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NWS TDL 80

USE OF OPERATIONAL 0-6 AND 3-9 H QUANTITATIVE PRECIPITATION FORECASTS FOR PREDICTING HEAVY RAIN EVENTS

Techniques Development Laboratory
Silver Spring, MD
June 1989

U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Weather Service

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Jerome P. Charba and J. T. Moeller

ABSTRACT

New 0-6 and 3-9 h objective quantitative precipitation forecasts (OBJ) for the conterminous United States have been recently implemented in the National Weather Service. The forecasts are issued in the form of isohyets of both the maximum point precipitation amount and the probability of equalling or exceeding specific amounts in 40 x 40 n mi boxes. After taking into account differences in the event forecast, the performance of the isohyetical maximum amounts were compared with manual and model-generated quantitative precipitation forecasts (QPF's) issued 2-12 h earlier from the National Meteorological Center (NMC). Results show the accuracy of the OBJ forecasts was substantially better than the longer range NMC QPF's, particularly for the heavier amounts.

The utility of the OBJ probability forecasts was also considered. The probabilities exhibit good statistical reliability, particularly where sample sizes are adequate. Also, several examples of very heavy rainstorms indicate the probabilities can be used to express confidence in the predicted isohyets and to assess the overall magnitude of the precipitation event.

It is concluded the isohyetical OBJ forecasts are a useful update of other centralized QPF's and that the probabilities add a useful measure of confidence to the predicted isohyets.

1. INTRODUCTION

Objective 0-6 and 3-9 h quantitative precipitation forecasts (QPF) have been available to National Weather Service (NWS) offices since May 1987 (National Weather Service, 1987). Although a standard multiple regression approach (Glahn and Lowry, 1972) is used, several special techniques are applied to enhance utilization of observational data and to focus on the rare heavy precipitation event (Charba, 1983, 1987). The objective QPF's are available on AFOS (Automation of Field Operations and Services) system in graphical form. The forecast map combines both categorical and probabilistic forecast information on a single chart in a unique format (National Weather Service, 1987). This article describes the performance of this product relative to similar NWS QPF products and demonstrates how the chart should be used for forecasting heavy rain events.

2. COMPARISON OF OBJECTIVE CATEGORICAL QPF WITH OTHER CENTRALIZED QPF'S

The main features of the objective QPF product (henceforth denoted OBJ) are summarized in Table 1. Note that a probability forecast is produced for each of four categories. The categorical QPF is obtained by first comparing each probability forecast with a predetermined threshold value for the category and selecting the heaviest category that equals or exceeds the threshold. After the heaviest category is selected, the specific precipitation amount assigned (which ranges between 0.0 and 3.5 inches) is computed by an interpolation procedure (see National Weather Service, 1987). Note that both the categorical and probability forecast apply to a point within a 40 x 40 n mi box and the categorical amount is for the maximum expected within the box.

The OBJ product is one of several QPF's issued by the National Meteorological Center (NMC) (Table 2). The product denoted MAN in Table 2 stands for manually-produced QPF (National Weather service, 1983), NGM for the QPF produced by the Nested Grid Model (Hoke et al., 1985) and LFM for the Limited-Area Fine Mesh model (Newell and Deaven, 1981). The 6-h LFM QPF's for the two projections listed in the table are actually not available to local NWS offices; only 12-h amounts are transmitted. For the NGM, in addition to the two projections shown, the product is also transmitted for the 0-6 h period but the latter was not considered in this study because it is practically obsolete by the time it's available at local NWS offices.

All products in Table 2 except the 3-9 h OBJ are issued for the same valid periods and all are in categorical form. Since the 0-6 h OBJ is issued later than the NMC products, it should be thought of as an update forecast. Another significant consideration is that the categorical precipitation amounts specified by the OBJ and NMC products have different meanings. Recall that the OBJ product is for the maximum point precipitation amount within a small box (Table 1), whereas the NMC QPF's should be viewed as average amounts over similar-sized areas. These factors must be carefully considered to achieve a proper comparison of forecast performance.

The categorical QPF products were verified on the basis of two different sets of precipitation data. One data set was the 6-h precipitation amounts contained in conventional hourly surface observations (SAO's). Early results of the present study using this data set are contained in Charba et al. (1988). The other data set was 6-h precipitation accumulations from the climatic hourly precipitation data base. The climatic data set contains at least three times the number of SAO precipitation observations. Since the OBJ QPF is properly verified with the "local" maximum point amount based on the higher density climatic precipitation data, while the NMC products are properly verified with an areal mean, all products were verified (with the climatic precipitation data) with the event defined both ways. However, for the verification with the low density SAO data set, only the areal mean precipitation event was used.

The comparative verification based on "areally averaged" precipitation using SAO data is shown in Tables 3, 4, and 5. The areal average was obtained by application of a modified Cressman (1959) objective analysis to the precipitation observations (see Charba et al., 1988). Two verification scores are shown, the CSI being the Critical Success Index (Donaldson et al., 1975) and bias being the number of events forecasted divided by the number observed. Table 3, which is for 1987 and Tables 4 and 5 which are for 1988, show the areally averaged precipitation event is not appropriate for the OBJ QPF, i.e., the bias values are greatly above the expected range of 1.2-1.4. This result was expected since areally-averaged precipitation, especially in the convective season, would be a small fraction of the local maximum point amount.

For the NMC QPF products, the areal event seems appropriate, as most bias values do not deviate greatly from 1.0. Thus, the NMC products in Tables 3-5 can be compared with one another but not against OBJ.

The CSI and bias scores in Tables 3 through 5 indicate the MAN and NGM achieved roughly the same level of forecast accuracy. The LFM scored substantially poorer, as it greatly underforecast warm season precipitation in 1987. During the late summer and fall of 1988 (Table 4), the MAN and NGM again exhibited comparable overall verification scores. During the 1988 fall season (Table 5), the CSI and bias scores (taken together) indicate the NGM performed slightly better than MAN for ≥ 0.50 inches. This interpretation of the scores takes into account the fact that the CSI is enhanced by systematic overforecasting as exhibited by MAN, and severely hampered by systematic underforecasting as exhibited by the NGM. The LFM again is seen to perform poorer than the MAN and NGM. In contrast to the 1987 summer, the LFM strongly overpredicted precipitation during the fall 1988 (Table 5).

A reasonably fair comparison of performance between the OBJ and the NMC products was achieved when the high density climatic precipitation data was used in the verification. Tables 6 and 7 show the comparative scores for the OBJ, NGM, and LFM for the late spring through fall of 1987. (The MAN product was not included in this verification because of the unjustifiable manual effort that would have been required.) For Table 6 all products were verified based on the maximum point precipitation in the 40 x 40 n mi box, while an areal average as obtained by the Cressman (1959) objective analysis was used for Table 7. As expected, the bias values for the NGM and LFM in Table 6 reveal the local maximum precipitation is not appropriate for their verification. Correspondingly, the bias values for OBJ in Table 7 signify the areal average is not appropriate for this product. However, the bias values in these tables <u>do</u> indicate it is fair to compare the scores for OBJ in Table 6 with the scores of the model QPF's in Table 7.

A comparison of the OBJ scores in Table 6 with the NGM and LFM scores in Table 7 reveal several features. First, the CSI's of OBJ are substantially higher than those for the NMC models, especially for the upper precipitation categories. For instance, at ≥ 0.25 inches the 0-6 h OBJ CSI is almost double that for the NGM and slightly more than double the LFM value. For the upper categories the differences are much greater when comparing with the NGM but less with respect to the LFM. At the 3-9 h projection, the OBJ CSI's drop off appreciably from those at 0-6 h but retain a substantial margin of improvement over the corresponding NGM and LFM. Second, the NGM overforecasted precipitation slightly at ≥ 0.25 inches but <u>severely underforecasted</u> precipitation for ≥ 1.00 inches and above. The LFM does not show such increased underprediction with increasing amount and therefore the CSI's don't show the extreme drop off exhibited by the NGM.

Two obvious limitations in the verification study inhibit definitive statements concerning the relative accuracy among all <u>four</u> QPF products considered. One is the exclusion of the MAN product in the verification with the climatic precipitation data for 1987 and the other is the inability to extend the verification with this data set to the 1988 season (these data were not available). However, if we consider the results with the SAO data in Tables 3 through 5 with the results in Tables 6 and 7, strong inferences are possible. First, it seems clear the OBJ product performed substantially better at forecasting the local maximum than did the other NMC products in forecasting the local means. Second, the MAN and NGM performed next best with comparable overall levels of accuracy. In fact, both of these products exhibited overforecasting for the light amounts (though the bias was slight for the NGM) and severe underforecasting with increasing amount. Finally, the LFM QPF was clearly inferior in accuracy to all other products.

While the above findings rest on the scores for the different products, it would be grossly unfair to judge the value and skill of the different products from the verification scores alone. One obvious reason is, the different products have different forecast lead times. Therefore, the shorter-range products should be thought of as "updates" of the others because later data and even the QPF products issued earlier are available. For instance, the OBJ is clearly an update of all other products, but only the LFM QPF's are used as predictive input to the OBJ system (Charba, 1983). The MAN product in most instances represents an update of the NGM and LFM. Even the NGM should be considered an update of the LFM because the NGM uses later significant level rawinsonde data in its initialization. Another relevant factor is the MAN and OBJ products contain forecast information which was not considered in the categorical QPF verification. For instance, in addition to the predicted isohyetical field, the MAN product also indicates the maximum precipitation amount for an unspecified point within the heaviest isohyet (see National Weather Service, 1983). For the OBJ product, the predicted isohyets are based on forecast probabilities, and these probabilites were not considered in the verification. The next section shows the probabilites are very useful for assessing the significance of the predicted precipitation amounts.

3. COMBINED USE OF THE OBJ QPF PROBABILITIES AND ISOHYETS

A. Procedure

As noted previously, the OBJ product contains an isohyet when the forecast probability exceeds a predetermined threshold value. The predicted isohyet at a given point is then the heaviest category for which the threshold is exceeded. Now, the degree of confidence one may apply to the isohyet should be based on the magnitude of the probabilities (within the isohyet) relative to both the threshold probability and the maximum expected value (also predetermined). The utility of this forecast probability consideration depends on two factors. One is that the probabilities must be reliable (see Murphy and Epstein, 1967) and, two, the forecast probabilities need to have a sizable range of values.

Figs. 1 through 3 show examples of reliability of the OBJ probabilities for selected precipitation categories for the 0-6 and 3-9 h projections. For the 0-6 h period, the probabilities for $\geq$ 0.50 inches (Fig. 1) show good reliability over the entire range of forecast values, which extend to near 100%. For $\geq$ 2.00 inches (Fig. 2) and for $\geq$ 1.00 inches at the 3-9 h projection (Fig. 3), the reliability is good except at the highest probability intervals, where the sample sizes are quite small. The probability ranges in the latter two examples is also smaller, which reflects the extreme rariety of these very heavy precipitation events (note relative frequencies in figure captions) and the increased difficulty in forecasting them. Also indicated on each reliability diagram is the mean threshold probability corresponding to the precipitation interval. Recall that the threshold probability is used to trigger the categorical forecast of the precipitation interval. It is noted that for all three diagrams the mean threshold probability is considerably less than the median forecast probability (not shown). This means the forecast probabilities have a relatively broad range between the threshold and maximum. Therefore, on a given day, the level of the peak probability value (inside a predicted isohyet) between the threshold and the maximum can help establish the confidence a user may have in the isohyet. If the peak probability is near the threshold, the likelihood of occurrence of the isohyet should be considered marginal. If the probability is near the expected maximum, the threat of occurrence of precipitation corresponding to the isohyet approaches that for the <u>strongest cases in the eight seasons of data</u> used to develop the OBJ product.

Fig. 4 shows an example OBJ forecast as depicted on AFOS. Note that the highest (or peak) probability inside the heaviest isohyet in each geographical region is plotted. At the lower left of the AFOS chart this peak probability value is listed in a table together with the predetermined threshold and maximum probability. The probability plotted on the map is difficult to read in the reproductions in this paper but it is more clearly readable as listed under the "HIGH" category in the table. (Other items in the table are described in the figure caption.) For example, the peak probability plotted for the NP (Northern Plains) region is 5.7%, which is well above the threshold probability for category 4 ($\geq$ 2.0 inches) of 2.6% and near the expected maximum of 6%. Thus, very high confidence should be placed on the 2.0 inch isohyet. [For category 4, high confidence is also indicated by the appearance of the 3.0 inch isohyet as described in National Weather Service (1987)]. The table at the lower right lists the same information as the left table but for the next higher precipitation category (isohyet). The peak probabilities in the lower right table are not plotted on the map because these peak probabilities are always below the threshold and, thus, the corresponding isohyet will not appear. This table therefore indicates how close the model was to forecasting the next higher category. For example, in Fig. 4 the lower right table shows the model was not close to forecasting category 4 in the NE (Northeast) and SP (Southern Plains) regions as the highest probabilities were well below the respective thresholds.

B. Case Studies

In this subsection, the combined use of the OBJ isohyets and probabilities appearing on the AFOS chart is demonstrated for three heavy rain cases. These cases were selected from the 1987 sample involved in the comparative verification discussed in Section 2. In all cases the event comprising the verifying precipitation map is appropriate for the OBJ product, i.e., the event is the maximum point amount in a 40 x 40 n mi box.

