P3.14 VALIDATION OF GLOBAL SIMULATIONS OF MICROWAVE AND INFRARED BRIGHTNESS TEMPERATURES USING AMSR AND AIRS DATA

Thomas Greenwald*
University of Wisconsin-Madison

Ralf Bennartz
University of Wisconsin-Madison

Chris O'Dell
University of Wisconsin-Madison

Andrew Heidinger
NOAA/NESDIS

1. INTRODUCTION

Satellites are the leading source of observational data assimilated by numerical weather prediction (NWP) models. In fact these observations comprise about 99% of all data brought into NCEP's Global Data Analysis System (GDAS). One approach that has been gaining acceptance for merging observations and NWP models is the direct use of radiance data, though currently it is restricted to clear sky areas. Direct insertion of radiance data offers several advantages over the use of data products, such as providing better control of errors in the assimilation environment and the opportunity to study the direct interactions between clouds and radiation.

Recent efforts have compared global model-produced brightness temperatures to satellite observations in order to evaluate the ability of these models to produce clouds and precipitation (Chevallier and Bauer 2003; Chevallier and Kelly 2002; Chevallier et al. 2001). These types of comparisons are an important first step in direct radiance assimilation of these data. This study seeks to evaluate model-simulated brightness temperatures in preparation for assimilating satellite data in cloudy regions into the GDAS, but uses the latest measurements from the Advanced Microwave Scanning Radiometer-EOS (AMSR-E) and the Atmospheric Infrared Sounder (AIRS) aboard NASA's Aqua platform. This study differs from previous work in that multiple scattering is accounted for at infrared wavelengths. Only the microwave comparisons for cloudy but non-precipitating conditions will be shown here. Comparisons involving AIRS data will be presented at the conference.

2. DATA

2.1 *Global model*

The current version of NCEP's GFS uses a spectral atmospheric model with horizontal resolution at T254 (about 0.5^o x 0.5^o latitude/longitude) and 64 vertical levels in sigma coordinates. The deep convection scheme is based on Pan and Wu (1995), while shallow convection is parameterized following Tiedtke (1983). The percent area of cloud coverage for a given grid point is not predicted but computed from the relative humidity, saturation specific humidity (q) and a minimum threshold of q using the approach of Xu and Randall (1996). Cloud water and ice are both predicted via a scheme by Zhao and Carr (1997).

GFS degraded products (1^o x 1^o horizontal grid and 26 vertical levels) were used in the analysis since they were readily available online at ftp://ftpprd.ncep.noaa.gov/pub/data/nccf/com/avn/prod. The following 12-hr forecast products were selected: temperature, relative humidity, and cloud water mixing ratio at all levels; surface temperature, and 10 m wind vector.

2.2 *Satellite*

AMSR-E was designed to provide vital information on the Earth's water budget, including water vapor, clouds, precipitation and soil moisture. AMSR-E scans conically, measuring vertical and horizontal polarization separately at various microwave window channels (see Table 1). The spatial resolution of AMSR-E varies from 74 x 43 km for the low frequency channels up to 6 x 4 km for the highest frequency channels.

AIRS is a spectrometer with 2378 thermal infrared channels (3.7-15.4μm) and 4 channels in the visible and near-infrared (0.4-1μm) to provide accurate profiles of temperature and humidity. It is a cross-track scanning instrument with a spatial resolution of 13.5 km at nadir.

3. RADIATIVE TRANSFER MODELING

Microwave and infrared forward brightness temperatures were both computed from model forecast fields using the successive order of interaction (SOI) plane-parallel radiative transfer (RT) model (Heidinger et al. 2004). In 4-stream mode, the SOI model has been

* *Corresponding author address*: Tom Greenwald, CIMSS, University of Wisconsin, 1225 W. Dayton St., Madison, WI 53706-1695; e-mail: tomg@ssec.wisc.edu.

shown to be faster in most cases and more accurate than the commonly used delta-Eddington model. The SOI model has errors to within about 1 K over a wide range of thermal wavelengths and atmospheric conditions. Delta scaling has also been incorporated into the SOI model to improve its accuracy when particles become large compared to incident wavelength (i.e., forward scattering increases).

Table 1. AMSR-E characteristics.

Chan	Polarization	Frequency (GHz)	Sensitivity
1	V	6.925	Sea surface temperature, soil moisture, intense precipitation
2	H	6.925	
3	V	10.65	Sea surface temperature, soil moisture, precipitation
4	H	10.65	
5	V	18.7	Boundary layer (BL) water vapor, surface roughness, precipitation
6	H	18.7	
7	V	23.8	
8	H	23.8	
9	V	36.5	Water clouds, surface, BL water vapor, precipitation
10	H	36.5	
11	V	89.0	BL water vapor, water clouds, surface, precipitation
12	H	89.0	

Required as input to the SOI RT model are the effective extinction and single-scattering properties of the atmosphere (i.e., particle extinction, single-scatter albedo, and asymmetry factor, and gas extinction) and boundary conditions (i.e., ocean surface emissivity and skin temperature). Because the following comparisons are limited to the microwave for non-scattering situations, only the particle and gas extinction coefficients are needed. Gas optical depth (water vapor and oxygen) was obtained from OPTRAN (McMillin et al. 1995), which is the gas absorption model used operationally by the GDAS. Absorption due to cloud liquid water was computed from Liebe et al. (1992).

