VALIDATION OF TEMPERATURE PROFILE ENVIRONMENTAL DATA RECORDS (EDRs) FROM THE CROSS-TRACK INFRARED MICROWAVE SOUNDING SUITE (CrIMSS) USING COSMIC DRY TEMPERATURE PROFILES

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1. INTRODUCTION

Atmospheric temperature is an important input to numerical weather prediction (NWP) models used to provide medium range weather forecasts. Traditionally the temperature profiles used in NWP data assimilation have come from the global WMO network of radiosonde launch sites. The distribution of these sites is biased toward land areas and concentrated mainly in developed countries like the continental United States and Europe. Since the 1970's, the use of satellites to provide temperature information on the atmosphere has taken on increasing importance. Microwave sounders in particular have been successfully integrated into operational weather forecast data assimilation system. The infrared sensors on the NOAA series of satellites, ATOVS, have also been assimilated with an emphasis on observed channels that peak high above the surface and clouds. More recently, radio occultation has been used to provide temperature profile information in the stratosphere and upper troposphere (Kursinski et al. 1997; Healy and Eyre 2000). High spectral resolution infrared sounders represent the latest contribution to atmospheric temperature sounding (Susskind et al. 2003, Smith and Weisz 2012). The synergy of high vertical resolution temperature sounding from GPS RO and high vertical resolution moisture sounding from infrared spectra has also shown potential (Borbas et al. 2003).

This paper presents a methodology for validating the measurements from the Cross-Track Infrared Microwave Sounding Suite (CrIMSS), which uses combined observations from the Advanced Technology Microwave Sounder (ATMS) and the hyperspectral infrared Cross-track Infrared Sounder (CrIS) on the Suomi NPP satellite, the first satellite of the newly created U.S. JPSS program (http://npp.gsfc.nasa.gov/science/scie-ncedocuments/2013-01/474-00056_RevABase-line.pdf). The atmospheric vertical temperature profiles (AVTPs) from the CrIMSS operational product are compared to temperature profiles obtained from radio occultation (RO) from the COSMIC GPS RO network (Rocken et al.; 2000). Mean bias, RMS, and standard deviation profile statistics are presented for global and 30 degree latitude zones for selected time periods in 2012. Similar validation statistics using AIRS and COSMIC profile matchups were created for the same space and time periods. The matchup methodology has been previously evaluated comparing a ray path method to the closest IR sounding (Feltz et al. 2012). In this paper, a comparison is made of the CrIMSS EDR performance relative to NASA AIRS L2 v5 product using the COSMIC GPS RO network as a common reference. This evaluation is in support of the NOAA calibration/validation activities for the checkout of the CrIMSS EDRs.

2. DATA

COSMIC data was obtained from the COSMIC Data Analysis and Archival Center-CDAAC (http://cosmic-io.cosmic.ucar.edu/cdaac/products.html). The product used was the COSMIC real-time version 2010.0001 named 'atmPrf', which contains dry temperature profile measurements. The vertical resolution varies between 0.1 and 1 km depending on altitude. A typical COSMIC profile is obtained in about 100 seconds with over 3,000 vertical samples. The netcdf files contain time in units of GPS seconds, which are about 15 seconds ahead of UTC. The netcdf files also contain azimuth angle of the occultation plane at the tangent. The angle is measured between North and the GPS direction of the ray path. A quality control flag is included in the GPS RO netcdf files. For an example day, 19 October 2007, the percentage of GPS profiles marked bad was 2.5%. These bad profiles are excluded from the analysis.

The CrIMSS 42/22 layer EDR IDPS product used in the study was obtained from the NOAA CLASS system. The data for time periods prior to mid October (for the Oct. 1st to 10th analysis) was version Mx5.3 and (for the Oct 22nd to 31st analysis) was version Mx6.3. A CrIMSS aggregated file contains about 8 minutes of data. Quality control was applied using the overall retrieval quality flag—non-converged retrievals were not included in the analysis.

