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Atmospheric Measurement Techniques
Discussions

AMTD

7, C2094–C2105, 2014

Interactive Comment

Interactive comment on "Application of GPS radio occultation to the assessment of temperature profile retrievals from microwave and infrared sounders" *by* M. Feltz et al.

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General Comment Response:

Discussion Comment: "General Comments: In this paper, the authors are trying to use three comparisons to reach the conclusion "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 three comparisons conducted by the authors are: i) Use GPS RO data as common references to quantify the quality of temperature profile retrievals from AIRS v5.2 and AIRS v6.0: this is the

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case for the same sensor, using the same samples, but using different inversion algorithm. ii) Use different RO data that matching with AIRS, CrIMSS, and IASI separately to quantify the quality of AIRS, CrIMSS, and IASI retrievals: this is the case for different sensors, using the different samples, and different inversion algorithms. iii) Use IASI as references and compare IASI temperature profile with co-located COS- MIC data and GRAS data then to quantify the differences between GRAS and COSMIC temperature profiles. To have a fair comparison between two satellite-derived profile retrievals, one will need to at least consider i) temporal and spatial sampling mismatching, ii) vertical resolution differences, and iii) possible errors due to different inversion methods and a priori in different lat zones. Using a method introduced by Feltz et al. (2014), the authors largely eliminate the spatial and temporal sampling mismatches of RO-sounder pairs. However, the vertical resolution difference is in general ignored in this study. Although 1km smoothing is applied to RO data, large vertical oscillations (+/-2K in some cases) still exist, which is most likely due to unresolved smoothing errors. For some comparisons (i.e., see Section 4.2 and 4.3), the temporal/spatial sampling errors are mixed with the vertical resolution errors. In this study, the sounder errors defined as the bias and RMS error, which are used to quantify the "performance" of the sounder products from different sensors on different satellite platforms using different retrieval algorithms. Although the authors intend to use the proposed approach to "quantify" the sounder errors, most of the biases and RMS errors due to i) vertical resolution differences, ii) sampling differences, and iii) a priori differences are not isolated and are largely unexplained. In general, the authors are intended to solve three very complicated inter-satellite com- parison issues. However, the current results do not completely support the conclu sions. Main results are presented in three short sections and each section contains only one figure and a short paragraph to explain the complicated causes of the bias and RMS. More works are needed to isolate above errors so that the "performance" for different instruments can be truly quantified. More detail explanations and algorithm descriptions are needed too."

Author Response: To start, your comment and detailed assessment of the paper was appreciated and we largely agree with commenter's opinion regarding the importance of isolating the components of the total error. As noted the Feltz et al. (2014) JGR paper addressed the issue of minimizing sampling errors in time and space. That paper also included a study of the vertical resolution dependence of the bias and RMS of which the commenter may find interesting.

In response to commenters #1 and #2, we performed a calculation for the AIRS, CrIS, and IASI averaging kernels (AK) corresponding to the mean state computed for the May 2012 Antarctic zone ERA-Interim profiles. This approach is consistent with the Rodgers and Conners (2003) paper, which suggests computing the averaging kernel for the mean of the comparison dataset. The Antarctic zone was chosen because it has the largest vertical oscillations in the bias. We then calculated the three following differences for the May 2012 Antarctic AIRSv5-COSMIC case on the 101 AIRS pressure levels: AIRSv5 minus COSMIC, AIRSv5 minus AK*COSMIC, and AK*AIRSv5 minus AK*COSMIC. The notation AK* denotes the application of the averaging kernel matrix. The Figures Aa-c below show these respectively. Application of the AK to both the AIRS and COSMIC profiles does largely remove the vertical oscillations in the bias and RMS. However, this figure is qualitatively similar to the manuscript Figure 2 which uses slab layer averaging (with noted x-axis scale difference), and therefore we do not see the need to modify the current manuscript in this regard. Additionally, similar figures were created for the "sounder comparison case" of Section 4.2 in the manuscript. These are shown in Figures Ba-c below and similar conclusions can be drawn from them as from Figures A.

