# Reanalysis of Radiosonde Data from the 1996 and 1997 Water Vapor Intensive Observation Periods: Application of the Vaisala RS-80H Contamination Correction Algorithm to Dual-Sonde Soundings

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## Background

Since 1994, comparisons between radiosondes used by the Atmospheric Radiation Measurement (ARM) Program and other instruments deployed at the Southern Great Plains Cloud and Radiation Testbed (SGP CART) have suggested that significant batch-to-batch variations exist in the accuracy of radiosonde relative humidity measurements (Lesht 1995; Lesht and Liljegren 1996). This variation was statistically confirmed (Lesht 1997, 1998) by experiments conducted during the 1996 Water Vapor Intensive Observation Period (WVIOP). The discovery by ARM of a manufacturing calibration error that occurred in November 1994 pointed to the calibration process as the source of the variation. Subsequent investigation by the manufacturer (Vaisala), however, indicates that the problem is rather a result of contamination of the humidity sensor during storage. This possibility was originally discounted because Vaisala has long done storage drift tests as part of their normal quality control process; the problem was that these tests were conducted with sensor packages only, rather than with completely assembled radiosondes that seem to be the source of the contamination. The manufacturer has developed a preliminary and proprietary algorithm that can be used to estimate corrected values of relative humidity as a function of the radiosonde 'age' (the time between calibration and use).

## Correction Algorithm

The details of the correction algorithm are proprietary. We obtained access to the current working version of the correction algorithm by executing a non-disclosure agreement that requires us to keep the details confidential. After more testing and verification, Vaisala intends to release the results of the algorithm to its user community, most likely in the form of look-up tables. Separate corrections are required for the H-humicap sensor used in all ARM soundings and for the more common A-humicap. In general terms, the correction procedure has three component factors: one that accounts for small errors in the basic humidity sensor calibration model; one that accounts for the cumulative effect of contamination of the sensor with age; and one that includes an improved representation of the humidity sensor's temperature response at saturation. These correction factors are illustrated in Figures 1 through 3.