AIRS data was provided by the Goddard Earth Sciences Data and Information Services Center (GESDISC) at http://disc.sci.gsfc.nasa.gov/AIRS-/dataholdings/by-data-product/data_products.-shtml. The Support Product used was Level 2 version 5 AIRX2SUP, which uses both AIRS IR and AMSU observations and provides temperature measurements at 101 levels. Each AIRS granule contains about 6 minutes of data, 45 scan lines of L2 soundings. The nominal size of an AIRS L2 retrieval field of view is 45 km (3x3 L1B), while the vertical resolution varies between 1 and 5 km depending on altitude. A latitude-longitude bounding box for each AIRS granule was extracted from the XML files obtained from the Goddard data archive. Along with latitude, longitude, time, temperature, and pressure, the AIRS L2 data file contains a quality flag, PBest, which was used to exclude profile levels with pressures greater than PBest.

3. METHODOLOGY

The matchups used in this study have the GPS RO profile occurrence within one hour of the beginning time of the corresponding IR granule. The latitude and longitude of the perigee at the occultation point of the COSMIC profile must be collocated within the bounding box of the IR granule. Comparisons are made between the GPS RO temperature profile, the closest single IR profile, the average IR profile within a circle of diameter equal to the nominal GPS horizontal scale, and the average IR profile computed along the GPS RO ray path trajectory at each altitude level. Figure 1 illustrates the three profile comparison methods with the circular and closest profiles calculated with reference to the GPS RO 100mb latitude and longitude. Figure 2 depicts the three matchup methods and the ray path vector on horizontal maps of the 30mb, 100 mb, and 300mb levels.

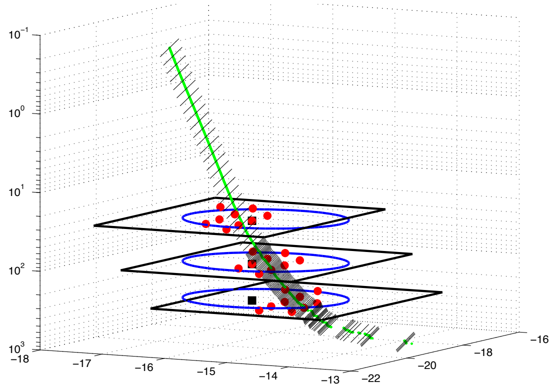


Figure 1. Illustration of the closest (black squares), circular (blue circle), and ray path (red dots) averaged IR profiles on the 30mb, 100mb, and 300mb levels overlaid on the GPS RO profile (green) and ray path (thin black lines) with a z-axis of pressure in mb.

In order to determine the ray path averaged IR profile, calculations are done to create an average temperature value at each IR sounding pressure level. The GPS azimuth angle closest in pressure to the IR sounding level is selected and a horizontal ray vector is calculated. Then, the IR profiles within one-half the distance of the largest FOV diameter to the ray vector are averaged to obtain that level's ray path averaged IR temperature value. One-half of the largest FOV diameter is approximately 50 km for AIRS and 70 km for CrIMSS at slant view angles.

