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INTRODUCTION

In precipitation situations it can be desirable to have the on-station capability of updating centralized guidance of short-range forecasts of precipitation amount. This is especially true when the potential for flooding exists. Any method chosen to do this update should be relatively simple and quick; otherwise, its utility will diminish. The purpose of this note is to describe an objective, on-station method to provide short-range forecasts of precipitation amount in probabilistic and categorical form for 6-hr periods.

DESCRIPTION OF THE METHOD

The method I propose applies the Model Output Statistics technique (Glahn and Lowry, 1972) to probability of precipitation amount (POPA) forecasting. Forecasts, in both probabilistic and categorical form, are made for the categories $\geq .25$, $\geq .50$, and ≥ 1.0 inch for the periods 6-12 and 12-18 hr after 0000 GMT and 1200 GMT. On any day, therefore, forecasts are available for four 6-hr periods (see Fig. 1). Generalized operator equations for each period and for each category for the cold season (October - March) were developed on 5 cold seasons of data for the 9 regions shown in Fig. 2. These are the same regions used in the POPA guidance supplied to the Quantitative Precipitation Branch of the National Meteorological Center (NMC) (Bermowitz and Zurndorfer, 1975). They were derived by a subjective analysis of the frequency of occurrence of observed precipitation amounts for various forecast amounts from the primitive equation (PE) model (Shuman and Hovermale, 1968).

Equations were developed with use of surface observations available at the beginning of the forecast period (e.g. equations for 1200-1800 GMT use 1200 GMT observations) together with only those PE and trajectory (TJ) model (Reap, 1972) forecast data routinely available on teletype bulletions for certain cities in the United States. Therefore, not all of the PE and TJ forecast fields normally used in our POPA developmental work were available for screening; however, the most important ones were. Of course, it would have been desirable to use manually digitized radar data as an additional predictor. However, it is not available for the entire United States and it has not been archived long enough to be used in this POPA work.

Recent work (Glahn and Bocchieri, 1975) has indicated that the addition of continuous predictors improved winter season probability of precipitation (POP) forecasting. Because of the similarity of POP and POPA forecasting, I allowed continuous predictors to be screened along with the usual binaries. Generally speaking, the most important predictors were found to be precipitation amount and mean relative humidity from the surface to 500 mb from the PE model, both in continuous and binary form, the observed weather in binary form only, and the observed previous 6-hr precipitation amount in continuous and binary form.

There are two potential problem areas with these POPA equations that should be pointed out. They are concerned with the differences in the way forecast predictor fields are interpolated to stations in the developmental sample and in pratice. The PE predictors used in the developmental sample are obtained by biquadratic interpolation to stations; the PE forecasts received on teletype are interpolated bilinearly. The TJ predictors used in the developmental sample are also obtained by biquadratic interpolation to stations; the TJ forecasts received on teletype are obtained from trajectories whose end points are at stations.

Up to this point I have discussed development of the equations that give probability of precipitation amount. Generally, a categorical forecast of precipitation amount is desired. Therefore, a method of transforming the POPA forecasts to categorical forecasts is needed. A discussion of several methods of doing this is given by Bermowitz (1975). The POPA forecasts could be transformed by maximizing the threat score[1] which is the primary statistic for verification of forecasts of precipitation amount at NMC. When this is done, the categorical biases[2] almost always exceed 1; that is, overforecasting of all categories occurs. If this is not desirable, the POPA forecasts could be transformed by minimizing the bias (bias nearly equal to 1). In this case, some decrease in threat score is likely to occur.

Each method requires calculation of a threshold probability for each category for each projection that either maximizes the threat score or minimizes the bias for dichotomous forecasts of that category. The threshold probability for a category, say $\geq$ .25 inch, is a value that if exceeded by a probability forecast for that category, would result in a categorical forecast of $\geq$ .25 inch. If the threshold value is not exceeded, the categorical forecast would be $<$ .25 inch. A set of threshold probabilities that maximize the threat score and another set that minimize the bias were derived for each region.

Unfortunately, it was not always possible to derive a stable threshold value for all categories for all regions. Indeed, it was not always possible to derive stable POPA equations for the higher amounts in all regions. For example, a categorical forecast for the category $\geq$ 1.0 inch is possible in only regions 1, 3, and 4 (Fig. 2). The reason for this is the low 6-hr frequency of occurrence of the higher amounts over certain areas of the United States.

AN EXAMPLE OF THE METHOD

Sample equations giving the probabilities for the categories $\geq$ .25, $\geq$ .50, and $\geq$ 1.0 inch for region 1 for the period 0600-1200 GMT are shown in Table 1. The equations, by column, contain the constant (first line) and coefficients

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[1]Threat score = H/(F+O-H) where H is the number of correct forecasts of a category and F and O are the number of forecasts and observations of that category.

[2]Bias is the number of forecasts of a category divided by the number of observations of that category. A categorical bias equal to 1 means unbiased forecasts of that category.

which are (1) to be multiplied by the value of the predictor given in the first column if the predictor is continuous or (2) the contributions to the probabilities if the predictor is binary and less than or equal to the specified limit.

