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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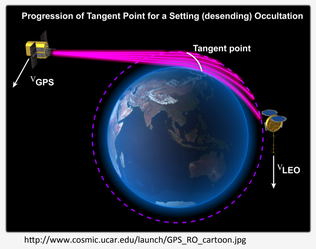
Abstract

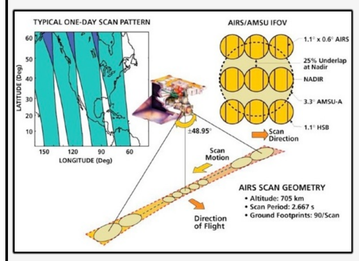
This paper presents a methodology for validating the measurements from the Cross-Track Infrared Microwave Sounding Suite (CrIMSS) using combined observations from the Advanced Technology Microwave Sounder (ATMS) and the hyperspectral infrared Cross-track Infrared Sounder (CrIS) on the Suomi NPP satellite, the first satellite of the newly created U.S. JPSS program. 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. In particular, bias, RMS, and standard deviation profile statistics will be presented for global and 30 degree latitude zones for selected time periods in 2012. Similar validation statistics using AIRS and COSMIC profile matchups will be created for the same space and time periods. The matchup methodology was used to evaluate the dependence of the ray path averaging on the statistical results by comparing the closest single AIRS profile, to the average along a ray path, and to the average of a circle of radius equal to the horizontal ray path length through the atmosphere. The optimal method of comparison between GPS RO and IR soundings from the Suomi NPP satellite will be presented. A comparison will be made of CrIMSS EDR performance relative to NASA AIRS L2 product in order to assess the CrIMSS product accuracy. This evaluation is in support of the NOAA NESDIS calibration/validation activities for the checkout of the Suomi NPP satellite.

Satellite Data

The COSMIC Data Analysis and Archival Center-CDAAC (http://cosmic-io.cosmic.ucar.edu/cdaac/products.html) was used to obtain COSMIC data. The product used for the results shown was the real-time atmPrf 'dry temperature'. A typical COSMIC profile is obtained in about 100 seconds with over 3,000 vertical samples. 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.



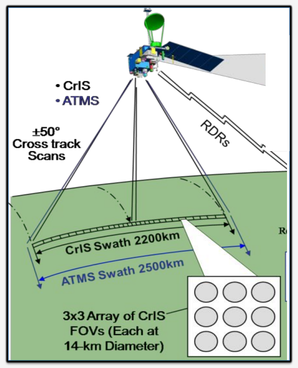
http://www.cosmic.ucar.edu/launch/GPS_RO_cartoon.jpg



AIRS Scan Geometry
with 30 cross track soundings
between ±49° and a horizontal
resolution of about 45 km

Onboard the NASA Aqua satellite, AIRS looks toward the ground through a cross-track rotary scan mirror which provides +/-49.5 degrees (from nadir) ground coverage along with views to cold space and on-board spectral and radiometric calibration sources every scan cycle. For each of the ninety ground footprints observed each scan, one spectrum with all 2378 spectral samples is obtained. The AIRS IR spatial resolution is 13.5 km at nadir from the 705.3 km orbit. The AIRS Level 2 products contain atmospheric temperature and moisture profiles from about 1 mb down to the surface with a horizontal resolution of about 45 km and provide nearly complete daily global coverage in ascending and descending modes. The version 5 support product AIRX2SUP was used in this analysis.

The Crosstrack Infrared Sounder (CrIS) and the advanced Technology Microwave Sounder (ATMS) together represent the latest addition to a long series of atmospheric satellite sounders that originated in the late 1970's. CrIS is a hyperspectral sounder that will make it possible to continue the advancements of observations and research that started with the Atmospheric Infrared Sounder (AIRS) in 2002, and ATMS will similarly continue the series of observations that started with the Advanced Microwave Sounding Unit (AMSU) first launched by NOAA in 1998. The CrIMSS 42/22 layer EDR IDPS product used in the study was obtained from the NOAA CLASS system. The data used prior to mid October (for the Oct. 1st to 10th analysis) was Mx5.3 and after mid October (Oct 22nd -31st analysis and case study) was Mx6.3.



