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R. C. J. Somerville, G. L. Potter, M. Kanamitsu, J. J. Hnilo, J. Woolen

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11.3 AN APPARENT MULTI-DECADAL TREND IN SHORTWAVE CLOUD FORCING OVER THE TROPICAL PACIFIC

Richard C. J. Somerville*[1], Gerald L. Potter[2], Masao Kanamitsu[3], Justin J. Hnilo[2], and Jack Woolen[3]

[1]Scripps Institution of Oceanography, UCSD, La Jolla, California
[2]Lawrence Livermore National Laboratory, Livermore, California
[3]Climate Prediction Center, NCEP/NWS/NOAA, Washington, DC

The NCEP/NCAR reanalysis (Kalnay et al. 1996) of atmospheric data beginning in 1948 has provided an opportunity to study a consistent half-century record of assimilated weather observations. Through the examination of several fields, we find an apparent long-term decrease in relative humidity, and hence a decrease in inferred cloud amount, in a large region in the central tropical Pacific. As a result, the apparent short-wave cloud radiative forcing in that region decreased by nearly 15 Wm^{-2} over the duration of the period. Two major questions arise from these preliminary results. The first question involves the extent to which the apparent trend over the 50-year period is a real phenomenon rather than an artifact, either of the reanalysis methodology or of observing system evolution. The second question is, if the phenomenon is not entirely an artifact, but is at least partially real, what is its cause?

Figure 1 shows a time-height plot of the average of the observed relative humidity fields in a region of the central tropical Pacific, which we denote by "PacIslan" region. These fields were used as input to the NCEP/NCAR reanalysis. The PacIslan region includes the 5 Pacific island stations listed in Table 1. In addition to the noticeable long-term drying trend around 500 hPa depicted in Fig. 1, there appears to be some indication of a trend toward increasing relative humidity in the lower atmosphere near the end of the period.

Figure 2 is a time series of the relative humidity at 500 hPa in the PacIslan region. This provides clear evidence of drying from 1948 to 1998. These radiosonde data show a reduction in relative humidity from almost 40% to just above 20% in 50 years. Schroeder and McGuirk (1998a,b) reported similar drying from 1979 to 1995 from satellite and radiosonde observations, although their conclusions were questioned by Ross and Gaffin

*Corresponding author address: Richard C. J. Somerville, Scripps Institution of Oceanography, UCSD, La Jolla, CA 92093-0024; e-mail: rsomerville@ucsd.edu

(1998) who attribute the apparent drying to radiosonde instrument changes alone.

Instrument changes may well have contributed to some of the apparent drying trend. However, it seems unlikely that the entire 50-year trend could be due to instrument changes alone. Nevertheless, a final resolution of this issue may require a detailed analysis of the observational record at each of the individual stations in the region, together with an investigation of the likely effect of the documented instrumentation changes. For the time being, we simply point out that the extent to which the apparent drying trend is real has not yet been well established. Table 1 shows the stations involved and the years that they experienced instrument changes.

Station	Years of change
Honiara 160.0E, 9.4S	1950, 1953, 1964, 1976, 1979, 1984, 1986, 1987
Bauerfield 168.3E, 17.8S	1992
Funafuti 179.2E, 8.5S	1960, 1981, 1989
Nadi Airport 177.5E, 17.8S	1960, 1989,1992
Willis Island 150.0E, 16.3S	1947, 1979, 1982, 1983, 1987, 1989, 1992

Table 1. Pacific Island region stations with the year of instrument changes, (taken from Gaffin Microsoft Access® Data Base available from ftp.ncdc.noaa.gov)

The result of the apparent decrease in relative humidity is apparent in the 50-year NCEP/NCAR reanalysis fields of short-wave cloud forcing. Cloud forcing at the top of the atmosphere is related to cloud cover, because it is the clear-sky minus total solar radiation. Short-wave Cloud Forcing (CRF_{SW}) is defined as:

$CRF_{SW} = S_{clear} - S_{total}$

Where:

S_{clear} = the clear sky solar flux at the top of the atmosphere
S_{total} = the total (all sky) solar flux at the top of the atmosphere

Figure 3 is a global map of the slope of the fitted trend in short-wave cloud forcing. With the sign convention used here, the positive trend in the equatorial Pacific indicates that in this region, clouds have become less effective reflectors of incoming solar radiation over the latter half of the twentieth century (1948 – 1998). The large area in the central equatorial Pacific has the most significant increase. Other regions such as the Sahel in Africa also indicate drying and reduced cloud amount. In continental regions such as the Sahel, one may speculate that land surface changes and desertification may have contributed to a downward secular trend in relative humidity and cloudiness.

However, it is difficult to imagine that this type of surface-based climate change mechanism is likely to have operated in the free atmosphere over the central tropical Pacific. The magnitude of the trend in the central Equatorial Pacific is large enough to have a significant impact on both surface heating and the large-scale circulation. Furthermore, the fact that the central equatorial Pacific trend is uniquely large, and that other regions displaying comparable trends are not generally apparent elsewhere, may support the hypothesis that this trend is real rather than an artifact of instrument changes or analysis methodology.