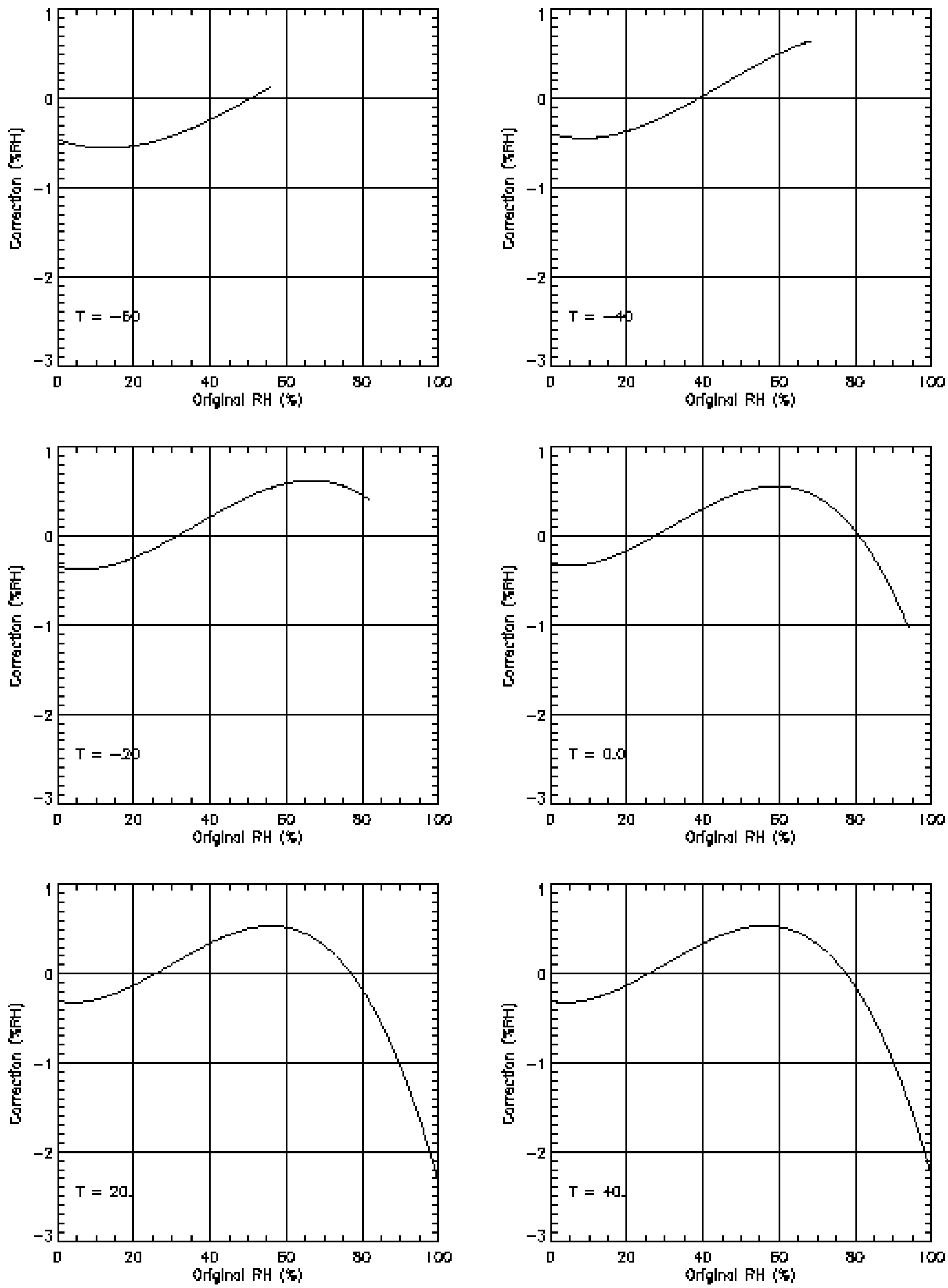


**Figure 1**. Correction factor to account for errors in the accuracy of the basic RS-80H calibration model. The correction depends on temperature and relative humidity (RH) and is shown to the approximate limit of saturation with respect to water for each temperature panel.