Finally, ocean surface emissivity was computed from FASTEM-2, a model originally developed by English and Hewison (1998) and further refined and improved by Deblonde and English (2000). FASTEM-2 needs surface skin temperature, observation zenith angle, frequency, and wind speed at 10 m height as its main inputs.

4. ANALYSIS METHODS

Several criteria were used to match the AMSR observations and GFS forecast fields in space and time and to filter the observations for effects that may bias the results. Forecast fields were available only every 6 hours, therefore, all observations were collected within each model grid cell that were within ±90 min of the forecast time. AMSR liquid water path (LWP) products were used to identify “cloudy” (i.e., clouds containing liquid water only) AMSR pixels based on a threshold of 0.03 kgm^{-2}. This approach works well even in the presence of ice clouds, even optically thick ones, since these clouds are transparent at these microwave wavelengths. However, it should be noted that the LWP products contain positive systematic errors that vary geographically and seasonally (Greenwald and Christopher 2003), which may overestimate the degree of cloudiness in some cases. There was an additional criterion that at least 50% of the observations within a model grid cell must be cloudy-sky pixels.

The same LWP threshold of 0.03 kgm^{-2} was also applied to the model grid points to identify cloudy conditions in the forecasts. Only when both observations and model simulations satisfied all cloud-related criteria were the comparisons made. Additional filtering of the AMSR measurements included eliminating areas over land, excluding pixels above 55^o latitude to eliminate sea ice, using the AMSR product rain flags to minimize precipitation effects, and only using data with sunglint angles greater than 20^o (sunglint has a measurable impact on the lower frequency channels).

5. RESULTS

Comparison results for all 12 AMSR-E channels for December 2003 and April 2004 combined are shown in Figures 1 and 2. Overall, the agreement between the simulations and the AMSR measurements is quite good, however, there are general patterns in the differences that emerge. For example, the variability in the scatter (reflected in the root-mean-square error) is greater and the correlation is less for the horizontal polarization than for vertical polarization at all frequencies. This is a result of greater sensitivity of the brightness temperatures at horizontal polarization to changes in the atmosphere and ocean surface emissivity induced by wind action. Also, most of the systematic errors can be attributed to biases seen in the clear sky comparisons (results not shown) since surface emissivity plays a significant role in influencing top-of-atmosphere microwave brightness temperatures. The negative biases at 6.9 and 10.7 GHz (Figure 1) are most likely partially due to excluding capillary wave effects on the surface emissivity. Positive systematic errors at 23.8 GHz (Figure 2) are likely attributed to positive biases (~ 1 mm) in the model forecasts of total precipitable water. As might be expected, the frequencies most sensitive to water clouds, 36.5 and 89 GHz, have the largest rms errors; however, the biases are relatively small.

6. CONCLUSIONS

Initial comparisons between microwave brightness temperatures simulated from NOAA GFS model forecast fields and AMSR-E measurements over the oceans show good overall agreement. Since most of the microwave frequencies considered here are at least somewhat sensitive to the surface emissivity, these results imply that the surface emissivity model (FASTEM-2) is generally accurate, at least at these frequencies. At frequencies most sensitive to clouds, the relatively small biases between the simulations and measurements suggest that, on average, the GFS model does reasonably well at producing quantitative cloud liquid water contents. However, further study is needed to examine the differences in more detail and determine how they vary geographically. These results also demonstrate that such comparisons offer another means of validating forecast models beyond the traditional use of temperature and moisture observations.

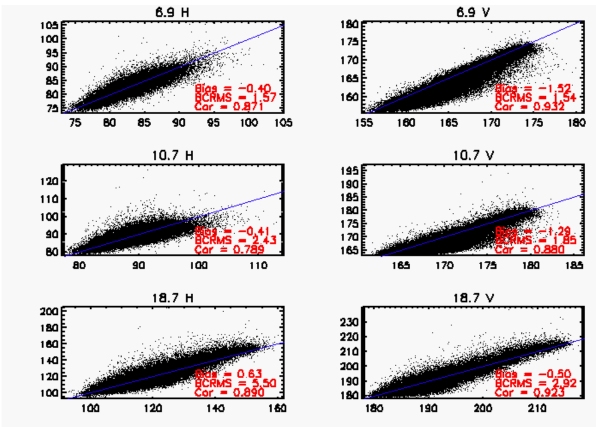

Fig. 1. Global forecast model simulations of microwave brightness temperatures versus AMSR-E channels 1-6 measurements showing results of statistical linear fits in red. Blue line is line of perfect agreement.

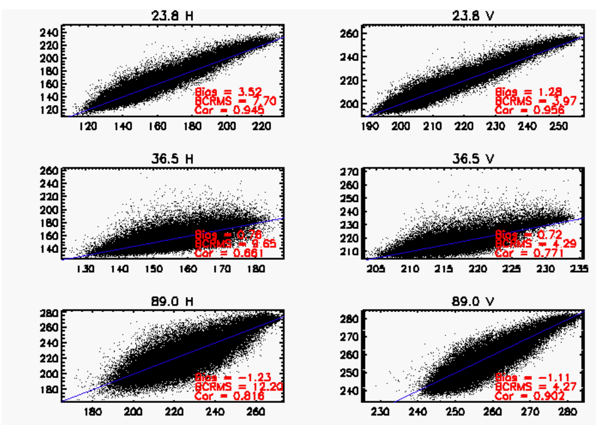

Fig. 2. As Fig. 1 but for AMSR-E channels 6-12 measurements.

7. ACKNOWLEDGMENTS

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