ARM Site Atmospheric State Best Estimates for AIRS Validation

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Introduction

The atmospheric infrared sounder (AIRS) is a high spectral resolution infrared sounder on the earth observing plan (EOS) Aqua platform. Temperature and water vapor profile retrievals from AIRS are expected to have very high accuracy; therefore, observations from high-quality ground sites are required for detailed validation of the products. This paper presents atmospheric state and surface property "best estimates" constructed from the Atmospheric Radiation Measurement (ARM) site observations at the Aqua overpass times and resulting comparisons to the AIRS radiance spectra and preliminary retrieved profiles.

Atmospheric Infrared Sounder

The AIRS, the advanced microwave sounding unit (AMSU), and the humidity sounder for Brazil (HSB) form an integrated cross-track scanning temperature and humidity sounding system on the EOS Aqua satellite. AIRS is an infrared spectroradiometer covering the 3.7 to 15.4-μm spectral range with 2378 spectral channels. AMSU is a microwave radiometer operating between 23 and 89 GHz with 15 channels. HSB is a microwave radiometer that makes measurements between 150 and 190 GHz with four channels. In addition to supporting National Aeronautics Space Administration's (NASA's) interest in process study and climate research, AIRS is the first hyperspectral infrared radiometer designed to support the operational requirements for medium-range weather forecasting of National Oceanic and Atmospheric Administration's (NOAA's) National Centers for Environmental Prediction and other numerical weather forecasting centers. AIRS/AMSU/HSB is expected to achieve global retrieval accuracy of better than 1K in the lower troposphere under clear and partly cloudy conditions. Aumann (2003) presents a thorough overview of the AIRS/AMSU/HSB science objectives, data products, retrieval algorithms, and the ground-data processing concepts.

Extensive evaluation and characterization studies of the AIRS Level 1 B (geolocated-calibrated radiances) have been conducted since the first AIRS science data was collected on June 14, 2002, and AIRS performance (noise) and calibration accuracies are exceptionally good. Many new uses of the high spectral resolution data are being realized on a global scale. AIRS Level 1 B data is now publicly available from the Goddard Distributed Active Archive Center (DAAC) (http://daac.gsfc.nasa.gov/data/datapool). Currently, a variety of validation efforts both within the ARM science team (Tobin 2003) and led by independent investigators are being conducted (Fetzer 2003). Particular studies include detailed characterization of clear-sky radiance biases with respect to the forward models (Strow 2003), and atmospheric profile retrieval algorithm refinement.

Particularly relevant to this study are biases that are due to calibration uncertainties in the AIRS radiances. Characterization of the AIRS radiometric and spectral calibration is required when assessing observed minus calculated spectra, and a number of studies have recently been conducted to assess the radiometric accuracy of AIRS Earth scene spectra (sea-surface temperature [SST] comparisons, buoy temperatures, geostationary operational environmental satellite [GOES] comparisons, moderate-resolution imaging spectroradiometer [MODIS] comparisons…). This paper includes a particularly critical assessment which involves comparison of the AIRS high spectral resolution radiances with collocated high spectral resolution radiances measured with the high altitude aircraft-based scanning high-resolution interferometer spectrometer (HIS). Two cases have been analyzed in detail to date: a clear-sky case over the ARM Southern Great Plains (SGP) site on November 16, 2002, as part of the ARM unmanned aerospace vehicle (UAV) campaign, and a clear-sky case over the Gulf of Mexico as part of the Texas-2002 Aqua Level 1B validation campaign. Comparisons of the Scanning-HIS and AIRS spectra for both cases are shown in Figure 1. Differences in sensor spectral resolution and sampling, spatial resolution and sampling, and platform altitudes are accounted for in the analysis technique. For both cases, in general, we find excellent agreement (of order 0.1K) between the AIRS and Scanning-HIS observed spectra (Revercomb 2003).