Figs. 5 through 8 show the 0-6 and 3-9 h OBJ forecasts and verifying maps from 1800 UTC August 16, 1987. In Fig. 5 (0-6 h forecast), the heaviest isohyet is 1.0 inch in the NP region with a corresponding peak probability of 7.7%. The lower left table suggests moderate confidence, i.e., the peak probability is moderately above the threshold but well below the maximum. Fig. 6 shows only small areas encircled by the 1.0 inch observed isohyets, which corroborates the forecast. Fig. 7, which is the 3-9 h forecast for the same issue time, exhibits two tiny 2.0 inch areas but the peak probability is barely above the threshold. Thus, the 2.0 inch isohyets are thought to be of marginal significance. The verifying map (Fig. 8), which shows substantial 1.0 inch areas but no 2.0 inch areas, agrees well with the forecast. The 0-6 h forecast from 0000 UTC August 17 (Fig. 9), which was discussed in the previous subsection, exhibits very strong confidence in the 2.0 inch isohyet around northern Illinois. The verifying map (Fig. 10) confirms the high confidence, as two 2.0 inch precipitation areas are shown. At the 3-9 h projection from the same initial time (Fig. 11), a very small 2.0 inch area is predicted in central Illinois (SP region), with a peak probability barely exceeding the threshold. Note however that peak probabilities associated with 1.0 inch area indicated in the lower right table are in the moderate confidence range. Fig. 12 verifies the forecast as the 1.0 inch observed area is substantial while the 2.0 inch area shown is tiny and displaced northeast of the predicted location.

Another example case demonstrating the relationship between forecast probability and the magnitude of the precipitation event is shown Figs. 13 through 16. In Fig. 13, a fairly strong rain event is forecast over the SP (Southern Plains) region, but the 2.0 inch predicted area is tiny, with the corresponding peak probability barely above the threshold (see lower left table). The lower right table shows the peak probability corresponding to the 1.0 inch isohyet for the SP region is well above the threshold, indicating a relatively high likelihood of occurrence. The verifying map (Fig. 14) shows the forecast was accurate although the observed 2.0 inch areas were underforecast. On the following day the same forecast issuance indicated a major event in roughly the same area with the highest probability inside the 2.0 inch isohyet (5.0%) near the expected maximum (6%). Fig. 16 shows the predicted intense magnitude of the rainstorm was quite accurate as the observed $\geq$ 2.0 inch area was rather extensive.

The final example is for the mammoth rainstorm that caused flooding of historical record proportions in Arkansas, Louisiana, and Mississippi in mid-November 1987. Figs. 17 and 19 show the 0-6 and 3-9 h forecasts, respectively, from 0000 UTC November 16. Note that both forecasts show an extensive 3.0 inch area, which signifies that the probabilities for category 4 were quite high. A close examination shows the peak probabilities for category 4 in the SE (Southeast) region were actually above the predetermined maximum in each case. Since the prespecified maxima represent the highest probabilities attained by the OBJ system over eight seasons of dependent data, the probabilities for the present case indicate a heavy rainstorm threat at least as strong as any in the historical sample. The respective verifying maps for these cases (Figs. 18 and 20) indeed show the predicted threat was well justified, as the $\geq$ 2.0 inch area for each valid period spans portions of Texas, Arkansas, and Louisiana.

4. DISCUSSION

In Section 2, the verification statistics indicated the predicted OBJ isohyets performed clearly better than those for the other NMC QPF products. Also, the reliability diagrams and the forecast examples discussed in the previous section indicated the forecast probabilities should have considerable value in assisting the user in ascertaining the degree of confidence to put in the OBJ isohyets. On the basis of these findings it seems reasonable to conclude the OBJ QPF's should serve as a useful update of the longer range NMC products.

In regard to the use and interpretation of individual forecast maps, several points bear noting. One is, some forecasts of heavy rain events will not perform up to the level of the example cases shown. The example cases were specially selected to illustrate the predominant relationships between the categorical and probability forecasts and the corresponding observed events. Considerable scatter about these relationships will result in many forecasts underperforming the example forecasts. Regarding another noteworthy point, the focus in the case studies has been on very heavy forecast and observed events. One may wonder about the utility of the OBJ QPF's for light and moderate rain events, e.g., in the 0.25-0.50 inch range.

Upon returning to the statistics for the categorical QPF's (Tables 3 through 7), one can see that the improvement in CSI by the OBJ product over the other NMC products is less for these lighter amounts than for heavier amounts. For example, from Tables 6 and 7 the CSI for the 0-6 h OBJ QPF is more than three times that for the NGM for ≥ 1.00 inches and less than twice that for the NGM for ≥ 0.25 inches. On the other hand, the smaller OBJ improvement in CSI over the NGM for the lighter amounts can be explained by the strong change in forecast bias exhibited by the NGM from light to heavy precipitation amount (see Section 2). Turning to the probabilities of the OBJ forecasts, when one compares their performance for light and heavy amounts (Fig. 1 versus Figs. 2 and 3), the former are clearly more reliable and have a greater range than the latter. When all of the above factors are considered together, it seems reasonable to conclude the OBJ QPF's have comparable update utility for light and heavy amounts.

A final point concerning the probability values plotted on the OBJ AFOS chart bears noting. When the heaviest isohyet for a QPF feature is 1.0 inch or less, the associated peak probability plotted on the chart will never greatly exceed the threshold value. The reason is, as the probability for a lower category increases well above its threshold, the greater the likelihood the threshold for the next higher category will be exceeded. Therefore, only for category 4 can one ever expect the plotted probability to approach the predetermined maximum.

5. CONCLUSIONS

We have examined the utility of the 0-6 and 3-9 h categorical OBJ QPF's and the associated probability forecasts. It was shown that the OBJ forecasts scored substantially better than NMC manual and model-generated QPF's issued 2 to 12 hours earlier. This was especially true for the very heavy 6-h precipitation amounts. This result indicates the OBJ forecasts are a useful update of the longer range NMC QPF's.

The value of the OBJ probability forecasts was assessed by examining their statistical reliability and utility in several very heavy rainstorms. The reliability was found to be good, especially where sample sizes were significant. For the heavy rain episodes, it was shown the level of the peak probability between the predetermined threshold and maximum expected value can be used to assign a confidence measure to the associated isohyet and to indicate the overall magnitude of the rain event. Thus, full utilization of the OBJ product is achieved when the isohyets and probabilities are used together.

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Table 1. Properties of the objective quantitative precipitation forecasts.

Valid for 40 x 40 n mi boxes		
Probability for:	$\geq$ 0.25 in	(Cat 1)
	$\geq$ 0.50 in	(Cat 2)
	$\geq$ 1.00 in	(Cat 3)
	$\geq$ 2.00 in	(Cat 4)
Categorical maximum amount of 0.0 - 3.5 inches		
Issued for projections of 0-6 and 3-9 h		

Table 2. Short range 6-h quantitative precipitation forecasts issued from the National Meteorological Center.

Product	Projection (h)
OBJ	0 - 6 3 - 9
MAN	2 - 8 4 - 10 6 - 12
NGM	6 - 12 12 - 18
LFM	6 - 12 12 - 18

Table 3. Forecast performance of four QPF products for three precipitation intervals over the conterminous United States. The sample was based on 274 forecast maps for each product for the nation. The sample for each product was formed from two forecast maps per day on most days over the period March 24-September 15, 1987. All products were valid for the periods 1800-0000 UTC and 0000-0600 UTC, with the shorter range NMC products applying to the former period. Observed precipitation events were based on an objective analysis (i.e., weighted areal average) of 6-h precipitation reports in conventional surface observations.

Product (Projections)	Precipitation Interval (Inch)	Number of Events			CSI	Bias
		Forecast	Observed	Correct		
0-6 H OBJ*	≥ 0.5	9258	2449	1095	0.103	3.78
	≥ 1.0	2735	416	130	0.043	6.58
	≥ 2.0	310	28	6	0.018	11.07
4-10 H MAN	≥ 0.5	4593	2449	400	0.060	1.88
6-12 H MAN	≥ 1.0	173	416	11	0.019	0.42
	≥ 2.0	3	28	0	0.000	0.11
6-12 H NGM	≥ 0.5	2223	2449	257	0.058	0.91
12-18 H NGM	≥ 1.0	106	416	17	0.034	0.26
	≥ 2.0	5	28	0	0.000	0.18
6-12 H LFM	≥ 0.5	961	2449	114	0.035	0.39
12-18 H LFM	≥ 1.0	172	416	7	0.012	0.41
	≥ 2.0	5	28	0	0.000	0.18

*Verification not appropriate for product (see caption and text).

Table 4. As in Table 3 except for the following differences. The sample for each product was formed from three forecast maps per day on most days over the period July 26-December 14, 1988 (305 forecast maps). The forecast valid period of 1200-1800 UTC was added to those for Table 3. The forecast projections of the NMC products corresponding to this period are: 2-8 h for MAN and 12-18 h for both the NGM and LFM.

Product (Projections)	Precipitation Interval (Inch)	Number of Events			CSI	Bias
		Forecast	Observed	Correct		
0- 6 H OBJ*	≥ 0.5	7962	1718	947	0.108	4.63
	≥ 1.0	2632	280	117	0.042	9.40
	≥ 2.0	274	13	4	0.014	21.08
2- 8 H MAN	≥ 0.5	3542	1718	456	0.095	2.06
4-10 H MAN	≥ 1.0	182	280	19	0.043	0.65
6-12 H MAN	≥ 2.0	4	13	0	0.000	0.31
6-12 H NGM	≥ 0.5	1902	1718	282	0.084	1.11
12-18 H NGM	≥ 1.0	113	280	1	0.003	0.40
	≥ 2.0	0	13	0	0.000	0.00
6-12 H LFM	≥ 0.5	3287	1718	319	0.068	1.91
12-18 H LFM	≥ 1.0	384	280	11	0.017	1.37
	≥ 2.0	0	13	0	0.000	0.00

*Verification not appropriate for product (see caption and text).

Table 5. As in Table 4 except for the subset period of September 17-December 14, 1988.

Product (Projections)	Precipitation Interval (Inch)	Number of Events Forecast	Observed	Correct	CSI	Bias
0- 6 H OBJ*	≥ 0.5	4620	1029	622	0.124	4.49
	≥ 1.0	1304	171	78	0.056	7.63
	≥ 2.0	112	5	1	0.009	22.40
2- 8 H MAN	≥ 0.5	2377	1029	319	0.103	2.31
4-10 H MAN	≥ 1.0	135	171	19	0.066	0.79
6-12 H MAN	≥ 2.0	4	5	0	0.000	0.80
6-12 H NGM	≥ 0.5	839	1029	172	0.101	0.82
12-18 H NGM	≥ 1.0	66	171	0	0.000	0.39
	≥ 2.0	0	5	0	0.000	0.00
6-12 H LFM	≥ 0.5	2844	1029	262	0.073	2.76
12-18 H LFM	≥ 1.0	329	171	9	0.018	1.92
	≥ 2.0	0	5	0	0.000	0.00

*Verification not appropriate for product (see caption and text).

Table 6. Forecast performance of four QPF products for four precipitation intervals over the conterminous United States. The sample was based on 409 forecast maps (except for LFM which had 408 maps) for each product for the nation. The sample for each product was formed from two forecast maps per day on most days over the period May 20-December 15, 1987. All products, except the 3-9 h OBJ, were valid 1800-0000 UTC and 0000-0600 UTC, with the shorter range NGM and LFM forecasts applicable to the former period. The 3-9 h OBJ forecasts were valid 2100-0300 and 0300-0900 UTC. An observed event, defined as the maximum 6-h precipitation amount in a 40 x 40 n mi area, was based on the climatic hourly precipitation data base.

Product (Projections)	Precipitation Interval (Inch)	Number of Events Forecast	Observed	Correct	CSI	Bias
0-6 H OBJ	≥ 0.25	21545	17423	7979	0.274	1.24
	≥ 0.50	11329	9551	3435	0.197	1.19
	≥ 1.00	3481	3151	702	0.118	1.10
	≥ 2.00	416	515	70	0.081	0.81
3-9 H OBJ	≥ 0.25	17519	16202	5823	0.209	1.08
	≥ 0.50	8681	8856	2454	0.163	0.98
	≥ 1.00	2911	2956	529	0.099	0.98
	≥ 2.00	542	491	53	0.054	1.10
6-12 H NGM* 12-18 H NGM*	≥ 0.25	13741	17423	4005	0.147	0.79
	≥ 0.50	2252	9551	650	0.058	0.24
	≥ 1.00	144	3151	33	0.010	0.04
	≥ 2.00	1	515	0	0.000	0.00
6-12 H LFM* 12-18 H LFM*	≥ 0.25	16632	17408	4236	0.142	0.96
	≥ 0.50	2729	9548	777	0.068	0.29
	≥ 1.00	478	3151	103	0.029	0.15
	≥ 2.00	68	515	13	0.012	0.13

*Verification not appropriate for product (see caption and text).

Table 7. As in Table 6 except that the observed precipitation events were based on an objective analysis (i.e., a weighted areal average) of 6-h precipitation accumulations from the climatic hourly precipitation data base.

Product (Projections)	Precipitation Interval (Inch)	Number of Events			CSI	Bias
		Forecast	Observed	Correct		
0-6 H OBJ*	≥ 0.25	25651	11247	6360	0.208	2.28
	≥ 0.50	13365	3133	1753	0.119	4.27
	≥ 1.00	4079	549	291	0.067	7.43
	≥ 2.00	501	44	19	0.036	11.37
3-9 H OBJ*	≥ 0.25	20720	11247	5138	0.192	1.84
	≥ 0.50	10110	3133	1422	0.120	3.23
	≥ 1.00	3367	549	231	0.063	6.13
	≥ 2.00	630	44	14	0.021	14.32
6-12 H NGM 12-18 H NGM	≥ 0.25	16489	11247	3518	0.145	1.47
	≥ 0.50	2692	3133	394	0.073	0.86
	≥ 1.00	178	549	26	0.037	0.32
	≥ 2.00	2	44	0	0.000	0.00
6-12 H LFM 12-18 H LFM	≥ 0.25	20488	11241	3528	0.125	1.82
	≥ 0.50	3195	3133	547	0.095	1.02
	≥ 1.00	569	549	68	0.065	1.04
	≥ 2.00	86	44	10	0.083**	1.95

*Verification not appropriate for product (see caption).

