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A GRAPHICAL AID FOR FORECASTING THE CONDITIONAL PROBABILITY OF FREEZING RAIN

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1. INTRODUCTION

Since 1 November 1972, an automated system for forecasting the conditional probability of frozen precipitation (PoF) (Bocchieri and Glahn, 1976) has been operational within the National Weather Service (NWS). In the PoF system, we define "frozen" precipitation as some form of snow or sleet (ice pellets); freezing rain and mixed rain and snow are included with rain and drizzle in the "unfrozen" category. Explicit probability forecasts for the freezing rain event are not available now in the PoF system. We've been working on a new, 3-category system in which probability forecasts of snow (and/or sleet), freezing rain, and rain will be given. Mixed precipitation will be included in the rain category. As a result of some preliminary work, we've developed a graphical method which gives 12 to 24-h forecasts of the conditional probability of freezing rain, the condition being that precipitation occurs. We emphasize that the graphical method should be used at the local forecast office only as an interim technique to supplement the PoF guidance until the new, more sophisticated, centralized guidance system is developed. Therefore, we have not verified the method on dependent or independent data.

As in the PoF system, we used the Model Output Statistics (MOS) technique (Glahn and Lowry, 1972) to develop the graphical aid. Our predictors consisted of forecast output from the Limited-Area Fine Mesh (LFM) model (National Weather Service, 1971). In the atmosphere, freezing rain is favored when precipitation falls through a warm upper layer into a shallow, below-freezing surface layer; the upper layer is too warm to support snow or sleet. Therefore, in deriving predictors to help isolate the freezing rain event from other precipitation types, we developed graphs showing the relative frequency of freezing rain as a joint function of the following pairs of LFM predictors valid at the same time as the precipitation event: 1000-500 mb thickness (10-50 TH) and boundary layer potential temperature (BLPT)[1], 850-mb temperature and BLPT, 850-500 mb thickness and BLPT, 850-500 mb thickness and 1000-850 mb thickness, and 10-50 TH and 1000-850 mb thickness. Of these pairs, the 10-50 TH and BLPT combination seemed to be the best to isolate the freezing rain event for the developmental data sample.

In a similar approach, Wasserman (1972) developed a graphical method for forecasting the probability of occurrence of four types of precipitation including freezing rain. His predictors were the 10-50 TH and BLPT as forecasted by the Primitive Equation (PE) model (Shuman and Hovermale, 1968). He designed the system for use within the Eastern Region of the NWS. Our method uses the same predictor variables as Wasserman's, but they are taken from the LFM instead of the PE model; also, it can be used at many stations across the conterminous United States. Younkin (1967)

[1]The BLPT is the mean potential temperature in the boundary layer of the LFM model. The boundary layer in the LFM model is 50 mb thick, with the bottom of the layer at the earth's surface. The earth's surface is represented in the model by smoothed topography.

related precipitation type to 1000-850 mb thickness and 850-700 mb thickness. However, Younkin used observed thickness values in deriving the relationship; in our method we used the MOS approach.

II. DEVELOPMENT

Our developmental sample consisted of data combined for 166 stations in the conterminous United States from the winter seasons (September through April) of 1972-73 through 1974-75. We could combine the data from different stations because our predictors, 10-50 TH and BLPT, were in terms of deviations from 50% values. We used the concept of 50% values for our operational PoF system (see Glahn and Bocchieri, 1975). Briefly, a 50% value of a variable is that value at which the conditional probability of frozen precipitation is 50%. These 50% values were computed by using the logit model (Brelsford and Jones, 1967; Jones, 1968) to fit the data. The logit model provides a means of fitting a sigmoid or S-shaped curve when the dependent variable is binary and the independent variable is continuous (see Fig. 2 in Glahn and Bocchieri, 1975). The 50% values vary from station to station mainly due to differences in station elevation. For the LFM model, we used data from three winter seasons, 1972-73 through 1974-75, to develop 50% values for 233 MOS stations; these are listed in National Weather Service (1976a).

