PE Progress Report 3-71

PRIMITIVE EQUATION MODEL PROGRESS REPORT

January 1971 - March 1971

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1. Monthly Mean Error Patterns

Figures 1, 2, and 3 depict the monthly mean error patterns for 24-hour PE sea-level pressure progs for January, February, and March 1971, respectively. Figures 4, 5, and 6 show the corresponding 48-hour error patterns.

Figures 7, 8, and 9 depict the monthly mean error patterns for 24-hour PE 500 MB height progs for January, February, and March 1971, respectively. Figures 10, 11, and 12 show the corresponding 48-hour error patterns.

Recalling that monthly mean error patterns are designed to show systematic bias in the model, note the improving trend during the period in the 24-hour surface progs as shown in Figures 1, 2, and 3. In general, most of the systematic errors were located over land areas in February and March. Figures 4, 5, and 6 also show improving trends in the 48-hour progs, particularly so in the Atlantic and Mediterranean.

Figures 7, 8, and 9 indicate this same improving trend at 500 MBS. The persistent negative bias over Northwest Africa and over the southwestern U.S. has been very difficult to diagnose. Elsewhere, the magnitudes are smaller and considerably easier to evaluate.

Figures 10,11 and 12 show that we still have significant systematic errors by 48-hours, at 500 MBS. Over Africa, this amounts to about -90 meters. Elsewhere, the biases are generally less than 60 meters.

2. Verification Statistics

Table 1 contains the RMS scores (in millibars) for PE Model sea-level pressure progs. It is important to note that the model is more courageous than the SLP in that it tends to predict about the same amount of change (in an RMS sense) that actually occurs. Comparing the actual change (persistence error) to the forecast error, one sees that the model contains a lot of skill to 36 hours and some skill even after 72 hours. In the forecast error column, note the remarkable consistency from month-to-month for each forecast tau.

Table 2 shows the model's performance in terms of percent improvement over persistence, summarized by tau and month. Table 3 has the same statistics for the SLP Model (until it was no longer run in parallel with the PE). The differences speak for themselves.

Table 4 illustrates the degree to which the model is predicting the observed changes (courage index). The five-month averages (by tau) show that we are very close in this regard. For any particular month and tau, the model generally predicts the amount of change within about 6%.

Project FAMOS compared the FNWC PE Model to the NMC PE Model during the month of January. Verification statistics (skill score and average error) were kept for 36-hour sea-level pressure progs at 60 points in both the Atlantic (25N-55N, 65W-15E) and Pacific (25N-55N, 135E-145W). In general, the FNWC Model was more skillful than the NMC Model in the Pacific, but slightly worse in the Atlantic. Recalling that a smaller skill score is better, the results were:

	FNWC	NMC
Atlantic	57.9	57.3
Pacific	57.3	59.1

Any score less than 60 was considered a good forecast.

A recent paper by David P. Baumhefner entitled "Global Real-Data Forecasts with the NCAR Two-Layer General Circulation Model" (NWR, Volume 98, Number 2) helps us keep our perspective. This rather complex model was used for a series of four-day forecasts using real data. The following quote is extracted:

"By the time the forecast has reached 48 hours, the skill shown by the surface pressure prediction was minimal. The central pressure of the three major storms in the Northern Hemisphere is in error by over 30 millibars."

3. Error Patterns as a Diagnostic Tool

Figures 13, 14, and 15 represent the mean sea-level pressure distributions in January, February, and March, respectively. Figures 16, 17, and 18 are the corresponding mean 500 MB distributions.

Analyst-forecasters using PE Model guidance materials (progs) should visually correlate the mean height and pressure patterns with the appropriate mean error patterns as an exercise. Caution is advised in putting too much faith in error patterns in poor data areas, especially the 500 MB patterns over oceans. A few illustrations follow.

a. Mediterranean Area

Note the 500 MB means for the Mediterranean region as shown in Figures 16, 17, and 18. In both January and February the trough was located in the central Med, but upstream the ridging was much more pronounced in February. Thus, flows tended to cross the mountains at a larger angle in February. Next, look at the 48-hour surface pressure errors in Figures 10, 11, and 12. The systematic negative bias shown in February is significantly worse (as a consequence). In March, however, the trough shifted position westward to a line from Spain down the Moroccan coast, with quasi-zonal flow across the Med. The systematic error essentially disappeared.

COMMENT. We realize that both model changes and seasonal factors are pertinent to a discussion of this nature. Additionally, we feel that the problem is intimately connected with the inability to model the complex topographic variations and land-water relationships that exist in this region with a coarse grid.

b. Eastern United States Area

Using the same chart set, note the 500 MB patterns over the continental U.S. Flow differences are at a minimum. In March the eastern Pacific ridging weakened somewhat, and in February the mean trough was located more toward the central U.S. California cut-off lows (troughs) were less prevalent in March.

From Figures 13, 14, and 15 one sees rather large differences in the surface pressure distributions. In January, for example, the mean ridge extending from the Dakotas southeastward to the Gulf was stronger in the mean than in subsequent months.

Yet, Figures 4, 5, and 6 indicate that model bias was minimal over the U.S. One is tempted to conclude that the Rocky Mountains, being of much larger horizontal extent than the European mountains, are much less difficult to treat in atmospheric models.

Critical evaluation of U.S. region forecasts during the quarter do indicate the following shortcomings in the model:

(1) under-translation of pressure systems (see PE Progress Report 2-71).

(2) slight over-development of surface highs over continents.

(3) slight under-development of lows which spawn in the lee of the southern Rockies. (This is more noticeable in "dry" small-scale storms.)

(4) over-development of Gulf of Mexico lows in the which the middle tropospheric westerlies overlay moist tropical air. (The main problem is related to an overactive convective precipitation mechanism, but other factors play a role. These are poor initialization, proximity to the restoration boundary, and the general inadequacy of dynamic methods in these latitudes.)

c. Western United States and Eastern Pacific

The basic problem in this region is lack of upper air data to initialize the model in the eastern Pacific. But other factors may be of importance.

Note the large, persistent negative errors at 500 MBS in Figures 10, 11, and 12. These patterns are as difficult to evaluate as those shown over northwest Africa, but may in fact be related. By this we mean that both of these negative biases coincide with kinetic energy sources for the three-wave (hemispheric) subtropical jet (STJ). We suspect that the missing error pattern (which would be over China) may well be non-existent because we have good upper air coverage. (This STJ hypothesis has not been tested).

Other factors which are relevant are proximity to restoration boundaries, and possible geostrophic adjustment problems for flows which are quasi-parallel to topography contours.

These are just a few illistrations of possible uses of these charts. The reader is invited to study the error patterns carefully, and supplement them with his own notes on regional model problems.

4. Model Changes During the Quarter

a. 6 January 1971

(1) eliminated bullseyes in some upper tropospheric height progs caused by scaling spills.

(2) eliminated bad spots on the surface prog borders.

(3) put in routine to ellipticize surface pressure progs small-scale highs.

b. 26 January 1971

(1) shifted PE internal boundary from 17N to 11N in an attempt to reduce the unrealistic growth of sub-tropical surface pressure gradients (experimental change).

(2) used a Laplacian-type smoother between equator and 23N on output surface pressure progs.

c. 8 February 1971

(1) took out ellipticizor and replaced it with a simple computational routine to fractionally reduce the pressure profiles of highs greater than 1020 MBS.

(2) eliminated topography south of 9 degrees North.

(3) devised and coded a different type of restoration boundary condition, the effect of which was to restore (after an integration time step, and in the tropical restoration area only) the values of the variables back toward their values at the previous time step (rather than toward their <u>initial</u> value). The geostrophic adjustment process was enhanced by this, and did lead to a much better control of sub-tropical and mid-latitude highs and the associated peripheral gradients on the south side.

COMMENT. All of the ramifications of this coding change were not understood until mid-March. Since the so-called "heating package" temperature changes are calculated once an hour (after the temperatures are restored in the boundary region), restoration back to the previous value vice initial value inadvertently caused systematic cooling in the upper atmosphere south of 23N. But because of this coding oversight we were able to detect that the long-wave radiational losses were excessive. It is our feeling that the February results were below par for this reason.

d. 13 March 1971

(1) devised and coded a diagnostic-type tropopause in the output temperature/height structure, based on a regression equation by Eady.

COMMENT. Tropopauses generally occur between the model's two uppermost computational levels on which temperatures are known. Distributions of temperatures (and heights between 300 MBS and 100 MBS were constructed assuming temperatures varied linearly in log-pressure between computational levels. This, of course, led to incorrect density and geostrophic wind forecasts at 250-, 200- and 150- MBS.

The tropopause pressure is computed as a function of the 300-500 MB and 150-100MB thicknesses at each output tau. It is constrained to lie between 400 MBS and 120 MBS, but varies in space-time consistent with the meteorological situation.

5. Model Changes in the Near Future

a. Re-partitioning of PE Model

At present, we partition the computational burden to achieve parallelism. By this, we mean that the various equations are evaluated in different processors, but each processor does its job on the entire horizontal-vertical domain. In the near future we will code a four-processor model which will do everything the current four-processor model does, but each processor will calculate the results for one-fourth of the grid points. By this we hope to achieve a speed-up of 10-15% (this amounts to a savings of two processor-hours per day).

b. Divergent Initial Winds

The final touches are being put on the solution of a three-dimensional omega equation from which the Chi-winds will be computed. Earlier experiments indicated that the Chi-winds are not too important for short progs, but become increasingly important as the forecast period lengthens. Further, by starting the model with initial vertical velocities, the time required for adjustment of the mass-motion fields is minimized.

c. Terrain

As discussed earlier, optimum specification of the underlying terrain is a difficult, complex task. One fact is clear: it is pointless (and even detrimental) to represent scale features in the terrain that the grid and finite-differencing scheme cannot resolve. Further, we know that by over-smoothing we can produce unrealistic meteorological patterns. By including too much terrain realism (precipitous terrain gradients; island spikes; knife-edge ranges) computational instabilities result.

In any event, more developmental effort in this respect is necessary. We hope to have this problem minimized before the end of the summer season.

d. Precipitation Rates

During the past several months precipitation patterns have, on occasion, been unrealistic. Sometimes the trouble appeared as a small bullseye; on the other occasions abnormally heavy bands of precipitation occurred near the subtropical internal boundary.

In the scheme which parameterizes cumulus clouds and precipitation, several empirical controls can be adjusted. For example, we can regulate the degree of conditional instability before precipitation and adjustment takes place. At present, this criterion is uniform over the entire hemisphere. Thus, we can tune the mechanism for optimum realism.

e. Wind Verification

Programs are being tested at present to verify both the independent PE winds and the derived geostrophic winds from the model. These winds will be compared to the observed winds over North America at the 850-, 500- and 300- millibar levels.

