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HOW TO USE THE LFM-BASED MOS POSA SYSTEM - A CASE STUDY

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1. Introduction

In Central Region Technical Attachment 87-23 (October, 1987), George Maglaras reviewed the MOS Probability of Snow Amount (PoSA) system and presented some guidelines for its use. I recently completed a case study that confirmed these guidelines and led to some additional conclusions. Here, I've reviewed the PoSA system (in case George's paper is not available to you) and provided an updated list of operational guidelines that you can refer to when time is short and the flakes start flying.

LFM-based PoSA guidance is generated from both the 0000 and 1200 UTC forecast cycles and is valid for 12-24 h periods thereafter. Fig. 1 depicts a sample FOUS12 bulletin containing the PoSA message and shows how to interpret the PoSA line. As you can see, probability forecasts of three categories of snow amount ($\geq$2, $\geq$4, and $\geq$6 inches) and a best category forecast are provided. The first two digits in each group give the conditional probability forecast of that category, while the second two digits give the unconditional probability forecast (both forecasts are expressed in percent). The best category forecast is found after the final slash.

2. Conditional PoSA Forecasts

The conditional probability of snow amount forecast (referred to as the CP from here on) is the probability of occurrence of a given snow amount category, assuming two conditions: (1) that more than a trace of precipitation occurs, and (2) that precipitation falls as snow, sleet, or a combination of the two. Equations to produce CP's were developed for each of the three snow amount categories. Another way to think of the CP's is that they tell you what the chance is of getting $\geq$2, $\geq$4, and $\geq$6 inches of snow during the 12-24 h period following 0000 or 1200 UTC, given that snow is a "sure bet" during that period.

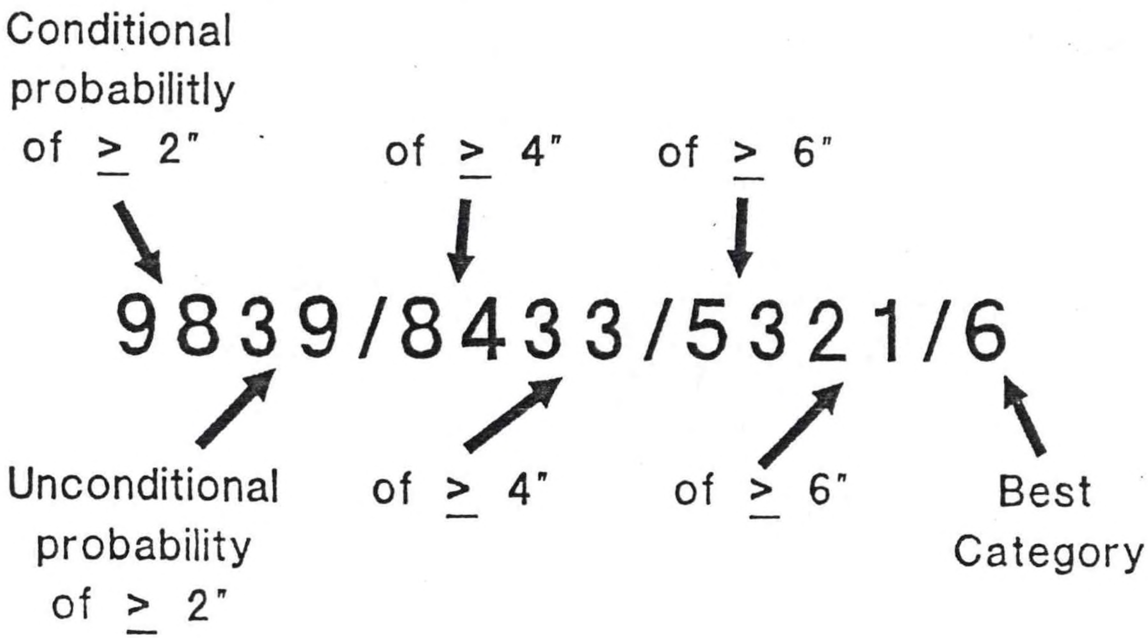
Because the equations assume precipitation will fall in the form of snow and/or sleet only, meteorological variables which help delineate between rain and snow (e.g., layer thicknesses and level temperatures) were not usually

FIGURE 1

Sample FOUS12 bulletin containing the PoSA message and a guide as to how the message should be interpreted