Specific Comments Responses:

Discussion Comment: "Specific comments: 1) Section 4.1: AIRS V5.2 – COSMIC vs. AIRS V6.0 – COSMIC This is the case for the same sensor, using the same samples, but using different inversion algorithm. Again, the sounder error is defined as the bias and RMS error. The "improvement" is defined by smaller AIRS-COSMIC biases and RMS errors. a. The sounding retrieval results are highly dependent on pre-defined a priori informa- tion, channel selection, underlying temperature contrast etc. The pattern of the large positive and negative biases (more obvious in 60S-90S zone) is showing the unre- solved vertical resolution difference between RO and AIRS. Please consider using the method introduced by Rodgers and Connor 2003 to eliminate the vertical resolution and a priori effects (i.e., averaging kernels) then make the comparisons. Otherwise, please explain how the globally 1km smoothing of GPS RO data would affect the bi- ases and RMS in different lat zones ? How will the results differ if you use 2 km smoothing ? Can the vertical smoothing explain a part of the larger biases in 60S-90S since the correlation length is too short in a colder environment ? This is a complicated issue and it is pity only simple but incomplete explanation is provided."

Author Response: a. As discussed in the general comment response three conclusions can be drawn concerning Figure 2 of the manuscript and Figure A below: 1. The figures A and B below suggest that the oscillations present in the AIRS-COSMIC Antarctic zone bias shown in the manuscript Figure 2 are being introduced by the AIRS product and are not caused by the higher vertical resolutions of the GPS RO. 2. Application of the AIRS AK to the AIRS products does greatly reduce the vertical oscillations in the original 101 level comparison, thus the original vertical oscillations prior to smoothing are likely due to the null space error for the Antarctic conditions. 3. However, a comparison of the AK*AIRS-AK*COSMIC smoothed bias and the slab layer bias shows that the slab layer also reduces the vertical oscillations and thus largely removes the AIRS null space error. It is outside the scope of this paper to explore the cause of this vertical oscillation in the AIRS product; however, the fact that bias changes between version 5.2 and version 6.0 should be a clue to the root cause. The actual slab layer smoothing applied in the manuscript is not 1 km. The actual average slab layer widths range from ∼0.75-2.8km with an average of 1.5km over the vertical range of 1-300hPa. A table could be added to the manuscript noting the actual layers and heights for each latitude zone. We intend to study the vertical resolution question in greater detail for a future publication and show how it varies with latitude.

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Discussion Comment: "b. Not enough information of AIRS V5.2 and AIRS V6.0 in terms of the a priori informa- tion (averaging kernels and a priori profile) is presented. Are the same a priori profiles used in both V5.2 and V6.0 ? How does the averaging kernels different in different lat zones ? Please explain how is the different pre-defined a priori information, channel selection and different approaches in AIRS V5.2 and AIRS V6.0 contribute the biases ? These are complicated issues and will need to be addressed in depth before any solid conclusions can be obtained."

Author Response: Providing information on the specific a priori used for different algorithm versions and different sensors are the responsibility of the product providers, in this case NASA and NOAA. References have been included to the primary source material. It is outside the scope of this paper to diagnose the underlying causes of the product error characteristics. The point of this paper is that the use of a common GPS RO reference can help product providers better understand their product error characteristics. We agree with the author that this information would be invaluable both for the IR and GPS RO products in order to provide an analysis of the type suggested by Rodgers and Conners (2003). If access to this a prior information were available from the product providers, it would be extremely helpful for refining this analysis.

Discussion Comment: "c. P7, line 27, it is confused to state "COSMIC dry temperature profiles do not have these vertical oscillations" because COSMIC profiles are used as references. Please revise and provide the reason for "arguably larger in magnitude in the biases" in next sentence."

Author Response: See figures C and D for clarification of this statement. We recommend that we include figure C in a revised manuscript.

Discussion Comment: "2) Section 4.2: for comparisons of AIRS V5.2 – COSMIC pairs; CrIMSS – COSMIC pairs; IASI-COSMIC pairs This is the case for different sensors (with different weighting functions, a priori infor- mation, averaging kernels), using the different samples, and different inversion algo- rithms. Note that, no all profiles retrieved by using any different algorithms can be directly compared and the causes of the biases can be freely explained. Therefore, if possible, please state the difficulties for why it is not straightforward to directly compare, for example, IASI and AIRS ? Are there any studies for the AIRS vs. IASI comparisons ? Although the retrieval results from these sounding data are reported in 101 vertical levels, AIRS, CrIMSS, and IASI measurements can only provide around 5 to 10 degree freedom of signals depending on locations and times. It is really unjustified to compare bias and RMS from different sampling pairs from AIRS-RO, CrIMSS-RO, and IASI-RO mathcups in the same plot. Is it possible to find a common RO pairs for AIRS, CrIMSS, and IASI ? Is there is a way If it is not possible, then please at least consider quantifying bias and RMS due to i) temporal sampling errors, ii) spatial sampling errors, iii) vertical resolution errors, iv) errors due different a priori profiles separately. Otherwise, please consider removing the whole section since all the i) temporal sam- pling errors, ii) spatial sampling errors, iii) vertical resolution errors, iv) errors due dif- ferent a priori profiles, v) different inversion methods are all mixed and hard to be explained. It is not justified to state which results are better and why."