The results will be summarized for bi-weekly or monthly periods, and be expressed in terms of vector mean wind errors at each verifying station together with some measure of error vector dispersal (standard deviation), by wind type, forecast length, and level.

f. Staggered Grid

The problem of truncation error was addressed in PE Progress Report 2-71. Recall that two alternatives were discussed: shifting to fourth-order differencing; and/or computing on a finer mesh; noting that the latter was not possible with our present computers.

Actually, a third possibility might well be considered; that is, reprogram the model using a staggered grid. In one such type of scheme, the wind components are carried at odd-numbered points (say) and mass-field parameters at even-numbered points. Other more complicated schemes have been devised and summarized in the literature.

The essential points are that both the truncation error and the central memory requirements can be significantly reduced.

Table 1

RMS VERIFICATION OF PE MODEL SURFACE PRESSURE PROGS
(by month and tau; in millibars)

Tau	Month	Forecast Change	Actual Change	Forecast Error
12	NOV	4.4	4.3	3.0
	DEC	4.6	4.3	3.0
	JAN	4.7	4.7	3.0
	FEB	4.4	4.3	3.0
	MAR	4.3	4.3	2.9
24	NOV	6.8	6.9	4.5
	DEC	7.0	6.7	4.6
	JAN	7.4	7.3	4.4
	FEB	6.7	6.8	4.4
	MAR	6.5	6.8	4.2
36	NOV	8.3	8.3	5.9
	DEC	8.5	8.2	5.9
	JAN	9.1	9.1	5.9
	FEB	8.3	8.4	5.9
	MAR	8.0	8.5	5.5
48	NOV	9.2	9.3	7.1
	DEC	9.4	9.0	7.1
	JAN	10.3	10.4	7.1
	FEB	9.4	9.2	7.2
	MAR	8.9	9.3	6.8
60	NOV	10.1	10.1	8.5
	DEC	10.1	9.7	7.8
	JAN	11.2	10.9	8.0
	FEB	10.0	9.8	8.4
	MAR	9.5	9.8	7.9
72	NOV	10.4	10.2	8.9
	DEC	10.5	10.2	8.6
	JAN	11.4	11.4	8.8
	FEB	10.8	10.3	9.5
	MAR	9.8	10.2	8.9

Table 2

PE MODEL PERFORMANCE

PERCENT IMPROVEMENT OVER PERSISTENCE

(SEA LEVEL PRESSURE PROGS)

Tau	NOV 1970	DEC 1970	JAN 1971	FEB 1971	MAR 1971
12	30.2	30.2	36.2	30.4	33.6
24	34.8	31.4	39.5	34.7	37.7
36	29.0	28.1	35.2	29.9	35.2
48	24.8	21.2	31.8	21.9	27.7
60	15.0	19.6	26.6	14.1	19.2
72	11.7	15.7	22.8	7.7	13.6

Table 3

SLP MODEL PERFORMANCE

PERCENT IMPROVEMENT OVER PERSISTENCE

Tau	November 1970	December 1970	January 1971
12	18.6	23.2	19.1
24	16.0	16.4	16.4
36	8.4	7.3	8.8
48	1.1	1.1	3.8
60	-5.0	-2.1	-4.6
72	-10.9	-11.8	-9.7

NOTES: (1) The SLP Model has not been run in parallel with the PE Model since January.

(2) A negative sign indicates that persistence was better.

Table 4

PE MODEL PERFORMANCE

FORECAST CHANGE AS A PERCENTAGE
OF ACTUAL CHANGE

Tau	NOV 1970	DEC 1970	JAN 1971	FEB 1971	MAR 1971	AVERAGE
12	102.3	106.9	100.0	102.8	100.0	102.4
24	98.6	105.2	101.4	99.3	94.3	100.2
36	100.0	103.6	100.0	99.0	93.4	99.2
48	99.0	104.4	99.9	101.7	95.6	100.1
60	100.0	103.0	102.7	102.0	97.1	101.0
72	101.9	102.9	100.0	105.3	96.0	101.2

NOTE: A number 101.5 indicates that the Model predicted 1.5% more change in an RMS sense that actually occurred.

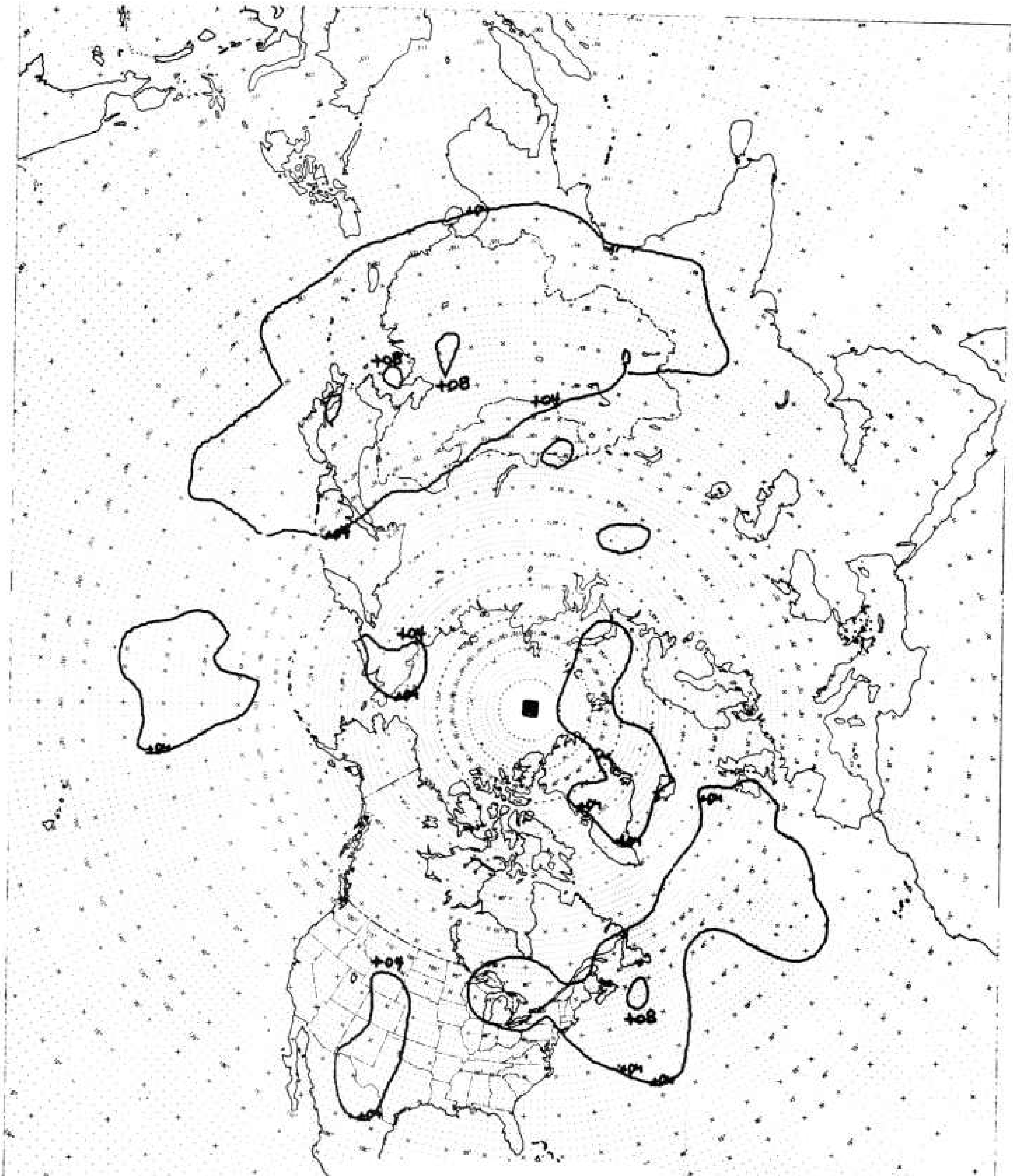

Figure 1. January 1971 Mean Error Patterns for 24-Hour PE Surface Pressure Progs

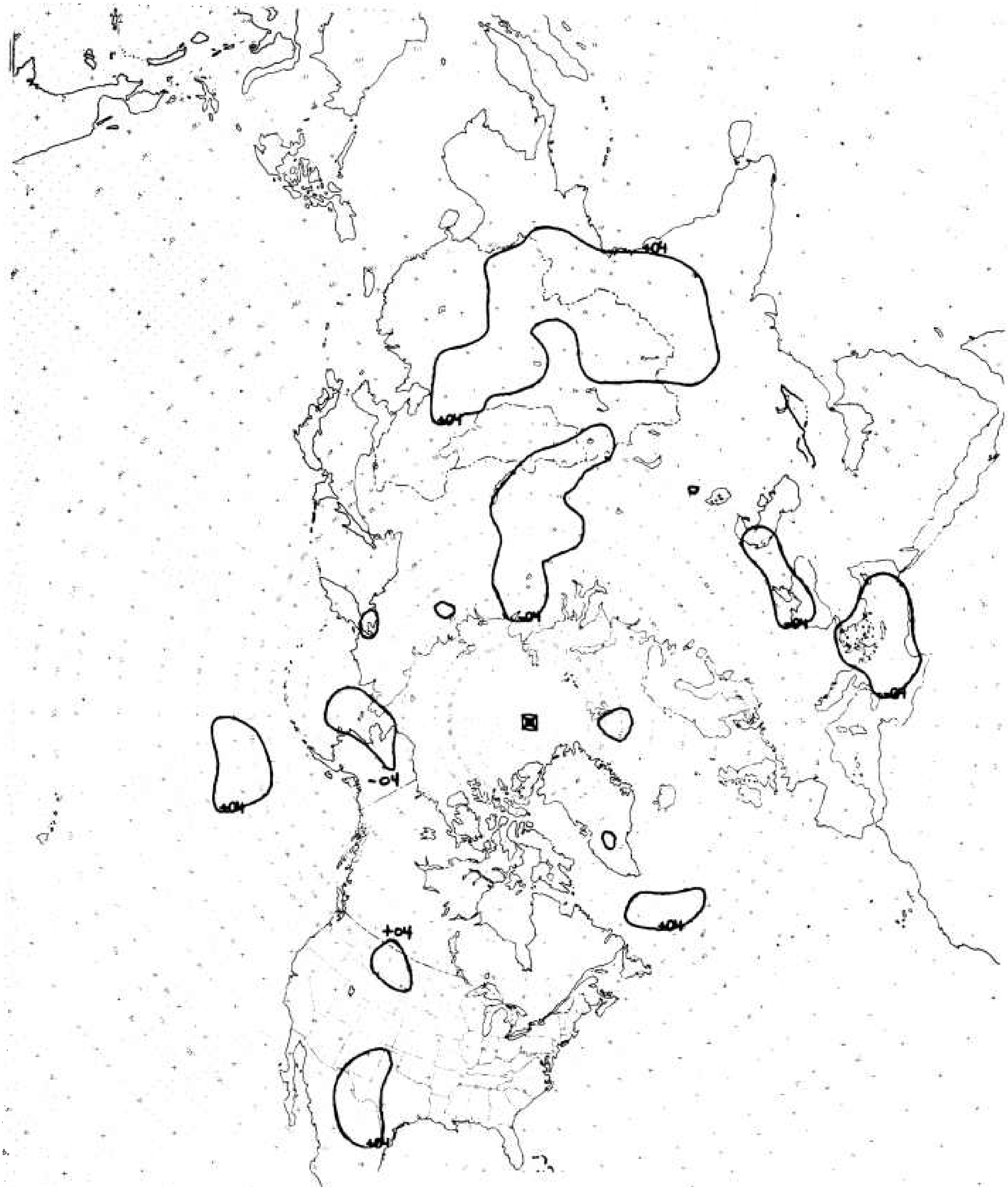

Figure 2. February 1971 Mean Error Patterns for 24-Hour PE Surface Pressure Progs

