Water Vapor Measurement Biases in the Tropical Tropopause Layer: Aura Microwave Limb Sounder vs Frost Point Hygrometers

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Introduction

Dehydration within the TTL regulates the amounts of water vapor entering the tropical lower stratosphere. It should not be assumed that dehydration is always 100% efficient; some air masses exiting the TTL are supersaturated or even subsaturated. Consequently, high accuracy water vapor measurements in the TTL are required to accurately quantify the efficiency of dehydration. A growing number of TTL water vapor data sets exist, but important discrepancies between them continue to limit our understanding of dehydration in the TTL. Here we demonstrate how small water vapor measurement biases between frost point hygrometers (FPs) and the Aura Microwave Limb Sounder (MLS) can lead to significant disparities when evaluating the efficiency of dehydration within the TTL.

Hurst et al. (2014) reported agreement better than 1% between the NOAA frost point hygrometer and MLS from 68 to 26 hPa over three sites, including Hilo, Hawaii. Below 68 hPa, at 83 and 100 hPa, statistically significant biases of 0.1 to 0.3 ppmv (3 to 8%) were found. Here we extend the comparison to upper tropospheric pressure levels 121 and 147 hPa, and augment the analysis with FP data from San José, Costa Rica.

The Instruments

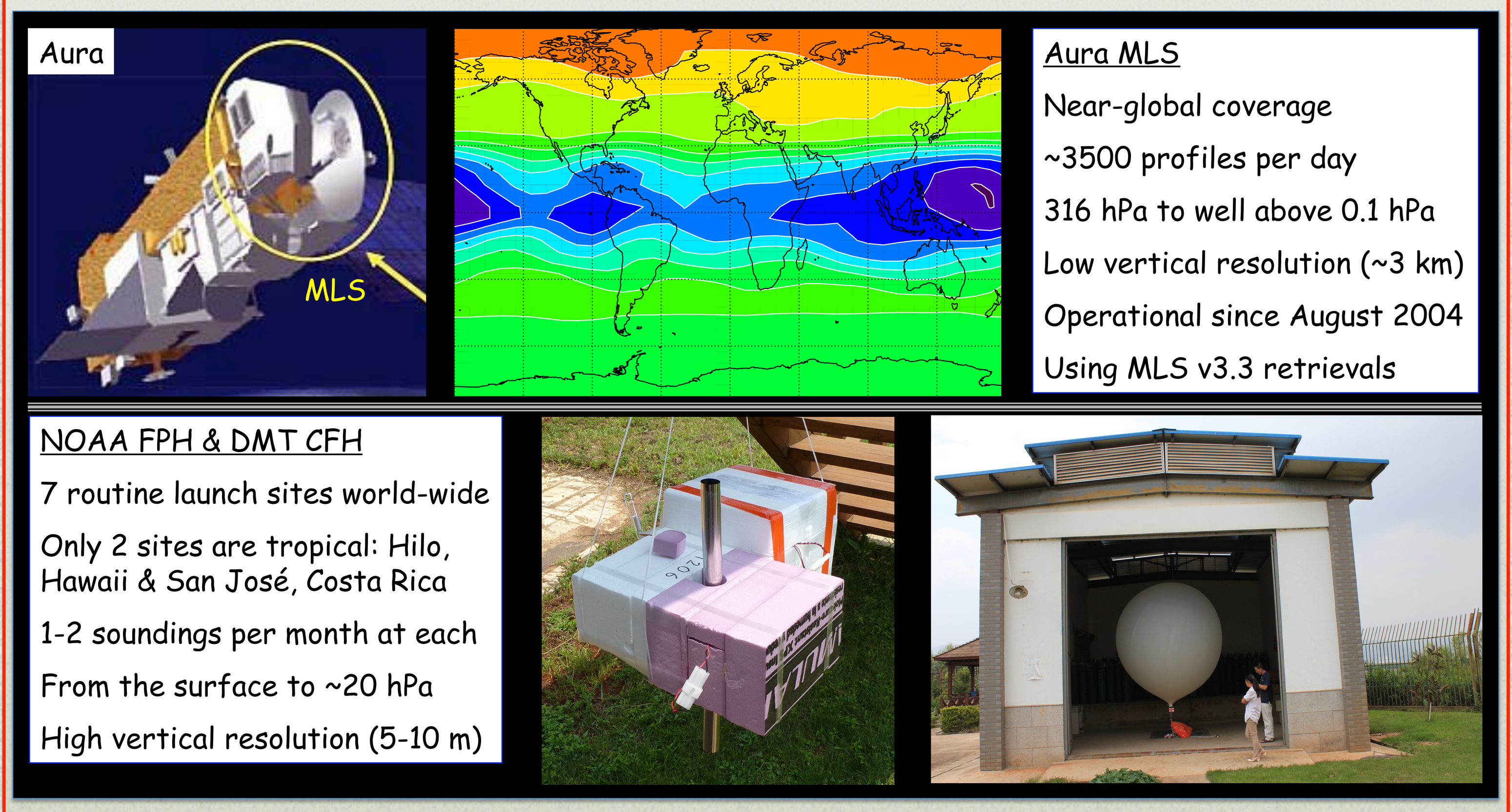


Figure 1. Spatiotemporal coincidences between MLS overpass profiles and the FPH and CFH soundings at Hilo and San José, Costa Rica are identified using criteria ±2° latitude, ±5° longitude and ±16 hours. Typically 3-6 coincident MLS overpass profiles for each FP sounding are distilled into a single median mixing ratio profile for comparison purposes.

