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AN OBJECTIVE AID TO FORECASTING SUMMERTIME SHOWERS OVER THE LOWER RIO GRANDE VALLEY OF SOUTH TEXAS

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ABSTRACT

Accurate precipitation forecasts are essential to a good weather service program for the agricultural community of the Lower Rio Grande Valley of South Texas. This local forecast study involves, primarily, the short range forecasting of areal coverage of summertime airmass showers over the valley by using predictor variables extracted from the latest Brownsville atmospheric sounding. The highest correlated predictor variable with areal shower coverage was the combination of the mean relative humidity in the 850 mb to 700 mb layer and the 650 mb to 500 mb layer. In addition, these two predictors were used to construct a graph to estimate the average and maximum 24-hour precipitation amounts.

I. INTRODUCTION

The Lower Rio Grande Valley (hereafter called "the Valley") is largely an agricultural area and accurate precipitation forecasts are essential to a good weather service program. Areal coverage of summertime showers (hereafter called "areal shower coverage") is difficult to predict in the Valley because of its location between the data-sparse areas of the Gulf of Mexico and Mexico. Dynamic influences, although important, are sometimes difficult to detect, not only because of the data sparsity, but also because of the barotropic character of the semi-tropical summertime airmass over the Valley. These dynamic influences are not easily adapted to an objective forecast study. Radar is of immense value but only, of course, after showers have already formed. Satellite imagery has also been of value in detecting active easterly waves over the Gulf of Mexico days in advance. For the most part short range (up to 24 hours) forecasts of areal shower coverage, before the activity has formed, have relied heavily on the character of the latest atmospheric sounding.

In view of the above, this study represents an effort to get maximum benefit from the Brownsville soundings and ultimately improve forecasts of areal shower coverage. For reasons stated above, cases of obvious dynamic effects (fronts, strong troughs, etc.) were eliminated.

As with most local studies, this one is not the "last word" and it is not intended to substitute for sound forecaster judgment or other aids available. It is believed, however, that this study, particularly the graph for the 11 A.M. forecast, does give more meaning to the local soundings and supplies the forecaster with a good indication of shower potential. The forecast graphs are quick and easy to use and the predictor variables are as available as the sounding.

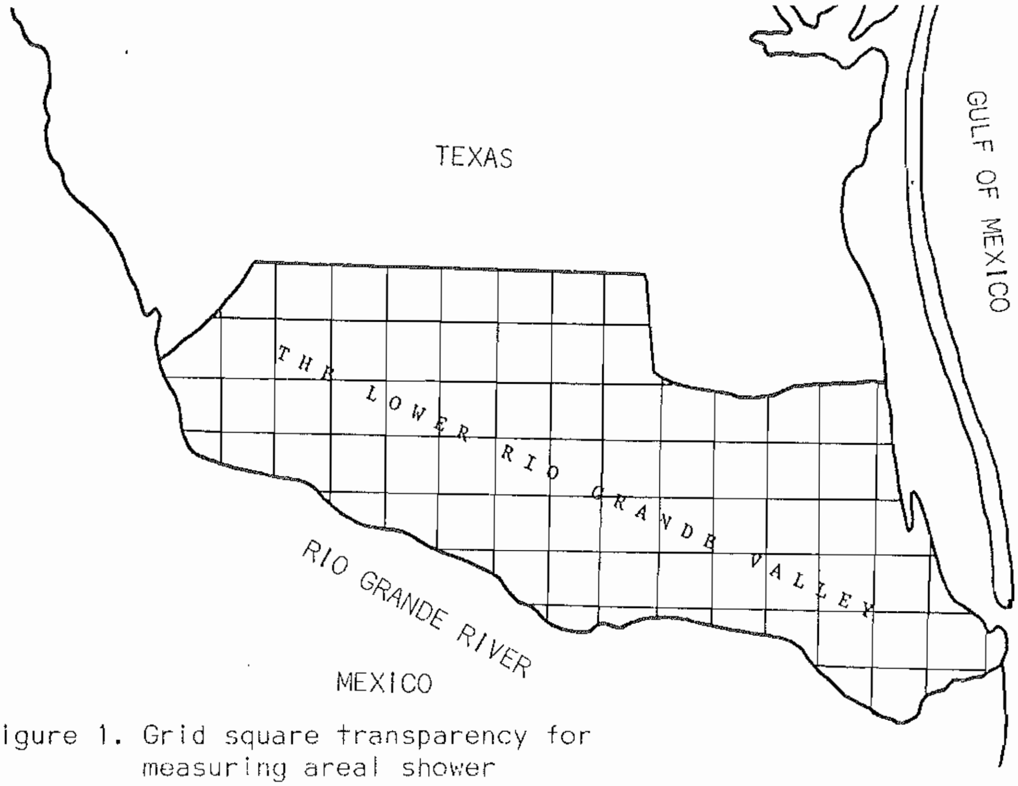

Figure 1. Grid square transparency for measuring areal shower coverage over the Valley.

Figure 2. Map of the Valley and the 11-station rain gage network.

