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Six case studies from the forecast model intercomparison experiment, February 1977 to May 1978

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1. Introduction

This note complements another note (Cullen (1978)) which summarised the results of all the 54 cases dealt with in the model comparison experiment. A large amount of diagnostic information was produced for each case and in this note six cases, from different seasons, are discussed in more detail and the diagnostic information related to the synoptic assessment.

The models used in the experiment were described in Cullen (1978) and references therein. They are referred to by letter as follows:

- A: Operational 10 level model
- B: 10 level sigma coordinate model
- C: 11 level general circulation model
- D: 5 level spectral model
- E: 5 level finite element velocity potential model

Their main characteristics are summarised in Table 1.

The diagnostic information produced from each case was as follows:

a) Charts of PMSL and 500 mb height for each day up to day 5.

b) Error fields (forecast minus actual). Those used were for PMSL at day 2 and 500 mb height at day 3.

c) Hovmoeller diagrams of the 500 mb height for wavenumber groups 1-2, 3-5, 6-10 and 11-16.

d) RMS errors and height change correlation coefficients for 500 mb and 1000 mb at each day up to day 5. Persistence values were also calculated. (The height change correlation is between (forecast -initial data) and (actual-initial data))

The full diagnostics were only available for models A and C, and sometimes D. The cases selected were chosen so that there were substantial differences in the forecasts produced by some of the models. They were as follows:

20 February 1977, 8 May 1977, 14 August 1977, 20 November 1977, 1 January 1978, 9 April 1978.

One case is described in each of the following sections. The synoptic assessments for models A, B and C are given. Diagnostic information was never available from

B, so it is given for A and C only. The first three cases were performed with an extended octagon analysis for C (see Cullen (1978)), the next two with the extended octagon (CO) and the merged analysis (CM), the last with the merged analysis only. It is expected that these cases will be run with higher resolution versions of models D and E at a later date.

The synoptic assessments are based on those made from a complete study of all the charts from the cases concerned, not just from those presented in this note. They concentrate on the changes over the British Isles and Atlantic, features elsewhere are discussed more briefly.

TABLE 1

Summary of model characteristics

NUMERICAL MODEL		A	B	CO	CM	D	E	F
FORECAST AREA		OCTAGON North of $15^{o}N$	OCTAGON North of $15^{o}N$	N.HEMISPHERE	NORTH OF $15^{o}S$	N.HEMISPHERE	N.HEMISPHERE	RECTANGLE (INCLUDES N. HEMISPHERE)
VERTICAL COORDINATE SYSTEM		P	σ	σ	σ	σ	σ	σ + TROPOPAUSE
RESOLUTION	VERTICAL LEVELS	10	10	11	11	5	5	7
	HORIZONTAL	300 km ($60^{o}N$)	300 km ($60^{o}N$)	220 km	220 km	T42 (500 km)	450 km	174 km ($60^{o}N$)
	TIME STEP	30 min	30 min	$7\frac{1}{2}$ min	$7\frac{1}{2}$ min	30 min	28 min	5 min
CPU Time/24 hr Forecast		$2\frac{1}{2}$ min	$2\frac{1}{2}$ min	26 min	31 min	9 min	8 min	30 min
INTEGRATION SCHEME		SPLIT EXPLICIT STAGGERED F.D.	SPLIT EXPLICIT STAGGERED F.D.	EXPLICIT UNSTAGGERED F.D.	EXPLICIT UNSTAGGERED F.D.	SEMI-IMPLICIT SPECTRAL GALERKIN	SEMI-IMPLICIT PIECEWISE LINEAR GALERKIN	EXPLICIT UNSTAGGERED F.D.

2. 20 February 1977 Models run A, B, C

a) Synoptic assessment

Fig 2.1 shows the 500 mb chart at day 3. Figs 2.2, 2.3 and 2.4 show the forecasts produced by models A, B and C. Initially there are 500 mb troughs over the east and west Atlantic with an amplifying ridge in mid-Atlantic. A deep surface low over Nova Scotia moves north towards west Greenland. On day 3 a further 500 mb trough forms over the central USA. Model A forecasts these developments well. By day 4 the three upper troughs are all readily identifiable, lacking amplitude, but quite well placed. After day 4 the developments are poor. B gives an almost identical forecast to A, the intensities are marginally greater. C does not amplify the mid Atlantic ridge convincingly and the northern part becomes cut off. The new American trough is not forecast. Thus by day 3 the Atlantic picture is going astray.

Over the eastern Pacific a shortened wavelength develops by day 3 with a weak ridge at 120W and a sharp ridge at 155W. The rest of the Pacific is zonal, as is much of Asia. None of the models forecast the sharp ridge, and the trough ahead of it is 10° slow at day 3 in A and B and 15° slow in C. The ridge at 120W is too strong in A and B and too strong and 10° too far east in C, associated with the poor forecast of the new American trough. The rest of the Pacific is well handled, but the broad trough near Japan is 10° slow at day 3 in all models.

b) Hovmoeller diagrams

Fig 2.5 shows the actual Hovmoeller diagram for wavenumbers 6 to 10 and figs 2.6 and 2.7 the forecasts produced by A and C. The results from the other wavegroups are discussed also but not shown.

In the long waves, (1-2), model A fails to forecast a recovery in amplitude at day 3. After day 3 the movement of existing waves is also either in the wrong direction or else stationary waves are forecast to move. C gives a better overall amplitude but the movement is still not forecast reliably. Wavegroup 3-5 in model A is not sufficiently progressive after day 2, the amplitude is lost between 40 and 180E but is excessive between 40 and 100W. Model C also fails to keep the progression going, existing waves are handled well but new developments are all forecast in the wrong places. The general amplitude is better than in A. Model A gives excessive movement in wavegroup 6-10 (Figs 2.5 to 2.7), for instance the trough initially at 90W is moved 20° too far over the 5 days, and the amplitudes are too low; in the sector 120 to 180E they are less than half the observed. The waves tend to move too uniformly without breaks in the pattern. Model C also fails to forecast the amplitudes correctly, the pattern is less uniform but not correctly so. Wavegroup 11-16 can only be assessed for amplitude in the results from C since these are only available every 24 hours. The amplitude becomes inadequate in the area 0-90E after 3 days. A loses amplitude to a greater extent and the phase speeds are only half the observed.

c) Error fields

Figs 2.8 and 2.9 show the 500 mb error fields from models A and C at day 3. Model C has negative errors over the eastern USA and western Atlantic, over the Aleutians, and in high latitudes. Model A has no comparable negative centres but has a general negative error over Eurasia and a positive area near the pole. The variation of the model C error in space is very much greater than that of model A, the patterns are quite different.

The PMSL error fields at day 2 (not shown) show similar patterns from both models over the Atlantic and USA except over Newfoundland where C has negative errors. C also has negative errors over the Aleutians and A negative errors over most of Siberia. Elsewhere there is little to choose between them.

d) Objective scores

Table 2 gives the rms errors for this case. The breakdown of error by wavenumber was not performed, nor were the height change correlations available.

Table 2

500 mb error

Parameter	Model	1	2	3	4	5
RMS forecast error	A	4.1	7.7	9.9	11.1	12.7
RMS persistence error		7.6	12.2	13.0	13.9	14.3
forecast error/persistence error x 100		54	63	76	80	89
RMS forecast error	C	4.6	7.0	10.6	13.0	14.3
RMS persistence error		8.0	13.2	14.0	14.9	15.3
forecast error/persistence error x 100		57	53	76	87	93

Time (days)

1000 mb error

Parameter	Model	1	2	3	4	5
RMS forecast error	A	3.6	6.3	8.0	8.3	8.8
RMS persistence error		5.9	9.8	10.4	9.9	8.5
forecast error/persistence error x 100		61	64	77	84	104
RMS forecast error	C	4.9	6.9	9.3	9.1	9.3
RMS persistence error		6.2	10.4	11.1	10.5	10.2
forecast error/persistence error x 100		79	66	84	87	91

Time (days)

e) Summary

The synoptic assessment of this case shows that models A and B are much the same but C gives an inferior forecast over the Atlantic. This is because it cuts off a ridge at high latitudes and allows the jet to be re-established to the south of it. The 500 mb error patterns show large differences between A and C. The greater intensity of the error patterns in C could be because of the generally higher amplitudes forecast. The Hovmoeller diagrams show that neither model has much skill in forecast anything other than simple translation. In the larger waves (1 to 5) C has more amplitude than A. The rms errors show that A is better than C early in the forecast at 1000 mb, but C becomes better by day 5. At 500 mb A is slightly better most of the time.

3. 8 May 1977

Models run A, B, C. D and E were also run but are not discussed here. Radiation was included in B (not included in the previous case).

a) Synoptic assessment

Fig 3.1 shows the 500 mb chart at day 4, and figs 3.2 to 3.4 the forecasts produced by A, B and C. At 500 mb a trough initially over the UK moves slowly east, a secondary trough forms in the mid-Atlantic at day 2 and merges with it to give a trough at 5°E at day 5. The middle of the Atlantic is initially cyclonic, becomes anticyclonic at day 3 to 4 and cyclonic again at day 5. A gives the change to cyclonic and indicates the trough moving into the UK but leaves it at 5°W and does not make the Atlantic cyclonic at day 5. B is similar but the associated surface features are weaker than in A and much weaker than actual. C is rather better, especially at the surface. At day 4 all the models have the ridge 15° too far west in mid-Atlantic and the UK trough 10° too far west. B is the worst forecast. A further trough is almost stationary over the eastern USA, secondary troughs break away on day 2 and day 5. C is the only model to suggest the first breakaway and no model forecasts the second. A large trough remains stationary over the western USA. A almost loses it, B retains it rather better, C maintains a good amplitude but allows it to move after day 3. Another trough in the west Pacific moves east through 30° to 180W by day 5. This is very slow and weak in A and C, 20° slow in A, 15° in C and so is the ridge ahead of it. B gives a rather different forecast to A and the features are 15° further west still. At the surface developments near China are exaggerated, and the Pacific high is too strong. In C the lows in the N Pacific are too stationary for the first two days.

b) Hovmoeller diagrams

Fig 3.5 shows the actual Hovmoeller diagram for wavegroup 3 to 5 and Figs 3.6 and 3.7 the forecasts produced by A and C. In wavegroup 1 to 2 the model A forecast loses all amplitude from 150E through 90W to OW after day 3. The phases are correct up to this time. Model C also loses amplitude between days 3 and 4 but recovers by day 5. The progression is insufficient for the first three days and excessive thereafter. Wavegroup 3 to 5 is well forecast by A up to day 2, then amplitude is lost around 100W. The rest of the hemisphere remains reasonable. Model C retains the amplitude at 100W and is equally good elsewhere. Wavegroup 6–10 is slow in model A, 5° at 150E and 10° at 50W. The amplitude drops to half the actual near 150W but is maintained near 50W. C also loses amplitude near 150E where the pattern disrupts, the speeds are correct. Model C gives larger and more correct amplitudes in wavegroup 11 to 16, the speeds are well forecast by both models.

c) Error Fields

Figs 3.8 and 3.9 show the 500 mb error fields at day 3 produced by models A and C. Both models have large positive errors over the Pacific with a negative area near Japan. Both models have positive errors in the Atlantic and a spurious gradient over the UK, NE in model A, E in model C. Overall, model A shows a positive bias, C a slight negative bias. The PMSL error fields at day 2 (not shown) show large negative errors over Eurasia in model C. Model A has strong positive errors over the USA and N Pacific, C has tendencies this way but not so strongly as A. Both models have negative errors over Labrador.

d) Objective scores

Table 3 gives the rms errors for this case. The breakdown of error by wavenumber was not performed, and the height change correlation coefficients were not available.

Table 3

500 mb error

Parameter	Model/Time(days)	1	2	3	4	5
RMS forecast error	A	3.2	5.4	6.6	8.0	8.6
RMS persistence error		5.9	9.0	10.2	10.6	11.4
forecast error/persistence error x 100		54	60	65	75	76
RMS forecast error	C	4.0	5.8	7.0	7.6	7.9
RMS persistence error		6.1	9.4	10.8	11.3	12.2
forecast error/persistence error x 100		66	62	65	67	65

1000 mb error

Parameter	Model/Time(days)	1	2	3	4	5
RMS forecast error	A	2.6	4.1	4.4	5.4	5.8
RMS persistence error		4.2	6.1	6.5	6.6	6.5
forecast error/persistence error x 100		62	67	68	82	89
RMS forecast error	C	3.5	4.4	4.9	5.6	5.9
RMS persistence error		4.3	6.2	6.8	6.9	6.8
forecast error/persistence error x 100		81	71	72	81	87

e) Summary

All the models do reasonably well in the Atlantic up to day 3 but the continued progression afterwards is lost, C does better than A and B. This is supported by the Hovmoeller diagrams which show C giving a recovery in amplitude by day 5 in waves 1 to 2 and maintaining amplitude in waves 3 to 5 whereas A fails to do so. The error fields show the models fairly similar at day 3; so the subsequent divergence of the forecasts must be due to rather small but critical differences at day 3. The models have a different bias at 500 mb, A being positive and C slightly negative. C gives lower surface pressure over land. B is markedly different from A in some areas and is unrealistic over the west Pacific. This could have been due to problems with the new radiation scheme. The rms errors show A to be better than C up to day 3 and worse thereafter at 500 mb, equal thereafter at 1000 mb. An obvious explanation for this is the need to interpolate data for model C, and also extend it to the hemisphere.

4. 14 August 1977 Models run A, B, C.

a) Synoptic assessment

Fig 4.1 shows the 500 mb chart at day 3 and figs 4.2 to 4.4 the forecasts produced by A, B and C. A sharp trough to the west of the British Isles moved eastwards. An upper cold pool and surface low formed in the southwest approaches on day 2 and moved across southern England giving a great deal of rain. An anticyclone to the north of Scotland persisted for most of the period and a deep depression moved into the NW Atlantic from SE Canada. Over the USA and Pacific there is a large amplitude pattern with a ridge at 140W at day 3 and troughs either side. A cold upper vortex covers much of Eurasia. A and B both indicate the cold pool near the British Isles on day 3, it is further east (better) in A. C moves it too far south so that the main ridge axis is over the UK at day 3 and the cold pool at 15W. The surface depression over the UK was therefore missed. All the models forecast the NW Atlantic depression well. The large scale pattern over the USA and Pacific is present in all the forecasts but the amplitude is inadequate. The ridge is a little stronger in A and B than in C. The trough over Eurasia is equally well forecast by all models, C gives the lowest contour heights and B the highest. B gives excessive surface pressure over the Pacific after day 3.

b) Hovmoeller diagrams

Fig 4.5 shows the actual Hovmoeller diagram for wavegroup 3 to 5 and Figs 4.6 and 4.7 the forecasts produced by A and C. In wavegroup 1 to 2 C exaggerates the amplitude near 150W and retrogresses the pattern incorrectly after day 1. A also does this from the beginning of the forecast. C forecasts the phases of waves 4 to 5 well except near 30E where it is too retrogressive. The amplitude is too low. A gives similar phases to C but the amplitudes are better. In wavegroup 6 to 10 both models give rather slow phase speeds in the area 0 to 90E. There are major changes in the pattern from 90 to 180W not well forecast by either model. A gives better amplitudes for waves 11 to 16 than C.

c) Error fields

Figs 4.8 and 4.9 show the 500 mb errors at day 3. The models show similar patterns except west of the UK where model C has negative errors. Both models have positive errors near the UK, the Great Lakes and the central Pacific, C also has near the Caspian; both have negative errors over West Canada and E Europe, C also has to the west of Norway. At day 2 both models have anomalous gradients at 1000 mb; westerly over South Alaska, easterly over Biscay. C also has a SE anomaly over the USA, but A has negative errors over Canada while C has positive errors. C has negative errors over much of Eurasia.

d) Objective scores

Table 4 gives the rms errors and height change correlation coefficients for this case. The breakdown of error by wavenumber was not performed.