The Approach

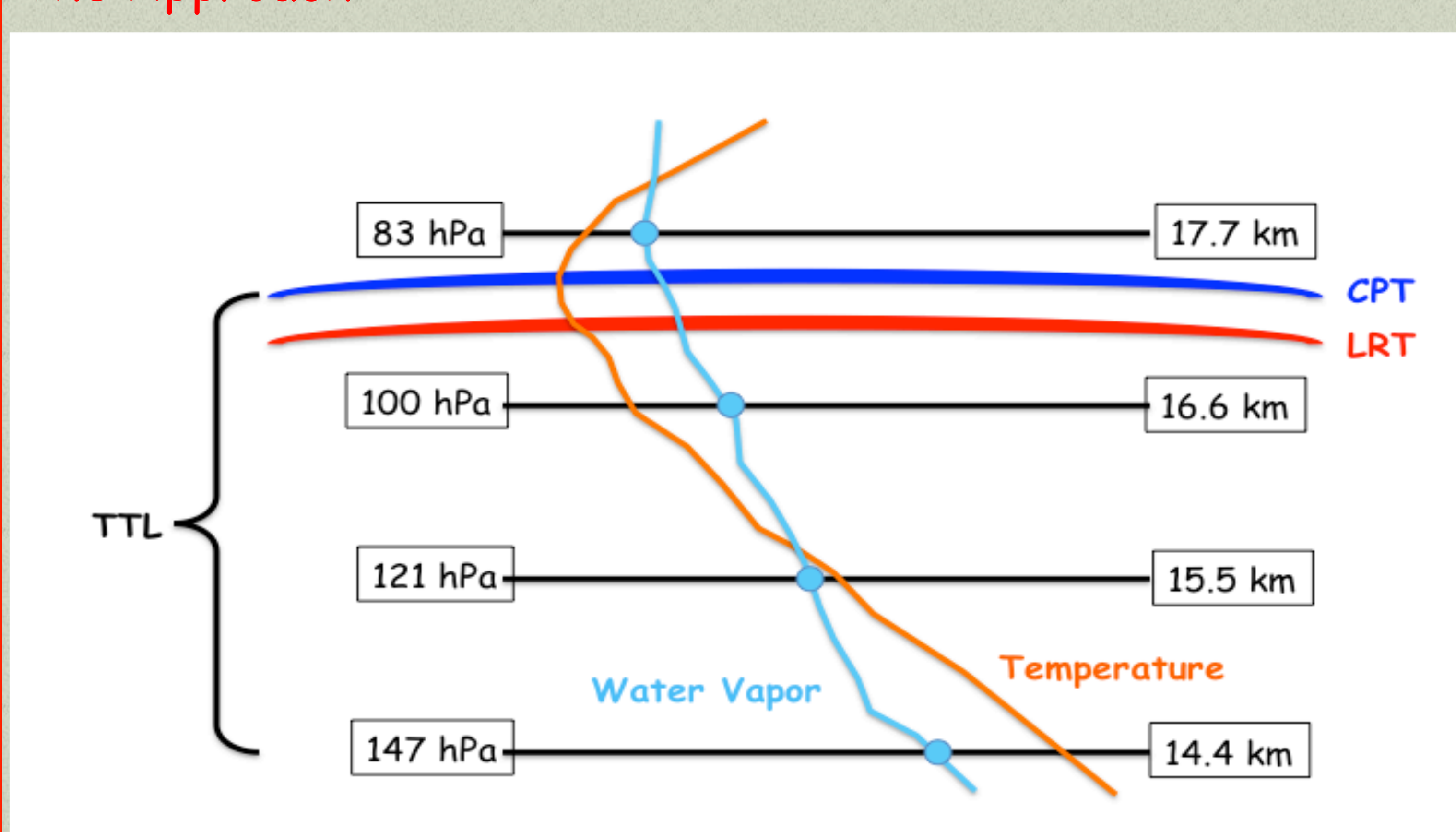


Figure 2. The Lapse Rate Tropopause (LRT) and Cold Point Tropopause (CPT) are identified from the radiosonde Temp profile for each FP sounding. Four MLS retrieval pressures are used to study the TTL. For FP-MLS bias evaluations the FP profiles are convolved with the MLS averaging kernels.