2. SELECTION OF VARIABLES TO BE FORECAST

Areal shower coverages for June, July, and August of 1973 were obtained by overlaying a grid square transparency (Fig. 1) over hourly traces of radar echoes covering the Valley's four counties (Fig. 2). (Zapata County is also our forecast responsibility but it was excluded because it is in a different climatic area and there are no verifying rain gages there. Also, it is not considered part of the lower Valley.) The percent of the Valley covered with echoes was calculated for two twelve-hour periods (00Z to 12Z and 12Z to 00Z) daily.

The number of cases used in the study included 75 days of radar-measured areal coverages for 1973 and 113 days of estimated areal coverages for 1971 and 1972 to total 188 in all. (84 radar-measured cases of 1974 used to verify the forecast graphs were later added to make 272 cases.) These areal coverages were estimated by using a combination of available data including: 24-hour rainfall reports from the eleven rain gauges in the Valley (Fig. 2), the Brownsville radar reports (WBAN Forms 60), the Brownsville and McAllen FSS 6-hourly rainfall reports, and the times of precipitation logged by a few of the cooperative observers on their WS Forms E15 and E22. To check the accuracy of this method of estimating 12-hour areal shower coverage from the above data, the 75 radar-measured coverages of 1973 were correlated with independently estimated coverages for the same period. A correlation coefficient of +.85 resulted, indicating it is probably an adequate method. In addition, the percent of the eleven rain gages receiving measurable precipitation over 24-hour periods was correlated with the 24-hour radar-measured areal shower coverages with a correlation coefficient of +.86 resulting. This high correlation indicates two things: when shower activity is strong enough to produce an echo on the WSR-57 radar, there is, in general, a high probability of measurable precipitation on the ground, and the areal shower coverage in the Valley is adequately represented by the eleven rain gauges (this does not generally hold true for areal coverages of less than 25 percent).

Average and maximum 24-hour precipitation amounts were obtained from the eleven daily reports. These covered the 24-hour period ending at about 7 A.M. local time. Average precipitation amounts were computed by averaging the rainfall reports. This was the easiest method even though the Thiessen (2) and, particularly, the Isohyetal (2) methods are better.

In summary, the variables to be forecast for the Valley are the 12-hour (00Z to 12Z and 12Z to 00Z) areal shower coverages and the average and maximum 24-hour precipitation amounts (ending at about 7 A.M.).

3. SELECTION OF PREDICTOR VARIABLES

An IBM 1800 computer at Weslaco, Texas, was used to calculate linear correlation coefficients for the 188 cases of the summers of 1971, 1972, and 1973 using areal shower coverages from 12Z to 00Z and 00Z to 12Z as independent variables and various parameters extracted from the 12Z and 00Z Brownsville sounding as predictor variables. The most highly correlated

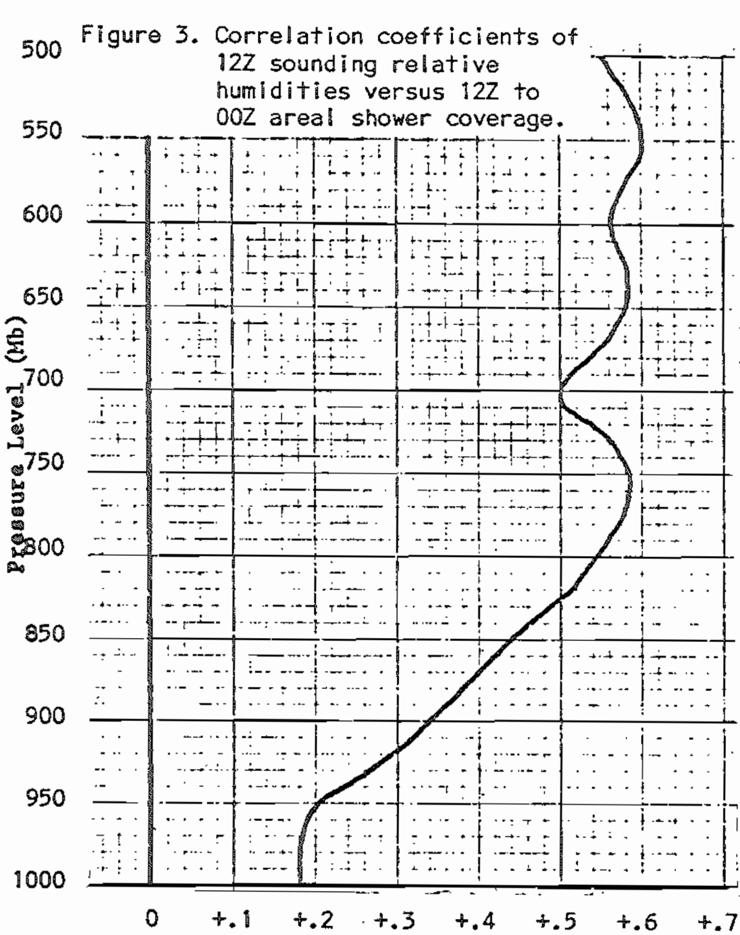

Figure 3. Correlation coefficients of 12Z sounding relative humidities versus 12Z to 00Z areal shower coverage.