HDNG FOUS12 LFM-MOS GUIDANCE **April 19, 1983** **0000 GMT**

DY/HR	19/06	19/12	19/18	20/00	20/06	20/12	20/18	21/00
BDL E								
POP06		70	100	80	60	50	40	40
POP12				100		70		60
QPF06		210/2	420/3	210/2	210/2	100/1	100/1	
QPF12				6310/4		3200/2		2100/1
TSTM				20		17		8
POPT	0026/3	0047/2	0132/3	0150/2	0048/2	0050/2	0047/2	0078/2
POSA		98	39/8433/5321/6					
MX/MN				47		34		51
TEMP	39 38	40 42	44 44	42 40	38 36	40 46	49 48	45 43
DEWPT	29 30	34 36	36 35	34 35	33 31	32 32	33 34	33 33
WIND	0110	0112	0414	3607	2806	2506	3506	3105
CLDS	2017/4	0019/4	0019/4	0019/4	001 /4	0018/4	0038/4	0136/4
CIG	011233	012231	014430	013430	013 30	022331	012450	001252
VIS	001117	003214	003214	002105	002 06	002106	001108	001118
C/V	5/5	3/3	2/3	2/3	/3	3/6	4/6	4/6
OBVIS	60X5/4	40X7/4	40X6/4	60X6/4	60X /1	60X4/1	80X3/1	80X3/1



selected as predictors. On the other hand, variables which are strongly related to the observed precipitation amount, such as LFM forecasts of surface-490 mb mean RH and precipitation amount, were frequently chosen. Other important predictors in the equations include LFM forecasts of 700 mb vertical velocity and wind components at 700 and 850 mb.

The snow amount equations are regionalized, which means that the same set of three equations (one for each amount category) is used to produce forecasts for a group of stations. As can be seen in Fig. 2, five station groupings were used in development. Separate sets of equations were derived for each cycle, although the same regional stratification was used for both cycles. Thus, only ten equations sets are needed to produce CP's for the entire country. Note that PoSA guidance was not developed for stations from southern Texas to Florida, and for stations along the West Coast (as denoted by the dashed lines in Fig. 2), because snowfall occurs too infrequently in these areas for stable regression equations to be derived.

3. Unconditional PoSA Forecasts

Unconditional PoSA forecasts (referred to as UP's from here on) give the absolute probabilities of the various categories occurring. Unlike the CP's, UP's do account for the following: (1) that precipitation may not occur at all, and (2) that if precipitation does occur, it may not all be in the form of snow and/or sleet.

We did not develop a separate group of equations to produce UP's. Instead, the UP's are calculated from the CP's, the 12-h probability of precipitation (PoP) forecasts, and conditional probability of frozen precipitation (PoF) forecasts for the 12-, 18-, and 24-h projections. (The PoF forecasts appear as the second two digits in the PoPT message.) To illustrate how this is done, refer back to the top of Fig. 1, which depicts the FPC message for Hartford, Connecticut based on 0000 UTC data on April 19, 1983. Note that the CP for ≥ 2 inches is 98 percent, while the corresponding UP is 39 percent. The algorithm for converting a CP to a UP for a given category is shown below:

UP = CP * (12-24 h PoP) * PoF,

where PoF is defined as:

