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Replies to Interactive Comments on "Evaluation of two Vaisala RS92 radiosonde solar radiative dry bias correction algorithms"

March 10, 2016

Prelude

The authors would like to thank the reviewers and Dr. Isaac Moradi for their feedback on this study. The following document contains replies to each comment posted on the discussion board at http://www.atmos-meas-tech-discuss.net/amt-2015-258/.

This document is organized such that the name (if given) of each referee/commenter is given, and their original comment will be bolded. Replies from the author will be in *blue italics*.

In addition to addressing each individual comment provided, we have updated every figure in the paper to be neater and more professional looking – all plots are now in EPS (PDF) format, and are scalable such that image "graininess" is no longer an issue. Any comments or modifications made to the original text have been marked using Microsoft Word's "Track Changes" tool. Specific comments and modifications are reproduced, where appropriate, to the reviewer's comment(s).

Thank you again for taking the time to review our manuscript – we already notice an immediate difference in the quality of the paper. We look forward to hearing back from you.

Sincerely,
Andrew, Dave and Eli

2. Comments from *Isaac Moradi*

The paper evaluates two different bias correction schemes for Vaisala RS92 measurements. Given that RS92 sensors are used globally to measure tropospheric humidity, the comparison is valuable. Because of my interest in the topic, I am providing a few comments that may help to improve the paper. However, please note that the comments here should not be considered as editor's decision but solely as an independent review.

Thank you for your comments!

PWV is mainly from the boundary layer where the radiation dry bias is not significant so it should be clarified that PWV may not be able to even show the difference between the radiation dry bias correction methods.

This is very true, and a primary motivator for the radiance closure experiments. We addressed this by adding an additional sentence to p. 10761, L11, where a better transition was needed. Emphasizing that PWV mainly comes from the PBL (regardless of climatic regime) is a necessary point to make there. The new sentence is as follows:

*"**Regardless of the climate, PWV is mainly contained in the lowest 1-2 km of the atmosphere, thus corrected RH in the middle and upper troposphere influences the results shown here very little.**"*

P10757 L5: there are a few more references that can be cited here including Moradi et al, JGR 2013 DOI 10.1002/jgrd.50589, Moradi et al. TGRS 2013 DOI 10.1109/TGRS.2012.2220551

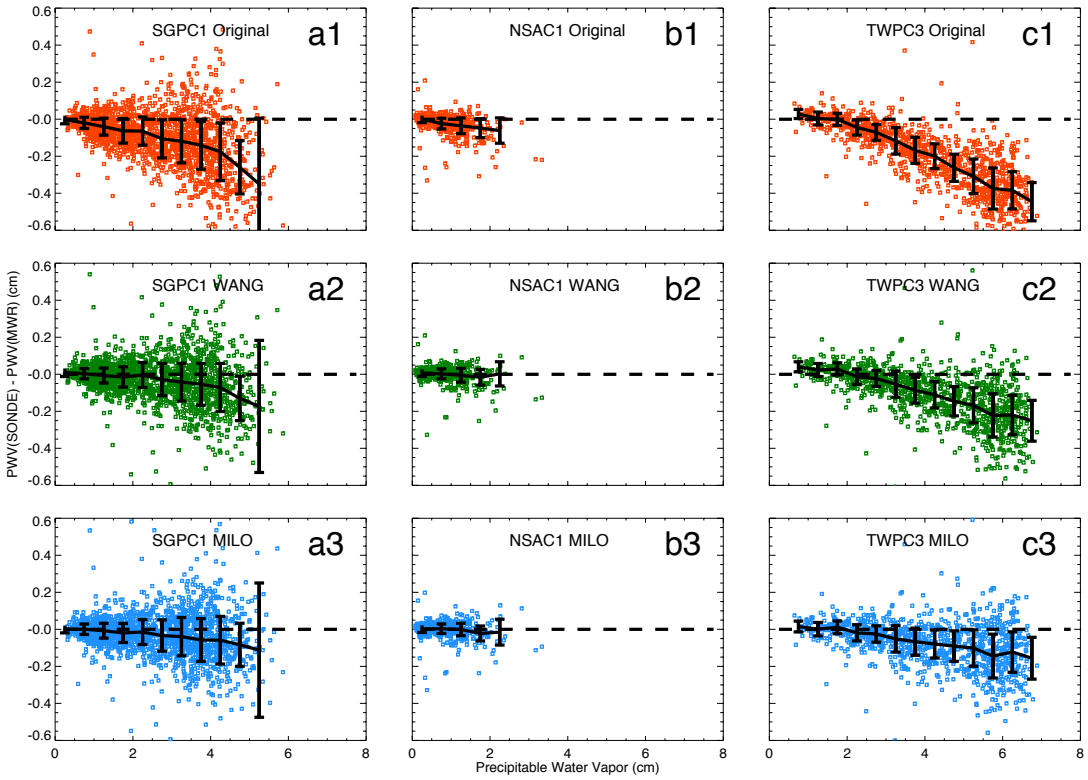
*Thank you for these reference suggestions. After reading both papers, both are in fact extremely relevant to our study, thus have been included in the references. The citation starting on line 5 now reads (changes in **bold**):*