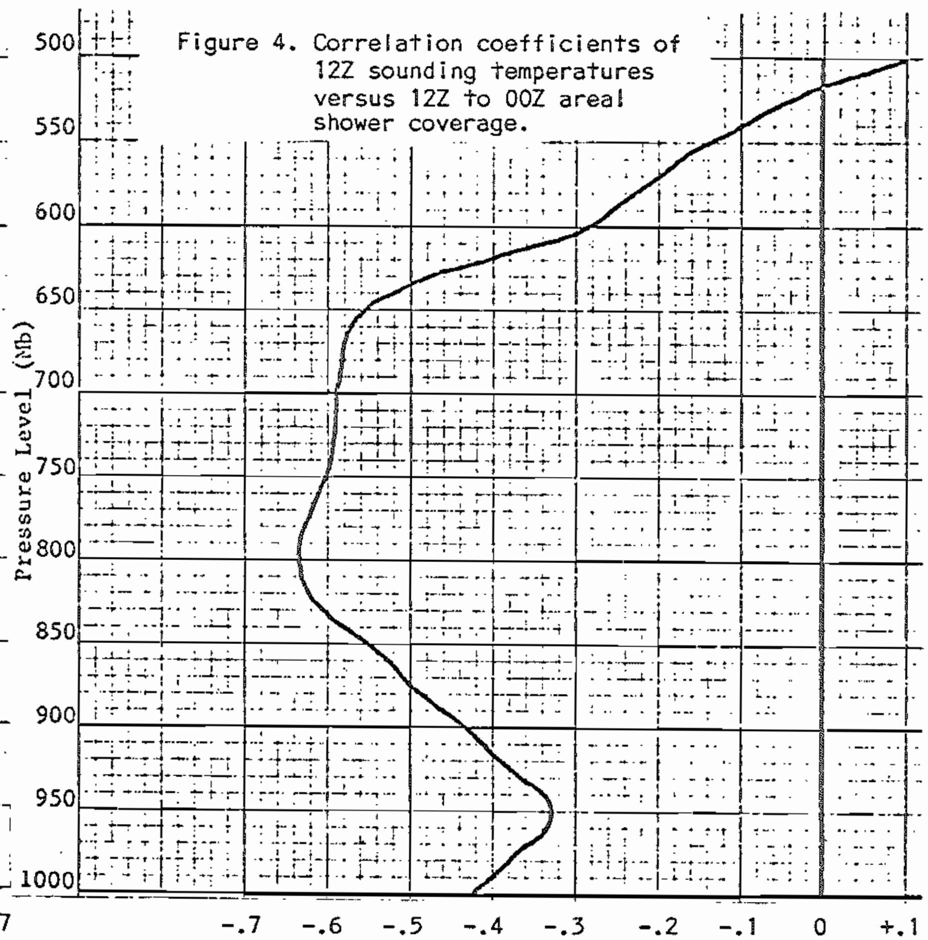

Figure 4. Correlation coefficients of 12Z sounding temperatures versus 12Z to 00Z areal shower coverage.

predictor variables that resulted were then used to develop the final forecast graphs. These same predictor variables were tested in this program with correlation coefficients included where applicable:

a. Relative humidity: Correlation coefficients were computed for relative humidities at each 50 mb level from 1000 mb to 500 mb (Fig. 3). Higher levels were excluded based on low correlations above 500 mb as presented by Neumann at Miami, Florida (1). Because the mean relative humidity from surface to 500 mb is a commonly used parameter, it too was correlated with areal coverage yielding a +.57 coefficient.

Based on Fig. 3 the mean relative humidity from 800 mb to 500 mb was originally chosen for use in the forecast graphs. This layer yielded a coefficient of +.65 which is higher than that for the surface to 500 mb value. This is likely because of the lower correlations below 800 mb (Fig. 3) which is due to the persistence of low level Gulf moisture over the Valley during the summer months even though strong subsidence may be occurring aloft.

The original forecast graphs used this 800 mb to 500 mb mean relative humidity as a predictor but it, and the graphs, were ultimately rejected. It was found that too many cases occurred where the sounding was dry from approximately 800 mb to approximately 700 mb but very moist above. This resulted in a forecast of showers even though the lack of moisture from 800 mb to 700 mb actually prevented showers from building. Therefore, this variable was replaced with two variables: the 850 mb to 700 mb mean relative humidity and the 650 mb to 500 mb mean relative humidity. This solved the problem of over-weighting upper-level moisture when moisture at lower levels is lacking. The multiple non-linear correlation coefficient of these two predictors with areal shower coverage was +.74 (272 cases). These two levels are similar to the KWBC FOUS (3) mean relative humidity layers of 950 mb to 720 mb and 720 mb to 490 mb. The use of these FOUS layers in the final forecast graphs is explained later (4e).

b. The 12-hour change in 800 mb to 500 mb mean relative humidity was tested with a resulting low correlation coefficient of +.09. This variable was rejected.

c. Precipitable water (surface to 500 mb) was so highly intercorrelated with 800 mb to 500 mb mean relative humidity (.93) that it would be redundant to use in combination with a moisture variable, so it was not used.