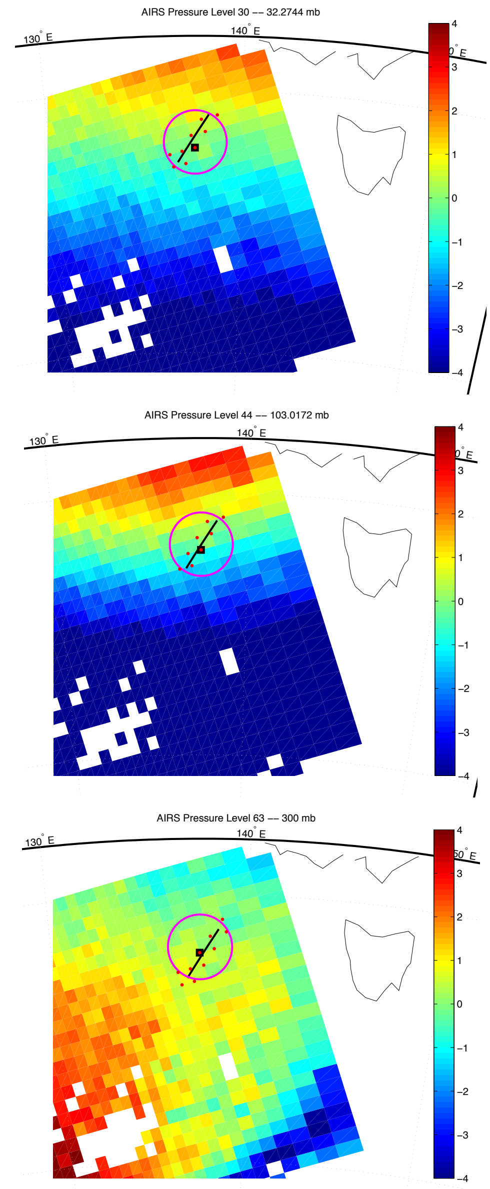


Figure 2. Top to bottom, AIRS a) 32.3 mb (level 30), b) 103 mb (level 44) and c) 300 mb (level 63) temperatures differenced from the AIRS closest profile temperature (K) showing the pixels representing the closest profile (black square), circular averaged profile radius (within magenta circle), ray averaged profiles (red dots), and the COSMIC RO ray path (black line) on 19 October 2007 for granule 052 (around 05:12 UTC).

To facilitate the GPS RO and IR profile comparison, both CrIMSS and COSMIC temperature profiles are computed at the AIRS 101 levels using nearest neighbor linear interpolation. Statistical analysis is performed on global and zonal matchup sets to compute mean bias, RMS, and standard deviation for each AIRS pressure level. Figure 3 compares a single GPS RO profile with a coincident closest, circular averaged, and ray path averaged AIRS profile. Note the higher vertical structure apparent in the GPS profile. The deviation of AIRS and COSMIC for altitudes below 500 mb is due to contamination of the GPS RO dry temperature profile by water vapor (Kursinski et al. 1997, Anthes et al. 2008).

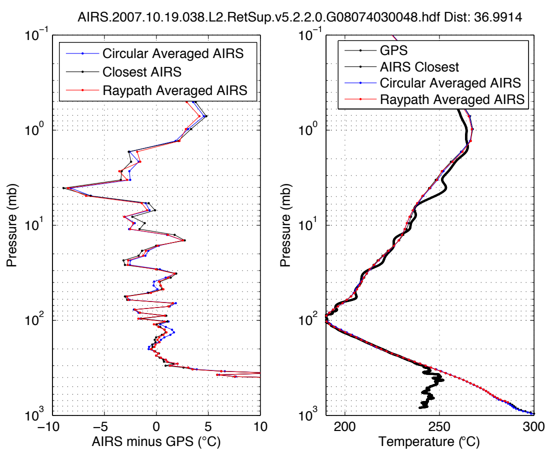


Figure 3. Comparison of a COSMIC RO temperature profile to the closest, circular averaged, and ray path averaged IR profiles; overlay (right) and as a difference profile (left) from 19 October 2007 at 03:50 UTC.

4. RESULTS

In order to assess a CrIMSS software version update in the JPSS operational production system (IDPS) on October 15, 2012, the CrIMSS minus COSMIC statistics were compared for the first and last ten days (October 1st to 10th and October 22nd to 31st respectively) of the month of October 2012. For comparison, the AIRS minus COSMIC statistics were also computed for the October 22-31 time period.

Following Yunck et al. 2009, we compute the mean bias, RMS, and standard deviation of difference profiles for COSMIC GPS RO and IR matchups for Global, Arctic, Northern Mid-Latitude, Tropical, Southern Mid-Latitude, and Antarctic zones. Figure 4 is an overlay of the 10-day period global statistics for the two different product versions. Note that the magnitude of the global bias is significantly improved in the updated version.