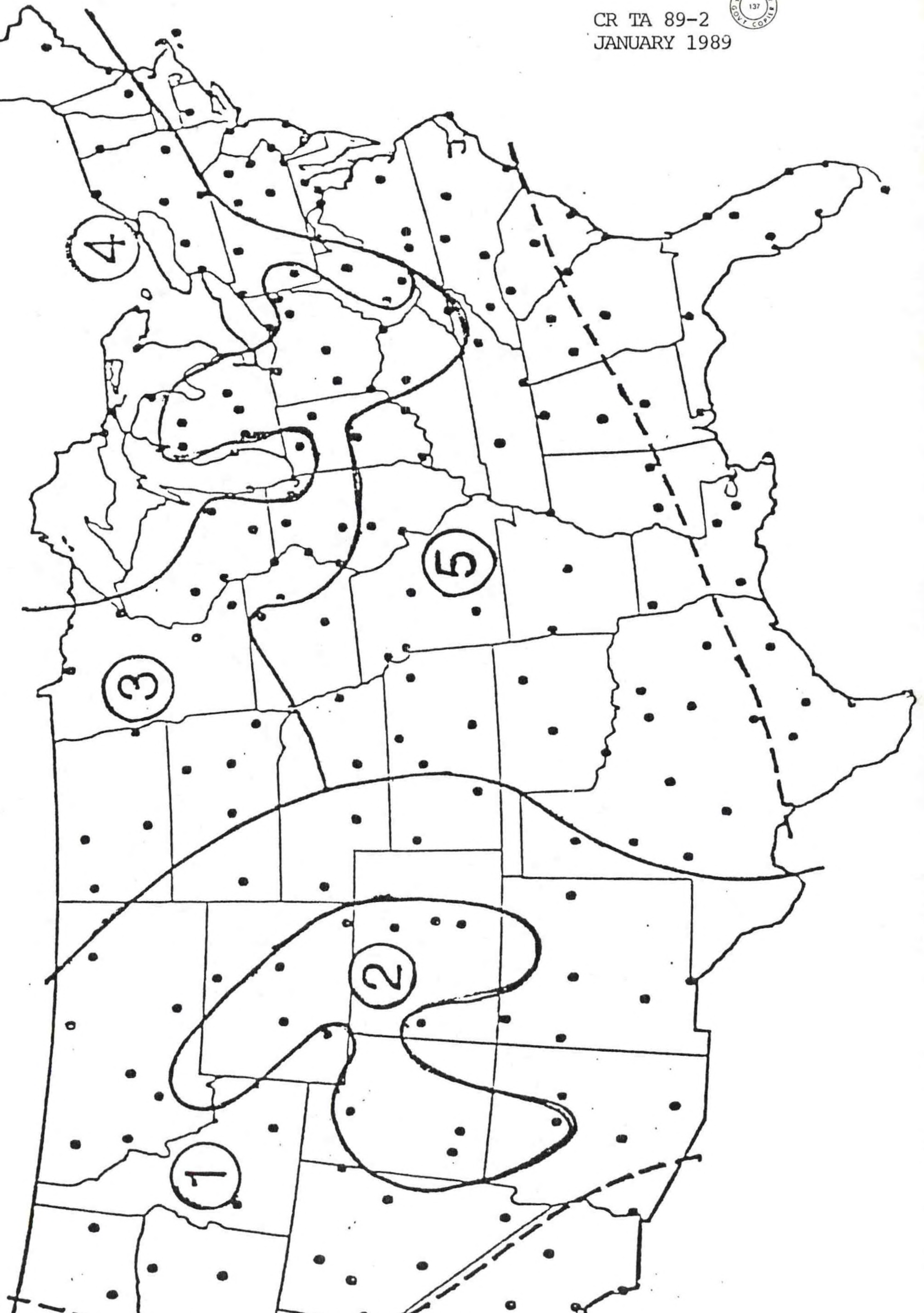
$$\frac{(12\text{-h PoF}) + (2)(18\text{-h PoF}) + (24\text{-h PoF})}{4}$$

Multiplying the CP by the 12-h PoP for the 12-24 h period accounts for the possibility that precipitation may not occur at all, while multiplying that product by the weighted PoFs accounts for the possibility that precipitation may occur in a form other than snow and/or sleet. Note that the 12-24 h PoP in this case is 100 percent, while the 12-, 18-, and 24-h PoFs are 47 percent, 32 percent, and 50 percent, respectively. Thus,

UP = .98 * 1.00 * (.47 + .32 + .32 + .50)/4 = .39 or 39 percent.

FIGURE 2

Regional Groupings Used For PoSA Equation Development



This same procedure is used to convert CP's to UP's for the $\geq$4- and $\geq$6-inch categories. You may want to convince yourself that this is the case. Can an understanding of how this conversion is done be of use to you operationally when time is short? I think so, and I'll show you how when I get to the case study. Before doing that, there's one more facet of the PoSA guidance to explain.

4. The Best Category Forecast

The CP's and UP's are provided for each of the three categories, but they do not indicate which category the forecaster should select. Thus, a best category forecast (BC from here on) is also provided. There are four possible categories that can be chosen:

0 - $\leq$2 inches
2 - 2 or 3 inches
4 - 4 or 5 inches
6 - $\geq$6 inches

The BC is chosen by systematically comparing the UP's to statistically determined threshold values for the 2-, 4-, and 6-inch levels. The method of comparison is illustrated in Fig. 3 and the actual threshold values for each of the ten equations are given in Table 1. (Threshold values have been rounded to the nearest percent in some of the tables presented below to save space.) Note that all three UP thresholds must be exceeded in order for $\geq$6 inches to be forecast. On the other hand, if the 2-inch threshold isn't exceeded, the process stops and the BC is set to 0.

5. A PoSA Case Study: December 13-16, 1987

With the background information provided so far, we can now go on to the case study. Fig. 4 depicts the progress of a major winter storm that had its origins in the desert Southwest and then moved through extreme southern Texas. The storm later "exploded" as it moved northward through the Midwest into southern Ontario. In association with this system, heavy snow fell across extreme western Texas and from Oklahoma to the Great Lakes.

Fig. 5 shows the observed snow amounts over three consecutive 12-h periods beginning at 1200 UTC on December 14. Contours are drawn at 2-inch intervals from 2 to 6 inches so that the observed snow amounts can be easily compared with the BC's for the corresponding time periods, as shown in Fig. 6. In both Figs. 5 and 6, the hatched area corresponds to $\geq$6 inches, the stippled area corresponds to 4 or 5 inches, and the unshaded area corresponds to 2 or 3 inches. A comparison of the BC's with the observed data reveals that MOS did a relatively good job of outlining the area where significant snowfall occurred.

