Using Radiance Closure Experiments to Evaluate Vaisala RS92 Radiosonde Solar Radiation Dry Bias Correction Algorithms

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Downwelling Experiment

- Use original RH, Wang (2013) RH and Miloshevich (2009) RH profiles from the ARM CJC (Cerro Toco, Chile) site.
  - Located ~5 km above sea level.
  - Very low humidity; PWV < 5mm.
- Use these sonde profiles as input for the **Monochromatic Radiative Transfer Model (MonoRTM)** from 170 to 183.31GHz at 10MHz steps.
- Convolve brightness temperature output from frequencies for the **G-band Vapor Radiometer Profiler (GVRP)**, also 170 to 183.31 GHz.
- Why use the GVRP?
  - Atmospheric emission primarily due to water vapor in these channels.
  - 183.31 GHz channel ~30x more sensitive to water vapor compared to the frequencies of a two-channel microwave radiometer (MWR) for PWV < 2.5mm.

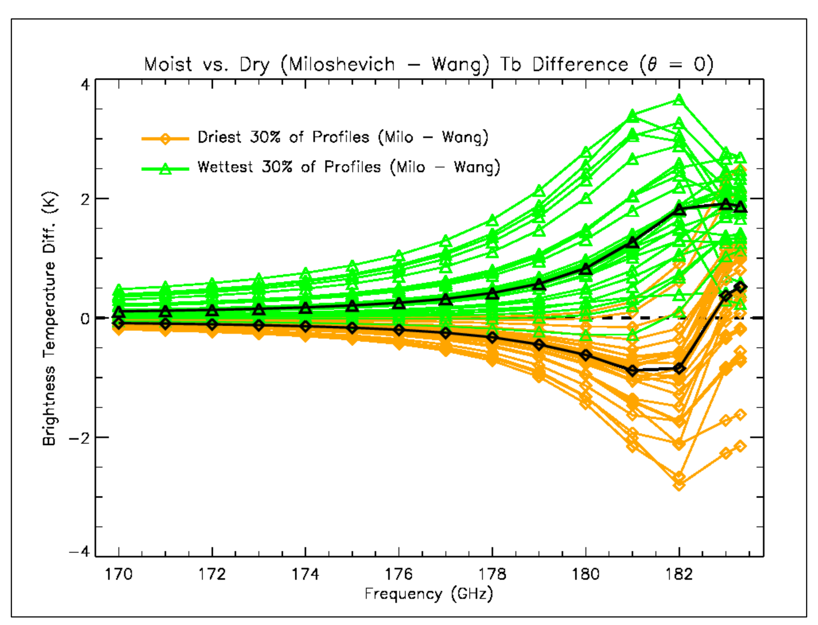


Figure 4: Brightness temperature differences between MonoRTM calculations using Wang (2013) and Miloshevich (2009) corrected RH profiles. The data is sorted by 30% moistest and 30% driest profiles.

