HOW TO USE THE NGM MOS GUIDANCE EFFECTIVELY: PART II - PROBABILITY OF PRECIPITATION TYPE

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1. INTRODUCTION

This report is the second Eastern Region Technical Attachment (TA) on how to use the NGM Model Output Statistics (MOS) guidance effectively. · The first TA (Maglaras 1993), was entitled "How to Use the NGM MOS Guidance Effectively: Part I - Probability of Precipitation." The focus of this paper is on the MOS Probability of Precipitation Type (PoPT) guidance (Erickson 1995a). The NGM MOS PoPT system provides probability and categorical forecasts of frozen, freezing, and liquid precipitation. This guidance is considerably different than its predecessor, the LFM MOS PoPT system, which is no longer operationally available. The purpose of this report is to provide general information about the NGM MOS PoPT system, and to provide tips and guidelines on how to use the guidance effectively. Some of the critical differences between the NGM and LFM PoPT systems are also discussed.

2. BACKGROUND AND DEFINITIONS

The NGM MOS equations that produce the conditional forecasts of frozen, freezing, and liquid precipitation were derived from six seasons of data (September 16 through May 15) from 1986 through 1992. The NGM PoPT forecasts are "conditional" since only precipitation cases where included in the data sample.

The MOS PoPT system is regionalized. Hence, one equation produces the set of probability forecasts for a particular projection and cycle for a group of stations in a specific area. The values of the predictors used in the equations are based on input from the NGM. The values of the predictors change from station to station within a particular region, but the equation remains the same. Figure 1 depicts the regions used to develop the NGM PoPT equations (Erickson 1995a).

The definitions of the precipitation type categories for the NGM MOS PoPT system are considerably different than those used for the LFM PoPT system (Erickson 1992). Table 1 lists the observed precipitation types that are included in each category (ZR/IP, SNOW, RAIN) for both the NGM and LFM systems. The NGM PoPT freezing

precipitation (ZR/IP; Category 1) category includes all cases when freezing rain or ice pellets were observed, including freezing rain or ice pellets mixed with any other type of precipitation. For this category, the old LFM PoPT system included cases when only freezing rain occurred or freezing rain mixed with any other type of precipitation. The NGM PoPT frozen precipitation (SNOW; Category 2) category includes cases when only snow was observed, while the old LFM PoPT system included cases when either snow or ice pellets where observed. Finally, the NGM PoPT system liquid precipitation (RAIN; Category 3) category included all those cases when rain or drizzle were observed, or rain or drizzle mixed with snow occurred. The old LFM PoPT system's liquid precipitation category was nearly the same, except it also included cases of rain or drizzle mixed with ice pellets. Although the number of ZR/IP cases is small (approximately 3% of all precipitation cases), the NGM PoPT system has about 30% more cases included in the ZR/IP category than it would have using the old definitions (Erickson 1992).

The NGM MOS PoPT system categorical selection procedure is nearly identical to the one used by the LFM PoPT system (Erickson 1995a) and works in two basic steps:

1) The probability of ZR/IP forecast is compared to the ZR/IP threshold. If the probability forecast exceeds the threshold value, then ZR/IP is forecasted. If the threshold is not exceeded, the SNOW category is checked (the ZR/IP threshold values for the Eastern Region were generally 20 to 30%); and,

2) The probability of ZR/IP forecast is added to the probability of SNOW forecast. This value is then compared to the SNOW threshold value. If the threshold value is exceeded, then SNOW is forecasted. If the threshold is not exceeded, then RAIN is forecasted (the SNOW threshold values for the Eastern Region were generally 48 to 52%).

In general, the most important predictors in the NGM MOS PoPT equations are thickness and temperature predictors at various levels (Erickson 1995a). Specifically, these levels include the 1000-850, 850-700, and the 700-500 mb thicknesses, as well as the 1000, 950, 900, 850, 800, 750, and 700 mb temperatures. Most of these predictors are in a new form called grid-binary predictors (Jensenius 1992). The old LFM PoPT used simple binary predictors, which are model predictors calculated specifically for the station location, and then set to zero or one depending on whether or not the model predictor exceeds a given binary limit. This can sometimes result in large changes to the MOS forecast when the model predictor changes only slightly. The grid-binary predictors were developed in part, to avoid large changes to the NGM MOS PoPT forecast, which are associated with small variations in the forecast value of a model predictor. Unlike the simple binary predictor, which uses the value of the model predictor at a single point (i.e., the station location), the grid-binary predictor examines the value of the model predictor at numerous grid points around the station. Based on the value of the model predictor, each grid point is given a value of zero or one. The entire grid point field of zeros and ones is then smoothed and interpolated to the station location. Hence, grid-binary

predictors can be assigned a value between zero and one. This means that a slight difference in the model predictor will only produce a slight change to the value of the grid-binary predictor, resulting in only a slight change to the PoPT forecast.