Table 4

500 mb error

Parameter	Model/Time(days)	1	2	3	4	5
RMS forecast error	A	2.0	3.4	4.4	5.2	6.1
RMS persistence error		3.7	6.0	7.0	7.3	8.0
forecast error/persistence error x 100		54	57	63	71	76
RMS forecast error	C	3.3	5.0	6.5	7.4	7.9
RMS persistence error		4.0	6.6	7.6	8.0	8.9
forecast error/persistence error x 100		82	76	86	92	89
Height change correlation (%)	A	83	82	79	74	69
Height change correlation (%)	C	74	76	68	64	64

1000 mb error

Parameter	Model/Time(days)	1	2	3	4	5
RMS forecast error	A	2.0	3.2	4.0	4.2	4.7
RMS persistence error		2.7	3.9	3.9	4.3	4.5
forecast error/persistence error x 100		74	82	103	98	104
RMS forecast error	C	3.2	4.4	5.1	5.2	5.2
RMS persistence error		2.8	4.0	4.1	4.6	4.8
forecast error/persistence error x 100		114	110	124	113	108
Height change correlation (%)	A	64	65	60	59	54
Height change correlation (%)	C	58	55	45	48	47

e) Summary

As in the earlier cases there is a difference between the forecasts over the Atlantic given by A and B, and by C. A and B gave a much more realistic progression across the UK than did C. Elsewhere A and B have greater amplitude at 500 mb than C, this is supported by the Hovmoeller diagram for waves 3 to 5. The error patterns produced by A and C are fairly similar except for the critical area near the UK. This suggests that either there was an important data difference here, or else a critical amplitude for some feature was just reached by one model and not the other. C has extensive low pressure over Eurasia as in the previous case discussed. The objective scores show A to be much superior to C early in the forecast and still superior at the end. By day 4 the height change correlations at 1000 mb have fallen to near 50% which is the asymptotic level given by reversion to climatology, so representing no skill. The scores for C at 1000 mb are very bad indeed, this may be due to the large biased areas being established in a pattern where the synoptic changes were not very large. Thus the development of spurious low pressure over land areas may dominate the statistics.

5. <u>20 November 1977</u> Models run A, B, CO, CM

a) <u>Synoptic assessment</u>

Fig 5.1 shows the 500 mb chart at day 4 and figs 5.2 to 5.5 the forecasts produced by A, B, CO and CM. The pattern was dominated throughout by two blocks - an omega block over the Atlantic and a diffluent block over the Northern Pacific. The main flows were from Gibraltar to Japan and in low latitudes across the Pacific and USA with the jet exit near the Great Lakes. This latter flow extended eastwards with disruption of the Newfoundland trough occurring, the northern portion moving on round the ridge and extending again to the west of the UK on day 3. This has the effect of interrupting the northerly flow over the UK, with a temporary backing as a deep surface low moves eastward close to North Scotland and subsequently reinforcing the eastern trough over Europe. The small amplitude ridge in northern latitudes phases in with the blocking ridge at 25W and reinforces it. By day 5 a strong NW flow has developed across the USA extending a trough towards Florida and inducing a strong SW flow across the W Atlantic. Little change took place in the Pacific block. An oscillation developed in the jet near the Caspian sea.

A handled the interruption and re-establishment of the northerlies over the UK and N Sea very well. The major fault was the lack of extension of the European trough towards Italy. The rest of the hemisphere was well forecast in general, though the vortex and trough over the central USA are the wrong shape by day 4 and most other features are on the weak side. B maintained a surface anticyclone over Greenland throughout the period instead of moving it east. Thus the northerly flow over the UK did not extend far enough south and a SW flow was forecast for Southern England. Otherwise it was similar to A but with several 500 mb centres better marked, the ridge at 60E, the troughs at 90W, 130W and 150E. This was usually an improvement but the wrong shape of the ridge at 60E was accentuated further as a result. CO handled the disruption of the Newfoundland trough but did not forecast the strong flow in the disrupted part, therefore the resulting short wavelength feature did not move east and amplify. Instead a WNW flow develops from Greenland to the Adriatic and the pattern is too zonal and mobile. The Atlantic ridge is disrupted with the northern part remaining over Greenland and the southern part breaking away from it. Elsewhere the positions of features are well forecast but the amplitudes are too low. The Pacific block cuts off, leaving a high centre at 70N. This is a better forecast than A and B while in the Atlantic the reverse was true. CM showed similar behaviour to CO but to a greater extent. Thus part of the Newfoundland trough moves into the Atlantic as a separate centre at 50W and destroys the southern part of the ridge almost completely. The cut-off high over Greenland is more intense. Over the Pacific the cut-off high and lows to SE and SW of it are all more intense.

b) Hovmoeller diagrams

Fig 5.6 shows the actual diagram for waves 3 to 5 and figs 5.7 to 5.9 the forecasts produced by A, CO and CM. In wavegroup 1 to 2 A breaks the pattern down after day 4, a ridge at 40W is too strong and too far west at day 2. CO and CM give similar results but different from A. The forecast is good except for a build up of amplitude near 180W at day 5. CM has a marked oscillation centred on day 1. A forecasts the phases of wavegroup 3 to 5 well except near 60E where it is too retrogressive. The amplitudes are too large. CO and CM have better amplitudes. CO splits the trough at 120E wrongly and the phase behaviour at 60W is quite wrong. CM also makes these errors but to a lesser extent. In wavegroup 6 to 10 A is too progressive in the area 0-90-180E, but too retrogressive near 60W. The amplitudes are well forecast. CO and CM both give quite accurate phases as well as amplitudes. In wavegroup 11 to 16 CM gives reasonable amplitudes in about the right areas. A gives reasonable amplitudes, but in the wrong areas, CO does not give enough amplitude.

c) Error fields

Figs 5.10 to 5.12 show the error fields at 500 mb at day 3 for models A, CO and CM. A has large positive errors over N America and the pole, and negative errors over the UK, Russia and Alaska. There are weaker positive errors over the Pacific and Japan. CO has a similar pattern over the Pacific and Alaska but has negative errors over the Atlantic and little error over America. The negative errors are more strongly marked than in A, reflecting the generally lower values produced by CO. CM has weaker error patterns than CO but the centres of error correspond. At the surface A has positive errors over the N Pole, N Atlantic, E USA and much of the Pacific, negative errors over Siberia and the E Pacific. CM has smaller areas of large error and is largely correct over Siberia, it has negative errors over North Africa and the UK. CO has generally higher pressures than CM but does not have the extensive positive errors of A. It is correct over Siberia.

d) Objective scores

Table 5 gives the r.m.s errors and height change correlations for this case, also the breakdown of r.m.s. error by wavenumber at 500 mb.

Table 5

500 mb error

Parameter	Model/Time (days)	1	2	3	4	5
RMS forecast error	A	4.3	7.0	8.4	9.9	10.6
RMS persistence error		7.4	10.5	11.3	12.8	14.2
forecast error/persistence error x 100		58	67	75	77	75
RMS forecast error	CO	4.5	6.9	9.6	10.7	13.1
RMS persistence error		7.7	11.1	12.1	13.7	15.2
forecast error/persistence error x 100		59	62	79	78	86
RMS forecast error	CM	5.7	6.9	8.4	10.2	12.2
RMS persistence error		7.7	11.1	12.1	13.7	15.2
forecast error/persistence error x 100		74	62	69	74	80
height change correlation (%)	A	84	81	76	74	72
	CO	83	82	72	71	65
	CM	76	84	79	75	69

1000 mb error

Parameter	Model/Time (days)	1	2	3	4	5
RMS forecast error	A	4.0	5.7	6.4	6.6	7.3
RMS persistence error		6.1	7.5	7.1	8.5	9.7
forecast error/persistence error x 100		66	76	90	78	75
RMS forecast error	CO	4.0	5.7	7.4	7.7	9.8
RMS persistence error		6.3	7.9	7.6	9.0	10.4
forecast error/persistence error x 100		64	74	97	86	94
RMS forecast error	CM	5.1	5.6	6.4	8.2	8.8
RMS persistence error		6.3	7.9	7.6	9.0	10.4
forecast error/persistence error x 100		81	73	84	91	85
height change correlation (%)	A	78	73	64	66	67
	CO	81	76	59	61	53
	CM	74	77	68	61	62

Wavegroup 11-16

Model/Time (days)		1	2	3	4	5
RMS persistence error	A	1.7	1.9	1.8	1.7	1.5
forecast error/persistence error x 100	A	65	94	78	94	73
	CO	79	87	87	87	100
	CM	71	81	73	81	93

500 mb error by wavenumber

All errors expressed as percentage of model persistence. Only model A persistence is quoted.

Mean value

Model/Time (days)		1	2	3	4	5
RMS persistence error	A	1.6	1.9	3.0	3.8	3.9
forecast error/persistence error x 100	A	175	205	127	142	154
	CO	127	174	180	167	189
	CM	200	205	133	139	168

Wavegroup 1-2

Model/Time (days)		1	2	3	4	5
RMS persistence error	A	4.8	7.3	7.4	8.2	8.8
forecast error/persistence error x 100	A	63	64	72	77	82
	CO	68	63	68	60	74
	CM	94	59	63	56	73

Wavegroup 3-5

Model/Time (days)		1	2	3	4	5
RMS persistence error	A	4.6	6.1	7.3	8.3	9.7
forecast error/persistence error x 100	A	43	67	84	75	62
	CO	44	51	77	88	95
	CM	38	47	70	86	83

Wavegroup 6-10

Model/Time (days)		1	2	3	4	5
RMS persistence error	A	4.9	7.3	7.2	8.4	9.2
forecast error/persistence error x 100	A	35	36	50	56	55
	CO	33	40	54	46	43
	CM	31	42	51	56	51

e) Summary

Over both the Atlantic and Pacific C tended to produce a cut-off high as in the 20 February case. As a result the forecast was better than A in the Pacific and worse in the Atlantic. B tended to produce stronger centres than A but not to the extent of giving a major cut-off feature over the Atlantic as in C. The change of initial analysis to give CM did not affect the different behaviour of C. There are also quite large differences in the Hovmoeller diagrams in the longer wavegroups, a cut-off high away from 50N does not register as a wave on the diagrams while a ridge such as those produced by A will. In most groups A gives larger amplitudes than CO. The error fields show big differences in the 500 mb patterns over the Atlantic and America. CM has smaller errors than CO, but both have a negative bias. At 1000 mb the loss of pressure over land in C no longer occurs. A has extensive positive errors, mostly over the sea. Siberia is much better handled by C. This is a change in behaviour from the summer cases, reflecting the change of season. At 500 mb the rms errors from all models are similar, except that CM is very bad at day 1. This is presumably due to initialisation as it also happens at the surface. In general A is slightly better than C. The correlation coefficients for A and CM are similar, CO is worse. This agrees with the impression given by the error fields. At 1000 mb the rms errors in A are generally lower, especially on days 4 and 5. At day 2 the errors are almost equal which is rather different from the impression given by the error fields. The same applies to the correlation coefficients. The breakdown of error by wavenumber shows that serious errors occur in the zonal mean field, CO and CM are worse than A. In wavegroups 3-10 there is considerable skill for the first three days. The initialisation problem in CM only shows up in waves 1 to 2. The disagreement of the statistics with other means of assessment is probably partly because of the large errors in zonal mean, which are sometimes noted also as obvious bias in the error fields.

6. 1 January 1978 Models run A, B, CO, CM. A included several improvements to the physics and lower boundary condition.

a) Synoptic assessment

Fig 6.1 shows the 500 mb chart at day 3 and figs 6.2 to 6.5 the forecasts produced by A, B, CO and CM. At day 1 there is a large amplitude trough pair over European Russia and eastern Canada with a strong zonal flow over Northern Europe and the Atlantic. At day 2 a ridge develops over the Atlantic with marked cyclogenesis near Newfoundland. A trough associated with a surface wave moves east across the UK. From day 3 on the ridge continues to develop and move across the UK, by day 5 it is east of the UK with the large troughs over Europe and the mid Atlantic. A, B and CM all had the Atlantic ridge a little too weak and the movement one day slow. The trough crossing the UK on day 2 was well forecast by these models and developed as a strong trough over Europe. A did not develop low pressure over Greenland sufficiently and move it eastwards, B developed it better but did not move it. CO and CM were both similar to A here. CO did not give sufficient amplitude over the Atlantic, the trough crossing the UK did not develop enough and the ridge was much too weak, though it was correctly placed at day 3; it was 10° too far west in the other models.

Over the Pacific the general level of surface pressure was not low enough. A and B gave better gradients than CO and CM. The large amplitude block over west Canada was well forecast by all models.

b) Hovmoeller diagrams

Fig 6.6 shows the actual Hovmoeller diagram for waves 3 to 5 and figs 6.7 to 6.9 the forecasts produced by A, CO and CM. Model A loses the trough amplitude at 150E in wavegroup 1 to 2, the ridge at 30E is wrongly forecast to retrogress. CO forecasts these features correctly. CM follows A though the errors are less great. In wavegroup 3 to 5 A gives too much retrogression in the area 0 to 90E and no progression at 90W. The ridge at 130W is too strong. CO forecasts these features correctly but has too much amplitude from 90 to 180W and gives incorrect retrogression at 150E. CM gives roughly the average of the other two, the errors are less serious than in A. In wavegroup 6 to 10 A gives too uniform a pattern with no developments, the total movement of features is thus too great though the speeds of the simple waves are correct or slow. The general level of amplitude is correct but the detail wrong. CO gives a very weak pattern. Such speeds as can be checked are correct. CM gives good amplitudes and the phases are better than A. Wavegroup 11 to 16 gave no useful information on this occasion.

c) Error fields

Figs 6.10 to 6.12 show the error fields at 500 mb at day 3 from A, CO and CM. CO has extensive negative errors over the east Atlantic, CM and A have less extensive errors here. CM has extensive negative errors over the USA and positive errors in the west Atlantic and North Pacific. CO has some of the positive errors but not the negative, it has a negative error over Alaska. A has small errors over much of the USA, has positive errors over the Rockies and much of the Pacific and a negative error in the SW Atlantic. At the surface CO and CM are similar, CO has lower pressure over the USA and CM over eastern Europe. A has a rather different pattern over the UK and generally higher pressure over the north Atlantic and USA. Otherwise the pattern is similar to C.

d) Objective scores

Table 6 gives the rms errors and height change correlations for this case, also the breakdown of rms error by wavenumber at 500 mb.

Table 6

500 mb error

Parameter	Model/Time (days)	1	2	3	4	5
RMS forecast error	A	3.0	5.8	7.8	10.7	11.1
RMS persistence error		7.3	9.9	10.7	9.9	10.1
forecast error/persistence error x 100		41	58	72	108	109
RMS forecast error	CO	4.2	6.9	8.6	8.9	9.6
RMS persistence error		7.4	10.1	11.3	10.4	10.8
forecast error/persistence error x 100		57	68	76	86	89
RMS forecast error	CM	3.8	6.4	8.7	10.7	12.1
RMS persistence error		7.4	10.1	11.3	10.4	10.8
forecast error/persistence error x 100		51	63	77	103	112
height change correlation (%)	A	90	82	73	51	42
	CO	86	81	77	76	70
	CM	88	83	76	65	52

Table 6 (cont'd)

1000 mb error

Parameter	Model/time (days)	1	2	3	4	5
RMS forecast error	A	2.9	4.4	6.5	8.2	7.8
RMS persistence error		5.6	7.2	8.2	8.0	7.8
forecast error/persistence error x 100		51	61	79	102	100
RMS forecast error	CO	3.9	5.4	7.0	8.1	8.1
RMS persistence error		5.8	7.7	8.7	8.4	8.2
forecast error/persistence error x 100		67	70	80	96	99
RMS forecast error	CM	3.5	5.2	7.4	9.2	8.9
RMS persistence error		5.8	7.7	8.7	8.4	8.2
forecast error/persistence error x 100		60	68	85	110	109
height change correlation (%)	A	84	79	66	49	48
	CO	81	79	73	70	67
	CM	84	79	71	65	63

500 mb error by wavenumber

All errors are expressed as percentage of model persistence. Only the model A persistence is quoted.

