J.E.; Bennartz, R.; Vomel, H.; Walden, V.; Newchurch, M.; Minnett, P.J.; Atlas, R.; Schmidlin, F.; Olsen, E.T.; Goldberg, M.D.; Sisong Zhou; HanJung Ding; Smith, W.L.; Revercomb, H., 2003: AIRS/AMSU/HSB validation. IEEE Transactions on Geoscience and Remote Sensing, 41, 2, 418- 431.

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.

b) Future plans

There are four areas that we would like to work on within the next year:

- We have put considerable efforts in the validation of level 1 and level 2a AMSR products. We would like to finish this activity and provide NASA with a full report assessing the accuracy of AMSR calibration and navigation. This report will have 20 - 50 pages and will summarize the activities that are described very briefly below. We anticipate that this report can be ready within 6 to 8 month from now. We are especially encouraged by the good and stable calibration that we see comparing global AMSR data as well as direct broadcast AMSR data to radiative transfer simulations based on global forecast models.
- There are several scientific studies that arise from the current work and that are about 75% finished. Those studies address the liquid water validation, the physical validation of precipitation retrievals at high latitudes and the identification of snowfall at the surface. We would like to finish those studies and publish the results. We anticipate to be ready wit this work in mid 2005.
- We would like to continue supporting the old and new AMSR precipitation team members (Wiheit, Kummerow, McCollum/Ferraro, Petty) in their efforts to validate their products at higher latitudes. We will continue to build up an easy to use database of high latitude precipitation events with collocated radar, AMSR and AMSU data.

- We would like to continue working with the direct broadcast group at the University of Wisconsin. This informal collaboration turned out to be very successful scientifically, in that we are able to validate their implementation efforts of AMSR products into IMAPP. Also, Ralf Bennartz will be co-chairing a special session on AMSR and its applications in the 1st IMAPP Remote Sensing Training Workshop in June this year in Nanjing, China. We anticipate this work to be done in summer 2005.

c) 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). There is a data gap in summer 2003 due to failure of the BALTRAD processing system. 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 2 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 an 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 2: 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
Mar 03	Apr 03	May 03	Jun 03	Jul 03	Aug 03	
58	57		No Baltrad data available			

3. Scientific results

a) Validation of Level 1 products

AMSR-E calibration (bias monitoring versus GFS)

AMSR-E official NASA products are cross-calibrated using various SSM/Is and TMI by Wentz. We are currently monitoring the AMSR-E calibration against NCEP's Global Forecasting System (GFS) using completely different radiative transfer tools than Wentz. This monitoring allows to:

(1) Perform and independent sanity check the Wentz's calibration
(2) Perform an initial analysis of the AMSR biases against the GFS system. Eventually if AMSR data might be incorporated into any operational data assimilation system, this will be an important first step.

While we can not provide an absolute reference for calibration of AMSR, **the encouraging result here is that the overall performance of AMSR is good and at least comparable to other sensors that are currently being monitored against GFS operationally (SSM/I, AMSU).** We provide two figures that show biases of AMSR versus GFS for January 04. AMSR data had to be within a GFS box, with less than 30 minutes time difference. Both datasets were quality controlled and a stringent test was applied to ensure only cloud-free observations were taken into account.

