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TWO CASES OF INACCURATE PROBABILITY OF FROZEN PRECIPITATION (PoF) FORECASTS

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by

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1. INTRODUCTION

During this winter, the early guidance PoF forecasts have been generally too low (well below 50%) on many occasions when snow has occurred at stations on the coastal plain east of the Appalachian Mountains. In this paper, we'll analyze data for two such occasions, 7 and 25 January 1977, for Dulles International Airport (IAD) and John F. Kennedy International Airport (JFK).

To review briefly, PoF forecasts are available in both the early and final FOUS12 guidance packages (National Weather Service, 1975; Bocchieri and Glahn, 1976). The PoF forecasts in the early FOUS12 are computed solely from the Limited-area Fine Mesh (LFM) (Howcroft and Desmarais, 1971) model output; the PoF forecasts in the final FOUS12 are computed solely from the Primitive Equation (PE) (Shuman and Hovermale, 1968) model output. The basic predictors in PoF are PE and LFM forecasts of 850-mb temperature (850 T), 1000-500 mb thickness (1000-500 TH), and boundary-layer potential temperature (B.L.P. T). Actually, the predictors are included in the forecast equations as deviations from 50% values. The 50% value of a variable is that value below which the probability of frozen precipitation (snow) is greater than 50%. We determined 50% values for each of the above variables, for each MOS station, and for both the LFM and PE models. 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 to develop the 50% values--September through April, 1972-73 through 1974-75. For the PE model, we used data from five seasons--1969-70 through 1973-74.

Table 1 shows the 50% values for B.L.P. T, 850 T, and 1000-500 TH for IAD and JFK for both the LFM and PE. Note that the LFM and PE 50% values are similar except for the B.L.P. T; we'll discuss this difference for B.L.P. T later.

For our two case studies, we obtained LFM and PE forecasts of 850 T, 1000-500 TH, and B.L.P. T for IAD and JFK. We also obtained the observed values of these variables from RAOBs. Our intent was to compare the forecast values of these variables to the observed values, and to their respective 50% values, to determine the reason for the low PoF forecasts. That is, we would expect to find low PoF forecasts associated with forecast values of these variables above (on the warm side of) their 50% values. Also, high PoF forecasts should be associated with forecast values of these variables below (on the cold side of) their 50% values.

2. THE 7 JANUARY CASE

Tables 2 and 3 show the data for IAD for the LFM and PE respectively; similarly, Tables 4 and 5 show the data for JFK.

For IAD, the LFM PoF was about 33% near the time when the snow started. (Incidentally, the LFM PoF for Washington National Airport was about 15% for this case.) For JFK, the LFM PoF was about 36% near the time when the snow started. Note that the PE PoF was near or above 50% for both stations; therefore, the PE PoF forecasts were more accurate.

The LFM and PE forecasts were too warm for all variables and for both models with respect to the observed values. This was especially true for B.L.P. T. In considering the PoF forecasts, the deviations of the forecast values from their 50% values are important. The 850 T and 1000-500 TH forecasts were generally quite close to or below the 50% values for both models. However, the B.L.P. T forecasts were above their 50% values, especially for the LFM model. Remember that the B.L.P. T 50% values for the PE are higher than those for the LFM (Table 1). Therefore, even though the LFM B.L.P. T forecasts were more accurate, the LFM showed larger plus deviations than the PE for this variable. We concluded that the low LFM PoF forecasts were mostly due to the large plus deviations for the B.L.P. T forecasts.

3. THE 25 JANUARY CASE

Tables 6 and 7 show the data for IAD for the LFM and PE models respectively; Tables 8 and 9 show the data for JFK. For IAD, the LFM and PE PoFs were about 33% at 0000 GMT, 25 January; the snow started about four hours earlier. For JFK, the LFM and PE PoPs were near 15% at about the time the snow started.

As with the 7 January case, the LFM and PE 850 T, B.L.P. T, and 1000-500 TH forecasts were too warm with respect to the observed values. With respect to the deviations from the 50% values, again the problem seems to be mainly with the B.L.P. T forecasts. The LFM shows higher plus deviations for B.L.P. T than the PE, even though the LFM B.L.P. T forecasts were more accurate than the PE's. As with the 7 January case, the reason is that the LFM 50% values for the B.L.P. T are about 4°C lower than the PE's for these stations.