Author Response: We appreciate the author's comment regarding the difficulty of directly comparing the sounder products from sensors in different orbits. AIRS and CrIS are in the AM orbit while IASI is in the PM orbit used for data assimilation into operational weather prediction. AIRS and CrIS differ in time by between 0 and 90 minutes since they are in the same orbit but are at different orbital altitudes. The AM and PM orbits are coincident only at about +/- 78 degrees latitude. This issue is well known to the sounder community, however, for the general audience of this paper we recommend using the following sentence in a revised manuscript. " The AIRS and CrIS sensors operate in the same orbit but are not time coincident. The IASI sensor on the Metop platform is in a different orbit with few coincident matchups with AIRS and CrIS."

We are not aware of any published studies of detailed comparisons of AIRS and IASI products for stratospheric temperature.

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The issue of information content in the sounding products is well documented in the literature. The commenter is correct that the number of vertical levels is much higher than the number of independent pieces of information. However, AIRS, CrIS (unapodized), and IASI (apodized) all have very similar information content in the altitude range of interest. Subtle differences in vertical weighting function among these sensors is the subject of active study. The authors believe it is justifiable to compare AIRS-RO, CrIMSS-RO, and IASI-RO on the same figure especially since they are all attempting to make the same measurement. The author refers the commenter to the previous discussion of application of averaging kernels to the differences shown in figure B with regard to the vertical information content.

Regarding the issue of common RO pairs amongst the AIRS, CrIMSS, and IASI, with a one hour time constraint between the RO and sounder profiles the number of coincident matchups is greatly reduced relative to each matchup pair. However, there is a subset of matchups which could be evaluated, particularly for AIRS and CrIS which are in the same orbit.

The Feltz et al. (2014) JGR paper addresses temporal, spatial, and vertical resolution errors for the same latitude zones used in this study but for a different month (October 2007). The methodology described in that paper was used here because it was shown to be robust to changes of matchup constraints (e.g. time difference). The use of averaging kernels appropriate for each sensor would be an improvement in the assessment of the vertical smoothing error and we hope to include this in a future more comprehensive analysis. The issue of the use of a priori information getween the sounder products, the GPS RO products, and the comparison dataset is a subject of future study following the approach of Rodgers and Conners (2003). Not enough information on the a priori used for each for each product is available currently to include that assessment in the current paper.

Discussion Comment: “3) Section 4.3 This is the case to use the mean bias of IASI-COSMIC matchups to minus the bias of IASI-GRAS to define COSMIC-GRAS bias.

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Again, the mean bias and the RMS are used to quantify the quality of the retrievals. How justify to state that IASI data can be used as a common references ? Will the quality of IASI data vary with location and time ? How the quality of IASI data (i.e., averaging kernels) vary with locations and how to quantify that ? Again, since IASI-COSMIC and IASI-GRAS matchups are collected from different times and locations, how can you quantify the temporal and spatial sampling errors and how will that affect the results in Fig. 4 ?"

Author Response: The quality of the IASI data is irrelevant because the method used in this analysis is a double difference (IASI – COSMIC) – (IASI – GRAS). In this commonly used approach systematic errors in the IASI data cancel out and reveal the systemic biases between COSMIC and GRAS. The assumption is that the IASI matchups sample the same zonal average atmosphere in the COSMIC matchup and the GRAS matchup datasets. Feltz et al. (2014) concludes that the difference statistics become stable for a number of matchup cases greater than 200 and each of the zones has at least 600 samples contained in each dataset. The reason IASI was chosen as the reference sounder was to obtain the largest number of matchups with GRAS possible.

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/7/C2094/2014/amtd-7-C2094-2014-supplement.pdf

Interactive comment on Atmos. Meas. Tech. Discuss., 7, 5075, 2014.