As can be seen from Table 1, a desk calculator would speed the arithmetic operations, especially multiplication of coefficients by the value of continuous predictors. In some cases, the units of the forecast fields received on teletype differ from those contained in the equations (for example, PE precipitation amount). In these cases, a change of units is required either in the forecast field every time it is used or in the coefficients--a one time only change. Obviously, operational computation would be speeded if a change is made in the coefficients. If it is desirable to have the forecast earlier than its valid period, observations one hour preceeding the start of the forecast period can be used with probably only little loss in accuracy. Unfortunately, it is not possible to use observations at any hour as predictors in developing the equations; the developmental data contains observations at only 0000, 0600, 1200, and 1800 GMT.

As an example of the use of this method, let's assume the probability forecasts for the 3 equations shown in Table 1 are .42, .17, and .03. Let's further assume that we want to transform these probability forecasts by maximizing the threat score. The threshold probabilities to do this for this region and projection are .27, .19, and .08. To determine the categorical forecast, we start at the category $\geq$ .25 inch and compare the probability forecast (.42) with the threshold value (.27) for that category. Since the threshold value is exceeded, we proceed to the category $\geq$ .50 inch and see if the probability forecast (.17) exceeds the threshold value (.19) for that category. Since it does not, this procedure is stopped and the forecast amount is $\geq$ .25 and $<$ .50 inch.

Of course, if the probability forecasts had exceeded the threshold values for all categories the forecast amount would have been $\geq$ 1.0 inch. Similarly, if the probability forecast was less than the threhold value for the category $\geq$ .25 inch, the forecast amount would have been $<$ .25 inch.

VERIFICATION

To obtain some indication of how the on-station POPA method would perform on independent data, I made a comparative verification of categorical forecasts produced by it against those prepared (1) subjectively at NMC, (2) by our guidance product supplied to NMC, denoted by 1975-1976 POPA, and (3) by the limited area fine mesh (LFM) model (Howcroft and Desmaris, 1971). Categorical forecasts from both POPA methods were made by maximizing the threat score. Threat scores and biases were computed at 230 cities for the category $\geq$ .25 inch for the projection 1200-1800 GMT. The category $\geq$ .25 inch was the only one verified since NMC did not record categorical forecasts greater than that for 6-hr periods. The period of verification was 26 days during March 1975. This consisted of the relatively small total of 175 observations of $\geq$ .25 inch.

The results of the verification are shown in Table 2. They indicate that the on-station POPA forecasts were slightly better than the others. The biases were rather high for all systems; the 1975-1976 and on-station POPA systems were designed that way.

SUMMARY

A relatively simple and quick on-station method for short-range forecasting of precipitation amount in probabilistic and categorical form for 6-hr periods has been presented. The method uses the latest surface observations together with PE and TJ forecast data available on teletype for selected cities in the United States. A rather limited comparative verification indicated that the technique has skill.

Equations giving the probabilities for the categories $\geq$ .25, $\geq$ .50, and $\geq$ 1.0 inch are available, where possible, for 9 regions. A set of threshold probabilities that maximize the threat score and another set that minimize the bias are also available.

This method is highly suitable for use with the Automation of Field Operations and Services (AFOS) system (Klein, 1976). Computation of the forecasts could be performed by minicomputer after receipt of the hourly surface observations. The PE and TJ data, having been received earlier and stored, could be recalled from memory and ready to use.

ACKNOWLEDGMENTS

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PROJECTION (HOURS)		00	06	12	18	24
VALID TIMES	00Z Cycle	00	06	12	18	24
	12Z Cycle	12	18	00	06	12
		.	.	.	.	.
ON STATION POPA METHOD			.- - -	-.- - -	-.	

Figure 1. Forecast periods for the on-station POPA method are indicated by the dashed lines.