4. ANALYSIS OF LFM B.L.P. T 50% VALUES

Because of these case studies and other similar situations this winter, we questioned the reliability of the LFM 50% values for B.L.P. T. Possibly, the developmental data sample was too small to be really representative of the LFM model with regard to B.L.P. T. Another possible explanation is that, for some reason, the LFM model has been forecasting uncharacteristically high values of B.L.P. T. That is, a bias in the LFM B.L.P. T forecasts would not be detrimental to PoF, since the MOS technique adjusts for a consistent bias. It is important, however, that the current bias is similar to that present in the developmental data sample.

Figs. 1 and 2 show the logit curves for B.L.P. T for IAD for the LFM and PE respectively. Similarly, Figs. 3 and 4 show the logit curves for JFK. We determined the 50% values for each station and each model from these curves. Also shown are the total number of precipitation cases and the actual relative frequency of snow (frozen precipitation) per two degree intervals based on the developmental data samples for each model. The figures show that the logit curves for the LFM have less of a slope than those for the PE for both stations. Also, the relative frequenceis show more scatter about the LFM curves. These differences indicate that the B.L.P. T is a better predictor for PoF for the PE than for the LFM. Note also that the LFM logit curves are shifted to the left relative to the PE curves; therefore, the 50% values are lower for the LFM.

In analyzing the case studies, we saw that the LFM B.L.P. T forecasts showed large plus deviations from the 50% values (an average of about +6°C). In this regard, let's examine the LFM curves for IAD (Fig. 1) and JFK (Fig. 3) more closely. From the logit curves, a forecast deviation of +6°C (corresponding to a forecast value near 278K) gives a very low PoF, near 10%. If the curves were shifted to the right, so that the 50% values were near 278K (close to the PE value), the LFM PoF forecasts would have undoubtedly been higher. But it is hard to justify a 6°C increase in the 50% values when three years of developmental data give the logit curves shown in the figures. Note that the number of cases per two degree intervals falls off sharply below about 274K, so that the data points in that region are not very reliable. But in the area near 280K, there were about 100 precipitation cases and a relative frequency of snow of 10% or less. So while some adjustment of the 50% values for LFM B.L.P. T might be in order, an adjustment of +6°C is hard to justify. However, if the LFM B.L.P. T forecast bias has changed since the developmental data period, then of course the logit curves and 50% values are no longer valid.

We're also disturbed by the large difference between the LFM and PE B.L.P. T 50% values, not only for JFK and IAD, but also for many stations on the coastal plain east of the Applachians; Fig. 5 shows an analysis of this difference. Note that LFM and PE 50% values differ by as much as 7°C. For the area in the figure west of the Appalachians, the differences were mostly less than a degree. Also, such differences do not generally exist for 850 T or 1000-500 TH in this region.

5. SUMMARY

In our case studies, both the PE and LFM 850 T, B.L.P. T, and 1000-500 TH forecasts were too warm with respect to observed values. The bias seemed especially large for B.L.P. T. In considering the PoF forecasts, the deviations of 850 T, B.L.P. T, and 1000-500 TH forecast values from their respective 50% values are important. In this respect, the problem in these case studies was most serious with the LFM B.L.P. T deviations. Although the LFM was more accurate than the PE in forecasting B.L.P. T, the LFM showed larger plus deviations, because the LFM 50% values are lower than the PE's. This is true not only for IAD and JFK, but also for many stations on the coastal plain east of the Appalachians (differences as much as 6 to 7°C were found). While some adjustment of the LFM B.L.P. T 50% values might be in order, we could hardly justify a 6 to 7°C change when we examined the logit curves developed from three winters of data. However, such an adjustment would be necessary if the LFM forecast bias has changed for B.L.P. T.

Before the 1977-78 winter season, we intend to investigate whether or not the LFM B.L.P. T forecast bias has changed since the 1974-75 winter season. If the bias has changed, then we'll rederive the B.L.P. T 50% values using only data from the 1975-76 and 1976-77 winter seasons. We'll also consider eliminating the B.L.P. T forecast as a predictor for PoF.

During the present winter, forecasters at stations located on the coastal plain east of the Appalachians should favor the PE PoF (final guidance) over the LFM PoF (early guidance). This is not true for the Eastern Region in general, or other NWS regions, since recent verifications have shown the LFM PoF to be more accurate than the PE PoF.

REFERENCES

Bocchieri, J. R., and H. R. Glahn, 1976: Verification and further development of an operational model for forecasting the probability of frozen precipitation. Mon. Wea. Rev., 104, 691-701.