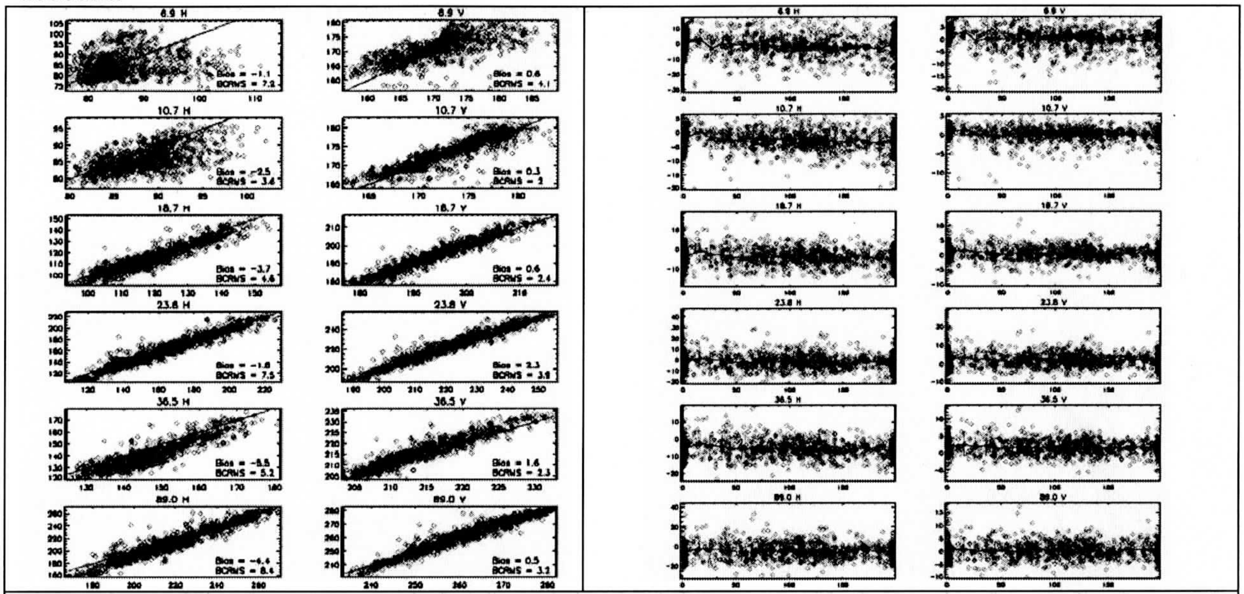

Figure 1: Left panels: Scatterplot of AMSR versus GFS-derived brightness temperatures for cloud-free observations January 2004. Biases are in general small and both datasets are in good agreement. Right panels: Difference AMSR- GFS as a function of AMSR scan position.

AMSR-E direct broadcast versus global data

In addition we are also monitoring the direct broadcast AMSR data that is received in house at the University of Wisconsin (A. Huang, L. Gumley PIs). This data is calibrated differently from the global data using a static version of Wentz's calibration procedure. Both datasets, even though calibrated differently, are in good agreement. **Biases between the two different calibration pathes are less than 0.3 K for all channels.** We do not provide a figure here.

b) Validation of Level 2 products

Cloud liquid water from AMSR

One objective of the project was 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). Initial results were shown in the previous progress report. We have now finished this activity.

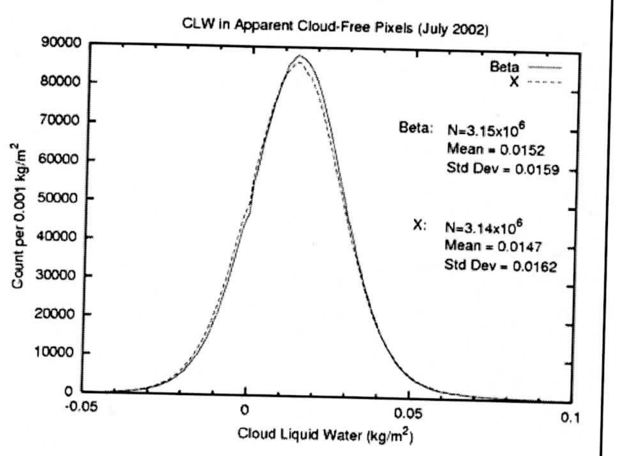

Figure 2: Distributions of Wentz AMSR-E-derived CLW for cloud-free pixels, as determined using the 89 GHz variance-based method. Results are shown for two versions of the Wentz AMSR calibration products (X and B versions of calibration).

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 possible 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 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 TRMM 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 variance-based method yields essentially the same CLW validation results as the visible albedo-based method (see previous progress report). The advantage of the 85 GHz variance method is that it can be adapted to the AMSR 89 GHz imagery and used to identify cloud-free scenes without the need to process a large volume of coincident visible imagery. Fig. 2 shows global results for July 2002; very similar results are found for other months. In all cases an apparent positive bias of 0.015 kg/m2 was noted. The standard deviation about the mean was 0.016 kg/m2

Results: Wentz CLW retrievals are biased positive by about 0.015 kg/m^2, with a standard deviation of about 0.015 kg/m^2. No significant systematic dependence on water vapor, SST, was noted. The bias depends on wind speed (not shown here).

c) Rainfall validation

Collection of validation datasets has been established and is ongoing, for details see section 2.c. Earlier results were reported in last year's validation report. Since then, we have put our main emphasis on the validation of rain- and snowfall retrieval measurements at mid- and high latitudes, the main questions being:

- Support AMSR rainfall PIs in validating AMSR at mid- and high latitudes.
- Distinction between snowfall and rainfall at the surface

- Physical validation efforts for AMSR rainfall products

Sample results for those three areas are presented below

1. Support of AMSR rainfall PIs

We have generated rainfall validation datasets that are currently being used to validate AMSR at mid- and high latitudes by the AMSR precipitation PIs. The below Figures were kindly provided by J. McCollum (NOAA) and show how the validation dataset is used to improve AMSR performance over inhomogeneous high-latitude areas.