*"(e.g. Ferrare et al., 1995; Revercomb et al., 2003; Ferrare et al., 2006; Suortti et al., 2008; Krämer et al., 2009; **Moradi et al., 2013a; Moradi et al., 2013b**)"*

P10760 L21: It doesn't seem logic to remove 20% of the data as outlier

We agree – as it turns out, this was a mistake we missed because we intended to remove only 10% of the data total, such that the influence of outliers does not manifest itself in Table 1 and Figure 1. Both Table 1 and Figure 3 have been updated such that only 10% of the original data were removed, and the text has been modified to reflect this change. While making this change, we found in the computer code that an additional 10% of the data was removed by accident for the numbers shown in Table 1 except for where the number of points are given (the values given in the updated Table 1 and the old Table 1 for N = … are correct).

Note that an additional change to Figure 3 was made – the y-axis label was updated to correctly show PWV(sonde) – PWV (MWR). The new figure is reproduced below:



P10761 LL9-10: the sentence doesn't seem to be correct

*Thank you for pointing this out. The sentence starting on line 9 has been updated to reflect this change (the change is **bolded**):*

*"A close inspection of Table 1, however, suggests that the MILO correction seems to add more PWV compared to **WANG** in the tropics, whereas WANG adds more PWV in drier climates such as SGP and NSA."*

P10761 L21: the aforementioned reference seem relevant here

*Both references are appropriate to include in the citations starting on L21. The citation now reads (changes are **bolded**):*

*"(e.g. Turner et al., 2003; Soden et al., 2004; Mattioli et al., 2008; Kottayil et al., 2012; **Moradi et al., 2013a; Moradi et al., 2013b**)"*

P10762 L5: please define a.s.l.

*We agree that a.s.l. should have been defined, however, we also found that the abbreviation a.s.l. was not used before or after P10762 L5. Thus, we defined it but left out the abbreviation since it is not referenced after that sentence. The sentence has been updated to read (change is **bolded**):*

*"The CJC site is located approximately 5.3 km **above sea level** in the Atacama Desert; this site can be considered a mid-tropospheric site due to its altitude and water vapor conditions."*

P10762 L16: please reword water vapor profile shape, may be something like ".... more sensitive to the middle and upper tropospheric water vapor ..."

*"Water vapor profile shape", as you imply by mentioning, does sound weird to us. We have updated this sentence such that it reads (changes are **bolded**):*

*"The lower frequency channels (e.g., below 178 GHz) are more sensitive to the total PWV, while the higher frequency channels are more sensitive to **middle/upper-tropospheric water vapor** (Cimini et al. 2009)."*

P10762 L25: instrument function => instrument response function AND derive model calculations => calculate brightness temperatures

*We agree that these two changes are essential to clarifying the meaning of the sentence starting on P10762 L25. That sentence has been updated to read (changes are **bolded**):*

*"These computed clear-sky monochromatic spectra were convolved with the GVRP's instrument **response** function to **calculate brightness temperatures** corresponding to each GVRP channel."*

P10763 L7: rationale behind 2.25 K?

This threshold was determined qualitatively from the data, as totally clear-sky conditions often had T_B standard deviations in the 0.5-2.0 K range. While cloudy-sky soundings were very few (as determined by RH/RHI data), determining environmental homogeneity similarly to the upwelling experiment was needed. The 2.25 K threshold, compared to the upwelling experiment, falls in-line with the thresholds determined for April/May and September.

Sections 3&4: The radiative transfer error should be taken into account and discussed when interpreting the results - some discussion is provided in the aforementioned papers as well as Moradi et al, JGR 2010: DOI: 10.1029/2010JD013962

The LBLRTM and MonoRTM models used in this study have been heavily validated. We have added several references to Payne et al. and Alvarado et al. when the models were introduced that describe some of these validation efforts.