Howcroft, J., and A. Desmarais, 1971: The Limited-area Fine Mesh (LFM) model. NWS Tech. Proc. Bull., No. 67, 11 pp.

National Weather Service, 1975: Operational probability of frozen precipitation (PoF) forecasts based on model output statistics (MOS). NWS Tech. Proc. Bull., No. 170, 8 pp.

Shuman, F. G., and J. B. Hovermale, 1968: An operational six-layer primitive equation model. J. Appl. Meteor., 7, 525-547.

Table 1. LFM and PE 50% values for B.L.P. T, 850 T, and 1000-500 TH at IAD and JFK.

Variable	50% Values			
	IAD		JFK	
	LFM	PE	LFM	PE
B.L.P. T (°C)	-0.7	4.4	0.0	4.1
850 T (°C)	-2.2	-1.1	-2.2	-2.3
1000-500 TH (m)	5378	5379	5360	5358

Table 2. LFM 12-, 18-, and 24-hr forecasts (FCST) of B.L.P T, 850 T, and 1000-500 TH for IAD from the 1200 GMT, 6 January initial data. DEV is the deviation of the forecast value from the 50% value. OBS is the observed value obtained from the RAOB. Snow started at about 0300 GMT and ended about 1300 GMT, 7 January.

Valid Time (GMT) 1/7/77	B.L.P. T (°C)			850 T (°C)			1000-500 TH (m)			LFM PoF (%)
	FCST	DEV	OBS	FCST	DEV	OBS	FCST	DEV	OBS	
0000	+2.2	+2.9	-2.0	-3.0	-0.8	-5.3	5388	+10	5368	33
0600	+6.4	+7.1	-	-1.4	+0.8	-	5378	+0	-	32
1200	+6.8	+7.5	-0.5	-2.2	-0.0	-4.7	5330	-48	5298	57

Table 3. Same as Table 2 except that the data are for the PE model.

Valid Time (GMT) 1/7/77	B.L.P. T (°C)			850 T (°C)			1000-500 TH (m)			PE PoF (%)
	FCST	DEV	OBS	FCST	DEV	OBS	FCST	DEV	OBS	
0000	+5.8	+1.4	-2.0	-2.8	-1.7	-5.3	5386	+7	5368	53
0600	+8.0	+3.6	-	-2.6	-1.5	-	5372	-7	-	64
1200	+6.1	+1.7	-0.5	-3.0	-1.9	-4.7	5328	-51	5298	90

Table 4. Same as Table 2 except that the data are for JFK. Snow started at about 0700 GMT and ended at about 1830 GMT, 7 January 1977.

Valid Time (GMT) 1/7/77	B.L.P. T (°C)			850 T (°C)			1000-500 TH (m)			LFM PoF (%)
	FCST	DEV	OBS	FCST	DEV	OBS	FCST	DEV	OBS	
0000	+6.6	+6.6	-2.5	-3.8	-1.6	-5.1	5341	-19	5337	27
0600	+8.4	+8.4	-	-3.0	-0.8	-	5348	-12	-	36
1200	+9.8	+9.8	-0.5	-2.0	+0.2	-5.9	5345	-15	5334	47

Table 5. Same as Table 4 except that the data are for the PE model.

Valid Time (GMT) 1/7/77	B.L.P. T (°C)			850 T (°C)			1000-500 TH (m)			PE PoF (%)
	FCST	DEV	OBS	FCST	DEV	OBS	FCST	DEV	OBS	
0000	+7.6	+3.5	-2.5	-3.2	-0.9	-5.1	5331	-27	5337	37
0600	+9.6	+5.5	-	-2.2	+0.1	-	5352	-6	-	44
1200	+9.1	+5.0	-0.5	-2.3	+0.0	-5.9	5339	-18	5334	66

Table 6. Same as Table 2 except for 24 January initial data. Snow started at about 2015 GMT, 24 January 1977 and ended about 1030 GMT, 25 January 1977.

