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# AN OBJECTIVE TECHNIQUE FOR FORECASTING THE PROBABILITY OF AN AFTERNOON SUMMER SHOWER AT SAVANNAH, GEORGIA

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## ABSTRACT

An objective technique for forecasting the probability of an afternoon summer shower in Savannah, Georgia was derived. A pilot study revealed that the 500 millibar temperature and precipitable water between 1000 and 500 millibars used as predictors would yield good results. A set of curves relating these two predictors to the probability of an afternoon summer shower was constructed. The forecasts given by the curves were verified for the summers of 1964 through 1966 using Brier's verification method for forecasts expressed in terms of probability (1). The improvement of these forecasts over climatological forecasts was +15%. These forecasts were also compared to the 1600 GMT forecasts issued by the Weather Bureau Airport Station in Savannah and State Forecast Center in Atlanta for the summer of 1966. The improvement over the forecasts issued by the forecast center and Savannah office was +19% and +07% respectively. Verification of this forecast technique indicates that it is a reliable method for objectively forecasting the probability of an afternoon summer shower in Savannah.

## INTRODUCTION

Several changes in Weather Bureau policy during recent years led us to undertake this study. 1) Weather Bureau Offices have been instructed to implement precipitation probability forecasts. 2) These offices have also been asked to confine their greatest efforts in forecasting to the first six to twelve hours of the local forecast, while relying heavily on the guidance forecasts received via facsimile and teletype transmissions from the Weather Bureau's National Meteorological Center and State Forecast Centers for the remaining portion of the forecast. 3) Local offices have been encouraged to develop objective forecast techniques.

In addition, the afternoon summer shower in Savannah presents a difficult forecast problem. Using subjective forecast techniques it is very difficult to forecast an accurate probability figure. How does the forecaster transform his degree of confidence of observing precipitation which he arrived at through subjective forecasting techniques into an accurate probability figure? Also, many days in which weather data is examined by subjective techniques may appear equally likely of having precipitation, while substantially different amounts of shower activity are actually observed on each of those days. The objective forecast technique herein described solves, to a great extent, the problem of arriving at an accurate probability forecast for the afternoon summer shower in Savannah, Georgia.

## SELECTION OF PREDICTORS

In developing the objective technique we set four rules for the selection of predictors. 1) They must be selected from measurable meteorological quantities which experience and physical reasoning indicate are closely related to the probability of receiving an afternoon summer shower[1]. 2) They must be easy to obtain and (or)compute. 3) The number of predictors should be limited to two in order to facilitate development and use of the technique. 4) Data for the predictors should be selected from observations taken each morning and available for the local forecast issued at 1600 GMT.

It is well known to meteorologists that the amount of moisture and temperature lapse rate in the lower half of the atmosphere are directly related to the probability of observing a shower. Further, it has been our experience in Savannah that during summer afternoons cumulus clouds must generally build to about the 500 millibar level before precipitation is possible.

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[1]The word shower will be used to mean precipitation $\geq$.01 inches recorded by the Weather Bureau Airport Station at Savannah between 1800 and 2400 GMT, June through September. This criteria was selected to be compatible with Weather Bureau policy in its forecast program. June through September are those months during which precipitation is largely from convective showers in Savannah.

For this reason, the predictors were selected from measurable meteorological quantities obtained in the layer of the atmosphere up to and including the 500 millibar level. Radiosonde observations would provide this data.

The first predictor that was selected is a quantity which is a measure of moisture. Our experience in Savannah indicated that precipitable water between 1000 and 500 millibars[2] is an excellent indicator of the amount of shower activity likely. Other investigators such as Frank and Smith (2) and Chalker (3) found that showers are more likely in a deep moist layer, although their investigations were limited to Florida. We investigated the use of precipitable water as a predictor in a pilot study and further verified these findings (see fig. 1). Hence, precipitable water was selected as one of the predictors.

Four other quantities which we have found of value in forecasting showers were investigated to obtain the second predictor. These were selected because they are related entirely or in part to the temperature lapse rate. The four investigated were: the algebraic difference of the 850 and 500 millibar temperatures, lifted index (4), Showalter Stability Index, and 500 millibar temperature. In the pilot study each was tested as the second predictor with precipitable water to assess their relative values. Each exhibited a reasonably stable pattern.