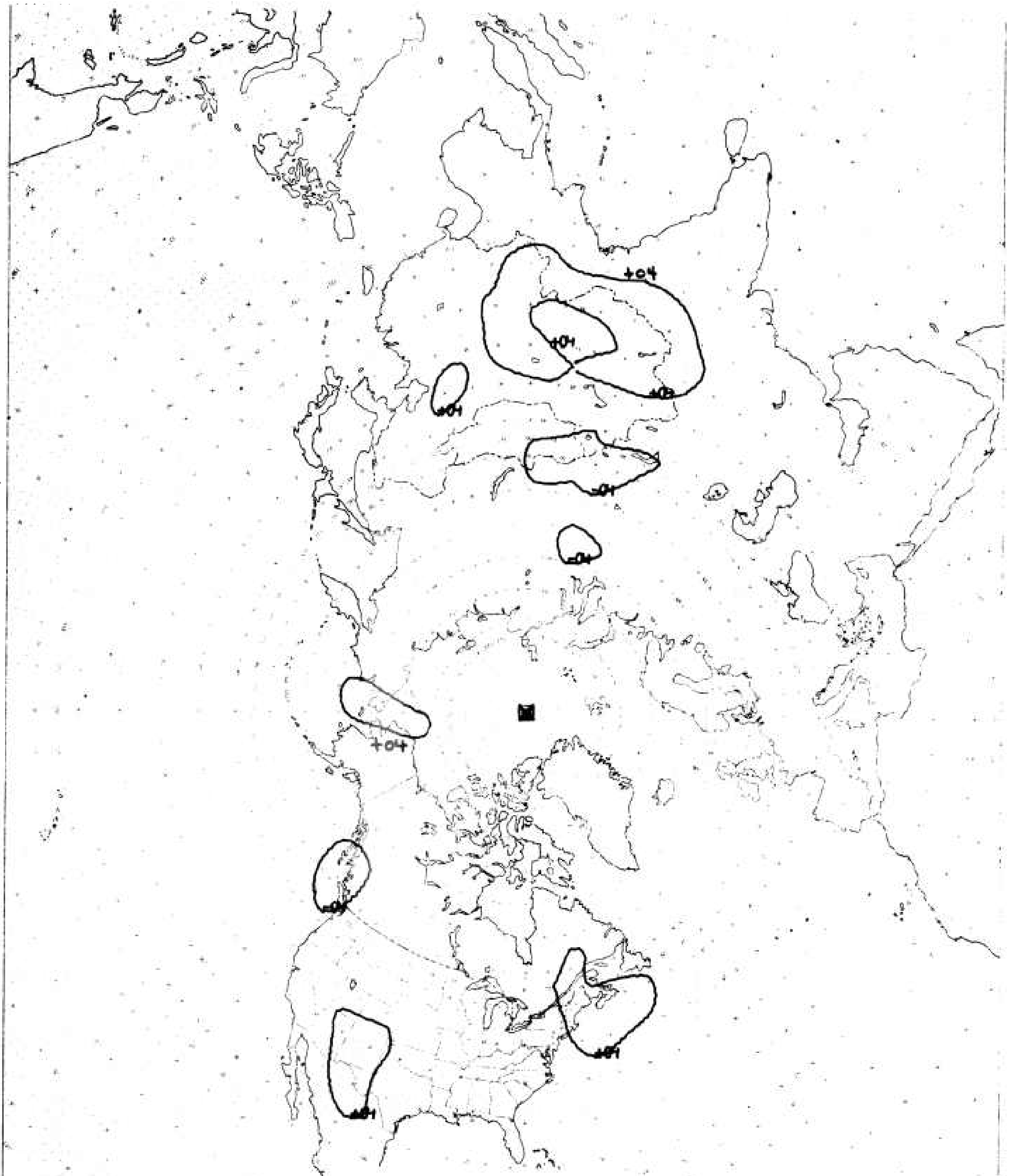

Figure 3. March 1971 Mean Error Patterns for 24-Hour PE Surface Pressure Progs

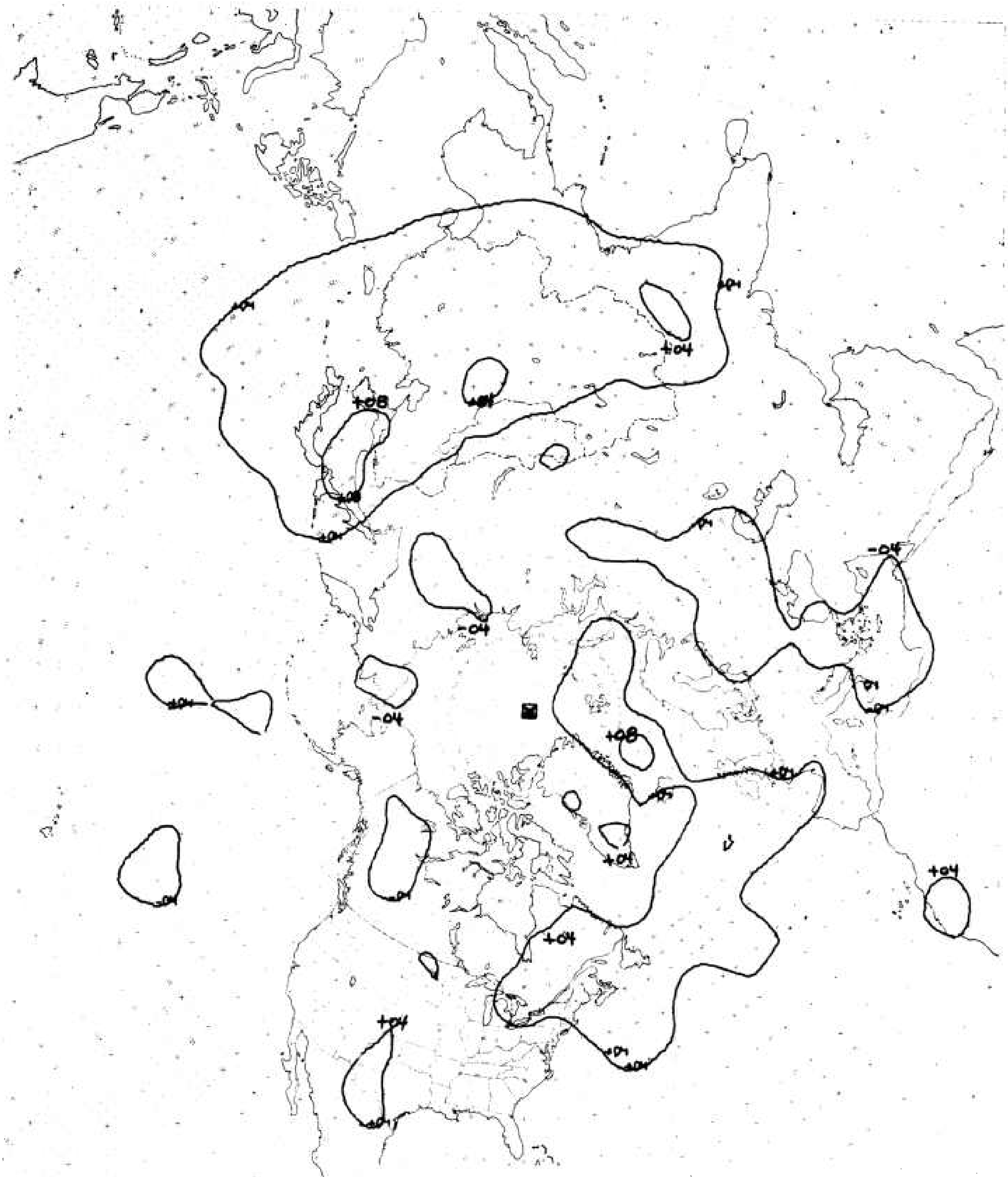

Figure 4. January 1971 Mean Error Patterns for 48-Hour PE Surface Pressure Progs

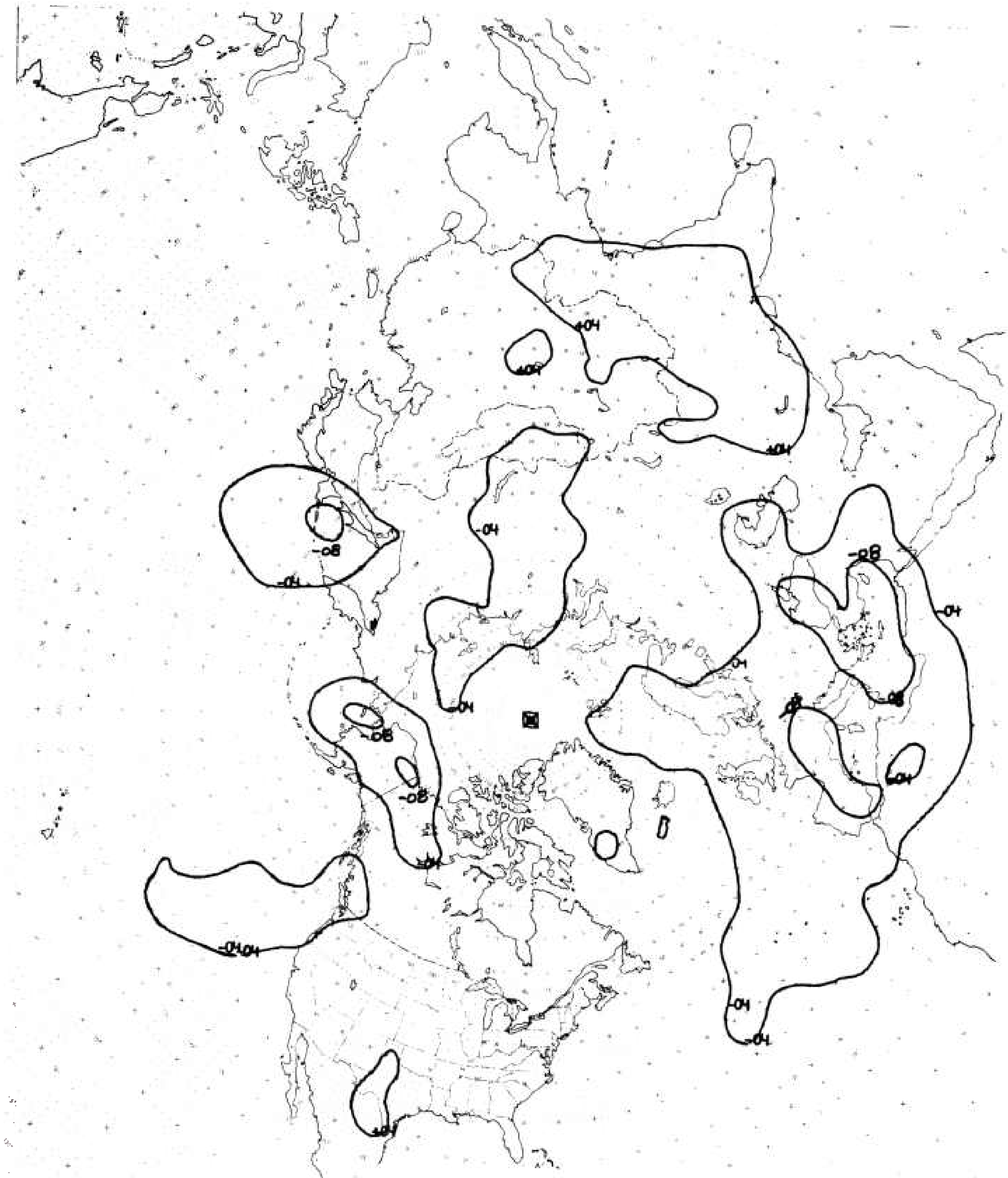

Figure 5. February 1971 Mean Error Patterns for 48-Hour PE Surface Pressure Progs