Valid Time (GMT) 1/25/77	B.L.P. T (°C)			850 T (°C)			1000-500 TH (m)			LFM PoF (%)
	FCST	DEV	OBS	FCST	DEV	OBS	FCST	DEV	OBS	
0000	+2.2	+2.9	-3.2	-2.4	-0.2	-6.7	5382	+4	5340	34
0600	+4.5	+5.2	-	-2.0	+0.2	-	5371	-7	-	37
1200	+1.4	+2.1	+0.9	-2.6	-0.4	-7.1	5339	-39	5305	64

Table 7. Same as Table 6 except that the data are for the PE model

Valid Time (GMT) 1/25/77	B.L.P. T (°C)			850 T (°C)			1000-500 TH (m)			PE PoF (%)
	FCST	DEV	OBS	FCST	DEV	OBS	FCST	DEV	OBS	
0000	+7.1	+2.7	-3.2	-1.2	-0.1	-6.7	5382	+3	5340	33
0600	+6.3	+1.9	-	-1.3	-0.2	-	5367	-12	-	47
1200	+7.4	+3.0	+0.9	-1.2	-0.1	-7.1	5346	-33	5305	69

Table 8. Same as Table 6 except that the data are for JFK. Snow started at about 0100 GMT and ended at about 0930 GMT, 25 January 1977.

Valid Time (GMT) 1/25/77	B.L.P. T (°C)			850 T (°C)			1000-500 TH (m)			LFM PoF (%)
	FCST	DEV	OBS	FCST	DEV	OBS	FCST	DEV	OBS	
0000	+7.2	+7.2	-0.2	-2.6	-0.4	-8.9	5362	+2	5350	18
0600	+11.4	+11.4	-	-0.8	+1.4	-	5384	+24	-	14
1200	+9.0	+9.0	-1.2	-0.6	+1.6	-3.3	5369	+9	5335	30

Table 9. Same as Table 8 except that the data are for the PE model.

Valid Time (GMT) 1/25/77	B.L.P. T (°C)			850 T (°C)			1000-500 TH (m)			PE PoF (%)
	FCST	DEV	OBS	FCST	DEV	OBS	FCST	DEV	OBS	
0000	+9.7	+5.6	-0.2	-1.4	+0.9	-8.9	5374	+16	5350	14
0600	+10.1	+6.0	-	-0.8	+1.5	-	5377	+19	-	21
1200	+11.3	+7.2	-1.2	+0.1	+2.4	-3.3	5379	+21	5335	27