The GVRP

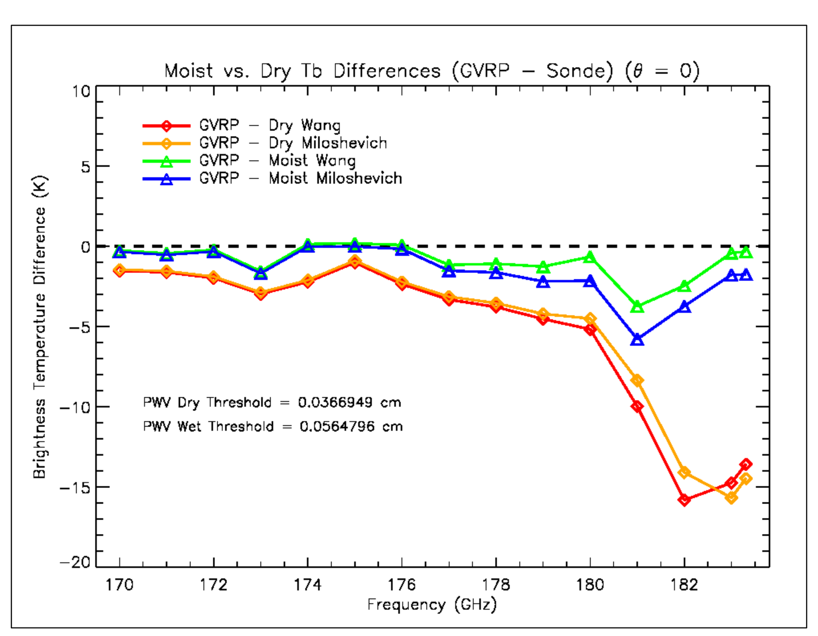


Figure 5: Wang (2013) vs. Miloshevich (2009) brightness temperature biases, separated by 30% moistest and 30% driest radiosondes.

Analysis

- For moist radiosondes (PWV > ~0.6mm), Wang (2013) T_b bias < 1 K at 183.31 GHz.
- Both correction algorithms have large moist bias (i.e. > 13 K T_b bias at 183.31 GHz) for PWV < ~0.4mm.
- The GVRP's sensitivity to water vapor and general likelihood of higher PWV in a typical atm. suggests Wang (2013) offers a less-biased measurement.

History & Motivation

- Turner et al., (2003): ~5% dry bias compared to microwave radiometer (MWR).
- Vomel et al., (2007): First quantified water vapor dry bias errors in Vaisala RS92 radiosondes.
- Numerous studies (e.g. Yoneyama et al., (2008), Agusti-Panareda et al., (2009)) confirmed the water vapor dry bias.
- **Two solar radiation dry bias (SRBD) correction algorithms are evaluated in this study: Wang et al, (2013) and Miloshevich et al., (2009).**
- Both algorithms correct differently as a function of height (Figures 1 and 2).
- Each algorithm corrects approximately the same in terms of precipitable water vapor (PWV; Figure 3).
- **How do these differences matter when computing radiance?**

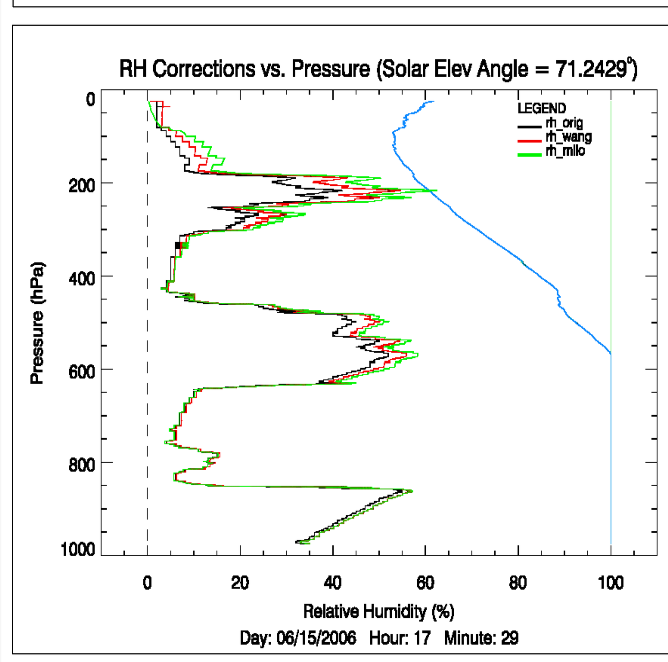


Figure 1: An randomly-selected example (from the ARM SGP site) of how the Wang (2013) and Miloshevich (2009) RS92 SRBD correction algorithms vary with height and RH.