**Scores not considered reliable because of small sample size.

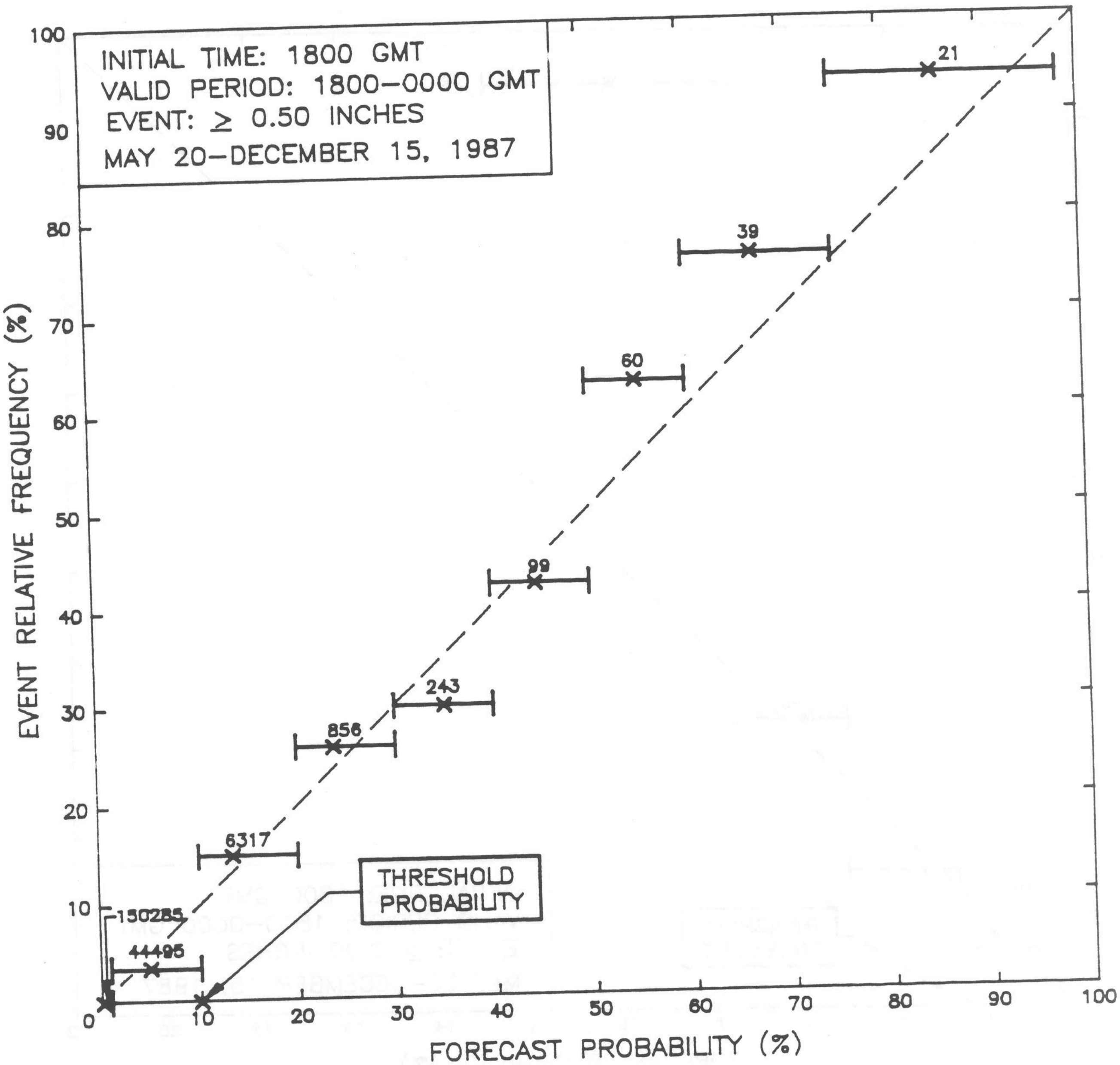


Figure 1. Forecast probability reliability diagram for ≥ 0.50 inches. The forecasts are combined over the entire conterminous United States. The sampling period is the same as that for Tables 6 and 7. The average relative frequency is plotted for the forecast probability intervals shown, with the average probability within the interval indicated by an "X". The number of cases in each interval is shown. Perfect reliability is indicated by the dashed line. The threshold probability shown is the national average over three seasons (spring, summer, and fall). The overall sample relative frequency for the ≥ 0.50 inch event is 1.46%.

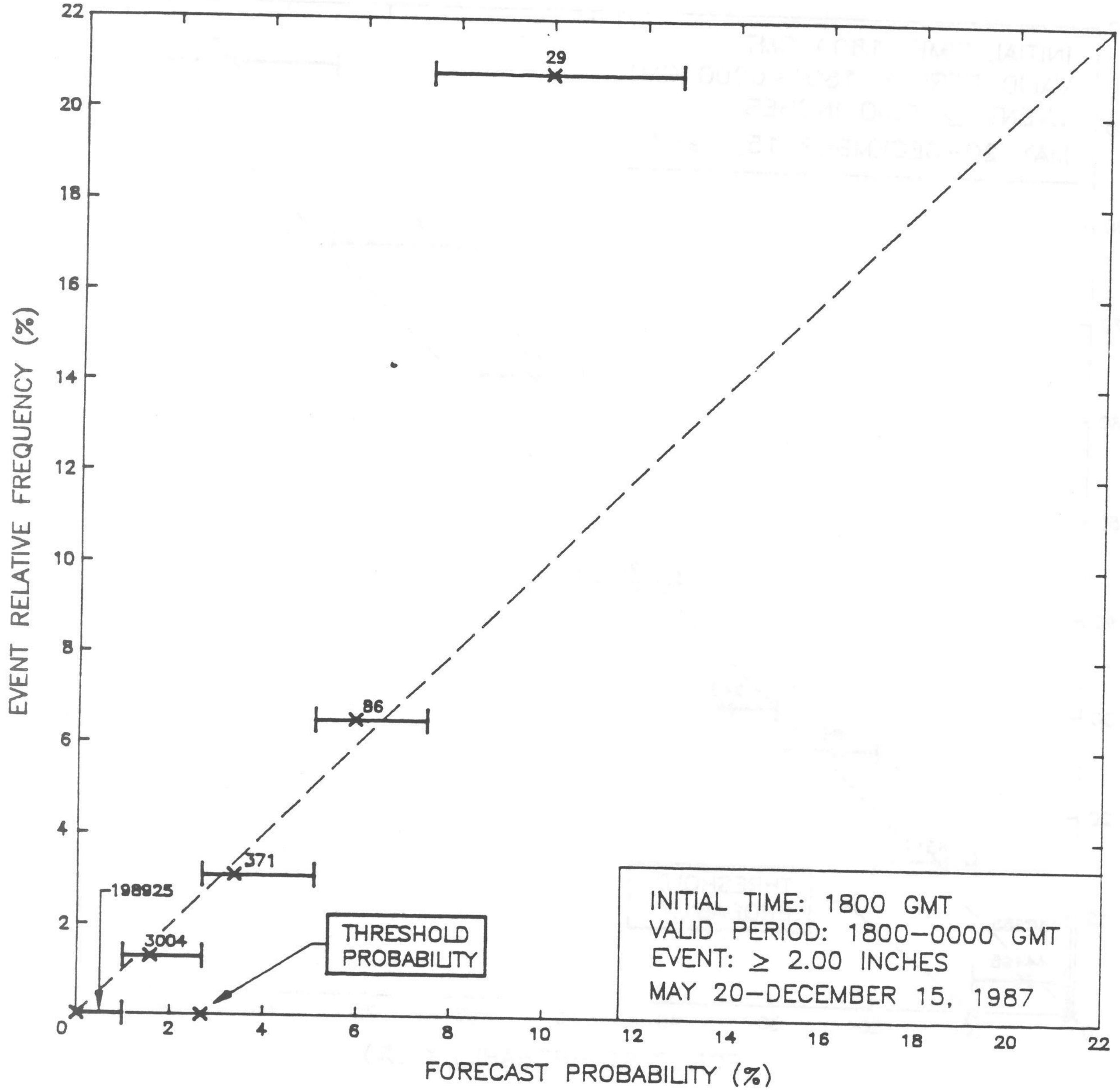


Figure 2. As in Fig. 1 except for ≥ 2.00 inches. The overall sample relative frequency for the ≥ 2.00 inch event was 0.07%.

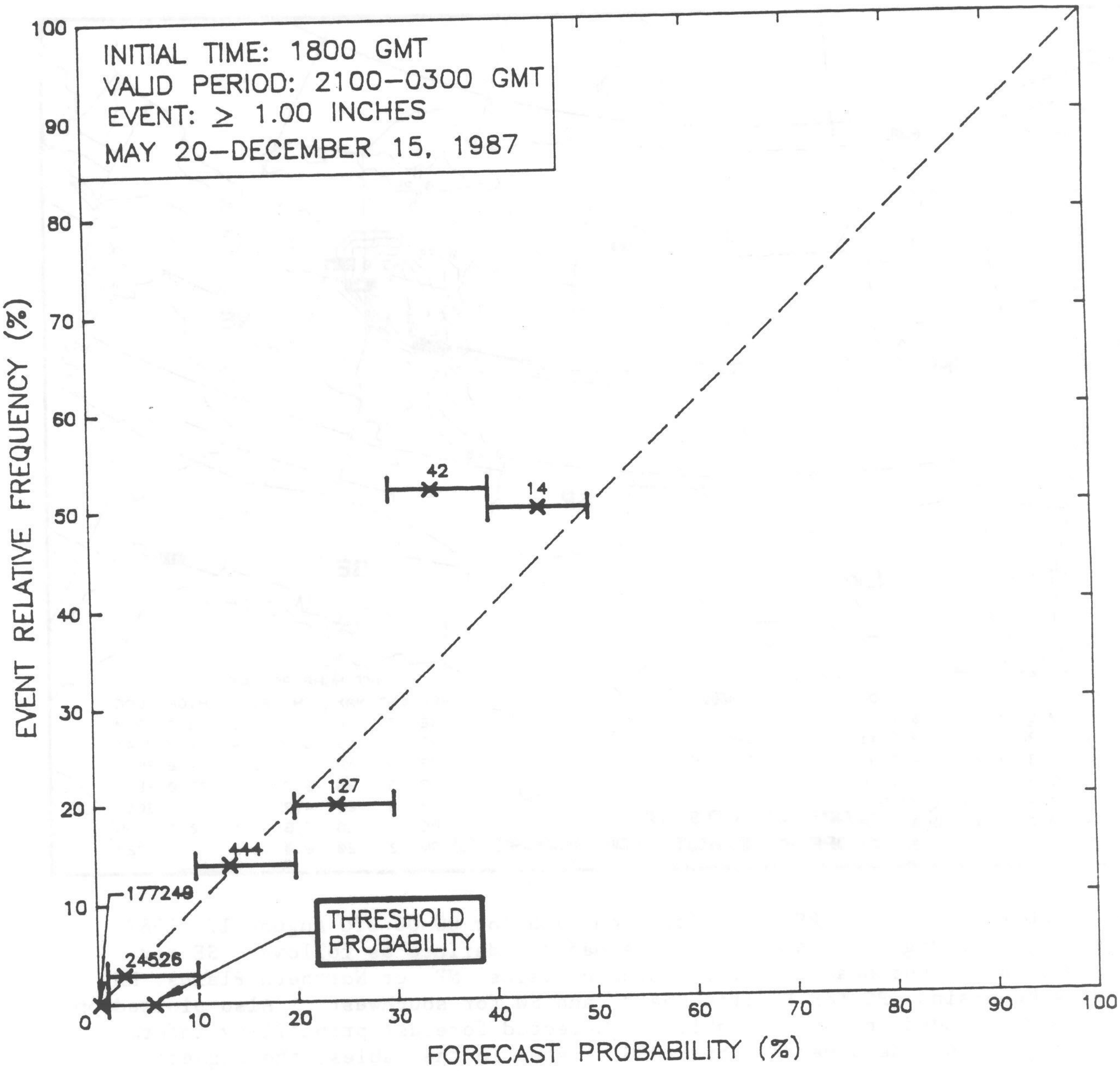
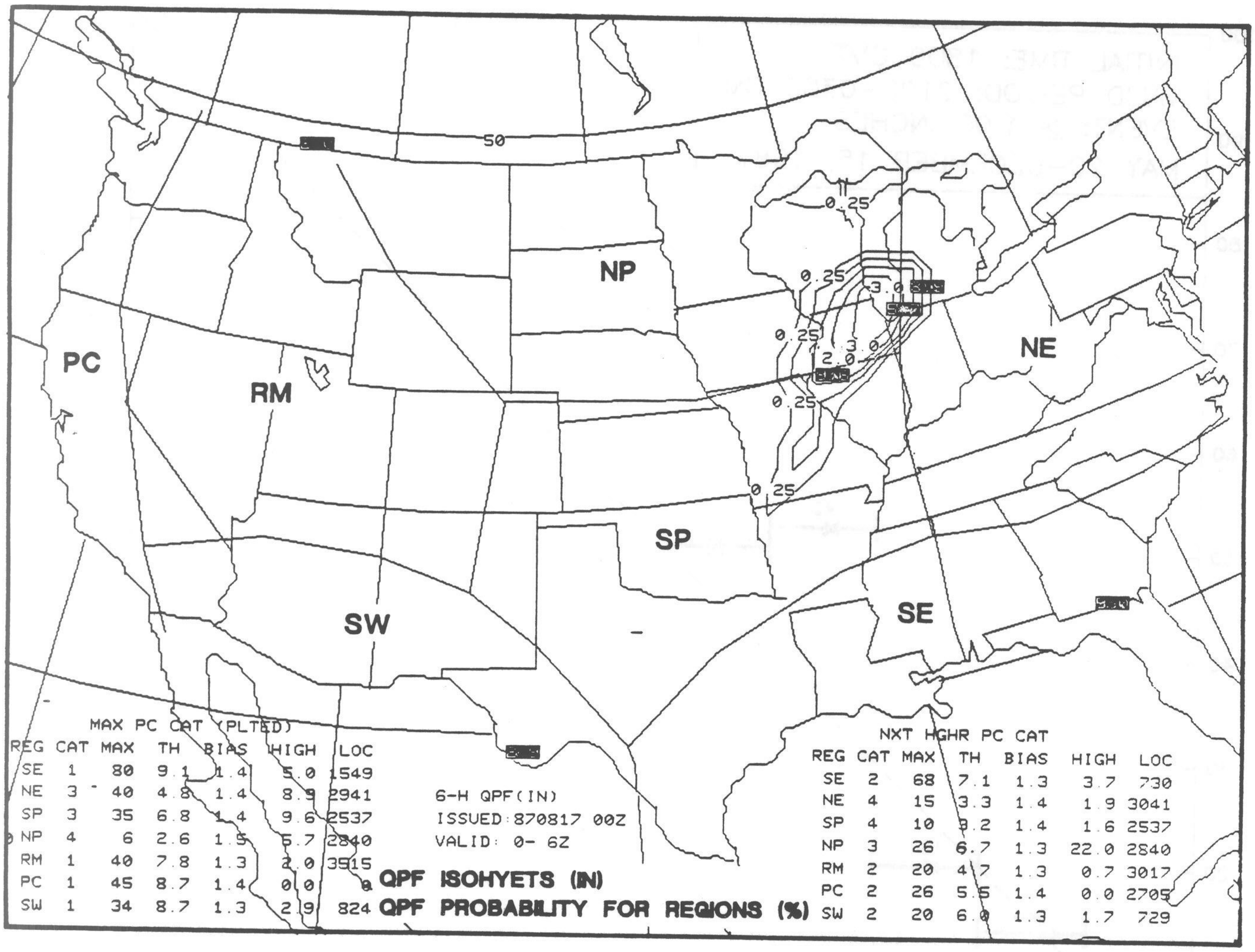