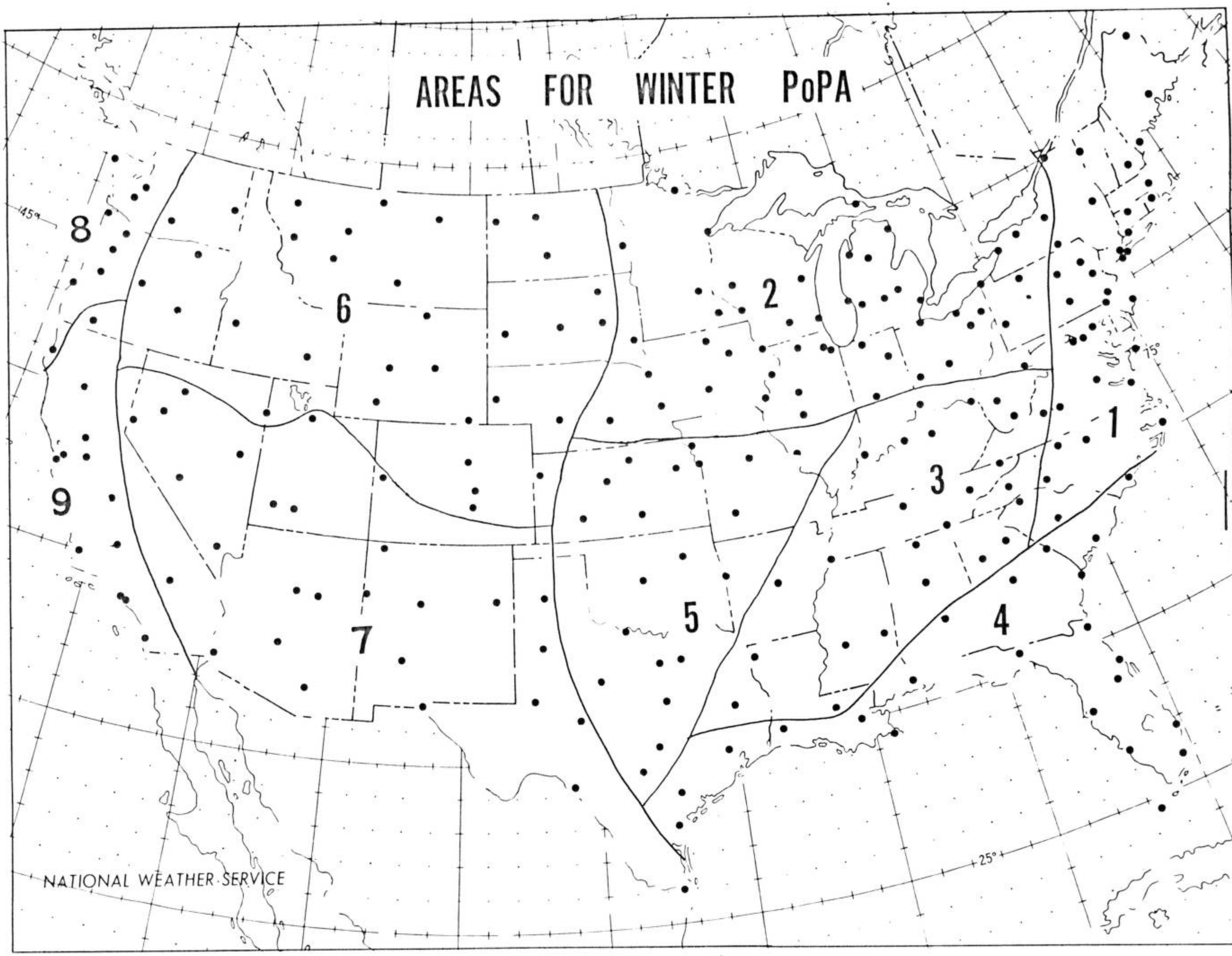

Figure 2. The 9 regions used to develop equations for the on-station POPA method.

Table 1. POPA cold season (October-March) equations for categories $\geq$ .25, $\geq$ .50, and $\geq$ 1.0 inch for region 1 for the period 0600-1200 GMT. Observed quantities are at 0600 GMT. See text for an explanation of these equations. The total reduction of variance is given below each equation.

Predictor	Constant and Coefficients for Categories		
	$\geq$ .25 inch	$\geq$ .50 inch	$\geq$ 1.0 inch
	.2422	.1483	.0273
PE PREC AMT FOR 12Z-24Z IN METERS	+14.76	+8.295	+2.868
OBS WX $\leq$ 3*	-.0826	-.0288	-.0052
PE 1000-500 MB MEAN RH AT 12Z $\leq$ 97%	-.0852	-.0375	-.0031
OBS PREC AMT FROM 00Z-06Z $\leq$ .50 INCH	-.0311	-.1040	-.0371
OBS U WIND $\leq$ -12 KNOTS	.1508	.0930	.0180
OBS DEWPT $\leq$ 55° F	-.0336	-.0364	-.0190
PE PREC AMT FOR 12Z-24Z $\leq$ .00217 METERS	.0525	.0351	.0143
OBS PREC AMT FROM 00Z-06Z $\leq$ .25 INCH	-.1010	-.0380	-.0085
OBS U WIND $\leq$ -6 KNOTS	.0510	.0248	-.0043
PE 1000-500 MB MEAN RH AT 18Z $\leq$ 97%	.0259	.0375	.0157
TJ 850 MB 12HR NET VERT DISP AT 24Z $\leq$ 50 MB	.0463	.0335	.0213
PE LAYER 2 RH AT 12Z $\leq$ 97%	-.0431	-.0157	-.0072
TOTAL RV	.3063	.1763	.0635

* A code of $\leq$ 3 means no precipitation except L--, L-, L, and L+. That is, if precipitation is not occurring (except L--, L-, L, and L+) then the contributions to the probabilities are the coefficients (negative for all 3 predictands in this case).

Table 2. Comparative verification of NMC subjective, 1975-1976 POPA system, LFM, and on-station POPA forecasts for the category $\geq$ .25 inch for the period 1200-1800 GMT for 26 days in March 1975.

Score	SUBJ	POPA 75-76	LFM	On-Station POPA
Threat Score	.231	.238	.240	.252
Bias	1.81	2.18	2.07	2.15