ARM Site Atmospheric State Best Estimate Products

The high accuracy retrieval goals of AIRS (1K root mean square [rms] in 1 km layers below 100 mbar for temperature, 10% rms in 2 km layers below 100 mbar for water vapor, 0.5K for surface skin temperature), combined with the large temporal and spatial variability of the atmosphere and certain difficulties in making accurate measurements of the atmospheric state, necessitates careful and detailed validation using well-characterized ground-based sites. As part of ongoing AIRS Science Team efforts and a collaborative effort between NASA and ARM, data from various ARM and other observations are used to create best estimates of the atmospheric state at the Aqua overpass times. This draws upon previous and ongoing studies and careful characterization and knowledge of the ARM data streams (Lesht 2002; Turner 2003; Revercomb 2003; Tobin 2003; Milosovich 2002; Wang 2002). For some overpasses that meet specific view-angle and weather related requirements, dedicated radiosondes are launched just before (~45 minutes) and at the overpass time. For all overpasses, the basic methodology for producing the best estimate profiles is (1) Obtain necessary data including microwave radiometer (MWR), sondes, atmospheric emitted radiance interferometer plus (AERI+) retrievals, ground- and tower-based met data, rapid update cycle (RUC)-2 fields, GOES retrievals, and ceiliometer data.
(2) Apply MWR percipitable water vapor (PWV) scaling to the sondes, AERI+, and RUC-2 water vapor fields.

