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NMC MODEL PERFORMANCE IN THE NORTHEAST PACIFIC

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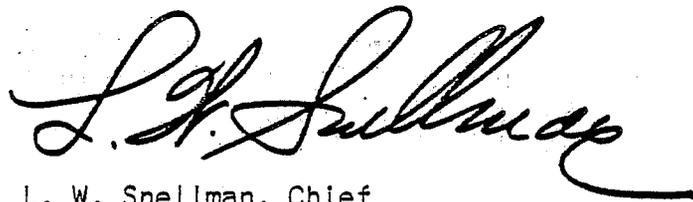
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Scientific Services Division
Western Region Headquarters
Salt Lake City, Utah

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TABLES AND FIGURES

NMC MODEL PERFORMANCE IN THE NORTHEAST PACIFIC*

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ABSTRACT. Central pressure and position errors of low
centers for 36-hr sea-level pressure forecasts were
compared between the LFM-II and 6LPE models for December
1977 and the LFM-II and 7LPE models for 19 January
through 28 February 1978. Nine storms provided 41 cases
in December and 20 storms provided 66 cases in January
through February. During December the LFM-II was supe-
rior to the 6LPE in locating rapidly moving storms.
The position errors for the LFM-II in December were on
the order of 250 km. During February both the LFM-II
and the 7LPE had median position errors on the order of
450 km; also, both had a high percentage (25%) of
observed-but-not-forecast low centers. The larger
errors in February were related to resolution of initial
cyclogenesis.

I. INTRODUCTION

The objective of this study is to provide a preliminary evaluation of the
effectiveness of the National Meteorological Center (NMC) numerical models in
forecasting sea-level pressure in the East Pacific-Gulf of Alaska region
during winter. The change of models at NMC provided the opportunity to com-
pare the new Limited Area Fine-Mesh Model (LFM-II), with a resolution of 127
km at 60°N latitude, with the old 6-level hemispheric model (6LPE) and the new
7-level hemispheric model (7LPE). The 7LPE has a grid length of 190.5 km at
60°N, one-half that of the older 6LPE, 381 km. We considered two months of
LFM-II forecasts that coincided with the last month of the 6LPE model forecasts
and the first month of operational status of the 7LPE model. The evaluation
consisted of documenting the errors in central pressure and position of low
centers for 36-hr forecasts, a primary interest for coastal weather and ocean-
wave forecasting.

II. DESCRIPTION OF THE MODELS

Model characteristics are summarized in Table 1. The original primitive
equation model was the hemispheric 6LPE (Shuman and Hovermale, 1968), which
became operational June 1966. The LFM became operational September 1971 and
covered North America and adjacent waters. The LFM was replaced 31 August
1977, by the new LFM-II (Cooley, 1977a). The LFM-II was intended to incorpo-
rate higher spatial resolution, 127.0 km grid length at 60°N versus 190.5 km
in the old LFM, without otherwise changing the model's physics. The only major
internal change made to the LFM-II was the incorporation of a time-step averag-
ing technique to the pressure gradient terms (Brown and Campana, 1978), which
increased the maximum allowable time step. On 18 January 1978, the 6LPE was
replaced by the 7LPE. The hemispheric 7LPE has the same mesh length as the old
LFM, 190.5 km, and has an additional forecast layer in the stratosphere. The

additional layer has beneficial impact on regional forecasts in the upper layers, but no discernible effect on tropospheric forecasts (Cooley, 1977b).

III. EXPERIMENTAL DESIGN

The data for this study were the NMC grid-point sea-level pressure values for the 0000 and 1200 GMT analyses and 36-hr forecasts from each model for the month of December 1977 and 19 January through 28 February 1978. These grid-point fields were contoured on a polar stereographic projection over the North Pacific using the NCAR-computer graphics routines (Figure 1). Verifying positions and central pressures were determined by the NMC hand-plotted sea-level pressure analyses.

The winter synoptic regime for the Northeast Pacific is characterized by rapidly eastward-moving storms south of 50°N and a tendency for storms to stall and occlude in the Gulf of Alaska and when approaching the west coast of North America. Figures 2 and 3 show the set of tracks of the storms considered in this study for the December and February periods. The December storms moved on generally east-northeast trajectories of the jet stream, stalling near the coast. In February storms tended to curve up along the Canadian coast and move westward into the Gulf of Alaska due to blocking high pressure over Alaska and eastern Canada (Dickson, 1978). The spatial variation in storm movement characteristics led to the division of this region into a rapid movement area, A, and two stall regions, B and C (Figure 4). The contrast between December and February in terms of the larger number of storms, extent of storm generation within the region, and amount of storm recurvature indicated that we were comparing different synoptic climatologies in the two monthly samples.

The basis of forecast accuracy for each model was a comparison between the locations of the forecast low center and the observed low center, and calcu- lation of central pressure differences of these centers for the three areas during the two time periods. Comparisons considered only forecasts showing a reasonable feature for a low center, either an actual closed low or a trough feature, corresponding to an observed closed low or deep trough. Fore- casts that missed a surface feature were evaluated separately. Nine storms provided 41 cases in December and 20 storms provided 66 cases in January through February. The majority of December storms were in regions A and C, while most February cases were in region B.

Such a comparison was subject to gross errors. In some cases the continuity of storm systems was in question; in others, the resolution of weak storm systems was in question. Gross errors in selecting cases may have introduced data points that were not members of the population. Medians rather than means were chosen as the appropriate statistic for this study, as they are less subject to the influence of possibly erroneous outlying cases. The dis- persion analog to the standard deviation is the h-spread (Tukey, 1977), the numerical difference between the upper and lower quartile values in the data set.

IV. SEA-LEVEL PRESSURE ANALYSES

Three sea-level pressure analyses were available: two objective analyses, corresponding to initializing fields for the two models, and one hand analysis. The finer meshes for the 7LPE and the LFM-II are used only for finite difference computation; the analysis fields and the forecast output fields are on the scale of their parent models, 381 and 190.5 km at 60°N.

Table 2 and Figure 5 compare the two machine analyses with the hand analysis for central pressure. There was approximately a 2-mb positive bias in the LFM-II analysis and a 3-mb bias in the 6LPE and 7LPE analysis. The h-spread was 4 mb for the LFM-II in December and 3 mb for all other cases. The analysis bias of the PE models relative to the LFM-II may be due to the use of a coarse mesh for interpolation and smoothing. The hemispheric models also use a spectral type analysis scheme (Flattery, 1970), which is known to have a slight bias of not making sharp troughs and strong lows deep enough; whereas, the LFM-II uses local interpolation (Cressman, 1959).