Because of the simplicity of its use, we selected the 500 millibar temperature. This may seem surprising at first. Certainly the 500 millibar temperature is not itself an indicator of lapse rate. However, when used in combination with precipitable water, lapse rate is inherently used as a predictor. This is so because the temperature in the lower few thousand feet of the atmosphere is directly related to precipitable water in the Savannah area. Generally, southerly flow in the lower levels of the atmosphere brings an influx of warm and moist air, while the converse is true of northerly low level flow. This was further supported in the pilot study (see fig. 2). As a result, when the 500 millibar temperature is low and precipitable water is high, the lapse rate is steep, and vice versa.

## DERIVATION OF THE OBJECTIVE TECHNIQUE

Data. Radiosonde data from the Weather Bureau in Savannah is not available. However, this data is available at Charleston, South Carolina, 75 miles northeast and at Jacksonville, Florida, 105 miles south. In the past we have found that an arithmetic average of precipitable water and 500 millibar temperature from these two stations is an excellent approximation of these predictors for the Savannah area. Hence, an arithmetic average of these two quantities from Charleston and Jacksonville was used.

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[2] Herafter, precipitable water will be used to mean precipitable water between 1000 and 500 millibars in inches.

Period of sample: June through September, 1965

| Categories of precipitable water | Mid-point of each category | Number of cases in each category | Number of afternoons with a shower |
|---|---|---|---|
| 1.00-1.24 in. | 1.12 in. | 8 | 0 |
| 1.25-1.49 in. | 1.37 in. | 32 | 8 |
| 1.50-1.74 in. | 1.62 in. | 65 | 27 |
| 1.75-1.99 in. | 1.87 in. | 11 | 5 |