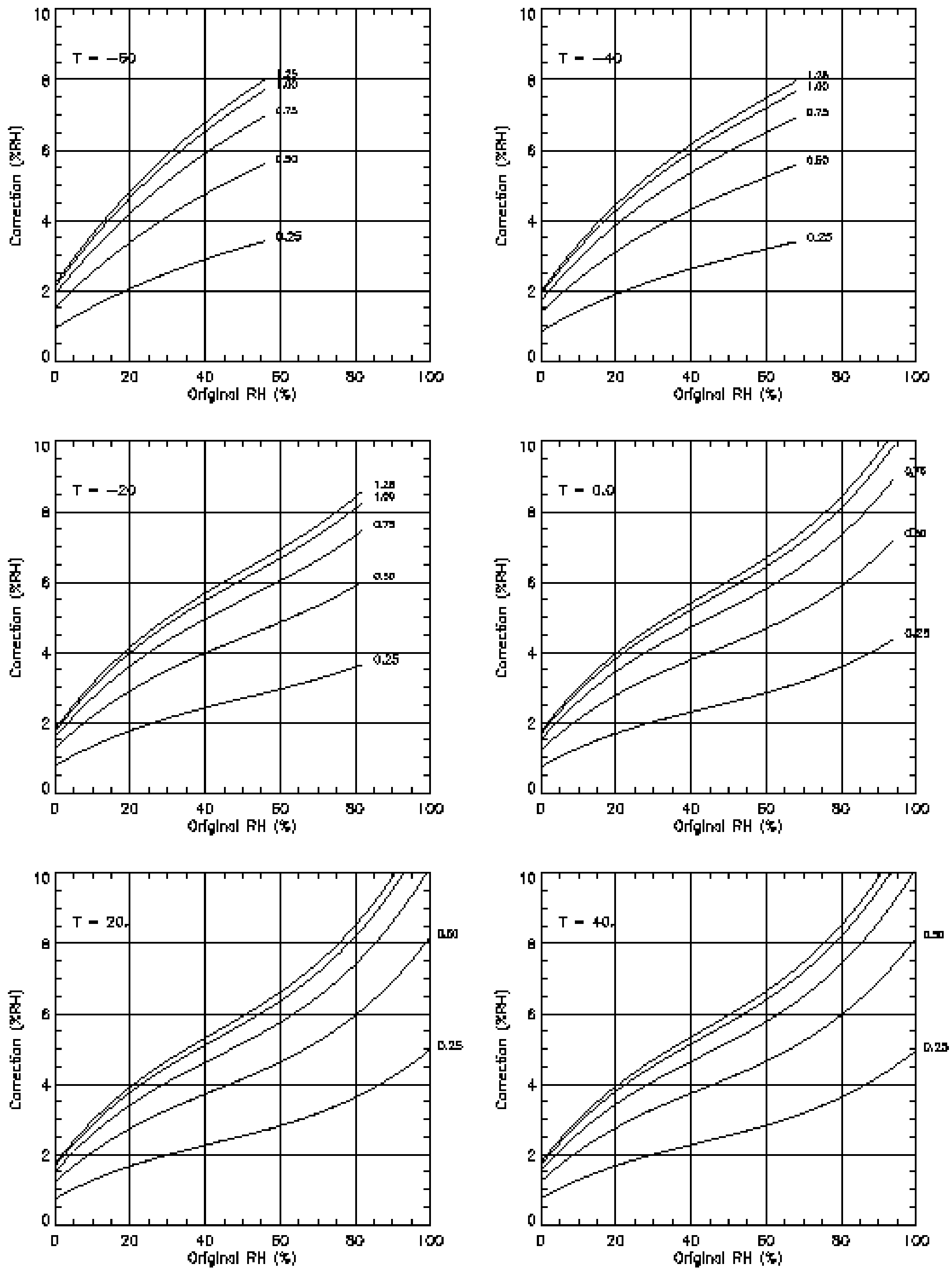


**Figure 2**. Correction factor to account for dry bias caused by contamination of the RS-80H humidity sensor. The correction depends on temperature, RH, and radiosonde age (curve families). The corrections are shown to the approximate limit of saturation with respect to water for each temperature panel.