Figure 3. As in Fig. 1 except for valid period 2100-0300 UTC and precipitation category ≥ 1.00 inches. The overall sample relative frequency for the ≥ 1.00 inch event was 0.46%.



MAX PC CAT (PLTED)

REG	CAT	MAX	TH	BIAS	HIGH	LOC
SE	1	80	9.1	1.4	5.0	1549
NE	3	40	4.8	1.4	8.9	2941
SP	3	35	6.8	1.4	9.6	2537
NP	4	6	2.6	1.5	5.7	2840
RM	1	40	7.8	1.3	2.0	3515
PC	1	45	8.7	1.4	0.0	0
SW	1	34	8.7	1.3	2.9	824

NXT HGHR PC CAT

REG	CAT	MAX	TH	BIAS	HIGH	LOC
SE	2	68	7.1	1.3	3.7	730
NE	4	15	3.3	1.4	1.9	3041
SP	4	10	3.2	1.4	1.6	2537
NP	3	26	6.7	1.3	22.0	2840
RM	2	20	4.7	1.3	0.7	3017
PC	2	26	5.5	1.4	0.0	2705
SW	2	20	6.0	1.3	1.7	729

Figure 4. Objective (OBJ) QPF as depicted on AFOS for 00-06 UTC August 17, 1987. The geographical regions indicated on the map are defined as follows: SE for southeast, NE for northeast, SP for Southern Plains, NP for Northern Plains, RM for Rocky Mountains, PC for Pacific Coast, and SW for southwest. Also plotted on the map and included in the two tables is selected forecast probability information. For each of the seven regions (REG) listed in the tables, the highest probability (HIGH), corresponding to the heaviest isohyet (or QPF category) appearing in the region, is plotted on the QPF field in "reversed video". In the lower left table the regional HIGH value is listed together with the category number (CAT), the threshold probability (TH), and the maximum expected probability (MAX). The grid location (LOC) of the HIGH is also listed, as is the expected forecast bias (= forecast area/observed area). The table at the lower right lists identical information for the next higher category (not plotted), for which the HIGH value is always less than TH, i.e., the category was not forecasted. (When the left table already contains the highest category (4) for a region, the right table will list the next lower category (3), wherein the HIGH value will always be greater than TH.) To illustrate, the plotted probability of 5.7% near Chicago (positioned at lower left corner of the reversed video box) was the highest probability value associated with the 2.0 inch isohyet. From the left table note that the probability along the 2.0 inch isohyet in the NP region is 2.6% (the TH value) and the HIGH value (5.7%) is near the maximum of 6%.

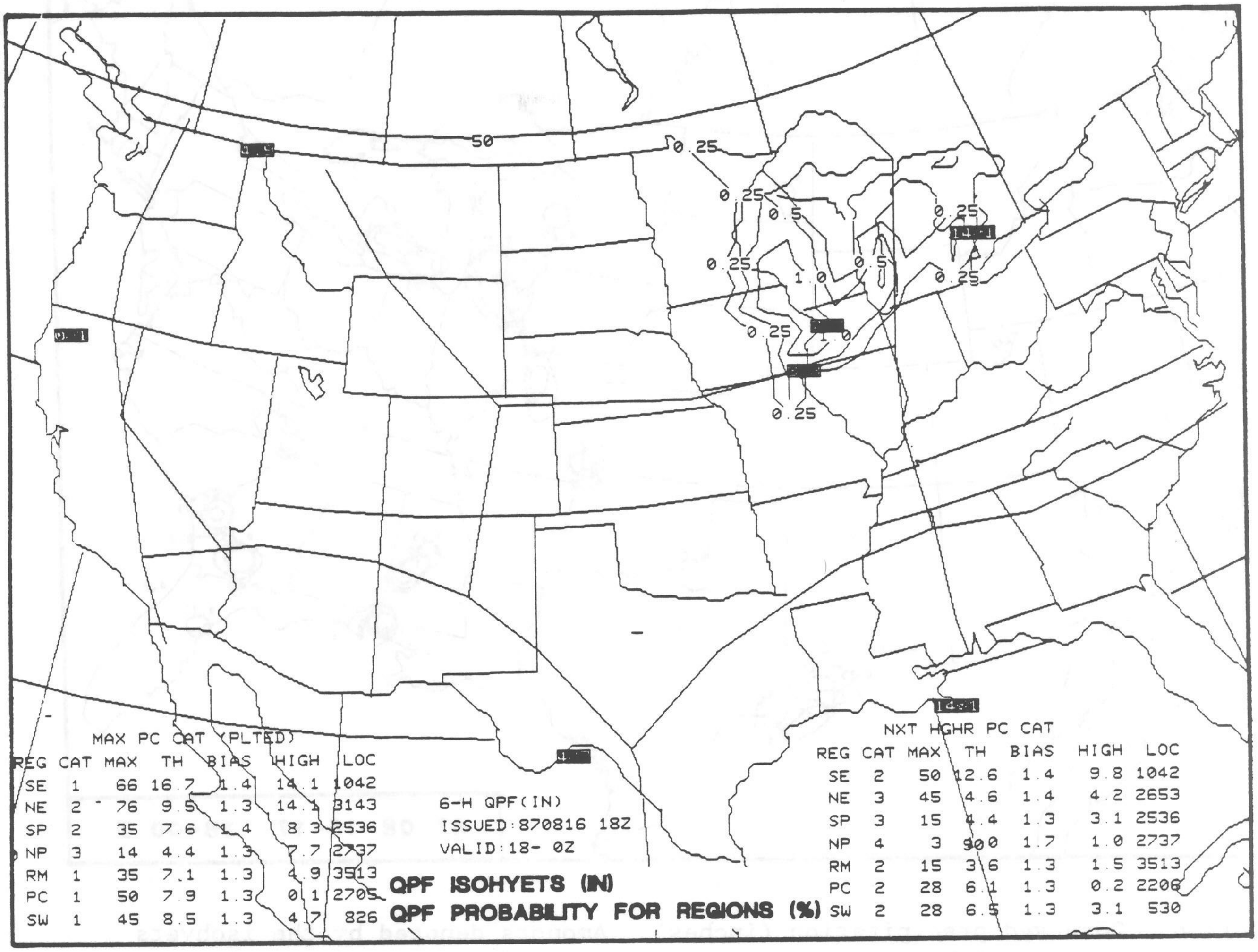


Figure 5. As in Fig. 4 except for date and time.

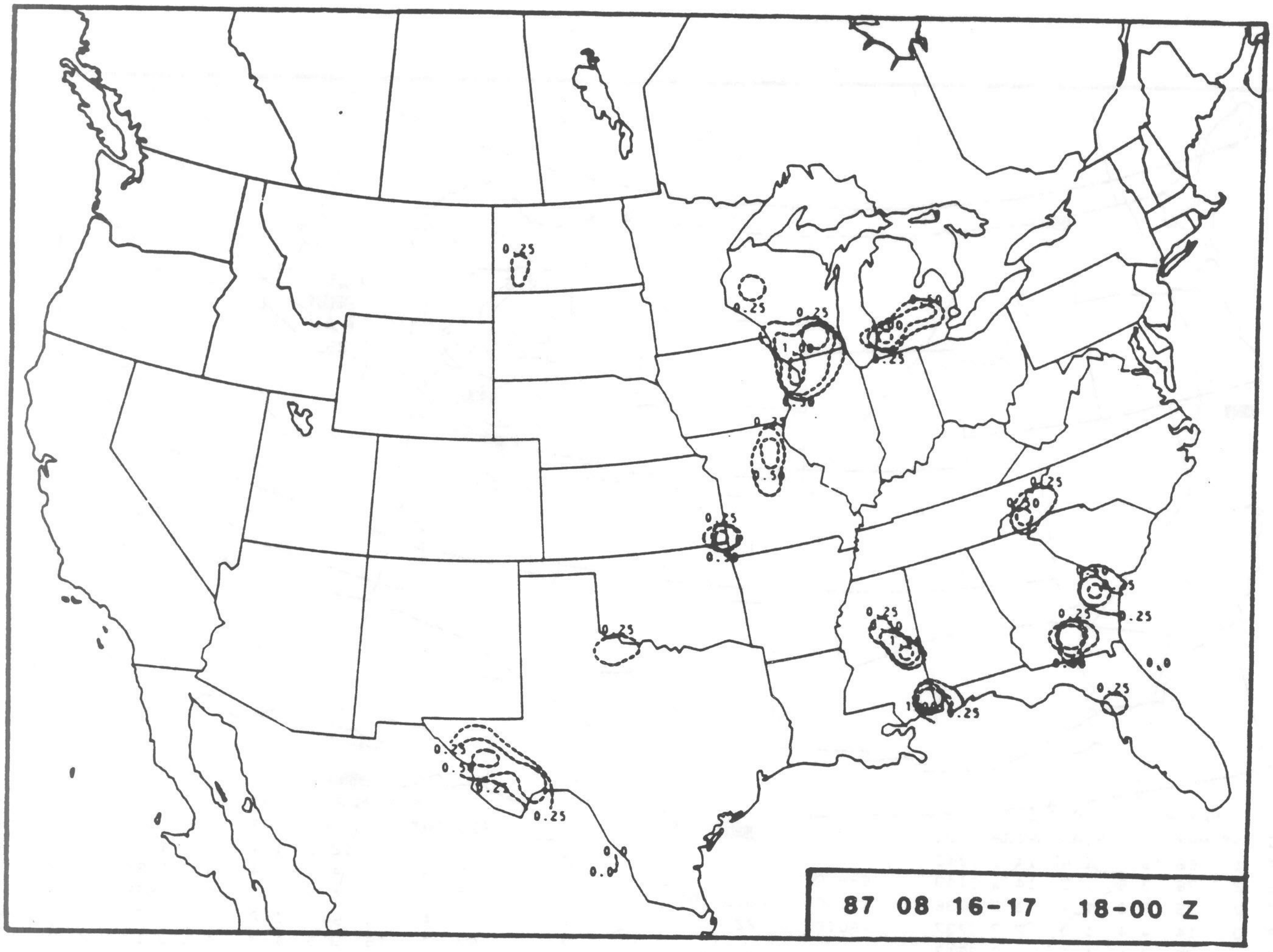


Figure 6. Observed precipitation (inches). Amounts denoted by the isohyets are point maxima within 40 x 40 n mi boxes. The date and valid period is the same as in Fig. 5.