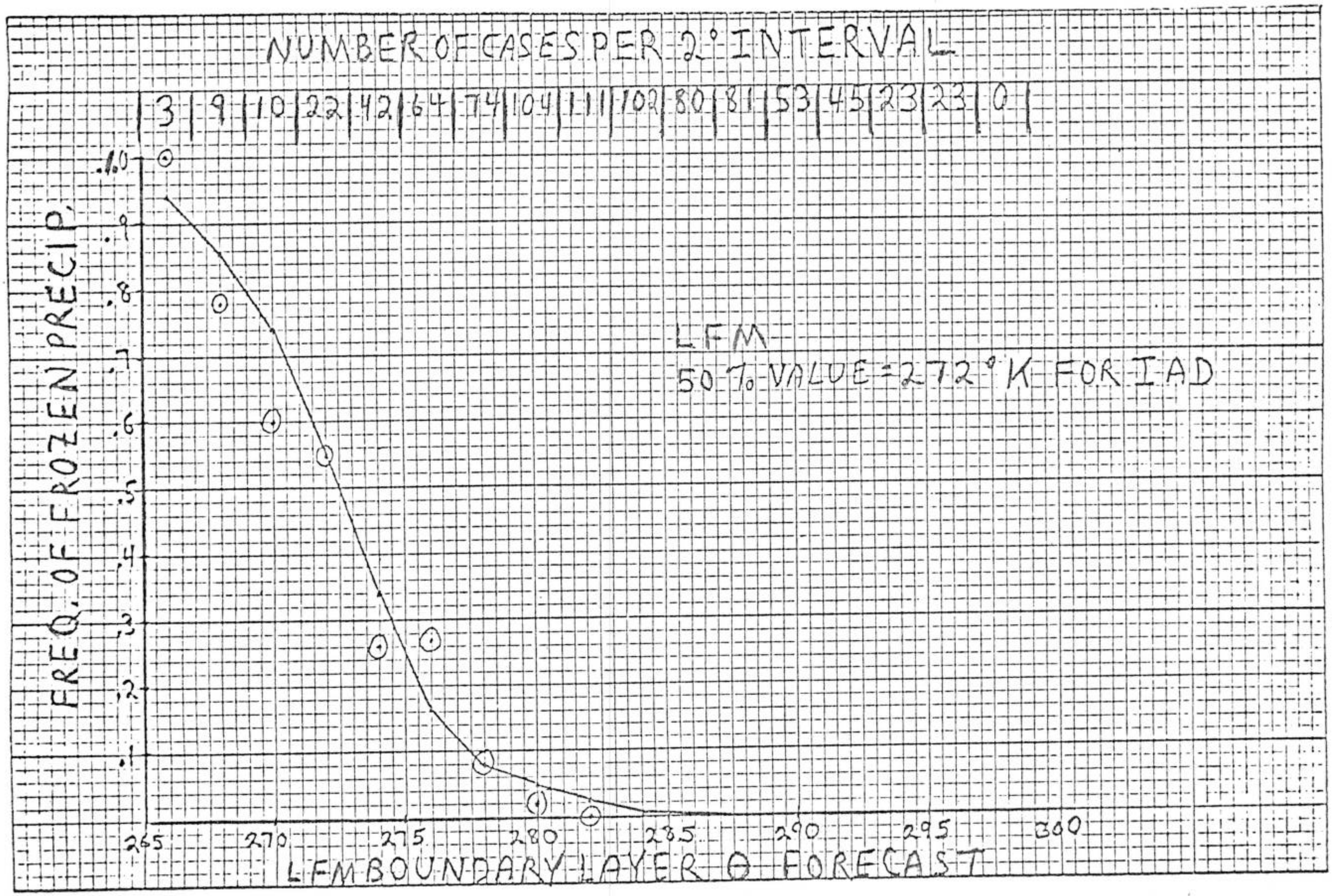


Fig. 1. The B.L.P. T logit curve for the LFM for IAD. ⊙ is the relative frequency of snow per 2 degree intervals based on data from three winter seasons, 1972-73 through 1974-75.

Fig. 2. The B.L.P. T logit curve for the PE for IAD. Θ is the relative frequency of snow per 2 degree intervals based on data from five winter seasons, 1969-70 through 1973-74.