FP-MLS Measurement Biases

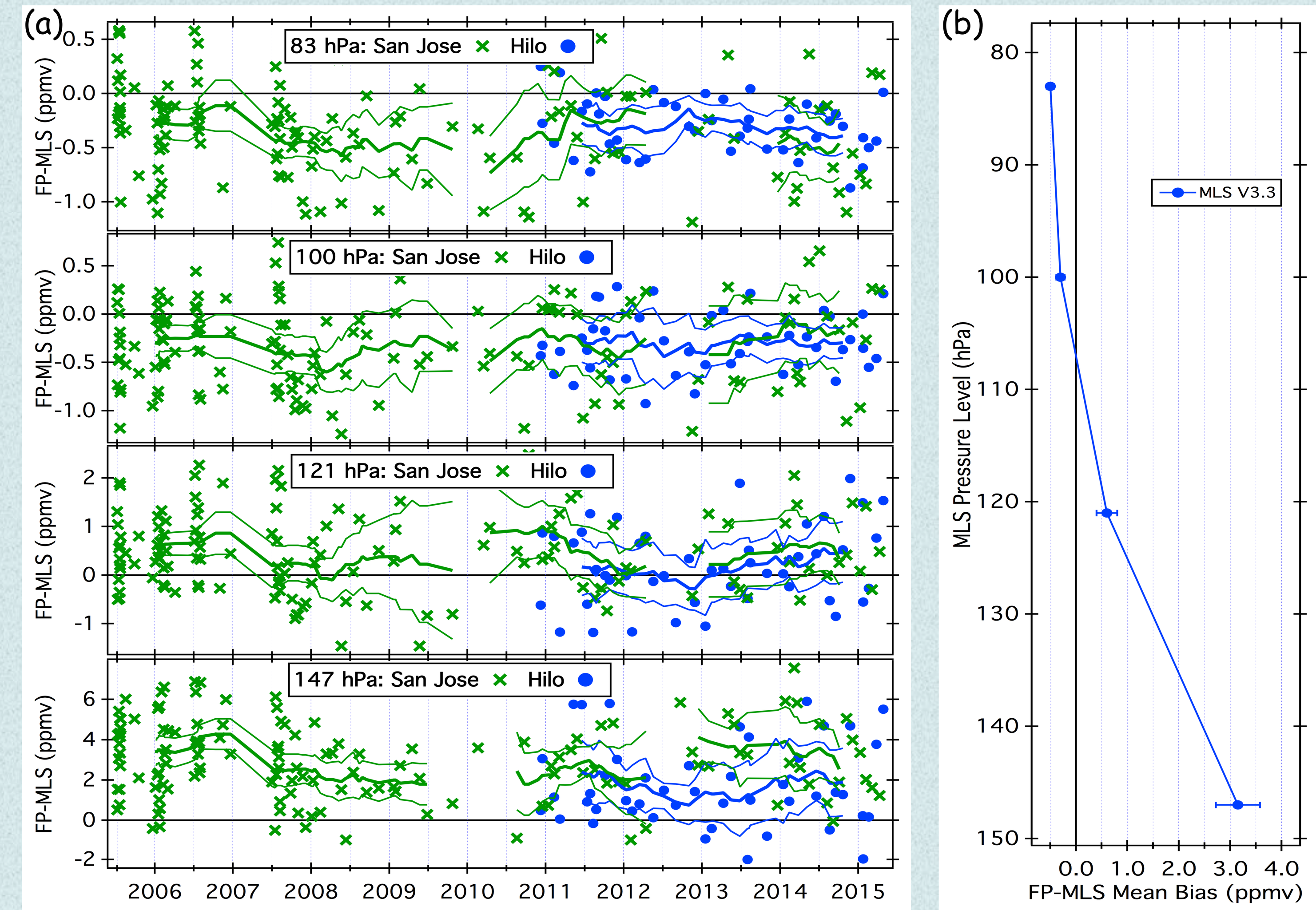


Figure 3. (a) Markers show FP-MLS differences for individual FP soundings while curves depict moving averages and 95% CIs of the moving averages. (b) Mean FP-MLS biases for the combined FP data sets over the full record interval. Though statistically significant, none of the mean biases exceed the combined instrument measurement uncertainties.