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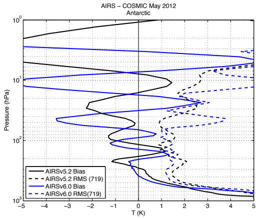

Figure Aa. May 2012 Antarctic zone AIRS v5.2 minus COSMIC (black) and AIRS v6.0 (blue) minus COSMIC bias (solid) and rms (dashed). No averaging kernel applied. Vertical sampling uses the AIRS 101 levels.

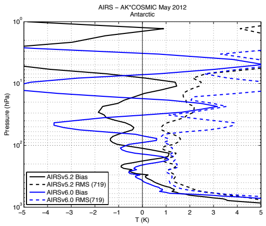

Figure Ab. Same as Figure 1a, with the COSMIC profiles being smoothed by an AIRS averaging kernel which was computed for the mean May 2012 Antarctic ERA-Interim atmospheric state. Application of the AK to COSMIC profiles has little impact on the bias and RMS.

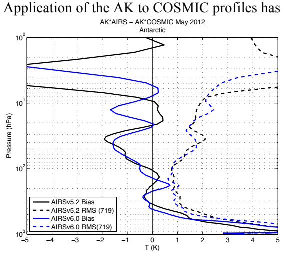

Figure Ac. Same as in Figure 1b, except with the averaging kernel applied to both the COSMIC and AIRS profiles. Application of AK to AIRS and COSMIC profiles does largely remove the vertical oscillations in the bias and RMS. This figure is qualitatively similar to the manuscript Figure 2 which uses slab layer averaging (with noted x-axis scale difference.)

Fig. 1. Figure A. May 2012 Antarctic zone AIRS v5.2 minus COSMIC (black) and AIRS v6.0 (blue) minus COSMIC bias (solid) and rms (dashed) with varying averaging kernel applications.

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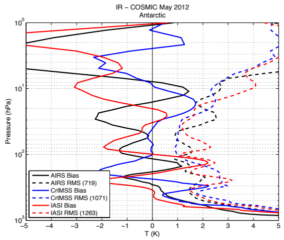

Figure Ba. May 2012 Antarctic zone AIRS v5.2 (black), CrIMSS (blue), and IASI (red) minus COSMIC bias (solid) and rms (dashed).

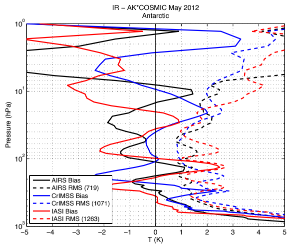

Figure Bb. Same as Figure 2a, with the COSMIC profiles being smoothed by an AIRS averaging kernel which was computed for the mean May 2012 Antarctic ERA-Interim atmospheric state.

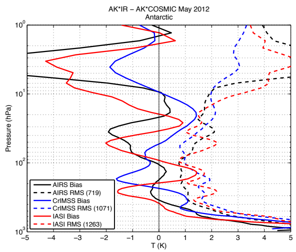

Figure Bc. Same as in Figure 2b, except with the averaging kernel applied to both the COSMIC and AIRS profiles.

Fig. 2. Figure B. May 2012 Antarctic zone AIRS v5.2 (black), CrIMSS (blue), and IASI (red) minus COSMIC bias (solid) and rms (dashed) for various avergaing kernel applications.