References

Anthes, R. A. et al., 2008: The COSMIC/FORMOSAT-3 mission: early results. Bull. Amer. Meteor. Soc., 89, 313–333. doi: http://dx.doi.org/10.1175/BAMS-89-3-313.
Borbas, E.,W. P. Menzel, J. Li, H. M. Woolf, 2003: Effects of GPS/RO refractivities on IR/MW retrievals, ITSC-13, Sainte Adele, Canada, 29 October - 4 November 2003.
Healy, S.B. and Eyre, J.R. 2000: Retrieving temperature, water vapour and surface pressure information from refractivity-index profiles derived by radio occultation: A simulation study. Q. J. R. Meteorol. Soc., 126, 1661-1683.
Kursinski, E.R., Hajj ,G.A., Schofield, J.T., Linfields, R.P. and Hardy, K.R. 1997: Observing Earth's atmosphere with radio occultation measurement using the Global Positioning System. J. Geophys. Res., 102, 23,429-23,465.
Tobin, D. C. et al., 2006: Atmospheric Radiation Measurement site atmospheric state best estimates for Atmospheric Infrared Sounder temperature and water vapor retrieval validation. J. Geophys. Res., 111, D09S14, doi:10.1029/2005JD006103.
Yunck et al., 2009: Use of radio occultation to evaluate atmospheric temperature data from spaceborne infrared sensors. Terr. Atmos. Ocean. Sci., Vol. 20, No. 1, 71-85.

Acknowledgments

We gratefully acknowledge the NPSO (Taiwan's National Space Organization) and UCAR (University Center for Atmospheric Research) for access to the COSMIC RO data. We would like to thank the Goddard Space Flight Center (GSFC) Data Archive for access to the AIRS Level 2 data products. This work was supported under JPSS NOAA grant NA10NES4400013.

Methodology

In this temperature profile matchup methodology, spatially and temporally coincident GPS RO profiles and IR granules were found. For each case, three matchup techniques were used for comparison and analyzed with the same statistical analysis. The closest profile, the circular averaged profile of a radius half the GPS RO horizontal resolution, and the ray-path averaged profile of AIRS data were computed. In order to investigate the effect of the horizontal resolution of the GPS RO, these three different approaches to creating an IR matchup profile were evaluated. The azimuth angle of the radio occultation for each COSMIC RO profile altitude was used to compute the horizontal extent of the nominal GPS RO horizontal resolution at each reported altitude level (Kursinski et al. 1997). Figure 1 below shows the spatial extent of a 135 km radius averaging circle on selected AIRS retrieval levels. Figure 2 to the right illustrates the closest, circular, and raypath methods as a 3D profile.

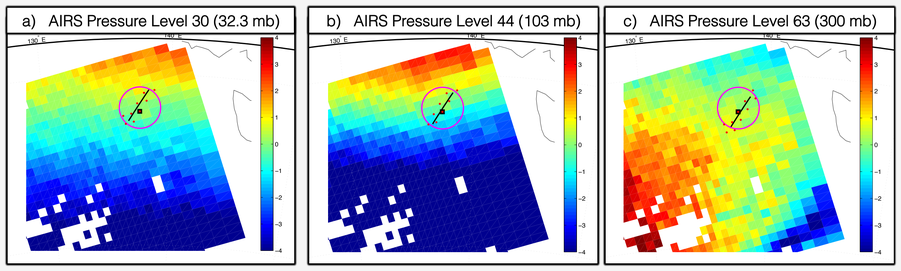


Figure 1. From left to right, AIRS a) 32.3 mb (AIRS Level 30), b)103 mb (AIRS Level 44) and c) 300 mb (AIRS Level 63) temperatures differenced from the AIRS closest profile temperature (K) showing the closest profile (black square), circular averaged profile radius (magenta circle), ray averaged profiles (red dots), and the COSMIC RO raypath (black line).

