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Disturbances in the Arizona Monsoon

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I. Significant Accomplishments During the Past Year

1. We have submitted two manuscripts for publication and have 2 more manuscripts in preparation. These publications are listed at the end of this report.

2. We have begun numerical modeling simulations of tropical squall lines to determine the role of large scale terrain features over Arizona and Mexico in their initiation and propagation.

3. We have completed the installation of a short-base, high resolution lightning location and detection network in and around Tucson.

4. Data from a Doppler wind profiler, on loan for 6 weeks last summer from Penn State University is being analyzed to determine the role of large scale heating over the inter-mountain plateau region in governing local diurnal wind variations and possible relationships to the monsoon flow.

5. We have completed development and calibration of the portable solar photometer for determining high temporal resolution values of the local precipitable water vapor.

6. We have nearly completed assembly of a multi-channel microwave passive radiometer to determine local temperature and water vapor profiles.

II. Focus of Current Research and Plans for Next Year

1. We will continue our simulation studies of tropical squall lines.

2. We plan to collect data (lightning location and local radar data) this coming summer during the passage of tropical squall line types of disturbances in the monsoon flow.

3. We will collect solar photometric precipitable water data and microwave temperature and humidity data to aid in the analysis of passing mesoscale disturbances.

III. Summary of Presentation to Review Panel

The Arizona Monsoon is a seasonal reversal of the mean winds over the southwestern U.S. and Mexico from generally westerly during most of the year to generally easterly during July, August and part of September. This reversal of the winds satisfies the usual definition of a Monsoon. In addition, in this area this reversal is accompanied by a considerable increase in rainfall. Most of this rainfall results from thunderstorms and in the past it has been assumed that these storms could be forecast simply by examining certain airmass parameters such as precipitable water. When these parameters indicate that the airmass is both fairly unstable and wet then thunderstorms will be widespread, otherwise they will be scattered or absent. This technique works well at times; however there are other times when it doesn't. On some days there are no storms even though airmass parameters say there should be and vice versa. It is apparent on those days that there must be some sort of disturbance present to either enhance or inhibit thunderstorm activity.

In the past it has been virtually impossible to either study or forecast these disturbances due to a lack of conventional data. With the recent availability of satellite derived data this is no longer the case. Thus we have spent the last two years attempting to use this new data from satellites, as well as any other non-conventional data, to describe the structure and dynamics of some of these disturbances. We have described a number of these disturbances in other review sessions. These include the monsoon boundary (Adang and Gall 1988), disturbances that form along the monsoon boundary (Moore, Gall and Adang 1988) and a system that forms over the mountains of Arizona and Mexico in the late afternoon, propagates westward after sunset and has many of the properties of tropical squall lines (Smith and Gall 1988). All of these studies have benefited from data sources in addition to those given by satellite and conventional devices. For example we have made extensive use of lightning location information to show the location and motion of convective systems. We recognize that any additional data source that we can develop may also prove important in our understanding of systems such as those described in the above mentioned references as well as others. Thus in this review, rather than again summarizing the work we have completed on the structure of monsoon disturbances, we will instead summarize our development work on a simple system to determine precipitable water.

As has been described in Adang and Gall 1988, the monsoon boundary is frontal-like and separates an extremely dry air mass, generally to the west and north of the boundary, from a very moist air mass to the south and east of the boundary. This boundary frequently lies over Arizona and its meanderings, or oscillations are extremely important determining the total precipitible water over any given region. Thus measurements of precipitated water are very useful in determining the location and motions of their boundary. The normal radiosonde data does not yield the required temporal resolution for tracking this boundary, and the spatial resolution is inadequate for determining the presence of many mesoscale disturbances along the boundary. The technique to be described here is capable of yielding daytime temporal resolutions on the order of minutes, providing the sun is not observed by clouds (on most days, there are adequate breaks in the monsoon cloud cover to provide at least some data). This temporal resolution may then be interpreted in terms of a spatial resolution for moving disturbances.

The solar photometric technique for determining precipital water utilizes the Langley method for determining the total atmospheric extinction of the direct solar beam at any wavelength, λ. Thus, if $F_{o\lambda}$ is the solar irradiance at the top of the atmosphere, then an instrument at the surface will measure an irradiance F_λ given by

$$F_\lambda = F_{o\lambda} e^{-m\tau} \quad (1)$$

where τ_λ is the total vertical optical depth and $m = \sec\theta_o$ where θ_o is the solar zenith angle. Writing eq. (1) logarithmically yields

$$\ln F_\lambda = \ln F_{o\lambda} - m\tau_\lambda \quad (2)$$

If a series of measurements at various solar zenith angles are made, and the logarithm of the measurements, $\ln F_\lambda$ is plotted against m, the points should fall on a straight line with intercept $\ln F_{o\lambda}$ and slope, $-t_\lambda$. In this manner the total optical depth at any wavelength may be determined. In a water vapor absorption band, the total optical depth may be written as

$$\tau_\lambda = \tau_{R\lambda} + \tau_{a\lambda} + \tau_{w\lambda} \quad (3)$$

where τ_λ is the known Rayleigh optical depth, $\tau_{a\lambda}$ is the aerosol optical depth, and $\tau_{w\lambda}$ is the desired water vapor optical depth. If other measurements are made outside the water vapor band (and without any other gaseous absorption) then, at these wavelengths,