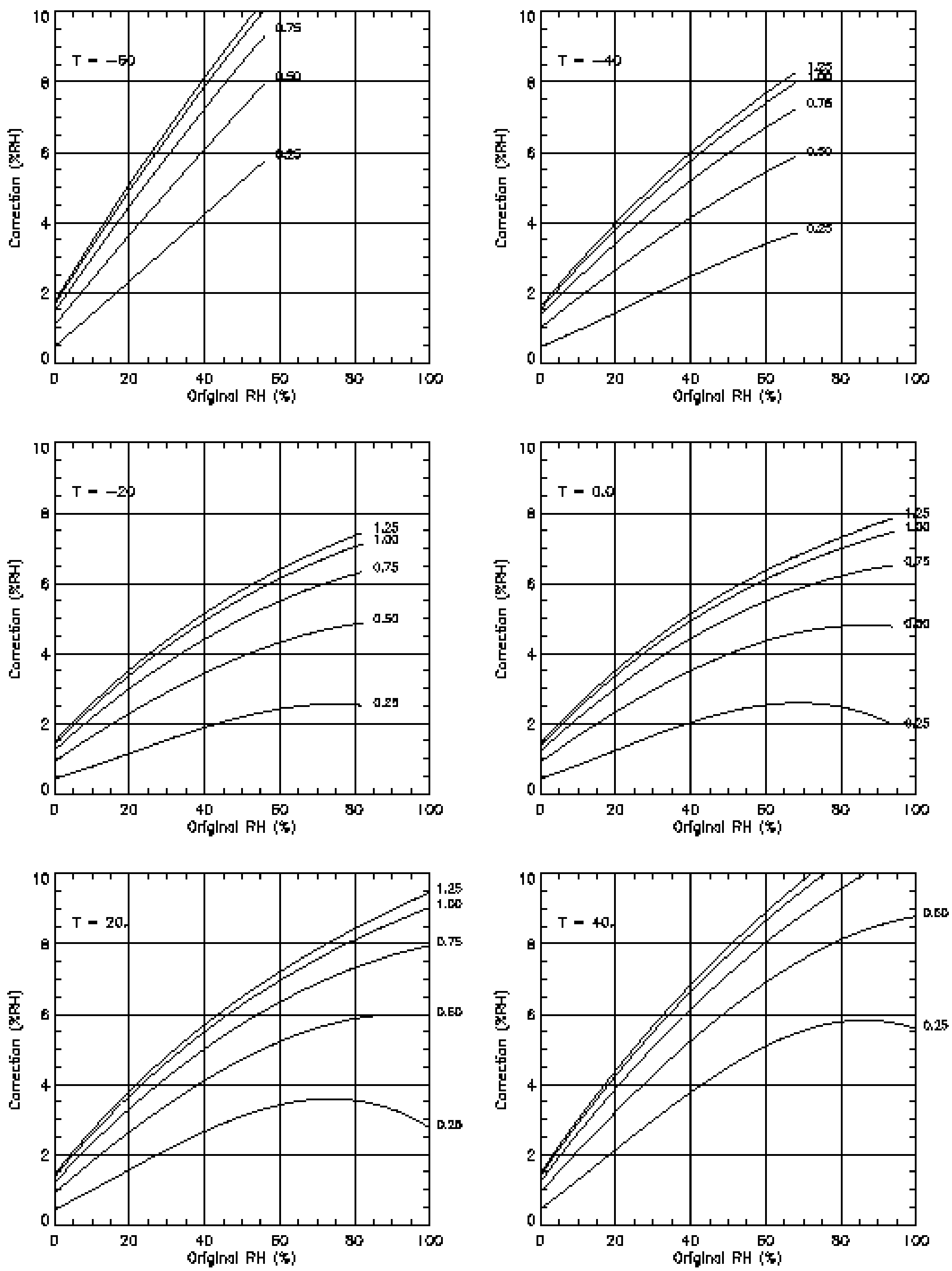


**Figure 3**. The total correction applied to the RS-80H humidity sensor. The total correction includes the calibration model and bias corrections (Figures 1 and 2) as well as an additional minor correction (not shown) related to the accuracy of the RS-80H humidity sensor at low-temperature saturation. As in Figure 2, the curve families in each panel are for radiosondes of ages between 0.25 and 1.25 years.

# Reanalysis of the 1996 WVIOP Results

One outstanding result of the 1996 WVIOP was that radiosondes calibrated in June 1996 (serial numbers 62XXXXXXX) measured lower values of RH than radiosondes calibrated in August 1996 (serial numbers 63XXXXXXX). These differences were statistically significant and were seen in both comparisons of RH and integrated precipitable water vapor (PWV) obtained from dual-sonde launches. Figures 4 and 5 show some results from the 1996 experiment.

Because we have always tracked the radiosonde serial numbers (the serial numbers are included in the radiosonde metadata), it is possible for us to calculate the exact age of every radiosonde launched by ARM. We thus can apply the correction algorithm in a forward calculation mode with radiosonde age as an exactly known independent variable rather than having to estimate the radiosonde age or rely on an empirical scaling. It should be noted, however, that the Vaisala procedure also includes an adjustment factor that can be applied if there is an accurate reference value of surface RH and temperature available. In essence, this adjustment factor scales the correction attributed to sensor contamination by the observed difference. By assuming that the difference between the radiosonde and reference values at the surface is due to contamination, the adjustment factor can be used in place of sonde age. We have chosen not to use this adjustment factor without further testing, however. We believe that ARM data, both those from the WVIOP and those from the continuing observations, provide the best source of information for independently testing the correction algorithm. Such tests are under way (see section on further analysis below).