In developing the graphical method, we combined data not only from different stations, but also from different forecast projections and LFM cycle times. That is, at each station, we matched LFM forecasts of 10-50 TH and BLPT (in terms of deviations from 50% values) and corresponding surface observations of precipitation type for five forecast projections--12-, 15-, 18-, 21-, and 24-hr. The data for all stations and all projections from both the 0000 and 1200 GMT LFM cycle times were then combined into one sample. We had to pool the data to insure that we had an ample number of freezing rain cases. In combining data from different forecast projections, we assumed that the bias, if any, of the LFM forecasts of 10-50 TH and BLPT did not change with time. This is a reasonable assumption since the time period covered by the projections is only 12 hr.

Next, we computed the relative frequency of freezing rain as a function of 10-50 TH and BLPT for the pooled data sample; only precipitation cases were included in the sample. The results are shown in Fig. 1 in graphical form. The number above each dot is the relative frequency of freezing rain; the number in parentheses below the dot is the number of cases used to compute the relative frequency. The relative frequencies at each dot were computed from all the cases within a 4°C BLPT interval and an 80 m 10-50 TH interval. For example, in Fig. 1, the relative frequency of freezing rain corresponding to a BLPT deviation of -12°C and a 10-50 TH deviation of +120 m is 42%. This relative frequency was computed from the 31 precipitation cases falling within a -10°C to -14°C BLPT deviation range and a +80 m to +160 m 10-50 TH deviation range. Note that we computed the relative frequencies using overlapping intervals. The solid, jagged line in Fig. 1 separates relative frequencies which were computed with $\geq$ 25 cases from those which were computed with $<$ 25 cases. A 999 indicates that no precipitation cases were observed for that particular combination of predictor categories. Fig. 2 is similar to Fig. 1, except that the relative frequencies have been analyzed. Note that dashed isopleths are used in the area where the number of cases was judged to be insufficient; the analysis in that area is, of course, questionable.

We can interpret the results shown in Fig. 2 as follows. For 10-50 TH, there is a very small chance of freezing rain when the forecasted deviation (from the 50% value) is > 240 m or < 0 m. For BLPT, there is a very small chance of freezing rain when the forecasted deviation is > 0°C or < -24°C. The chance for freezing rain is relatively high for a forecasted BLPT deviation near -14°C and a forecasted 10-50 TH deviation near +120 m. In this situation the atmosphere is too warm, in the mean, for the occurrence of snow; but the cold layer near the surface is favorable for the occurrence of freezing rain if precipitation occurs at all.

III. OPERATIONAL USE

The graph in Fig. 2 can be used at any station that has LFM 50% values for the 10-50 TH and BLPT (National Weather Service, 1976a) and receives LFM forecasts of these variables in real time. The FOUS 60-76 teletypewriter bulletins (National Weather Service, 1976b) provide LFM forecasts of the needed variables. The graph is valid at any time during the 12-24 hr period after the 0000 or 1200 GMT LFM cycle time. It's probably not a good idea to use the graph for other forecast projections since the bias in the predictors may not be the same as the bias for the projections used in development.

A forecaster can use the graph to supplement the early-guidance PoF forecast for a particular station. The PoF gives the conditional probability of occurrence of snow and/or sleet. The forecaster can then get the conditional probability of freezing rain from the graph. Note that the maximum possible conditional probability for freezing rain is about 40%. A self-explanatory graph for on-station use is provided on the last page of this Office Note.

Again we emphasize that we consider the graphical method to be only an interim aid until we can develop a more sophisticated, centralized forecast system. We'll probably be able to improve the accuracy of the freezing rain forecasts by using other predictors and predictor combinations.