Section 3: It would be good to see the Jacobians for the MW radiometer. Unless, I am missing something, the authors have sim-interpreted the results for the downwelling case.

We added the WV Jacobian at the GVRP frequencies to the paper as Figure 4. The new figure and associated caption are reproduced here. The figure reference was inserted on p. 10762, L16.

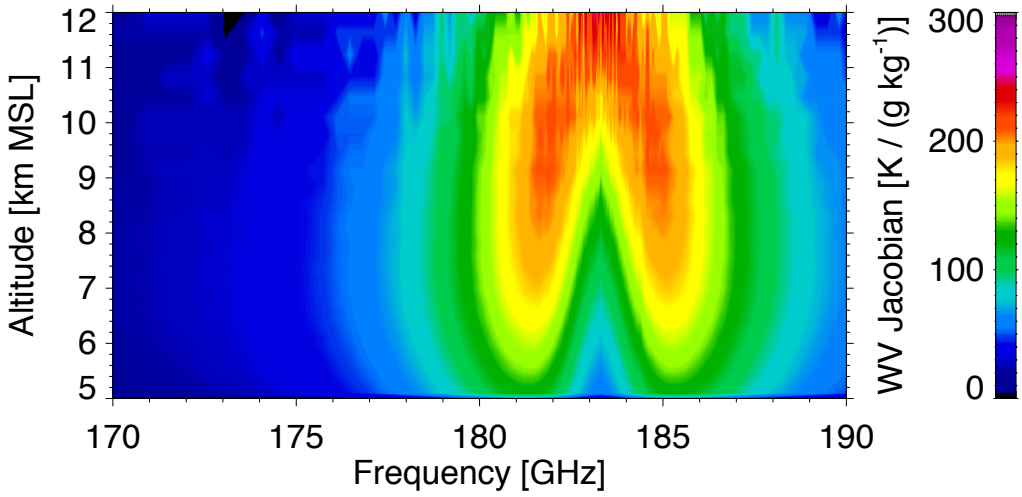


Figure 4: *The water vapor Jacobian computed for mean conditions at Cerro Toco at the GVRP frequencies.*

P10765 L22: Unfortunately » Since

We agree that "since" is a better word choice, however, we felt it would be best to re-word this entire sentence because of its "wordiness". We updated the manuscript such that this sentence (starting on L22) reads:

"Thus, downwelling radiance closure studies at the other sites would prove difficult because lower-tropospheric water vapor is much higher, meaning the downwelling radiance would have little sensitivity to change in upper-tropospheric humidity."

P10766 L5: the authors should show evidence for the claim made here

The referenced claim "During the cold season, upper-tropospheric IWV at SGP is representative of that measured at the ARM's NSA (Barrow) site, …" is supported in Figure 7, however, we see that we did not reference the figure in this sentence. Figure 7 indicates that IWV values of less than 0.1 cm occur rather frequently at the ARM SGP and ARM NSA sites. Likewise, IWV values greater than 0.2 cm do occur at the ARM SGP site but not as often compared to the ARM TWP site. Thus, we have clarified this sentence such that it reads the following (changes are ***bolded****):*

"During the cold season, upper-tropospheric IWV at ***the ARM*** *SGP* ***site*** *is representative of that measured at the ARM's NSA (Barrow) site* ***(Figure 7 – blue***

line)*, whereas* ***during*** *the warm season at* ***the ARM*** *SGP* ***site*** *the upper-tropospheric IWV is representative of a tropical location (e.g. the ARM's TWP sites****; see Figure 7 – orange line****).”*

P10767 L2: How the cloud filter works?
Section 4: it should be noted and discussed that the AIRS selected observations are for dry conditions because the cloud filter removes the moist regions from the analysis

The cloud filter is explained starting on line 20 on page 10767 and again on line 17 on page 10768. We did clarify the wording in the paragraph starting on page 10766, line 25, such that we introduced how we filtered the AIRS dataset for PWV homogeneity, cloud-free scenes and overall dry conditions. Significant changes were made to this paragraph, and now reads (all changes to the original text are bolded):

“Upwelling infrared radiation is highly sensitive to changes in water vapor, so we needed to ascertain if the PWV changed appreciably between the sonde launch and AIRS overpass. ***Clouds must also be filtered from the dataset, because measured upwelling radiation is very sensitive to changes in cloud properties. The development or advection of clouds at the time of the radiosonde launch or AIRS overpass can obscure the atmosphere below the cloud-top height.*** *To minimize* ***these impacts, we included data only:***

