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Over Ocean Atmopheric Validation of AIRS Derived Temperature/Moisture Profiles

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1. INTRODUCTION

A suite of in situ and remote sensing meteorological instrumentation has been in continuous operation on the cruise ship Explorer of the Seas based in Miami, Florida. A similar suite of observations was also deployed in the tropical North Atlantic Ocean during the NOAA sponsored 2004 Aerosol and Ocean Science Expedition (AEROSE) mission. The instrumentation includes calibrated research grade radiosonde launches for tropospheric temperature and moisture profiles and Marine Atmospheric Emitted Radiance Interferometer (M-AERI) downwelling radiance measurements for radiance validation. The M-AERI also provides highly accurate measurements of ocean surface skin temperature and high temporal resolution planetary boundary layer retrievals of temperature and moisture. This data set is being used to validate AIRS derived thermodynamic profiles during Aqua overpass times. Preliminary validation results between the shipborne meteorological observations and AIRS thermodynamic datasets are shown within this paper for clear sky conditions from 2002 – 2004 within the Caribbean and Atlantic areas.

2. SHIPBORNE DATA DESCRIPTION

The Royal Caribbean cruise ship, Explorer of the Seas, has “east” and “west” tracks (Fig. 1) that are followed on alternate weeks. The ship has a large suite of onboard meteorological instrumentation including the capability to launch radiosondes, M-AERI instrument, ceilometer, aerosol instrumentation, and wind profiler. Radiosondes were launched during predicted EOS AIRS overpasses for validation purposes. A list of coincident AIRS overpass times and Explorer of the Seas locations was generated and a subset selected by 1) accepting only RS-90 Vaisala radiosonde launches within one hour of the AIRS overpass, and 2) checking for the clearest available sky conditions using AIRS measurements in the atmospheric spectral windows. A set of 84 coincident radiosonde and AIRS overpass cases were selected for September 2002 - July 2004, and these were used for the validation of retrieved AIRS L2 100-level temperature and humidity profiles.

Figure 1: Sample image of cloud top pressure, derived using GOES-12 Imager data.

Another supplemental data set was provided by the AEROSE experiment conducted onboard the NOAA Ship Ronald H. Brown (RHB) in the tropical North Atlantic Ocean from 29 February to 26 March 2004 in collaboration with the NOAA Center for Atmospheric Sciences (NCAS) at Howard University. The RHB set out from Bridgetown, Barbados traveling eastward toward Africa. Near the African coast, the ship turned north

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toward the Canary Islands. After a port-of-call in Las Palmas de Gran Canaria, the ship returned to San Juan, Puerto Rico on 26 March. AEROSE provided unique complementary dataset of tropospheric temperature and moisture information containing tropospheric aerosols during several significant Saharan dust events. Atmospheric and oceanographic measurements were acquired from a number of in situ and remote sensing sensors. Special AIRS satellite validation radiosonde launches were conducted providing 41 radiosonde/AIRS overpass matches during the AEROSE time period.

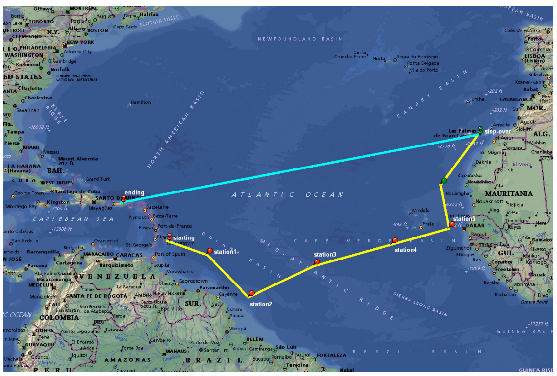

Figure 2: Ship track of the RHB during the AEROSE deployment from 29 February – 26 March 2004.