Mean Value

	Model/Time (days)	1	2	3	4	5
RMS persistence error	A	1.1	2.5	4.1	4.6	4.1
forecast error/persistence error x 100	A	90	104	97	147	148
	CO	182	131	90	111	146
	CM	191	123	90	116	146

Wavegroup 1-2

	Model/Time (days)	1	2	3	4	5
RMS persistence error	A	3.9	6.9	6.6	6.5	6.7
forecast error/persistence error x 100	A	51	56	72	96	94
	CO	58	43	71	80	84
	CM	47	52	81	108	128

Wavegroup 3-5

	Model/Time (days)	1	2	3	4	5
RMS persistence error	A	5.0	6.5	7.6	6.9	7.0
forecast error/persistence error x 100	A	32	46	65	91	105
	CO	48	75	82	79	69
	CM	39	56	78	92	99

Wavegroup 6-10

	Model/Time (days)	1	2	3	4	5
RMS persistence error	A	5.0	5.7	5.7	4.2	5.0
forecast error/persistence error x 100	A	34	58	68	121	110
	CO	37	63	56	76	82
	CM	33	57	54	89	76

Wavegroup 11-16

	Model/Time (days)	1	2	3	4	5
RMS persistence error	A	2.0	2.1	2.1	1.5	1.9
forecast error/persistence error x 100	A	55	71	71	120	94
	CO	63	70	68	93	76
	CM	53	65	74	113	82

e) Summary

As in all the other cases discussed there is a disagreement in the forecasts over the Atlantic. In this case it was removed by a change in initial data for model C, it seems most likely that the use of octagon winds (nonlinearly balanced) instead of linear balanced winds is the reason. No model gives sufficient amplitude and speed for the ridge. The wrong position and large amplitude in A may contribute to the sharp jump in rms error at 500 mb after day 3, which occurred at all wavenumbers. A similar jump occurred in CM statistics but not in CO. The large jump in error is exaggerated by the persistence 'errors' falling between days 3 and 4. It corresponds to a bad forecast of the Hovmoeller diagram for waves 1 to 2, and also waves 3 to 5. In waves 6 to 10 CO loses amplitude while A gets the phases wrong; thus A has a much larger rms error. The error fields show large differences in the pattern between the three forecasts; all disagree about equally. At 1000 mb CO and CM have similar error patterns while A is different. Thus the marked difference in the Atlantic ridge between the models is only part of a rather complex story which is revealed more by the extra diagnostics than the original charts. The improvements to the physics of model A are probably responsible for the greatly reduced zonal mean rms errors as compared to other cases.

7. 9 April 1978 Models run A, B, CM (referred to as C)

a) Synoptic assessment

Fig 7.1 shows the actual 500 mb chart at day 4 and figs 7.2 to 7.4 show the forecasts produced by A, B and C. On day 0 there was a large amplitude 500 mb trough over the UK and Iberia with a strong 500 mb ridge over the Atlantic. During the period these moved slowly east but the ridge axis remained west of Ireland and consequently cold surface northerlies were maintained over the UK. West of the Atlantic ridge there was a depression over Newfoundland from which a sharp 500 mb trough extended southward, and these also moved slowly east during the period. The depression deepened a little after day 4 as the next 500 mb trough moved from Canada into the old Newfoundland trough. As a result the Atlantic ridge was accentuated towards the end of the period. Over the Pacific, a 500 mb trough off the west coast of Canada moved east and merged with the Canadian low on day 3. Another trough initially at 180W moved steadily east as did a surface low which did not develop much. By day 4 a large ridge was established behind it at 150W. A further ridge became established at 50E ahead of the European trough. A maintained the Atlantic ridge up to day 3 but thereafter the northern part of the Newfoundland trough broke away and moved rapidly round the ridge, weakening it. The associated surface low reached Scotland by day 5, giving westerlies over the UK. B weakened the ridge steadily throughout the period and gave westerlies over the UK at the end. C maintained the ridge much better though the amplitude was low by day 5, the Newfoundland trough was not disrupted. Northerlies were maintained over the UK. Elsewhere, A moves the main Canadian low too far east by day 4 and the trough at 130W has been lost. The Pacific ridge is well forecast, as is the European ridge. B moves the Canadian low even further but is otherwise similar to A. The amplitude over the west Pacific is greater and better than in A. C retains more of the trough at 130W and the amplitude over the west Pacific is greater than in B and greater than the actual. The European ridge is weaker in both B and C than in A and is too far west in C.

b) Hovmoeller Diagrams

Fig 7.5 shows the actual Hovmoeller diagram for wavenumbers 1-2 and figs 7.6 and 7.7 the forecasts produced by A and C. In wavegroup 1 to 2 an initial wavenumber 1 pattern changes to a wavenumber 2 pattern by day 3 with increased amplitude. A does not forecast this change. C does, but the final amplitude is too low. In wavegroup 3 to 5 an initial wave 3 pattern changes to wave 4 by day 5, the pattern is retrogressive except between 0 and 90E. These changes are well forecast by A, but some of the phases become inaccurate in the final day. C also forecasts the wavenumber change but there are again large errors and a reverting to a wave 3 pattern in the last day. Wavegroup 6-10 is generally slowly progressive. A gives reasonable speeds but in some areas gives excessive speed and spurious developments (e.g. at 30W and 150E). The final amplitudes are rather low. C gives mostly correct speeds but incorrect developments in places, the final amplitudes are better than in A (40 per cent higher in the worst area). Wavegroup 11 to 16 has similar and insufficient amplitude in both forecasts.

c) Error fields

Figs 7.8 and 7.9 show the 500 mb errors at day 3 given by models A and C. C has an extensive negative bias. Both models have marked error patterns over eastern North America, the North Atlantic, and NW Europe. Over the UK the patterns disagree, elsewhere they agree. Both models have an enhanced westerly flow in the Pacific. At 1000 mb both models have positive errors over Canada, negative errors over the N Pacific and N Asia. The errors over the Atlantic are different; A has a high over Newfoundland and C low values over the UK and west Atlantic. A has a high in the South Pacific not given by C. The patterns at 1000 mb differ much more than those at 500 mb.

d) Objective scores

Table 7 gives the r.m.s. errors and height change correlation coefficients for this case, also the breakdown of r.m.s. error by wavenumber at 500 mb.

Table 7

500 mb error

Parameter	Model/Time (days)	1	2	3	4	5
RMS forecast error		2.7	4.3	6.0	7.9	9.3
RMS persistence error		5.9	9.0	9.3	9.0	9.7
forecast error/persistence error x 100		46	48	65	88	96
RMS forecast error		3.6	5.8	6.9	8.4	10.1
RMS persistence error		5.8	9.0	9.6	9.2	9.8
forecast error/persistence error x 100		62	64	72	91	103
height change correlation (%)	A	90	87	83	80	77
	C	83	85	85	83	83

1000 mb error

Parameter	Model/Time (days)	1	2	3	4	5
RMS forecast error		2.3	3.6	5.1	6.3	6.7
RMS persistence error		4.5	6.5	7.9	8.5	9.1
forecast error/persistence error x 100		51	55	65	74	74
RMS forecast error		3.3	4.3	5.6	6.6	6.8
RMS persistence error		4.6	6.9	8.5	9.0	9.7
forecast error/persistence error x 100		72	62	66	73	70
height change correlation (%)	A	84	82	77	68	66
	C	78	82	79	73	72

500 mb error by wavenumber

All errors expressed as percentage of model persistence. Only model A persistence is quoted.

Mean Value

	Model/Time (days)	1	2	3	4	5
RMS persistence error	A	1.5	2.5	3.2	3.8	4.2
forecast error/persistence error x 100	A	40	36	34	82	98
	C	93	100	137	147	165

Wavegroup 1-2

	Model/Time (days)	1	2	3	4	5
RMS persistence error	A	2.9	4.1	6.5	8.1	9.6
forecast error/persistence error x 100	A	65	71	66	62	56
	C	93	88	62	52	41

Wavegroup 3-5

	Model/Time (days)	1	2	3	4	5
RMS persistence error	A	3.6	6.2	8.0	8.7	9.0
forecast error/persistence error x 100	A	44	50	53	55	67
	C	53	40	41	48	51

Wavegroup 6-10

Model/Time (days)		1	2	3	4	5
RMS persistence error	A	5.2	6.8	6.7	8.2	8.3
forecast error/persistence error x 100	A	29	37	49	51	51
	C	33	39	51	44	41

Wavegroup 11-16

Model/Time (days)		1	2	3	4	5
RMS persistence error	A	2.2	2.5	2.1	1.7	2.2
forecast error/persistence error x 100	A	45	56	76	106	68
	C	53	62	79	114	68

e) Summary

There is again a major synoptic difference over the Atlantic though this is not well marked till late in the period. On this occasion C gave a rather static pattern which was correct while A became incorrectly mobile and lost amplitude. The amplitude difference is also noticeable in the Hovmoeller diagram for waves 6 to 10, and the diagram for waves 1 to 2 is much more accurately forecast by C than A. The greater amplitude in C is also repeated in the Pacific where it is incorrect. B is close to A in general but with rather larger amplitudes. The error fields show similar patterns from A and C at day 3, except over the UK. The large differences only develop later on. The differences at 1000 mb are much greater. Thus the difference between the forecasts seems to propagate upwards in this case, while the reverse tended to be true in the previous case. Once again the zonal mean r.m.s. errors in A are greatly reduced. In wavegroup 1-5 C has greater errors at the start but smaller errors at the end. The same behaviour occurs in the total r.m.s. error at 1000 mb and the correlation coefficients at 500 and 1000 mb. At 500 mb the total r.m.s. error is dominated by the behaviour of the mean error. There is still evidence of an initialisation problem in C at waves 1-2.

8. General Discussion

Some general patterns of behaviour emerged from a detailed study of six cases. Straightforward movement of 500 mb features was usually forecast and developments in the first three days took place but were nearly always either slow or weak. After day 3 developments were not usually forecast and models A and C often disagreed. B tended to follow A throughout and gave slightly greater amplitudes at 500 mb, whether correct or not. C tended to form cut-off highs at 500 mb and to move troughs rather slower than A; thus where A gave a progressive pattern with too little amplitude C might give a slower pattern with larger amplitude (9 April) while where A maintained the amplitude C might exaggerate the ridge into a cut-off (20 February). This behaviour was reversed in one case (1 January) though in this case it could be explained by different data. Thus over five days there seems to be a tendency for the models to produce rather different types of pattern. The Hovmoeller diagrams showed that speeds of simple patterns were usually well forecast, but developments of the pattern were badly forecast. Wavenumbers 1 to 2 were nearly always better forecast by C than A. Possibly this reflects the geometry of the models. CM was badly initialised in this wavegroup. The error fields and zonal mean r.m.s. errors showed strong bias in the models which varied with season. Those in A were substantially reduced by a better physics package in the last two cases. These tended to dominate the overall r.m.s. errors. At 1000 mb C tended to give low pressure over land areas in summer, particularly Eurasia, sometimes N. Africa. The r.m.s. errors in wavegroups 3 to 10 were often less than 50% of persistence indicating considerable still on synoptic scales. At 1000 mb the statistics in the two summer cases showed very serious loss in accuracy with r.m.s. errors often greater than persistence over most of the period and correlation coefficients near 50%.

In general these results show that there are certain faults which can be cured, such as biassed fields at 500 mb, but some issues are obscure such as the reason why models prefer different 500 mb patterns. No experiment to date with either model has altered its behaviour so as to look like the other. The 1 January case gives evidence that differences of the magnitude observed can be produced by different handling of the initial data.

Acknowledgements

This experiment involved co-operation from many of the staff of Met O 11, 20 and 2b. The forecasts were run by G W Purvis and J W Prince and the diagnostics produced by R Roskilly and R Downham. The synoptic assessments are based on those produced by P G Wickham, L P Steele and J McDougall.

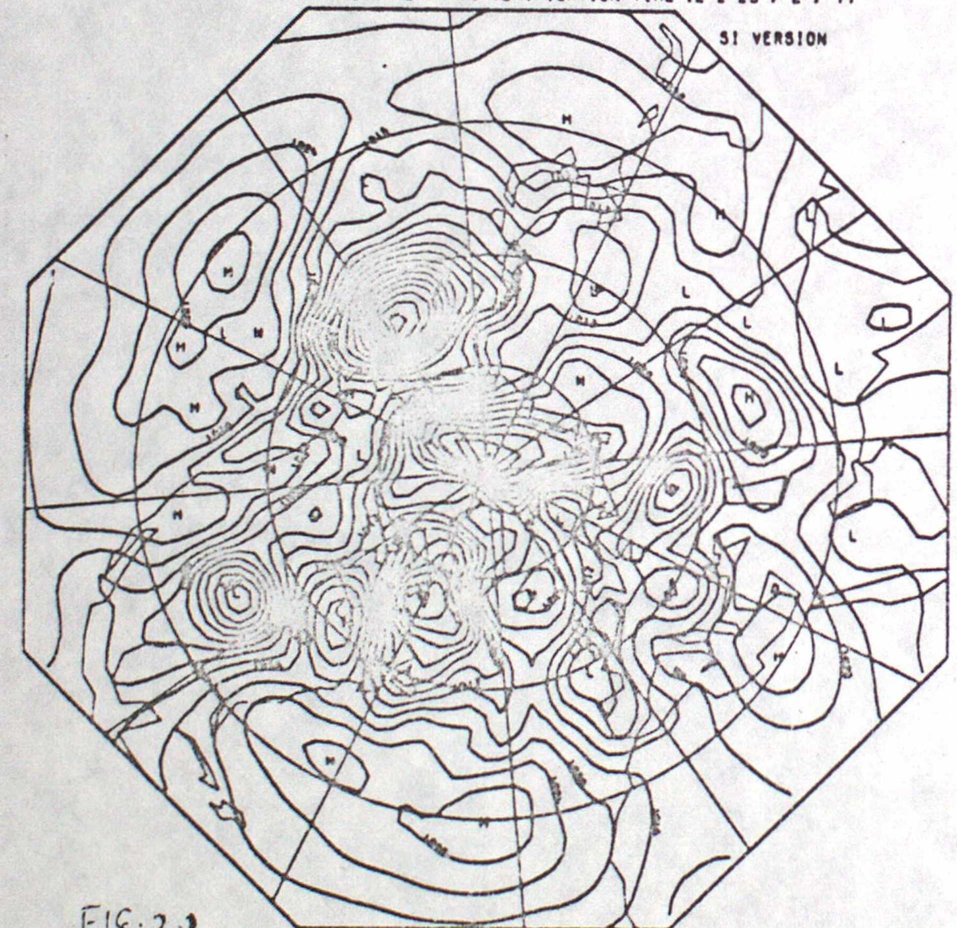
Reference

Cullen, M J P "A summary of synoptic assessments from the forecast model intercomparison experiment: February 1977 to May 1978" Met O 11 Tech. Note No. 111.