On the other hand, the BC's were quite erroneous for some areas. For example, the guidance was obviously overzealous in its snowfall predictions across the Northeast during the 12-h period ending at 0000 UTC on December 16. There were other noteworthy miscues at individual stations, and I have separated these into five types or "classes" of errors.

FIGURE 3

Determining the Best Category (BC)

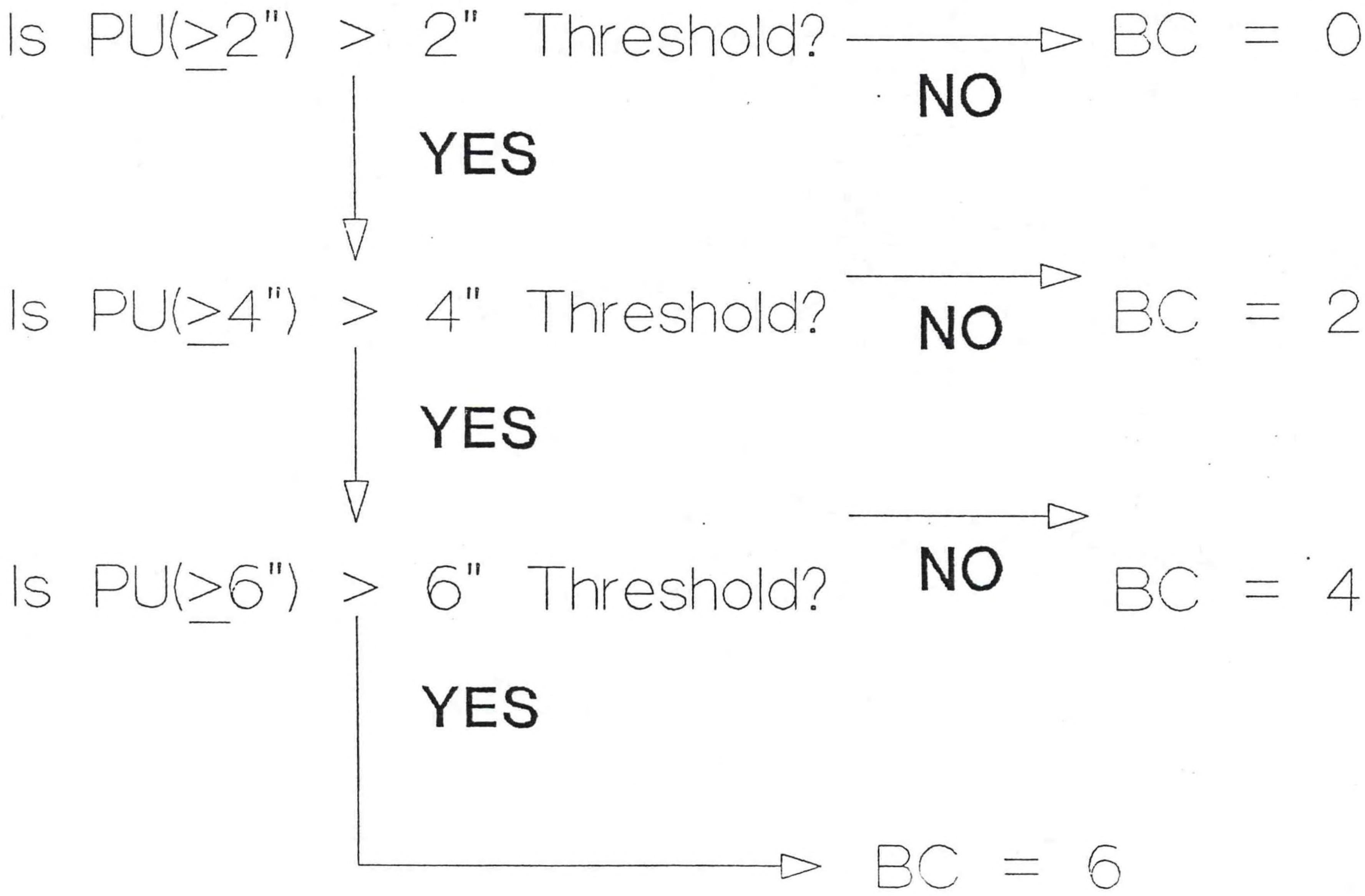


TABLE 1

PoSA Best Category Threshold Values

Values for 0000 UTC PoSA Equations

Region	Thresh(2")	Thresh(4")	Thresh(6")
1	.188	.118	.108
2	.260	.210	.162
3	.228	.210	.198
4	.250	.230	.229
5	.278	.230	.204