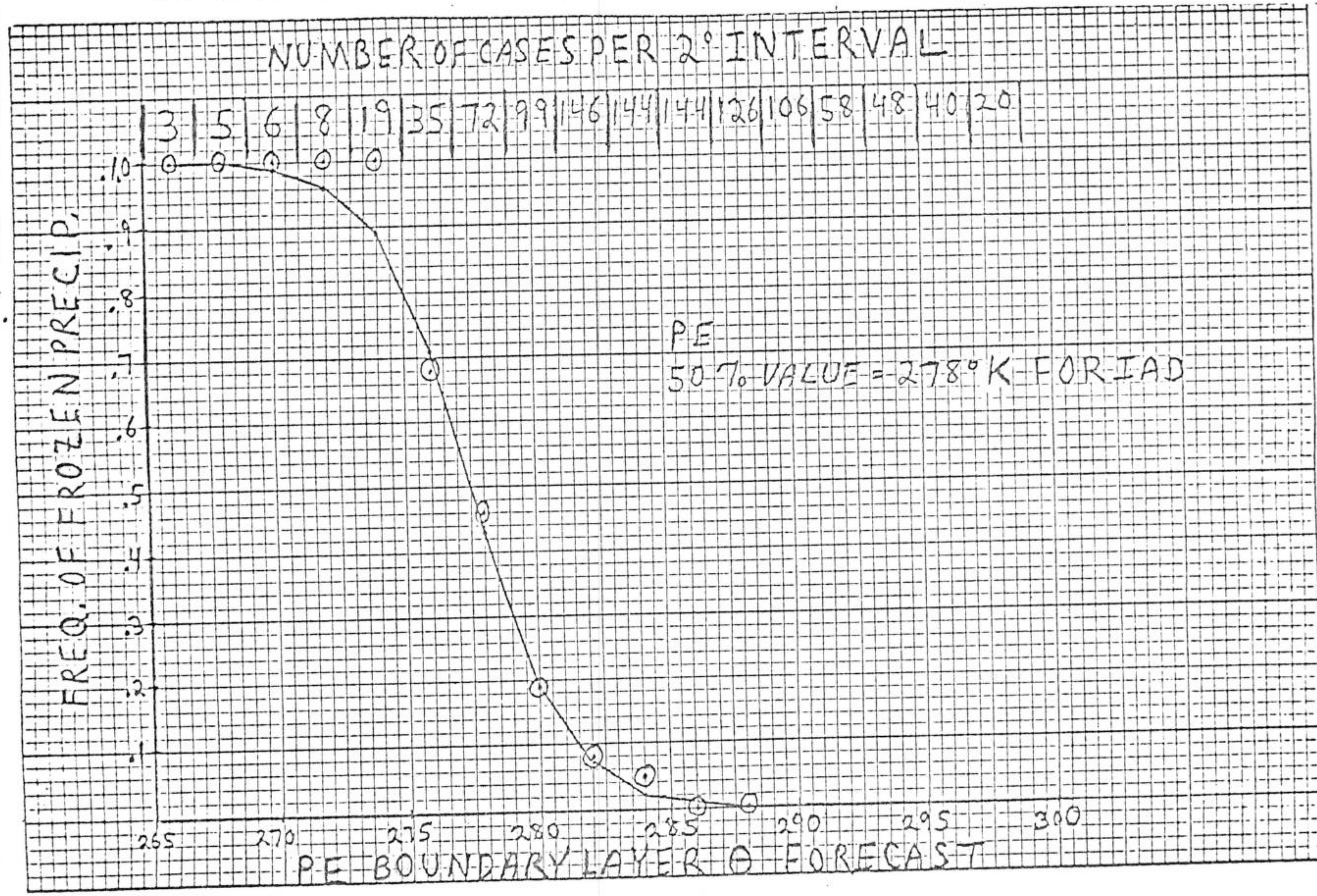


Fig. 3. Same as Fig. 1 except that curve is for JFK.