CONCLUSION

The apparent downward long-term trend we observe in central tropical Pacific mid-tropospheric moisture is currently unexplained. We cannot rule out the possibility that the trend may be due, in whole or in part, to instrument changes in relatively few isolated radiosonde stations, although we have given reasons for thinking that an entirely instrumental explanation is unlikely to account for the entire apparent trend in the reanalysis. When the data from these stations is assimilated into the reanalysis, the implied effect on the model clouds and subsequent cloud forcing is significant. It is interesting that recent satellite data from the CERES scanner on TRMM compared to earlier satellite remote sensing data from ERBE also show a reduction in cloud cover and also suggests tropical drying in the last two decades (Wielicki et al., 1999). In future work, we hope to investigate the issues raised above. We also plan to establish whether the apparent moisture reduction is consistent with changes in the large-scale circulation in the central Pacific. Finally, it would be worthwhile to search for independent data, such as insolation observations, that might be used to help determine whether the trend is real.

ACKNOWLEDGMENTS

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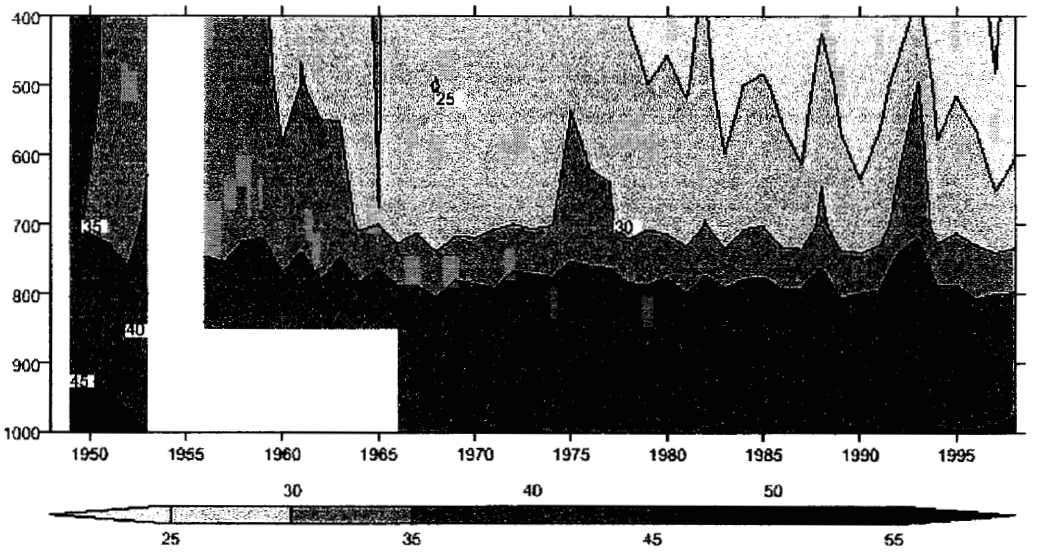

Fig 1. Time-height plot of the observed relative humidity (%) from the "PacIslan" region including Honiiara, Bauerfield, Funafuti, Nadi Airport, and Willis Island. White denotes missing data

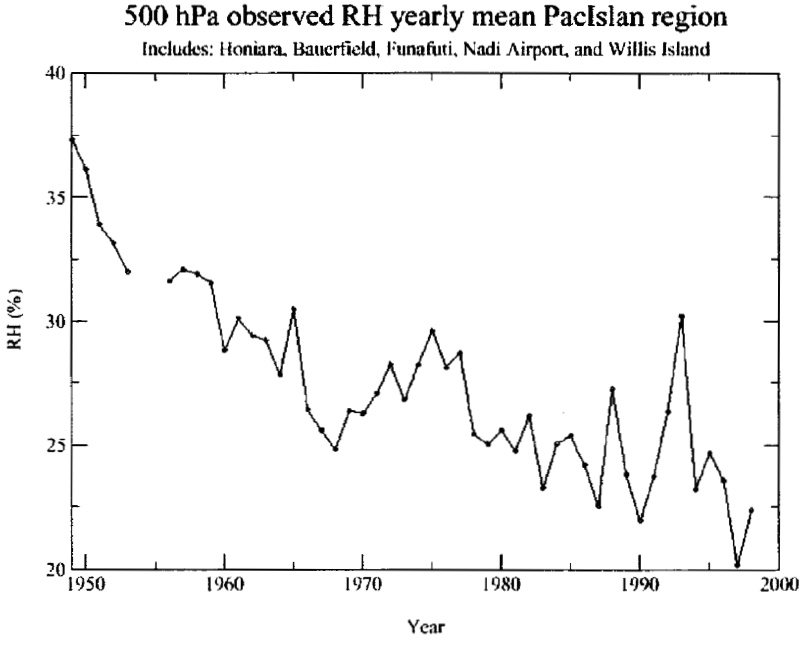

Fig. 2. Time plot of 500hPa yearly mean RH from the PacIslan region in the tropical Pacific.

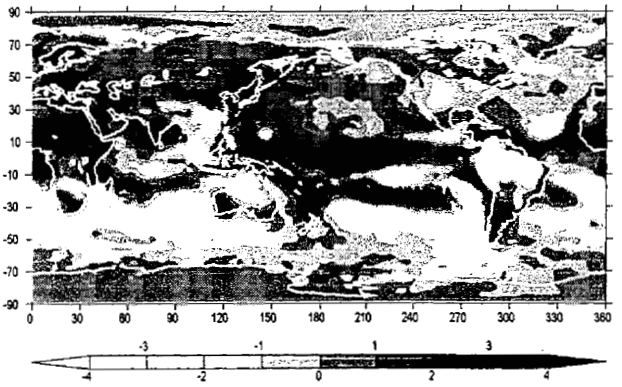

Fig. 3. Map of the trend in cloud forcing over the period 1948-1998. (Wm^{-2}/decade).