Example Profiles

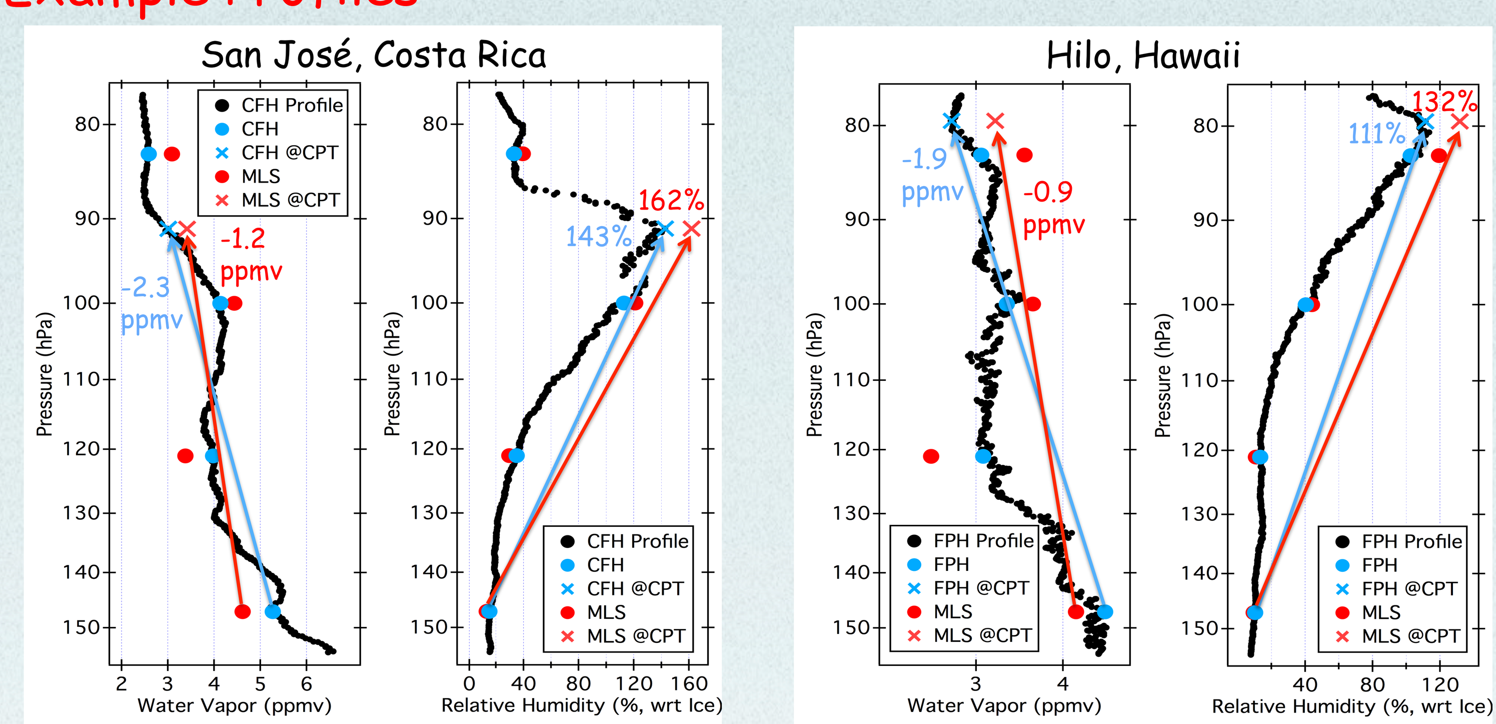
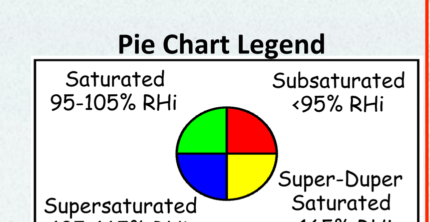


Figure 4. The water vapor losses to dehydration in the TTL (χ_{147}-χ_{CPT}) determined from FP profiles at both sites are approximately twice those based on MLS data. MLS-based RHi values at the CPT are almost always greater than those based on FP measurements.