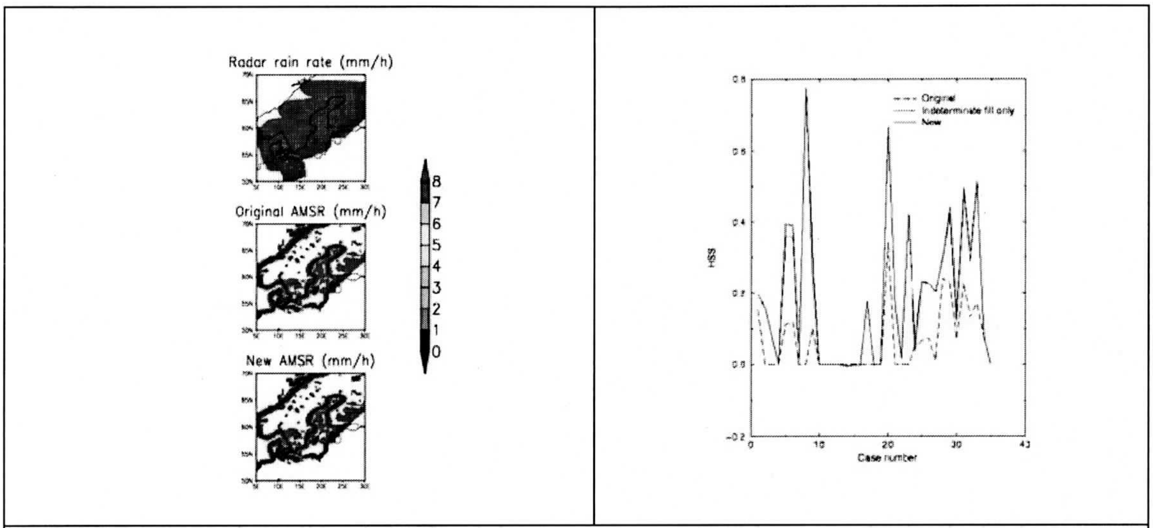

Figure 3: The left panels show the radar-derived surface rain rate (upper panel) as well as old (middle panel) and improved, new AMSR retrievals (lower panel) over the highly structured Baltic area. The right panel shows Heidke Skill Scores (HSS) for AMSR retrievals versus radar data for all overpasses in October 02. High HSS values are a measure for a good agreement between radar and AMSR retrievals. The improvement of the new AMSR algorithm over the old on is obvious. Figures courtesy of J. McCollum.

2. Snowfall at the ground.

Detailed scientific results of this study are reported in Bennartz (2004). Here we just show one Figure that shows the relative frequency of occurrence of snowfall at the surface for the two October 2002 and January 2003.

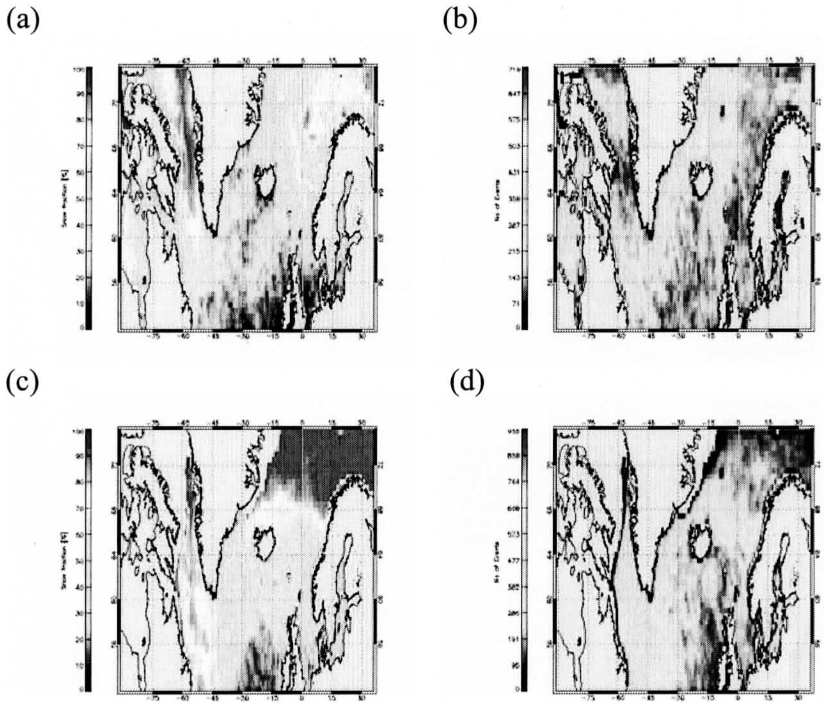

Figure 4: (a) Fraction of precipitation events with snowfall at the surface over the northern Atlantic for October 2002, (b) total number of precipitation events found per 0.5 x 0.5 degree box in October 2002, (c) same as (a) but for January 2003 (d) same as (b) but for January 2003. The grey areas in January near Greenland and Hudson Bay are covered with sea ice.

