Using GPS Radio Occultation in the Validation of IR Temperature Sounding Profiles from CrIS, IASI, and AIRS

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Introduction

This poster briefly outlines and shows the application of a methodology for the validation of sounder temperature profiles using Global Positioning System (GPS) radio occultation (RO).

Due to its stability and measurement principle that is fundamentally different from that of radiometric instruments, GPS RO can offer an independent reference dataset for comparison against sounding retrievals. This methodology is intended for use in the validation of the atmospheric vertical temperature profile product from Suomi NPP and the future JPSS U.S. operational weather satellite series, but is applied to multiple platforms, sensors, and product versions.

Methodology

The steps and criteria of the GPS RO profile to sounder profile matchup method are outlined below. A sounder ray-path profile method is used to account for the GPS RO unique profile geometry and theoretical spatial resolution. For further information on the matchup method and methodology sensitivities, see Feltz et al. (2014).

Matchup Steps:

1) Begin with set of GPS RO profiles and sounder granules for a specific time range (e.g. week, month, year)
2) Loop over the GPS RO profiles testing for each sounder granule if:
   i) GPS RO perigee point lat/lon is within the sounder granule lat/lon bounding box
   ii) GPS RO profile start time is within 1 hour of granule start time
3) For each sounder granule/GPS RO profile matchup case
   i) Create a 'ray-path' sounder profile by averaging the sounder FOVs within a certain distance of a computed GPS RO ray-path. This computed GPS RO ray-path makes use of the GPS RO lat/lon and azimuth angle profiles. (See Figure 1)
   ii) Apply quality control
   iii) Linearly interpolate GPS RO profile to sounder levels
4) Compute sounder minus GPS RO difference
5) Find bias, RMS, and stdev profile statistics of matchup set for various latitude zones

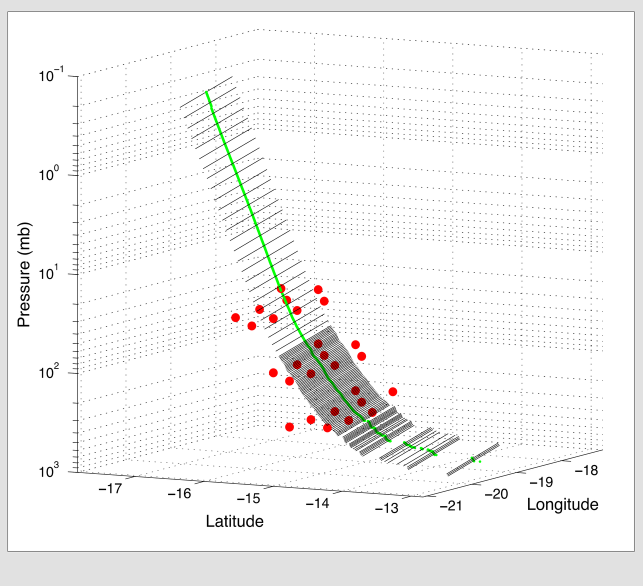


Figure 1 (LEFT). Illustration of the ray-path (red dots) sounder profile matchup method on 3 pressure levels for a single COSMIC profile (green with black lines showing the computed ray-paths every 50 levels).