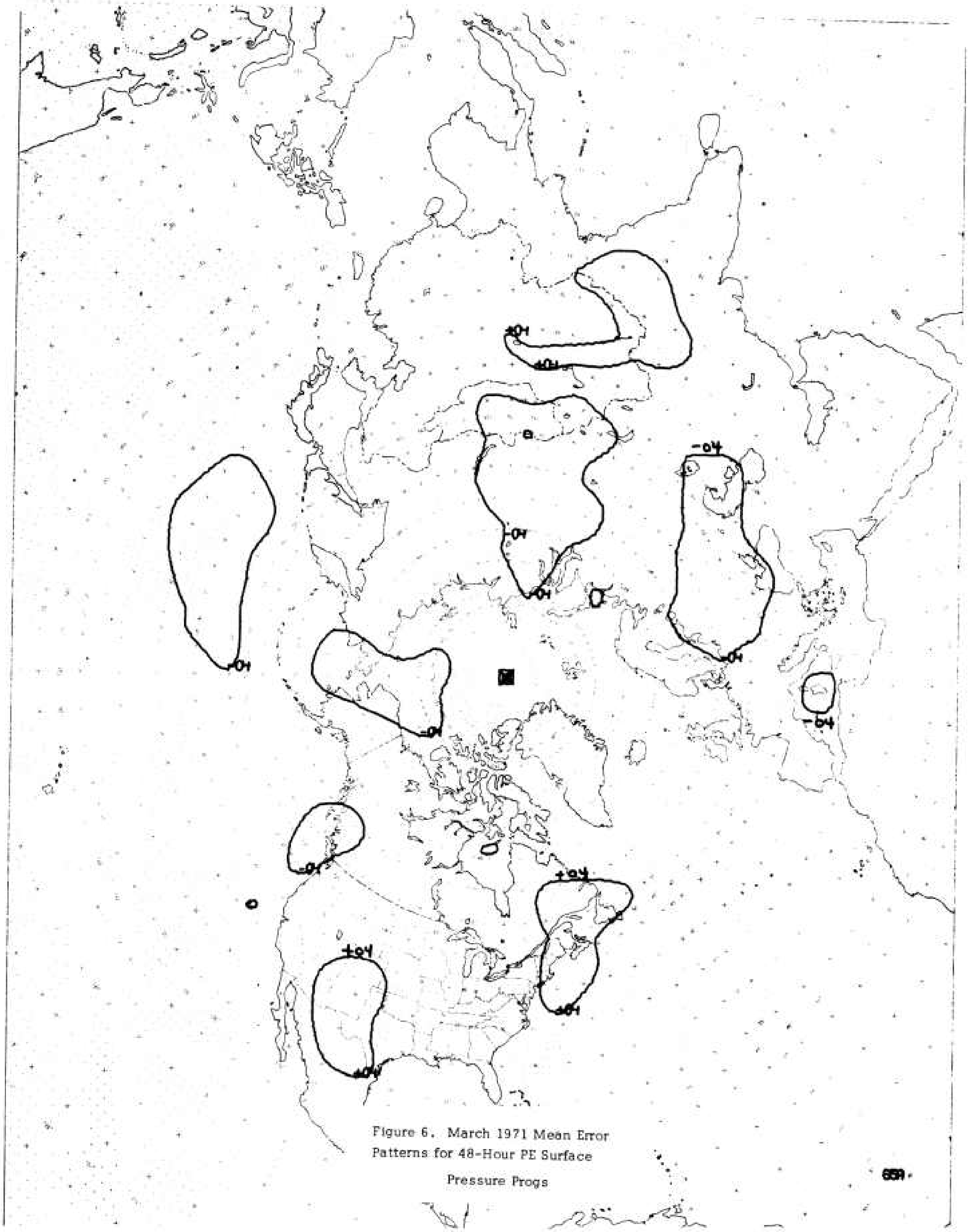

Figure 6. March 1971 Mean Error Patterns for 48-Hour PE Surface Pressure Progs

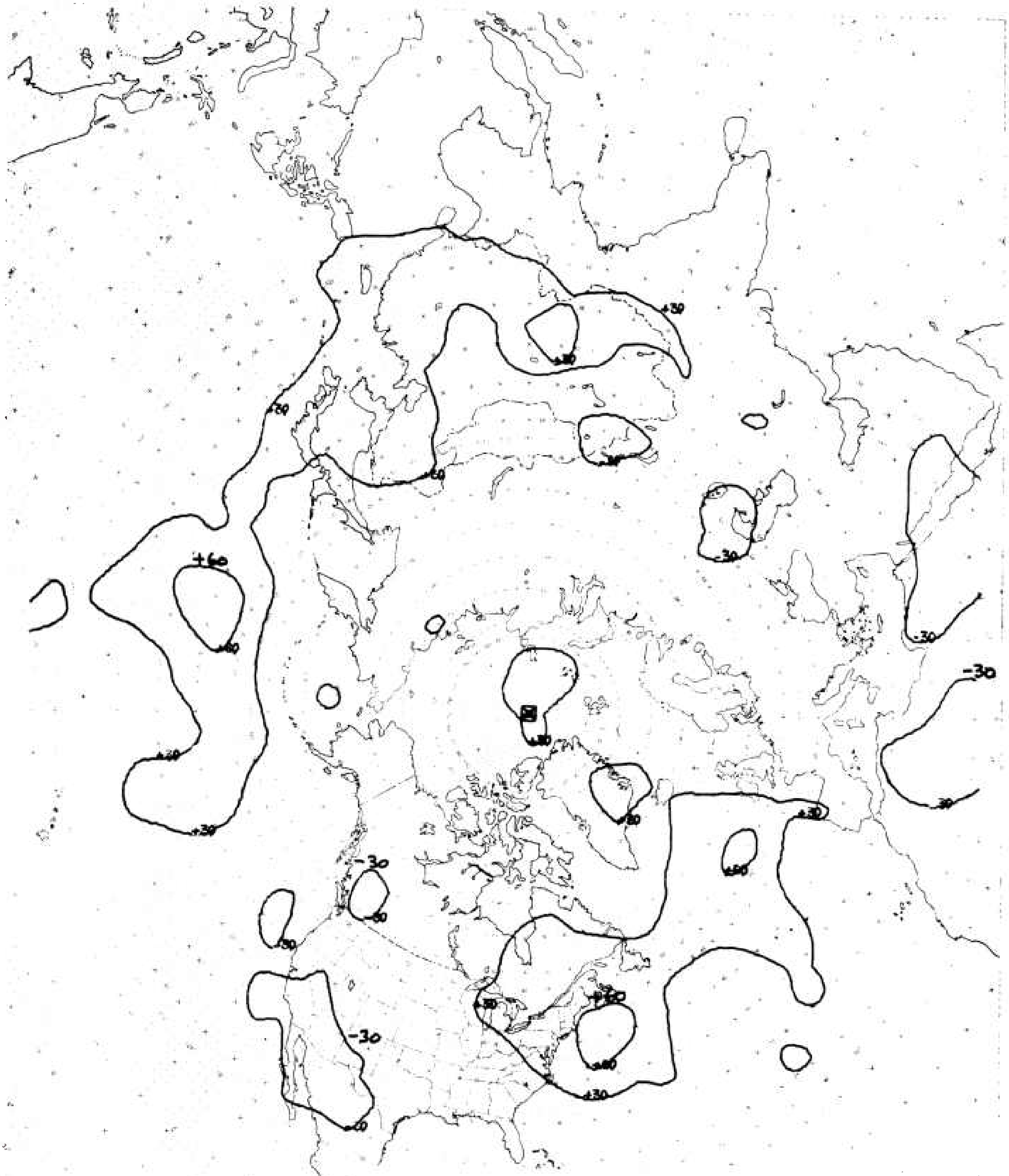

Figure 7. January 1971 Mean Error Patterns for 24-Hour PE 500 MB Progs

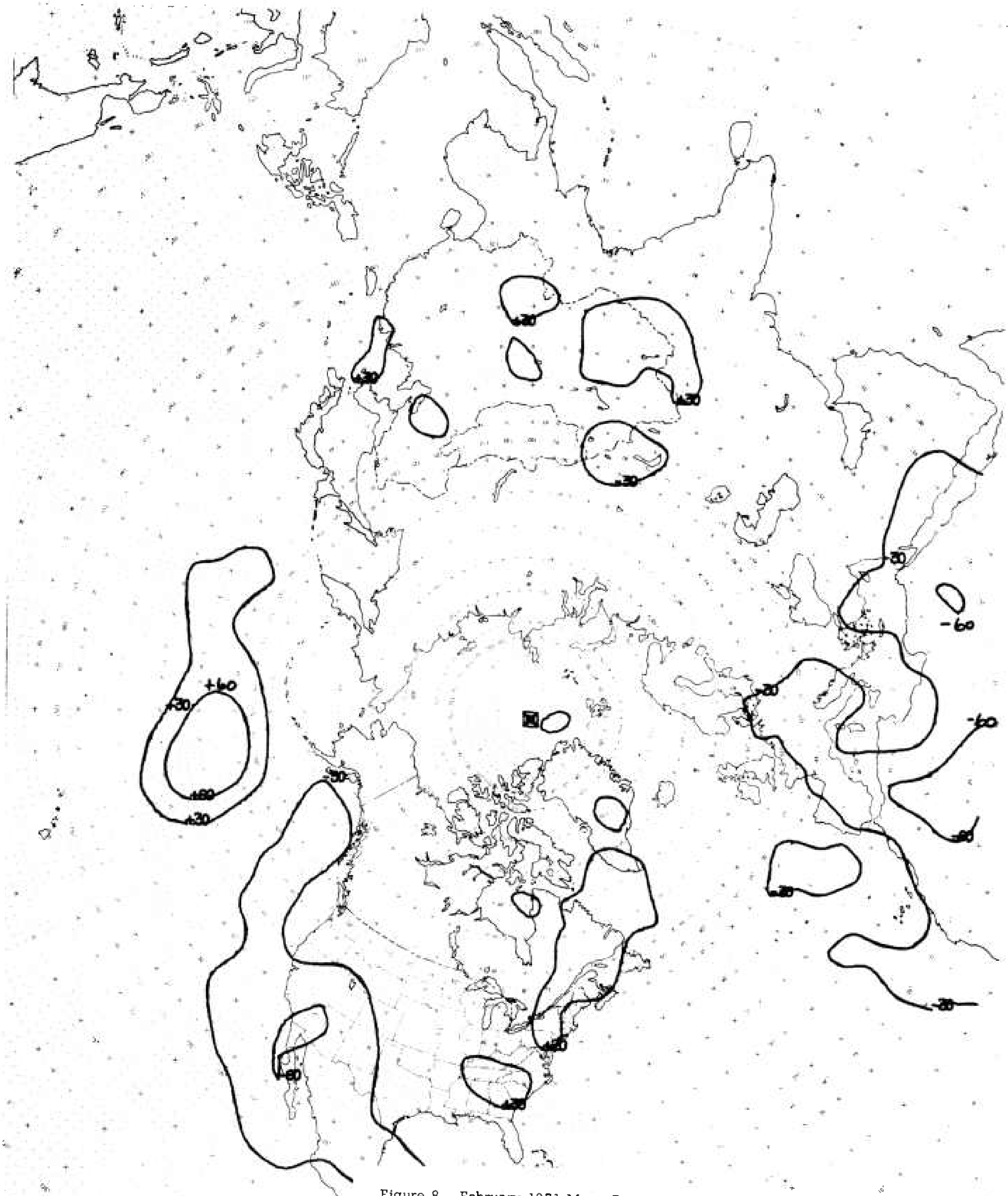