V. RESULTS

The separation of the forecast low center from the verifying observed low center for the three areas is shown for December for the LFM-II in Figure 6 and for the 6LPE in Figure 7. The x/y coordinates of the forecast position were recorded relative to the observed position as the origin. If one model failed to identify a case predicted by the other model, the forecast for the second model was indicated by an (x). These cases were subsequently excluded from the analysis. Figures 6 and 7 also show a histogram of central pressure errors. Table 3 lists mean and standard deviation of central pressure algebraic error, and the mean magnitude and standard deviation of the components of the vector error (x,y) in kms. Table 4 lists the median and upper and lower hinge values for the magnitude of the location vector error.

In region A for December, the LFM-II was superior to the 6LPE in locating fast-moving storms with median error distances of 250 km (LFM-II) and 574 km (6LPE). This is apparent from the scatter plots, Figures 6 and 7. The 6LPE had a fairly Gaussian distribution of forecasts about the verifying position; whereas, the LFM-II results consisted of a cluster of forecasts a short distance southwest of the origin with two major outlying points to the northeast. Central pressure errors were comparable for both models. Shifting to region B, 10 of the 13 cases considered a single storm that stalled in the central Gulf of Alaska. Both models showed small errors in position. Central pressures, however, were consistently underforecast, i.e., higher than observed. In two cases both models underforecast on the order of 10 - 15 mb. In region C the LFM-II had a slight advantage over the 6LPE in central pressure and similar errors in location. Both models, but particularly the 6LPE, tended to forecast south of the observed position.

During the period 19 January - 28 February, the performance of the LFM-II contrasted with that of December (Figure 8). In area A the mean and median position error and central pressure errors were greater than during the December period. The LFM-II tended to place storms to the north of their observed locations. As most storms were on a north-northeast trajectory, this implied speeds of propagation faster than those observed. The new 7LPE

(Figure 9) showed results similar to the LFM-II in region A. The 7LPE also had a position bias to the north, although not as great as that of the LFM-II. The position error diagrams for both models showed Gaussian-type scatter in contrast to those of the LFM-II for December. In the northern section, area B, the 7LPE was superior to the LFM-II. Neither model showed position error bias. In February, region C contained only five samples. The 7LPE had large position-error statistics based upon two outlying points in a small sample.

We now consider the category of missed features. A missed feature is any forecast that does not exhibit a strong similarity in cyclonic curvature of the isobars corresponding to a closed low or significant trough feature on the observed map, or any forecast that has a low center which is not observed. Table 5 lists observed-but-not-forecast low centers and forecast-but-not-observed centers. Storms in December consisted of several major lows with long trajectories that were consistently forecast by the LFM-II. In February, out of 66 forecasts, the LFM-II missed features on 18 and the 7LPE missed on 15. Recourse to the daily maps indicated that many of these cases occurred during the early development of lows within the analysis region. However, one 989-mb low center was missed for four consecutive 7LPE forecasts despite its continued presence in the initialization fields. The last column of Figure 5 indicates the cases in which only one model forecast showed a significant feature. The low numbers indicate that both the LFM-II and the 7LPE tended to miss features on the same forecasts. Five of the eight cases which were forecast by the 7LPE but not the LFM-II were in the northwest quadrant of the region near the edge of the LFM-II grid. In several of the cases where the LFM-II provided the forecast, the 7LPE tended to be either slow to develop or too fast to weaken a storm.

VI. DISCUSSION

This study provides a comparison of truncation errors of three different mesh sizes: 127 km, 190.5 km, and 381 km, for short-term forecasts over the North Pacific. As the December cases clearly indicate, there is an improvement in position error and ability to forecast observed features in the fine mesh LFM-II compared to the coarse-mesh 6LPE. Brown (1975) showed a similar conclusion after comparing the old LFM with the 6LPE for 30 forecasts of winter east-coast storms. However, our analysis showed the 7LPE in February performed at a comparable level to the LFM-II, suggesting the existence of a threshold value of mesh length for estimating storm motion in the North Pacific.

Shuman (1978) showed continued improvement in forecasting the location of surface low-pressure centers over the eastern United States for mesh lengths as small as 60 km. Shuman showed selected days of strong storm development that warrant a finer mesh. Indeed many of the storms in our observed-but-not-forecast category were tied to initial development, an implication consistent with the earlier studies of Leary (1971) and Brown (1974).

Although all three models in this study have ostensibly the same model physics, damping due to effective model viscosity and overt smoothing is reduced with smaller grid size. The LFM-II in December showed many good forecasts with a few extreme outlying cases. The average northward displacement of lows in region A in February also showed a tendency for the model to

move storms faster than observed. Given the data gaps in upper-air observations over the Pacific as compared to the coverage over the continental United States, one can speculate that misplaced features would develop more readily with a finer mesh model. Thus, while a fine mesh may give a superior forecast for a selected case, a mesh length of 100 - 200 km is a good compromise length for current NMC models when performance evaluation is median position statistics.

During February many storms passed near the Aleutian Island Chain near the edge of the LFM-II model domain. This led to observed-but-not-forecast errors for the LFM-II in February and, probably, larger position and central-pressure errors as well.

VII. CONCLUSIONS

A comparison was made between the LFM-II and 6LPE and 7LPE models based upon 107 36-hr forecasts of sea-level pressure from December 1977 and from 19 January through 28 February 1978. The magnitude of forecast errors depended on the location, speed, and age of the particular storm. The LFM-II was superior to the 6LPE in locating rapid movement of storms. The LFM-II median position error was 250 km in region A for December. The LFM-II and the new 7LPE performed in a similar fashion during February. Both had median position errors in region A on the order of 450 km and a high percentage of observed-but-not-forecast storm systems. Even within regional groupings, the set of storms formed a heterogeneous collection of central pressures, forward speeds, and directions. From this set of data no clear bias for position errors could be determined.

VIII. ACKNOWLEDGMENTS

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TABLE 1

CHARACTERISTICS OF THE VARIOUS NMC PRIMITIVE EQUATION MODELS

MODEL	AREA	NO. OF LEVELS	GRID SIZE @60 NORTH	DATES
6LPE	N. Hemisphere	6	381. km	June 66 - Jan 78
LFM	N. America	6	190.5	Sept 71 - Aug 77
LFM-II	N. America	6	127.0	Sept 77 -
7LPE	N. Hemisphere	7	190.5	Feb 78 -

TABLE 2

DIFFERENCE IN CENTRAL PRESSURE VALUES OF THE AUTOMATED SEA LEVEL PRESSURE
ANALYSIS AND THE HAND PLOTTED ANALYSIS (MACHINE CP) - (HAND CP) IN MB

	MODEL	CASES	MEDIAN	MEAN	SD
Dec.	LFM-II	37	1.	1.28	3.51
	6LPE	37	3.	3.11	3.31
Jan.-	LFM-II	39	2.	2.03	3.46
Feb.	7LPE	39	3.	3.56	3.60

TABLE 3

MEANS AND STANDARD DEVIATION OF FORECAST CENTRAL PRESSURE ERROR AND LOCATION VECTOR ERROR
MAGNITUDE AND COMPONENTS IN KMS.   CENTRAL PRESSURE ERRORS ARE OBSERVED MINUS FORECAST IN MBS.