d. Temperatures at 50 mb intervals from 1000 mb to 500 mb were correlated (Fig. 4) with the 800 mb to 650 mb layer indicating the highest correlation. An inspection of the summer soundings indicated there is normally less than a 3°C range of temperatures in this layer

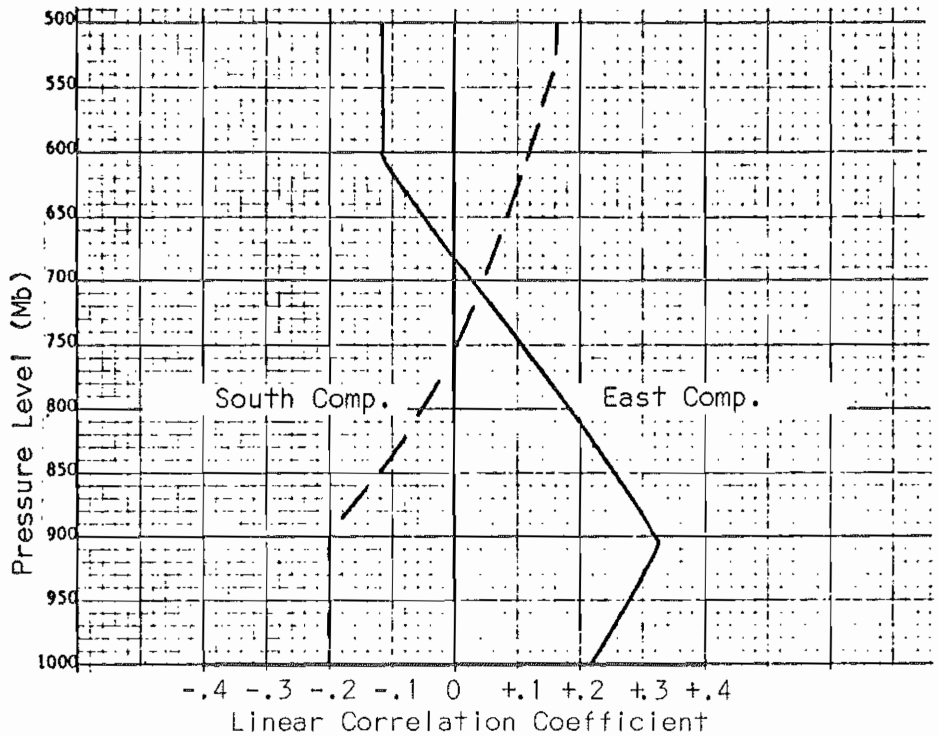

Figure 5, Correlation coefficient of 12Z sounding east and south wind components versus areal shower coverage from 12Z to 00Z.

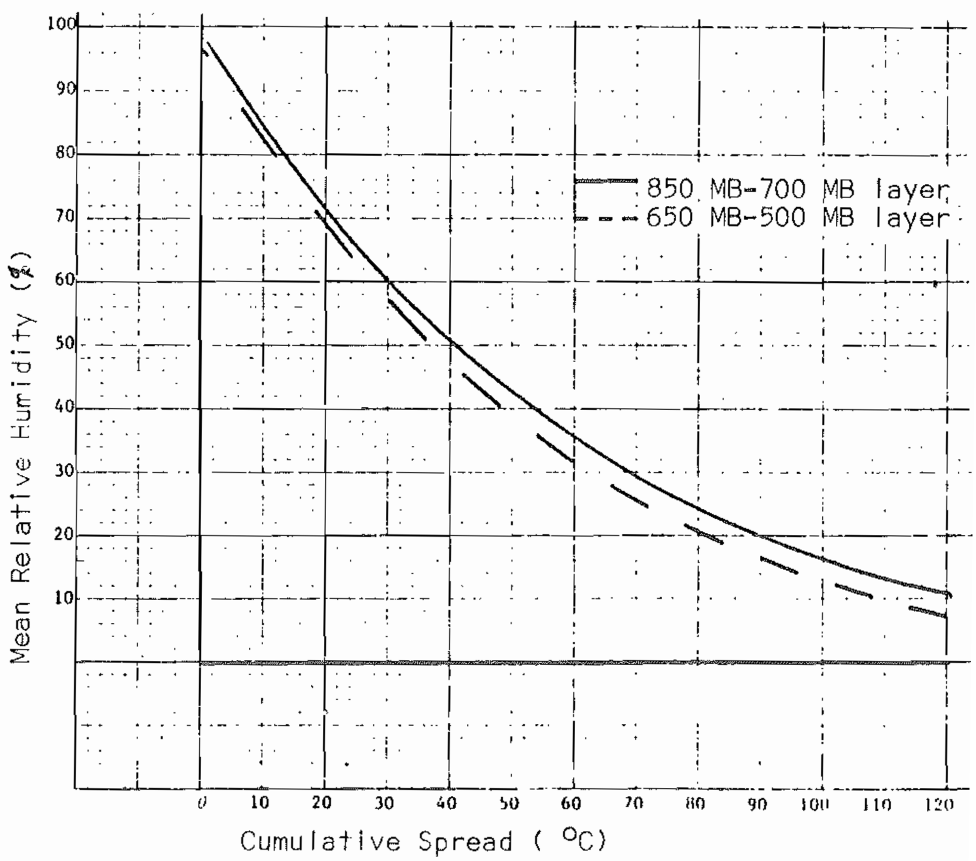

Figure 6. Conversion from cumulative temp-D.P. spread to mean relative humidity.