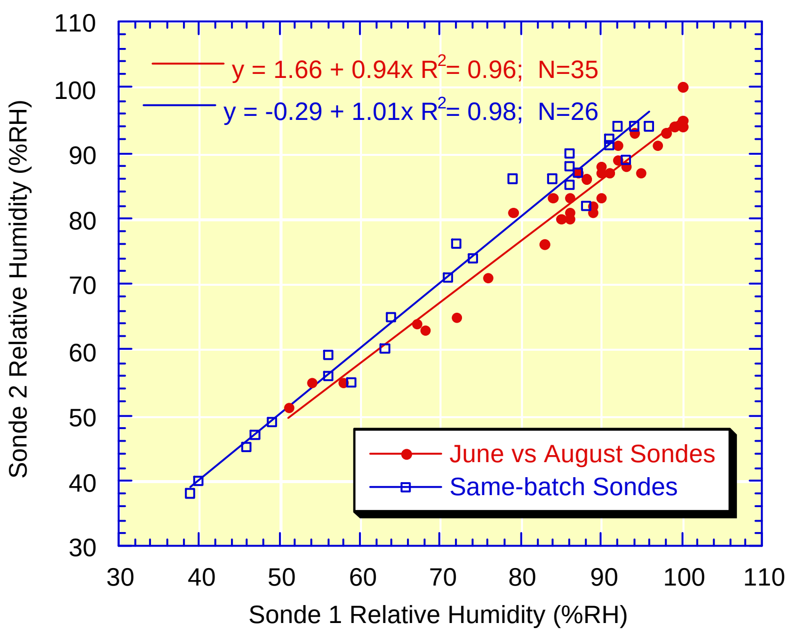


**Figure 4.** Comparison of uncorrected surface RH measured by dual-sonde soundings during the 1996 WVIOP. Results are grouped by calibration batch type (mixed or same).

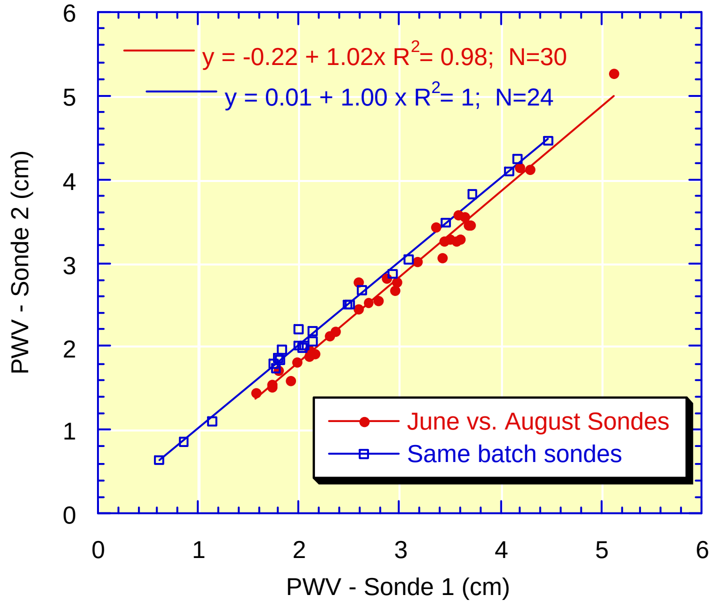


**Figure 5**. Comparison of uncorrected integrated PWV measured by dual-sonde soundings during the 1996 WVIOP. Results are grouped by calibration batch type (mixed or same).

We apply the correction algorithm to the entire sounding and calculate both the corrected values of RH for every point in the profile and the integrated PWV for every profile. For the ensemble of dual-radiosonde launches, the results show that the correction algorithm increases the RH of both the June and August sondes, and although it does not completely eliminate the differences between them, those differences are no longer significant. Figures 6 and 7 show the reanalyzed results for the same analysis shown in Figures 4 and 5.

## Analysis of the 1997 WVIOP Results

The dual-sounding experiment was repeated during the 1997 WVIOP. During that IOP, we again compared radiosondes calibrated in June with those calibrated in August. The results, however, were different from the 1996 results. In 1997, the June radiosondes were not significantly more dry than the August radiosondes (Figure 8). The reason for this is not clear. One possibility is that although the June sondes were older than the August sondes, they were not so much older that the contamination bias could be detected given the basic uncertainty in the measurements. Indeed, the average age of the older sondes used in 1997 was 93 days as compared to 109 days for the sondes used in 1996. The dry bias that results from sensor contamination is a rapidly increasing function of age (Figure 9) and it is at about 3 months that the expected bias exceeds the specified uncertainty of the measurement (3% RH). Applying the correction to these data does not substantially change the result (Figure 10).