The most difficult task addressed by the NGM MOS PoPT system is being able to identify the vertical atmospheric temperature profiles that produce ZR and IP. The LFM PoPT system attempted to do this through the use of interactive predictors. An interactive predictor would examine two model variables simultaneously, but contribute a single value to the final probability forecast. An example of such a predictor is the interaction of the 1000-500 and the 1000-850 mb thickness values. If the 1000-500 mb thickness was warm (i.e., above freezing), but the 1000-850 mb thickness was cold (i.e., below freezing), then the predictor would make a significant contribution to the probability of freezing precipitation.

The increased vertical resolution of the NGM model makes it possible to examine the atmosphere at 16 layers to determine if the vertical temperature profile is conducive to freezing precipitation. In order to accomplish this task, a new algorithm was developed for the NGM PoPT system. This algorithm attempts to identify the vertical temperature profile of the mean atmospheric soundings that produce freezing rain and ice pellet events (Erickson 1992). The mean atmospheric soundings forecast (24-h projection) used by the NGM PoPT system are illustrated in Figure 2. These mean soundings were constructed using 3 seasons seasons of data.

Specifically, the algorithm is comprised of three stages that search for any inversion above a cold surface layer. The first stage of the process identifies the earth-surface level for a given station, and then determines a multiplicative factor based on the conditions at the earth-surface level. The available NGM model pressure level that is closest (but not below) the station elevation is used as the earth-surface level. This is the level at which the atmospheric sounding evaluation begins. If the NGM wet-bulb temperature (WBT) at the earth-surface level is greater than or equal to +3°C, the multiplicative factor is set to zero (unfavorable for ZR or IP) and the algorithm stops. If the NGM WBT at the earth-surface level is 0°C or less, then the multiplicative factor is set to one (favorable for ZR or IP). For WBT values between 0°C and +3°C, the multiplicative factor is assigned a value between zero and one based on a linear scale.

Once the earth surface conditions have been determined, the second stage of the algorithm determines the value of the binary predictor. The algorithm examines the NGM WBT's at all available pressure levels. If the WBT is above (below) 0°C at all levels, including the earth-surface level, then the binary predictor is set to zero, which is indicative of a RAIN (SNOW) sounding, and the algorithm stops. If any level that is at or below 0°C is found to have a layer above it that is warmer than 0°C, the binary predictor is set to one. This is indicative of a ZR/IP sounding. Finally, for the special case where the earth-surface layer is between 0°C and +3°C and all the levels above the earth-surface layer are below freezing, the binary predictor is set to zero. This is indicative of a SNOW sounding.

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In the third stage of identifying inversions, the multiplicative factor and the binary predictor value are combined by multiplying them to get a final value that is between zero and one. This value is calculated for many grid-points around the station so that the binary predictor can be converted to grid-binary form.

Linear regression was used to develop the NGM MOS PoPT equations while the logit technique was used to develop the LFM MOS PoPT equations (Erickson 1995a). Linear regression is a statistical model which attempts to fit a straight line to a data sample, while the logit technique tries to fit an S-shaped curve to a data sample. Although the final regionalized NGM PoPT equations were developed using the linear regression method, the advantages of using the logit technique for a binary type predictand were still incorporated into the PoPT system (Erickson 1992; 1995a). This was accomplished by using the logit technique to transform certain variables into non-linear S-shaped predictors (Fig. 3). The logit transformation was performed on a single station basis and had the added benefit of allowing the NGM PoPT system to account for the differences between stations within the same region. The variables transformed in this manner were the 850 mb temperature, the 1000-850 mb thickness, and the 850-700 mb thickness.

Figure 3 illustrates a typical distribution of the relative frequency of snow (dots) for all precipitation cases within each 2K increment. Figure 3 also depicts how the logit technique (solid line) and the linear regression model (dashed line) might fit these data in order to produce a probability of SNOW forecast based on the NGM 850 mb temperature forecast. For example, for

precipitation cases that occur when the NGM 850 mb temperature is forecast to be 268K, the probability of SNOW based on the regression model would be about 68% (Fig. 3). However, for the logit technique the probability is about 87%, which is much closer to the actual relative frequency of snow at 268K. The logit technique has the advantage of being able to fit an S-shaped curve to a data sample, and thus, better represents the sharp change in the relative frequency of snow occurrence in the 268K to 274K critical range. The regression line also gives probability values that are below zero and above one, while the logit curve more realistically approaches these values asymptotically.