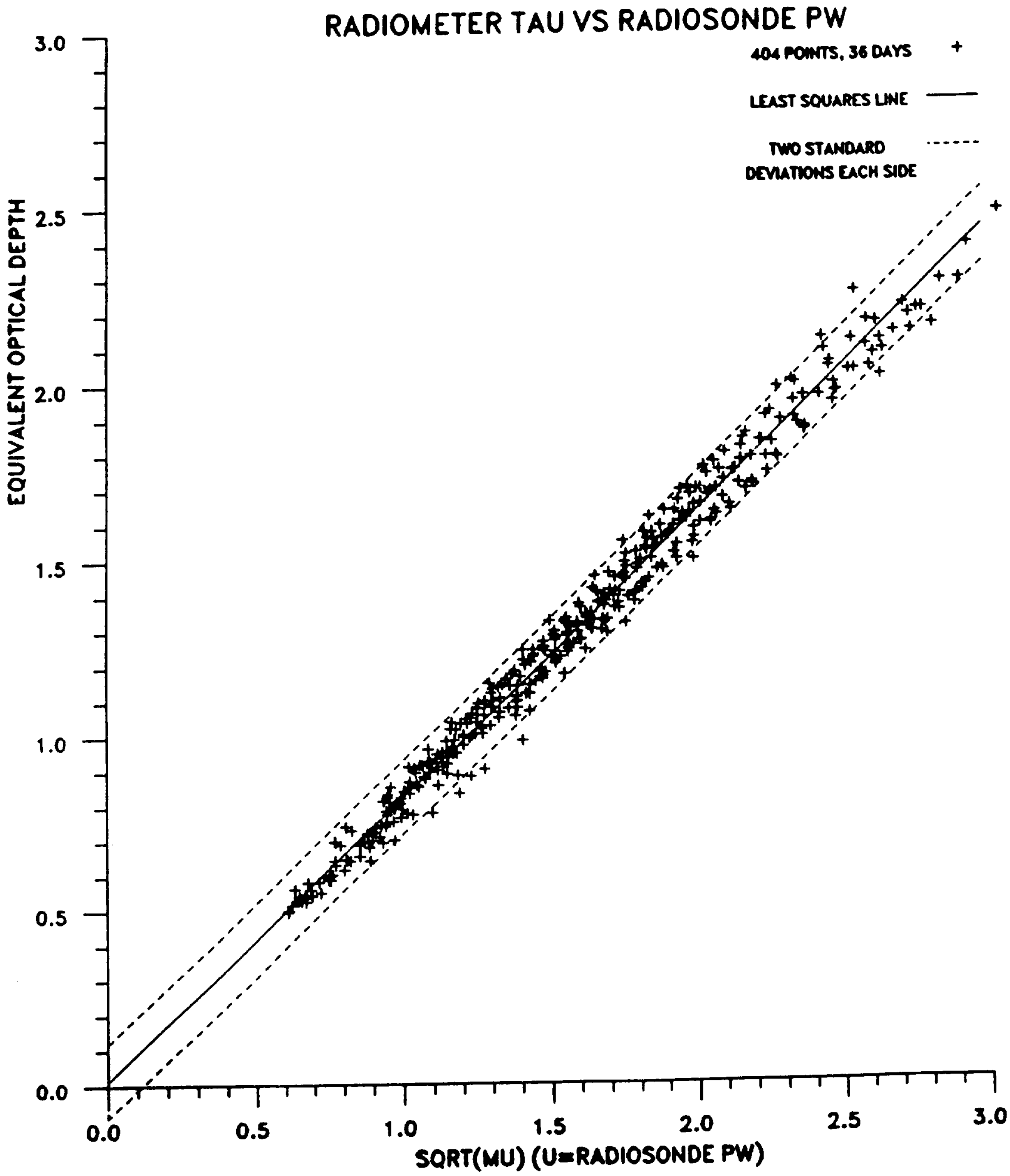
$$\tau_\lambda = \tau_{R\lambda} + \tau_{a\lambda} \quad (4)$$

and since the only unknown is $\tau_{a\lambda}$, the aerosol optical depth, this may readily be solved for at these wavelengths. From the known aerosol optical depth at non-absorbing wavelengths, the aerosol optical depth within the water vapor band may be inferred ($\tau_{a\lambda}$ in eq.(3)) by interpolation and then eq.(3) may be solved for $\tau_{w\lambda}$, the water vapor optical depth.