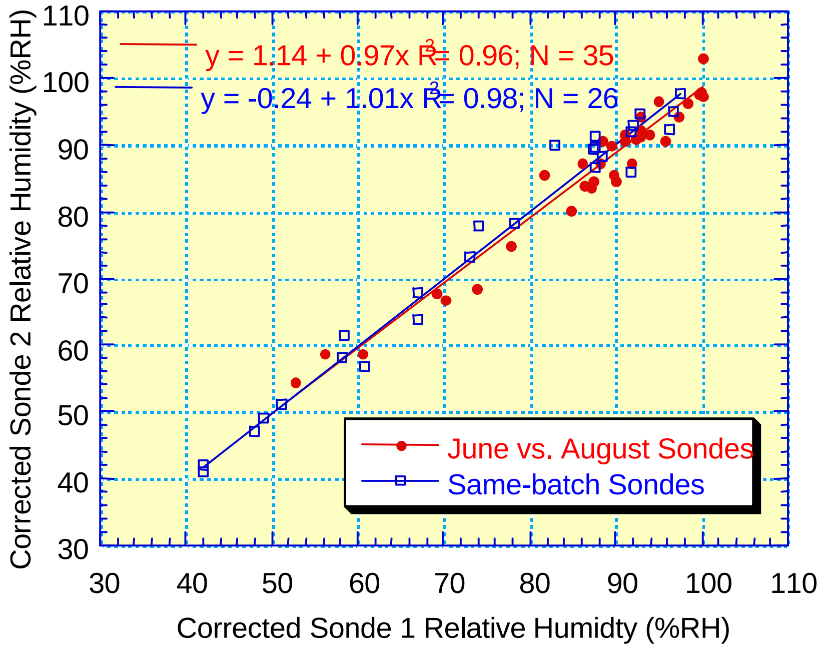


**Figure 6**. Comparison of surface RH measured by dual-sonde soundings during the 1996 WVIOP after the Vaisala correction is applied. Compare with Figure 4.

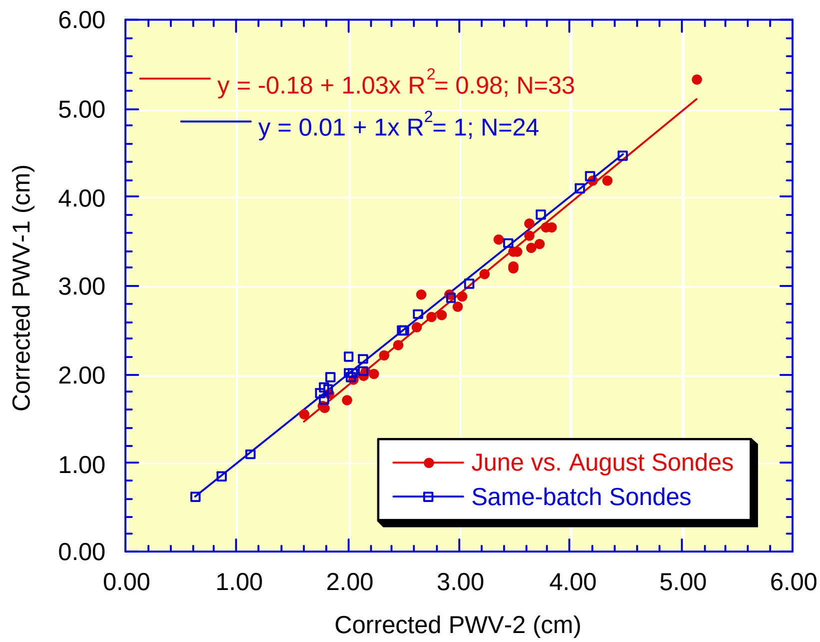


**Figure 7**. Comparison of integrated PWV measured by dual-sonde soundings during the 1996 WVIOP after the Vaisala correction is applied. Compare with Figure 5.