3. TIPS AND GUIDELINES

It is important to note that only one set of NGM MOS equations generate the PoPT forecasts for the entire season of September 16 through May 15. Since a large majority of the snow cases used in the developmental sample are from the primary winter period (i.e., December through early March), the forecast equations will tend to be biased toward winter type situations. For example, given the same 850 mb temperature and cloud cover on January 1 and April 1, respectively, the observed surface temperature on April 1 will likely be warmer due to the higher sun elevation, longer day, warmer ground temperature, etc. However, the NGM MOS probability of snow forecast for April 1 will tend to be nearly the same as for January 1. The monthly frequencies of both the freezing and frozen categories (unique to each station) were offered to the equations as predictors to help with this problem. These terms included in many, but not all equations.

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Maglaras and Goldsmith (1990) determined that for the Eastern Region of the National Weather Service, the old LFM MOS PoPT system over forecasted the occurrence of snow in the spring, and had on average, a bias of 1.31 for the period March 16 through May 31. Little or no bias was noted during the Autumn. Personal observations experienced by the author indicate that the tendency to over forecast the occurrence of snow during the spring still exists with the NGM MOS PoPT system, at least for stations located in the northeastern United States.

The NGM MOS temperature guidance has been stratified into three seasons, September-November, December-February, and March-May. As a result, the temperature guidance is more likely to correctly account for the varying surface to upper-level thermal relationships during the course of the year. A consistency check with the MOS 3-h temperature guidance is a good method to use to determine if the probability of snow is being over forecast. This check may be accomplished by comparing the MOS 3-h temperature values against real-time observations.

When ZR/IP is being forecast categorically, it is recommended to check the probability of SNOW forecast as well. The categorical selection procedure for the PoPT system compares the ZR/IP probability to the ZR/IP threshold first, and then automatically forecasts ZR/IP if the threshold is exceeded. Occasionally, the probability of SNOW forecast will also be high enough to exceed the threshold for forecasting SNOW as well. In these cases, it is usually best to forecast snow or snow mixed with freezing rain and ice pellets.

With high-resolution gridded model data available to operational forecasters, numerical model output can now be examined in far greater detail than ever before. Forecasters can examine time sections of the NGM model temperature forecasts for the entire troposphere, and can also create model forecast soundings for any location. These gridded data may also be used to evaluate the MOS PoPT forecasts. For example, since the NGM MOS PoPT system uses temperature variables in 50 mb increments, the high-resolution gridded NGM model data can assist forecasters in determining if a narrow elevated warm or cold layer exists in the NGM model, which may be unaccounted for by the PoPT system. If a warm elevated layer does exist, the PoPT forecasts can be evaluated accordingly.

Verification statistics for the 1993-94 cool season indicate that, overall, the NGM PoPT system was slightly better than the old LFM MOS PoPT system (Erickson 1995b). However, the NGM PoPT system was found to be substantially more accurate at forecasting ZR/IP, which may provide extremely useful guidance in the forecasting of this difficult to predict precipitation type.

ACKNOWLEDGMENTS

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Table 1. Definitions of the precipitation type categories used by the NGM and LFM MOS PoPT systems (from Erickson 1992).