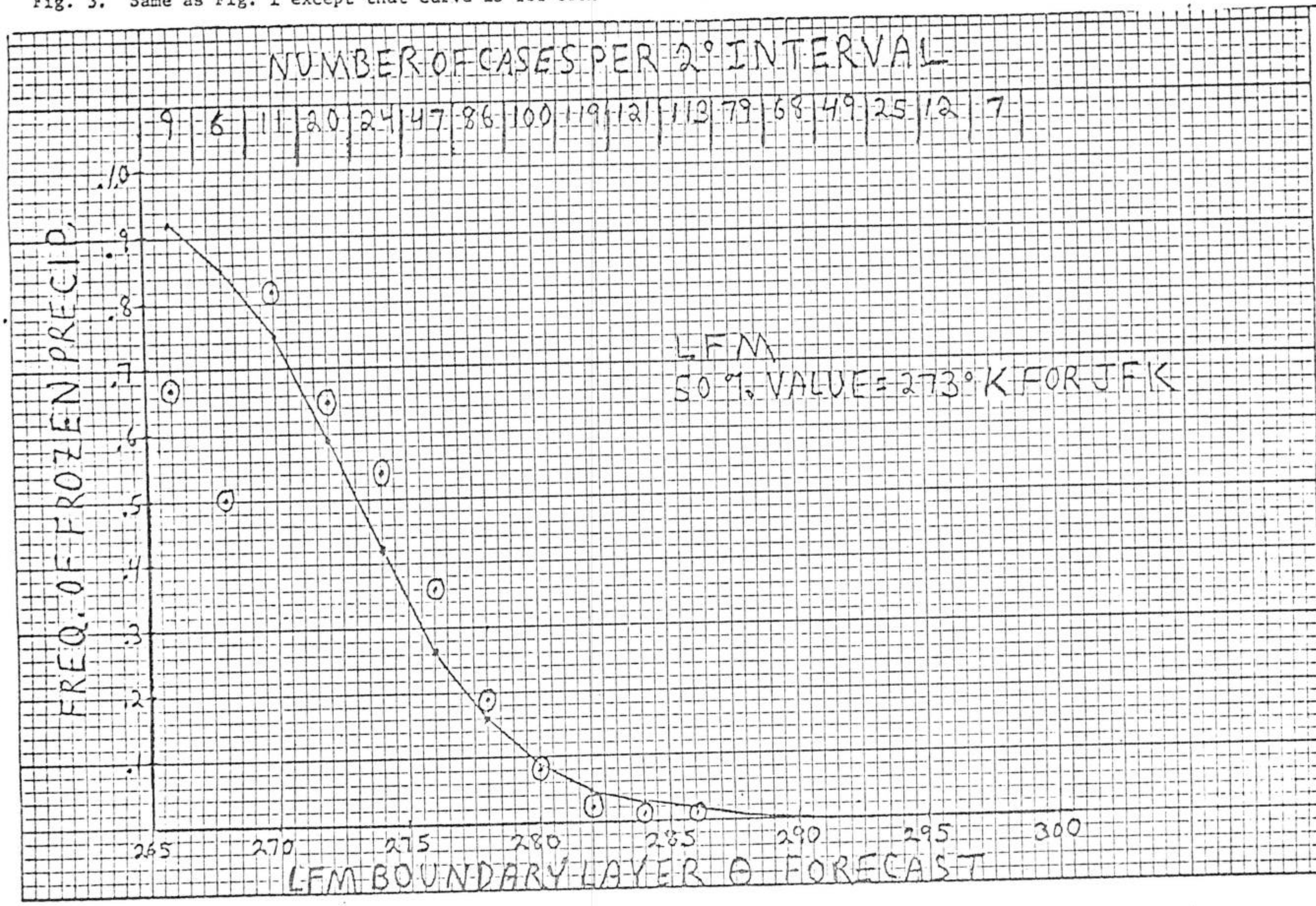
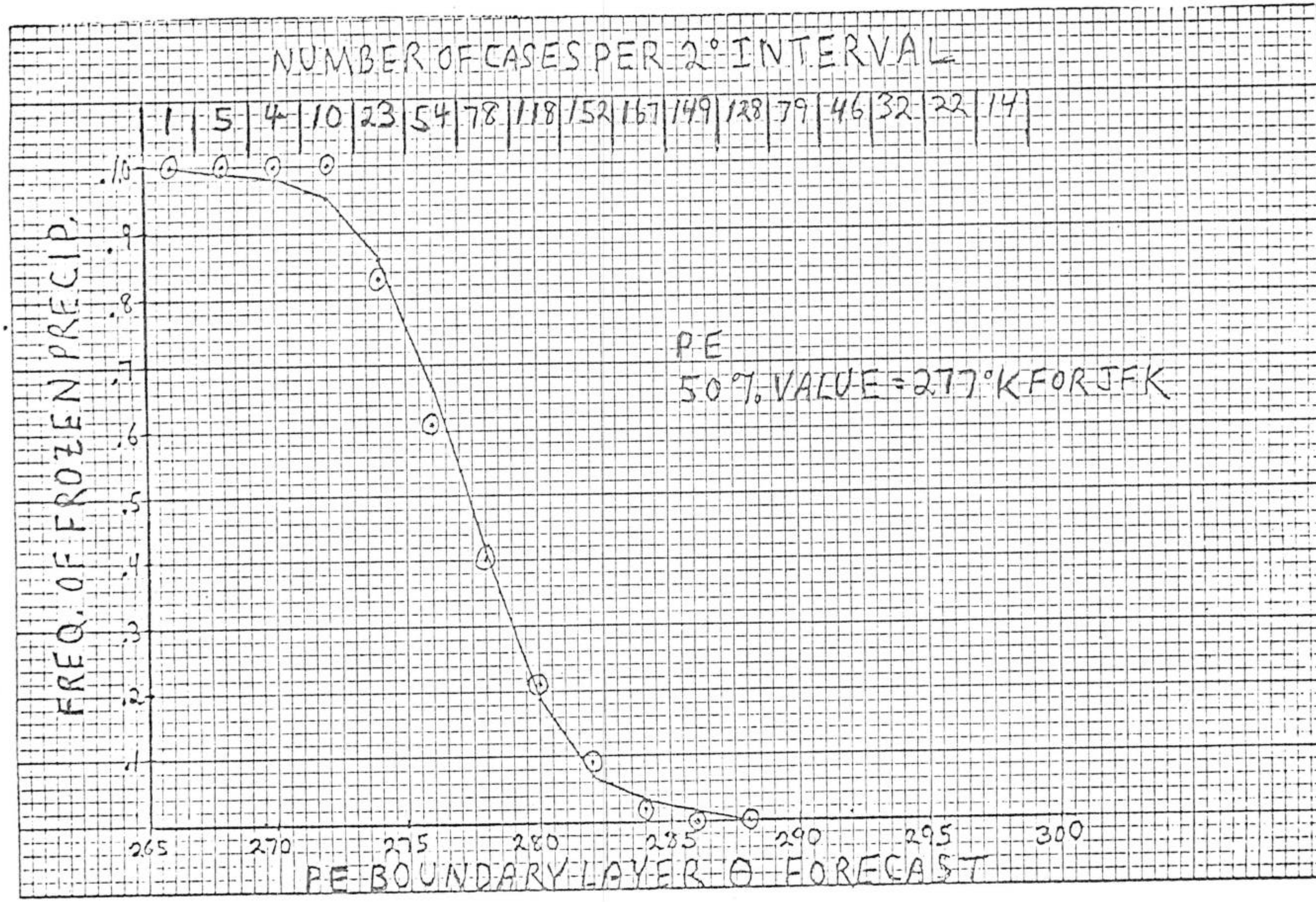


Fig. 4. Same as Fig. 2 except that curve is for JFK.