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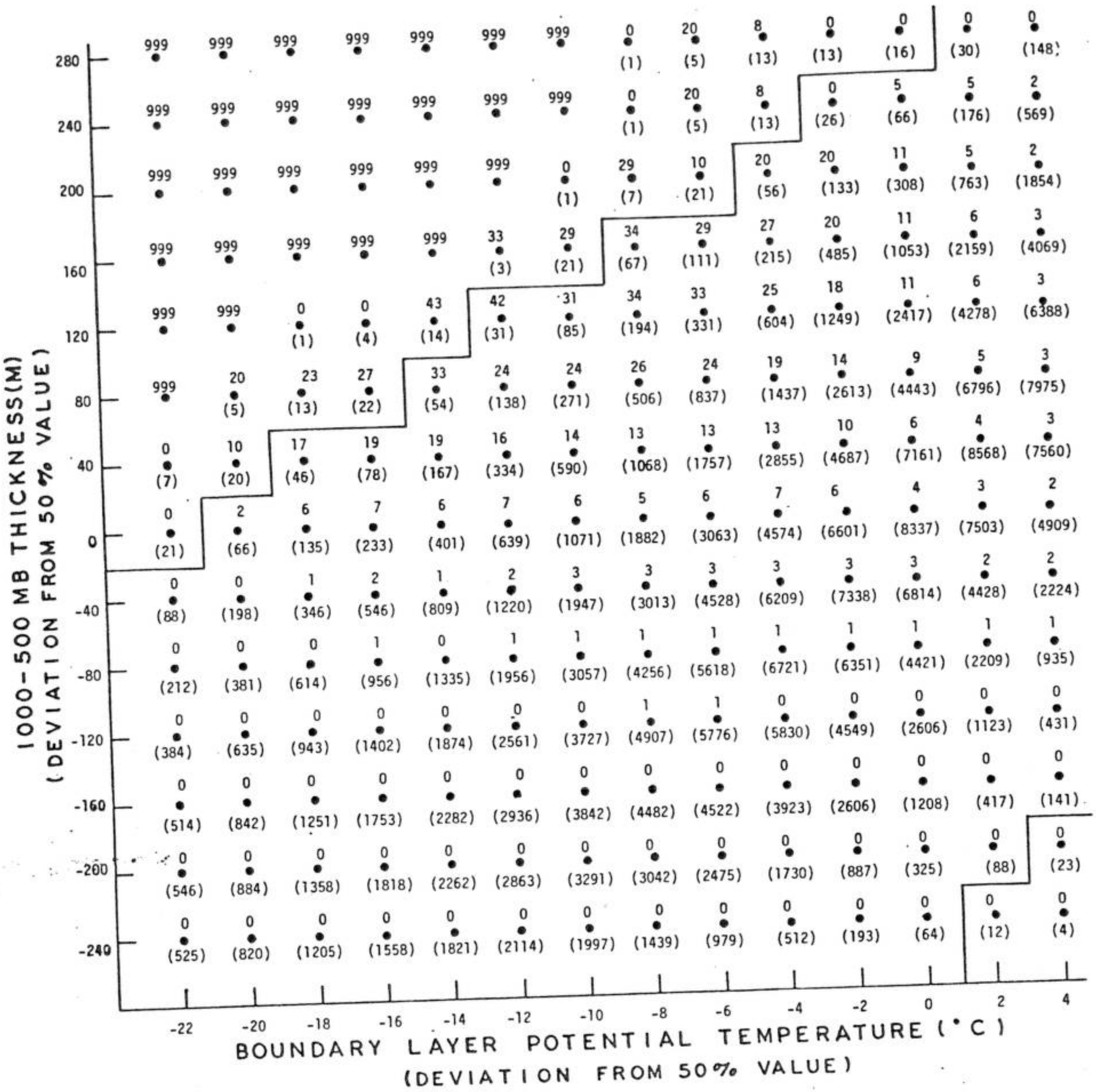

Fig. 1. The empirical probability of freezing rain as a function of 10-50 TH and BLPT. The predictors are forecast values from the LFM model and are given in terms of deviations from 50% values. The graph is valid at any time during the 12- to 24-hr period after the 0000 GMT or 1200 GMT LFM cycle time.

