Impact of Time-lag and Bias Corrections on CRYSTAL-FACE Radiosonde Humidity Data

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1. INTRODUCTION

Vaisala radiosonde relative humidity (RH) measurements are widely used in such applications as numerical modeling, radiative transfer calculations, climatology development, validation of remote sensor retrievals, and development of cloud parameterizations. The accuracy of these RH measurements can be improved, especially in the upper troposphere, by correcting for known sources of measurement error. Laboratory measurements conducted by Vaisala have led to development of corrections for sensor time-lag error (Miloshevich et al. 2001, 2002) and for dry bias errors (Wang et al. 2002, Miloshevich et al. 2001a). This poster summarizes the correction algorithm and its validation, and shows the effect of the corrections on the radiosonde data acquired during CRYSTAL-FACE.

2. CORRECTIONS APPLIED TO VAISALA RADIOSONDE HUMIDITY DATA

Time-lag: A numerical inversion algorithm that calculates the ambient ("true") RH profile from the measured RH and T profiles, based on laboratory measurements of the sensor time-constant as a function of temperature (Fig. 1).

Temperature-dependence: Addresses inaccuracy in the temperature dependence of the sensor calibration at cold temperatures (Fig. 2). Applies to RS80-H radiosondes only.

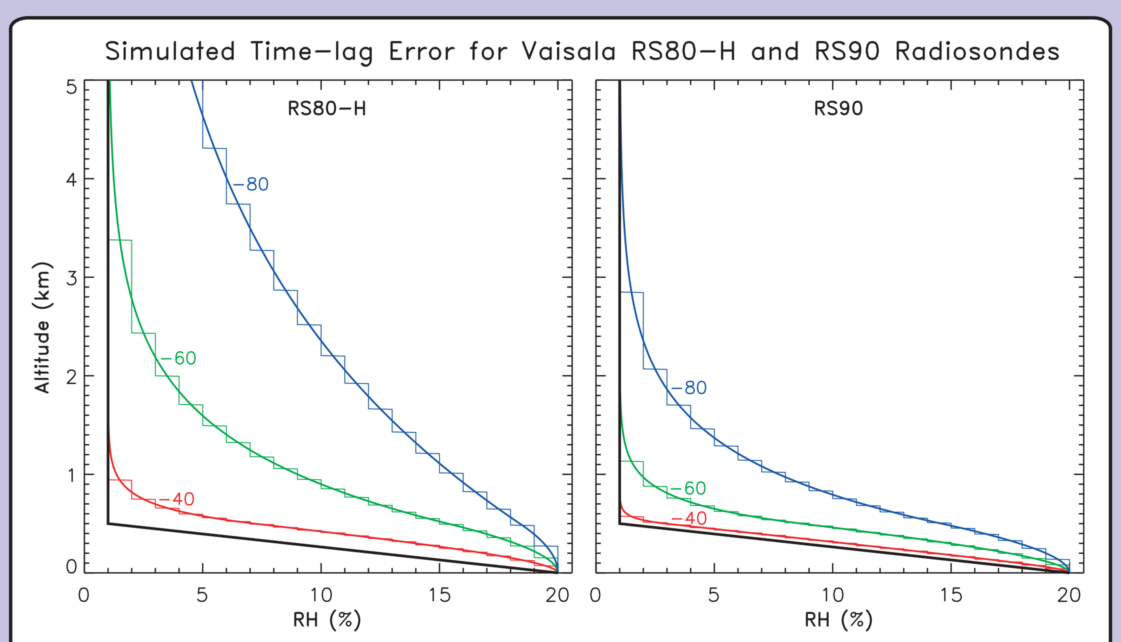

Figure 1: Simulated RS80-H and RS90 humidity measurements at three temperatures (colors) for a prescribed linear decrease in the ambient humidity (black). Stairstep curves represent data recorded with a resolution of 1% RH (like most data). The time-lag correction is the inverse process of calculating the ambient humidity from the measured humidity, after smoothing the data. The assumed ascent rate is 5 m/s .