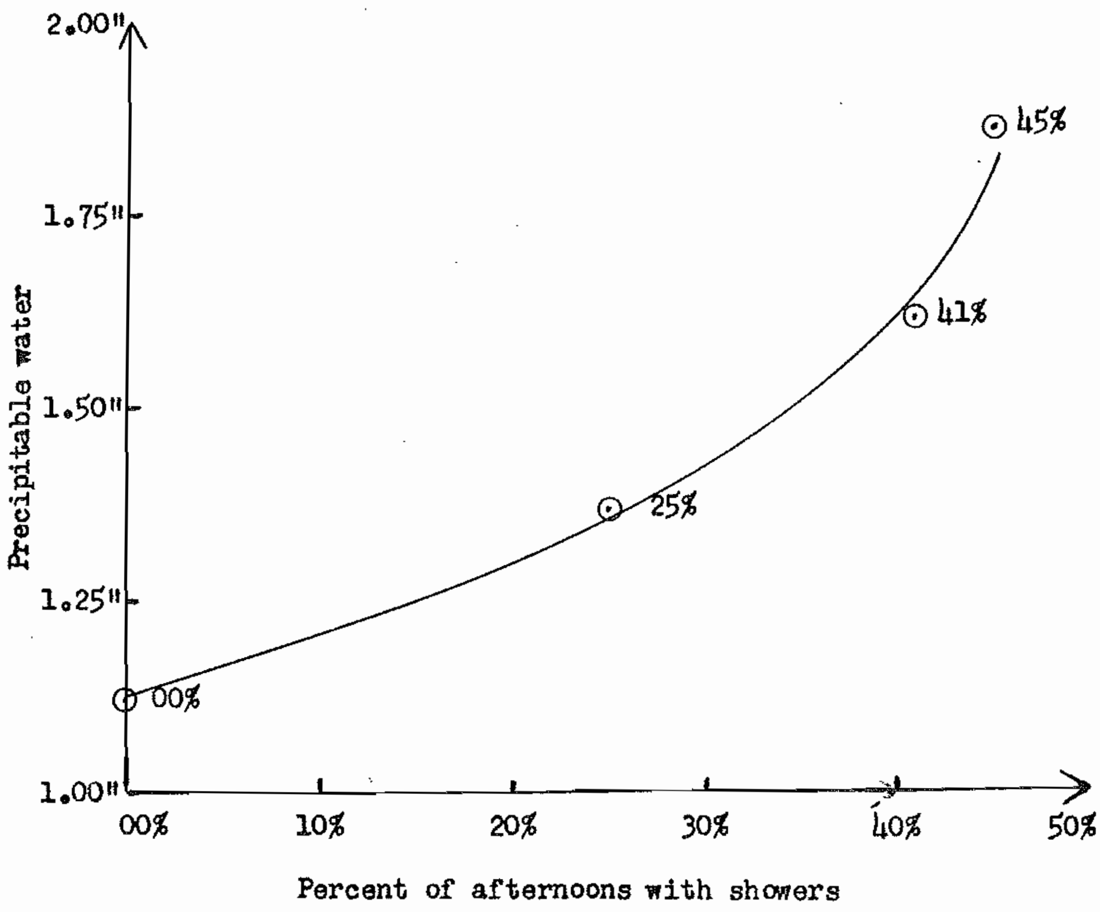


Figure 1. —— Percent of afternoon showers at Savannah as a function of the precipitable water.

Period of Sample: June through September, 1965.

⊙ indicates two occurrences.

Average deviation of temperature = 0.9°C.

Standard deviation of temperature = 1.1°C.

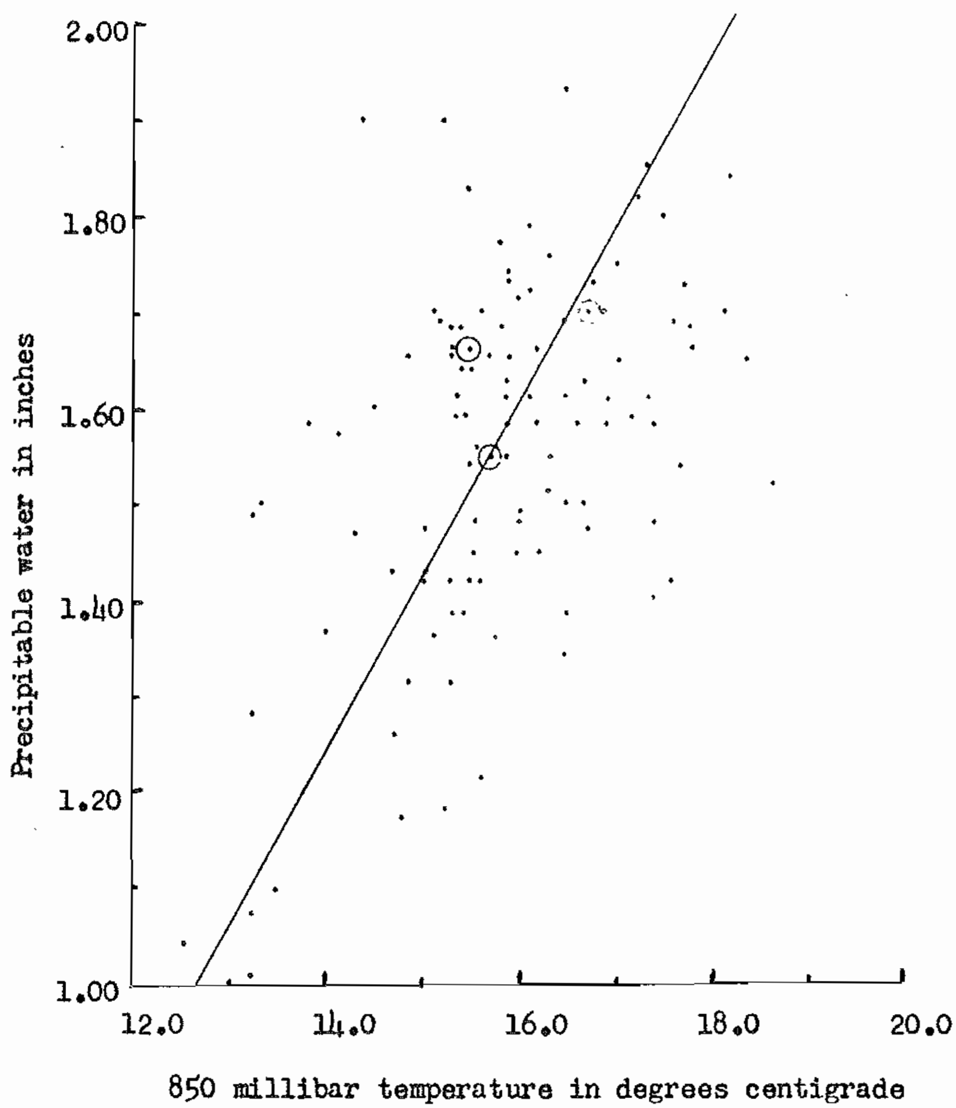


Figure 2. —— Scatter diagram relating precipitable water to 850 millibar temperature.