1. ***Where*** *the AIRS overpass occurred within 135 minutes of the radiosonde launch.*
2. ***During cloud-free scenes, as discerned by the AIRS and radiosonde observations (methodology explained in the following paragraphs).***
3. ***When the MWR PWV did not change by more than 5% between the time of the radiosonde launch and AIRS overpass.***

In short, only data during completely dry conditions are examined. This is especially necessary because both the WANG and MILO correction algorithms are intended for use mainly in clear-sky conditions.*”*

Table 1: it is better to present the values in mm

We agree. Table 1 has been updated such that the values displayed are now in mm as opposed to cm. The Table 1 caption has been updated to reflect this change, and now reads (change is ***bolded****):*

“A summary of the microwave radiometer and radiosonde un/corrected PWV biases ***(in mm)*** *with +/- 1 sigma uncertainty from the ARM's SGP, NSA and TWP (Darwin) site.”*

Figure 1: it would be better to show ORIG -MILO and ORIG - WANG as it is very hard to see the differences now

Figure 1 was intentionally presented this way to show how the differences in RH compare to the original RH profile, such that it visually emphasized that the actual changes in RH seem small or hard to discern. We do agree though that the numerical difference is hard to gauge, which could be valuable to the reader. Thus, we have updated Figure 1 to be a 2-panel plot: the left figure showing the baseline RH profiles (original RH profile and WANG/MILO corrected profiles) while the right figure shows ORIG – WANG and ORIG – MILO. The new figure is reproduced here (changes in figure caption are ***bolded****):*

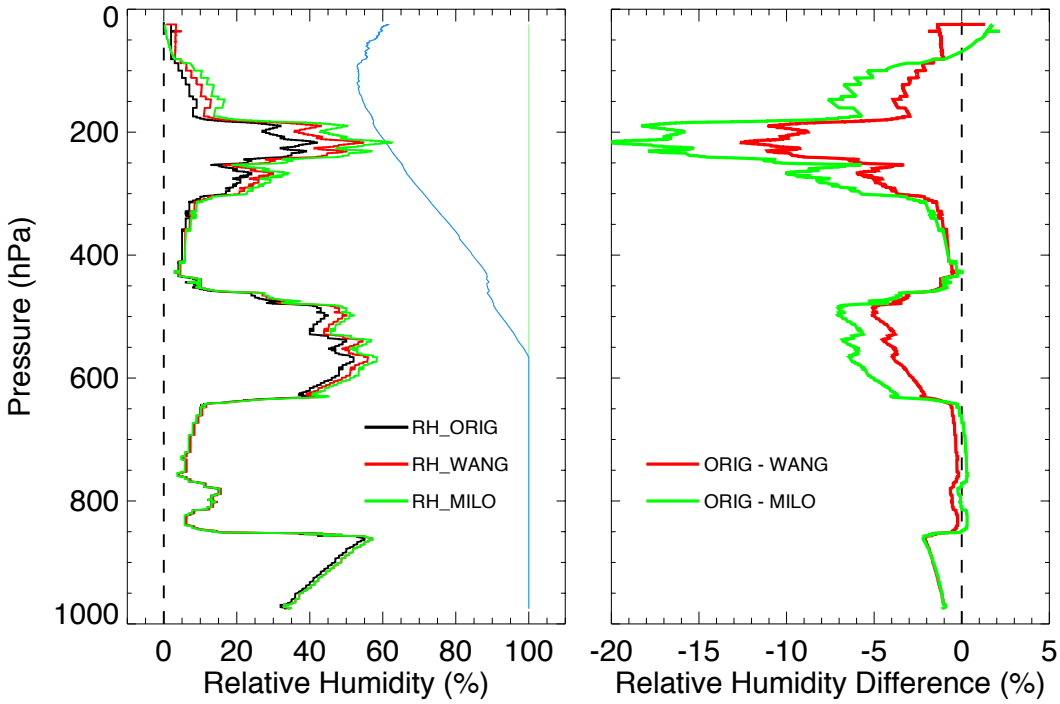


Figure 1: *A comparison of the WANG and MILO corrected RH profiles (****left plot;*** *red and green, respectively) compared to the original RH profile (black). The light blue line represents the saturation RH with respect to ice.* ***The right plot shows the difference between the original RH profile and the WANG/MILO RH profiles (red/green) respectively****. This example is the 18Z sounding for the SGP site from June 15, 2006.*