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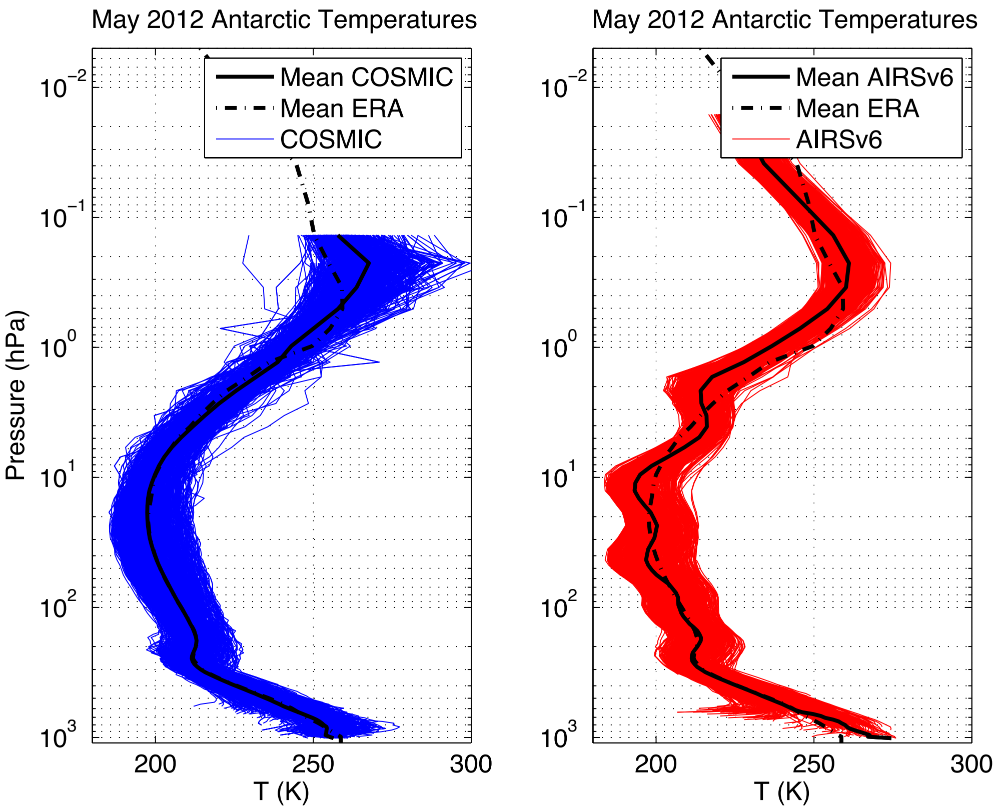

Fig. 3. Figure C. May 2012 Antarctic AIRS and COSMIC matchup average temperatures.

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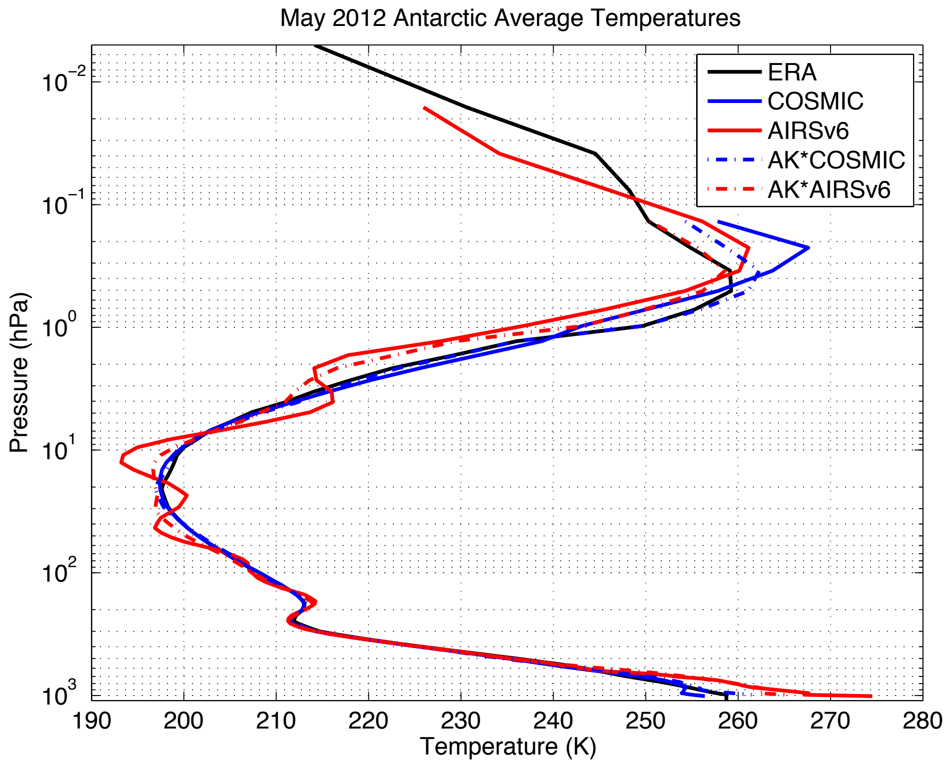

Fig. 4. Figure D. May 2012 Antarctic AIRS and COSMIC matchup average temperatures, with overlaid smoothed AIRS and COSMIC temperatures.

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