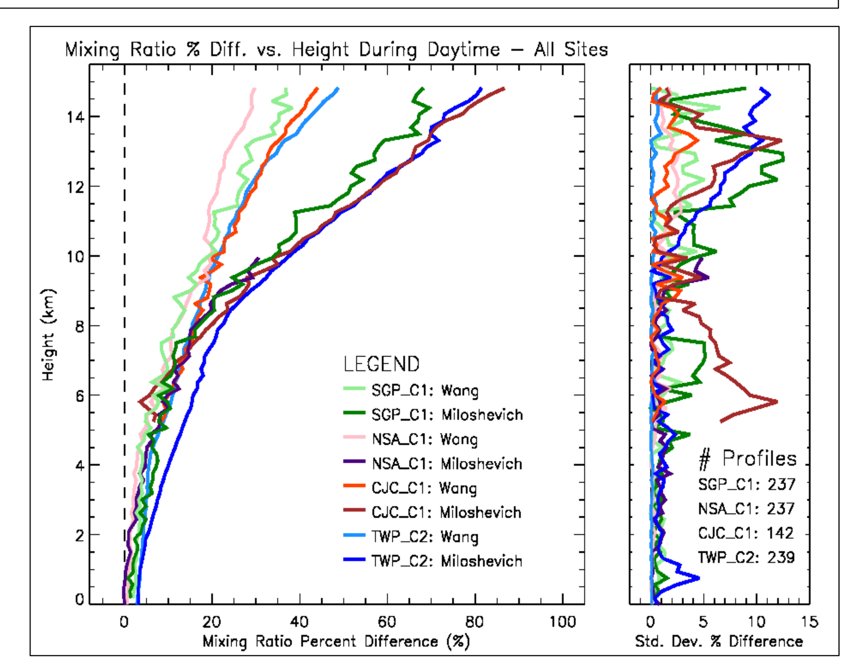


Figure 2: Mixing ratio percent profile difference profiles as a function of height. Data from three major ARM locations [SGP, TWP (Nauru Island) and NSA (North Slope, Alaska)] is given in addition to the Cerro Toco (CJC) data.