which makes it of doubtful value to an objective forecast study. The significance of this highly correlated layer is uncertain. Perhaps this reflects the degree of subsidence (or lack of it) which directly affects the available mean moisture. Temperatures were not used in the final study.

e. Thicknesses listed below were tested with the following correlation coefficients:

1000 mb to 850 mb ... +.06
1000 mb to 700 mb ... +.54
1000 mb to 500 mb ... +.45
850 mb to 700 mb ... +.63
850 mb to 500 mb ... +.39
700 mb to 500 mb ... +.29

The 850 mb to 700 mb thickness was selected for testing in the final study. Its value to the study was doubtful though in view of 3d above.

f. Stability indexes listed below were correlated with areal shower coverage (coefficients are indicated):

Lifted index (4) ... +.13
Showalter index (5) ... -.23
"K" index (6) ... +.40

The Showalter index was selected for testing in the final study. The "K" index was not used because of its high intercorrelation (+.84) with mean 800 mb to 500 mb relative humidity. Apparently, because there is very little range in temperatures from 850 mb to 500 mb over the Valley during the summer, these two indices mostly indicate moisture, which is better described by a mean layer moisture term.

The positive correlation coefficient of the Lifted index indicates no relationship with areal shower coverage because it should be negative. This, again, is likely because of the persistent low-level moisture over the Valley regardless of the moisture content aloft.

The cross totals, vertical totals, and total totals stability indices (7) were tested with about the same results as the Showalter index.

g. East and south wind components up to 500 mb were correlated (Fig. 5). North and west wind components were excluded because they are uncommon during the summer months.

The east and south wind components at 4,000 feet were chosen for final testing because of their higher correlations and apparent physical significance. Usually, the higher the east wind component the more moisture advection from the Gulf is taking place (positive coefficient) while the south wind indicates dry advection (negative coefficient).

In summary, the predictor variables selected to be used in the development of the final forecast graphs to predict areal shower coverage and average and maximum precipitation amounts were as follows:

a. 850 mb to 700 mb thickness.
b. Showalter index.
c. East and south wind components at the 4,000 foot level.
d. Mean relative humidities from 850 mb to 700 mb and 650 mb to 500 mb.

The mean relative humidity variables were the most highly correlated with areal shower coverage while all correlations were significant to at least the 95 percent level.

4. DEVELOPMENT OF THE FORECAST STUDY GRAPHS

Multiple correlation coefficients were computed with various combinations of the six predictors versus areal shower coverage and maximum precipitation amounts. A small increase in the multiple correlation coefficient, over that for the two mean relative humidity terms, was obtained with the inclusion of the east and south wind components and nearly no increase with the Showalter index or the 850 mb to 700 mb thickness. It was therefore decided that the added complexity of preparing forecast graphs with four or more predictor variables was not justified by the doubtfully significant increase in forecast accuracy. It was generally found that when moisture is lacking, particularly below 700 mb, showers will not form regardless of favorable values of other predictors (east winds, low stability, etc.). Conversely, unfavorable values of other predictors (strong south winds, high stability, etc.) will not prevent shower activity if moisture is high enough. Therefore, the only predictors used in the forecast graph preparation were the mean relative humidities in the 850 mb to 700 mb and 650 mb to 500 mb layers.

Because only two predictor variables were used, the data were hand plotted and the curves subjectively drawn. To facilitate the computation of mean relative humidities in the 850 mb to 700 mb and 650 mb to 500 mb layers, for use in the graphs, the following method was used. Because the mean temperatures in these layers change very little during the summer months, the mean relative humidities were computed by summing the temperature-dew point depressions of the four 50 mb levels in each level then converting these cumulative depressions to mean relative humidities using a mean 850 mb to 700 mb layer temperature of 13.5°C and a mean 650 mb to 500 mb layer temperature of -0.8°C (mean temperatures based on rawinsonde data in Environmental Data Service publication "Climatological Data"). In practice, the graph in Fig. 6 is used to convert mean relative humidities to cumulative temperature-dew point spreads.