Once $\tau_{w\lambda}$ is known, it must be converted into a value for the total precipitable water (P.W.) Several techniques, both experimental and theoretical, have been tested (Twomey et al,). All methods give results which agree with each other to within the experimental errors (i.e., to within about ± 10%). One method we have employed utilizes the twice daily radiosonde P.W. Fig (1) shows a plot of the slant path optical depth, $m\tau$ v.s. the square root of the total P.W., $\sqrt{mu}$ where u is the vertical P.W. determined from the radiosonde data. The best fit straight line has a slope of 0.807 and an intercept of 0.013. The theoretical technique gives a slope of 0.802 with a zero intercept. Both methods yield total P.W.'s generally within 10% of one another.

Fig. 2, 3, 4 show the P.W. determined in this manner as a function of time, together with the radiosonde P.W. as measured at 0600 and 1800 LST. As can be seen from these figures, the P.W. can, and often does, show great temporal variations that cannot be determined from the radiosonde data. During the present monsoon season, we will be employing this data, together with all of our other data sources, to help us obtain a better analysis of the various meso-scale disturbances within the monsoon flow that we are trying to study.

Figure 1. Least squares fit between radiometric slant path water vapor tau and radiosonde precipitable water.



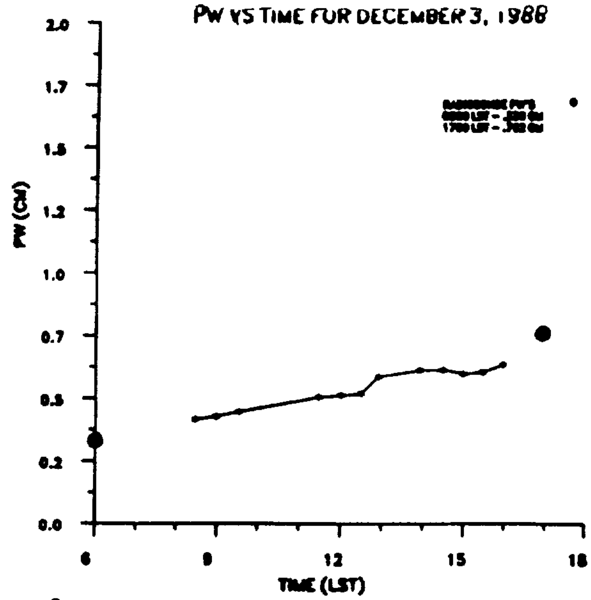


Figure 2. Radiometer precipitable water versus time for the five different models for case 1. Also shown are the radiosonde precipitable water.

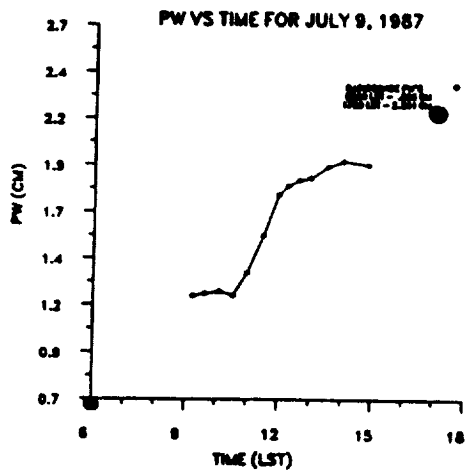


Figure 3. Radiometer precipitable water versus time for the five different models for case 3. Also shown are the radiosonde precir'table water.

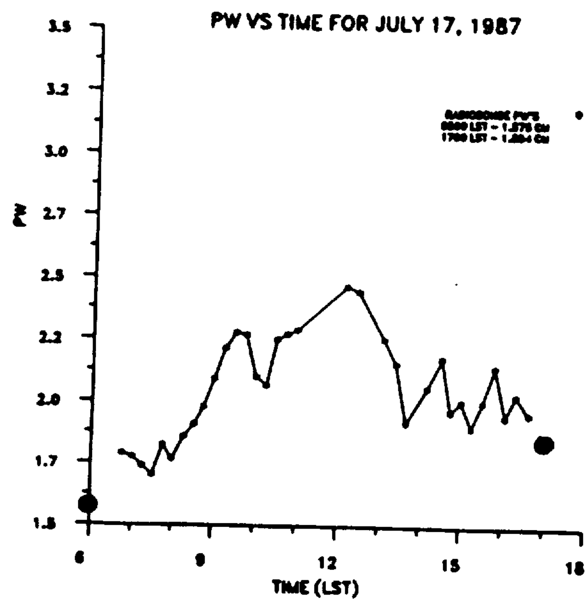


Figure 4. Radiometer precipitable water versus time for the five different models for case 4. Also shown are the radiosonde precipitable water.

IV. Publications

Adang, T. and R. Gall, 1988: "Structure and Dynamics of the Arizona Monsoon Boundary." Submitted to Monthly Weather Review.

Moore, T., R. Gall and T. Adang, 1988: "A Linear Stability Analyzer of the Arizona Monsoon Boundary." Submitted to Monthly Weather Review.

Smith, W. and R. Gall: "Tropical Squall Line in the Arizona Monsoon." In preparation.

Twomey, S., B. Herman and J. Reagan: "The Determination of Precipitable Water from Solar Transmission." Manuscript in preparation.