FP and MLS Frequencies of Saturation and Supersaturation at the CPT and 147 hPa



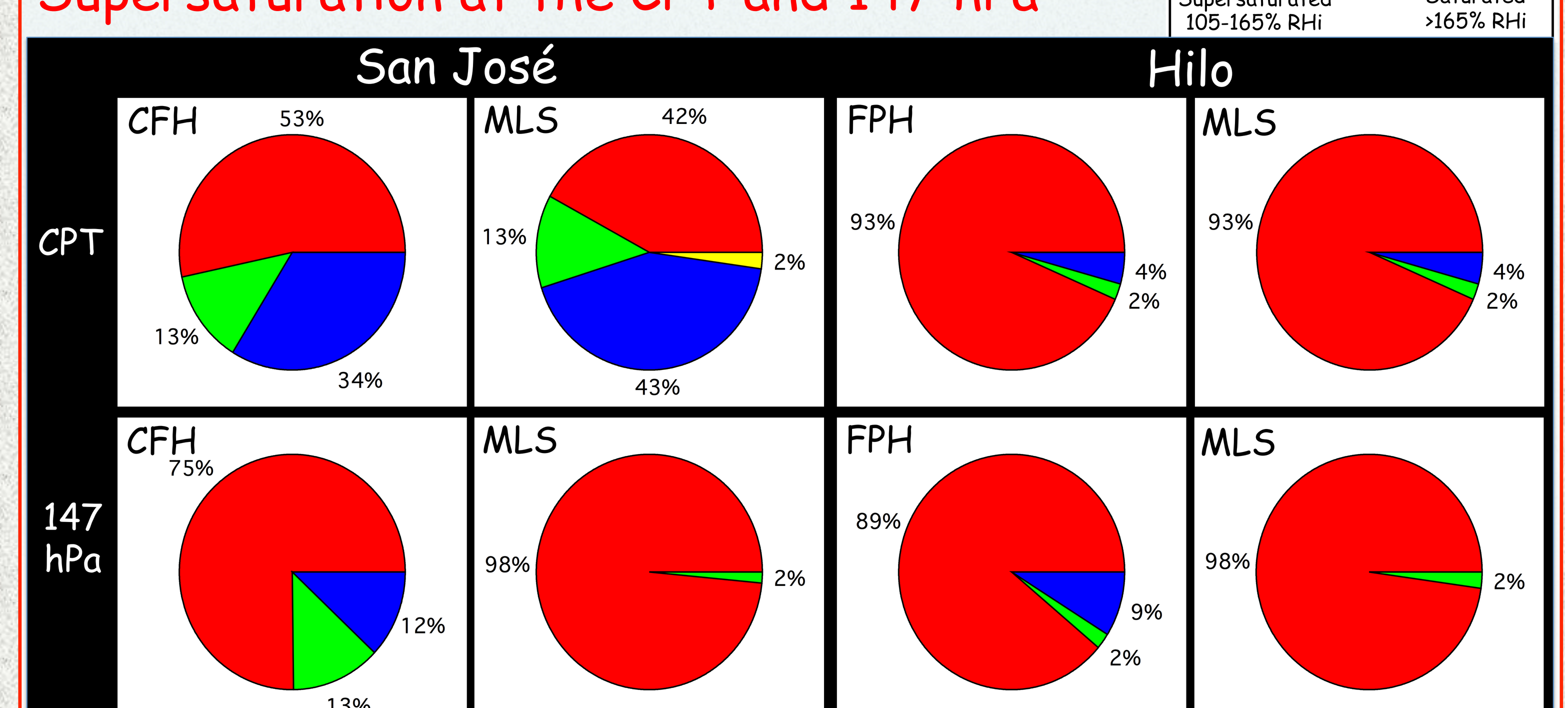


Figure 5. The FP-MLS measurement biases biases produce very different frequencies of saturation and supersaturation at the CPT over San José and at 147 hPa over both sites.