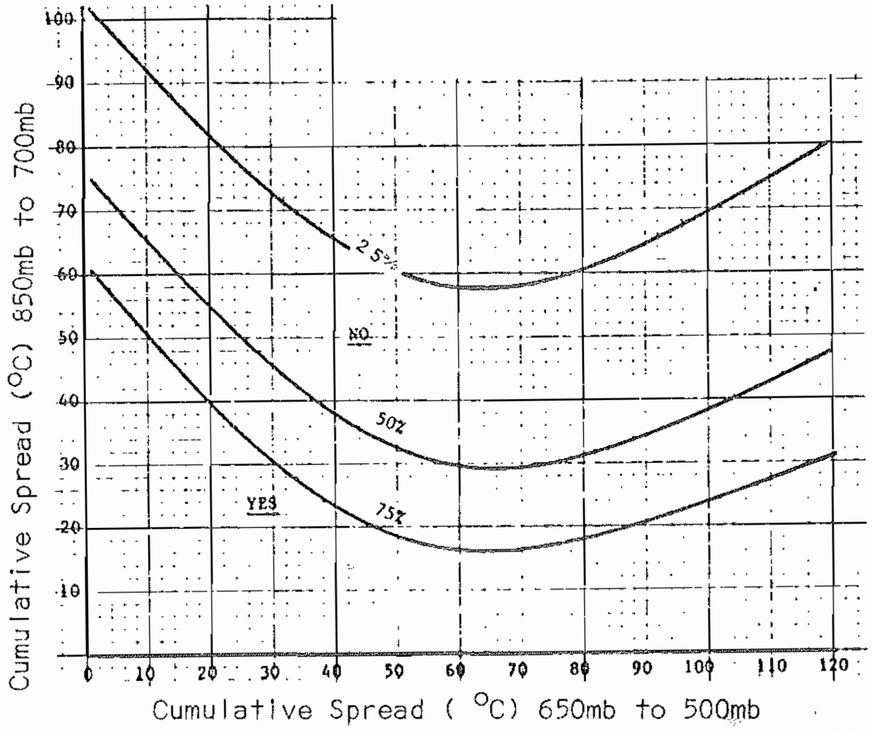

Figure 7. Forecast graph to apply at 5AM. Cumulative spreads are taken from the previous 00Z sounding. The curved lines are forecasts of the probability of 10% or greater areal shower coverage for the following 12Z to 00Z period. Yes or no forecasts are divided by the 50% value.

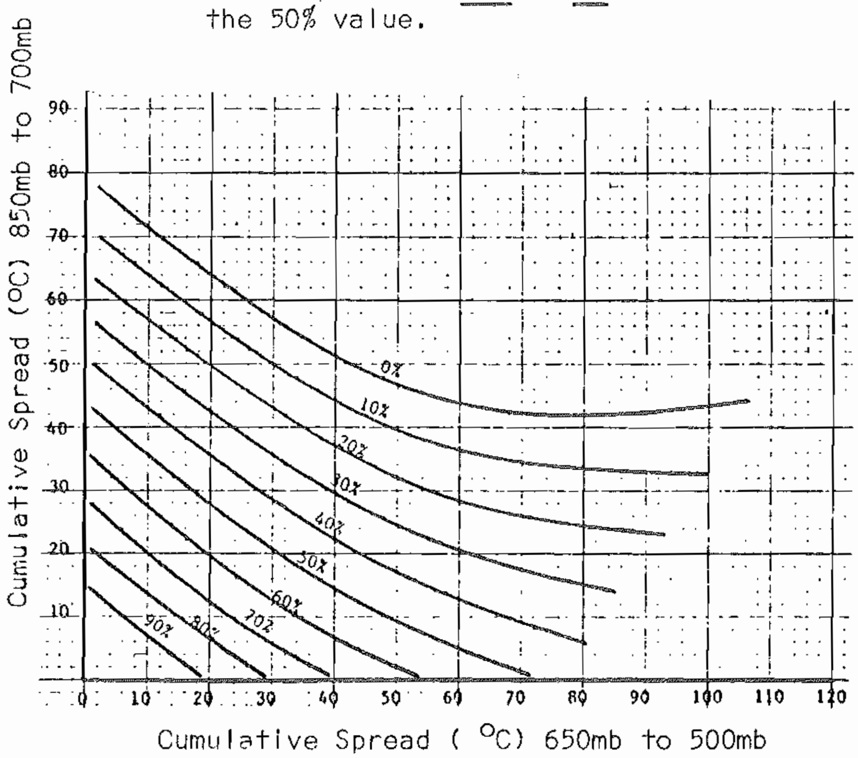

Figure 8. Forecast graph to apply at 11AM. Cumulative spreads are taken from the 12Z sounding. The curved lines are forecasts of areal shower coverage for the 12Z to 00Z period.