Values For 1200 UTC PoSA Equations

Region	Thresh(2")	Thresh(4")	Thresh(6")
1	.190	.106	.066
2	.222	.172	.184
3	.276	.200	.206
4	.228	.228	.242
5	.286	.216	.232

FIGURE 4

1200 UTC surface maps for: **a)** 12/13, **b)** 12/14, **c)** 12/15, and **d)** 12/16, 1987

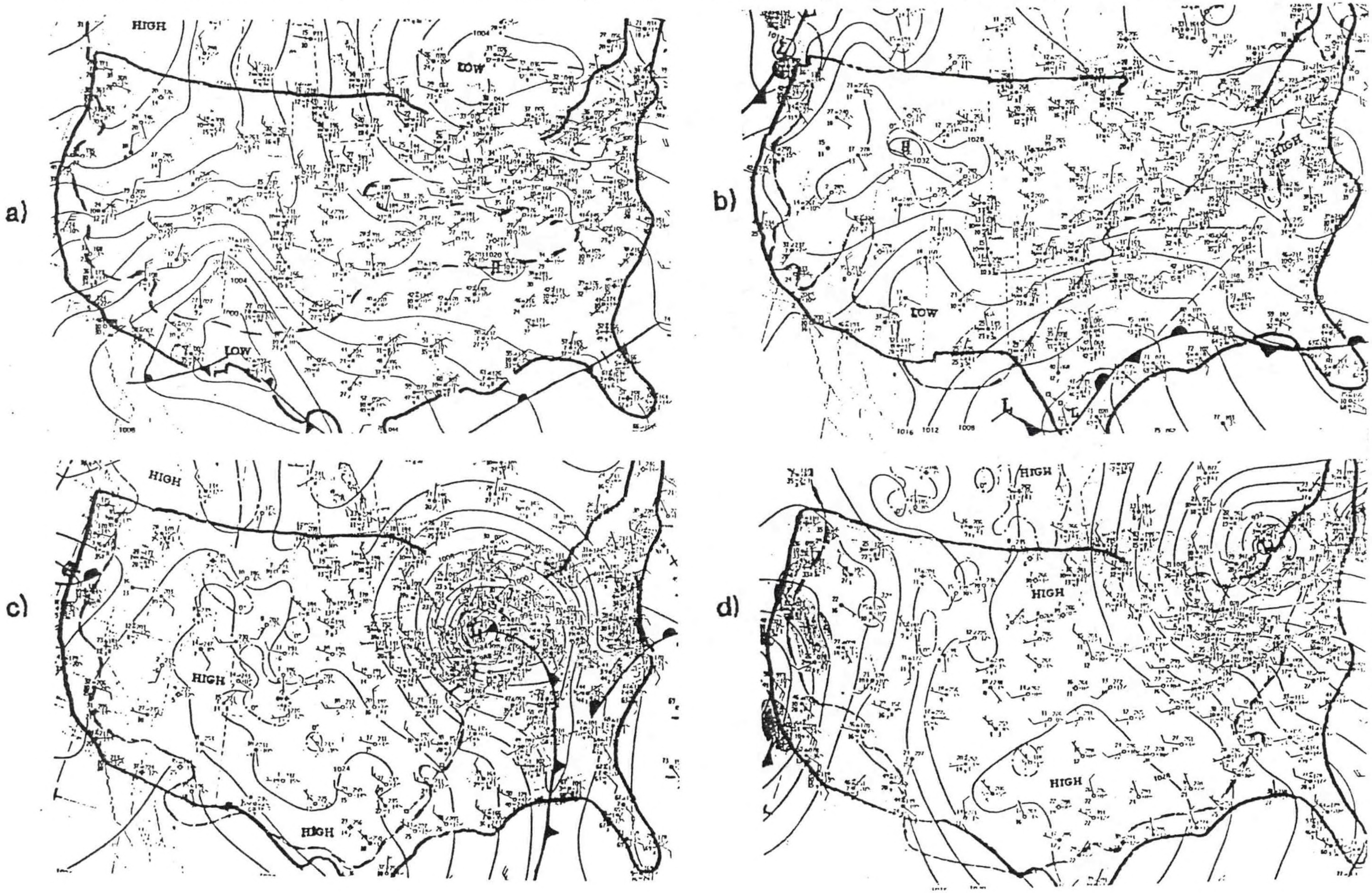
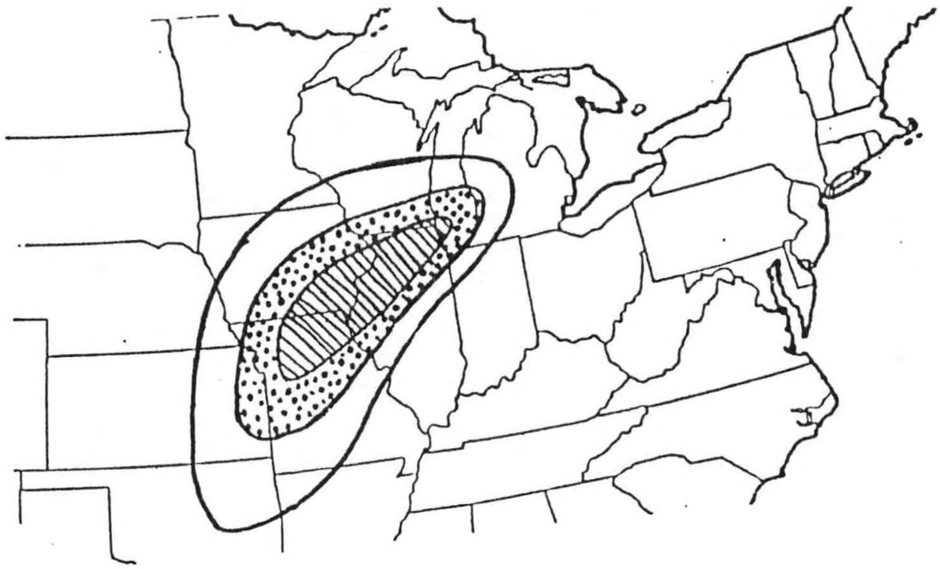