Period of sample: June through September, 1958 through 1963

| Precipitable water in inches | | | |
|---|---|---|---|
| 1.20 to 1.49 | # cases = 38. # cases with precipitation = 0. % of cases with precipitation=00%. Center of gravity = 6.3°C, 1.36". | # cases = 54. # cases with precipitation = 2. % of cases with precipitation =.04%. Center of gravity = 7.8°C, 1.38". | # cases = 35. # cases with precipitation = 7. % of cases with precipitation =20%. Center of gravity = 10.0°C, 1.36". |
| 1.50 to 1.69 | # cases = 66. # cases with precipitation =15. % of cases with precipitation =23%. Center of gravity = 6.4°C, 1.60". | # cases = 90. # cases with precipitation = 23. % of cases with precipitation =26%. Center of gravity = 7.9°C, 1.62". | # cases = 45. # cases with precipitation = 16. % of cases with precipitation =36%. Center of gravity = 9.4°C, 1.58". |
| 1.70 to 1.89 | # cases = 79. # cases with precipitation =27. % of cases with precipitation =34%. Center of gravity = 6.4°C, 1.79". | # cases = 108. # cases with precipitation = 48. % of cases with precipitation =44%. Center of gravity = 8.0°C, 1.78". | # of cases = 21. # cases with precipitation = 12. % of cases with precipitation =57%. Center of gravity = 9.3°C, 1.78". |
| 1.90 to 2.19 | # cases = 80. # cases with precipitation =35. % of cases with precipitation =44%. Center of gravity = 6.2°C, 1.99". | # cases = 22. # cases with precipitation = 15. % of cases with precipitation =68%. Center of gravity = 8.0°C, 1.94". | # cases = 2 This number is too few to include this category in the construction of the curves. |
| | -4.5 to -7.2 | -7.3 to -8.8 | -8.9 to -11.6 |

500 millibar temperature in degrees centigrade

Figure 3. —— Percent of afternoons with a shower at Savannah for categories of precipitable water and 500 millibar temperature.

Computation of the Predictors. The 500 millibar temperature was read directly from WBAN-33's[3]. Precipitable water was computed using a modification of the formula derived by Solat (5): $W_p = 0.0004q\Delta P$; where $W_p$ is precipitable water in inches, q is the mixing ratio of moisture in grams per kilogram of air, and $\Delta P$ is an increment of pressure. To assure accuracy in our computation of precipitable water and to use increments of pressure compatible with those of the data on the WBAN-33's, we set $\Delta P$ equal to a rather small increment, 50 millibars. Hence: $W_p = .02q$ for any increment of pressure which equals 50 millibars. Since there are 10 of these increments in the layer between 1000 and 500 millibars, we have:

$$W_{1000mb}^{500mb} = .02 \sum_{i=1}^{k=10} (q)$$

A total of nine years of radiosonde data with an observation and transmission time compatible with rule number 4 in section 3, selection of predictors, was available. The observation time of this data was 1200 GMT and the years available were 1958 through 1966. The first six years were used for constructing the curves, while the following three years were used for verification. In order to avoid the laborious plotting of radiosonde data, the values of "q" for each increment of pressure were approximated by directly converting the dew points given on the WBAN-33's at 1000, 950, 900, 850, ......, 550 millibars to mixing ratios by the use of a conversion table (6).

The sacrifice in accuracy of precipitable water computations using this modified method was small. In practice, however, forecasters should use the same method for this computation. Hence, the slight over-estimate which occurs in the computation of precipitable water for developing the curves becomes irrelevant.

Construction of Curves. A simple means of relating two variables to a third is by graphical representation as described by Panofsky and Brier(7). The categories, centers of gravity, percent of cases with precipitation, and total number of cases are shown in figure 3. The centers of gravity for each category were plotted on a cartesian coordinate system with 500 millibar temperature plotted as ordinate and precipitable water as abscissa. The percent of cases with a shower was placed at the point representing each center of gravity, respectively. The values at these points were carefully isoplethed and smoothed. The final set of curves used for the objective forecast technique is shown in figure 4.

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[3]The WBAN-33's are the forms on which the radiosonde data is available from the National Weather Records Center.