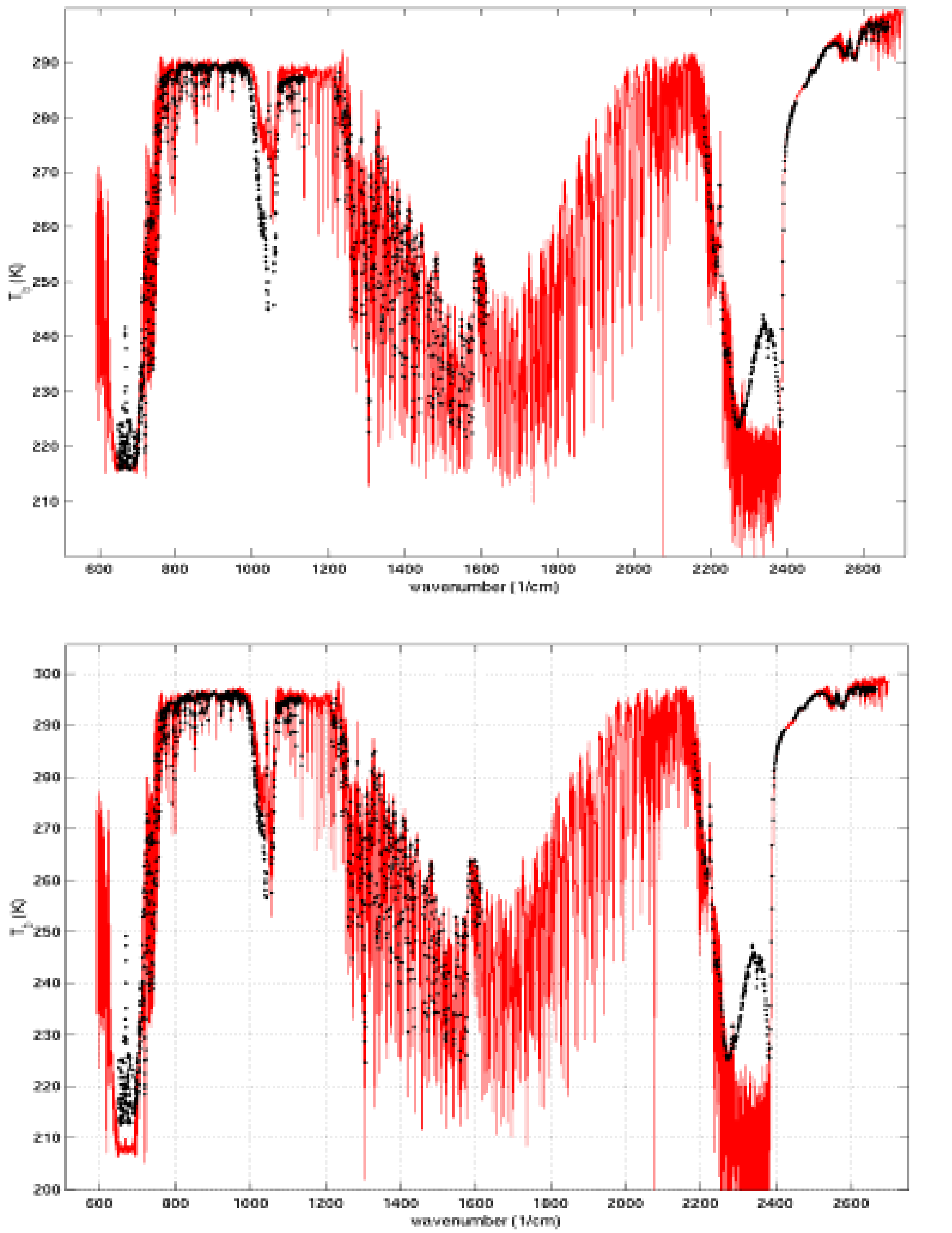

Figure 1. Comparisons of Scanning-HIS (red) and AIRS (black) clear-sky brightness temperature spectra for an ARM SGP CF site underflight on November 16, 2002, as part of the ARM UAV campaign (top panel), and a Gulf of Mexico underflight on November 21, 2002, as part of the Texas-2002 Aqua Level 1B validation campaign (bottom panel). To obtain more quantitative comparisons, an analysis technique which compares observed and calculated spectra for each instrument (e.g., $[AIRS_{obs}-AIRS_{calc}] - [SHIS_{obs}-SHIS_{calc}]$) is used to minimize effects due to different platform altitudes, different sensor resolution and sampling, and different spatial resolution and sampling.

(3) Use relative changes in continuous AERI+ retrievals to interpolate the sonde measurements to the exact overpass time for each level in the profile. (4) Compute a weighted average of profiles obtained before and after the overpass time. (5) Use RUC-2 and/or GOES retrievals to account for large-scale spatial gradients and the location of the ARM site within the AMSU field of view (FOV). Estimates of the spectral surface emissivity (Knuteson et al. 2003) and local skin temperatures are also constructed. These products and auxiliary images/plots are made available on the web for each overpass. An example case is shown in Figure 2.

AIRS Radiance Bias (Observed minus Calculated) Estimates

Accurate characterization of observed versus calculated clear-sky top of the atmosphere (TOA) radiance is required for the retrieval process and for various climate applications. (This can be thought of as the upwelling TOA analogy of the downwelling, ground-based AERI Line-By-Line Radiative Transfer Model Quality Measurement Experiment). This involves consideration of uncertainties in the AIRS radiances, in the underlying physics and parameterizations of the radiative transfer algorithm, and in the atmospheric profiles used as input to the calculations. The ARM best estimate products (and products from similar ARM-like sites) are proving to be invaluable for this effort. Bias estimates from the ARM site are compared to estimates derived from global ocean nighttime radiosondes and using European Centre for Medium-Range Weather Forecasts analysis fields as input to the forward model. Differences in both the mean and variability of the results, particularly regarding spectral channels sensitive to boundary layer and upper level water vapor, are attributed to better temporal/spatial collocation and accuracy of the ARM site profiles. Similar analyses are under way to assess AIRS cloud cleared radiances. The best estimate profiles are also currently being used to evaluate the AIRS retrievals.

Ongoing and Future Work

Future work related to development of the ARM site atmospheric state best estimates includes:

- Improved identification of clear-sky cases using AIRS, MODIS, GOES, and ARM data (Frey 2003)
- Improved land surface emissivity estimates, including vegetation fraction estimates
- Improved uncertainty estimates, particularly regarding RS-90 upper level water vapor
- Better characterization of large-scale spatial gradients at the North Slope of Alaska and Tropical Western Pacific sites.

Ongoing applications of the best estimate products include:

- Continued characterization of AIRS observed and calculated clear-sky radiances
- Validation of AIRS retrieved profiles
- Validation of Aqua MODIS retrieved profiles
- Planning for application to future advanced sensors including GIFTS (Tobin 2001) and CrIS.