SURFACE PRESSURE   ISOBARS AT 4MB INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 23 / 2 / 77. VERIFICATION TIME 12 Z 23 / 2 / 77

SI VERSION



500 MB CONTOURS   CONTOUR LINES AT 6 DECAMETER INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 23 / 2 / 77. VERIFICATION TIME 12 Z 23 / 2 / 77

SI VERSION

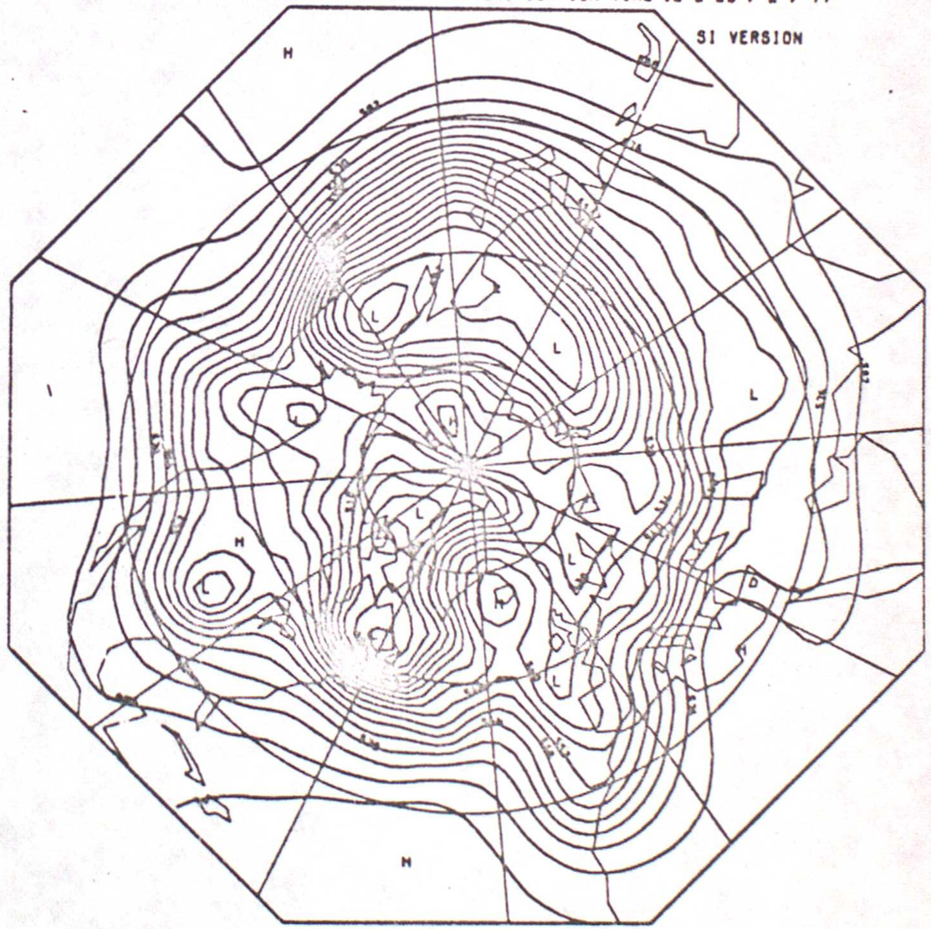


FIG. 2.1

DT 20/2/77

DT 12Z 20/02/77 VT 12Z 23/02/77 T+72 500 MB HEIGHT (60M INT)

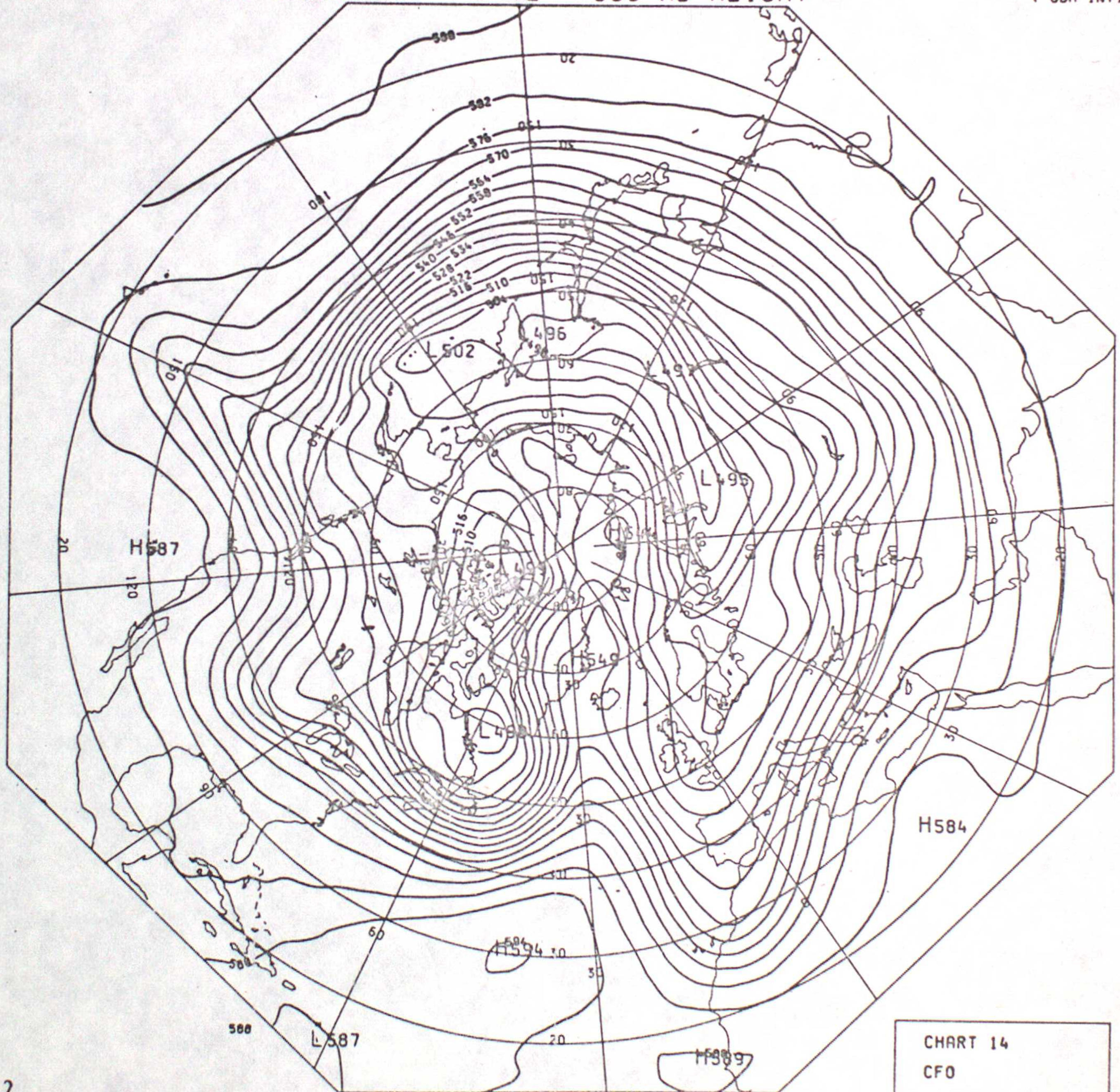


FIG 2.2

DT 12Z 20/02/77 VT 12Z 23/02/77 T+72 500 MB HEIGHT (60M INT) UPDATE

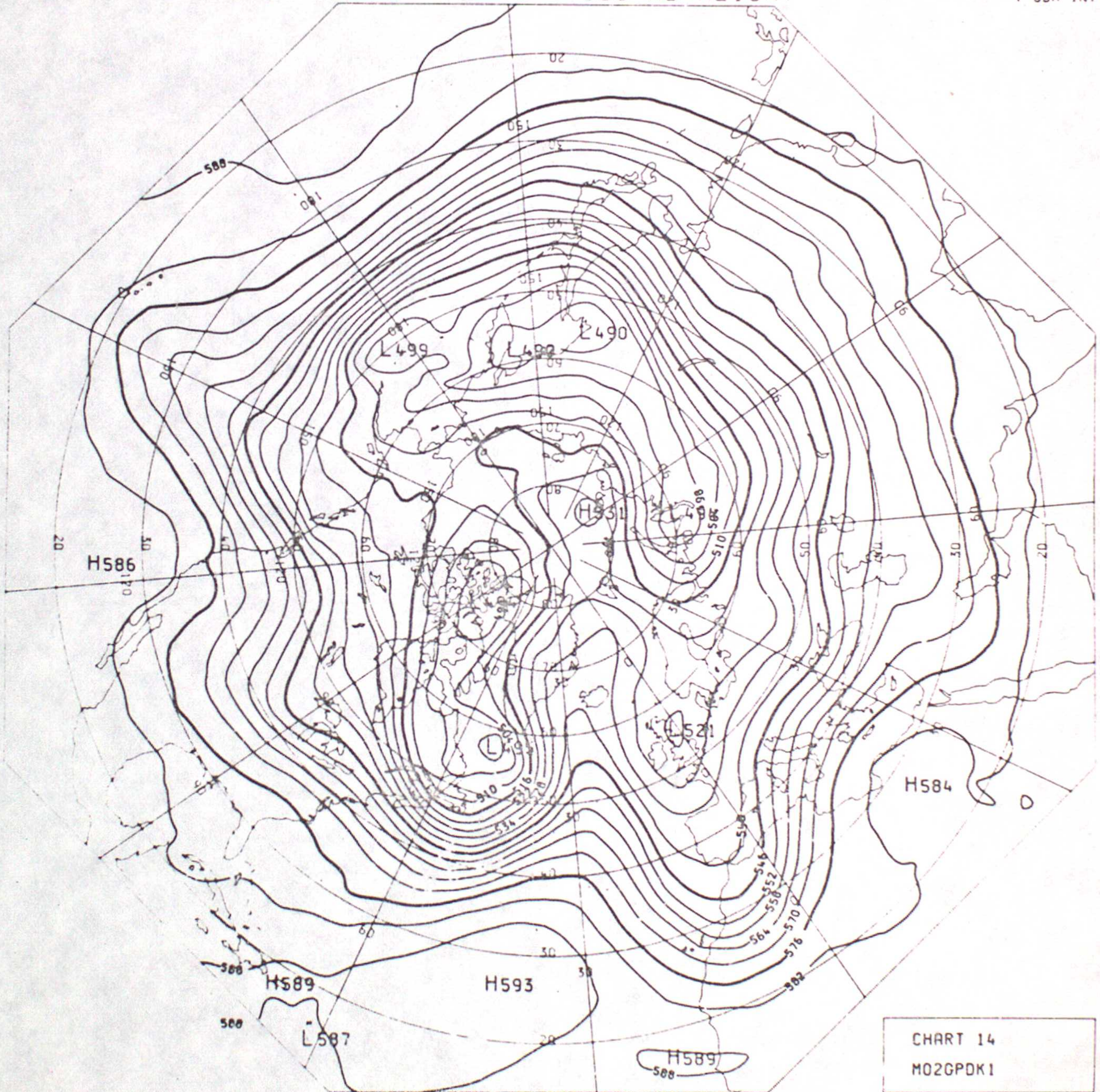
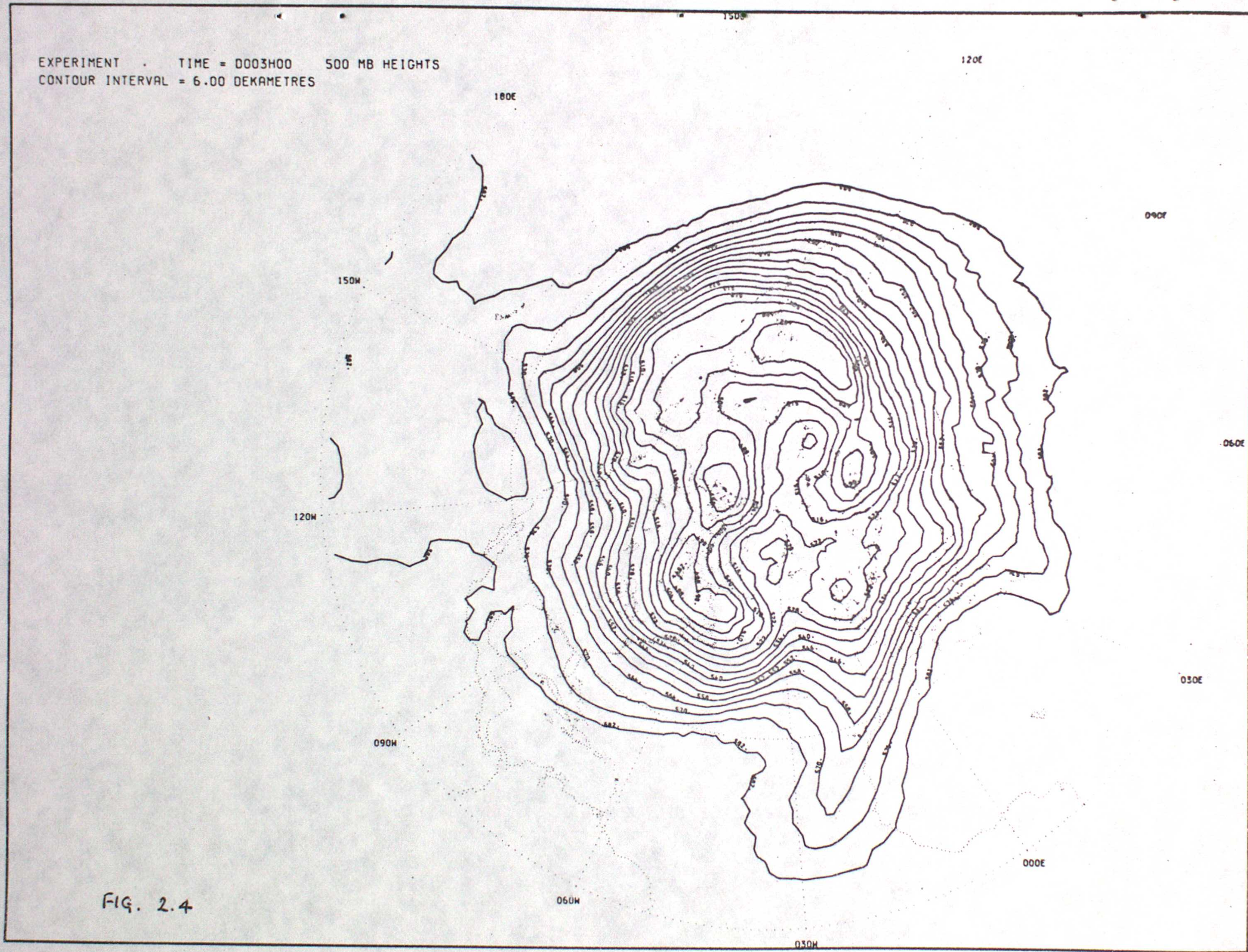


FIG 2.3



EXPERIMENT . TIME = 0003H00 500 MB HEIGHTS
CONTOUR INTERVAL = 6.00 DEKAMETRES
150E
120E
180E
090E
150W
060E
120W
030E
090W
000E
060W
030W