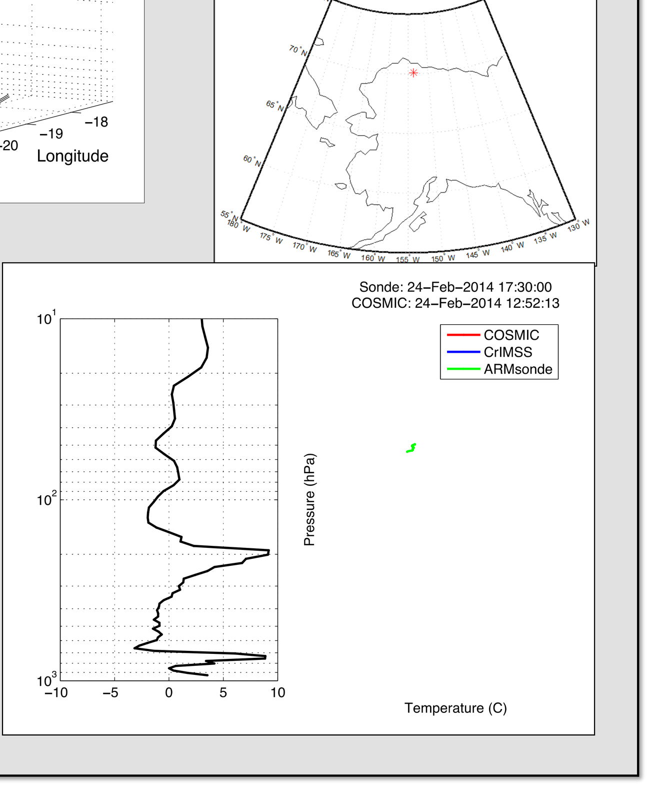


Figure 2 (RIGHT). Example COSMIC, CrIMSS, and ARMsonde matchup near Barrow, AK on 24 Feb 2014 around 1300 UTC. Map shows location of the matchup defined by COSMIC 100 hPa lat/lon. Plots show the CrIMSS minus COSMIC difference and overlaid temperature profiles. Note how in this example CrIMSS is not able to fully capture the cold tropopause temperatures.

Data

GPS Radio Occultation

GPS RO data came from the UCAR COSMIC Data Analysis and Archive Center at http://cdaac-www.cosmic.ucar.edu/cdaac/… products.html. The post-processed dry temperature, 'atmPrf', products used were the COMSIC version 2010.2640 and MetOp-A GRAS version 2011.2980. Differences in these product versions that are likely to have the biggest impact on the results shown are found in the excess phase processing. (The inversion processing differences affect the lower troposphere – an area where the results shown did not focus.)

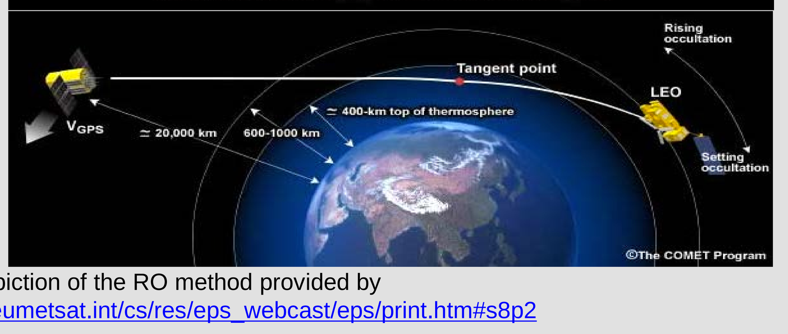


Figure 4. Depiction of the RO method provided by https://www.eumetsat.int/cs/res/eps_webcast/eps/print.htm#s8p2

Infrared/Microwave Sounder

NASA AIRS Level 2 Support Product, AIRX2SUP, a combination of IR and MW data, was obtained from the GESDISC at http://disc.sci.gsfc… .nasa.gov/AIRS/data-holdings/by-access-method.

NOAA IASI Level 2 data was obtained from the NOAA CLASS site at http://www.class.ncdc.noaa.gov/saa/products/welcome.

JPSS CrIMSS 42/22 layer EDR IDPS product was obtained from the NOAA CLASS site.

Conclusions

The GPS RO dry temperature is shown to be useful for the evaluation of MW/IR sounder retrieved temperature profiles in the 300 hPa to 10 hPa region on monthly time scales and zonal to global spatial scales. The absolute accuracy of the GPS RO COSMIC data is used to evaluate performance of the CrIMSS product and show improvement in the AIRS RMS from the v5.3 to v6 L2 product. In particular, the Antarctic zone tends to have the greatest sounder errors for the time period studied, May 2012.

The GPS RO network can be used as a common reference for the comparison of sounder products from different sensors on different satellite platforms using different retrieval algorithms. The sounder minus GPS RO statistics have characteristic structures on zonal scales. These facts support the conclusion that zonal analysis and validation needs to be done for the sounder profile products, not just global comparison with NWP products, as is common practice.

A limited study of the consistency between COSMIC and GRAS dry temperature products, both produced using UCAR processing, was performed on zonal scales. A hemispheric bias was seen between COSMIC and GRAS products, which nearly cancels in the global mean.