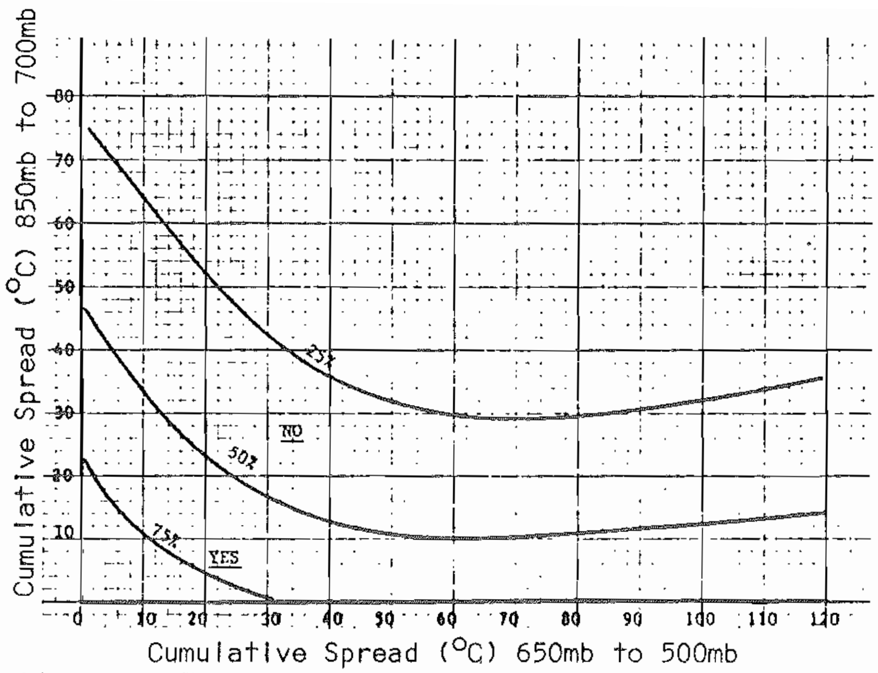

Figure 9. Forecast graph to apply at 5PM. Cumulative spreads are taken from the 12Z or 00Z soundings. The curved lines are forecasts of the probability of 10% or greater areal shower coverage for the following 00Z to 12Z period. Probability (<10% coverage) is a no forecast while Yes or no forecasts are divided by the 50% value.

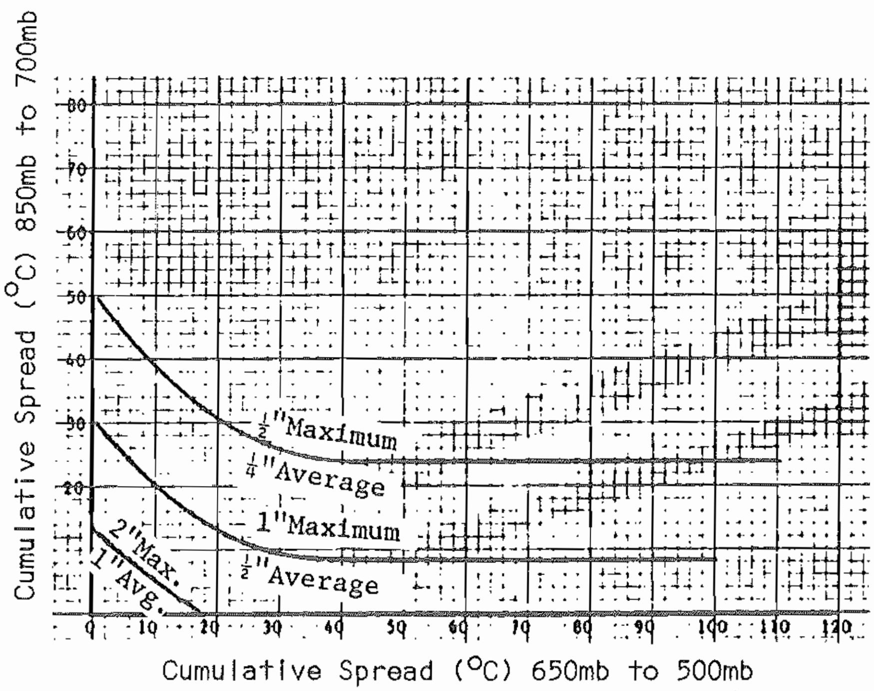

Figure 10. Forecast graph to apply at 5AM and 5PM. Cumulative spreads are taken from either the 12Z sounding (5PM forecast) or the 00Z sounding (5AM forecast). The curved lines are forecasts of average and maximum 24-hour precipitation amounts over the 24-hour period commencing with 12Z following the forecast time.

We now have the two predictor variables for use in the forecast graphs. (Obtaining these two predictors takes about a minute.) In the graphs described below enter with the appropriate cumulative spreads (which represent mean relative humidities for the layers) and read the forecast at the intersection. The following indicates which graphs to associate with the various forecast times:

a. 5 A.M. Forecast -- Enter Fig. 7 with cumulative spreads of the two predictor variables taken from the previous evening 00Z sounding, and read a forecast of "the probability of occurrence of ten percent or more areal shower coverage" for the following 12Z to 00Z period. When the data was finally analyzed, it was found that it was very difficult to fit forecast curves of actual 12Z to 00Z areal shower coverage, using the previous 00Z sounding predictor variables, because the scatter of areal coverage values was too great. Therefore, the forecasts curves of Fig. 7 are not of actual areal shower coverage, but, rather, probability of occurrence of at least ten percent areal shower coverage. Less than 50 percent probability would, in effect, be a less than ten percent areal shower coverage forecast and greater than 50 percent a ten percent or higher forecast.

b. 11 A.M. Forecast -- Enter Fig. 8 with cumulative spreads of the two predictor variables (explained above), taken from the 12Z sounding, and read a forecast of areal shower coverage for the 12Z to 00Z period that day. This graph can actually be applied before 11 A.M., as soon as the 12Z sounding becomes available.

c. 5 P.M. Forecast -- Enter Fig. 9 with cumulative spreads of the two predictor variables taken from the 12Z or 00Z sounding, and read a forecast of "the probability of occurrence of ten percent or more areal shower coverage" for the following 00Z to 12Z period. As was the case with Fig. 7, in 4a. above, the scatter of areal shower coverage values was too great to fit forecast curves of this variable.