3. THERMODYNAMIC PROFILE METHODOLOGY

AIRS 12μm (831 cm^{-1}) radiance scenes are shown in Figure 3 for a subset of Explorer of the Sea cases ranging from cloudy pixels (blue) to clear pixels (red), with the Explorer-AIRS match location shown as a star. Examples of individual plots of radiosonde and AIRS temperature and moisture profiles (V 3.0.08) are shown below in Figure 4. The radiosonde profiles were interpolated to the levels required for the fast radiative transfer model. The process of computing the AIRS retrieval performance statistics is consistent with the approach used by Susskind et al. (2003) and Tobin et al. (2005) in assessing the retrieval performance using simulated data. For each profile, the Explorer radiosonde profile is converted to layer quantities (layer mean temperatures and water vapor layer amounts in units of molecules/cm2) consistent with the AIRS fixed 101 pressure level grid, and the lowest valid layer values are adjusted to account for the fractional layer above the true surface. The AIRS 100 "pseudo-level" retrieval profiles provided in the Level 2 "support" product files are also converted to layer values (for temperature) and the bottom fractional layer values above the surface are similarly adjusted. For the temperature profile comparisons, the radiosonde and AIRS profiles are degraded to ~1 km vertical layer values, and mean differences (AIRS minus radiosonde) and RMS differences are then computed for each layer. For water vapor comparisons, the profiles are degraded to ~2 km vertical layer values, and mean percent differences (100 (AIRS-radiosonde)/radiosonde) and RMS percent differences are computed for each layer.

For water vapor, it should be noted that the mean percent differences (i.e. biases) and RMS percent differences are computed using the convention used in reporting AIRS retrieval statistics (e.g. Susskind et al. 2003), where water vapor layer amounts are used to weight the observed percent differences. The weighting is done independently for each ~2-km thick layer. For ensembles with higher water vapor variability, this process has the effect of down-weighting percent errors for cases with lower water vapor amounts. The weights are normalized for the ensemble, and the weighting therefore has lower impact on the results for ensembles with lower water vapor variability (e.g. in the tropics and in the upper troposphere).

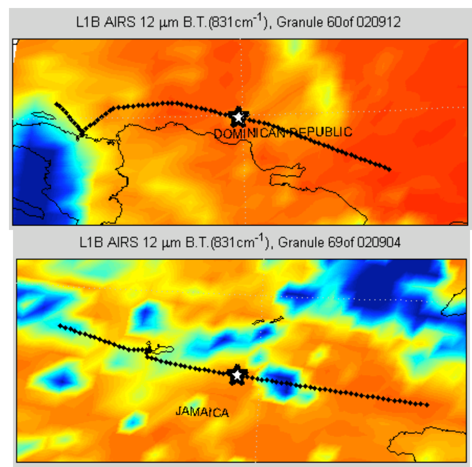

Figure 3: Sample image of cloud top height from the ASAP global cloud product.

The requirement accuracy retrieval goals of AIRS are 1 K RMS in 1 km layers below 100 mbar for air temperature and 10% RMS in 2 km layers below 100 mbar for water vapor concentration. Computation of mean bias and rms statistics is indicated for 100-level and 1km temperature layer averages in Figure 5. The temperature statistics are within the 1 K temperature rms requirement for mean 1 km layer averages except at the surface and above 300 mb. The mean bias generally oscillates around 0 K although dramatically increases above 200mb. This is probably a function of the strong tropopause temperature gradient and ECMWF data use to fill in missing radiosonde data above 200mb for some profiles. Figure 6 shows the same statistics for water vapor except that the mean layer average has been increased to 2km (requirement definition of AIRS water vapor profile validation). The 10% rms requirement for water vapor is exceeded above 700 hPa. This may be due to a variety of reasons, such as insufficient clear sky FOV from AIRS.

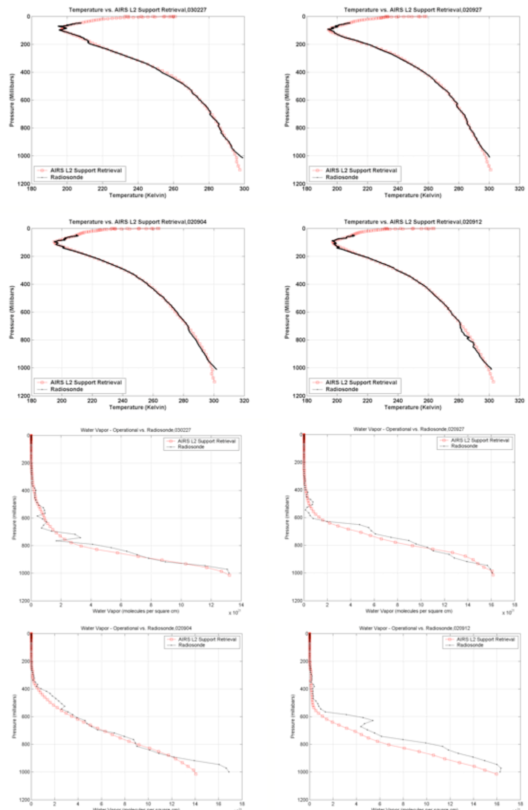

Figure 4: (top 4 panels) Examples of radiosonde vs AIRS temperature profiles. (bottom 4 panels) Examples of radiosonde vs AIRS moisture profiles in molecules/cm^2 vs pressure.