FIG. 2.4

20/2/77
Waves 6-10
11 level Actual

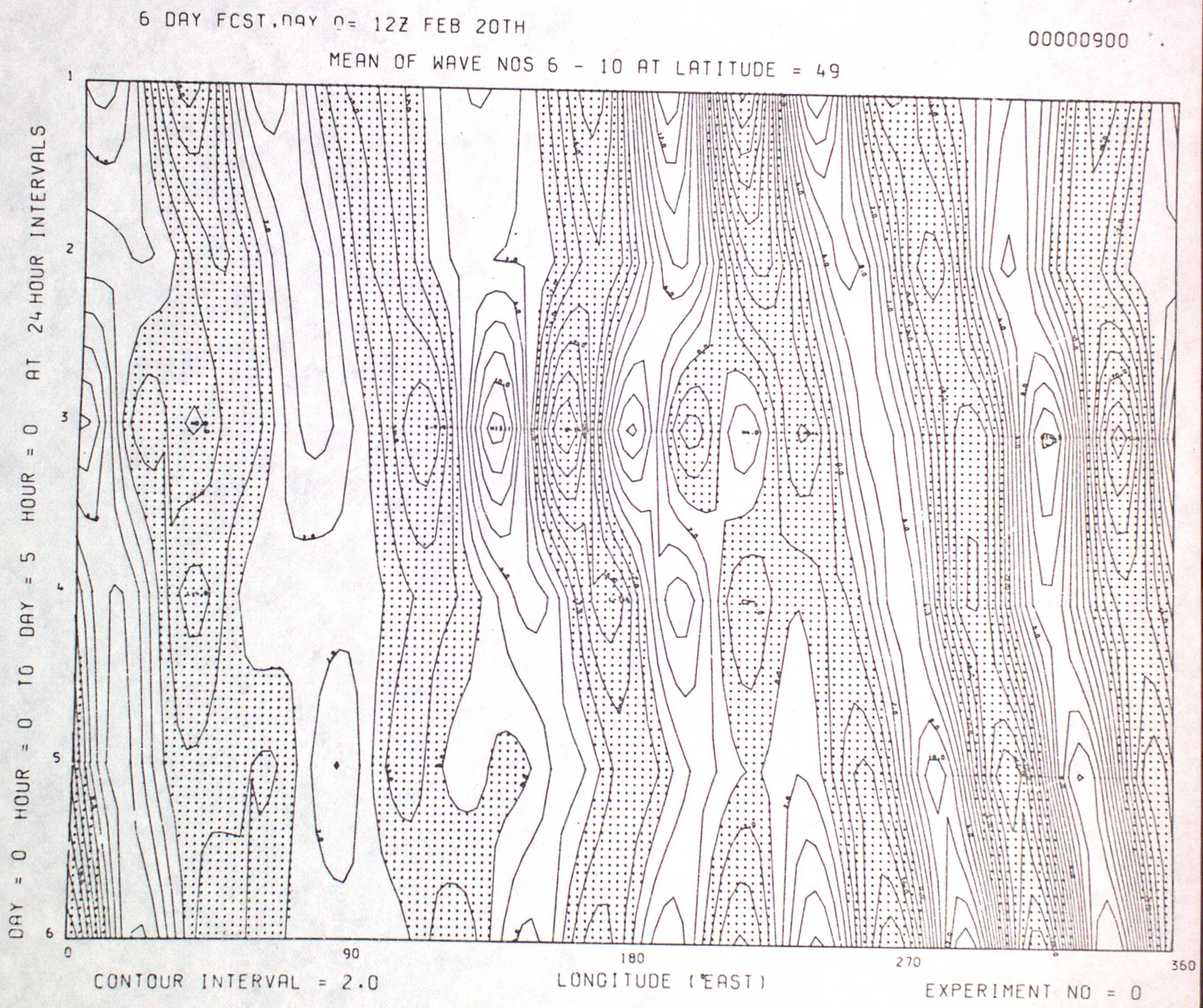
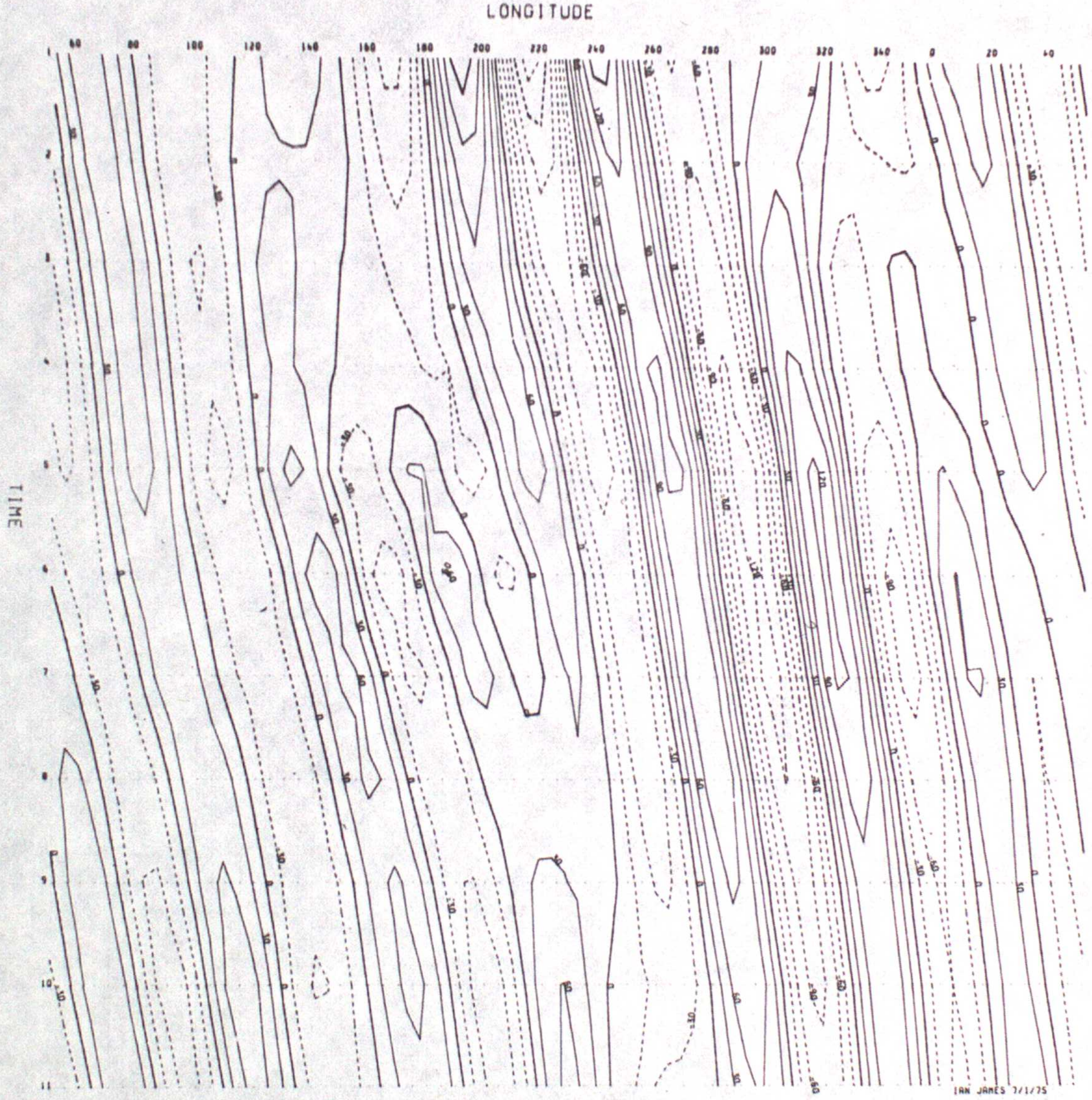


FIG 2.5

HOVMOELLER DIAGRAM FOR WAVENUMBERS 6 TO 10

DATA TIME IS 12Z 20/2/77

BASED ON 80 POINTS AT 50.0°N



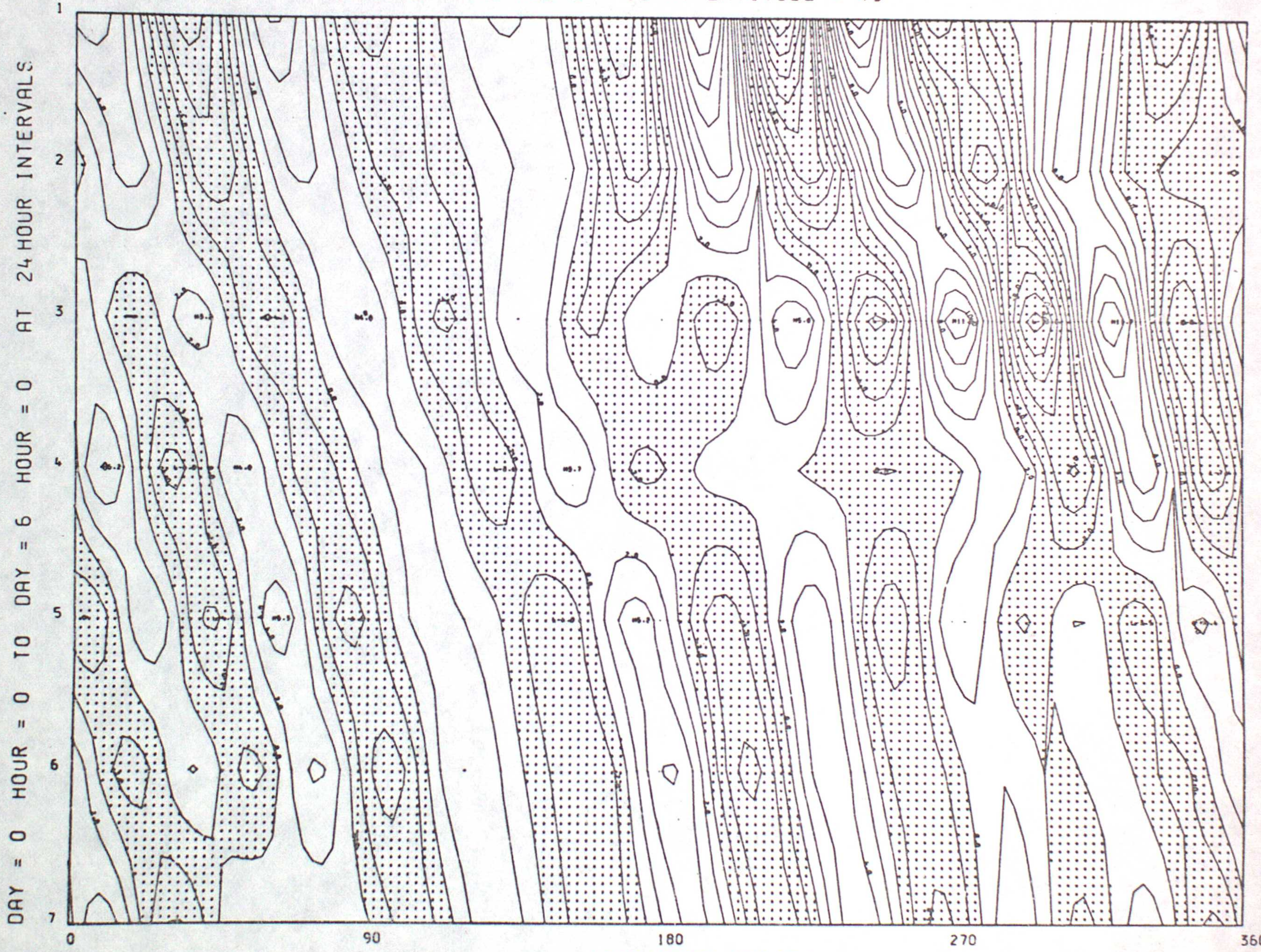
OPERATIONAL UPDATE F/C

CONTOUR INTERVAL IS 30.0 M

FIG 2.6

6 DAY FCST.DAY 0= 12Z FEB 6TH

MEAN OF WAVE NOS 6 - 10 AT LATITUDE = 49



CONTOUR INTERVAL = 2.0

EXPERIMENT NO = 0

20/2/77
Waves 6-10
1 level F/c

FIG 2.7

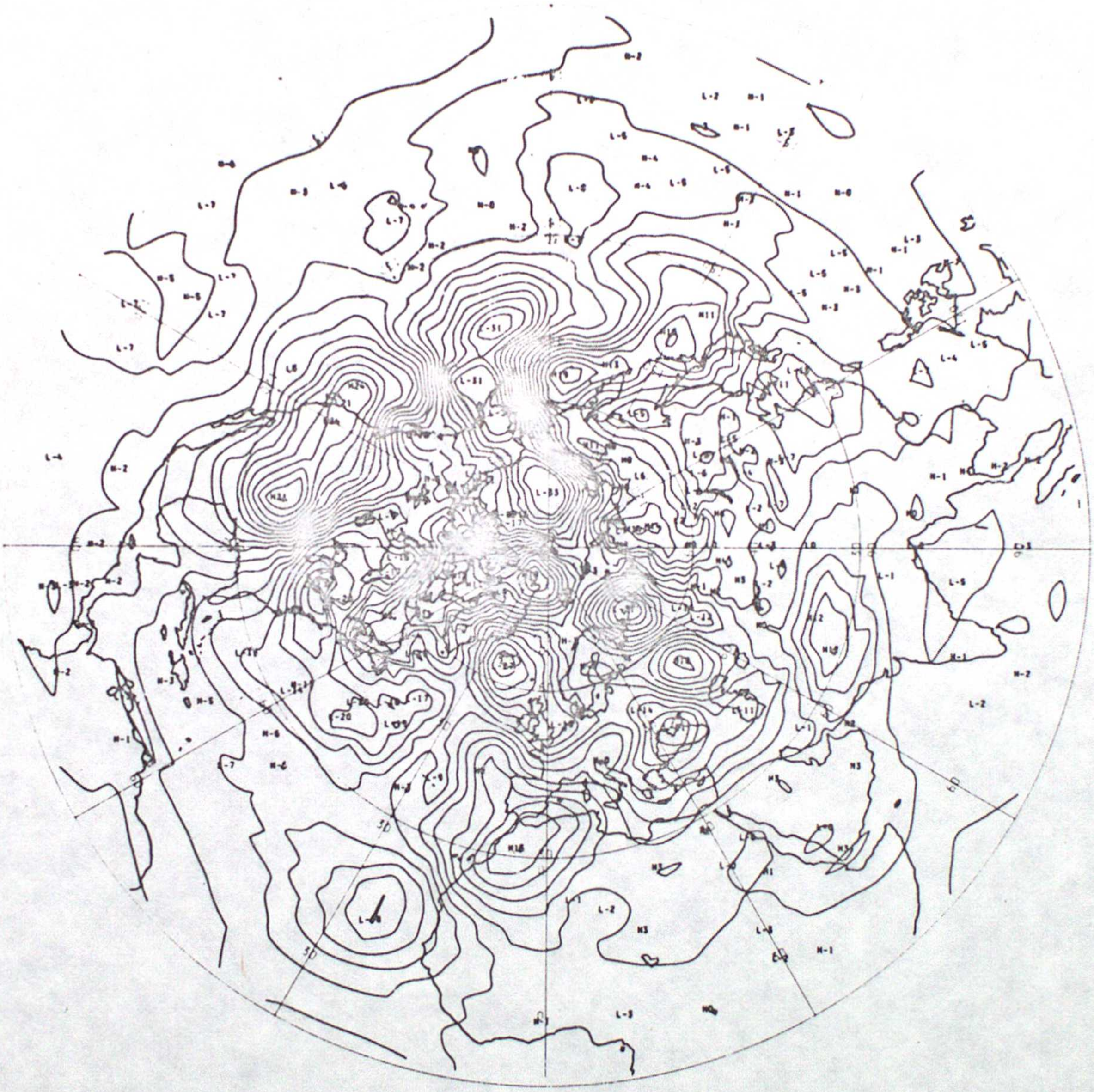
COMPARISON OPER UPDATE F/C & ACTUAL 500MB HT VERIFYING TIME 12Z 23/2/77

ERROR (F'CAST-ACTUAL) T+72 FORECAST FIELD

FIG 2.8

INTERVAL=6

72 hrs 500 mb error
DT: 20/2/77 12Z
11level.