Figure 8. February 1971 Mean Error Patterns for 24-Hour PE 500 MB Progs

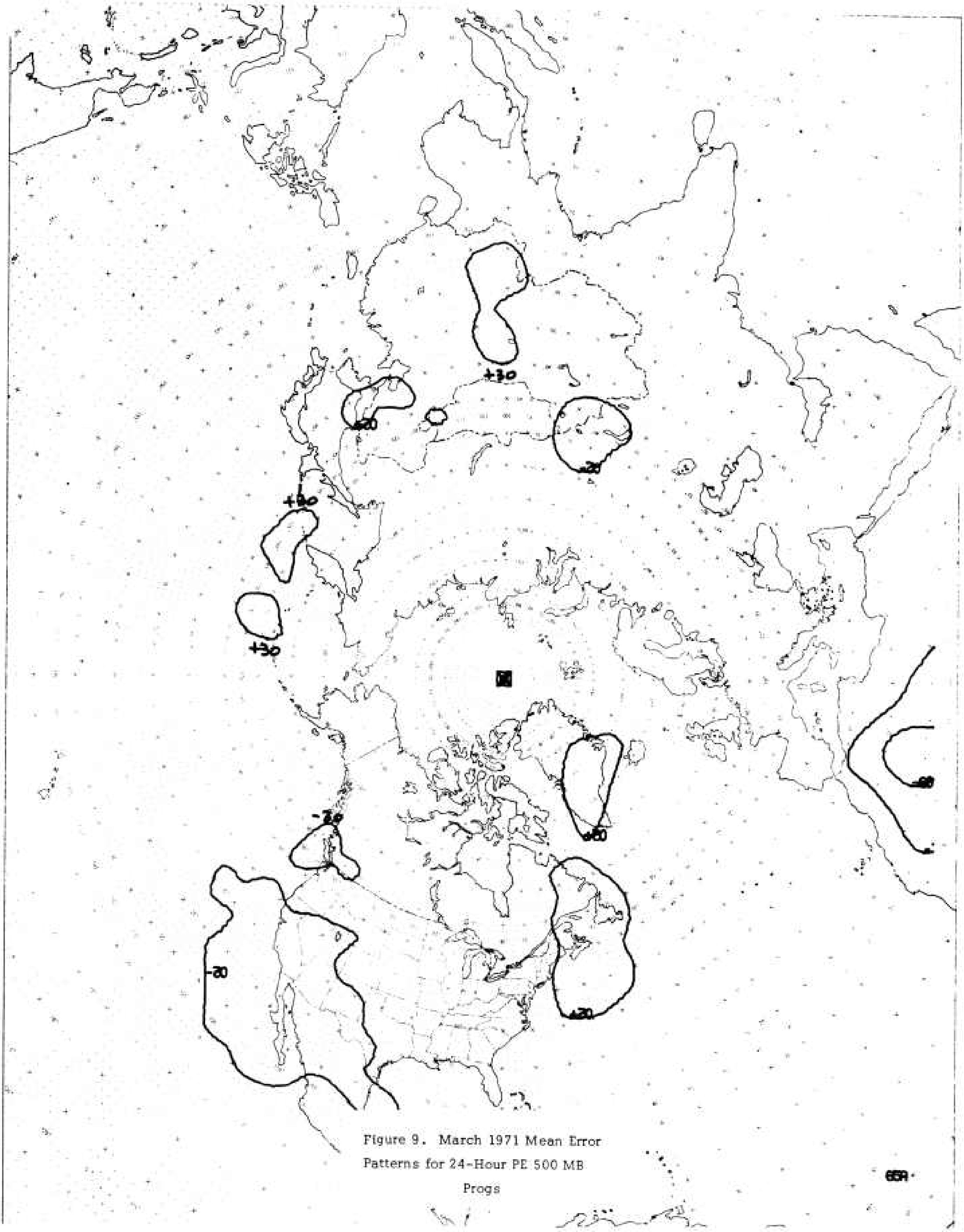

Figure 9. March 1971 Mean Error Patterns for 24-Hour PE 500 MB Progs

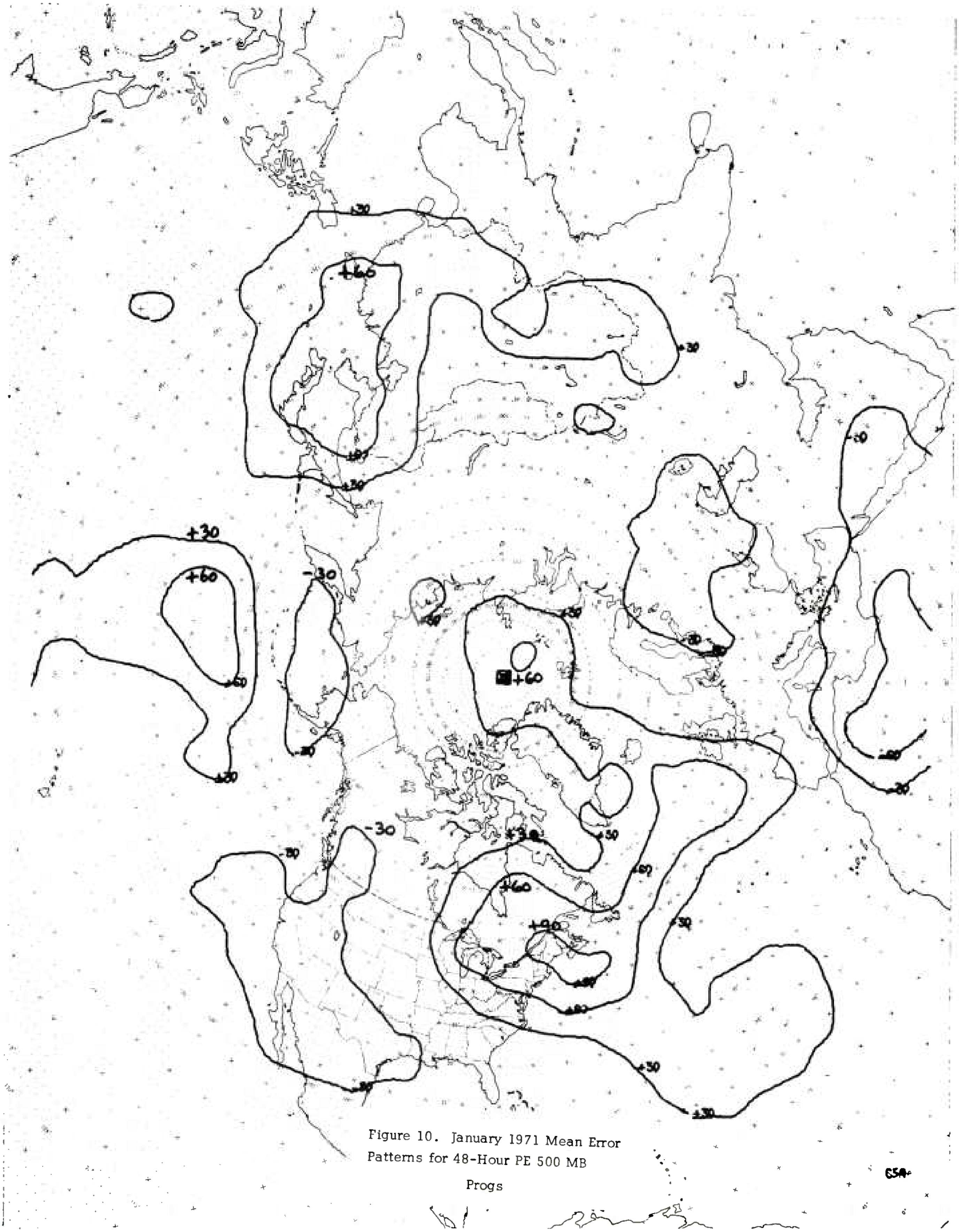

Figure 10. January 1971 Mean Error Patterns for 48-Hour PE 500 MB Progs