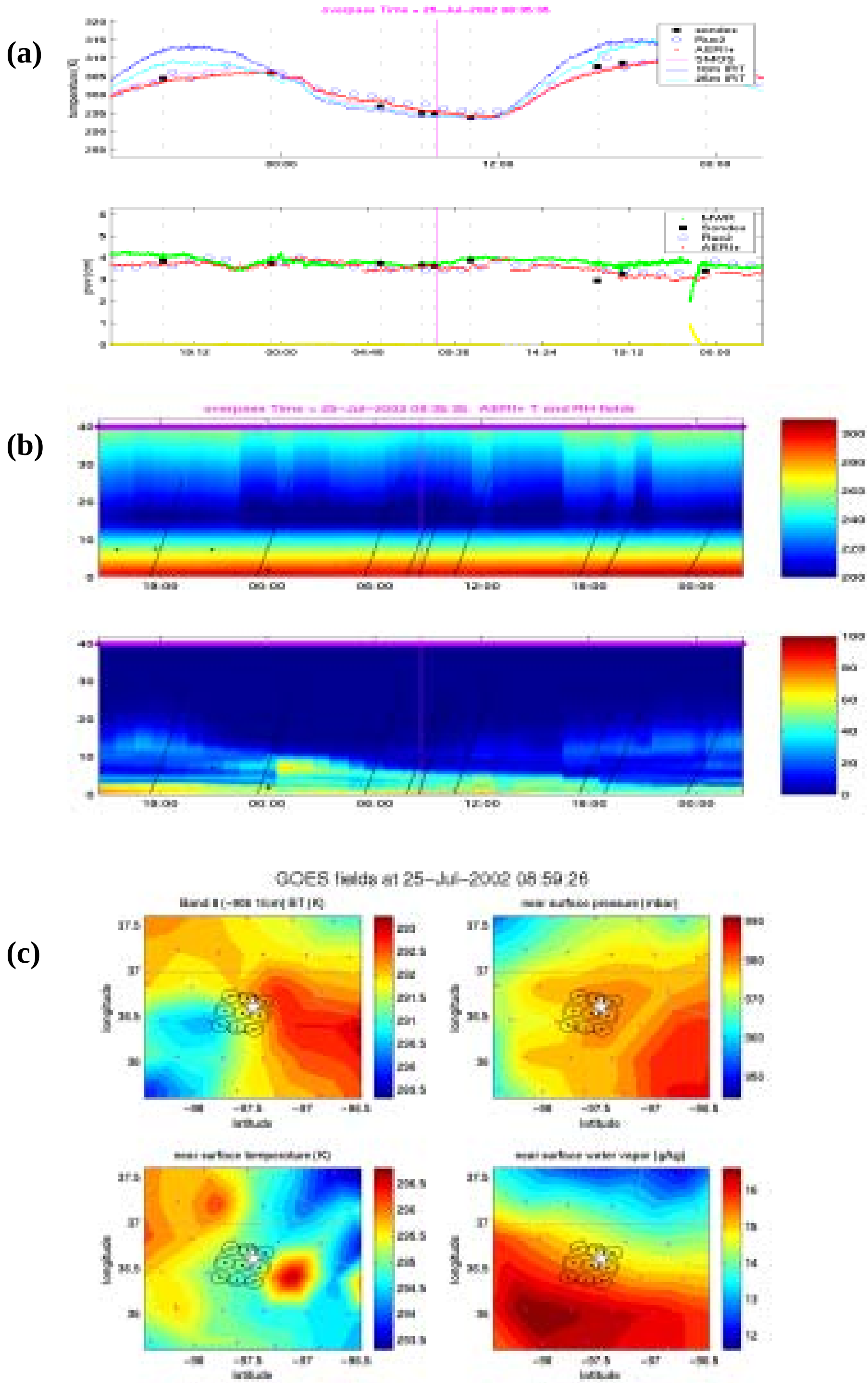

Figure 2. This figure illustrates some basic steps in construction the ARM atmospheric state best estimate profiles for an AIRS overpass on July 25, 2002, at 08:59 Universal Time Coordinates. Panel (a) simply shows the time series of various ground based and radiosonde measurements; panel (b) shows radiosonde trajectories overlaid on AERI+ fields, which are used to interpolate the sonde profiles to the overpass time; and panel (c) shows large scale spatial gradients depicted by GOES retrievals and the location of the ARM site within the AIRS and AMSU fields of view.

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