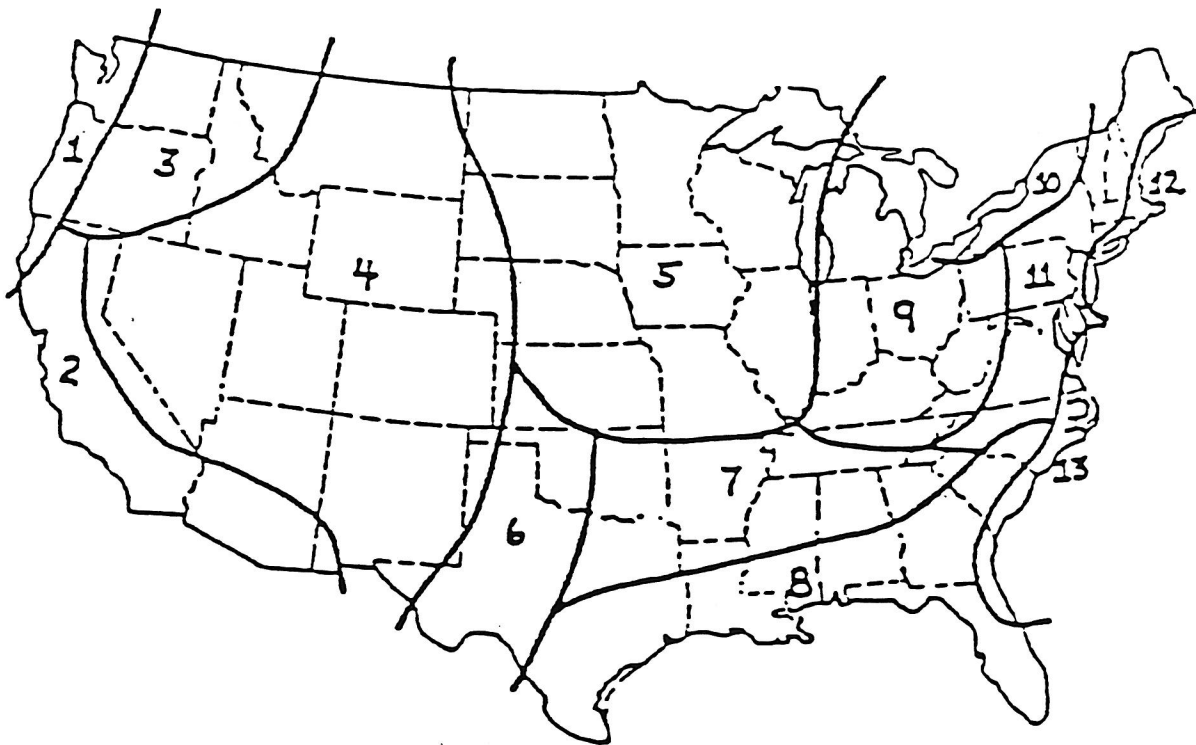|	NGM PoPT	LFM PoPT
Category 1 (ZR/IP)	ZR,ZL,ZR/S,ZL/S ZR/IP,ZL/IP R/IP,L/IP,S/IP,IP	ZR,ZL,ZR/S,ZL/S ZR/IP,ZL/IP
Category 2 (SNOW)	S	S S/IP,IP
Category 3 (RAIN)	R,L,R/S,L/S	R,L,R/S,L/S, R/IP,L/IP

Figure 1. The regions used in the development of the NGM PoPT forecast equations for the contiguous United States (from Erickson 1995a).
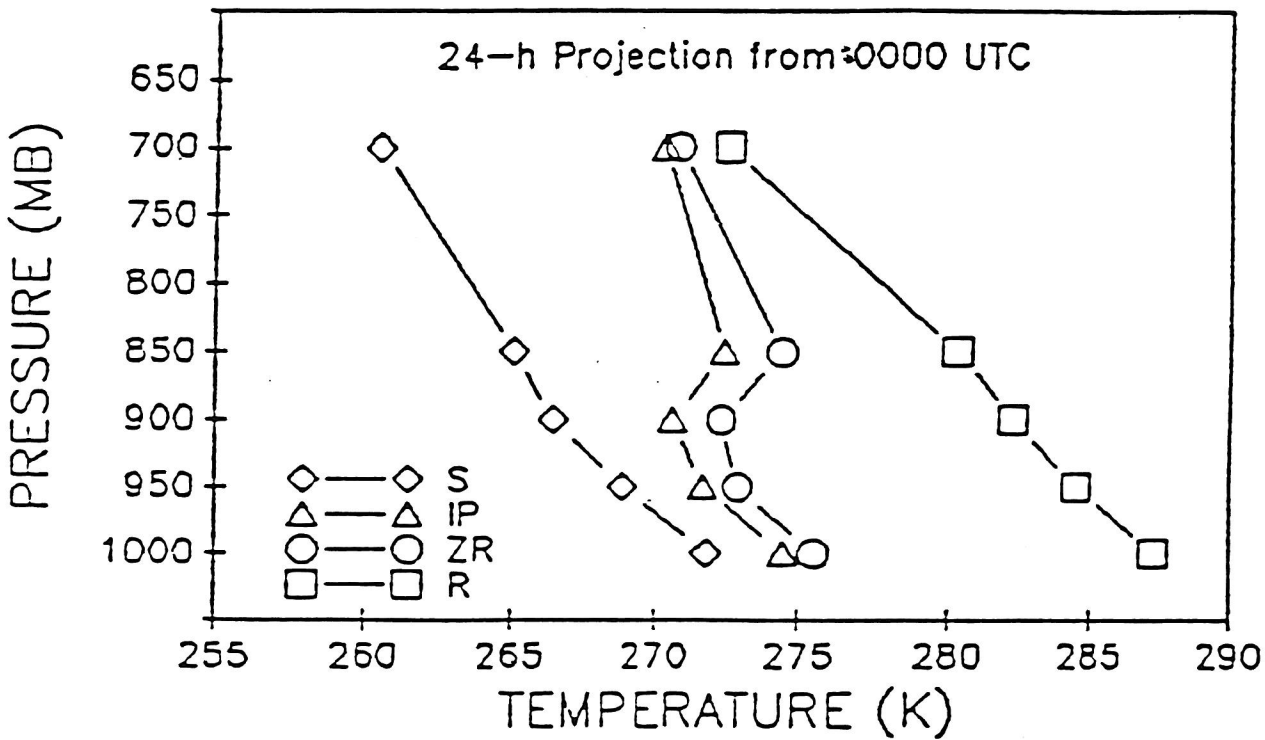