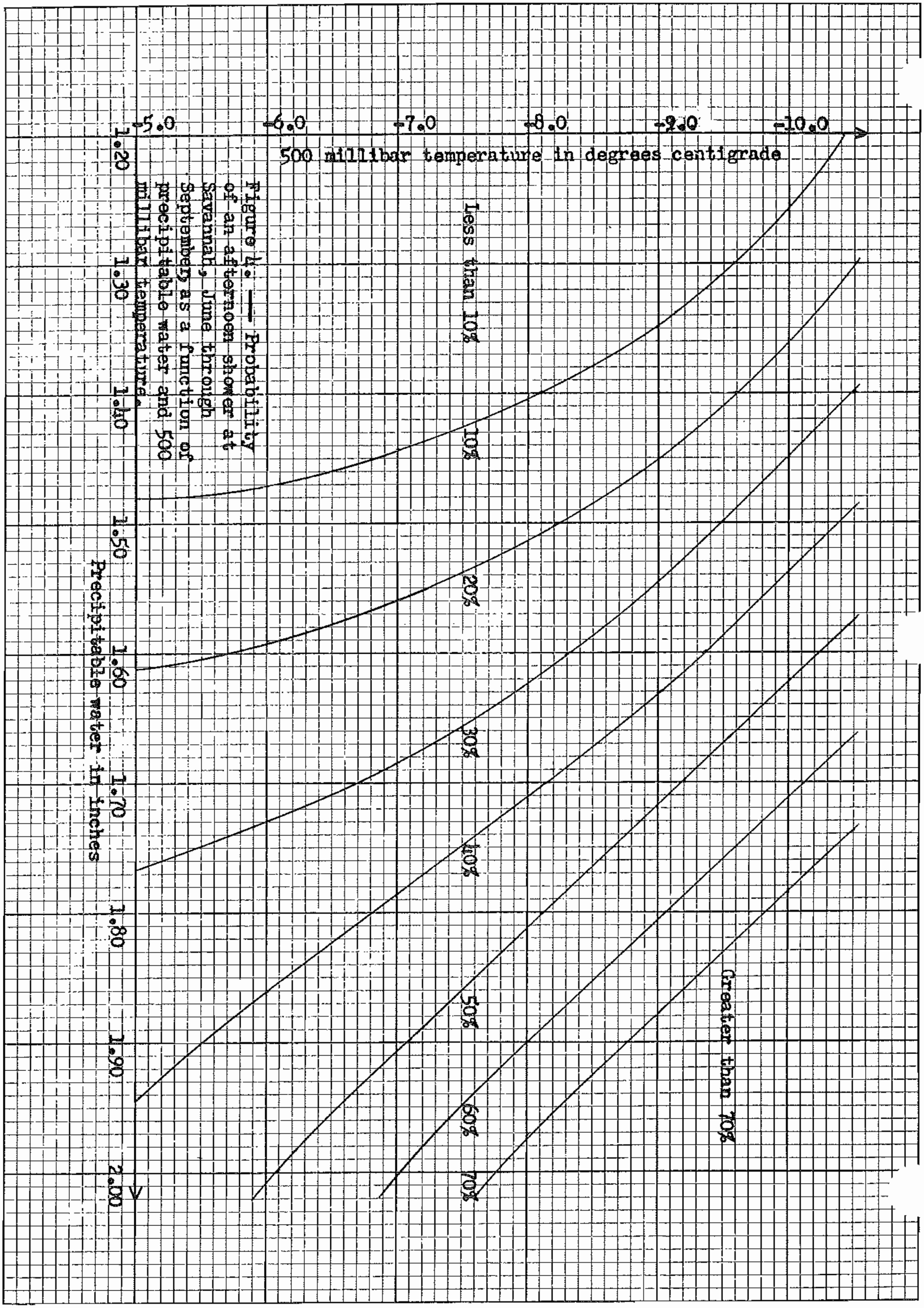


Figure 4. — Probability of an afternoon shower at Savannah, June through September, as a function of precipitable water and 500 millibar temperature.

VERIFICATION OF THE FORECAST TECHNIQUE

The set of curves derived for objectively forecasting the probability of an afternoon summer shower was subjected to several tests. These tests used Brier's method for verification of forecasts expressed in terms of probability (1). This method may be expressed as:

$$S = \frac{1}{N}(F-E)^2$$

where S is the Brier Score, N is the number of forecasts, F is the probability forecast in decimal form, and E is the occurrence or non-occurrence of precipitation. E equals 1.00 if precipitation occurs and 0.00 if precipitation does not occur.