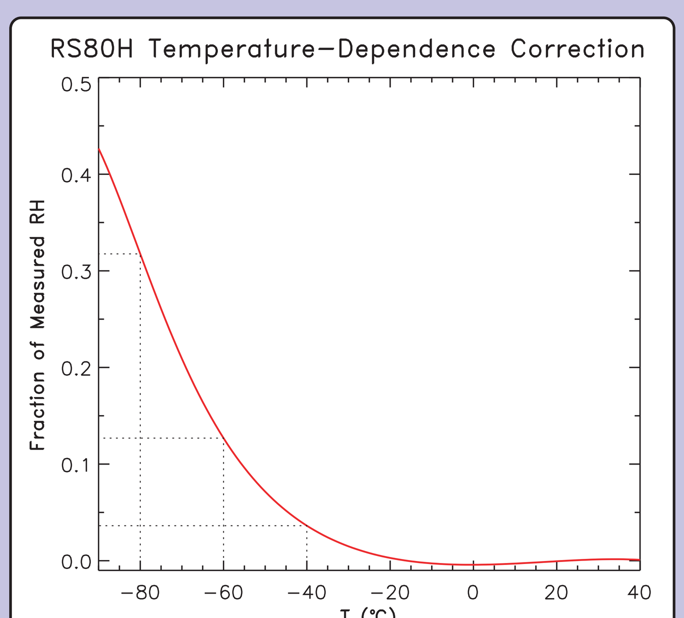

Figure 2: Correction for temperature-dependence error in the sensor calibration for RS80-H radiosondes, expressed as a fraction of the measured RH. No temperature-dependence correction was applied to the RS90 data.

3. VALIDATION OF THE CORRECTION ALGORITHM

The correction algorithm was evaluated by comparing simultaneous measurements from RS80-H radiosondes and the reference-quality NOAA/CMDL cryogenic hygrometer (Vömel et al. 1995). The figures show profile comparisons and analysis of the 40 dual soundings.

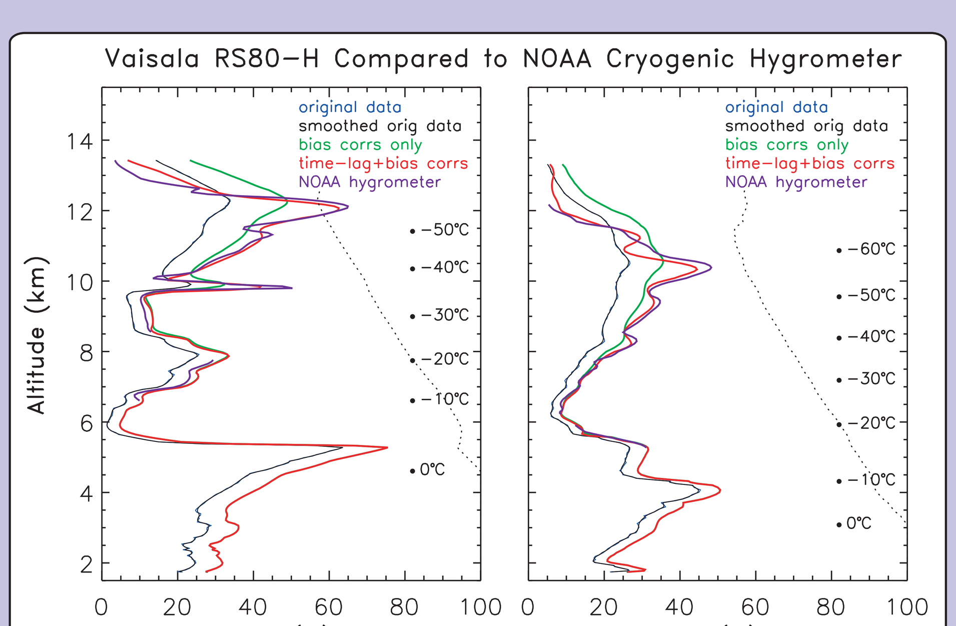

Figure 3: Comparison of Vaisala RS80-H humidity profiles after correction for time-lag and bias errors (red) with simultaneous measurements from the NOAA cryogenic hygrometer (dark blue). Dashed curve is ice-saturation.