Figure 2. The mean atmospheric temperature soundings forecast (24-h projection; 3 seasons of data) used by the NGM PoPT system to predict various precipitation types (from Erickson 1992).
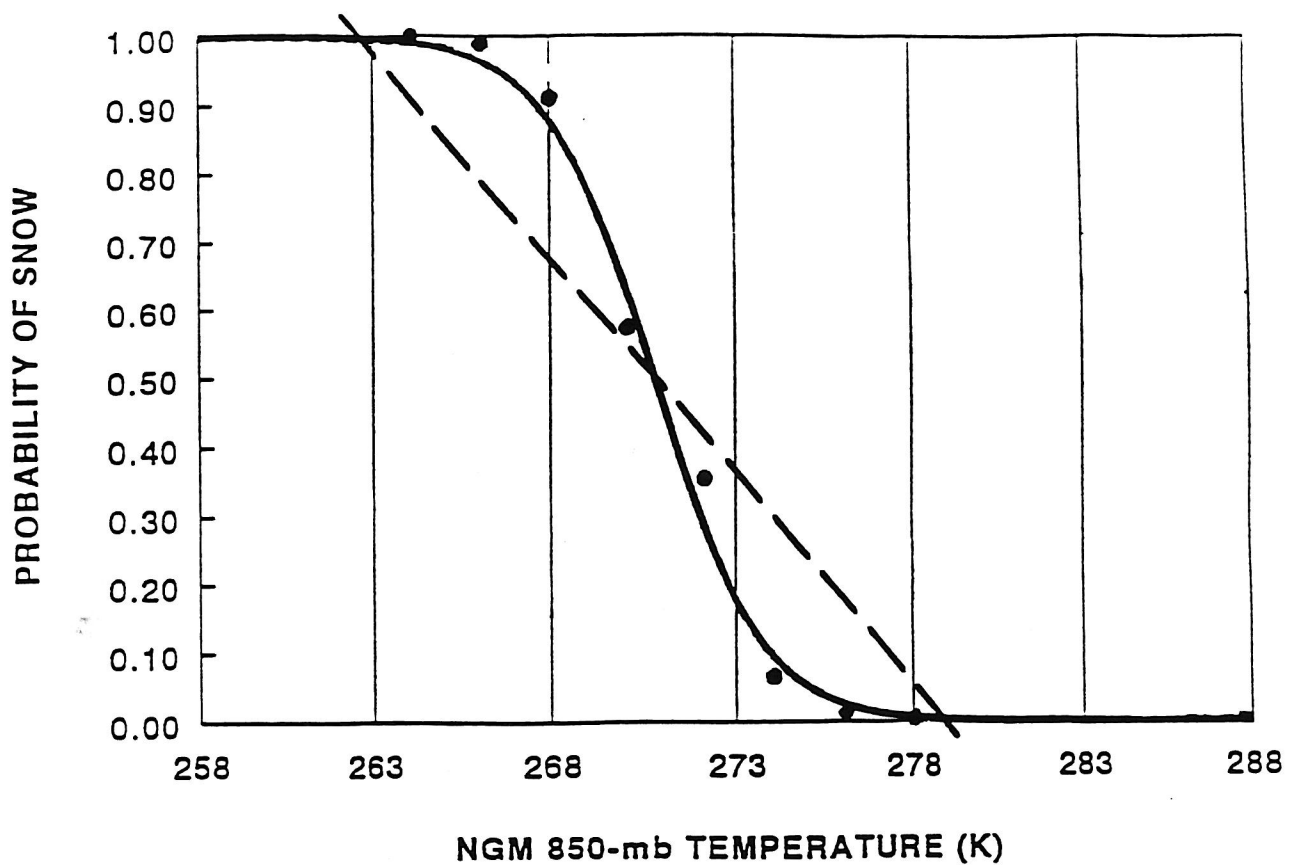
Figure 3. A hypothetical distribution of the relative frequency of snow (dots) for all precipitation cases within each 2 K increment. The solid (dashed) line illustrates how the logit technique (linear regression model) might fit these data.