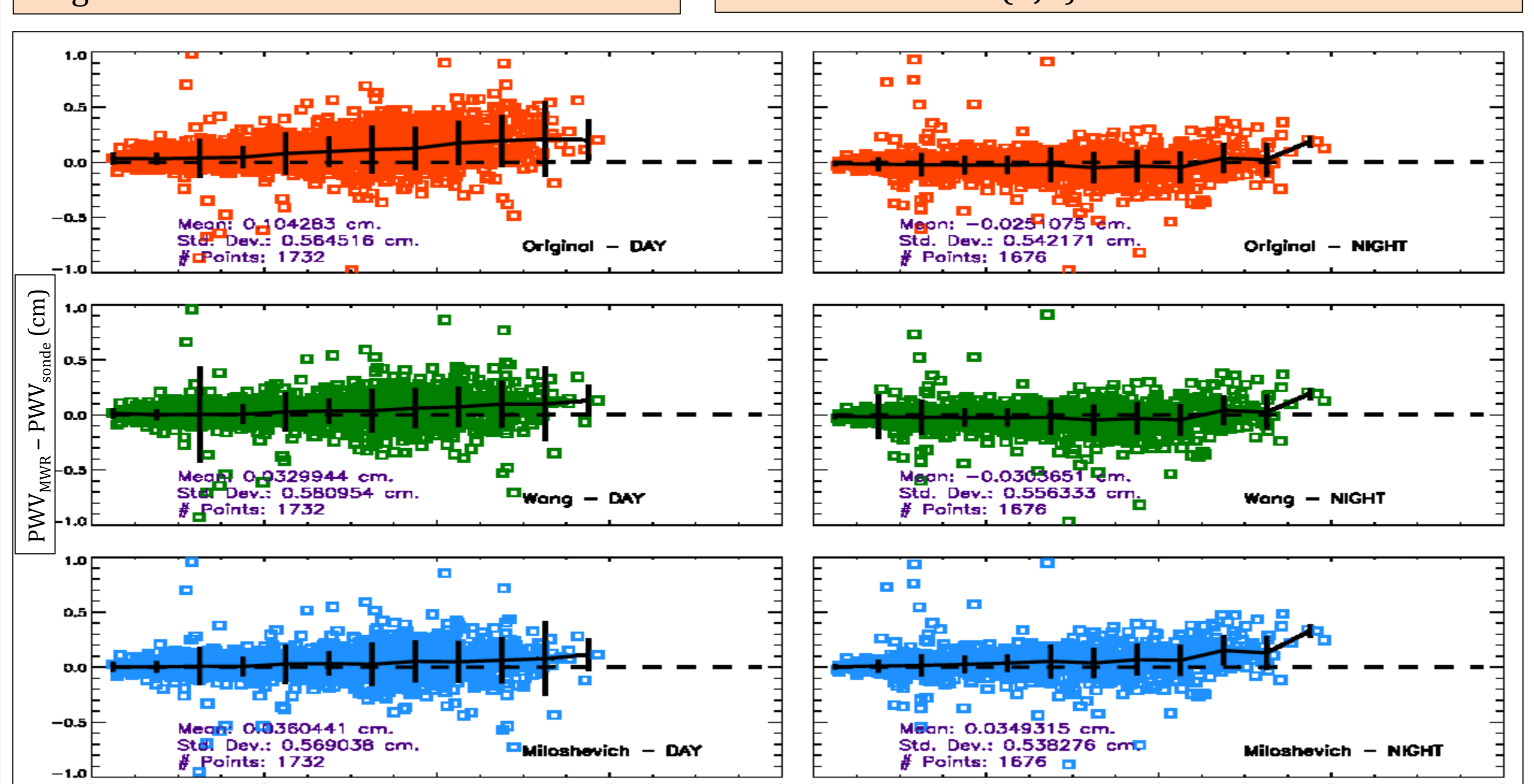


Figure 3: Difference between radiosonde-derived PWV and (collocated) microwave radiometer (MWR) PWV at the SGP site. Figures on the left represent daytime data, while figure on the right represent nighttime data. Units are in cm.

Wang et al., (JTECH; 2013)

$$RH_{CORR} = RH\left(\frac{e_s\left(T + hf * \Delta T_{CORR}\right)}{e_s(T)}\right)$$

- hf is a heating factor, set to 13.
- ΔT_{CORR} is equal to $cf * \Delta T_{CORR\_RSN}$, where cf is an adjustment factor (0.4 below 500hPa and 0.6 above 500hPa), and ΔT_{CORR_RSN} is given by Vaisala.

Vaisala RS92 Radiosonde Correction Algorithms

Miloshevich et al., (JGR; 2009)

$$RH_{CORR} = G(P, RH) \times RH_{TLAG}$$

- G(P,RH) is a function of pressure and RH, where G is derived from an empirically-derived "look up" table of coefficients.
- RH_{TLAG} is the time-lag corrected relative humidity.
- For RS92 sensors, RH has no significant time-lag error.

Discussion & Conclusions

- Overall: both correction algorithms offer better alternative to original sonde RH data.
- Wang (2013) correction less biased using sensitive GVRP brightness temperature data (Figure 5) and aloft using AIRS radiance data (Figure 7).
- Future work: Repeat upwelling experiment for ARM sites where other AIRS & sonde data is available (e.g. TWP and NSA ARM sites).

Upwelling Experiment

- Use original RH, Wang (2013) RH and Miloshevich (2009) RH profiles from the ARM SGP (Southern Great Plains) site.
  - Located ~0.3 km above sea level.
  - PWV has a seasonal dependence.
- Time between sonde launch and AIRS overpass often on order of ~2 hours. Solutions:
  - Environmental homogeneity test using microwave radiometer (MWR) PWV.
  - Reduce cloud cover contamination (Figure 6) and use max[$RH_{ice}(z)$] < 90% in original RH profile.
- Use these sonde profiles as input for the **Line-by-line Radiative Transfer Model (LBLRTM)**; find weighting function peaks in water-vapor sensitive channels.
- Convolve brightness temperature output from the LBLRTM to 2378 frequencies from the **Atmospheric Infrared Sounder (AIRS)**, also from 600 to 2600 cm^{-1}.

Figure 6: AIRS "footprint" brightness temperature standard deviations as a function of month. Standard deviations less than the lowest 25th percentile (red line - smoothed) for that month were used as thresholds to minimize cloud cover contamination.

