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Comment on "Widespread tropical atmospheric drying from 1979 to 1995" by Schroeder and McGuirk

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Schroeder and McGuirk [1998, hereafter SM] recently presented an analysis of a satellite-based precipitable water (W) dataset and concluded that a widespread drying of the tropical atmosphere occurred between two periods, 1979-87 and 1989-95. SM's conclusion is at odds with other published work on this topic. We note that the trends from other studies of radiosonde data that are consistent with their results are largely those at locations showing moisture increases. While previously published trends [e.g. Gaffen et al., 1992; Ross and Elliott, 1996a; Gutzler, 1996; and Zhai and Eskridge, 1997] did not include data as recent as 1995 (the end of the SM record), they all conflict with SM's primary conclusion of tropical drying. Furthermore, the temporal homogeneity of the data was an important consideration in each of these studies and influenced the selection of the stations and time periods analyzed. An earlier study of tropical water vapor trends by Hense et al. [1988] did not consider data homogeneity, and some of their results are suspect [Gaffen et al., 1991].

SM used radiosonde data to develop their W product from TOVS satellite radiances. SM note that there have been changes in radiosonde instruments that would yield a "slight apparent drying over time ..., but the worldwide average drying is much too large to be explained by that cause." However, they present no qualitative or quantitative analysis to support that contention. We show that the apparent decrease in W in their dataset may be largely attributable to changes in radiosonde instrumentation.

Monthly mean surface-500 hPa W data from 186 tropical radiosonde stations [Ross and Elliott, 1996b] are used for the same two periods (1979-87 and 1989-95) and for the same tropical domain analyzed by SM. Some stations have reported rather irregularly over this period; we computed differences between the two period means only for stations with at least three years of data in each period. The pattern of differences (not shown) agrees fairly well in sign and magnitude with the corresponding result of SM (their Fig. 3) except over the Atlantic Ocean. The overall good agreement demonstrates that the SM data set is closely connected to the radiosonde observations. Indeed, SM also noted that the drying signal is apparent in the radiosonde record.

Unfortunately, the radiosonde observations at many stations are contaminated by abrupt changes in mean values (level shifts) caused by instrument changes. Radiosonde station histories document the relatively frequent changes in instruments and observing practices during the period SM analyzed. However, in many cases the precise dates of changes are not known, or the records are incomplete, so the station histories must be used with care [Gaffen, 1996]. In most cases faster-response sensors were introduced resulting in lower W relative to observations from older sensors [Elliott, 1995 and references therein]. Figure 1 shows monthly W anomaly time series for two stations from different parts of the tropical belt. The station histories explain the abrupt drops in W in each record.

At Niamey, Niger, there is (at least) a 6 mm drop in annual mean W around 1982 (Fig. 1, top). A 1982 catalog of radiosondes in use indicated the station was launching Mesural radiosondes, with slow-response goldbeaters skin humidity sensors. By 1989, Vaisala radiosondes were in use with faster-responding capacitive thin-film sensors. Sometime between 1982 (or earlier if the catalog information was outdated) and 1989 a change was made, which likely accounts for the discontinuity in the data. Note that Niamey is located near the Saharan minimum difference of -6.6 mm shown by SM (their Fig. 3).

At Antofagasta, Chile (Fig. 1, bottom), the beginning of the record is based on observations made with VIZ sondes with carbon hygristors. In 1987, Vaisala sondes were introduced, and subsequent W values are lower. Although both radiosondes carry relatively fast-response humidity sensors, VIZ sondes tend to measure higher humidity values than Vaisala when relative humidity exceeds about 60% [Schmidlin and Ivanov, 1998]. The drop in 1987 is accentuated by moister conditions at the times of ENSO events in 1982/83 and 1986/87. Nevertheless, the post-1987 period is still noticeably drier than the non-ENSO pre-1987 period, consistent with the low bias in Vaisala sondes compared with VIZ.

Discontinuities of this kind will clearly affect the SM analysis. Moreover, the problems exemplified in Fig. 1 are endemic throughout the tropics. We used station history information to identify which stations experienced sensor changes that would suggest drying during the period in question. These changes are either from slow-response humidity sensors (goldbeater's skin, rolled hair, or lithium chloride

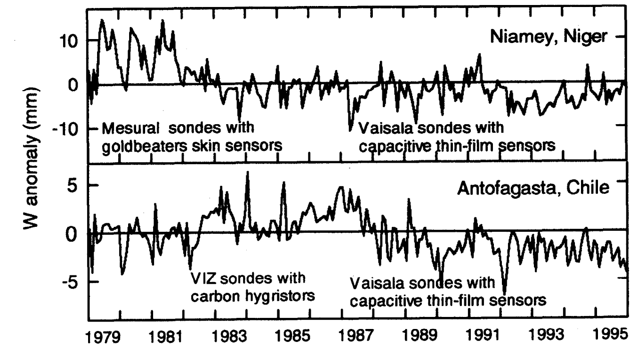

Figure 1. Time series of monthly precipitable water anomalies at Niamey, Niger (top), and Antofagasta, Chile (bottom).