Water Vapor Losses to Dehydration in the TTL

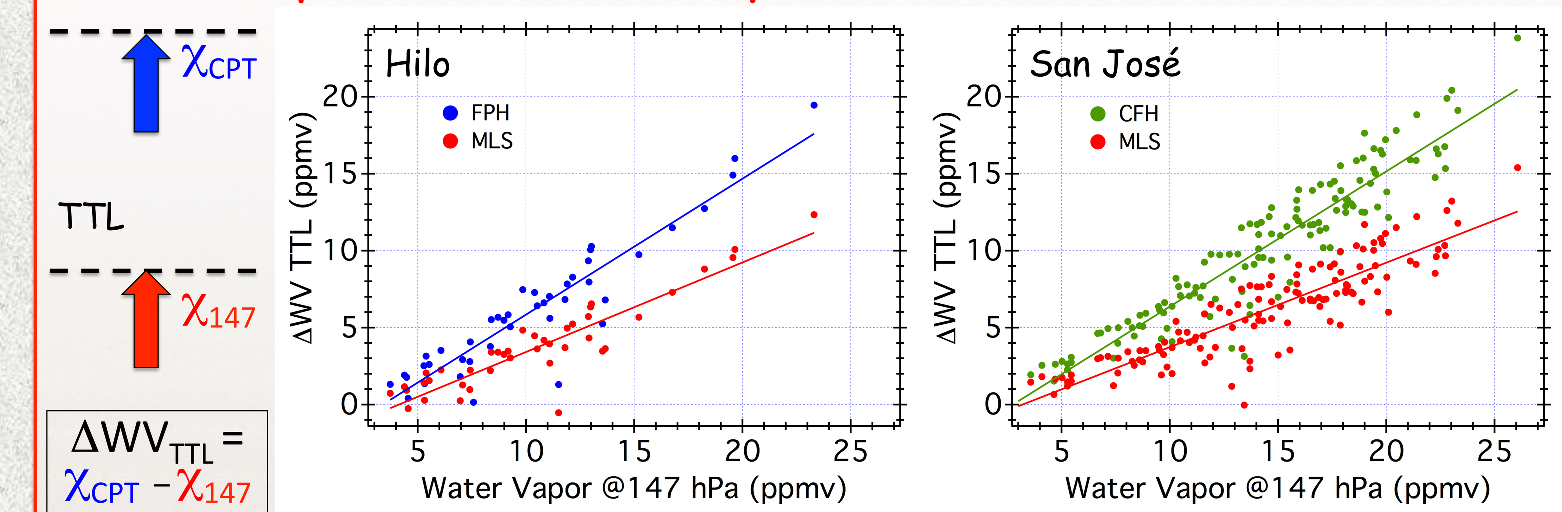
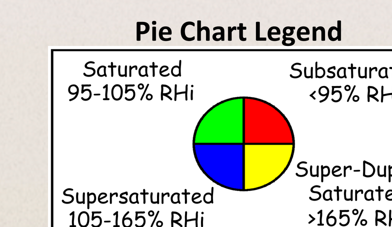


Figure 6. The losses of water vapor to dehydration in the TTL (ΔWV_{TTL}) implied by each data set are (intuitively) proportional to the amount of water vapor entering the bottom of the TTL near 147 hPa. The water vapor losses inferred from the FP and MLS data are very different; MLS losses average 58 ± 8% of the FP losses. These disparities lead to substantial uncertainties in our understanding of dehydration processes in the TTL.