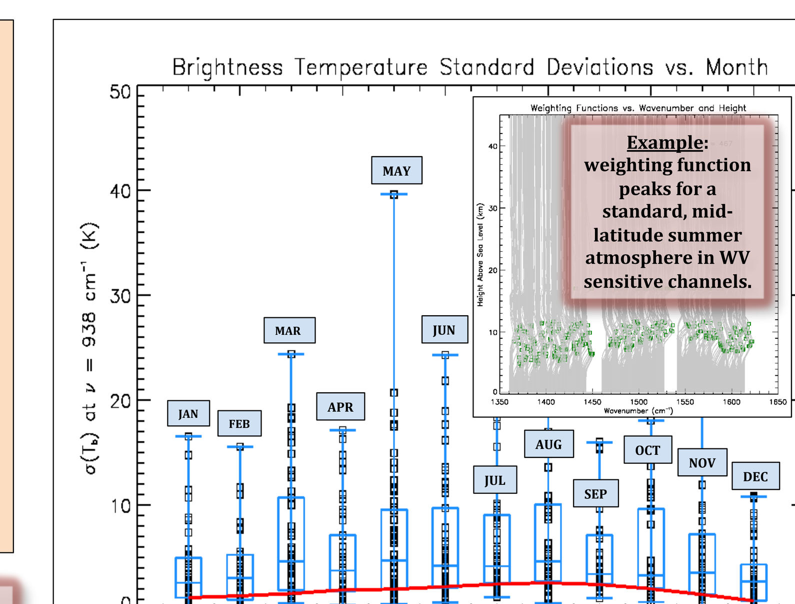
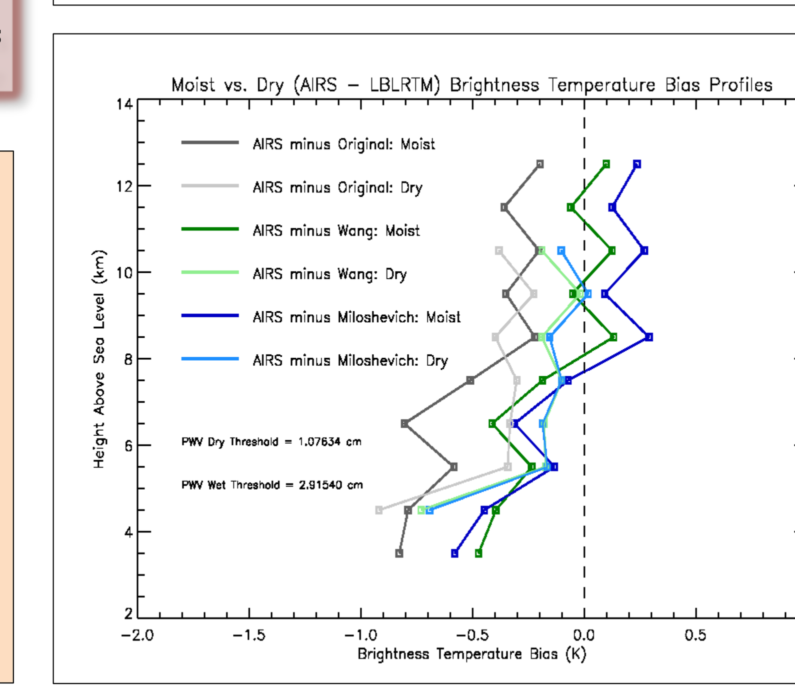


Figure 7: AIRS and LBLRTM median brightness temperature biases as a function of height. Biases at each height are "binned" where the weighting function (using the original RH profile) from water-vapor opaque channels peaked.



Analysis

- Drier profiles have less water vapor added to profile, therefore less impact on the resulting brightness temperature calculation compared to moist profiles.
- Median biases reaffirm MWR PWV analysis: both corrections work better than the original RH profile.
- Wang (2013) moist profiles, however, seem much less biased aloft compared to Miloshevich (2009).

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