	Type	Region	Cases	CP DIF		DIST		X(east)		Y(north)		$\sqrt{\bar{x}^2 + \bar{y}^2}$
				Mean	SD	Mean	SD	Mean	S_x	Mean	S_y	
D E C	LFM-II	A	16	-3.1	5.1	350	276	63	285	-85	339	106
	LFM-II	B	13	-9.2	6.8	252	150	-28	241	89	152	93
	LFM-II	C	8	0.5	6.8	367	102	159	250	-70	282	174
	6LPE	A	16	-2.1	5.0	507	220	-96	361	-106	395	143
	6LPE	B	13	-8.0	7.8	263	137	-48	204	39	193	61
	6LPE	C	8	-4.1	7.6	410	239	-48	258	-363	237	367
19 J A N F E B	LFM-II	A	11	-5.9	7.8	504	244	28	395	287	317	289
	LFM-II	B	23	-6.7	7.8	437	278	-61	415	-15	361	63
	LFM-II	C	5	-8.0	7.8	474	287	278	436	-30	258	280
	7LPE	A	11	-7.7	5.2	436	276	26	276	158	423	159
	7LPE	B	23	-5.6	6.6	358	309	-87	228	95	278	128
	7LPE	C	5	-5.2	3.6	471	228	-78	463	-82	526	113

-8-

TABLE 4

MEDIAN AND HINGE VALUES FOR LOCATION VECTOR ERROR MAGNITUDE

-9-

	Type	Region	Cases	DIST Hinge	DIST Median	DIST Hinge	X Hinge	X Median	X Hinge	Y Hinge	Y Median	Y Hinge
DECEMBER	LFM-II	A	16	148	250	389	-130	-37	130	-259	-93	-56
	LFM-II	B	13	111	259	371	-130	-56	56	-19	74	204
	LFM-II	C	8	287	417	426	-37	222	398	-278	-139	74
	6LPE	A	16	306	574	695	-398	-167	-28	-389	-195	222
	6LPE	B	13	185	241	278	-241	0	93	-93	-37	148
	6LPE	C	8	259	408	426	-148	9	158	-426	-380	-241
19 Jan-Feb.	LFM-II	A	11	352	445	621	-250	37	176	65	408	500
	LFM-II	B	23	241	371	621	-232	19	269	-46	0	139
	LFM-II	C	5	315	500	741	74	334	649	-222	-56	37
	7LPE	A	11	241	463	612	-158	74	195	-148	37	537
	7LPE	B	23	167	259	445	-195	-93	65	-56	37	185
	7LPE	C	5	259	537	649	-278	-204	-111	-259	-56	130

TABLE 5

GROSS ERROR TABLE

	Type	Observed, Not Forecast	Forecast, Not Observed	Single Forecasts
Dec	LFM-II	0	2	4
	6LPE	4	1	0
Jan	LFM-II	18	5	5
Feb	7LPE	15	4	8