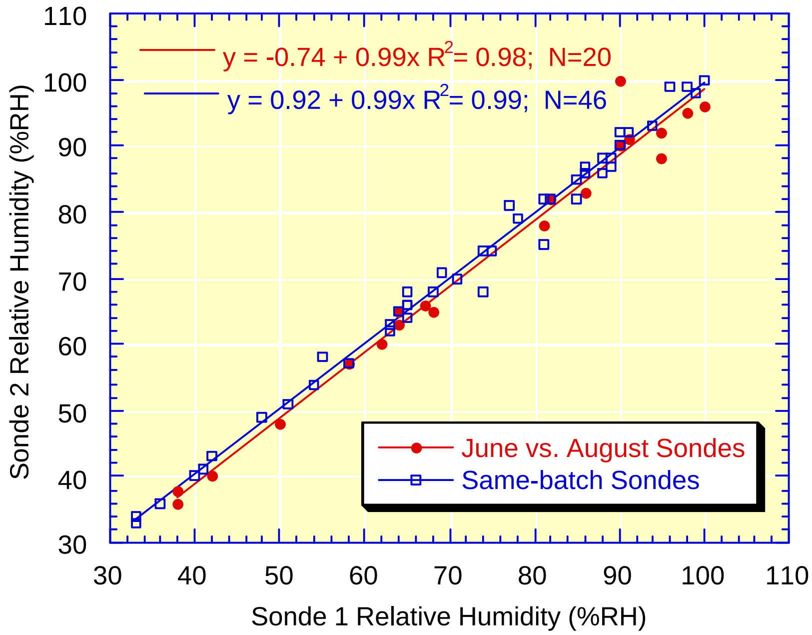


**Figure 8**. Comparison of uncorrected surface RH measured by dual-sonde soundings during the 1997 WVIOP.

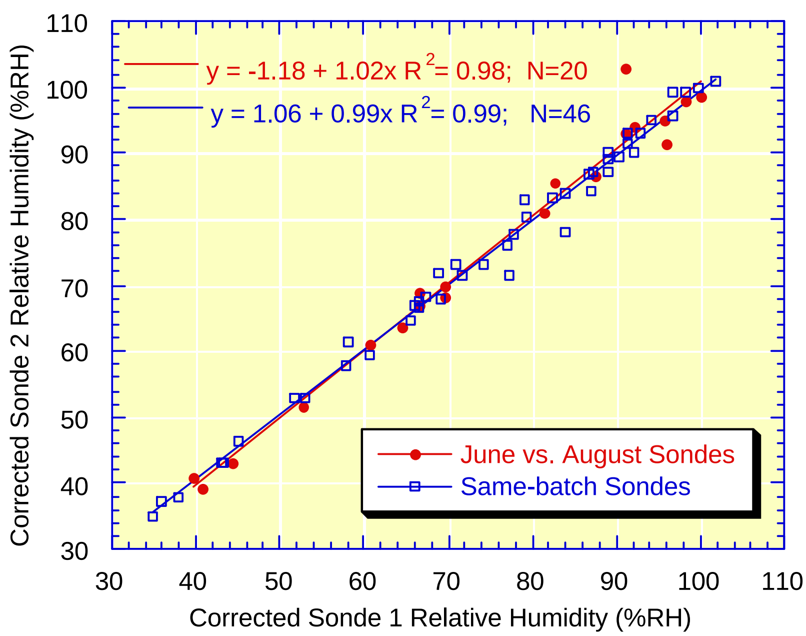


**Figure 9**. Comparison of surface RH measured by dual-sonde soundings during the 1997 WVIOP after the Vaisala correction is applied. Compare with Figure 8.