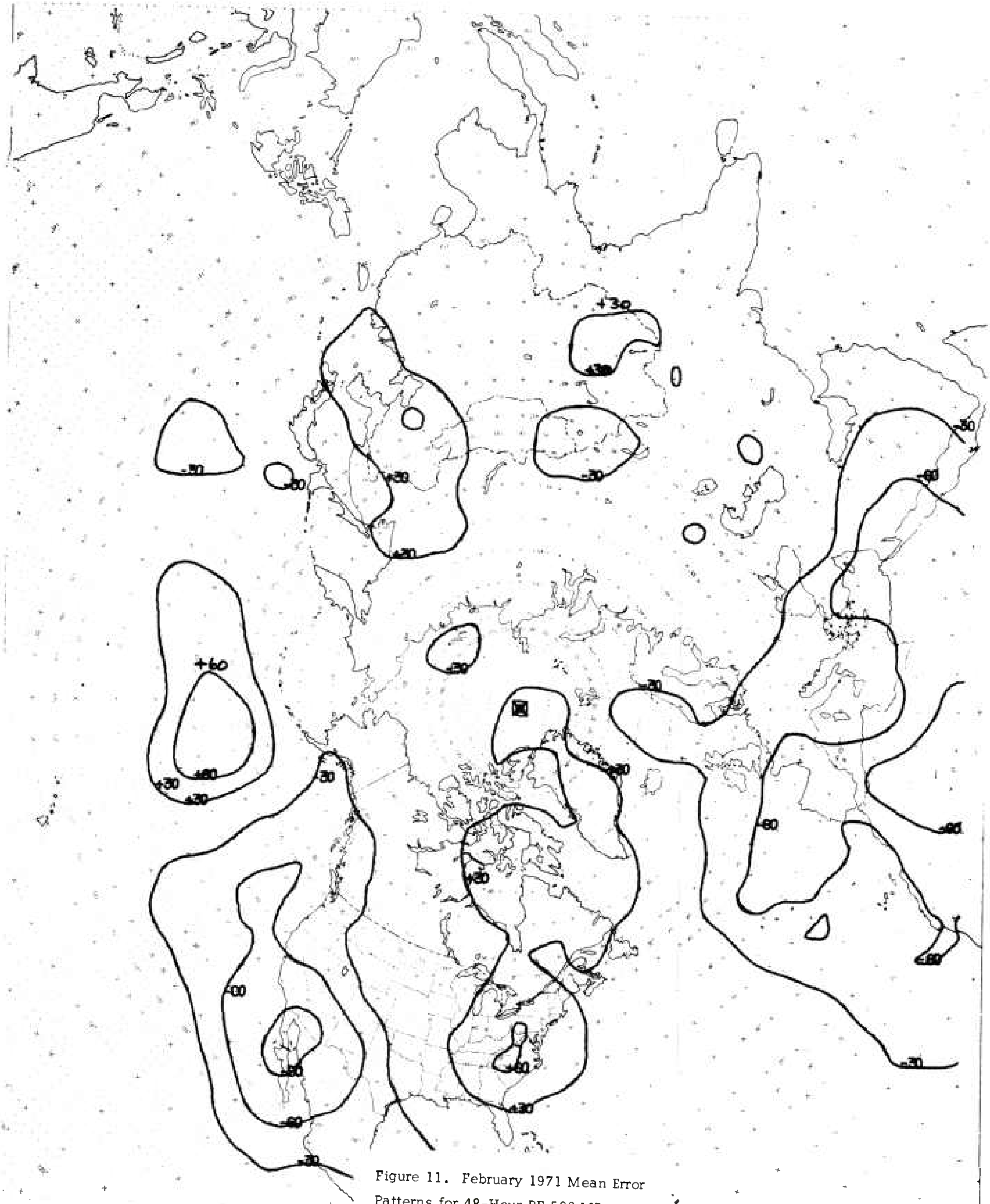

Figure 11. February 1971 Mean Error Patterns for 48-Hour PE 500 MB Progs

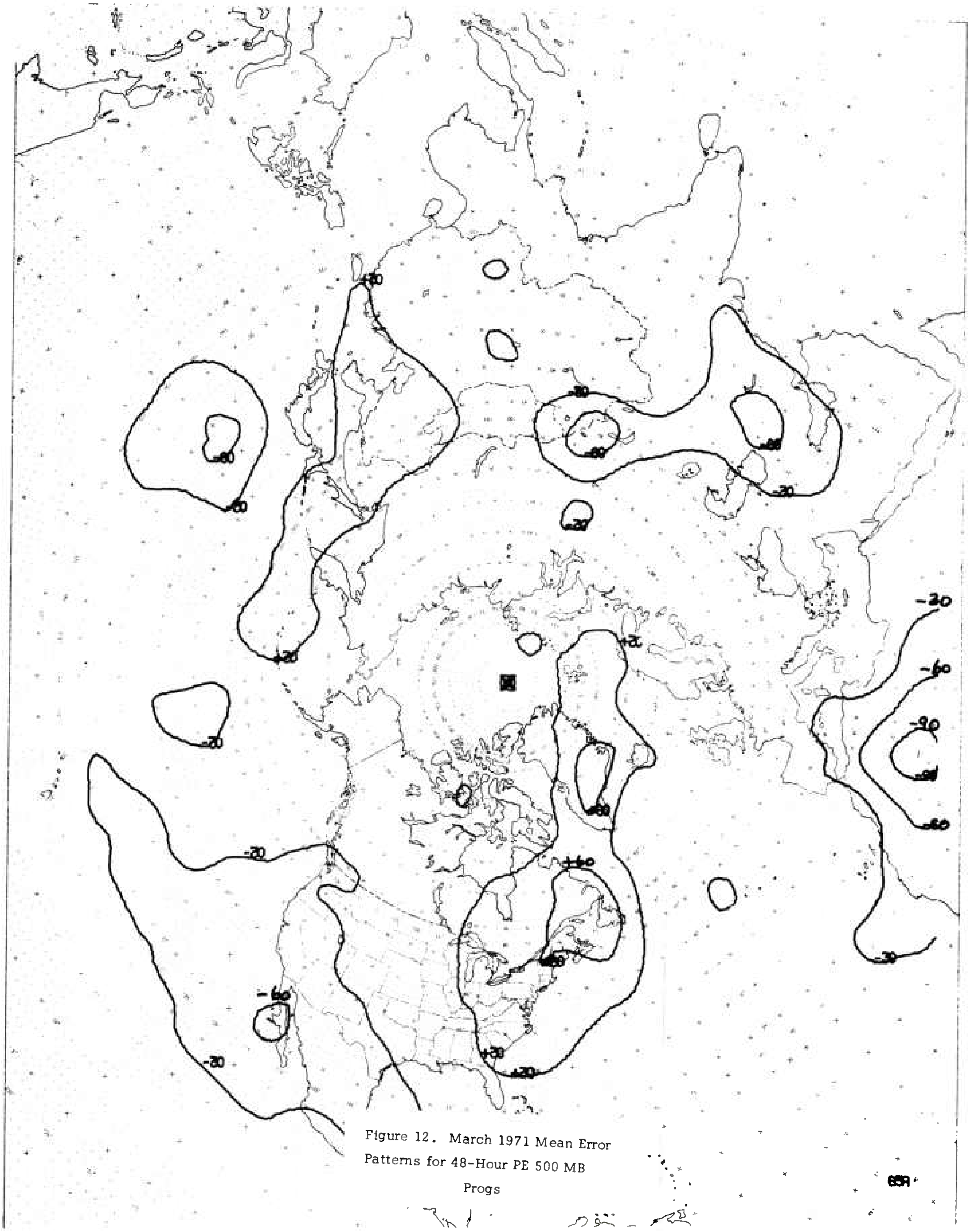

Figure 12. March 1971 Mean Error Patterns for 48-Hour PE 500 MB Progs

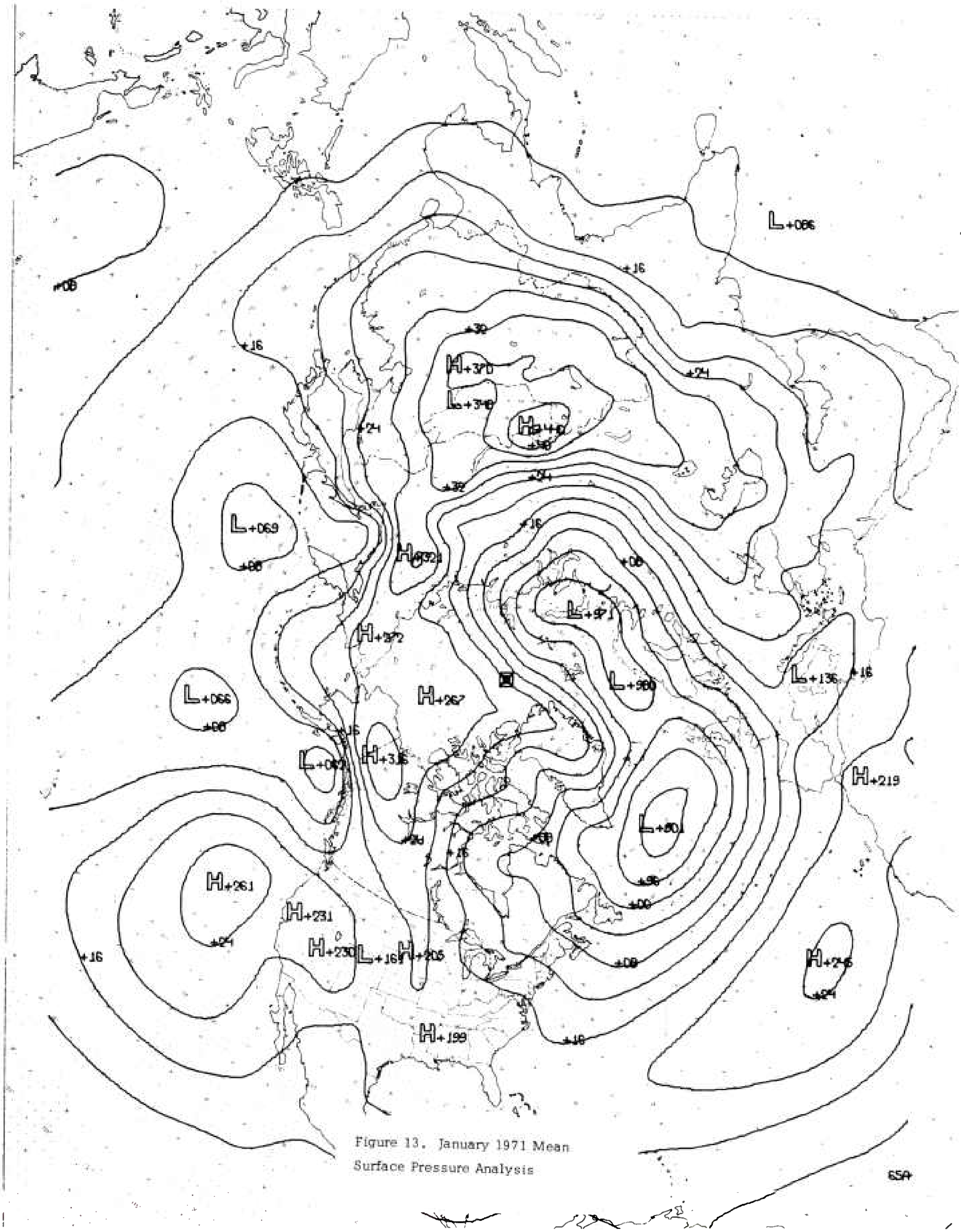