FIGURE 5

Observed snow amounts for 12-24 h periods ending at: **a)** 12/15/87, 0000 UTC, **b)** 12/15/87, 1200 UTC, and, **c)** 12/16/87, 0000 UTC. The areas where 2 or 3, 4 or 5, and 6 or more inches of snow fell are shown by the unshaded, stippled, and hatched areas, respectively.

a)

b)



c)

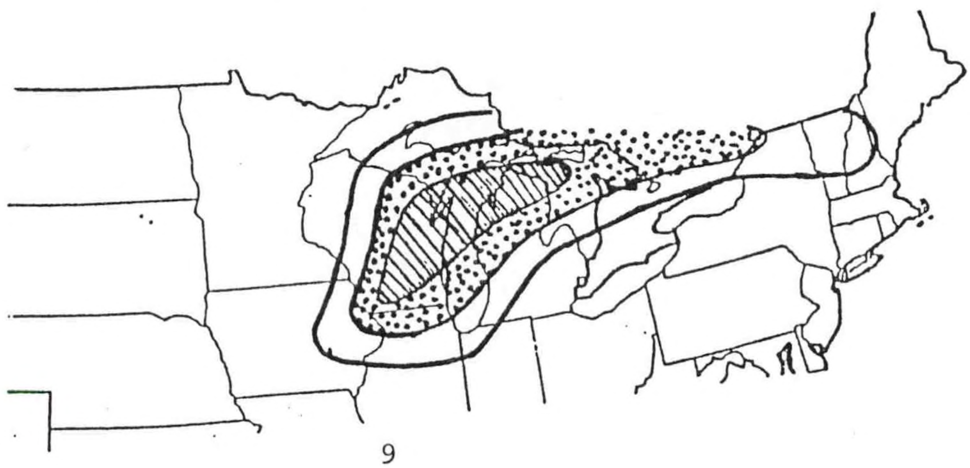
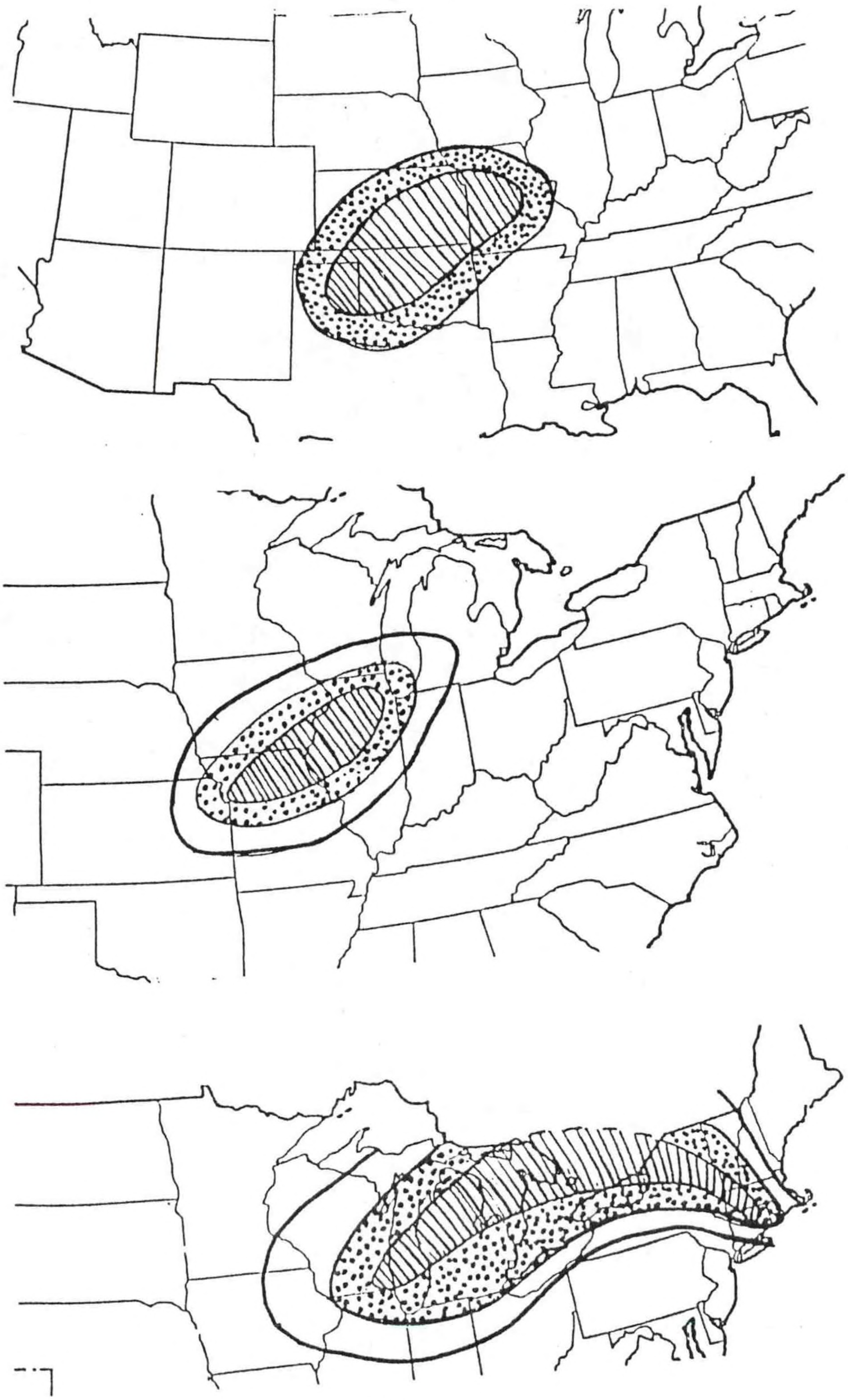