36 HR FCST SLP
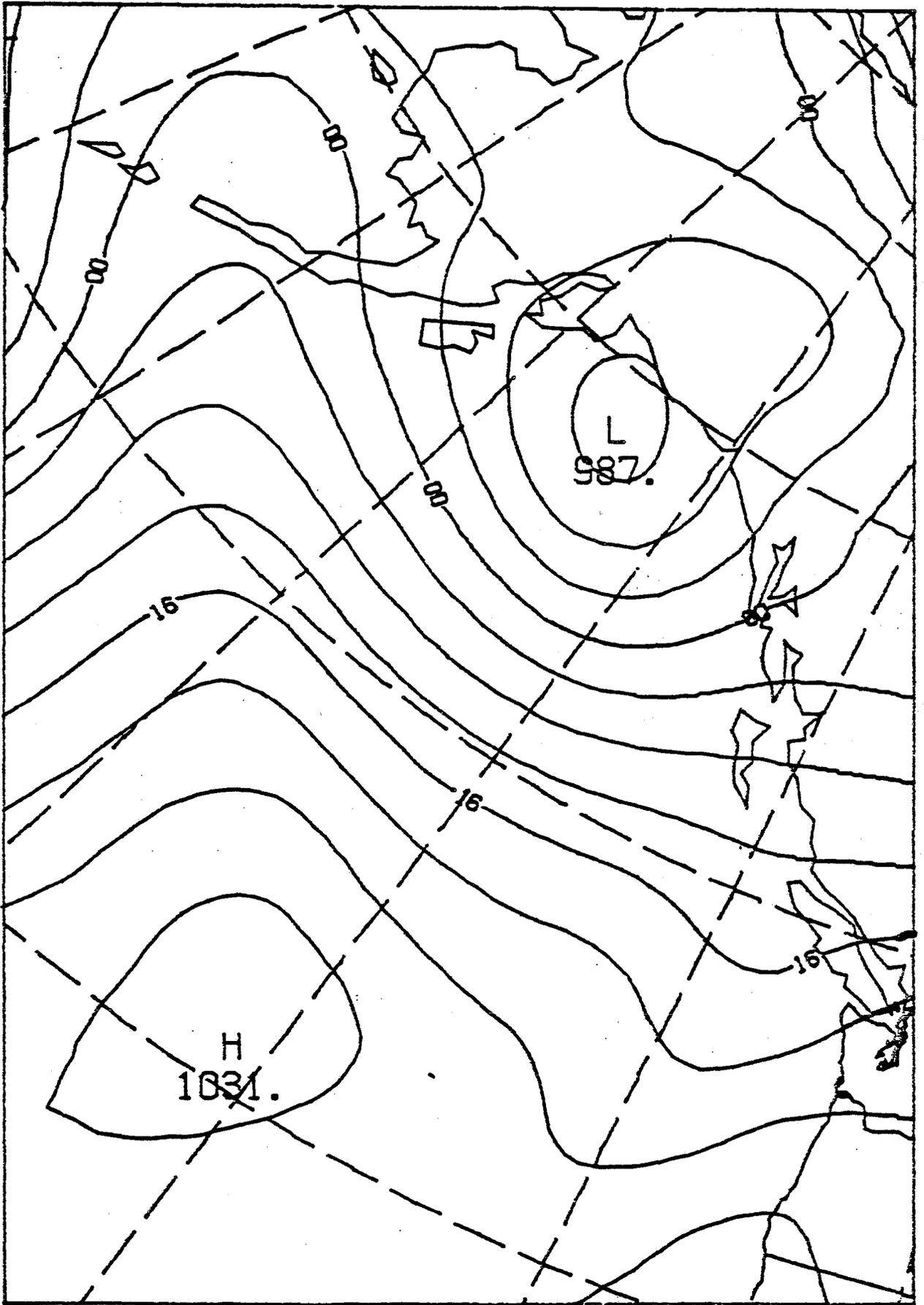
OOZ 23 JAN 1978

Figure 1.   Sample Sea-Level Pressure Plot.
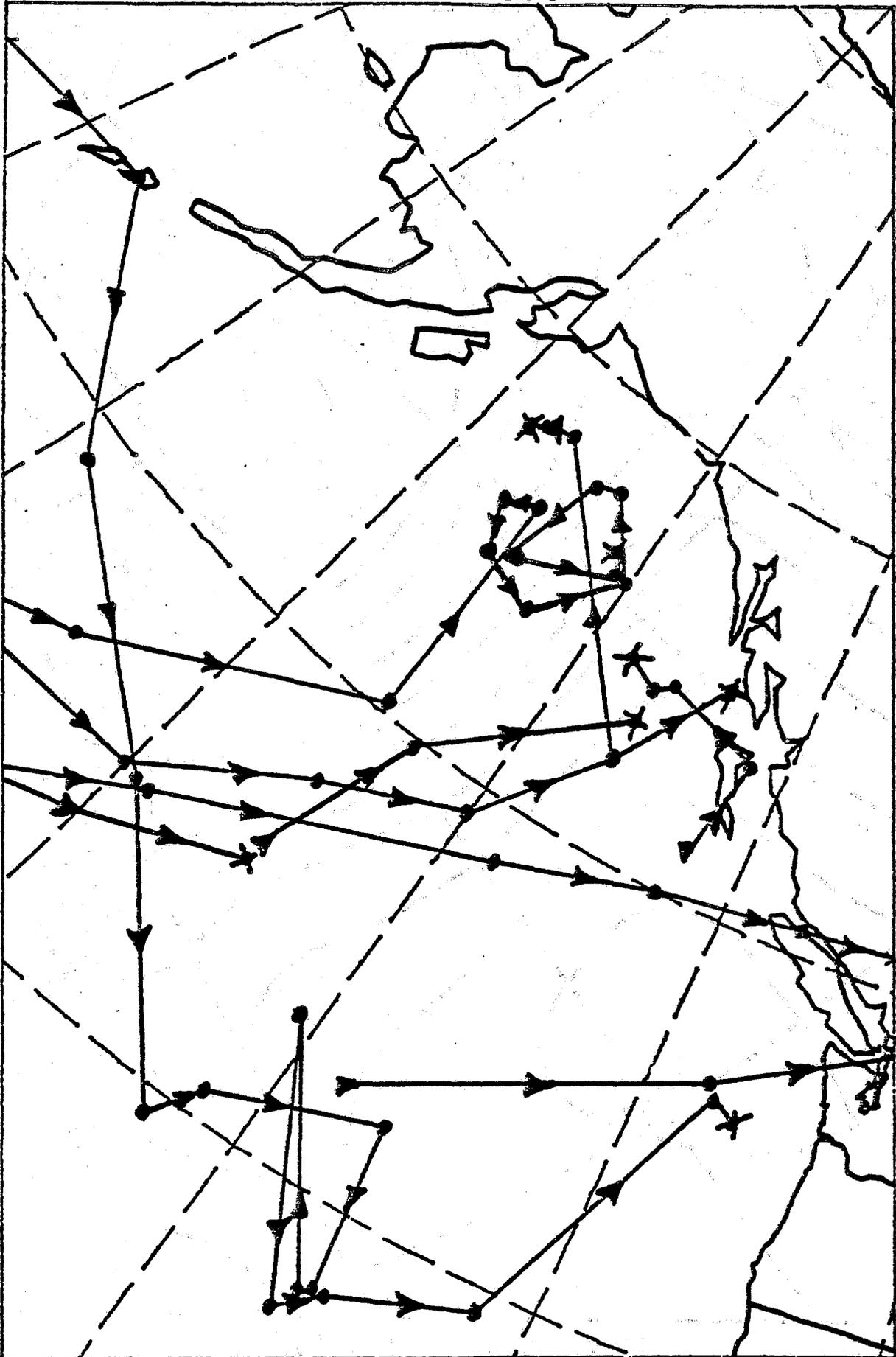
Figure 2. Storm Tracks for the Northeast Pacific, December 1977.

