Improved Daytime Precipitable Water Vapor from Vaisala Radiosonde Humidity Sensors

Contributors

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Research Highlight

Water vapor is the most abundant and the most highly variable greenhouse gas in the atmosphere. This temporal and spatial variability has a strong effect on the radiative fluxes at the surface and at the top of the atmosphere and on the radiative heating rates at all layers of the atmosphere. In addition, the distribution of water vapor is a fundamental driving force behind the formation of clouds and precipitation. The pivotal importance of water vapor to these atmospheric processes demands that numerical weather prediction and climate models use accurate water vapor profiles as part of their data assimilation process. The validation of retrieved water vapor from remote sensing instruments also requires accurate ground truth. Traditionally the profiles required for these tasks have been obtained from water vapor radiosondes launched from the global network of weather stations, among them the Vaisala RS80 and more recently RS90 and RS92. Radiosonde water vapor profiles are often considered “truth,” but inconsistencies between radiosondes and other instruments, between different types of radiosondes, or even between radiosonde profiles recorded by the same type of instrument have been noted repeatedly.

The objective of this study is to examine techniques for improving the daytime column-integrated precipitable water vapor (PWV) obtained from the Vaisala RS80-H and RS90/92 sondes. Several investigators have shown that scaling the water profile by the total column water vapor retrieved from a microwave radiometer (MWR) provides better agreement between the infrared radiance measurements and line-by-line calculations using the scaled profiles, as compared to using the unscaled sondes as input. For example, Figure 1 demonstrates that the unscaled radiosonde water vapor observations have a significant diurnal character with the daytime results having positive residuals (implying too little water vapor in the profiles provided by the radiosondes). On the other hand, the scaled radiosonde profiles do not present a diurnal character. Furthermore, the unscaled nighttime residuals are very similar to the scaled residuals, indicating that the trend with water vapor in the unscaled nighttime and daytime and scaled nighttime residuals arises from an error in the radiative transfer calculation. These observations indicate the existence of a daytime dry bias in the sonde humidity profiles that is due to a problem with the sonde measurement; scaling by the MWR not only reduces the scatter in the radiance residuals but also eliminates the daytime dry bias. However, MWR instruments are not usually available in operational settings, or even during many measurement campaigns.

In this work, analysis of the daytime differences between the MWR and the RS80-H/90/92 sondes (e.g., see Figure 2) led to a semi-empirical correction based on the solar zenith angle that was shown to effectively eliminate the

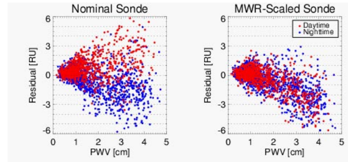

Figure 1: Atmospheric emitted radiance interferometer (AERI) minus Line-by-Line Radiative Transfer Model (LBLRTM) residuals in the 845 cm-1 microwindow for unscaled (left) and MWR scaled (right) sonde profiles as a function of water vapor amount. Daytime (12-24 UTC) residuals are in red, nighttime (00-12 UTC) residuals are in blue.

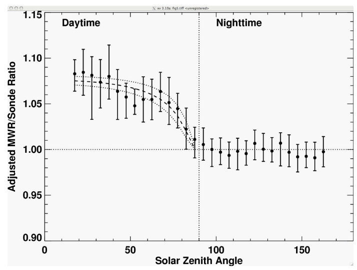

Figure 2: MWR scale factor for the clear-sky RS90/92 sondes at SGP from 2001 through 2005, scaled by mean nighttime batch MWR scale factor and binned by solar zenith angle (SZA). Circles indicate median value in each bin, bars indicate the quartiles above and below the median. Dashed line is given by 1.0+0.093 *exp(-sec(SZA)*tau_eff), with tau_eff set to 0.2. Dotted lines bracket the range of the MWR scale factor for tau_eff varying from 0.14 (above dashed line) to 0.26 (below dashed line).

daytime dry bias in PWV. This correction is consistent with the assumption of solar heating of the humidity sensor, can be applied without reference to the MWR, and is valid for all solar zenith angles. The correction, which was derived using Vaisala RS90 and RS92 radiosondes launched from the Atmospheric Radiation Measurement (ARM) Climate Research Facility (ACRF) Southern Great Plains (SGP) site from 2001 through 2005, for conditions of moderate water vapor and solar zenith angles, was tested successfully on data collected at the ACRF Tropical Western Pacific (TWP) sites with larger amounts of water vapor and smaller solar zenith angles. Incorporating this simple correction into the processing algorithms of Vaisala RS80-H/90/92 sonde profile data will greatly increase the quality of the profiles, and of the products derived from them, whether they are short-term severe weather forecasts or long-term climate change estimates.

Reference(s)

Cady-Pereira, K, M Shephard, E Mlawer, D Turner, S Clough, and T Wagner. 2008. Improved Daytime Column-Integrated Precipitable Water Vapor from Vaisala Radiosonde Humidity Sensors, Journal of Atmospheric and Oceanic Technology, DOI: 10.1175/2007JTECHA1027.1

Working Group(s)

Radiative Processes