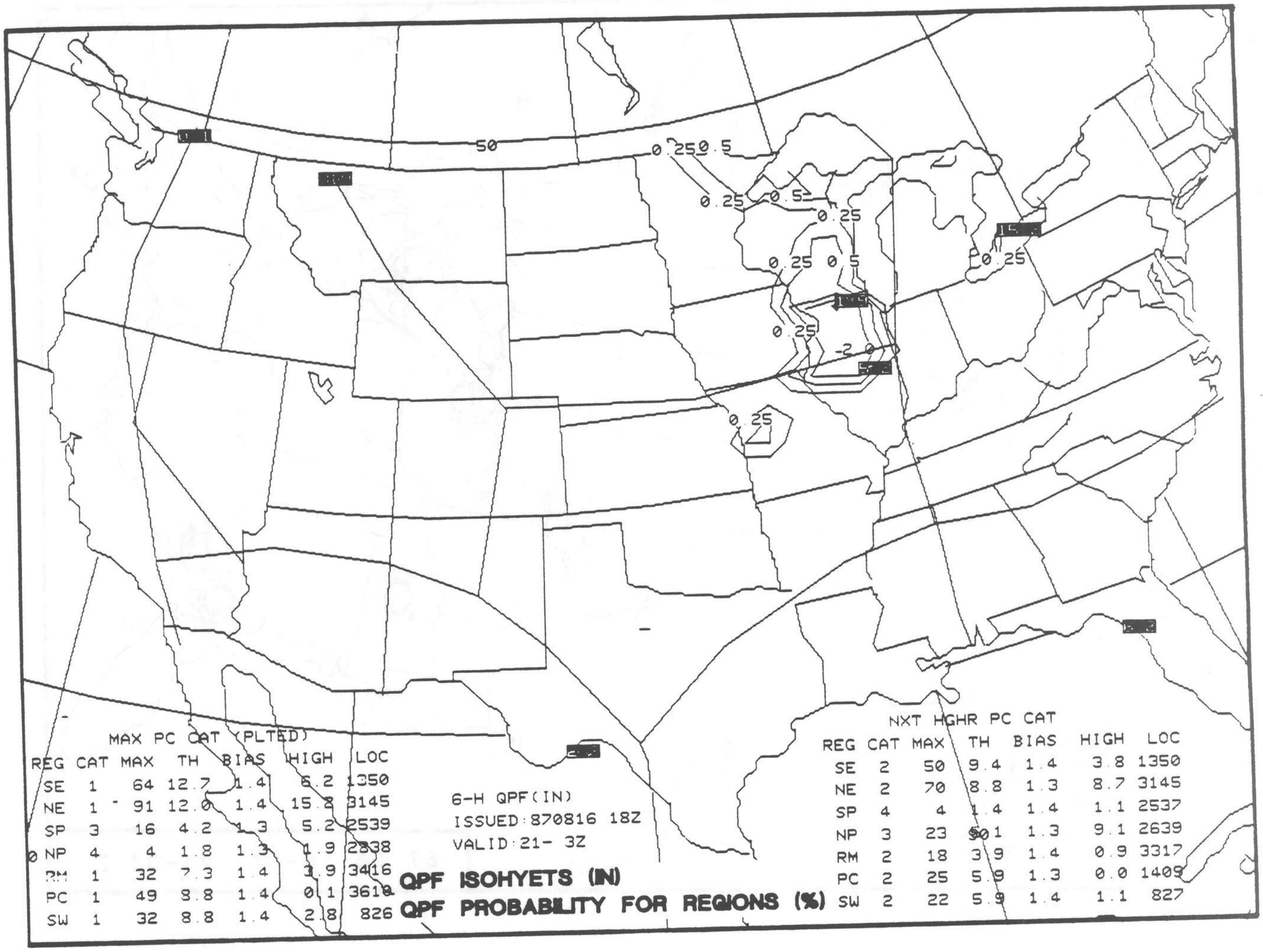


Figure 7. As in Fig. 4 except for date and time.

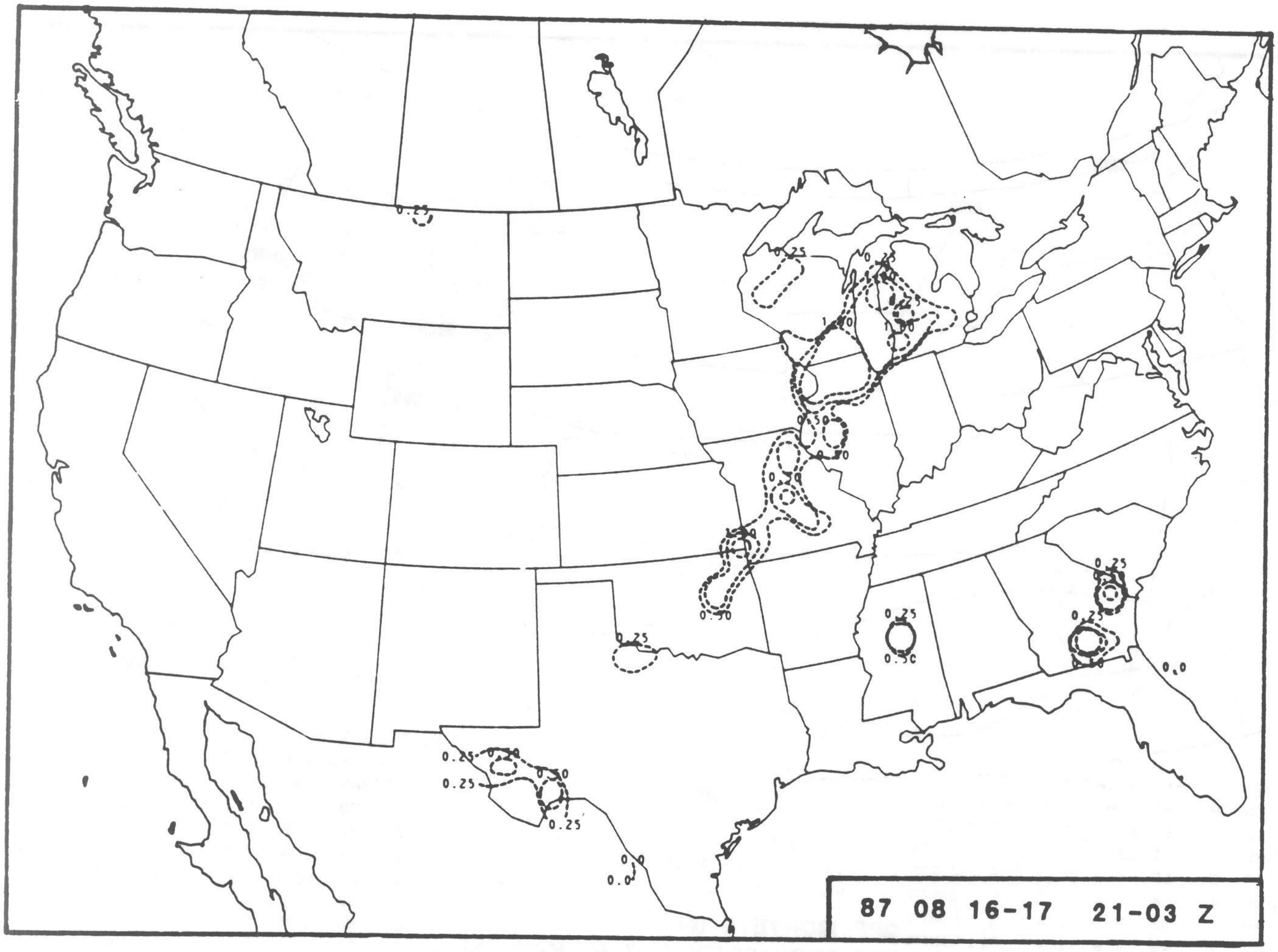


Figure 8. As in Fig. 6 except for date and valid period.

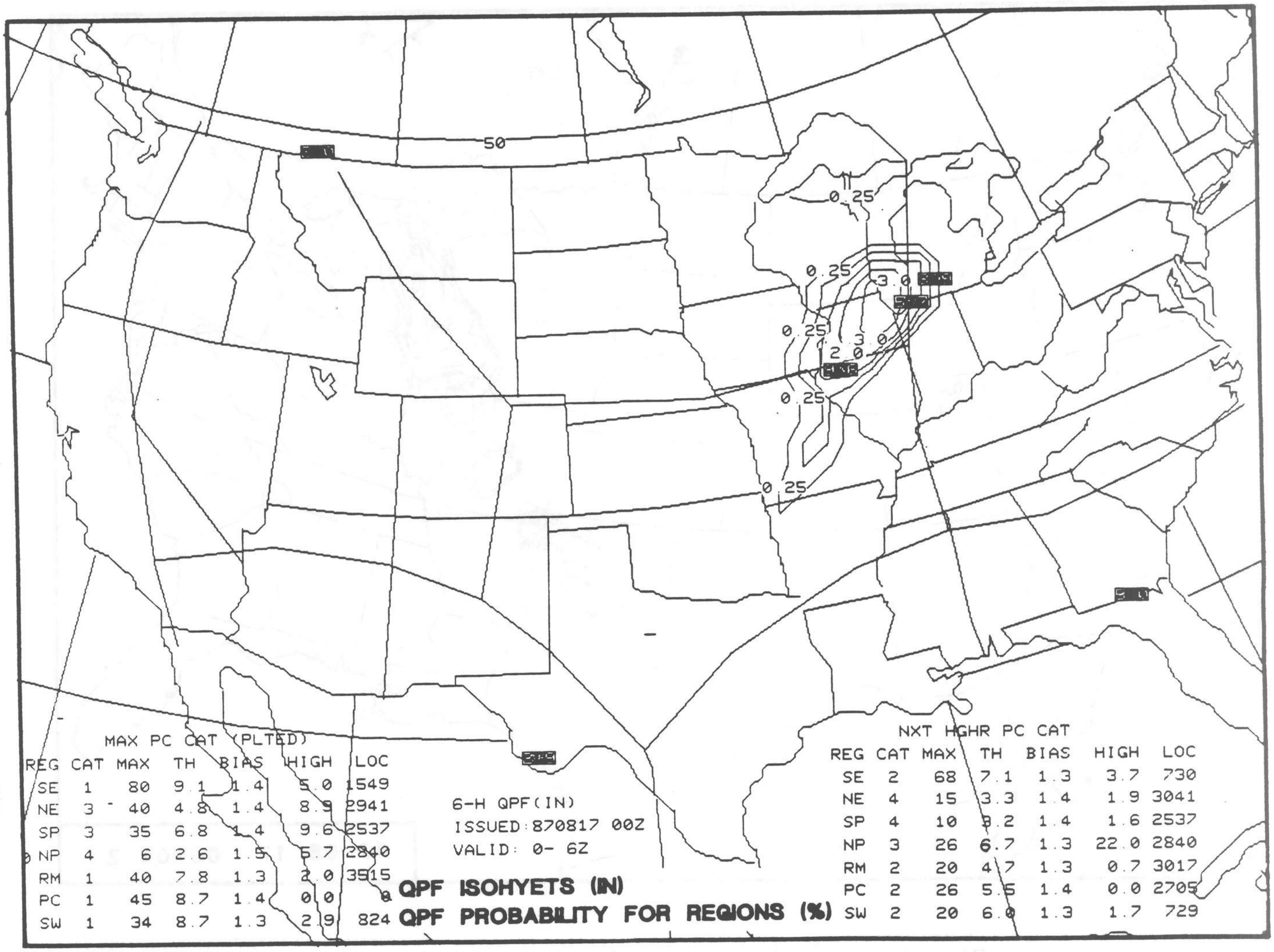


Figure 9. As in Fig. 4.

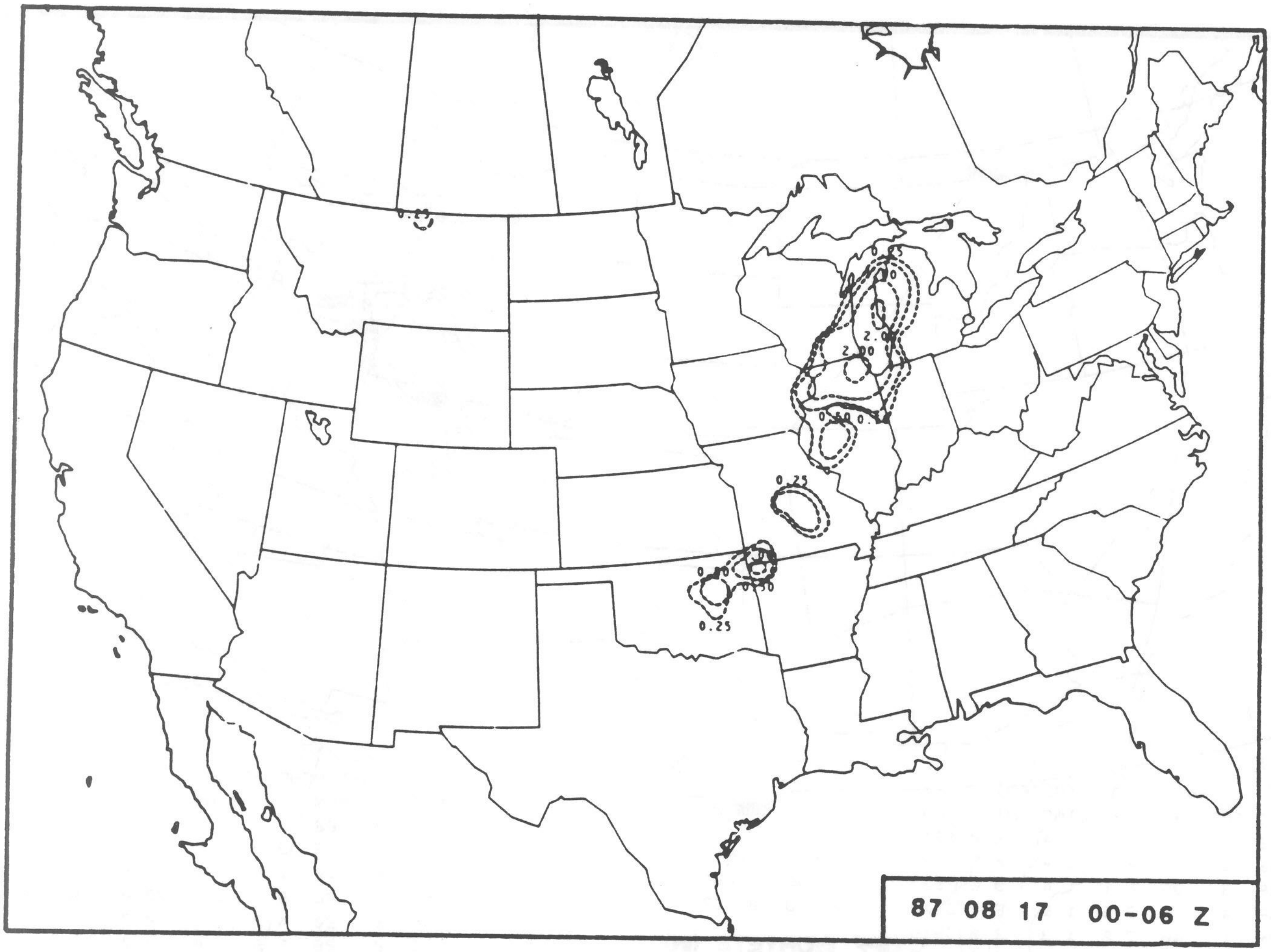


Figure 10. As in Fig. 6 except for date and valid period.