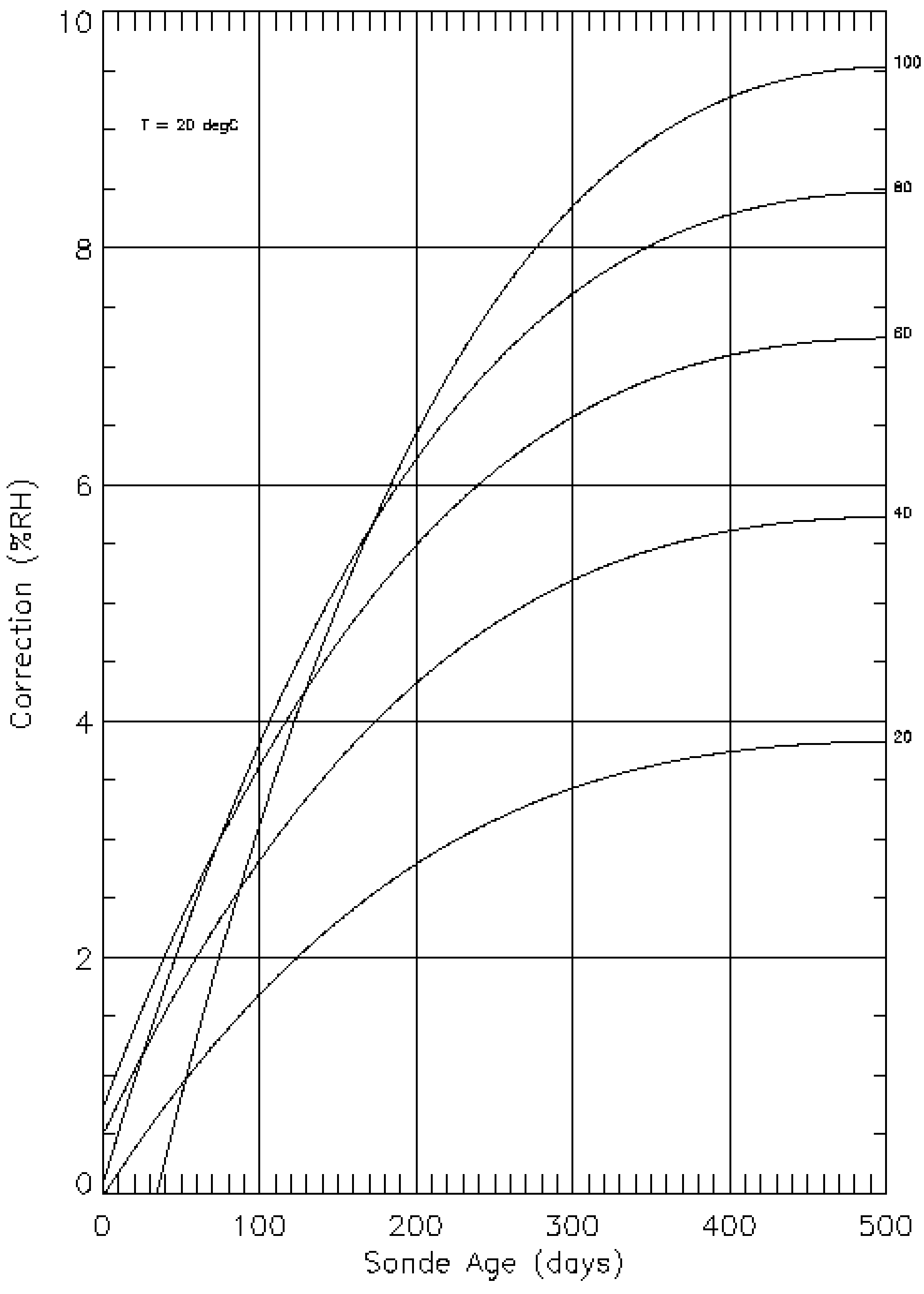


**Figure 10**. Total correction calculated for an ambient temperature of 20 °C for a range of RH values as a function of radiosonde age. The correction increases rapidly with sonde age and approaches a constant value beyond an age of 1.5 years.

## Other Analyses

We have applied the preliminary correction algorithm to all of the production soundings done at the SGP CART site central facility since 1996. The corrected sounding data have been compared to the surface observations made at the site (Richardson et al. 1999) to microwave radiometer estimates of PWV (Liljegren et al. 1999), to observations of water vapor profiles made by using the CART Raman lidar (Turner et al. 1999), and to calculated surface spectral radiances (Clough et al. 1999). In all cases, application of the correction algorithm seems to reduce the differences between the radiosondes and other instruments.

## References


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