FIGURE 6

PoSA BC's for 12–24 h periods ending at: **a)** 12/15/87, 0000 UTC, **b)** 12/15/87, 1200 UTC, and, **c)** 12/16/87, 0000 UTC. The areas where 2 or 3, 4 or 5, and 6 or more inches of snow were forecast are shown by the unshaded, stippled, and hatched areas, respectively.



a)

b)

c)

6. Class I - LFM Forecasts of Important Predictors Are in Error

This class of error applies to statistical forecasts for any weather element, including PoSA. Simply put, if LFM forecasts of important predictors in the equations are off base, the MOS forecasts will likely be off base. In the case of PoSA, poor LFM forecasts of mean RH and precipitation amount will produce poor CP's, which in turn will produce poor UP's and BC's.

This reasoning can be used to explain why the MOS BC was 0 for El Paso for the 12-h period ending 0000 UTC on December 15, while 6.4 inches of snow actually fell. The LFM QPF, MOS PoP, and observed precipitation at El Paso for this same 12-h period were:

LFM QPF	OBS PCP	POP	$\overline{POF}$	≥2" CP	≥2" UP	2" THRESH
.06"	.64"	39%	100%	23%	9%	19%

For this case, the LFM QPF used in the CP equations and the MOS PoP used to convert the CP's to UP's were much too low. Thus, the 2-inch UP erroneously fell below its threshold.

7. Class II - Unconditional Probabilities Are Close to Their Thresholds

Consider the following case at St. Louis for the 12-h period ending 0000 UTC on December 15:

CATEGORY	UP VALUE	THRESHOLD
> 2"	28%	27.8%
> 4"	31%	23.0%
> 6"	18%	20.4%

The UP's are shown side by side with their thresholds. Note how the UP for the 2-inch category just squeaked past the 2-inch threshold. As per the algorithm shown in Fig. 3, the UP for the 4-inch category was then compared to its threshold, which was surpassed more easily. This cleared the way for a comparison between the 6-inch UP and its threshold. The UP of 18 percent fell just below the threshold of 20.4 percent, so the BC was kept at 4 (4 or 5 inches). The observed snowfall was 6.4 inches.