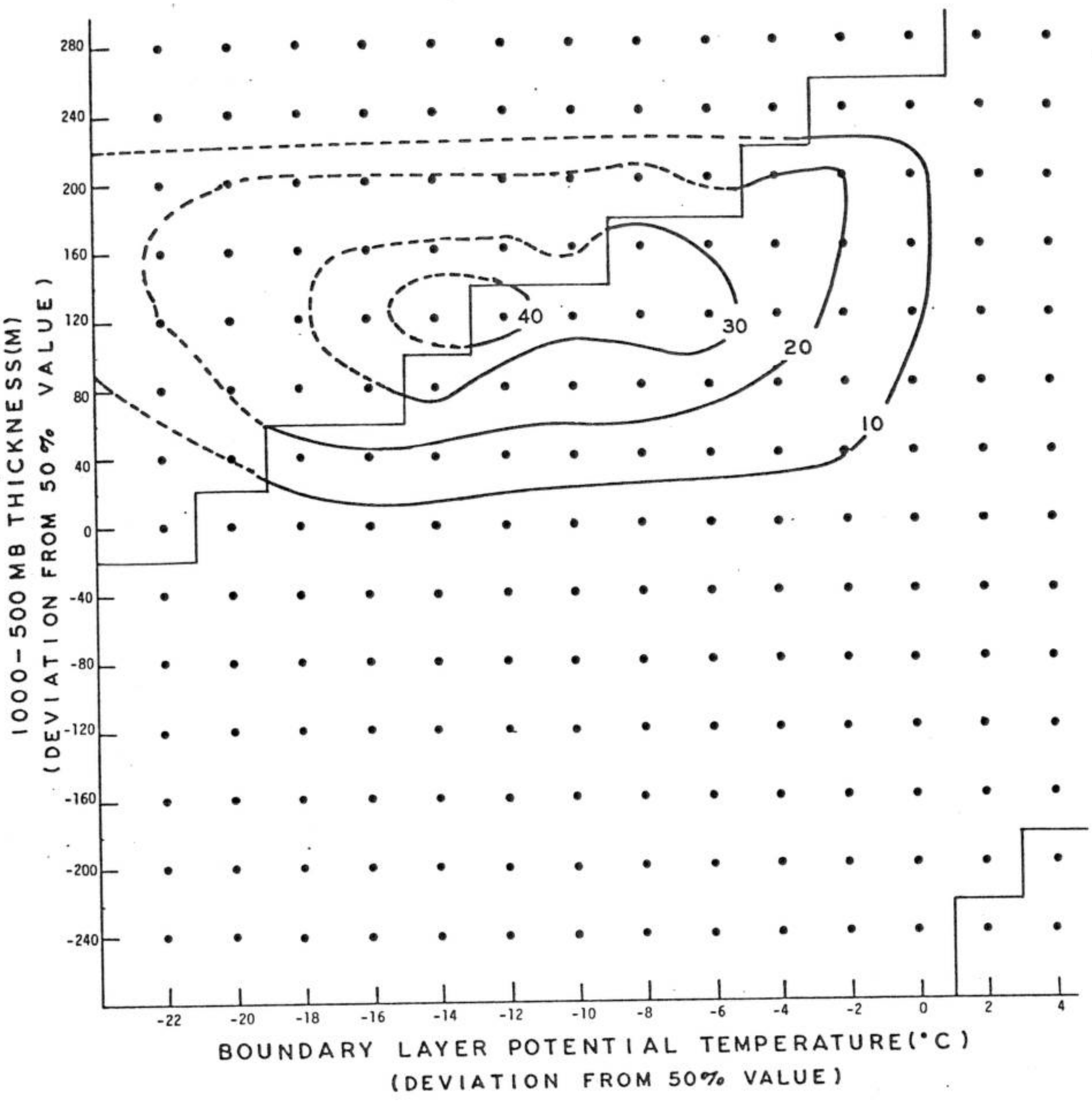

Fig. 2. Same as Fig. 1 except that the relative frequencies of freezing rain haye been analyzed.