19 january - february 1978
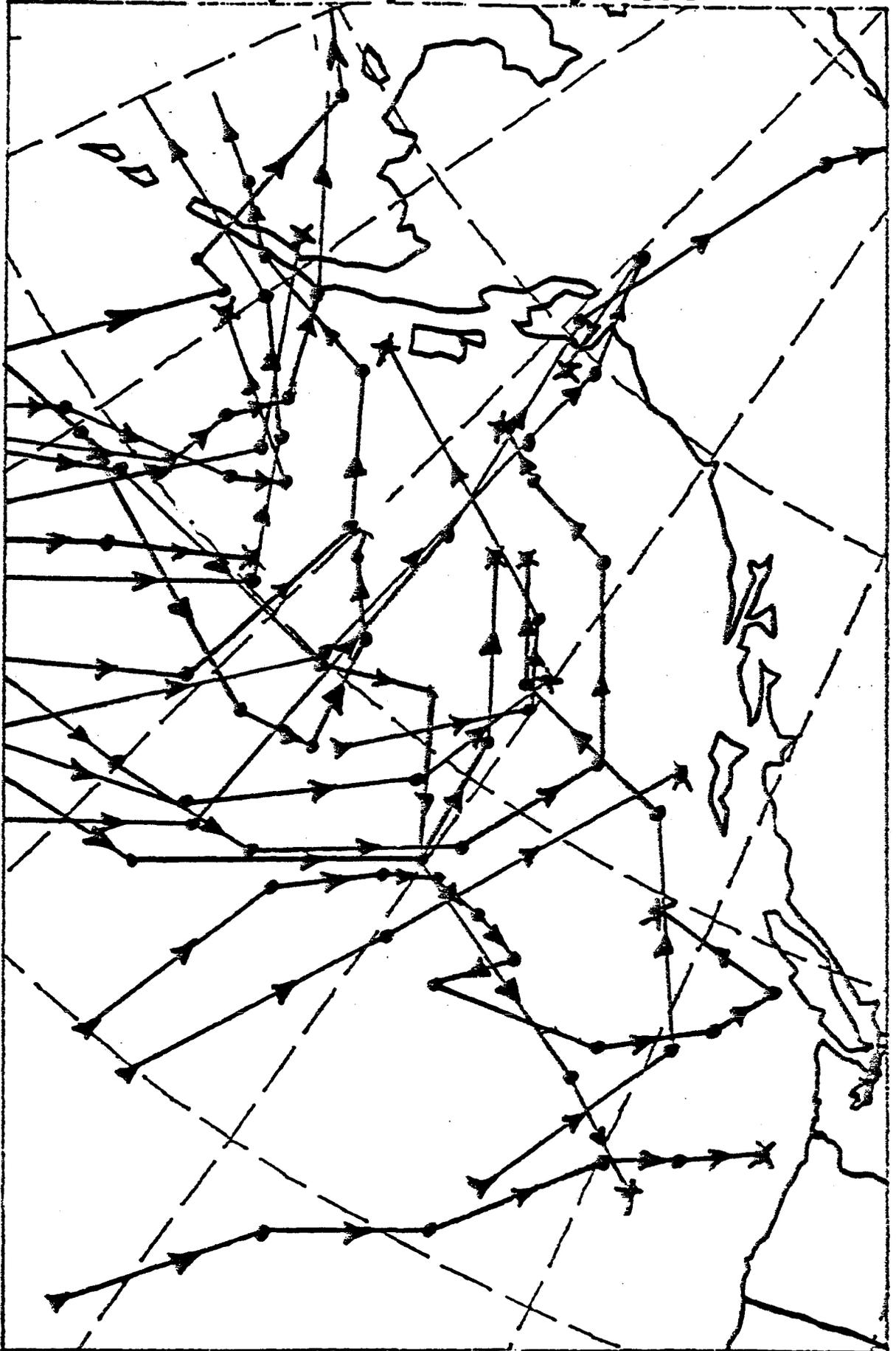
Figure 3.   Storm Tracks for the Northeast Pacific, 19 January - 28 February 1978.
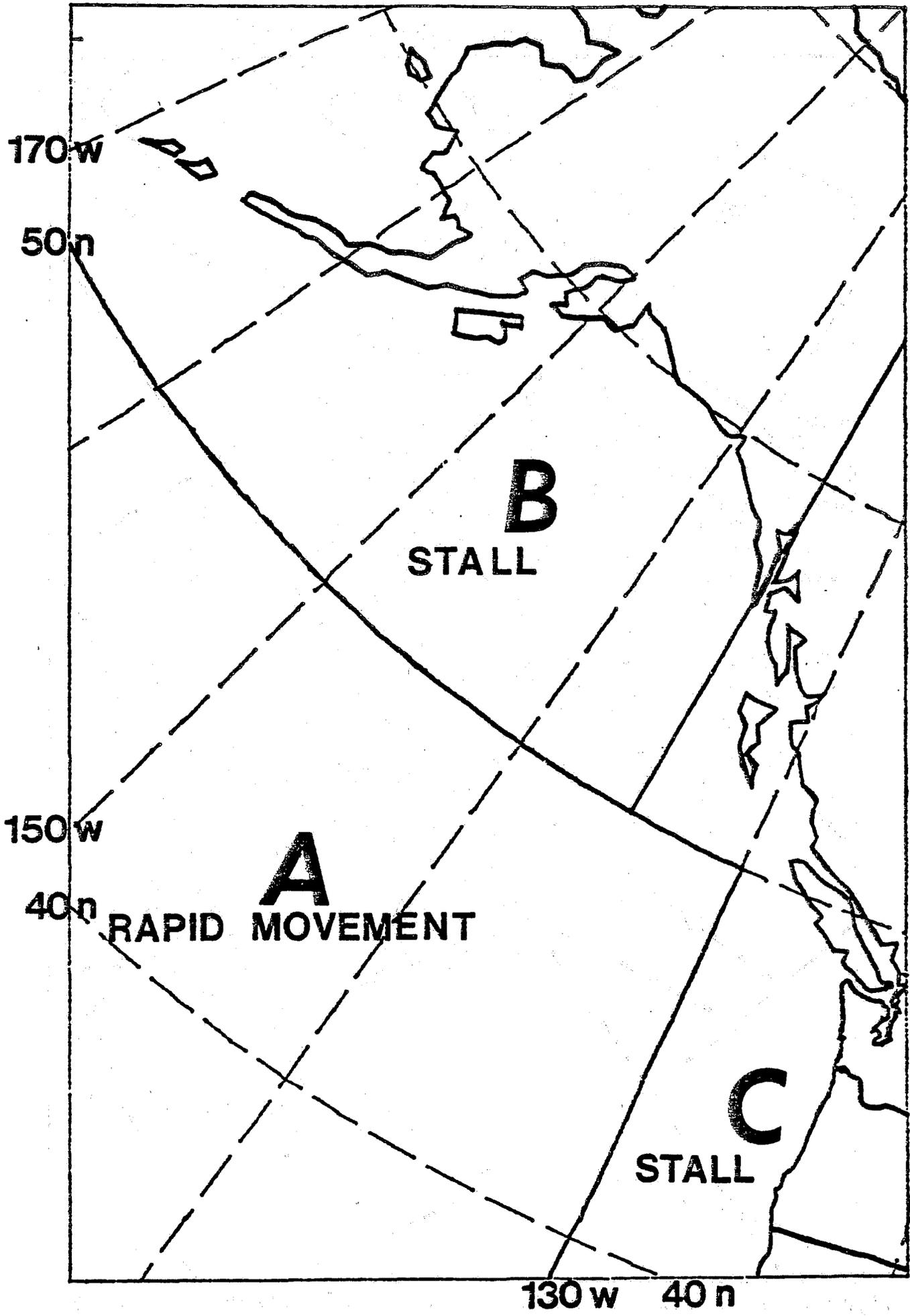
Figure 4.   Division of the Northeast Pacific into Three Analysis Regions.
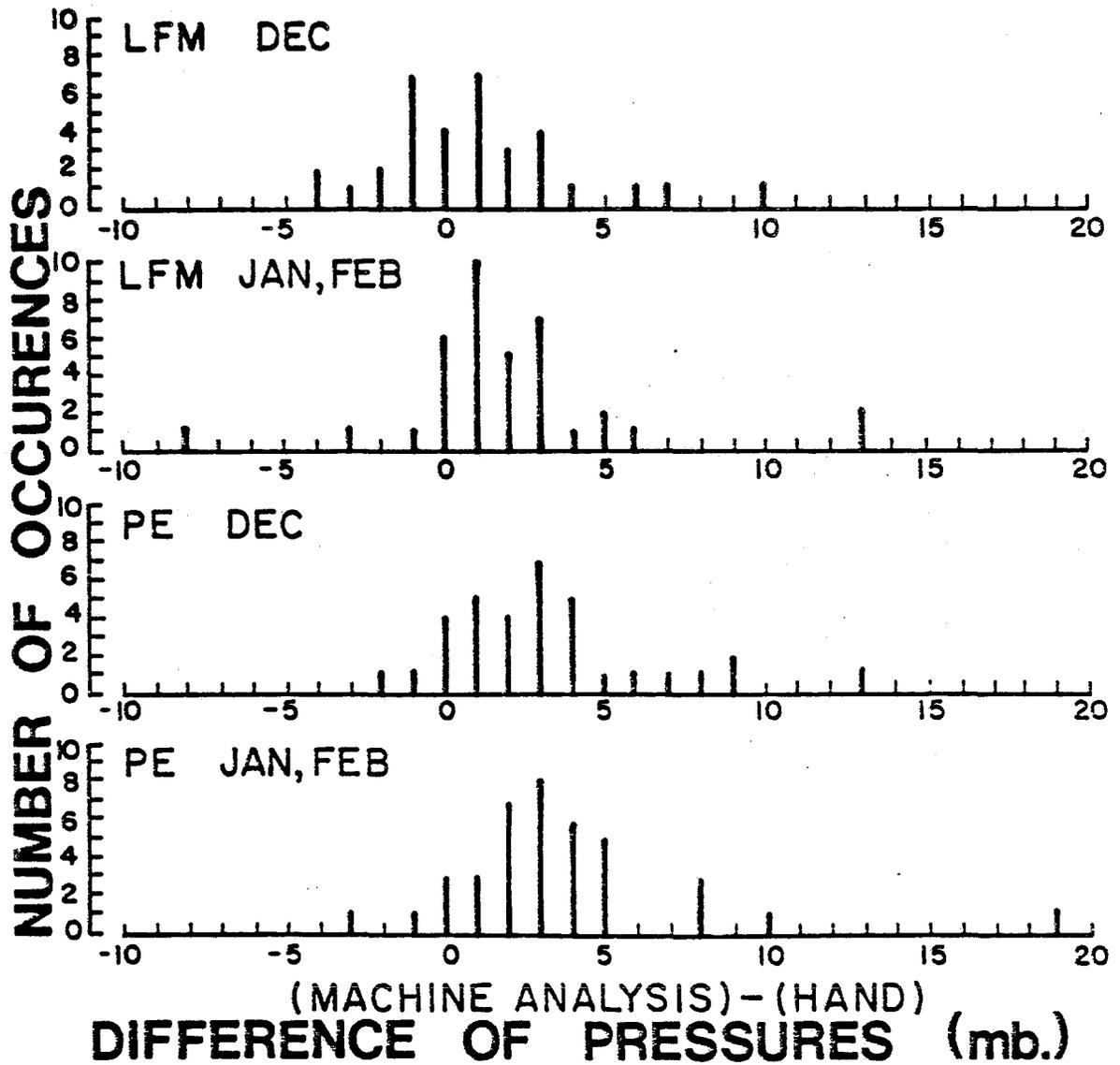
Figure 5.   Frequency diagram of the difference in central pressure values of the
NMC hand-plotted sea-level pressure analysis and the automated analysis