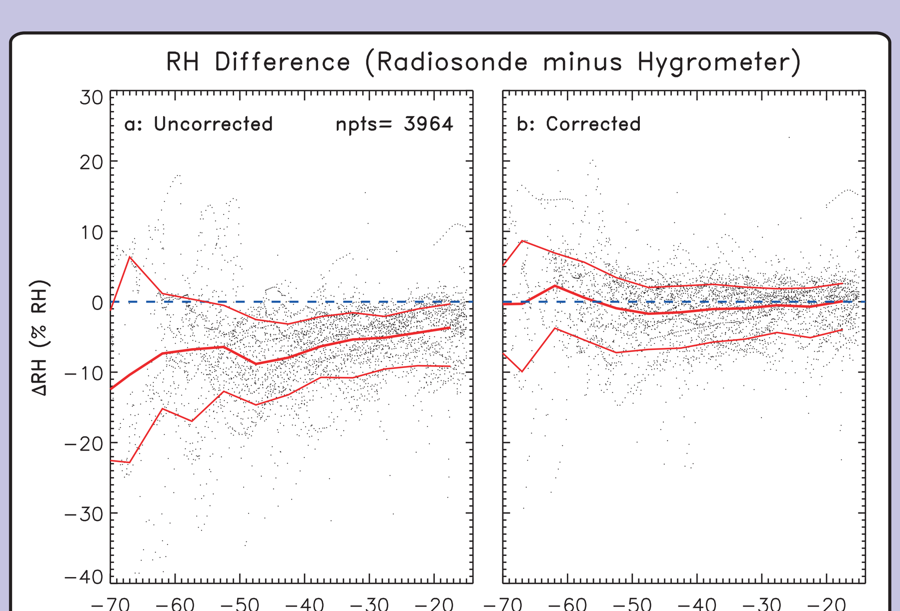

Figure 4: Difference between corresponding RS80-H and hygrometer measurements as a function of temperature, before and after correction. Curves are the mean and 68th percentile above and below the mean.

- The time-lag correction recovers vertical structure in the humidity profile that was "smoothed" by slow sensor response at cold temperatures (Fig. 3). Excellent overall agreement demonstrates that the physical basis of the correction algorithm is sound.
- Corrections reduce the T-dependent mean bias from 4% RH at -20°C and 10% RH at -70°C to about ±2% RH at all temperatures (Fig. 4). Variability is also reduced.

Miloshevich, L.M., A. Paukkunen, H. Vömel, and S.J. Oltmans, 2002: Impact of Vaisala radiosonde humidity corrections on ARM IOP data. Proceedings of the Twelfth ARM Science Team Meeting, 8-12 April, St. Petersburg, Florida.

Miloshevich, L.M., A. Paukkunen, and A.J. Heymsfield, 2001: Preliminary correction of Vaisala radiosonde humidity measurements for slow sensor time-response at cold temperatures. Proceedings of the Eleventh ARM Science Team Meeting, 19-23 March, Atlanta, Georgia.

Miloshevich, L.M., H. Vömel, A. Paukkunen, A.J. Heymsfield, and S.J. Oltmans, 2001a: Characterization and correction of relative humidity measurements from Vaisala RS80-A radiosondes at cold temperatures. J. Atmos. Oceanic Technol., **18**, 135-156.

Vömel, H., S.J. Oltmans, D.J. Hofmann, T. Deshler, and J.M. Rosen, 1995: The evolution of the dehydration in the Antarctic stratospheric vortex. J. Geophys. Res., **100**, 13919-13926.