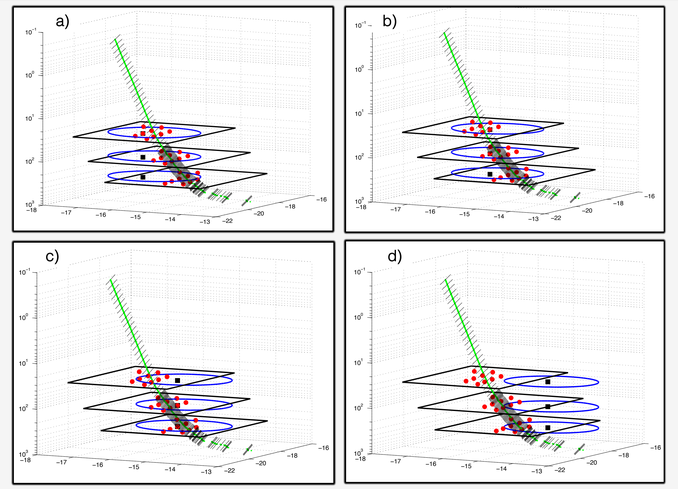


Figure 2. Illustration of the closest (black square), circular (blue circle), and ray path (red dots) methods for a single GPS profile (green) for the circle centered at the GPS RO level of (a) 30 hPa, (b) 100 hPa, (c) 300 hPa, and (d) the perigee point of GPS RO occultation.

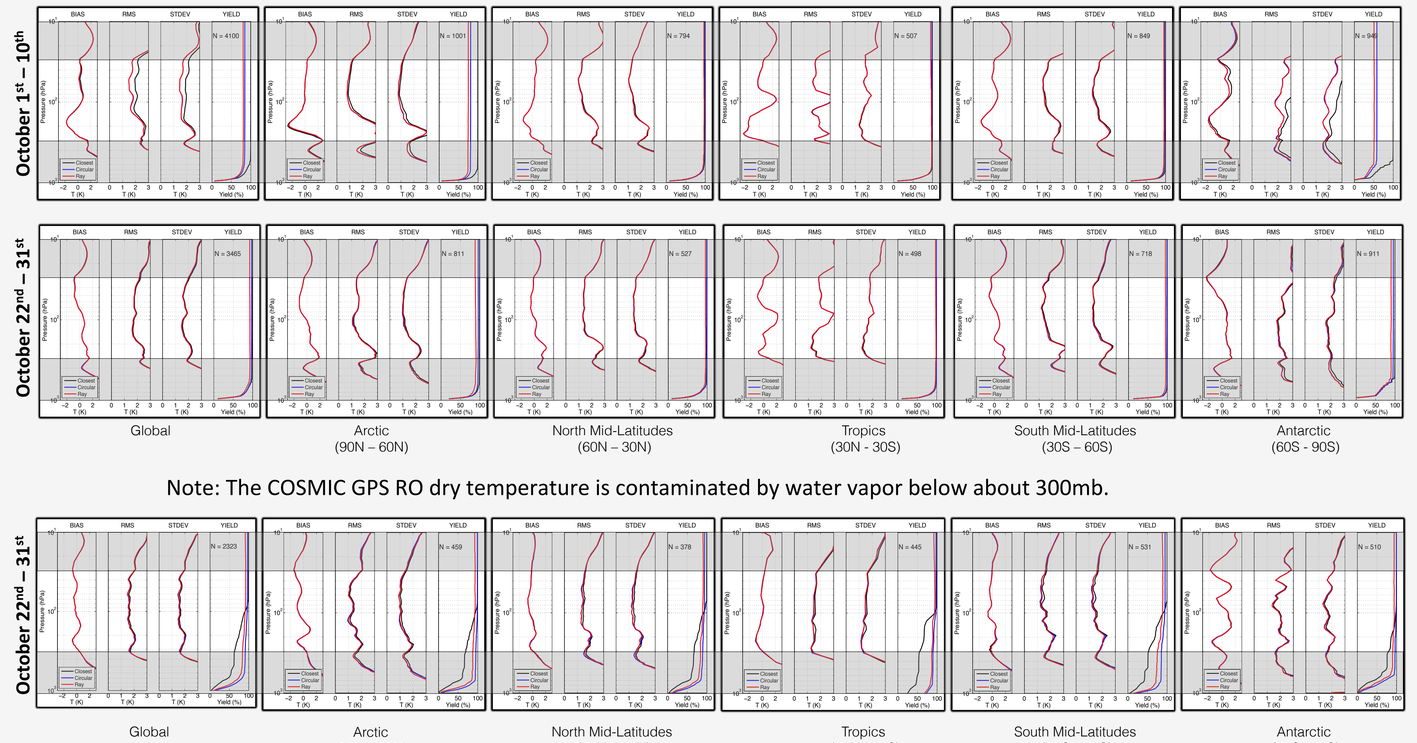
Assessment of CrIMSS Version Change (Mx5.3 → Mx6.3) on October 15th, 2012