Figure 13. January 1971 Mean
Surface Pressure Analysis

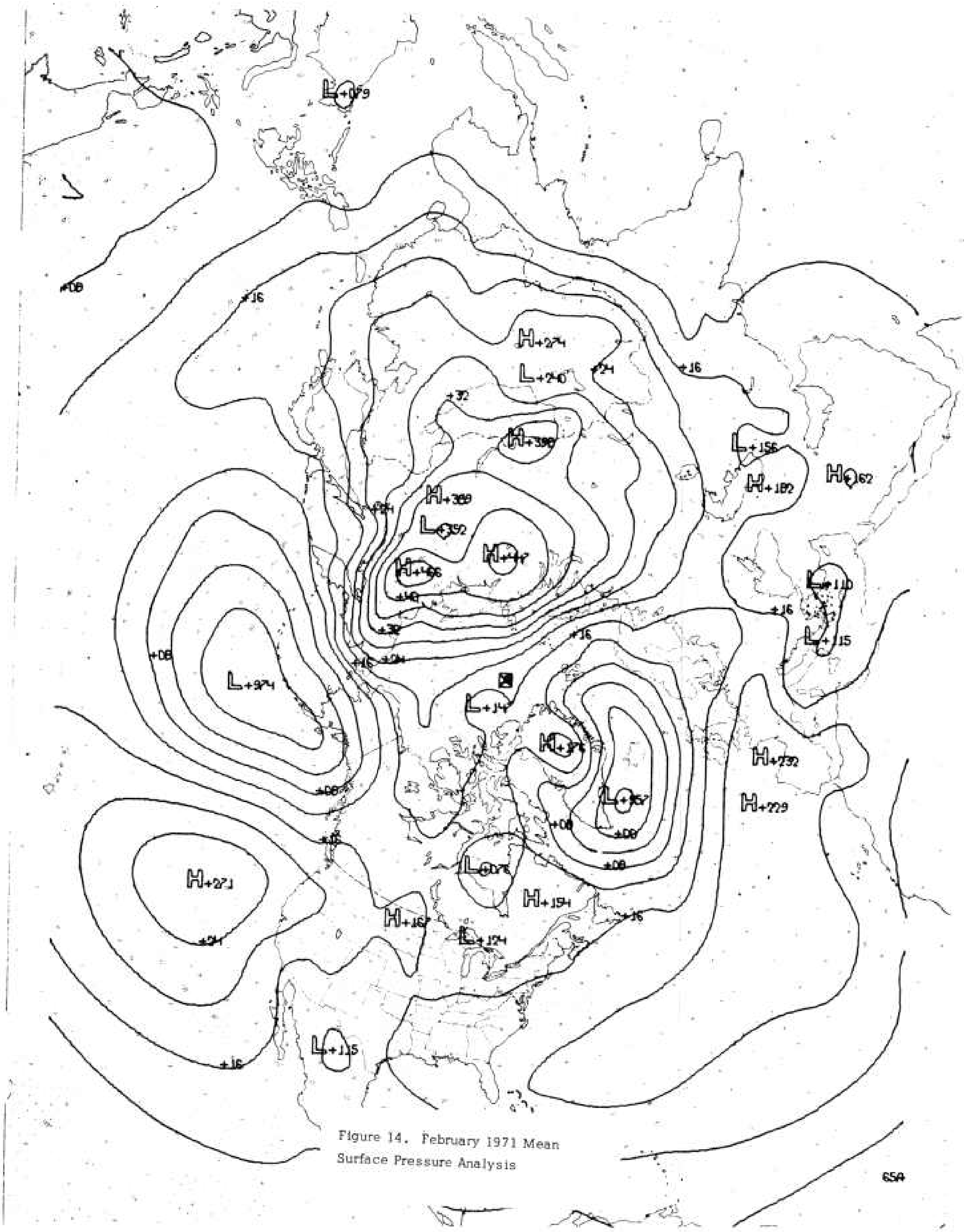

Figure 14. February 1971 Mean Surface Pressure Analysis

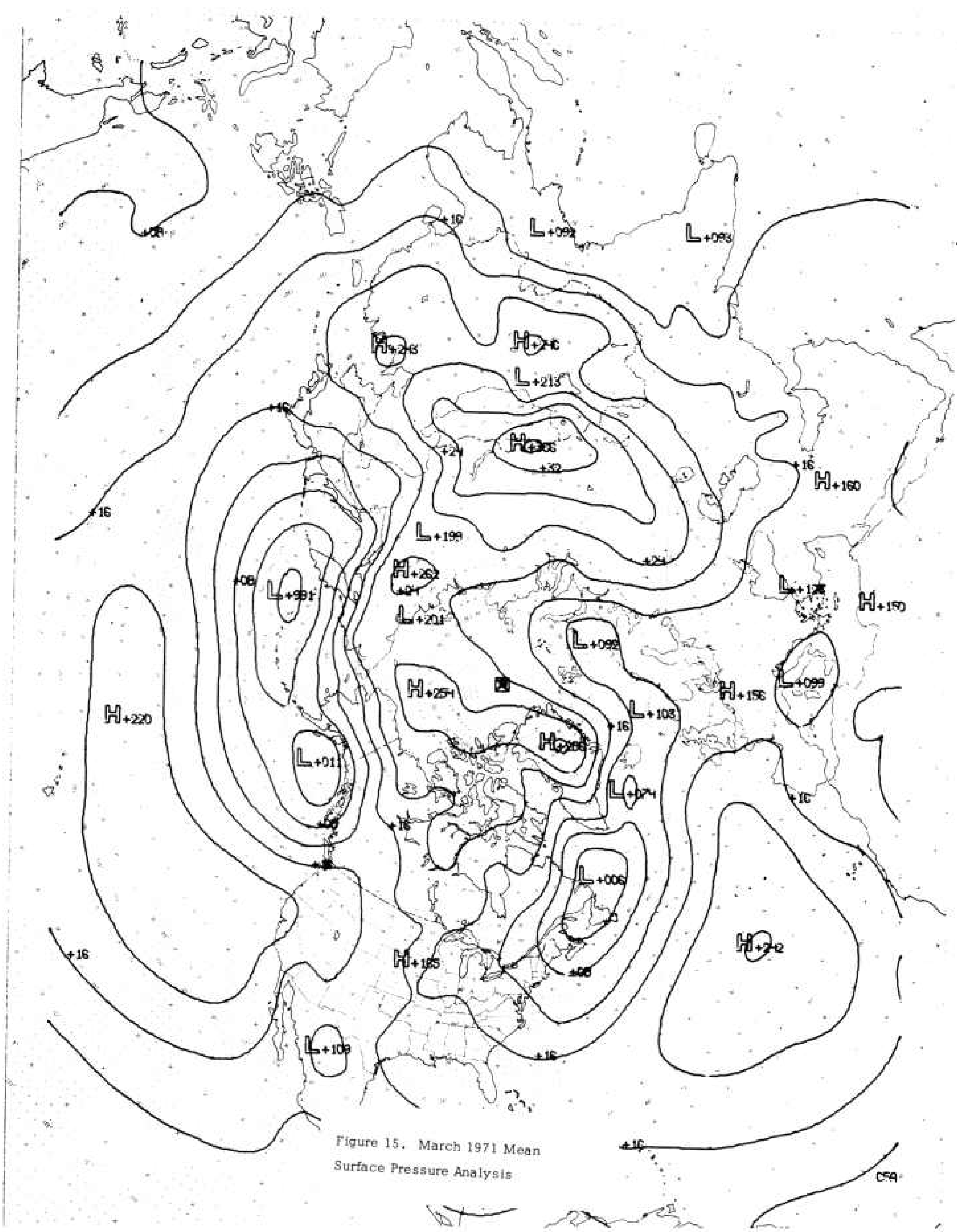

Figure 15. March 1971 Mean Surface Pressure Analysis

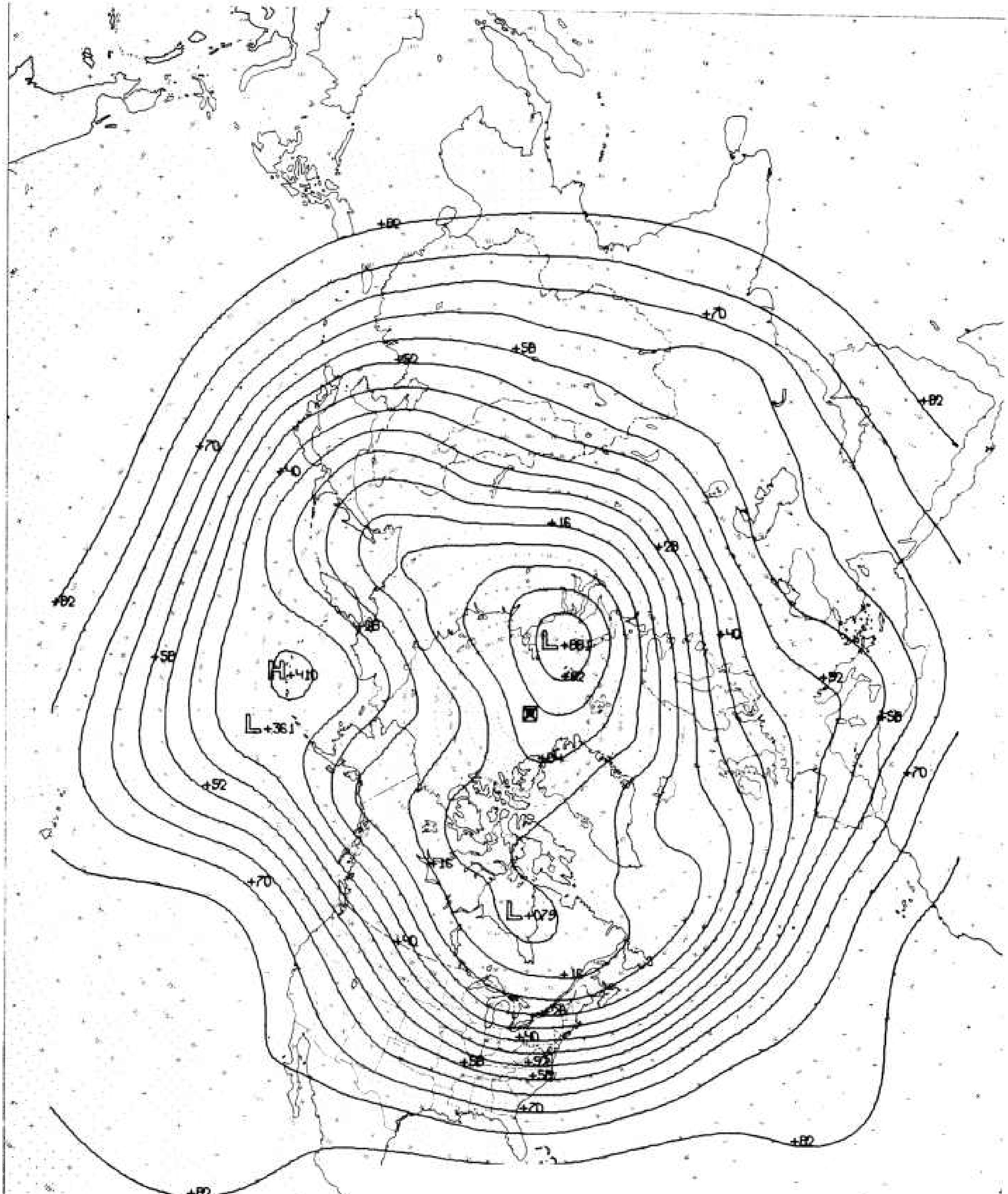