on the LFM and PE grid.
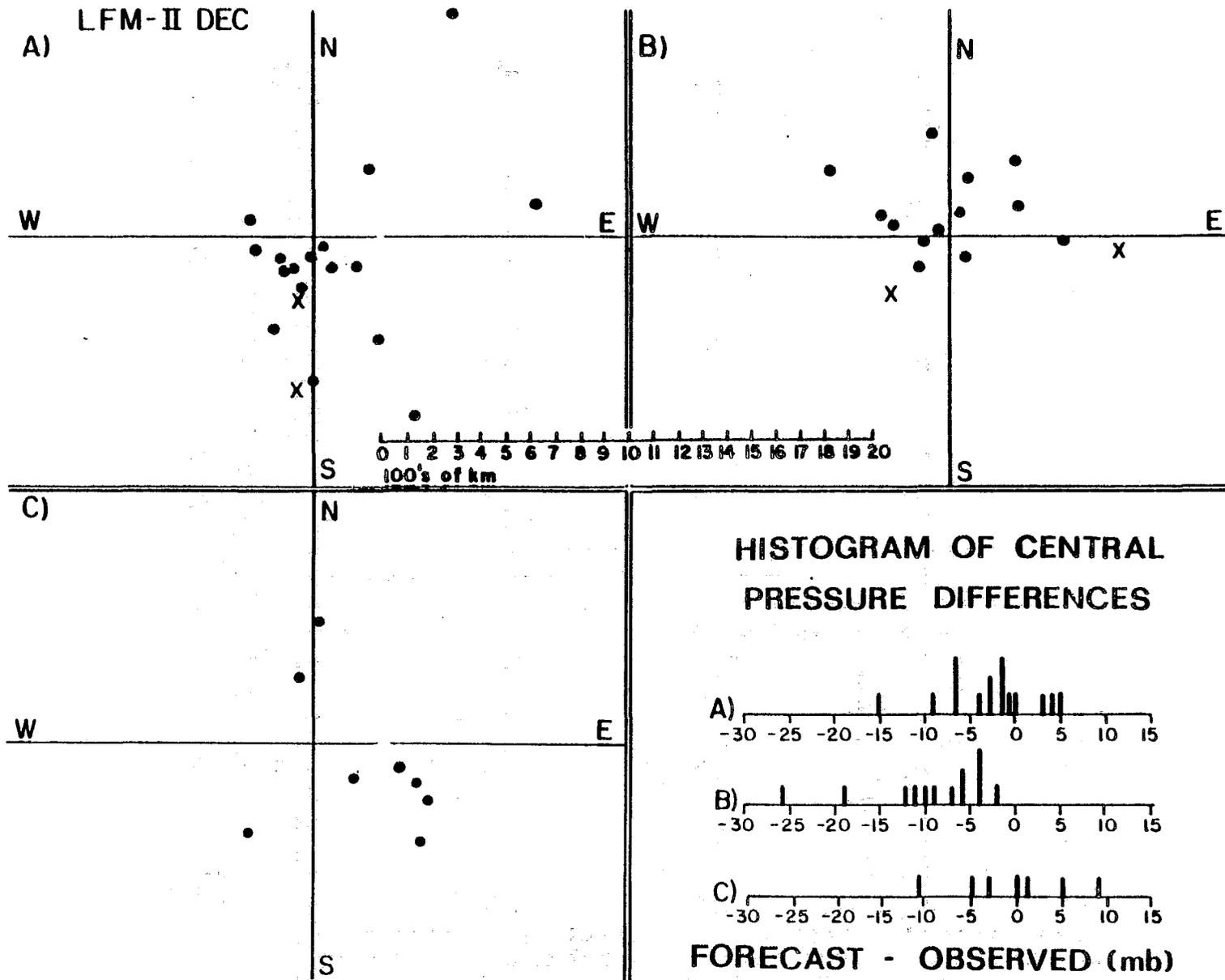
Figure 6. Scatter plot of forecast storm-center locations relative to the observed location as the origin for the LFM-II in December. Lower left corner shows the frequency distribution of forecast central pressures minus observed central pressures.
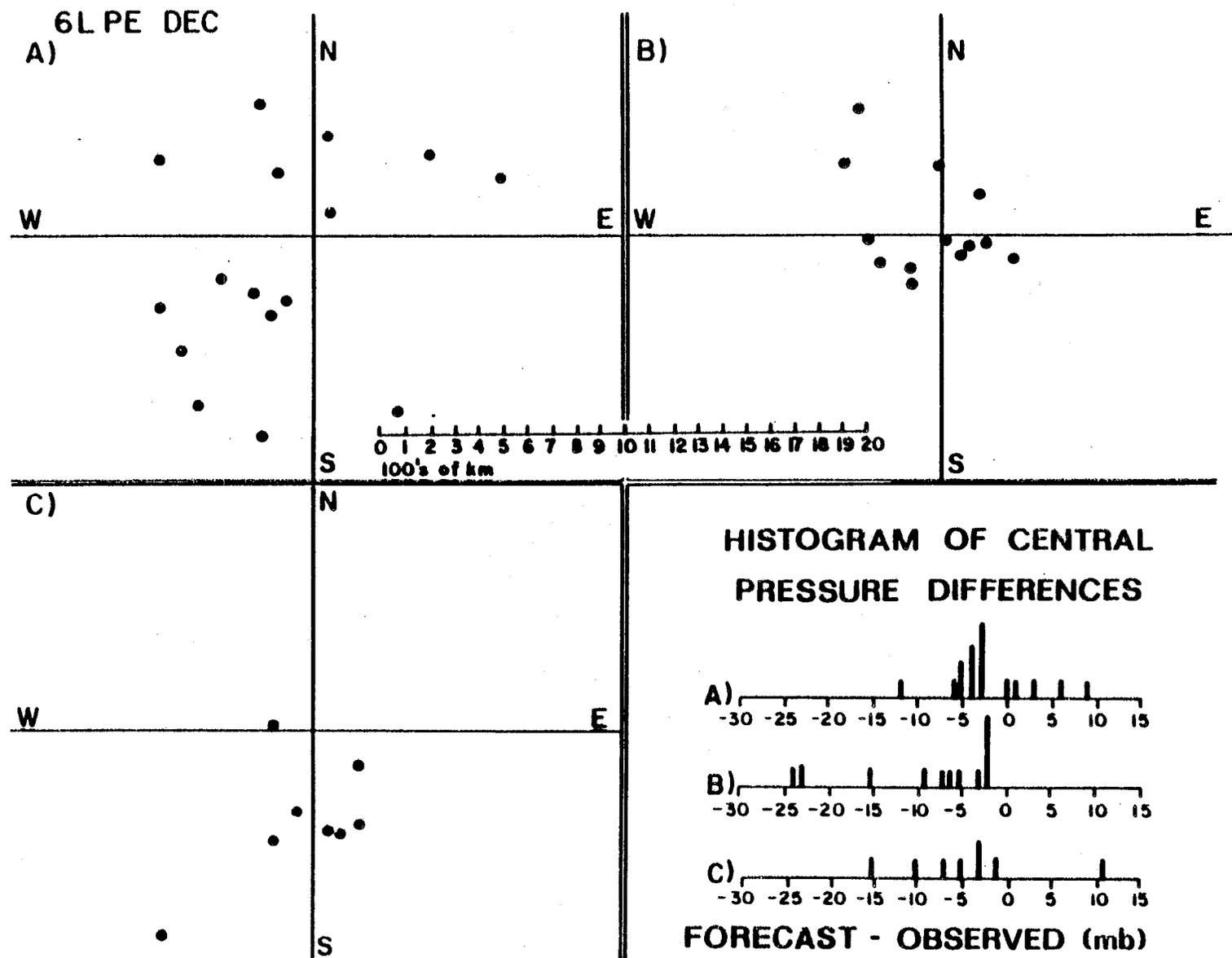
Figure 7. Scatter plot of forecast storm-center locations relative to the observed location