MLS Version 3.3 vs Version 4.2

FP-MLS Biases, Supersaturations and Water Vapor Losses to Dehydration in the TTL



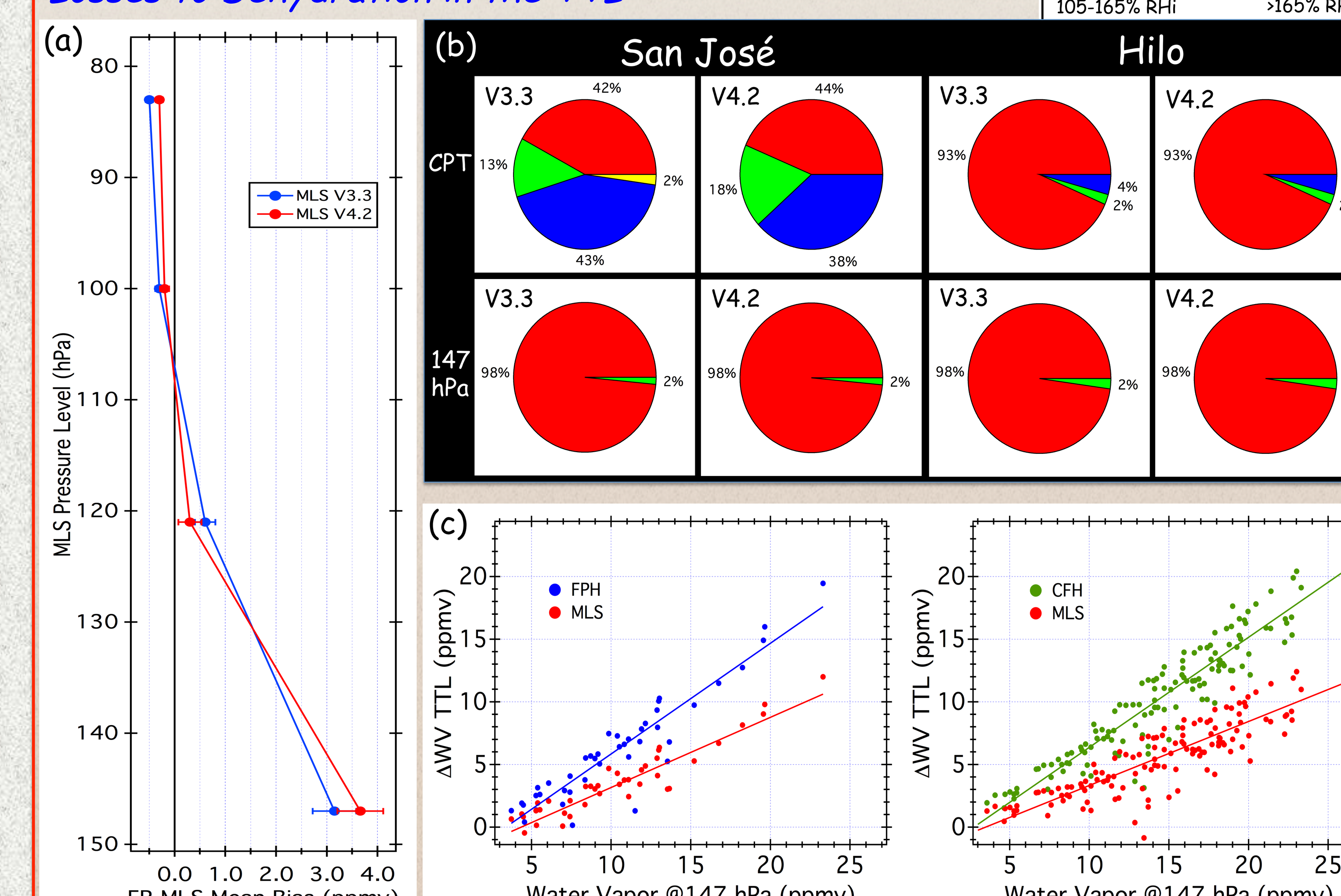


Figure 7. (a) FP-MLS mean biases for MLS v4.2 are smaller at 83, 100 and 121 hPa than for v3.3, but are larger at 147 hPa. (b) Updating from MLS v3.3 to v4.2 shifts 5% of the "supersaturated" air masses at the CPT over San José to "saturated". (c) As with MLS v3.3, the water vapor losses due to dehydration in the TTL implied by MLS v4.2 data average 52 ± 10% of those inferred from FP data. Using MLS v4.2 instead of v3.3 does not reduce the FP-MLS biases enough to significantly diminish the discrepancy between MLS- and FP-inferred water vapor losses to dehydration in the TTL.

Conclusions

» Statistically significant biases exist between water vapor measurements by the Aura MLS and two frost point hygrometers (NOAA FPH and CFH) at 83, 100, 121 and 147 hPa over Hilo, Hawaii and San José, Costa Rica.

» The biases make the MLS-based frequency of supersaturation at the CPT over San José significantly greater than that inferred from FP data.

» Water vapor gradients in the TTL measured by FPs indicate water vapor losses at both sounding sites that are 70-90% greater than those implied by MLS measurements.

» Using the new MLS version 4.2 data instead of v3.3 decreases the frequency of supersaturation at the CPT over San José but does not significantly reduce the discrepancy between MLS- and FP-inferred water vapor losses to dehydration in the TTL.

Reference

Hurst, D.F., et al. (2014), Validation of Aura Microwave Limb Sounder stratospheric water vapor measurements by the NOAA frost point hygrometer, *J. Geophys. Res. Atmos.*, *119*, doi:10.1002/2013JD020757.