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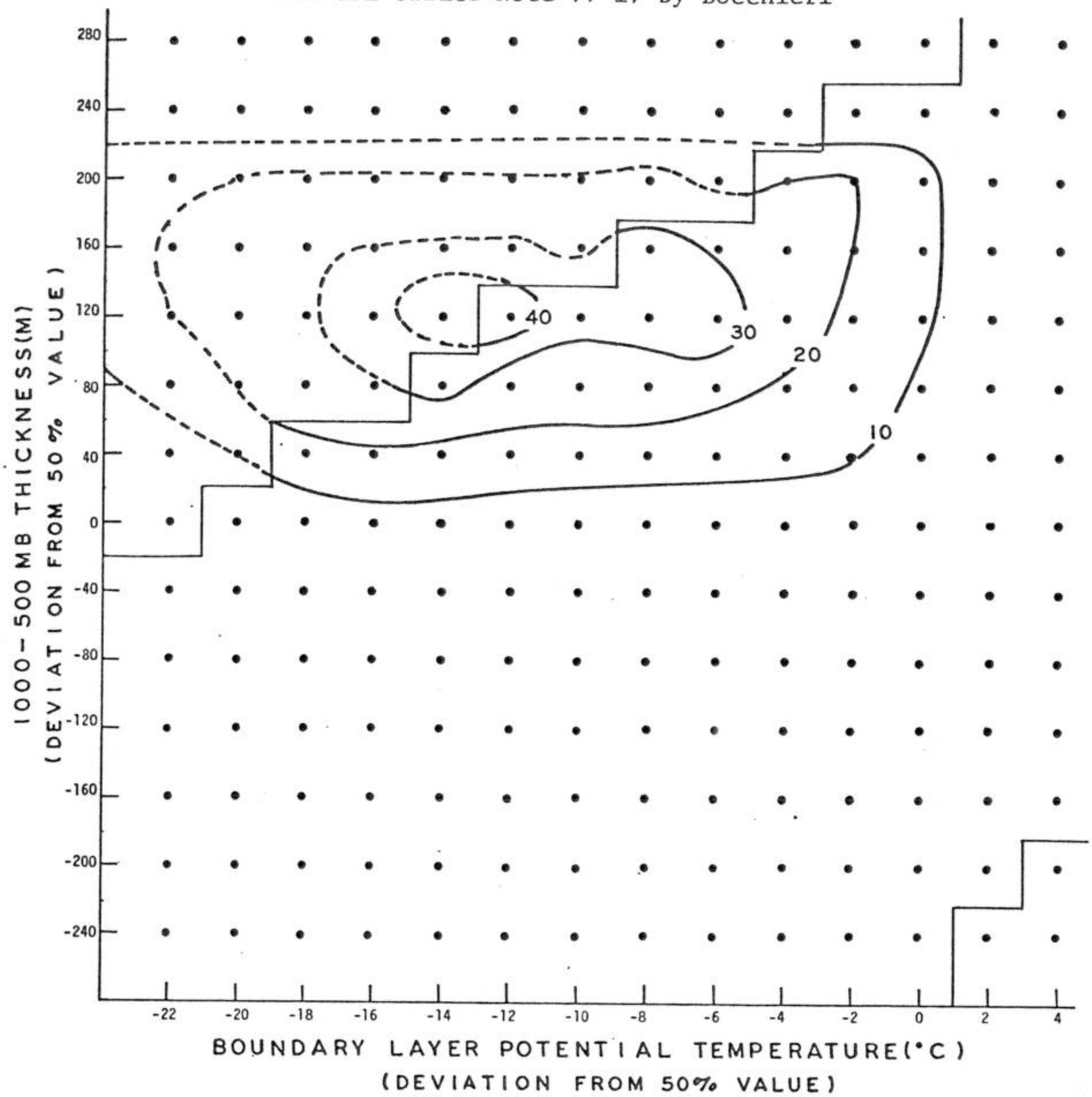

The empirical probability of freezing rain as a function of 10-50 TH and BLPT. The predictors are forecast values from the LFM model and are given in terms of deviations from 50% values. The graph is valid at any time during the 12- to 24-hr period after the 0000 GMT or 1200 GMT LFM cycle time.