as the origin for the 6LPE in December. Lower left corner shows the frequency distribution of forecast central pressures minus observed central pressures.
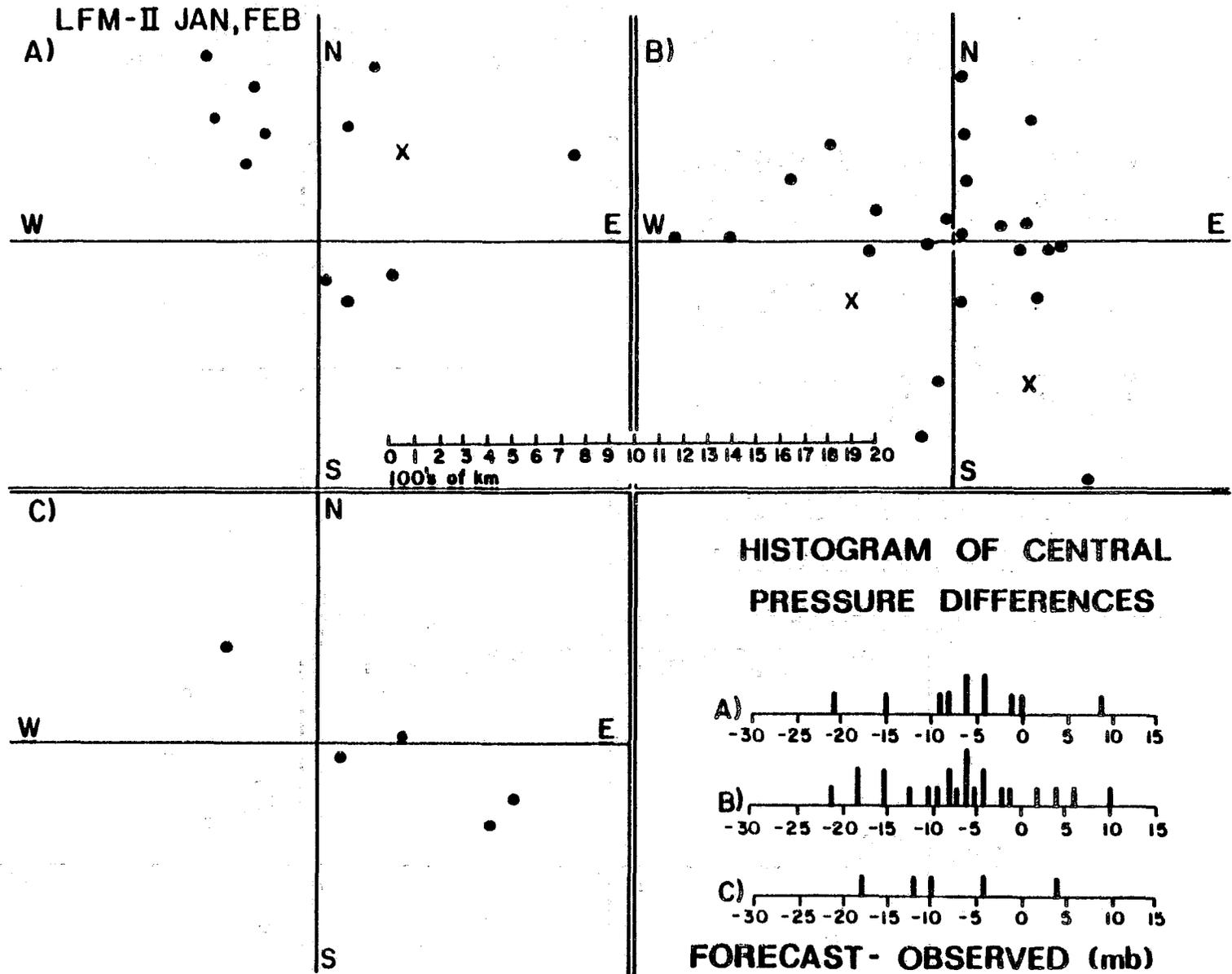
Figure 8. Scatter plot of forecast storm-center locations relative to the observed location as the origin for the LFM-II in January - February. Lower left corner shows the frequency distribution of forecast central pressures minus observed central pressures.