d. 5 A.M. and 5 P.M. Forecast -- Enter Fig. 10 with cumulative spreads of the two predictor variables taken from the 12Z sounding (5 P.M. forecast) or the previous 00Z sounding (5 A.M. forecast), and read a forecast of "average and maximum 24-hour precipitation amounts" covering the 24-hour period commencing at 12Z. Precipitation amount forecasts are routinely included in the Agricultural Advisories, issued by the Brownsville WSO, and Fig. 10 should be used only as a rough guide since the curves were considerably smoothed. We do believe, however, that because summertime quantitative precipitation guidance from NMC is usually too conservative for the Valley, Fig. 10 is of value when used judiciously. It must be restated that this graph is based on reports from the eleven rain gauges in the Valley and it should be kept in mind that many times the heaviest precipitation amounts occur at other valley points. Therefore, Fig. 10 may also be conservative.

e. All Forecast times: Predictor variables may be obtained from the Brownsville FOUS output (3) and applied to any of the forecast graphs for the period covered by the FOUS message. The FOUS mean relative humidity from 950 mb to 720 mb (R2 in the teletype message) can be converted to an equivalent 850 mb to 700 mb mean relative humidity by subtracting 10 percent from the FOUS value. The FOUS mean 720 mb to 490 mb relative humidity (R3 in the teletype message) can be converted to an equivalent 650 mb to 500 mb mean relative humidity by subtracting 5 percent from the FOUS value. These two conversions were based on mean relative humidities differences of the various layers.

To use the FOUS data (R2 and R3), apply the conversions and then use the resulting predictor equivalents in the appropriate forecast graphs after obtaining the cumulative spread from Fig. 6. For example FOUS R2 and R3 valid at 12Z would be used in the 11 A.M. Forecast graph (4.b. above), etc. Areal coverage forecasts can be made up to 48 hours using this "perfect prog" method. This method should be used judiciously since the summer FOUS relative humidities for Brownsville seem to have a tendency to be too high.

f. The forecast graphs are valid for the months of July through August but can be used during late May and early September if an airmass shower potential exists.

5. VERIFICATION OF THE FORECAST GRAPHS

The 84 radar-measured cases of the summer of 1974 were verified with the following results (the local verifications and the WSFO guidance verifications are included for comparison):

a. 5 A.M. Forecast (Fig. 7) graph using predictor variables from previous 00Z sounding to forecast the probability of at least ten percent areal shower coverage for the period 12Z to 00Z (greater than or equal to 50 percent probability was considered a "Yes" shower forecast while less than 50 percent a "No" forecast):

	Percent Correct Forecasts (80 cases)		
	Yes	No	All
Forecast Graph:	61%	75%	71%
Local Forecast:	56%	89%	71%
WSFO Forecast:	42%	93%	51%

b. 11 A.M. Forecast (Fig. 8) graph using predictor variables from 12Z sounding to forecast areal shower coverage from 12Z to 00Z. The forecast graph values were compared with the local and guidance probabilities of precipitation for this period:

	% Average Error (84 cases)	% Average Error when ≥ 10% Areal Coverage Occurred (34 cases)	% Average Error with Zero Areal Coverage (50 cases)
Forecast Graph:	6.8%	13.4%	2.4%
Local Forecast:	7.6%	12.4%	4.4%
WSFO Forecast:	10.2%	12.4%	8.7%

c. 5 P.M. Forecast (Fig. 9) graph where same information as 5.a. above applies except that the 12Z sounding is used for 00Z to 12Z shower occurrences:

	Percent Correct Forecasts (84 cases)		
	Yes	No	All
Forecast Graph:	50%	93%	90%
Local Forecast:	29%	100%	76%
WSFO Forecast:	17%	100%	55%

In general the forecast graphs performed rather well on the independent data of 1974. In general it beat WSFO guidance and about equalled local forecasts. The strongest attribute of the 11 A.M. graph (Fig. 8) is its ability to forecast zero shower coverage. This is of value since WSFO guidance issues 10 and 20 percent PoPs too frequently and this shows up in its 8.7 percent average error on days of zero areal coverage. Also the 5 P.M. graph (Fig. 9) is very conservative in forecasting showers from 00Z to 12Z while local and guidance forecasts use 10 and 20 percent much too frequently.

6. CONCLUSIONS

In general, areal shower coverage over the Valley during the summer is best forecast by considering moisture content below 500 mb as the most important predictor. This forecast study found the combination of mean relative humidities in the 850 mb to 700 mb and 650 mb to 500 mb layers as the best predictors particularly in the graph applied at 11 A.M. Other predictors such as stability indexes, thicknesses, winds, etc. do not significantly improve forecasts of areal shower coverage when combined with the two mean layer humidities. These other parameters seem to be of value only when used subjectively in conjunction with synoptic considerations.

The forecast graphs can be applied in less than 2 minutes, and when used on a continuing basis, can provide a "measuring stick" of shower potential. Because the FOUS mean relative humidities can be used as predictors, similar forecast graphs can be constructed for other climatologically similar areas.

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