DIFFERENCE IN PRESSURE LEVEL =500.0 FOR EXH 0 - EXH 0 D 3H 0
CONTOUR INTERVAL = 3.00

FIG 2.9

500 MB CONTOURS • CONTOUR LINES AT 6 DECAMETER INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 12 / 5 / 77. VERIFICATION TIME 12 Z 12 / 5 / 77

SE VERSION

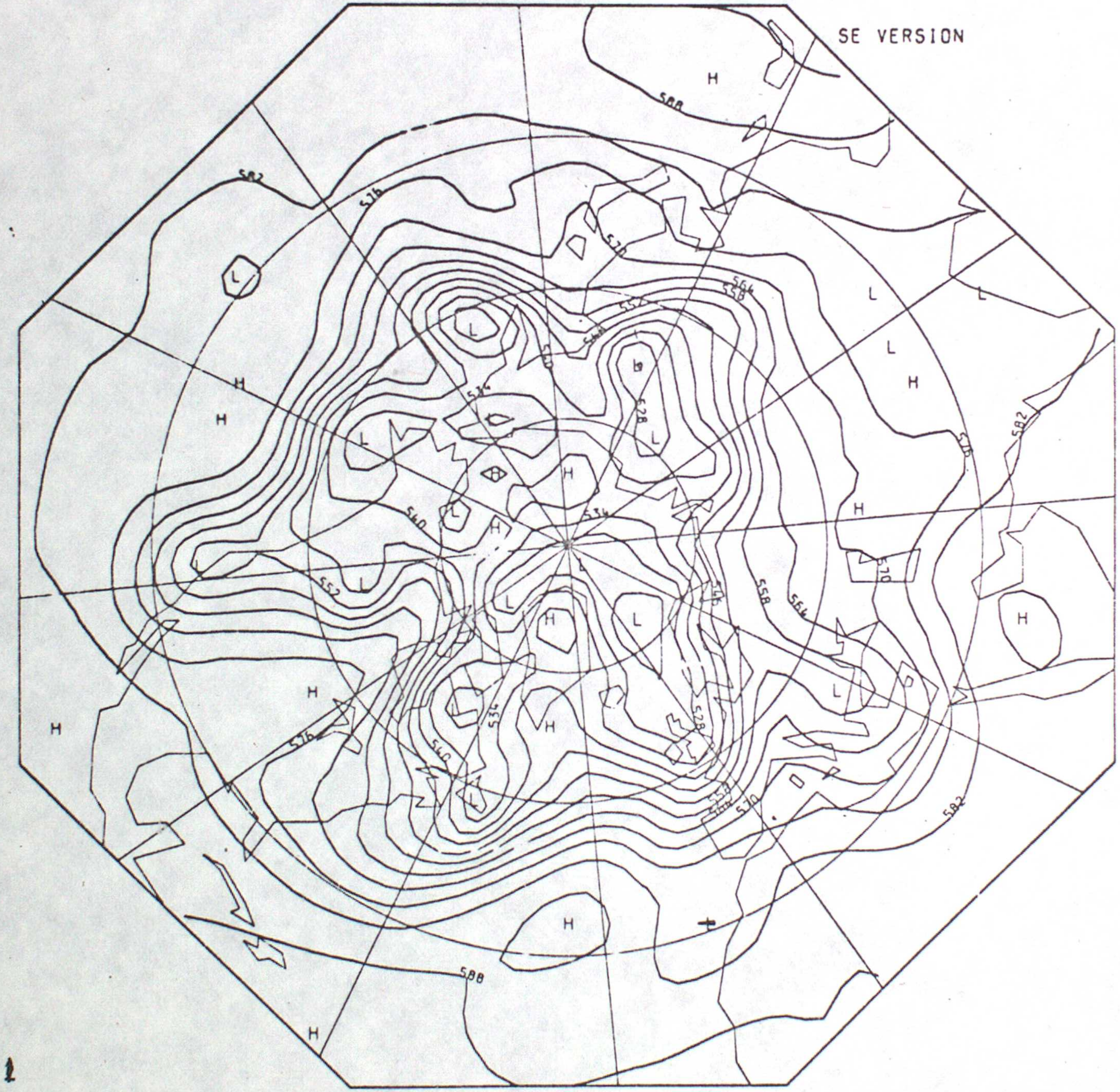


Fig. 3.1

DT 12Z 08/05/77 VT 12Z 12/05/77 T+96 500 MB HEIGHT (60M ...T) UPDAT

6 DAY F/C

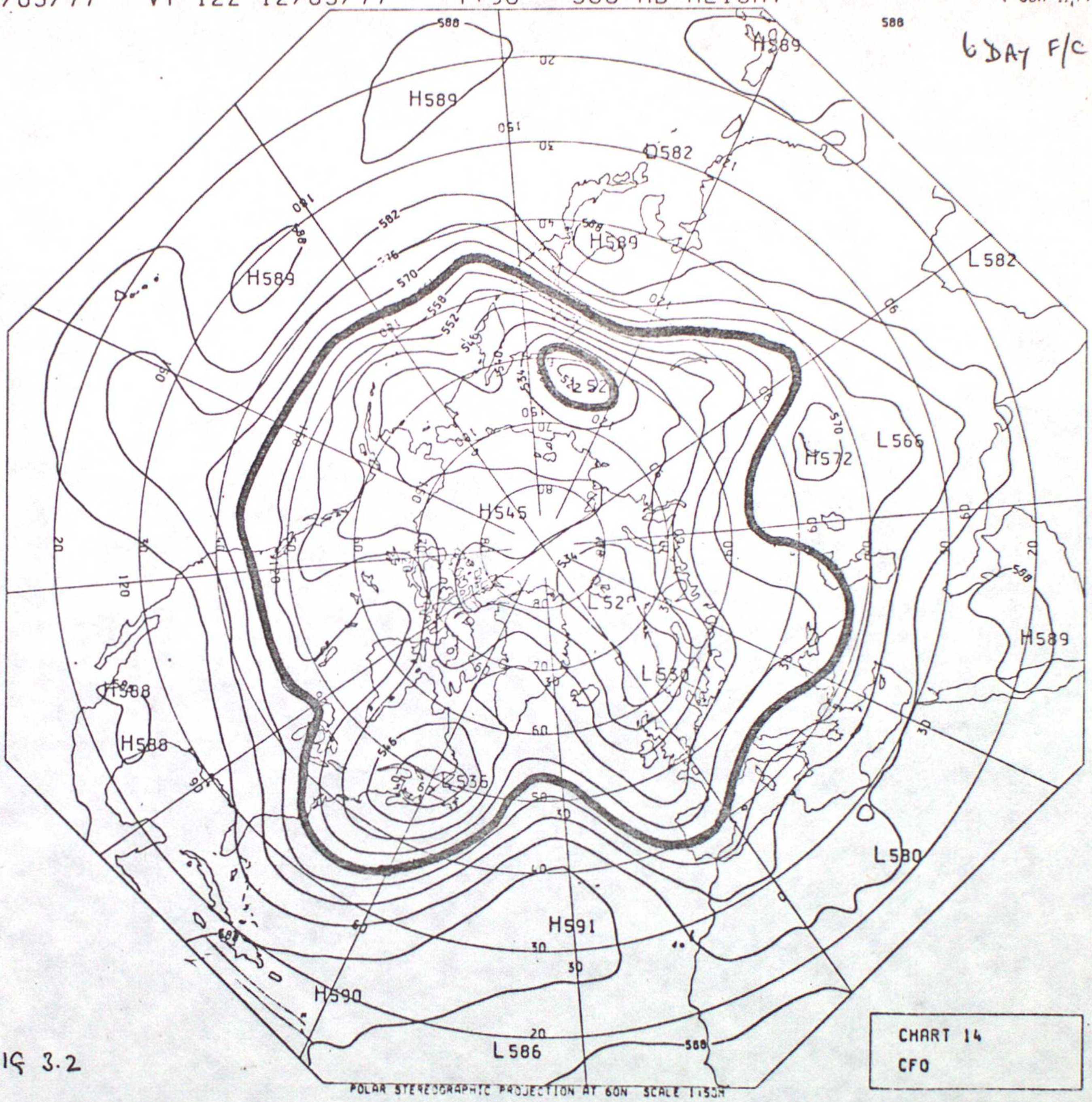


CHART 14
CFO

FIG 3.2

DT.