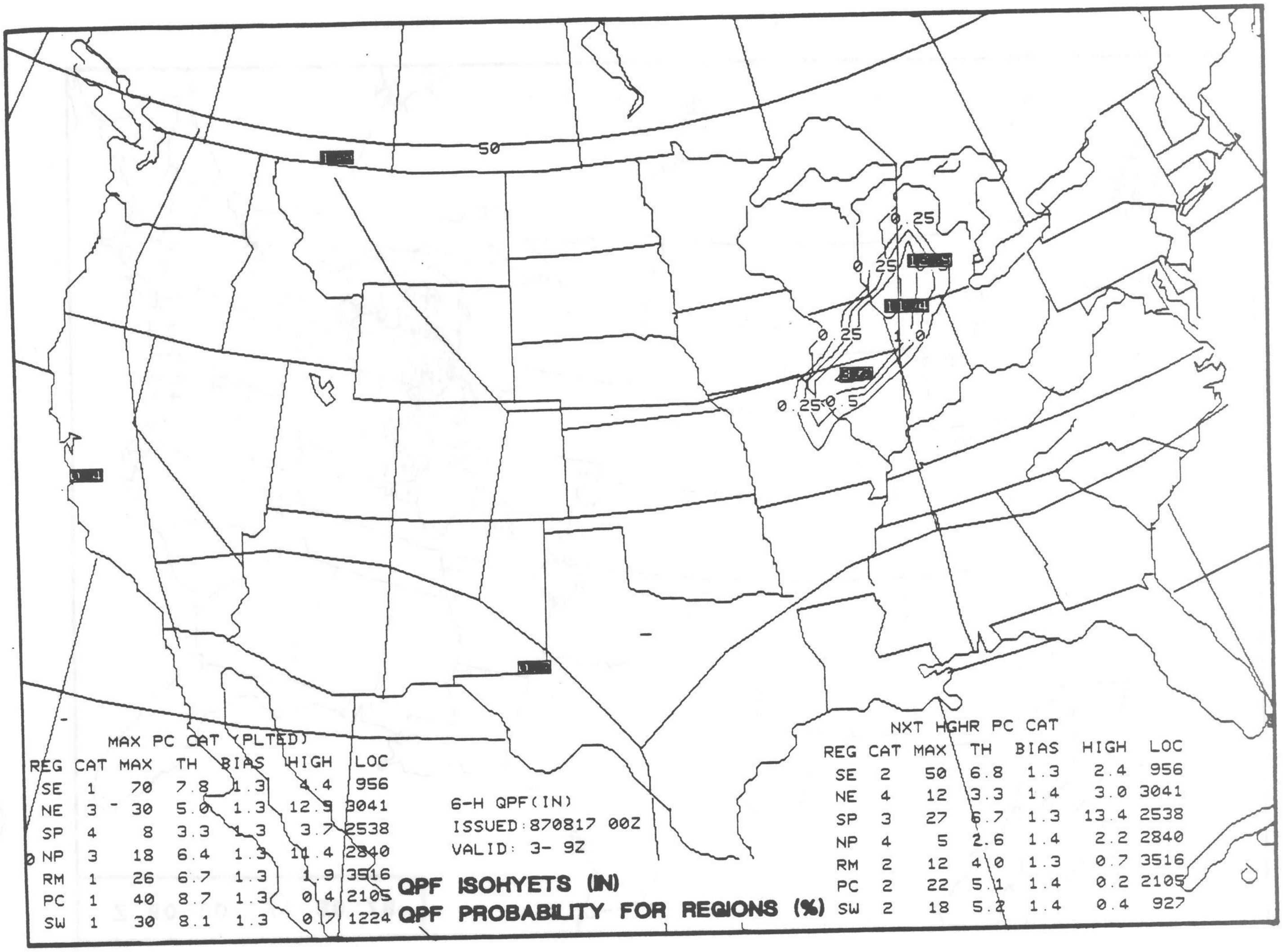


Figure 11. As in Fig. 4 except for date and time.

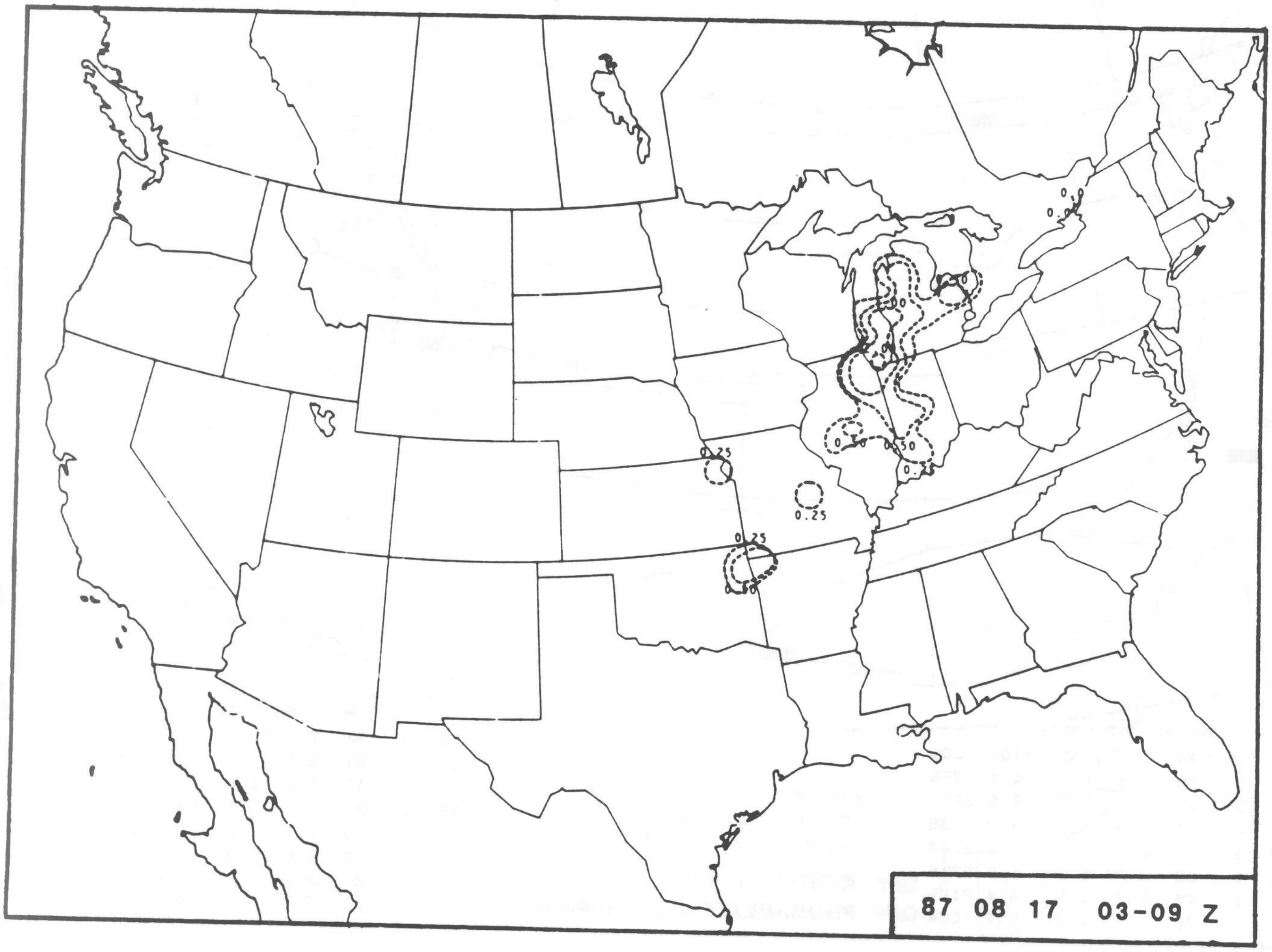


Figure 12. As in Fig. 6 except for date and valid period.

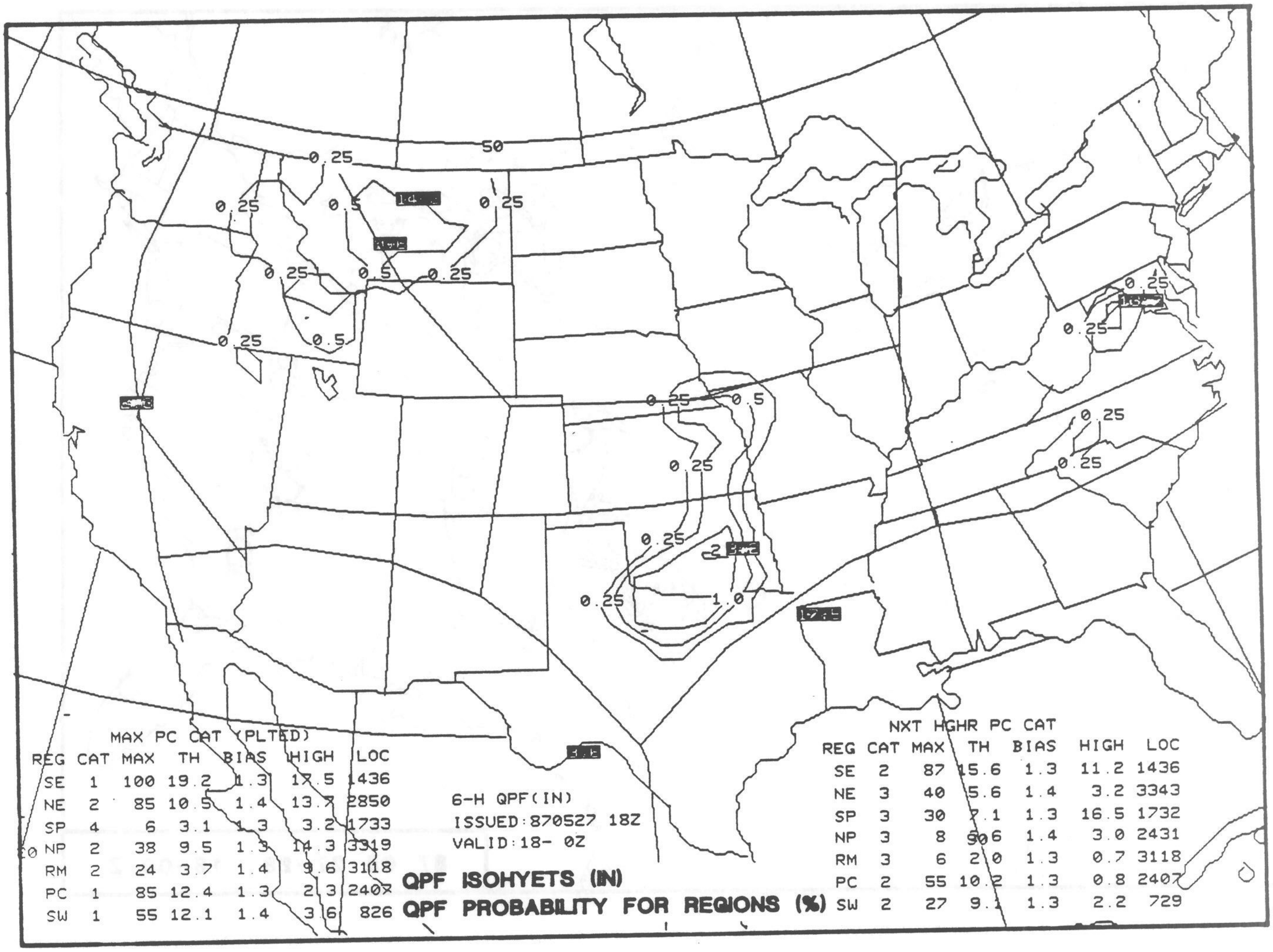


Figure 13. As in Fig. 4 except for date and time.