GPS RO vs. Sounder Comparison Results

AIRS, IASI, and CrIMSS Sounder Comparison

Zonal May 2012 { NASA AIRS v5.2 / NOAA IASI / IDPS CrIMSS Mx5.3 } minus CDAAC COSMIC

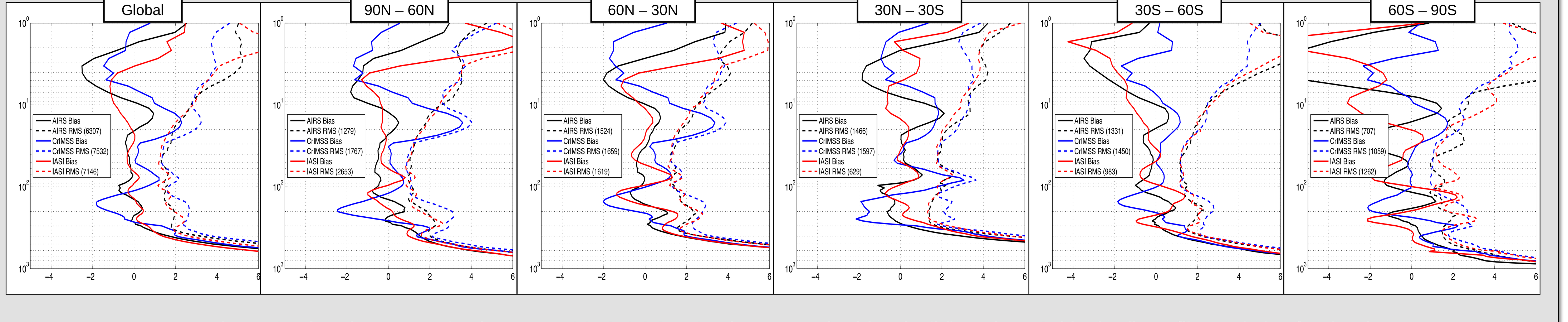
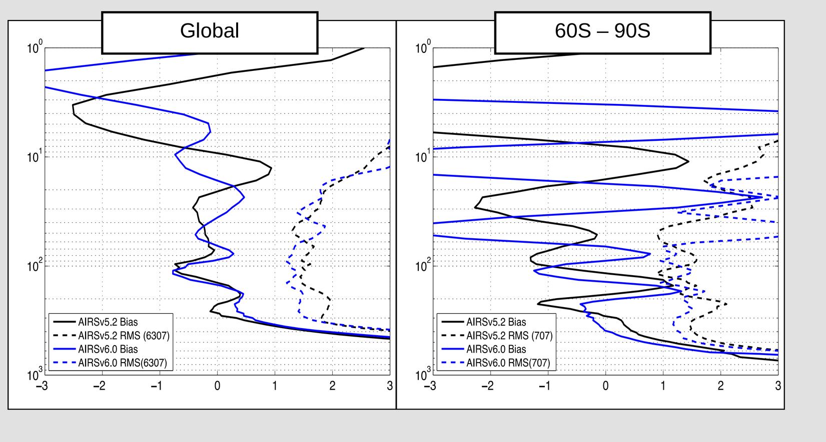


Figure 3. The above panels show May 2012 COSMIC minus sounder bias (solid) and RMS (dashed) profile statistics for the three matchup datasets for selected latitude zones. Note that for this time period the CrIMSS data was in beta release. Characteristic zonal structures of the profile errors can be seen. In the Antarctic region (60S-90S) AIRS and IASI exhibit vertical oscillations in bias.

IR Retrieval Version Comparison

Global/Antarctic May 2012 { NASA AIRS v5.2 / NASA AIRS v6.0 } minus COSMIC

Figure 4 (RIGHT). By using COSMIC as a common reference, the AIRS version 5.2 (v5.2) and 6.0 (v6) retrievals are compared for May 2012. Because the same matchups are used for each matchup dataset, the differences seen in the statistics are fully attributable to the differences in the AIRS version 5.2 and 6.0 retrievals.