The period of testing was 1964 through 1966. For all three years a comparison was made to climatological forecasts[4]. The Brier Scores for the climatological forecasts ($S_c$) and the forecasts computed from the curves ($S_f$) are compared in tables 1a & 1b. $I_c^f$ is the improvement of the objective forecast over the climatological forecast. Table 1b is included in addition to table 1a to test the technique as it would be used in practice using 10% increments in the forecasts. Note that both tables yield similar results.

The +15% improvement of the objective technique over a climatological forecast appears to be modest. However, during many summer days a "perfect" probability forecast would result in a figure within 5 or 10 percent of a climatological forecast for summer showers. So the climatological forecast is hard to improve.

Some meteorologists may argue with this statement and say that the perfect probability forecast is either 100% or 00%, which ever verified correct. This is technically speaking true, and in the case of rain it is , in practice, true also. Often, forecasts of 100% or 00% are made for rain and these usually verify as correct. However, except in very short range forecasts when individual shower cells, line, or cluster development and movement is noted on radar or by visual observation, the probability forecast for true convective showers can rarely be 100%.

Hence, the"perfect" forecast for these convective showers, assuming the forecast area to be homogeneous, would be the same as the forecast figure expressing the percent of the area to receive precipitation. This figure is rarely 100% in the summer for the Savannah area. Often it is very nearly the same as the climatological figure.

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[4]The climatological forecasts used are simply the percent of cases showers occurred. These climatological forecasts were made for each month and were based on the 16 years of record the Weather Bureau Airport Station has been located at Travis Field, Savannah.

| Year | Scores | June | July | August | September | Summer |
|---|---|---|---|---|---|---|
| | $S_f$ | .13 | .32 | .20 | .10 | .19 |
| 1964 | $S_c$ | .16 | .37 | .26 | .13 | .23 |
| | $I_c^f$ | +19% | +17% | +23% | +23% | +17% |
| | $S_f$ | .16 | .25 | .22 | .16 | .20 |
| 1965 | $S_c$ | .21 | .26 | .22 | .18 | .22 |
| | $I_c^f$ | +24% | +05% | +00% | +11% | +09% |
| | $S_f$ | .05 | .17 | .17 | .12 | .13 |
| 1966 | $S_c$ | .12 | .18 | .18 | .13 | .15 |
| | $I_c^f$ | +58% | +06% | +06% | +08% | +13% |
| All | $S_f$ | .12 | .25 | .20 | .13 | .17 |
| years | $S_c$ | .16 | .27 | .22 | .15 | .20 |
| | $I_c^f$ | +25% | +07% | +09% | +13% | +15% |

Table 1a — Verification of objective forecasts to nearest one percent.

| Year | Scores | June | July | August | September | Summer |
|---|---|---|---|---|---|---|
| | $S_f$ | .13 | .31 | .18 | .10 | .18 |
| 1964 | $S_c$ | .16 | .37 | .26 | .13 | .23 |
| | $I_c^f$ | +19% | +16% | +31% | +23% | +22% |
| | $S_f$ | .17 | .25 | .23 | .16 | .20 |
| 1965 | $S_c$ | .21 | .26 | .22 | .18 | .22 |
| | $I_c^f$ | +19% | +04% | +05% | +11% | +09% |
| | $S_f$ | .06 | .17 | .17 | .12 | .13 |
| 1966 | $S_c$ | .12 | .18 | .18 | .13 | .15 |
| | $I_c^f$ | +50% | +06% | +06% | +08% | +13% |
| All | $S_f$ | .12 | .24 | .19 | .13 | .17 |
| years | $S_c$ | .16 | .27 | .22 | .15 | .20 |
| | $I_c^f$ | +25% | +11% | +14% | +13% | +15% |

Table 1b — Verification of objective forecasts to nearest ten percent.

| Month | ATL ($S_a$) | SAV ($S_s$) | O.T.($S_f$) | $I_a^f$ | $I_s^f$ |
|---|---|---|---|---|---|
| June | .12 | .10 | .06 | +50% | +40% |
| July | .19 | .16 | .17 | +11% | -06% |
| August | .19 | .14 | .17 | +11% | -20% |
| September | .11 | .15 | .12 | -09% | +20% |
| All months | .16 | .14 | .13 | +19% | +07% |

Table 1c — Comparison of 1966, 1600 GMT forecasts issued by the forecast center (ATL) & local office (SAV) to the objective forecasts.