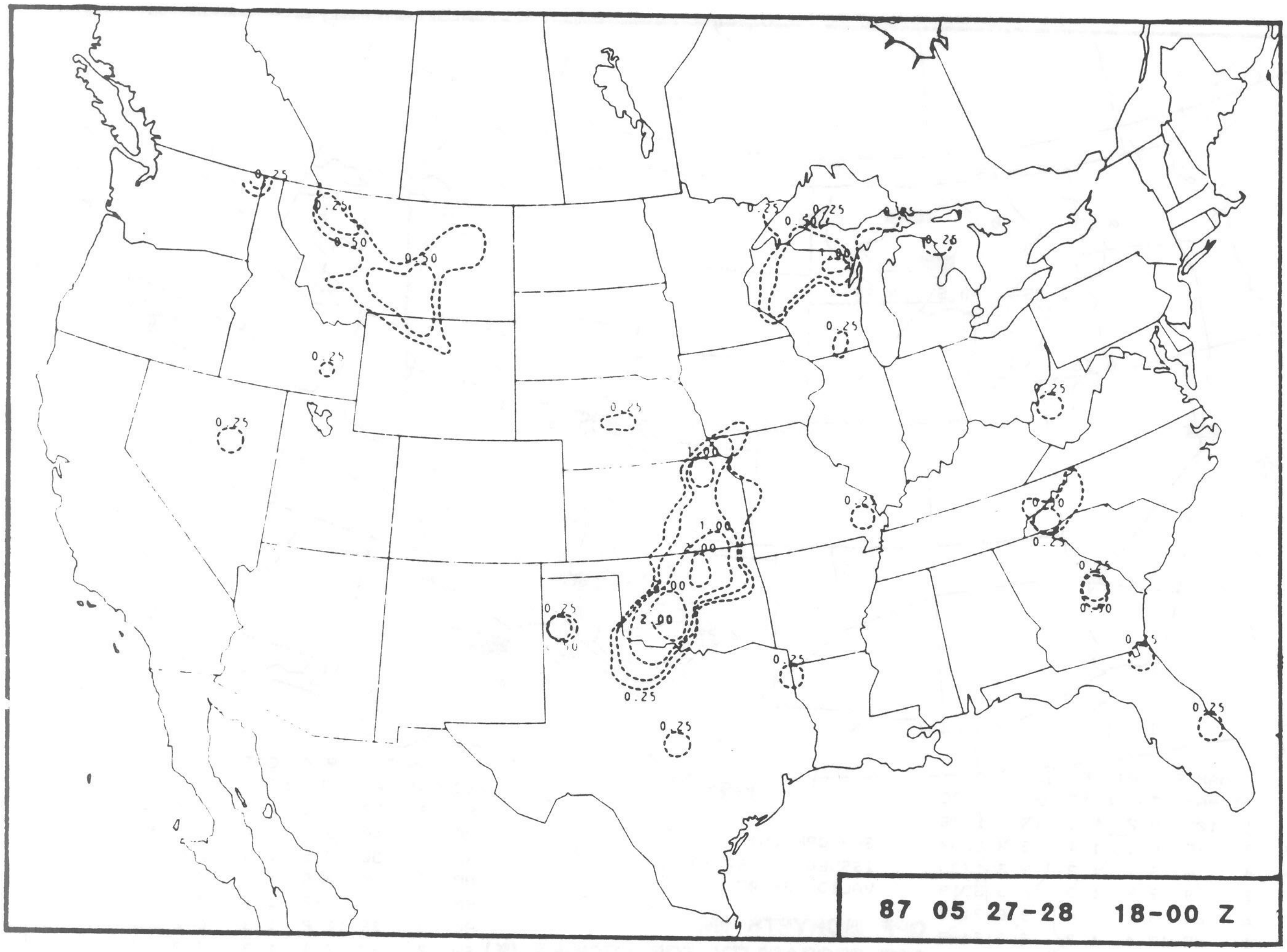


Figure 14. As in Fig. 6 except for date and valid period.

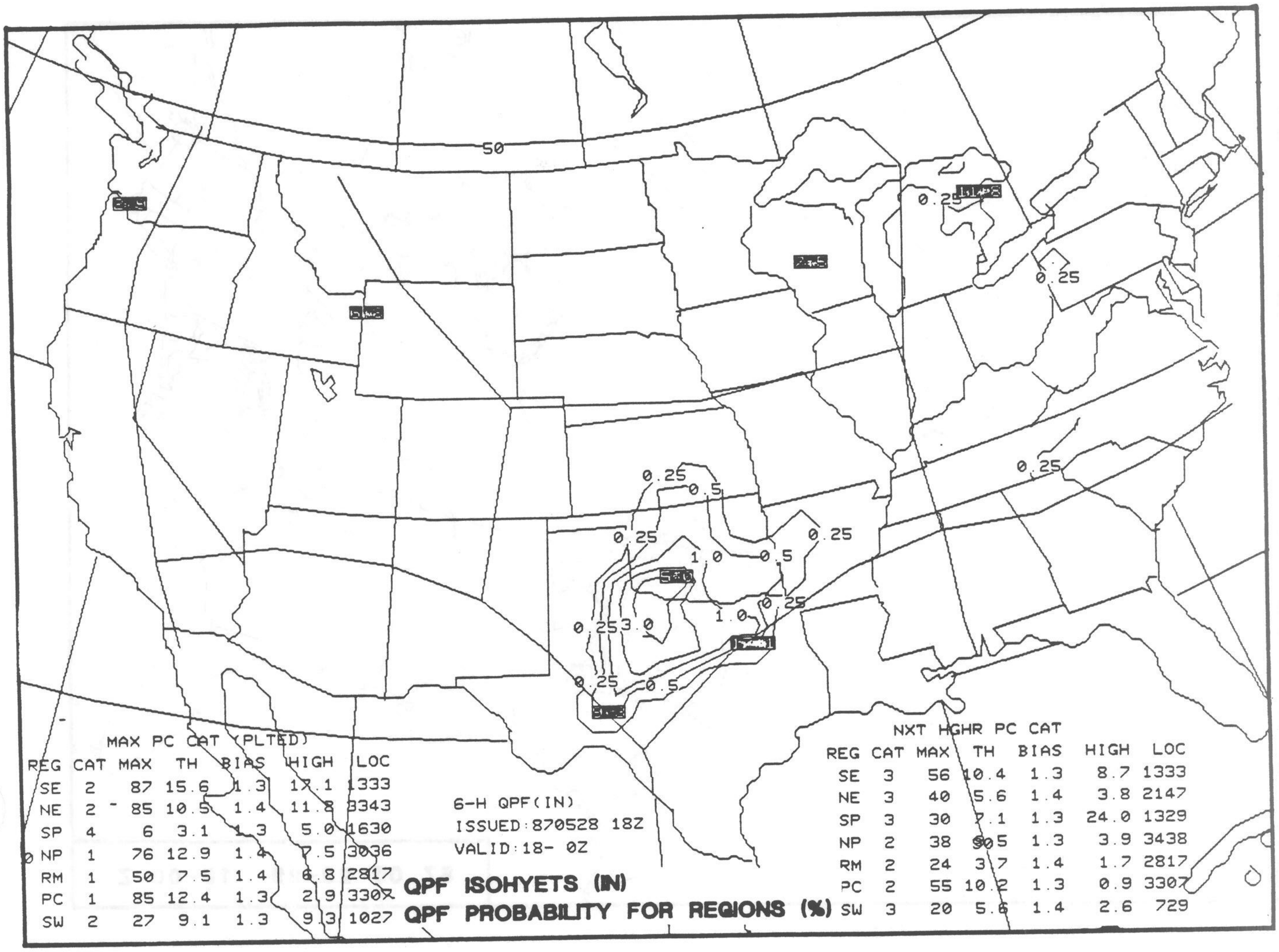


Figure 15. As in Fig. 4 except for date and time.

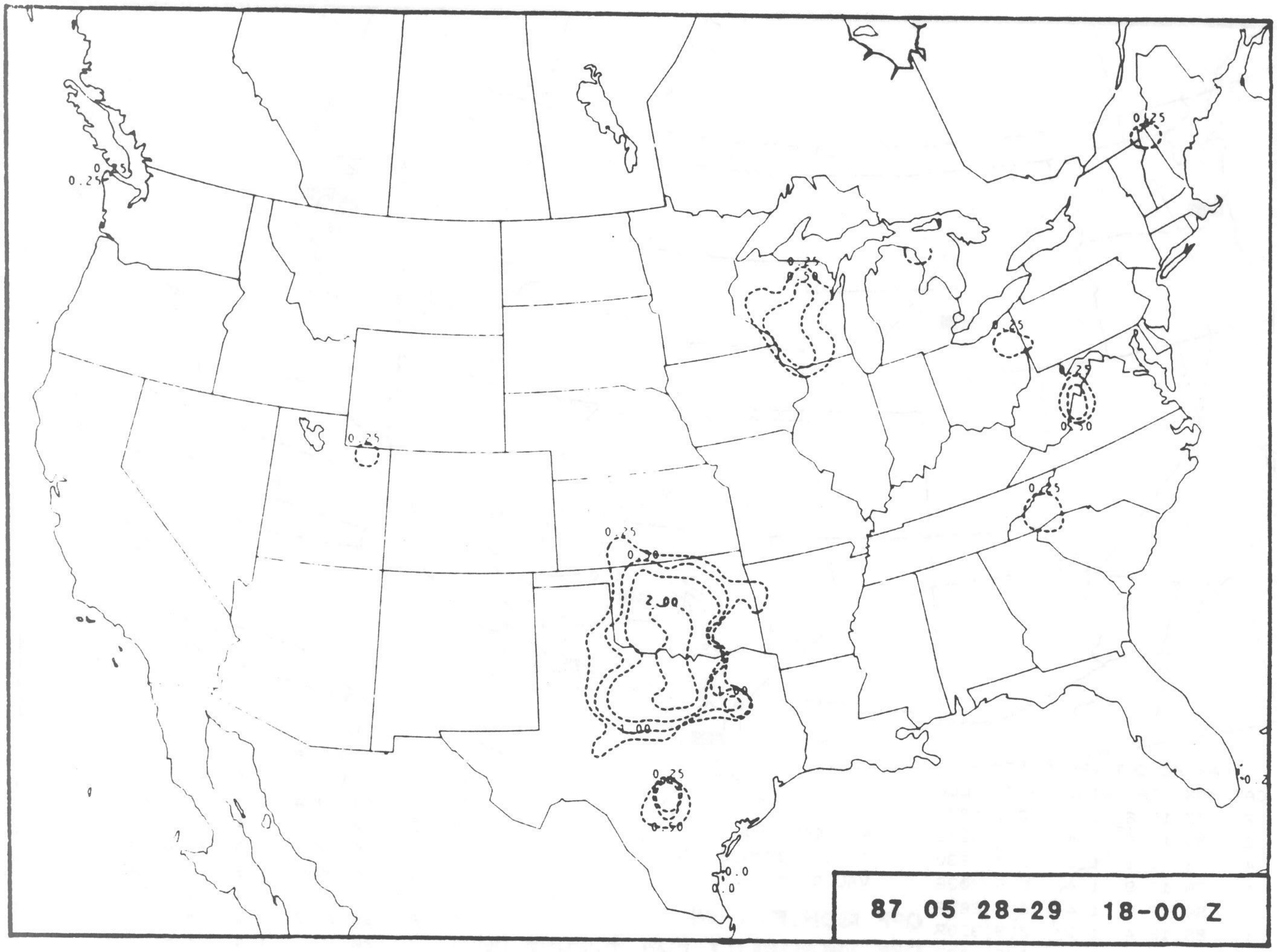


Figure 16. As in Fig. 6 except for date and valid period.

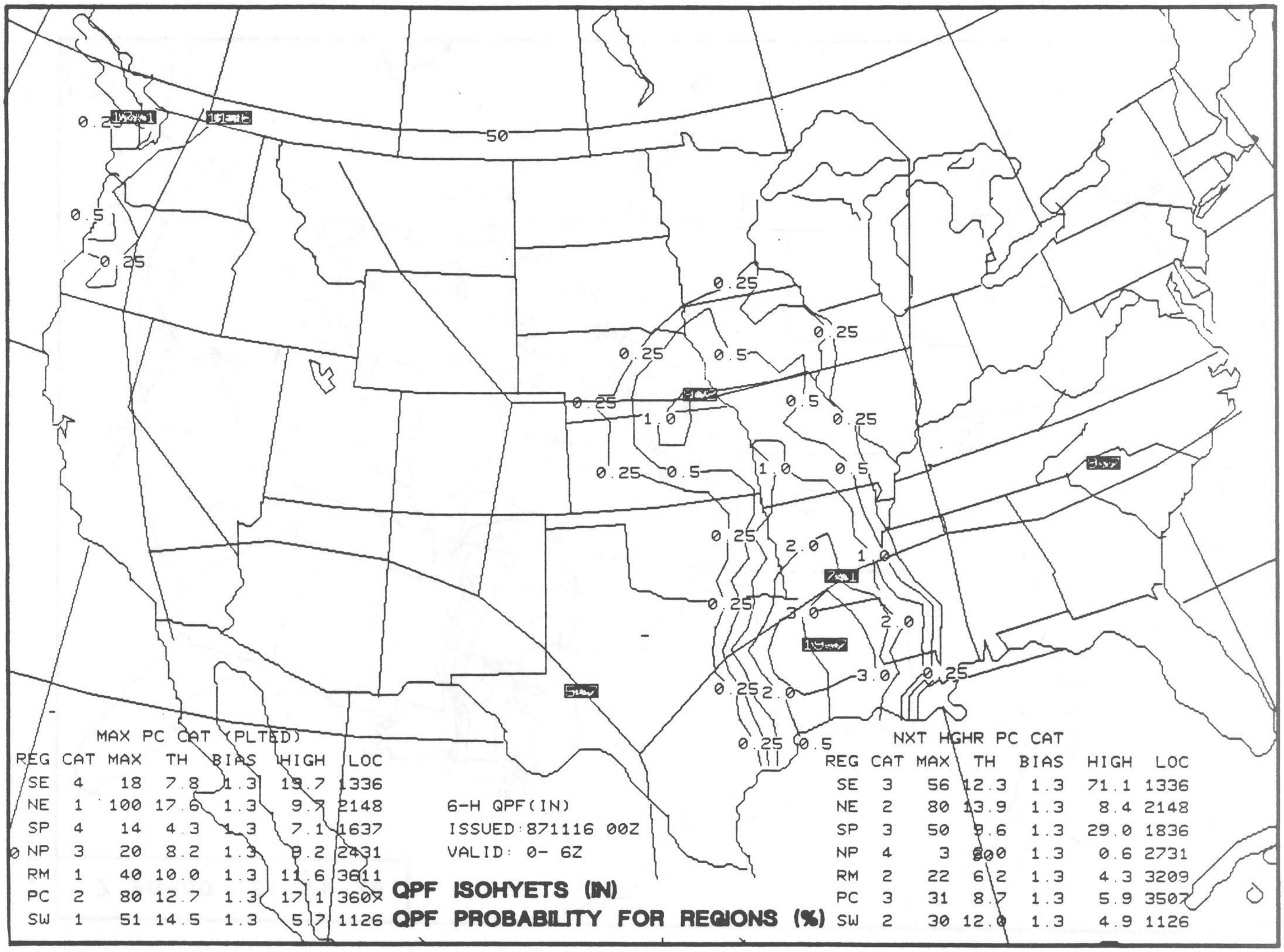


Figure 17. As in Fig. 4 except for date and time.