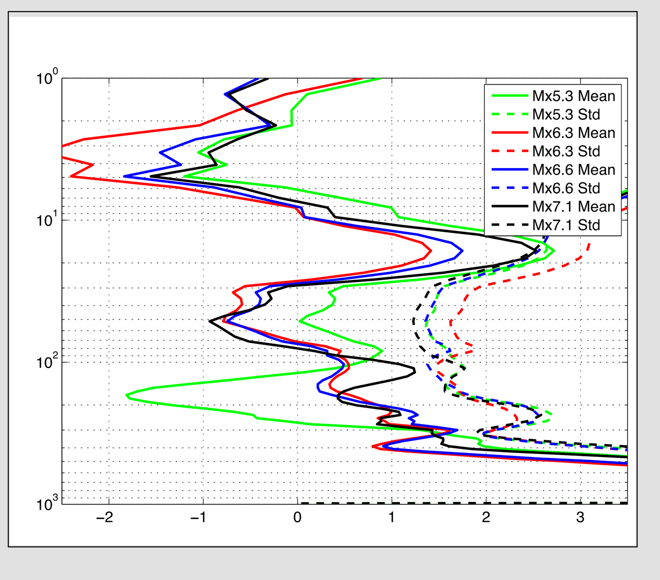


Figure 5. (ABOVE) Global bias and standard deviation profile statistics for 4 different time periods corresponding to 4 different CrIMSS IDPS retrieval versions are overlaid. Major improvements in the CrIMSS product are seen after the MX6.3 version update. Note that in the Mx7.1 version, the ~100 hPa level bias increased by more than 0.5K and RMS increased by more than 0.2 K.
Ample numbers of matchups were available for each time period for the creation of these statistics. Because these time periods were spread across the course of a year, seasonal effects may be present between the comparison of these profiles.

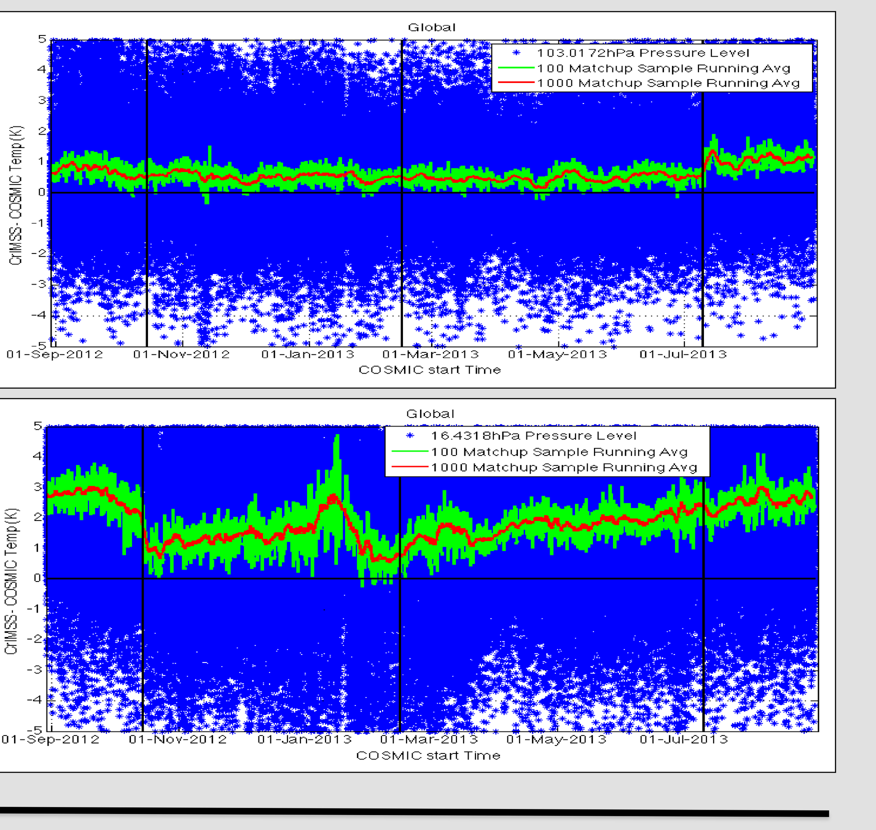


Figure 6. (RIGHT) The IDPS CrIMSS minus COSMIC global temperatures (blue dots) are overlaid with a 100 matchup (green line) and 1000 matchup (red line) running average for the 16.4 hPa (top) and 103.0 hPa level. Vertical black lines indicate the dates of various CrIMSS version updates - Mx5.3 to Mx6.3, Mx6.3 to Mx6.6, and Mx6.6 to Mx7.1 respectively from left to right.