Wang, J., H.L. Cole, D.J. Carlson, E.R. Miller, K. Beierle, A. Paukkunen, and T.K. Laine, 2002: Corrections of humidity measurement errors from the Vaisala RS80 radiosonde – Application to TOGA COARE data. J. Atmos. Oceanic Technol., **19**, 981-1002.

4. GENERAL CHARACTERISTICS OF THE HUMIDITY SENSORS AND CORRECTIONS

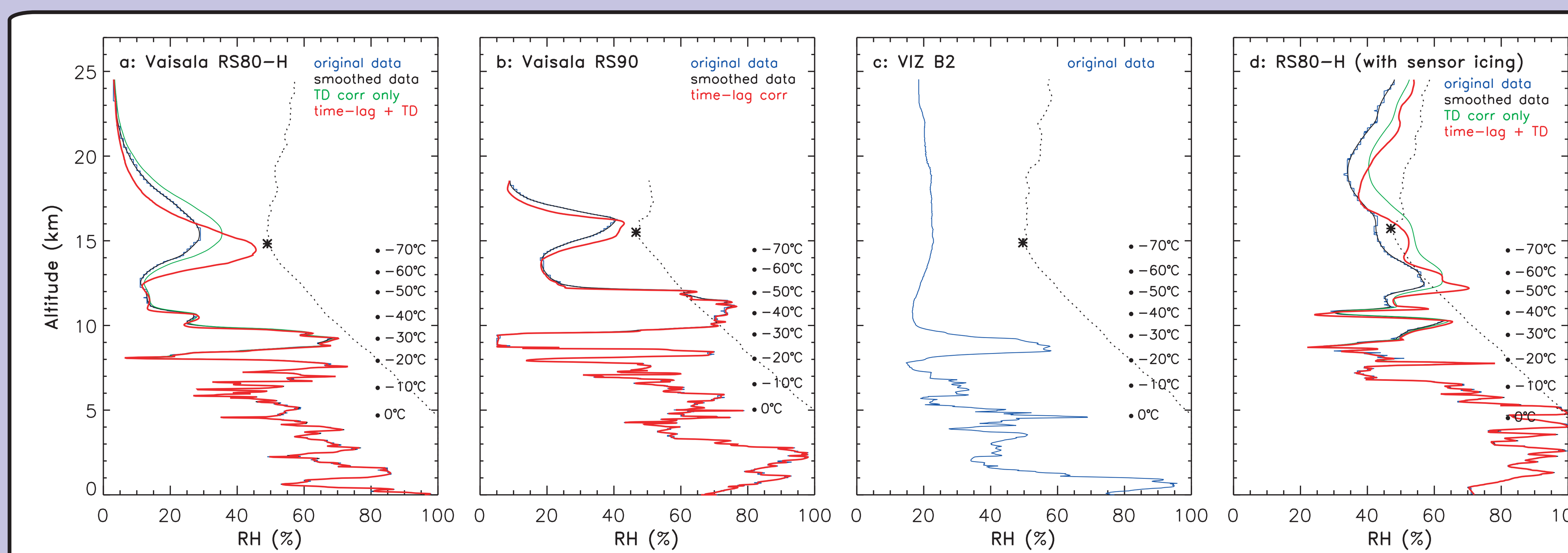

Figure 5: Example soundings that illustrate the general measurement characteristics and effect of corrections for three RH sensor types (Vaisala RS80-H and RS90, and VIZ-B2). Asterisk is the tropopause, and dashed line is ice-saturation.

- RS80-H corrections increase moisture in the UT and steepen humidity gradients above and below moist tropopause and cirrus layers (a). RS90 correction is much smaller (b).
- Sippican (VIZ) carbon hygristor sensors are unresponsive and not useful when T < -30°C (c).
- Supercooled liquid water may cause icing of RS80-H sensors (but not RS90). Icing is identified by outrageous measurements in the stratosphere (d), and are not trustworthy above the icing event. Icing cases at Miami and Tampa NWS sites are identified in the archived data.