DT 12Z 08/05/77 VT 12Z 12/05/77 T+96 500 MB HEIGHT (60M INT) UPDATE

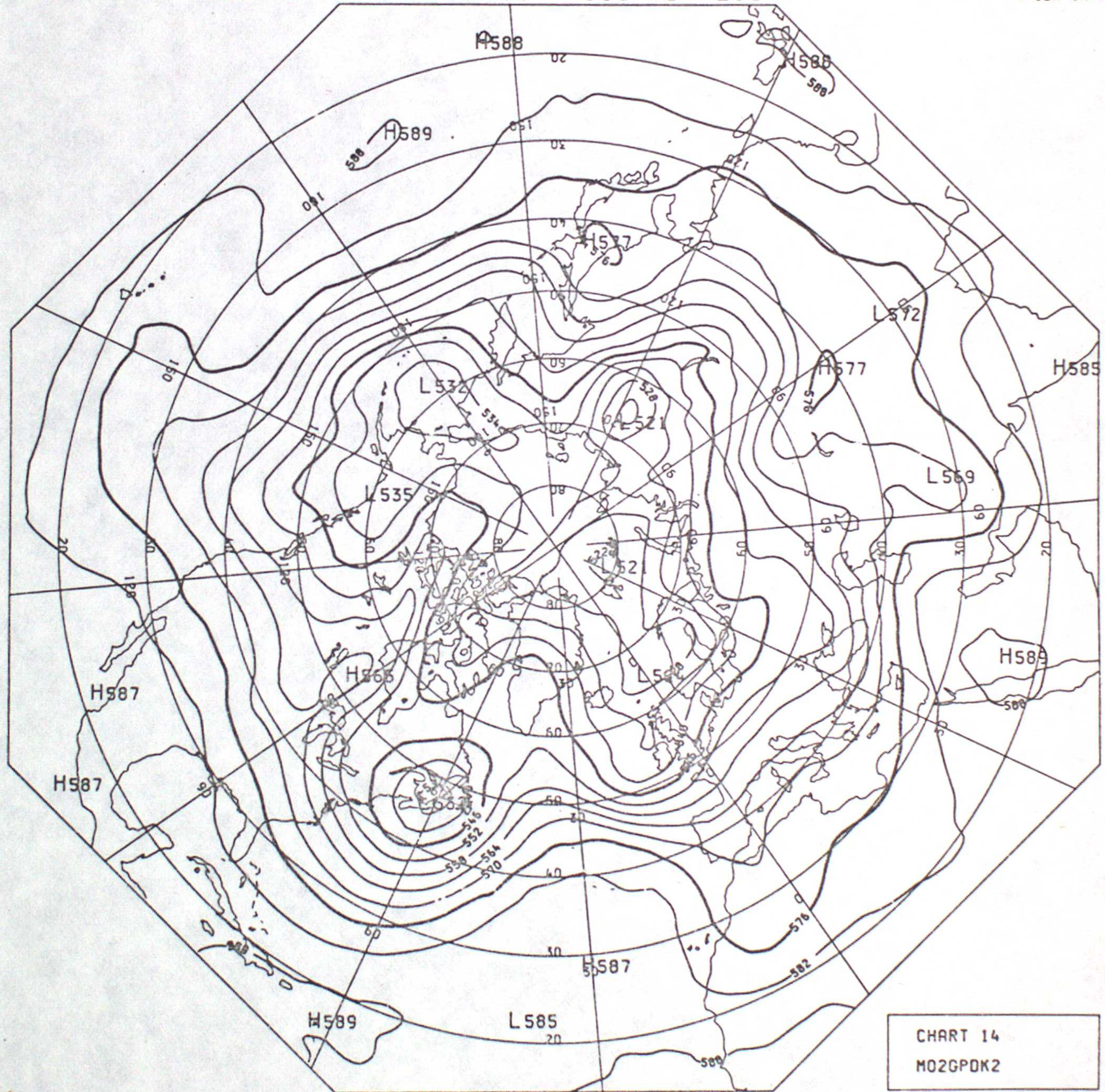


FIG 3.3

EXPERIMENT TIME = D004H00 500 MB HEIGHTS
CONTOUR INTERVAL = 6.00 DEKAMETRES

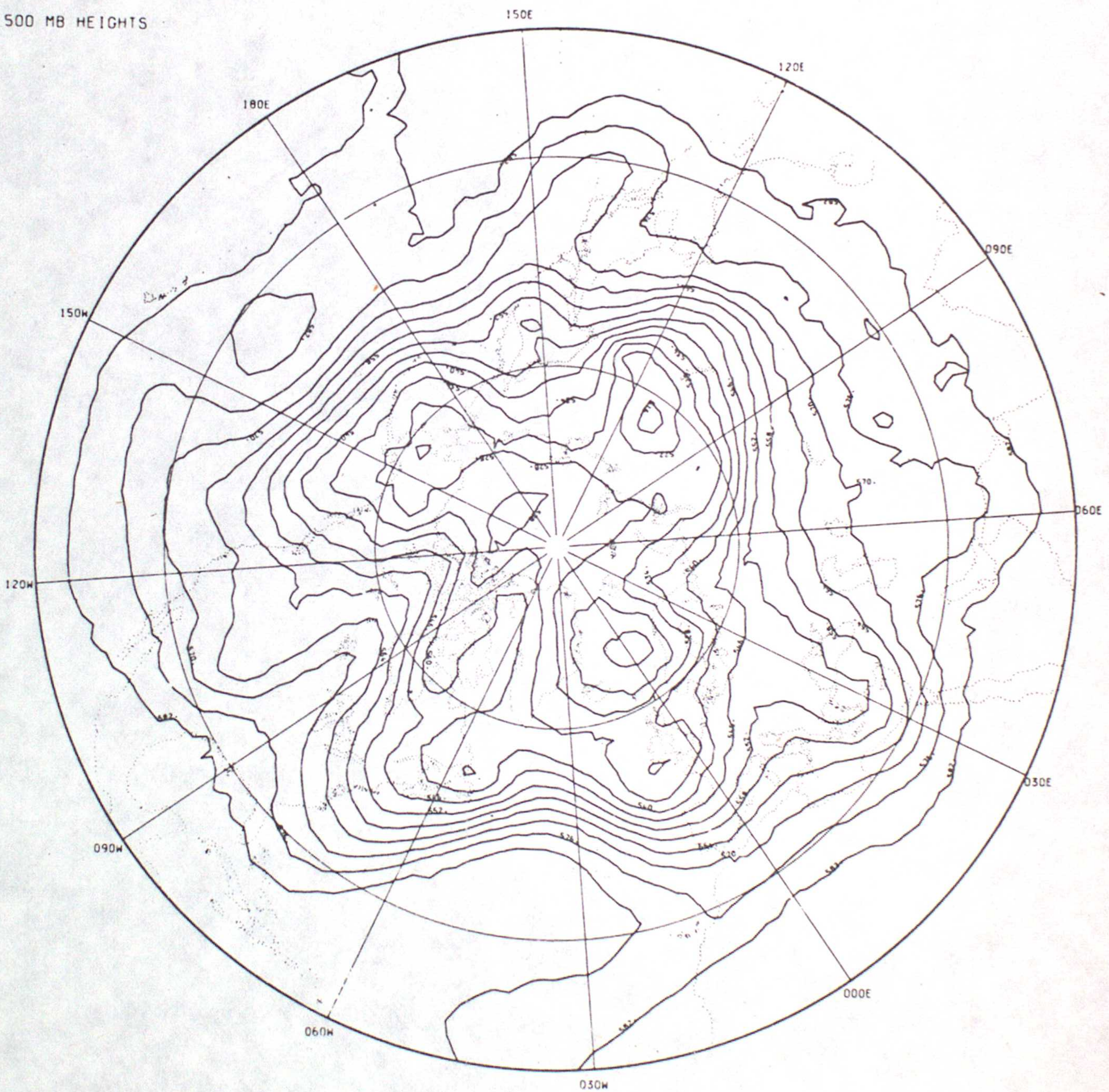


FIG 3.4

5 DAY FCST.DAY 0= 12Z MAY 08TH

MEAN OF WAVE NOS 3 - 5 AT LATITUDE = 49

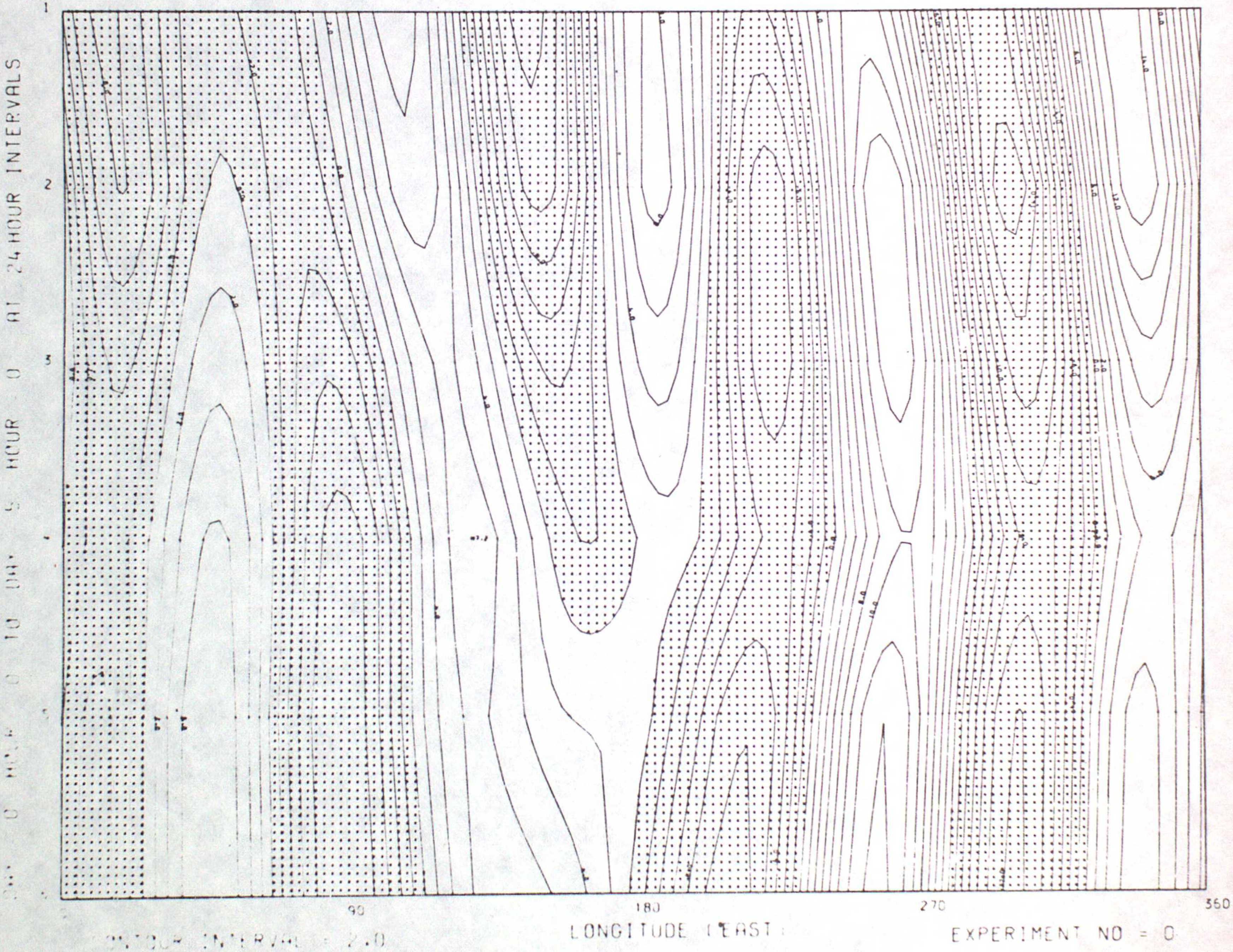
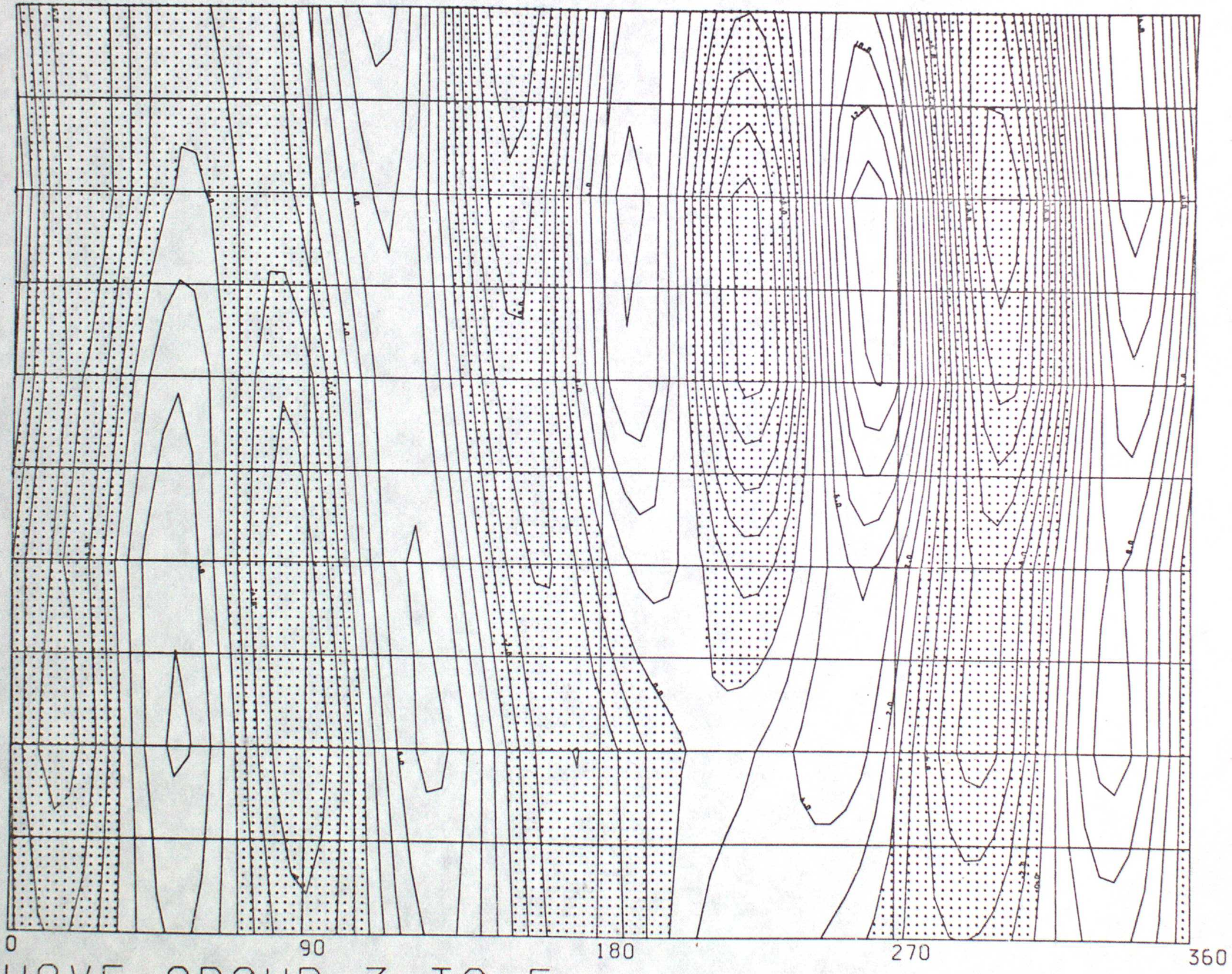


FIG 3.5

OP F/C
DATA TIME 12Z 8/5/77



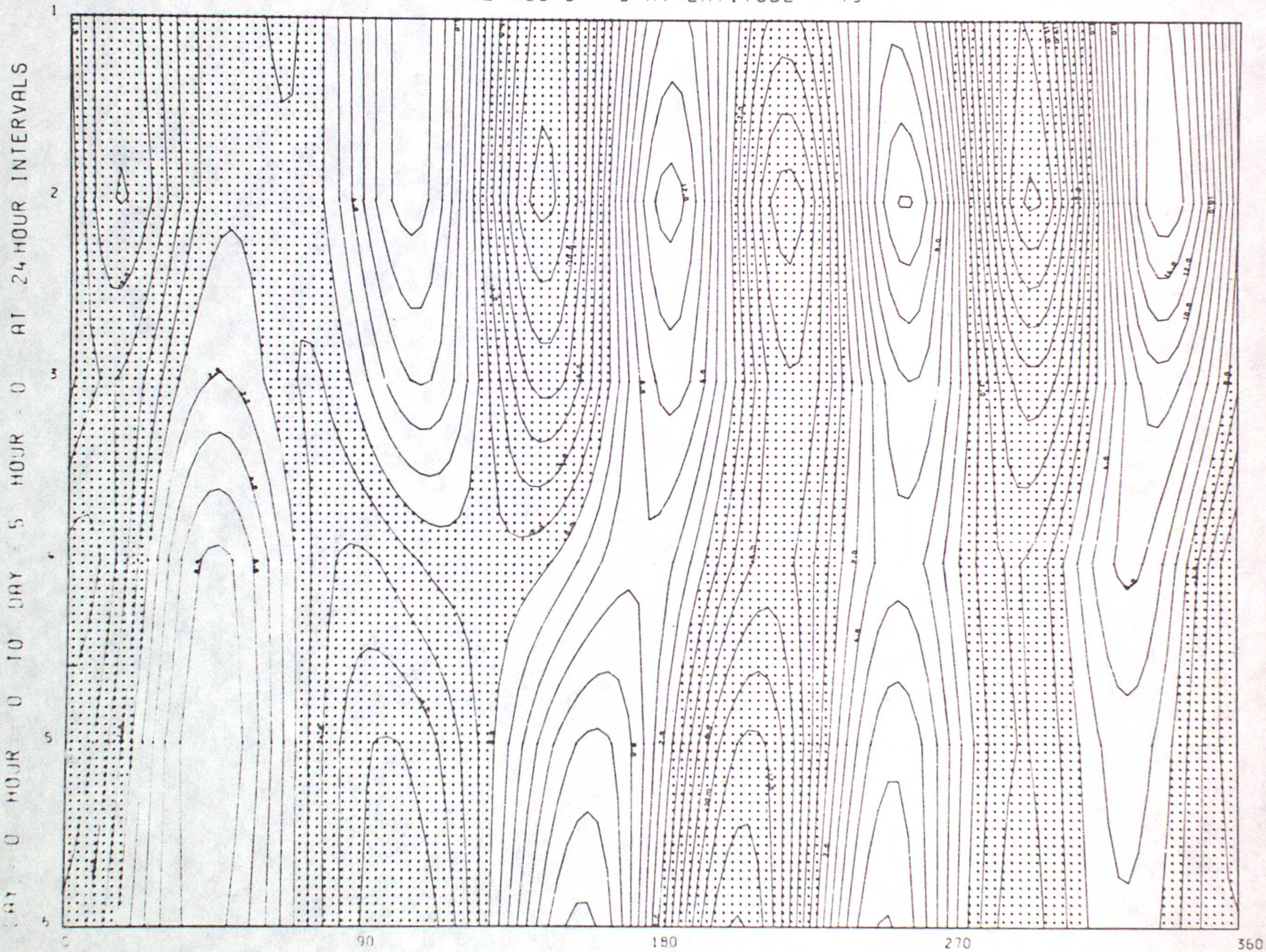
WAVE GROUP 3 TO 5
BASED ON 80 PTS AT 50N