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element) to faster-response sensors (carbon hygristor or thin-film capacitive elements) or from VIZ hygristors to Vaisala thin-film capacitive sensors.

Forty-nine of the 186 stations have data records contaminated by instrument changes that would suggest drying. It is likely that some of the 48 stations lacking historical information also experienced instrument changes. Most of the 80 stations that experienced no instrument changes showed increases in W between the two periods, not drying.

Furthermore, the largest drying between the two periods is generally at stations where an instrument change occurred. Of the 29 stations where more than 2 mm of apparent drying occurred, only three have temporally homogeneous data records. Sixteen stations experienced instrument changes that we expect would cause a spurious drying, and for 10 stations we have insufficient station histories.

Quantifying the level shifts in the record is less straightforward than it might seem. The same sensor change need not result in the same level shift at all stations because the magnitude of the shift depends both on ambient temperature and humidity [Schmidlin and Ivanov,1998] and on errors in both measurements. Nevertheless, to roughly indicate the magnitudes, we computed a simple difference in mean anomalies before and after known instrument changes. Because of natural variations, such an estimate can be sensitive to the averaging period. Averaging periods shorter than 1 or 2 years may not represent a stable mean but periods longer than 4 years may be affected by multiple sensor changes (as occurred in Australia). We used averaging periods of 1, 2, 3, and 4 years on either side of a instrument change; 2- or 3-year averages gave the most stable results.

The level shifts based on 3-year periods for 45 stations with sensor changes suggesting drying are shown in Fig. 2. Where station history was limited to radiosonde-in-use reports, we visually inspected the time series to identify the year of the change (as at Niamey, Fig. 1). Where both types of changes occurred (as at Australian stations) we show the level shift associated with the slow-response to fast-response instrument change rather than the VIZ to Vaisala change. Downward level shifts at Australian, Japanese island, and some South Pacific stations are usually greater than 2 mm and exceed 6 mm at some African stations. There are a few unexplained positive values, however.

The correspondence between the pattern of apparent drying and the downward level shifts associated with instrument changes suggests that Schroeder and McGuirk's conclusion of widespread tropical drying over the 1979-1995 period is at best premature. The estimated dry biases of several types of instrumentation changes appear large enough and the changes are widespread enough to account for much of the "drying" signal. Furthermore, level shifts at remote stations could influence large regions in the SM analysis via their interpolation and gridding process.

Any level shift is superimposed on natural variations that may either enhance or diminish the artificial shift at the time of the change and so the accuracy of the level shift estimate is difficult to determine. Incomplete station history data adds to the uncertainty. However, in the absence of other supporting evidence for the tropical drying in their dataset, the conclusion that this signal can be explained by radiosonde instrumentation changes seems reasonable. Our Comment focused on downward level shifts associated with humidity sensor changes but

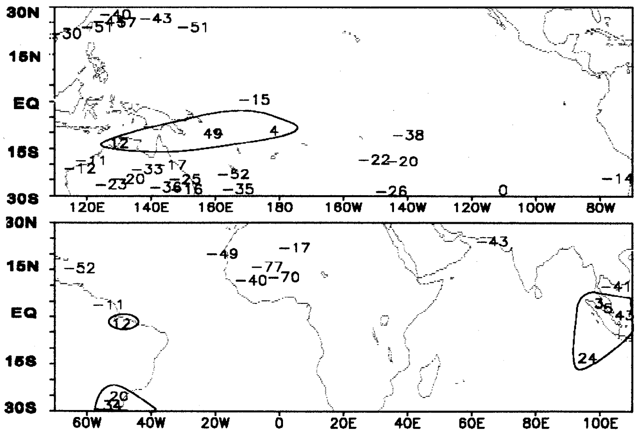

Figure 2. Level shifts in precipitable water (0.1mm) for stations with humidity sensor changes suggesting drying.

our concern with the SM analysis is more general. Namely, they used radiosonde data without screening for artificial signals in the time series. This analysis reinforces the conclusion of Karl et al. [1995] that the temporal homogeneity of data must be examined before they are used to detect changes in climate.

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