A comparison of the objective technique to the 1600 GMT forecasts issued for Savannah by both the Savannah Weather Bureau Airport Station and State Forecast Center in Atlanta was made for 1966 (see table 1c)[5]. In this table $S_a$, $S_s$ and $S_f$ are the Brier Scores for the center, local forecast office and the objective forecast respectively, $1_a^f$ and $1_s^f$ are the improvements of the forecasts made using the curves over the forecasts issued by the forecast center and local office, respectively.

In summary, the objective forecast technique improves significantly the climatological and forecast center forecasts. Only a small improvement is noted in the comparison with the local forecasts. However, it should be noted that a preliminary set of curves was used by the forecasters as a guide to determining the probability forecast in the local office, pending verification of the final set of curves.

## PRACTICAL USE OF THE FORECAST CURVES

Obtaining the Predictors. To obtain the estimate of precipitable water and 500 millibar temperature for the Savannah area, follow these steps using radiosonde observations available on the Weather Bureau's Service "C" teletype transmissions. These are available about 1420 GMT:

A. Precipitable Water.

1) Plot the dew points from the Charleston and Jacksonville radiosondes from 1000 to 500 millibars and connect each point with a straight line.

2) Record the mixing ratios obtained at the intersection of the dew point curves and the 1000, 950, 900, 850, 800, 750, 700, 650, 600 and 550 millibar pressure levels.

3) Add the 10 mixing ratios for each station and multiply by .02. This product for each set of data is the precipitable water for each station obtained by using the modification of Solat's method described in section 4. Add both and divide by two.

B. 500 millibar Temperature. Simply use an arithmetic average of the 500 millibar temperature obtained for Charleston and Jacksonville from the teletype transmissions.

### Obtaining the Probability Figure

A. Find the point on the graph in figure 4 that corresponds to the appropriate temperature and precipitable water estimate for Savannah.

B. Estimate the probability figure at this point by interpolation.

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[5] This was the only year probability forecasts were made by these offices.

## SOME SUGGESTIONS AND DISCUSSION

A. Be sure the precipitable water computation is representative.

1) By comparing surface dew points at Charleston, Savannah, and Jacksonville, it is possible to weight the precipitable water of one station more than the other depending on the dew points.

2) Be sure that an adjustment is made if advection of drier or more moist air is likely.

B. Be sure that the 500 millibar temperature is also representative. By examining the 500 millibar analysis available on the National Facsimile Service at about 1420 GMT, an adjustment may be made if advection of cooler or warmer air is present.

C. One assumption that had to be made for Construction of the Curves was that those cases when precipitation occurred due to mechanisms other than convection were few. It is doubtful that this assumption should cause alarm, since an increase in precipitable water and decrease in 500 millibar temperature occurs with several precipitation producing mechanisms in Savannah during the summer. Some of these cases include the front, cold low aloft, or trough aloft. At any rate, some discretion in the use of the curves during periods when precipitation is not strictly convective in nature is advised.

D. The preliminary curves used by this office during the summer of 1966 seemed to under-forecast the shower activity when cyclonic flow was present below 500 millibars, and vice versa. Unfortunately, we have not had sufficient experience with the technique to draw any firm conclusions with regard to this.

E. This technique need not be limited entirely to the 1600 GMT forecasts. Estimates of precipitable water and 500 millibar temperature may be made for the next day or for the same day on the 1000 GMT forecast, and the curves may be used. However, in the "today" or "tomorrow" periods (12 hours instead of 6) forecasters must subjectively increase the probability figure if there is a significant chance of having a shower in the morning period.

## SUMMARY

This technique in no way replaces the forecaster in forecasting summer showers at Savannah. It simply gives the forecaster an additional tool, one which is objective. Use of the above suggestions, experience, and adjustment of the probability figure using sound physical reasoning should result in an improvement in forecasting summer showers for Savannah. It should be noted that the verification was made using unadjusted figures. The precipitable water and 500 millibar temperature used in the construction of curves and tests were both straight arithmetic averages. Hence, the forecaster's verification should be even better than that indicated by the verification tables.

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