Prior to CrIMSS update: Mx5.3 IDPS 42/22

After CrIMSS update: Mx6.3 IDPS 42/22

Both CrIMSS and COSMIC temperature profiles are computed at the AIRS 101 levels using nearest neighbor linear interpolation prior to statistical analysis.

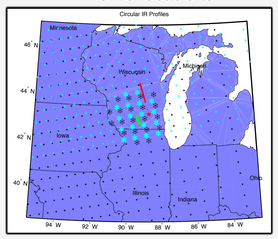
AIRS v5 minus COSMIC after CrIMSS update



Note: The COSMIC GPS RO dry temperature is contaminated by water vapor below about 300mb.

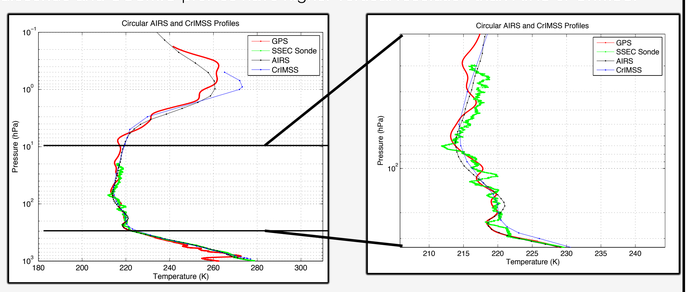
Case Study: November 4th 2012, Madison, WI

CrIMSS and AIRS Profile locations



Above, the red line indicates the track of the COSMIC GPS RO profile (18:27 UTC). The red star is the perigee point of occultation. The cyan stars indicate CrIMSS profiles (19:03-19:11 UTC) within150 km of Madison. The radiosonde track is shown in green (18:44-20:34 UTC).

The figures below contain an overlay of the GPS RO profile (red), the radiosonde launched from UW-SSEC (green), the circular weighted AIRS profile (black), and the circular weighted CrIMSS profile (blue). The right hand figure illustrates the 300 to 30 mb pressure range for which the COSMIC dry temperature profile is most accurate. Note that both the radiosonde and COSMIC profiles have higher vertical resolution than AIRS or CrIMSS.



Conclusions

- A methodology has been developed for the validation of CrIMSS AVTP in the upper troposphere and lower stratosphere using GPS radio occultation.
- GPS RO dry temperature from the COSMIC network is matched to CrIMSS profiles within one hour.
- The GPS RO horizontal resolution of 300 km is accounted for using a raypath method.
- This methodology has been used to evaluate a CrIMSS software version update that occurred on 15 October 2012.
- The overall quality control percentage of combined (IR+MW) to combined + IR only + MW only before the update was 6% and after the update was over 20%.
- The same methodology has been applied to AIRS v5 retrievals to provide a relative comparison.
- Coincident RS92 sonde launches from UW-Madison are being used in detailed case study analyses.

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