COSMIC and GRAS GPS RO Comparison

Zonal May 2012 NOAA IASI minus CDAAC { COSMIC / GRAS }

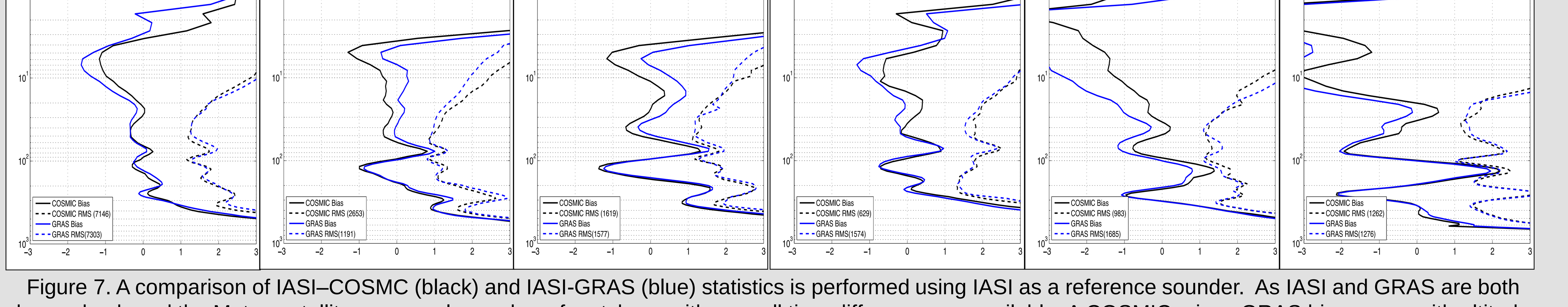


Figure 7. A comparison of IASI–COSMIC (black) and IASI-GRAS (blue) statistics is performed using IASI as a reference sounder. As IASI and GRAS are both housed onboard the Metop satellites, an ample number of matchups with a small time difference are available. A COSMIC minus GRAS bias grows with altitude throughout the stratosphere but with different signs for the two hemispheres. Since the hemispheric biases nearly cancel, the global bias is much smaller and would not indicate the problem that is illustrated in the zonal analysis.

References and Acknowledgments

- 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.
- Atmospheric Radiation Measurement (ARM) Climate Research Facility. 1994, updated hourly. Balloon-Borne Sounding System (SONDEWNPN). 2014-02-23 to 2014-02-27, 71.323 N 156.609 W: North Slope Alaska (NSA) Central Facility, Barrow AK (C1). Compiled by D. Holdridge, J. Kyrouac and R. Coulter. Atmospheric Radiation Measurement (ARM) Climate Research Facility Data Archive: Oak Ridge, Tennessee, USA. Data set accessed 2014-03-06 at http://dx.doi.org/10.5439/1021460.
- Feltz, M. L., Knuteson, R. O., Revercomb, H. E., and Tobin, D. C.: A methodology for the validation of temperature profiles from hyperspectral infrared sounders using GPS radio occultation: Experience with AIRS and COSMIC, J. Geophys. Res. Atmos., 119, doi:10.1002/ 2013JD020853, 2014.
- Kursinski, E. R., G. A. Hajj, J. T. Schofield, R. Linfield, and K. R. Hardy (1997), Observing Earth's atmosphere with radio occultation measurements using the Global Positioning System, J. Geophys. Res., 102, 23429-23465, doi: 10.1029/ 97JD01569.
- Yunck et al., (2009), Use of radio occultation to evaluate atmospheric temperature data from spaceborne infrared sensors, Terr., Atm., and Ocn. Science., 20(1), 71-85, doi: 10.3319/TAO.2007.12.08.01.

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