Figure 16. January 1971 Mean
500 MB Analysis

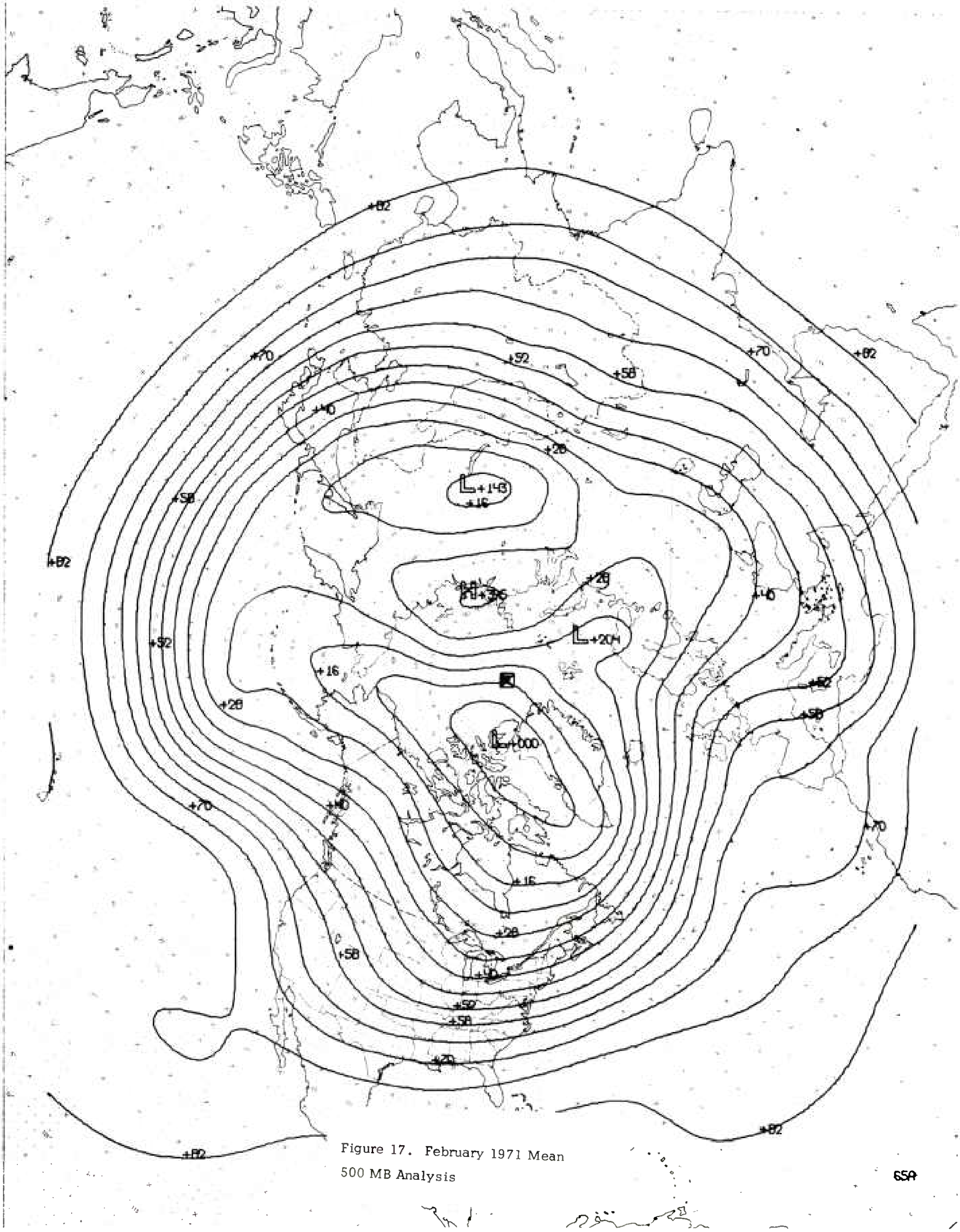

Figure 17. February 1971 Mean
500 MB Analysis

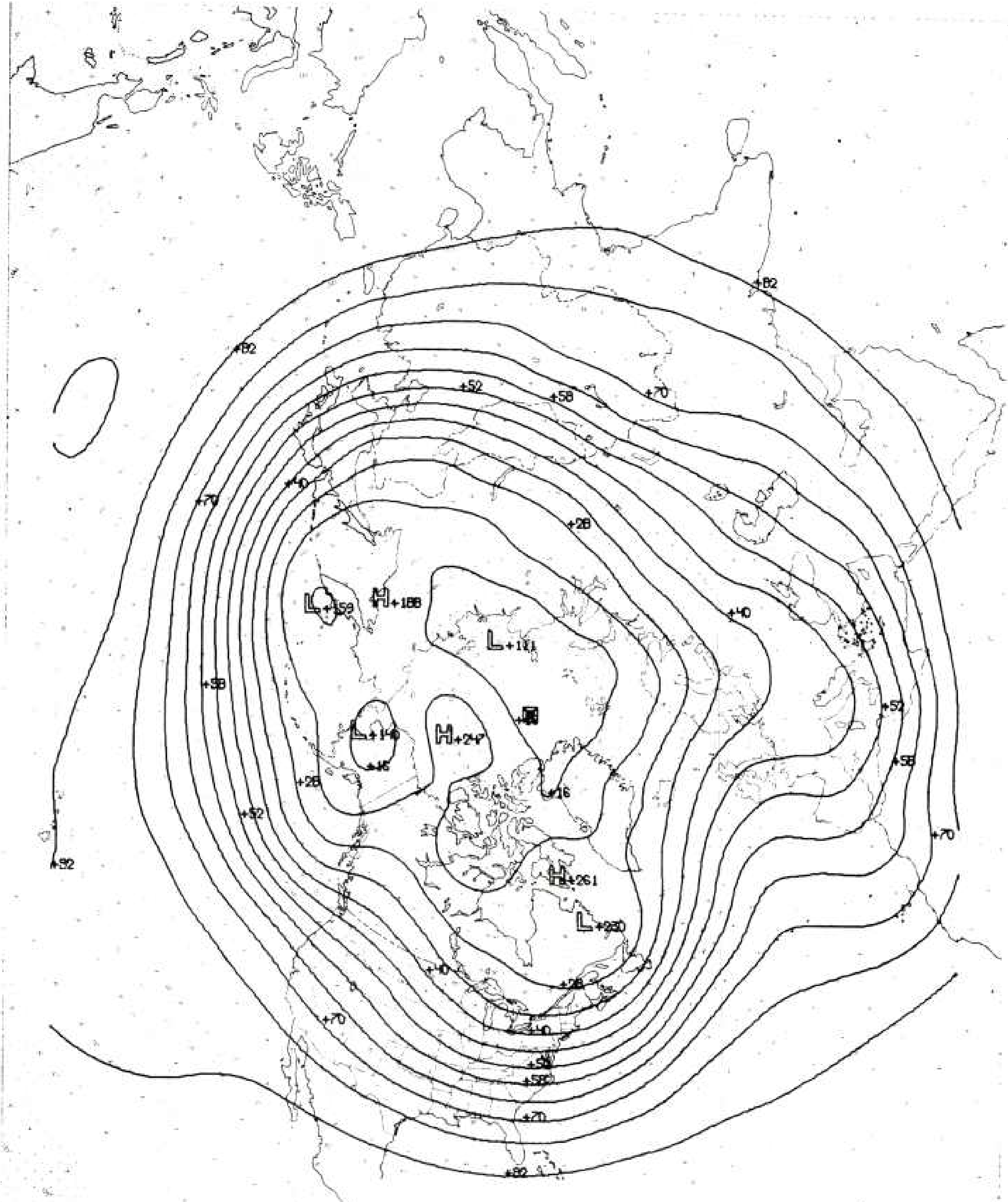

Figure 18. March 1971 Mean
500 MB Analysis

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