3. Physical validation

AMSR provides TRMM-like passive microwave observations with global coverage. Mid- and high latitude precipitation systems are different in many aspects from tropical system. Most importantly, rain rates are lower, and the freezing level is lower too. A physical validation of AMSR retrievals is needed that allows to relate the surface rain/snow rate to the brightness temperatures observed at the satellite. A consistent description of the scattering behavior of precipitation sized ice particles (via their drop size distributions and density) is an important first step in this direction. The Figure provided here shows a comparison between observed and simulated brightness temperatures (89 V) and observed and simulated scattering indices (Petty, personal communication) where the simulations are based on collocated radar validation data. This is a weak snowfall event with snow rates of 1.5 mm/h at maximum. We have put together a catalogue with collocated radar and AMSR (and AMSU) data for various precipitation events and are in the process of evaluating the relation between surface rain rate and scattering signature statistically.

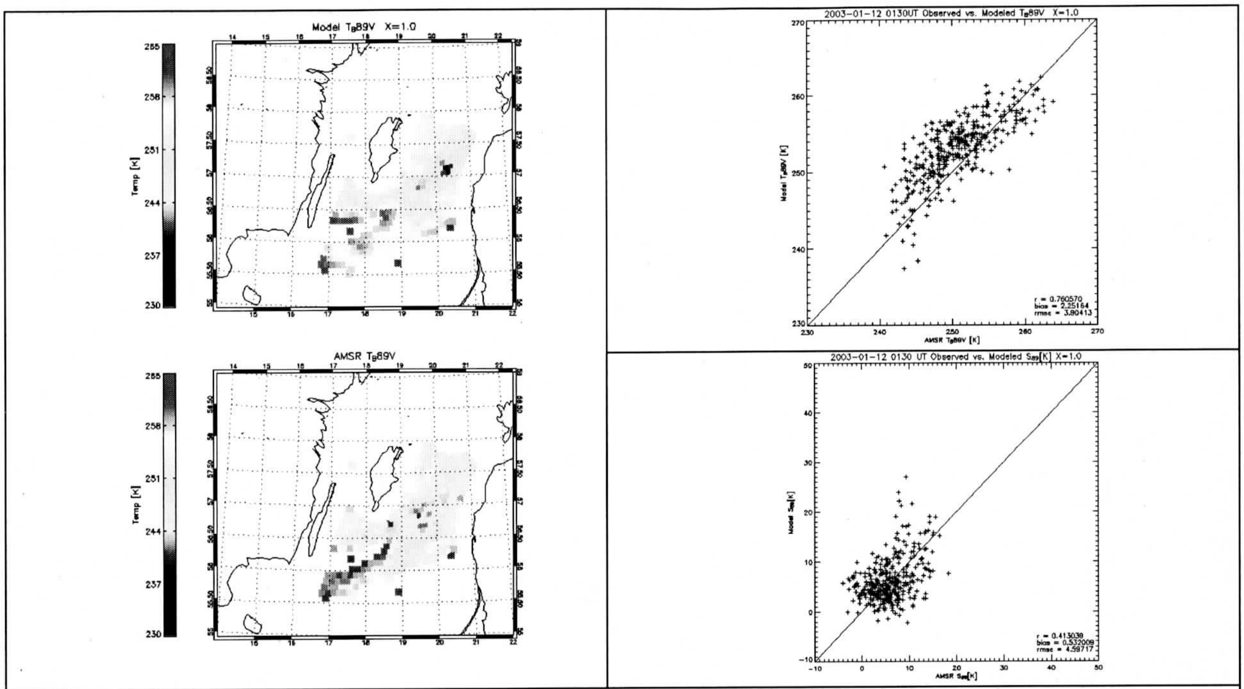

Figure 5: Left panels observed and simulated AMSR brightness temperatures for a light snowfall case in January 2003. Right panels: Scatter plot of observed versus simulated brightness temperatures at 89 GHz V (upper panel) and scatter plot of 89 GHz scattering index (lower panel). Only data with a non-zero rain rate (from radar) is shown.