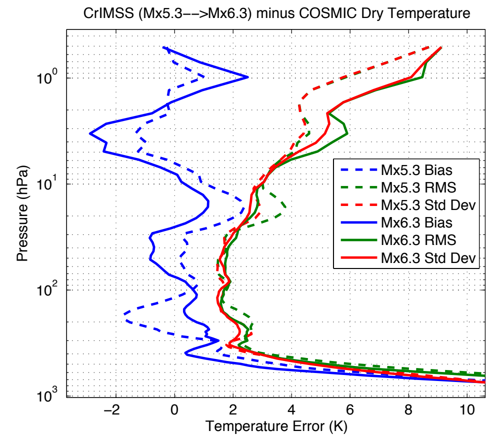


Figure 4. Global bias and standard deviation of CrIMSS minus COSMIC statistics for the ten day period Oct 1-10 (Mx5.3) compared to a ten day period Oct 22-31 (Mx6.3) following the IDPS version update on 15 October 2012.

A more detailed assessment of the version update change is shown in Figure 5 where zonal statistics for CrIMSS relative to the COSMIC network are compared to AIRS retrievals for the same time period.

The CrIMSS version update, illustrated in the change from version 5.3 to 6.3, included an update to the ATMS cross-track scan bias based on empirical evaluation against ECMWF analysis fields. One of the important aspects of evaluation of CrIMSS products against the COSMIC GPS network is that the COSMIC dry temperature is independent of NWP model analysis. The traceability of the COSMIC GPS RO to the SI time standard also provides independence from the temperature standard used in CrIS calibration.