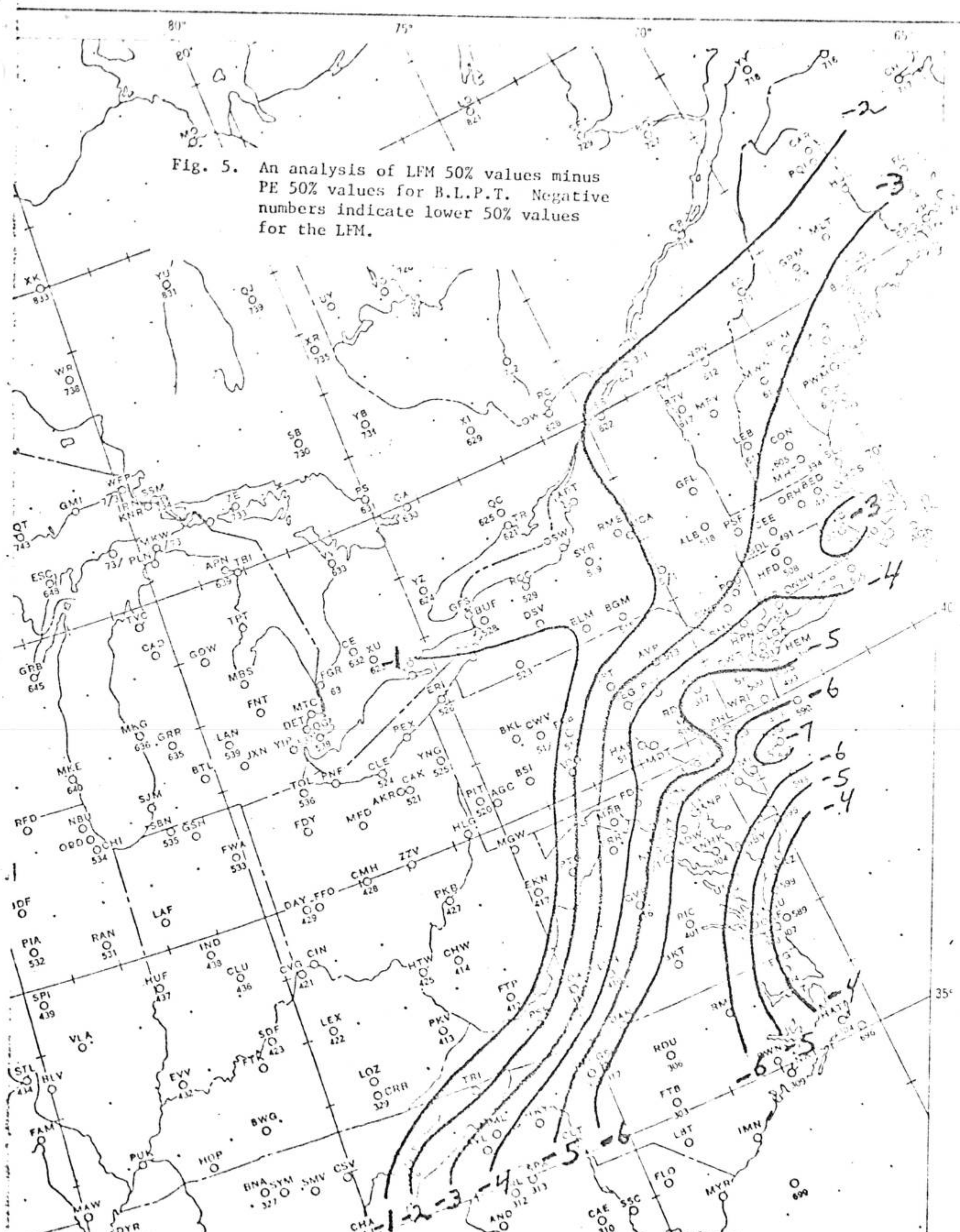


Fig. 5. An analysis of LFM 50% values minus PE 50% values for B.L.P.T. Negative numbers indicate lower 50% values for the LFM.