5. MAGNITUDE OF THE CORRECTIONS AT EACH RADIOSONDE LAUNCH SITE

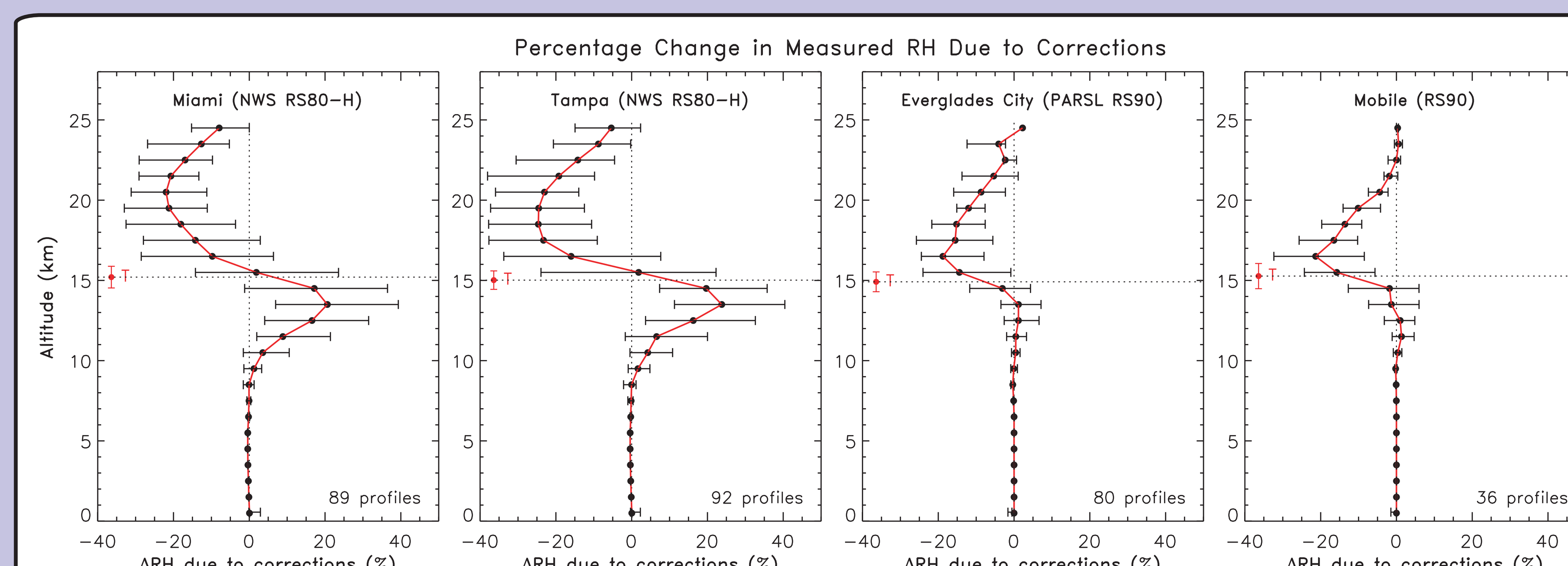

Figure 6: Percentage change in water vapor due to the corrections (%, not %RH). The mean and standard deviation are shown in 1 km altitude increments for all radiosondes at each site. Mean tropopause altitude is also shown ('T').

- Corrections increase water vapor in the UT by 20% on average, at RS80-H (NWS) sites only.
- Corrections decrease water vapor in the LS by 20% at all sites, steepening UT/LS transition.
- Variability is large due to dependence of time-lag correction on the local humidity gradient, so mean values are only descriptive in a statistical sense. Range of variability is important.