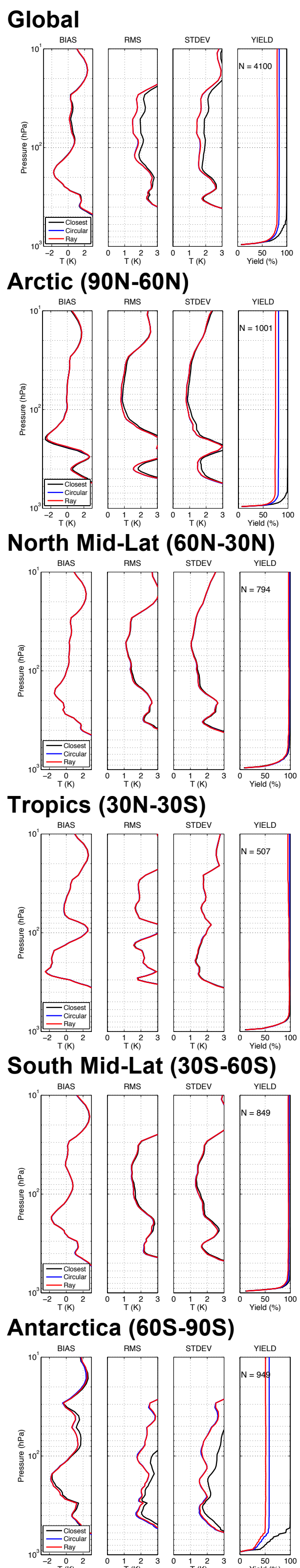
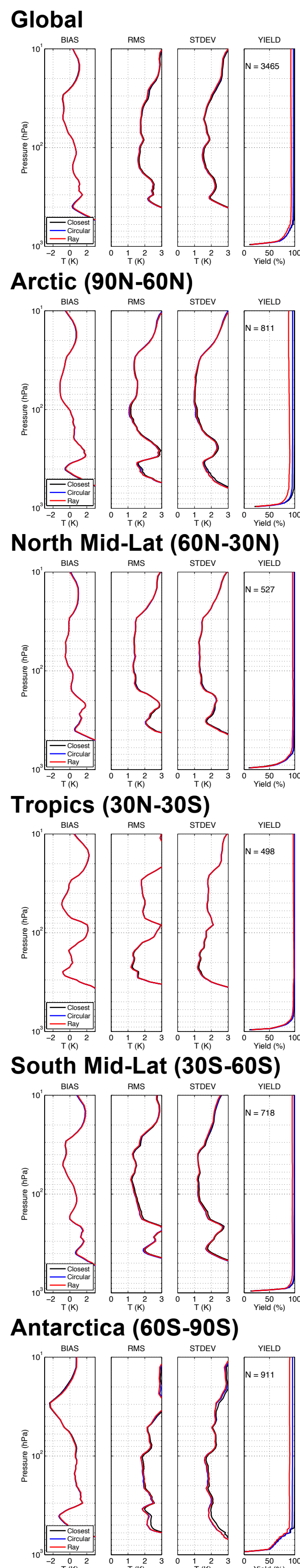
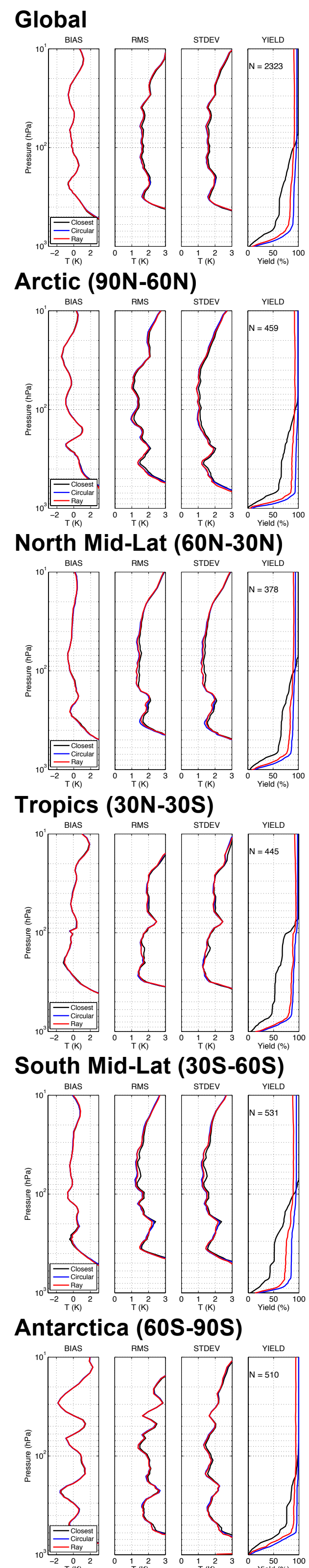


Figure 5. CrIMSS–COSMIC Oct 1st –10th 2012



CrIMSS–COSMIC Oct 22nd–31st 2012



AIRS–COSMIC Oct 22nd–31st 2012

5. CONCLUSIONS

A methodology has been developed for validation of CrIMSS AVTP in the upper troposphere and lower stratosphere using GPS radio occultation. In this methodology, matchups between the GPS RO COSMIC network dry temperature profiles and CrIMSS granules within a one hour time difference are found. By using a ray path method, the GPS RO horizontal resolution of 300 km is accounted for as a function of height.

This methodology is shown to be useful for validating CrIMSS products, even during the beta product period, and has been used to evaluate a CrIMSS software version update that occurred on 15 October 2012. The same methodology has been applied to AIRS v5 retrievals to provide a relative comparison.

Future work includes the application of the temperature averaging kernel to the COSMIC minus IR profile differences to remove vertical structure higher than the theoretical IR resolution. Application of this method to CrIMSS EDR product validation will continue during the validation phase.

Acknowledgment

We acknowledge the NPSO (Taiwan's National Space Organization) and UCAR (University Center for Atmospheric Research) for access to the COSMIC data. The AIRS Level 2 data products were accessed through the Goddard Space Flight Center (GSFC) Data Archive. CrIMSS data was obtained from the NOAA CLASS archive. This work was supported under JPSS NOAA grant NA10NES4400013.

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