The point here is that two of the three UP's were very close to their thresholds. Thus, although the actual BC of 4 was not a bad forecast, the forecaster should be aware that small changes in the model output could have led to large changes in the BC guidance.

8. Class III - BC Forecasts at Nearby Stations May Be Different if the Stations are in Different Regions

A separate set of BC thresholds was derived for each of the ten equation sets. The values of the thresholds differ from region to region because the statistical characteristics of the developmental data differ from region to region. Thus, if your area of responsibility includes stations that fall in different PoSA regions, watch out for cases such as the one shown below. These data are valid for the 12-h period ending December 15 at 0000 UTC.

STATION	POSA REGION	>6" UP	>6" THRESH	BC
DDC	1	16%	11%	6
RSL	5	14%	20%	4

Dodge City and Russell, Kansas are not far apart, but they happen to fall into different PoSA regions. The difference in the BC's at these two nearby stations probably was not due to meteorological factors, but rather, to the effects of regionalization.

9. Class IV - PoSA May Fail in Areas of Strong Temperature Advection

The BC at South Bend for the 12-h period ending 1200 UTC on December 15 was 4, while less than one inch of snow actually accumulated. Here is what happened during the 12-h period:

	00	03	06	09	12
Obs 6-h Pcp			.06"		1.07"
LFM 6-h QPF			.03"		1.13"
Obs Wx	-	**	**		

Note that very light snow fell between 0000 and 0600 UTC, that heavy rain fell between 0600 and 1200 UTC, and that the LFM did a good job of estimating when the heaviest precipitation would occur. Thus, the poor BC forecast probably was not the fault of the LFM. Some other relevant data are provided to help identify the problem:

≥ 2" CP	12-h POP	0000 POF	0600 POF	1200 POF	≥ 2" UP	2" THR	≥ 4" UP	4" THR	BC
100	97%	67%	29%	18%	25%	23%	26%	23%	4

Recall that LFM forecasts of precipitation amount and RH are the most important predictors for determining the CP. Given that the LFM forecasted over one inch of precipitation during the 12-h period, the forecast of 100 percent for the two inch CP was certainly reasonable, as was the 12-h PoP of

97 percent. In fact, given that the snow changed to rain shortly after 0600 UTC, even the three PoF values were acceptable. Why was the BC chosen to be 4?

It is important to understand the manner in which the PoF's are weighted in the current system. In this case, over 95 percent of the precipitation that occurred during the 12-h period fell during a time when PoFs were forecast to be between 18 percent and 29 percent. However, the 67 percent PoF was given the same weighting (1/4) as the 18 percent PoF. Thus, assuming you thought the LFM was reasonably on target with its QPF and the timing of the precipitation, it would have been a good idea to use a different PoF weighting to match the situation.

10. Class V - If the PoPs are Very High, BC Thresholds May Be Broken Too Easily

To illustrate this class of error, consider the following data at Springfield, Illinois, for the 12-h period ending 1200 UTC on December 15. The observed precipitation for this period was 1.11 inches.

12-h POP	POF	≥ 2" UP	2" THR	≥ 4" UP	4" THR	≥ 6" UP	6" THR	BC
100%	32%	32%	29%	32%	22%	29%	23%	6

Given that heavy precipitation was likely (the 12-h PoP and the CP's for both the ≥2- and ≥4-inch categories were 100 percent), the only way for the thresholds not to be broken would have been for the PoF's to be extremely low. In this case, the PoF's were not quite low enough to avoid an errant BC of 6 from being chosen. Yet, the relatively low weighted mean PoF of 32 percent was certainly low enough to alert the forecaster that MOS "thought" the precipitation type during the storm would be borderline.

There was other information available in the FPC message for Springfield that would have proved valuable here. While the PoP of 100 percent was inducing the PoSA 6-inch threshold to be broken, the PoPT best category forecasts valid for the 12-, 18-, and 24-h projections all called for freezing precipitation. Hence, the PoPT BC had a better idea of what would happen than did the PoSA BC, as mainly rain and mixed precipitation was observed at Springfield during the 12-h period in question (although, initially, a brief period of light snow was observed). Thus, it is suggested that the forecaster examine the PoPT best category forecast for additional guidance in such cases.

11. Summary

PoSA guidance is generally useful during prolonged, synoptic scale snow events, although there are specific situations where the guidance does not perform well. The flowchart in Fig. 7 provides suggestions as to how PoSA should be used in such situations and serves as a summary of the ideas presented here. NWS Technical Procedures Bulletin No. 318 contains additional information on the topic of MOS PoSA.

FIGURE 7

SUGGESTED APPROACH FOR USING POSA GUIDANCE