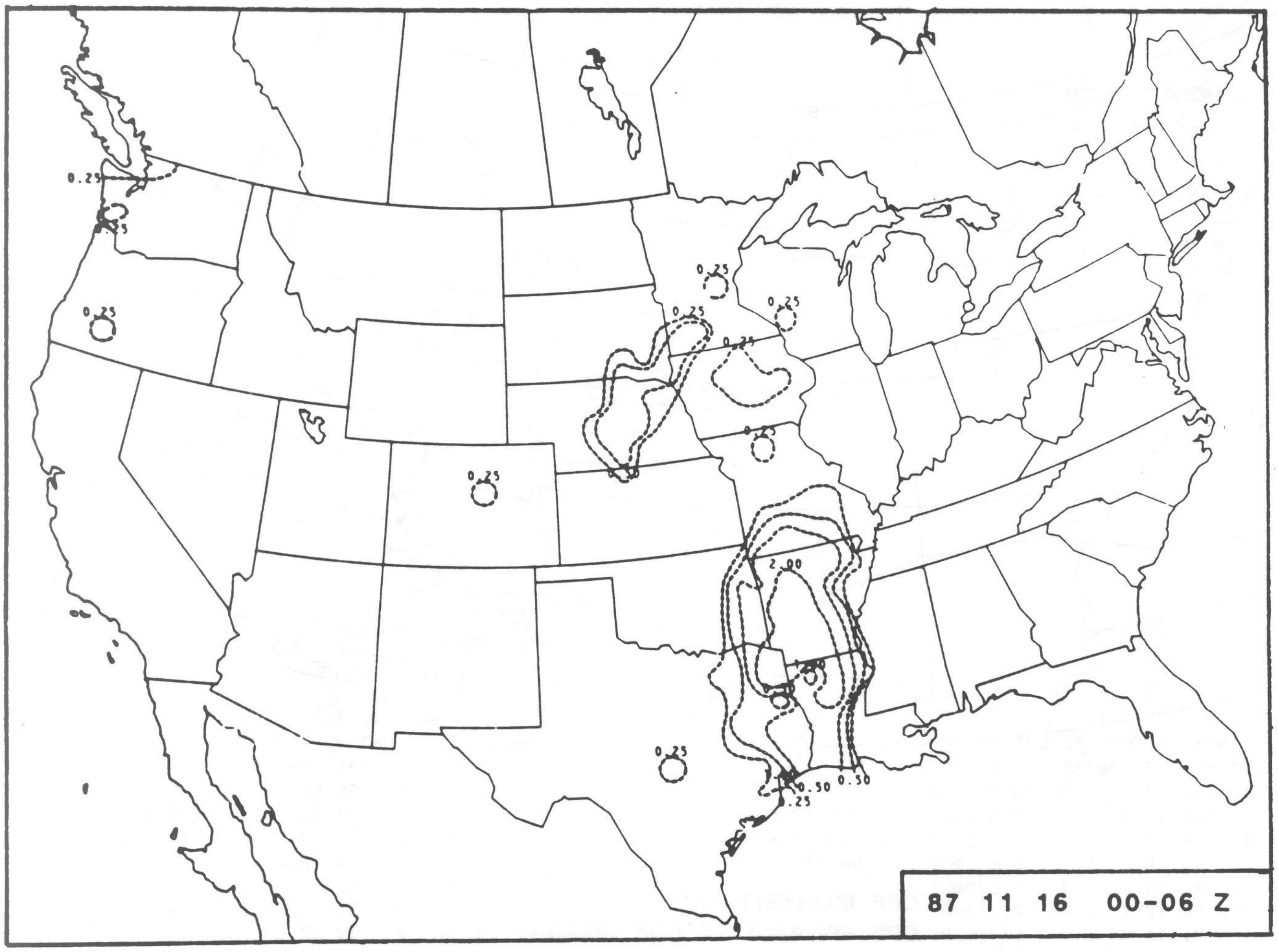


Figure 18. As in Fig. 6 except for date and valid period.

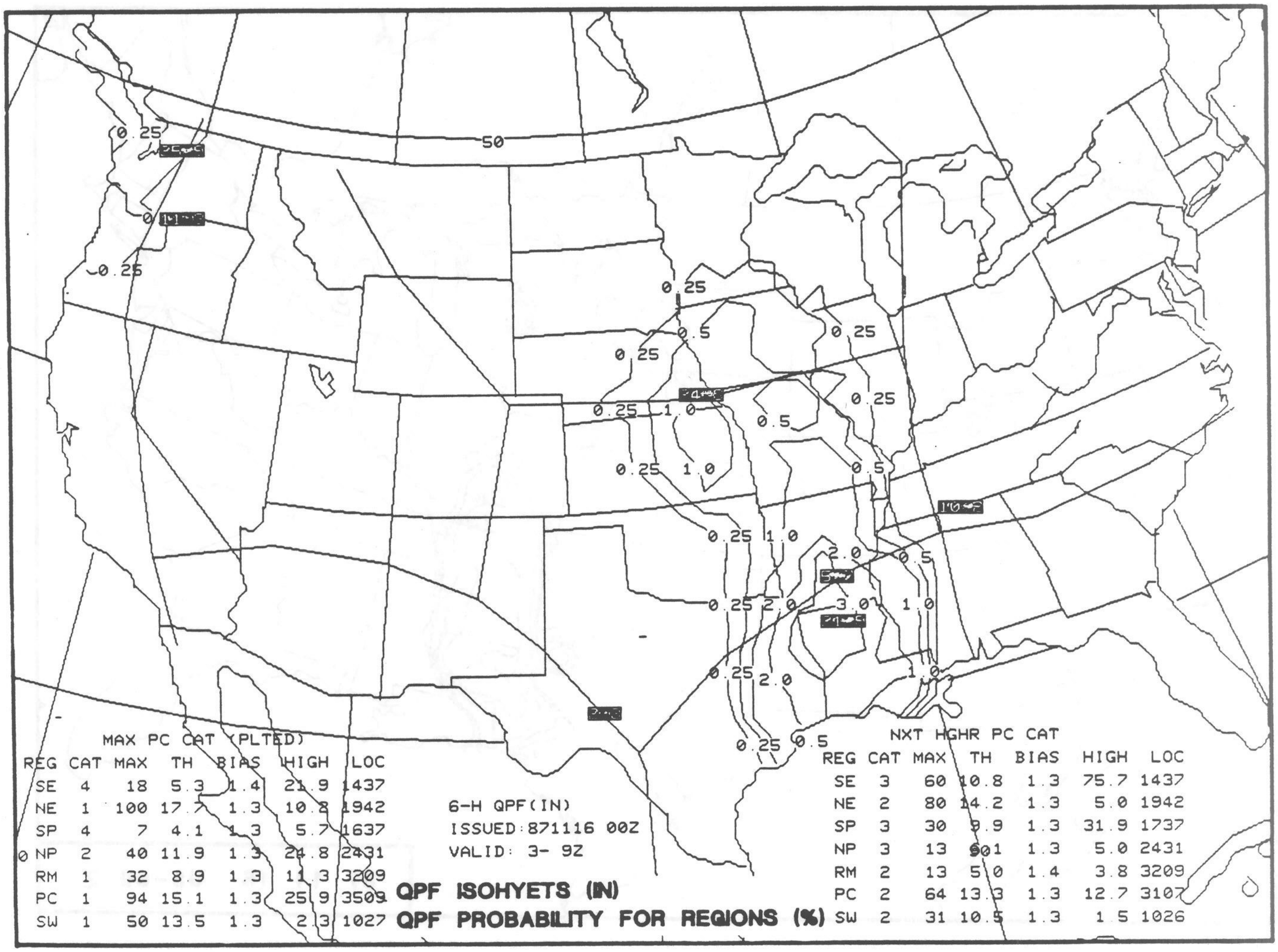


Figure 19. As in Fig. 4 except for date and time.

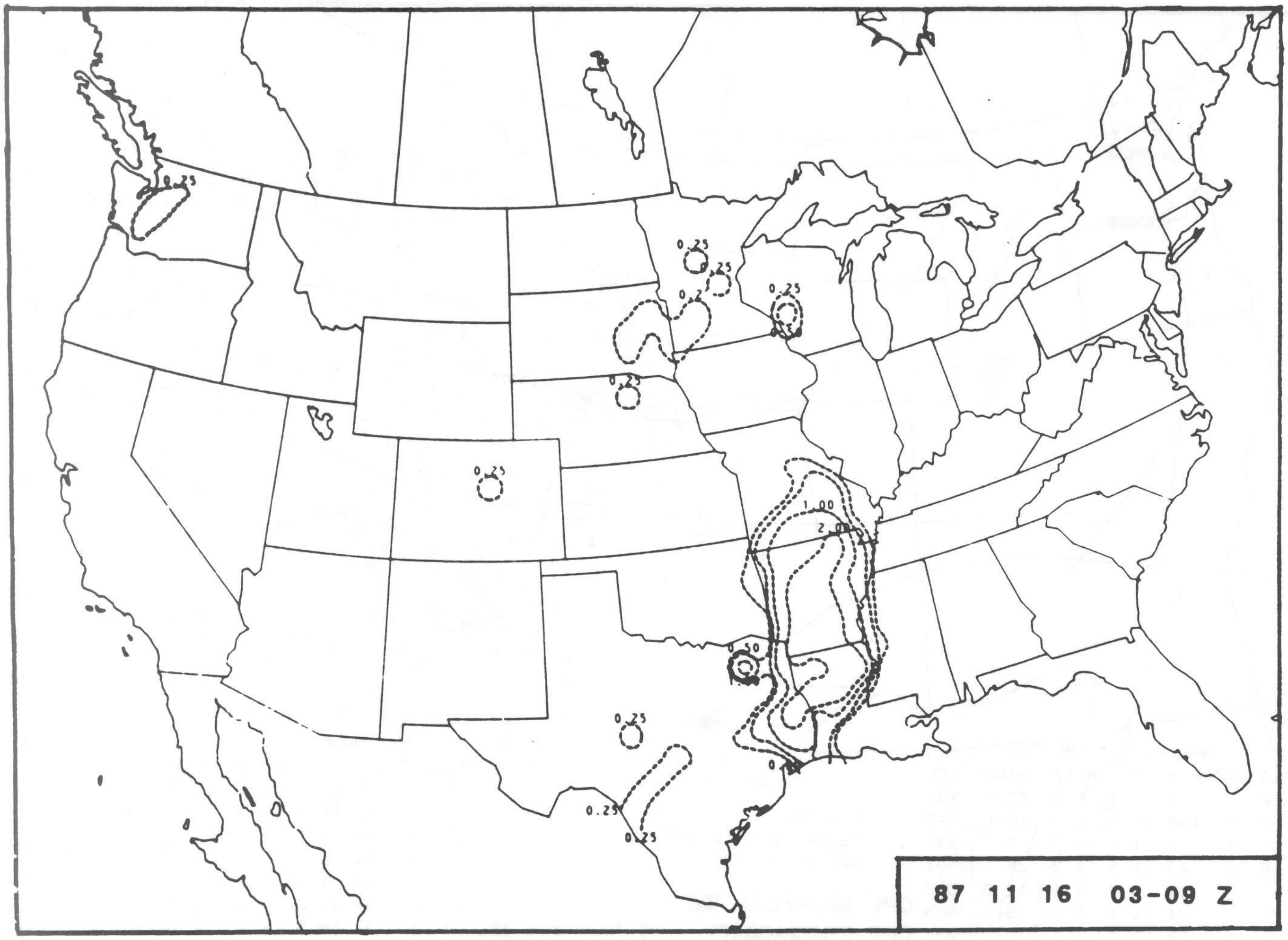


Figure 20. As in Fig. 6 except for date and valid period.

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NOAA Technical Memorandums

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NWS TDL 49 Synoptic Climatological Studies of Precipitation in the Plateau States From 850-Millibar Lows During Fall. August F. Korte and DeVer Colson, August 1972, 56 pp. (COM-74-10464)

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NWS TDL 79 Performance of Operational Objective 0-6 H Quantitative Precipitation Forecasts Relative to Manual and Model Generated Forecasts: A preliminary Assessment. Jerome P. Charba, Joel T. Moeller, and Paul D. Yamamoto, October 1988, 31 pp. (PB89 162028)