7L PE JAN,FEB

A)

B)

HISTOGRAM OF CENTRAL
PRESSURE DIFFERENCES

C)

100's of km

A)
-30 -25 -20 -15 -10 -5 0 5 10 15

B)
-30 -25 -20 -15 -10 -5 0 5 10 15

C)
-30 -25 -20 -15 -10 -5 0 5 10 15

FORECAST - OBSERVED (mb)
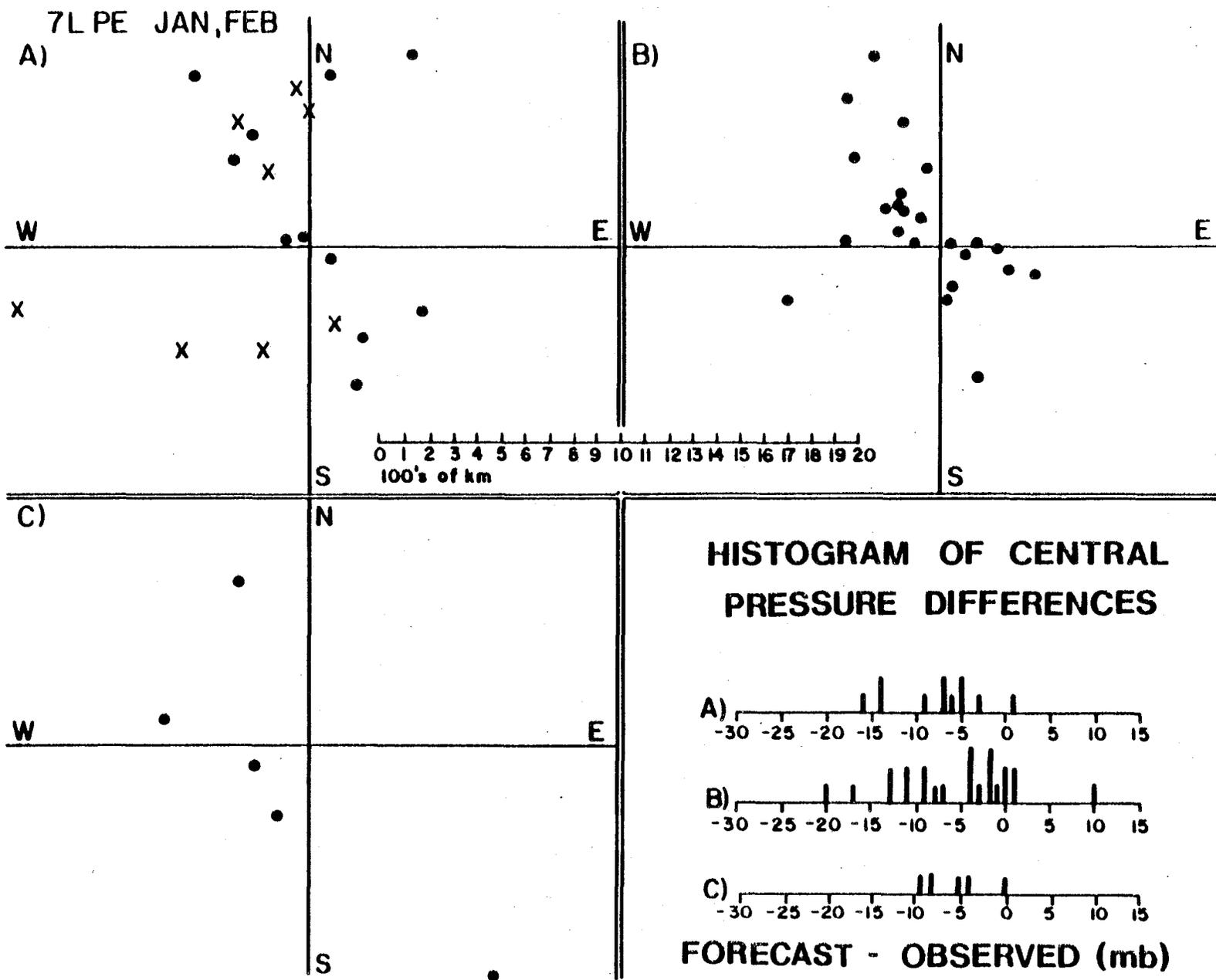
Figure 9.   Scatter plot of forecast storm-center locations relative to the observed
location as the origin for the 7LPE in January - February. Lower left
corner shows the frequency distribution of forecast central pressures
minus observed central pressures

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