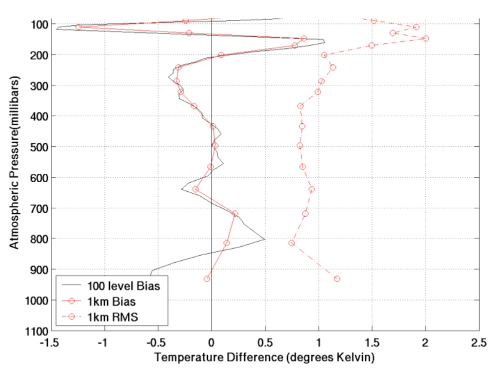

Figure 5: A plot of 100-level and mean layer derived bias and rms temperature difference between AIRS and radiosondes for 84 profile matches from September 2002 – July 2004.

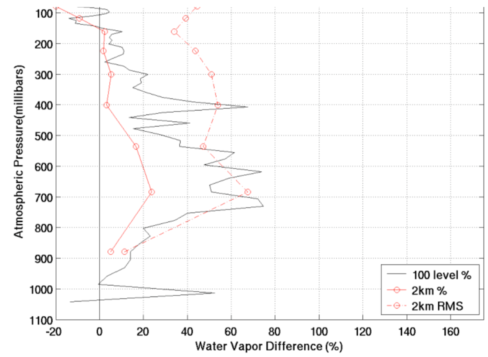

Figure 6: A plot of 100-level and mean layer derived bias and rms water vapor difference between AIRS and radiosondes for 84 profile matches from September 2002 – July 2004.

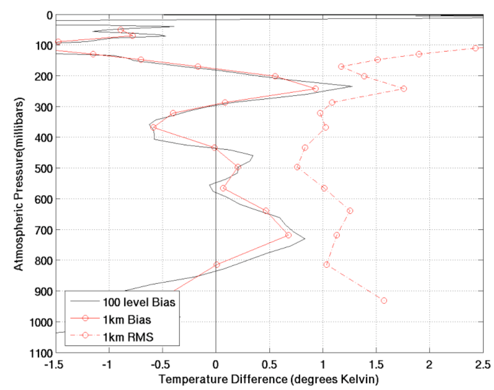

Figure 7: A plot of 100-level and mean layer derived bias and rms temperature difference between AIRS and radiosondes for 42 profile matches from AEROSE experiment.

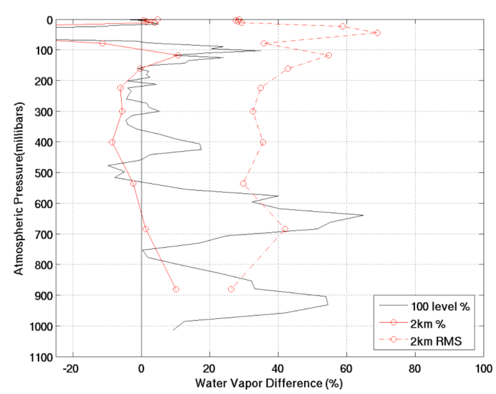

Figure 8: A plot of 100-level and mean layer derived bias and rms water vapor difference between AIRS and radiosondes for 42 profile matches from AEROSE experiment.

AEROSE radiosonde vs AIRS profiles match statistics are presented in figures 7 and 8.

The statistics indicate larger differences than the Explorer of the Seas data set. This is primarily due to more challenging thermodynamic variability such as strong vertical transitions in water vapor structure due to the Saharan dust layer presence within the sampled data set (Nalli et al. 2005).

4. SUMMARY

A set of 84 clear coincident oceanic Royal Caribbean Explorer of the Seas and 42 AEROSE radiosonde - AIRS overpass matches have been selected to provide preliminary AIRS thermodynamic validation. The analysis indicates consistent statistical validation within Tobin et al. 2005 and Szczodak 2005. Further validation will be conducted in radiance space to remove any cloud contaminated AIRS profiler outliers that exist within the above data set matches. An evaluation of line-by-line radiance calculations vs clear/cloud-cleared AIRS radiances will also be conducted.

5. ACKNOWLEDGEMENTS

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