6. MEAN RH PROFILES AT EACH RADIOSONDE SITE, AND IMPACT OF CORRECTIONS

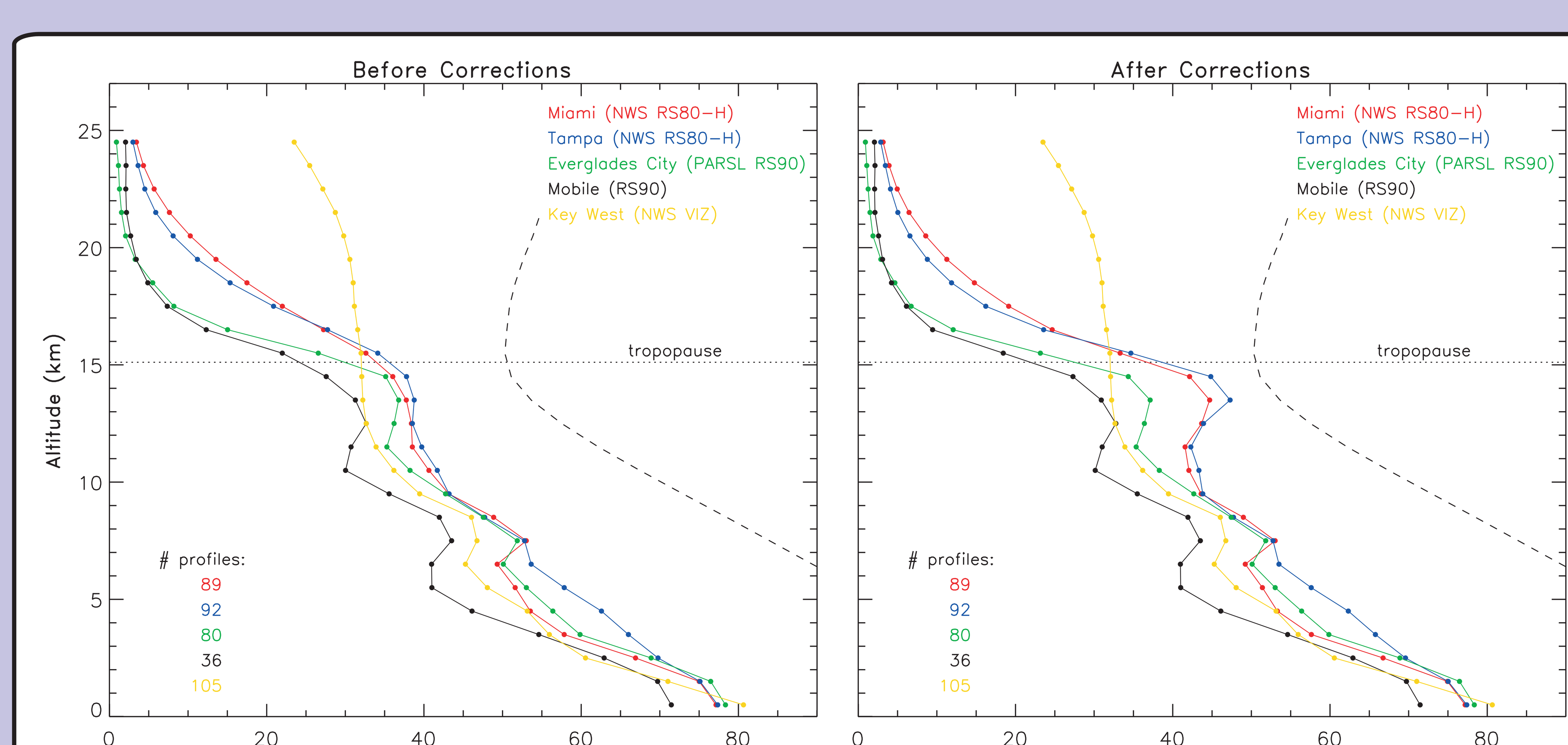

Figure 6: Mean RH profiles for all radiosondes launched from a given site, before and after corrections were applied. Also shown are the mean ice-saturation curve (long dashes), and the mean tropopause altitude (short dashes).

- High-RH layers are consistently seen at all sites in the UT, MT, and surface. (VIZ is bad in UT)
- After correction, RS90 sites are noticably drier than RS80-H sites in the UT. Two possibilities: 1) it is real; 2) a sensor-dependent bias remains (probably in RS90). Need correlative data!