FIG 3.6

5 DAY FCST.DAY 0= 12Z MAY 8TH

MEAN OF WAVE NOS 3 - 5 AT LATITUDE = 49

8/5/77
-5 waves
evel



CONTOUR INTERVAL = 2.0 LONGITUDE (EAST) EXPERIMENT NO = 0

FIG 3.7

COMPARISON OPER UPDATE F/C & ACTUAL 500MB HT VERIFYING TIME 12Z 11/5/77
ERROR (F'CAST-ACTUAL) T+72 FORECAST FIELD

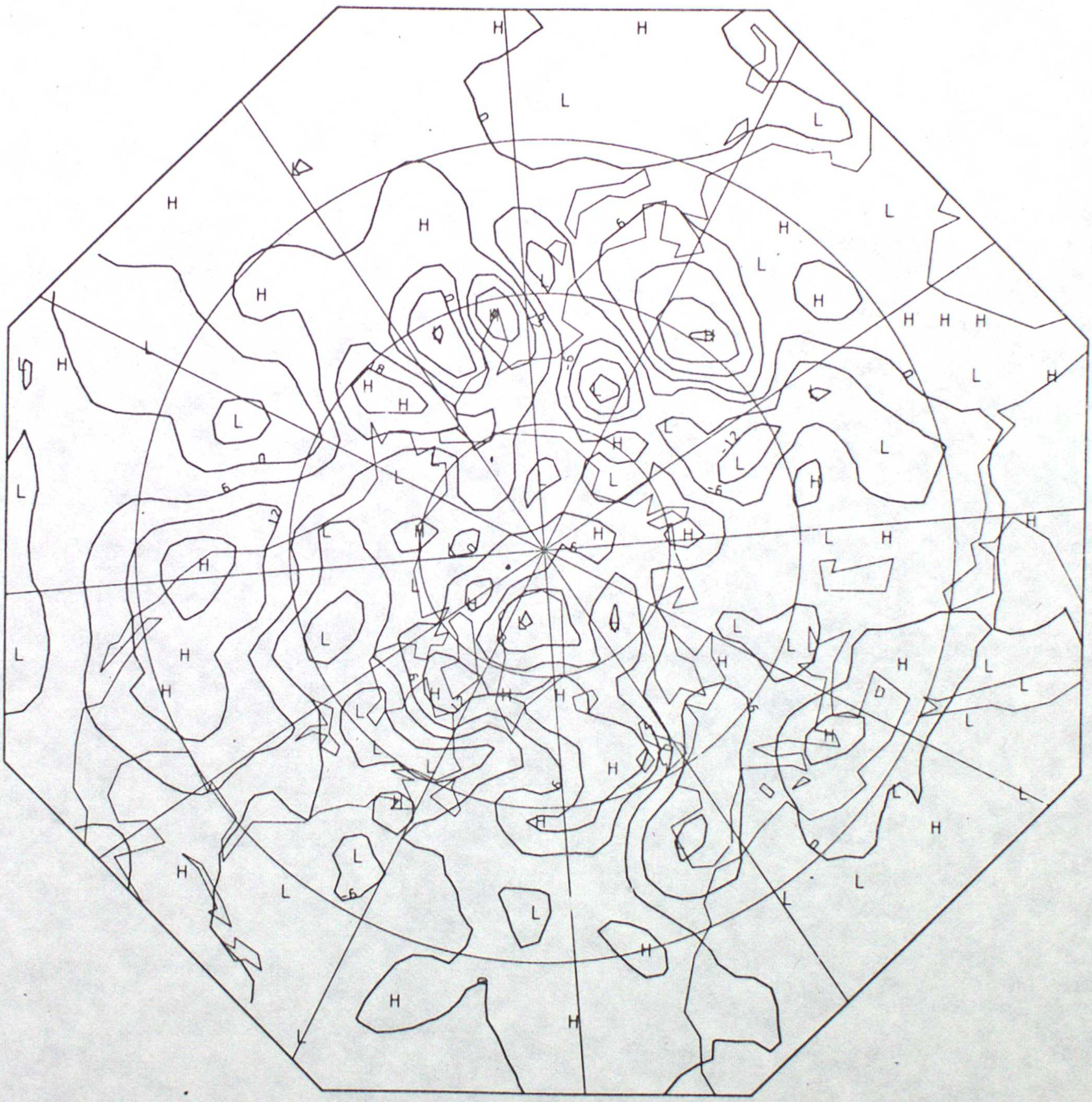


FIG 3.8

INTERVAL=6

72hr 500mb error
DT 8/5/77 12Z
11 level

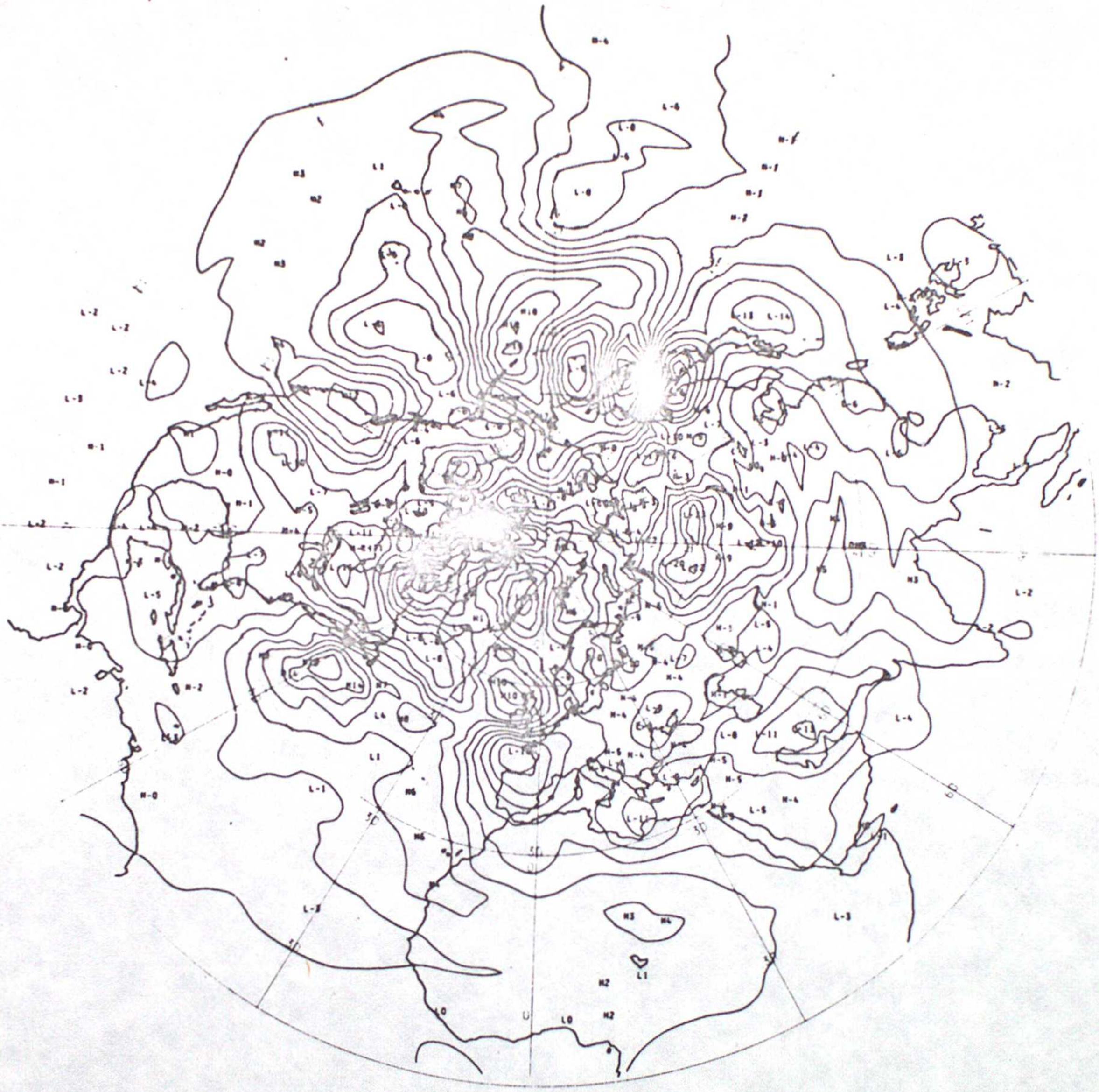


FIG 3.9

DIFFERENCE IN PRESSURE LEVEL =500.0 FOR EXH 0 - EXH 0 D 3H 0
CONTOUR INTERVAL = 3.00

500 MB CONTOURS   CONTOUR LINES AT 6 DECAMETER INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 17 / 8 / 77. VERIFICATION TIME 12 Z 17 / 8 / 77

SE VERSION

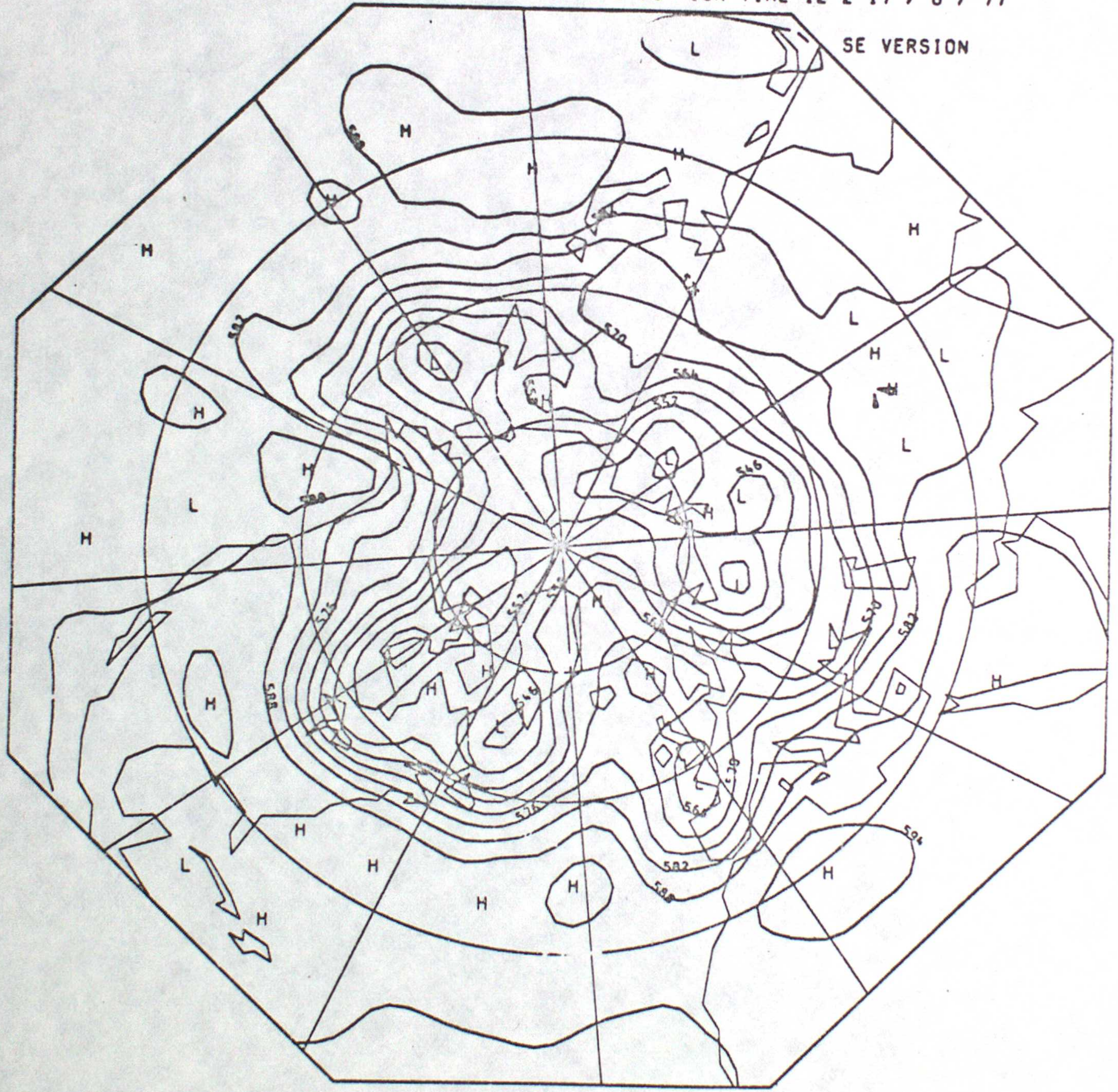


FIG. 4.1

6 Day F/C
14-8-77

T 12Z 14/08/77 VT 12Z 17/08/77 T+72 500 MB HEIGHT (6DM INT) UPD

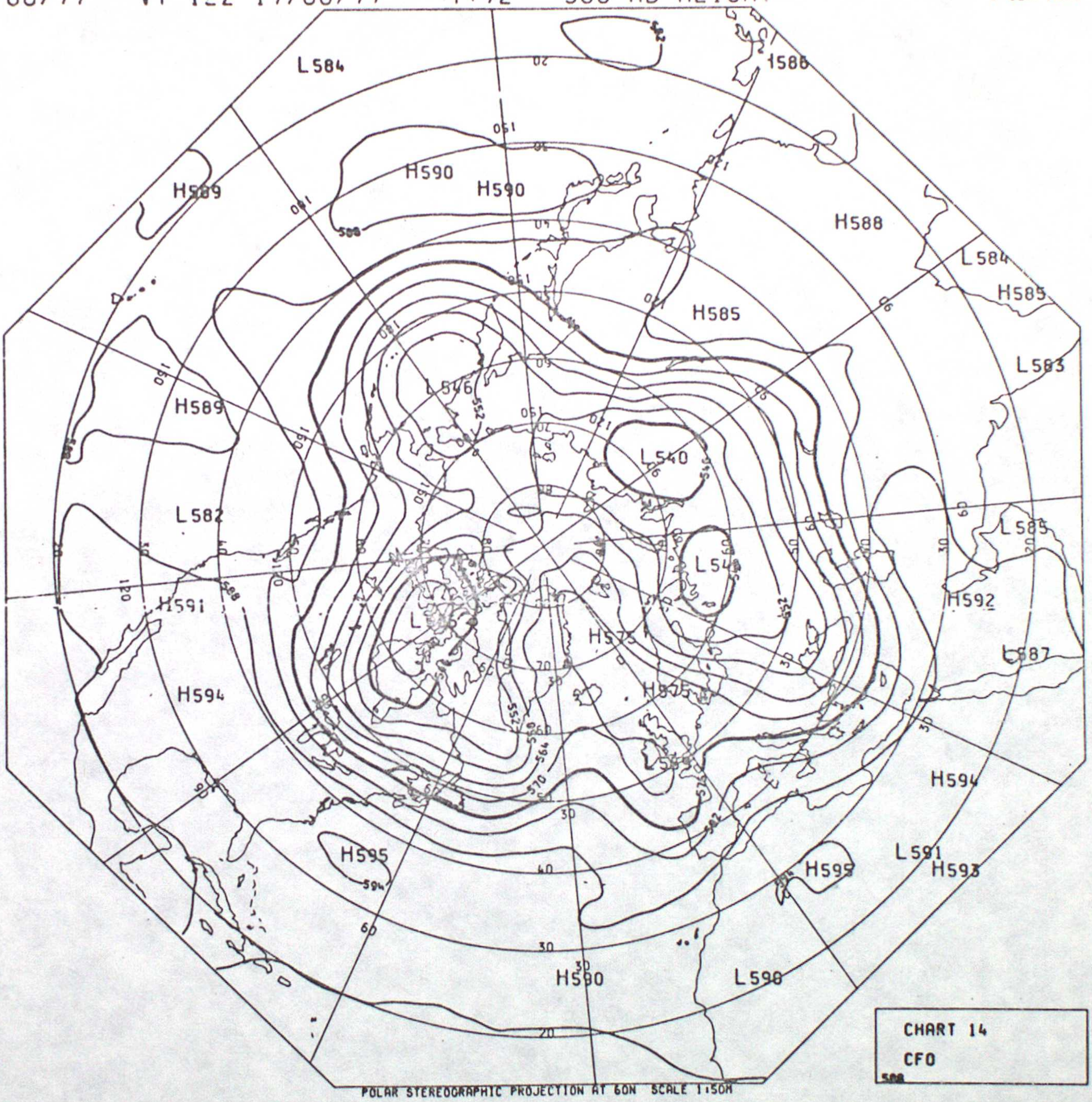
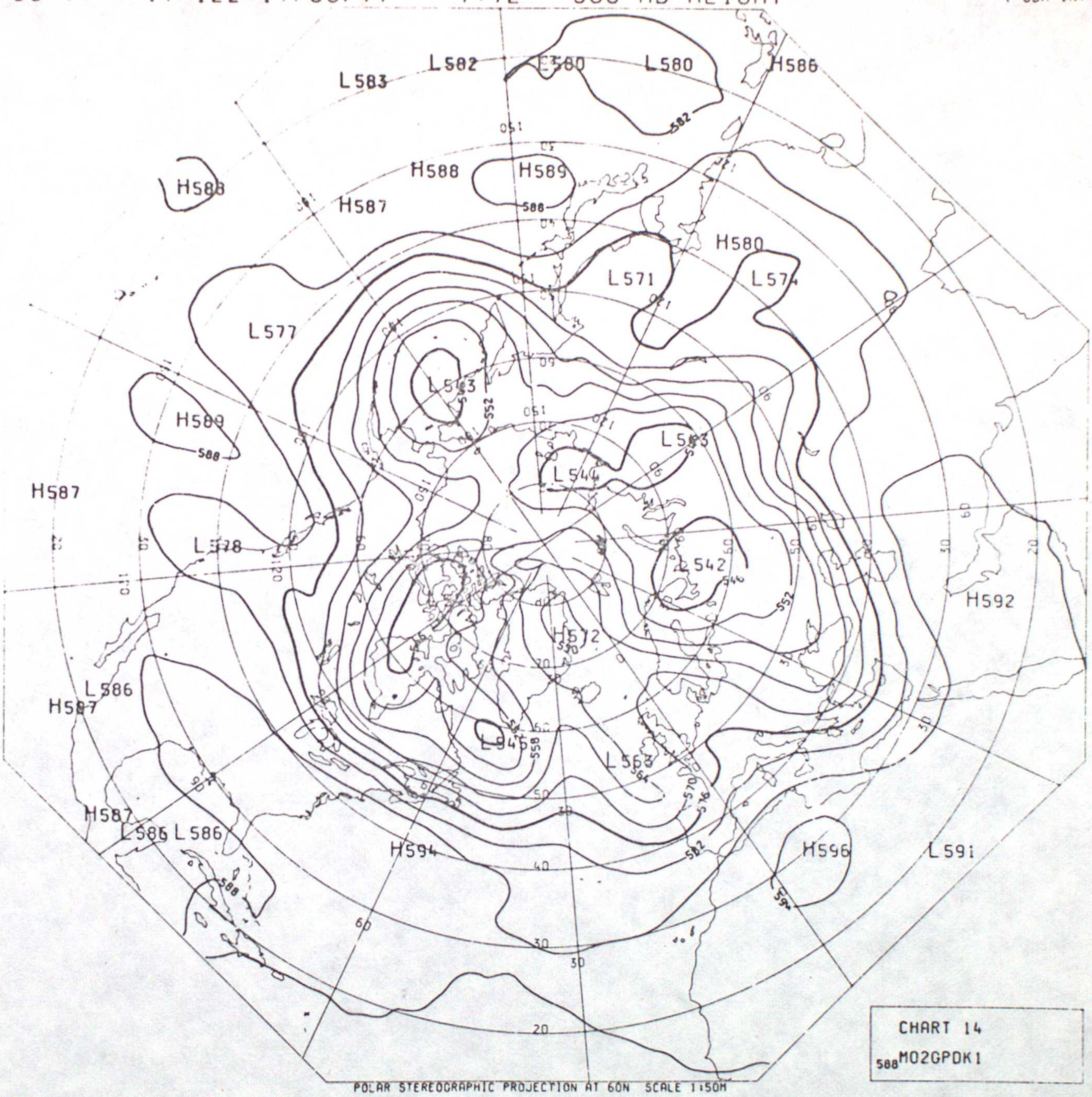


FIG 4.2

SIGMA
DT 14.8.77

DT 12Z 14/08/77 VT 12Z 17/08/77 T+72 500 MB HEIGHT (60M INT) U



POLAR STEREOGRAPHIC PROJECTION AT 60N SCALE 1:50M

FIG 4.3

EXPERIMENT   TIME = D003H00   500 MB HEIGHTS
CONTOUR INTERVAL = 6.00 DEKAMETRES

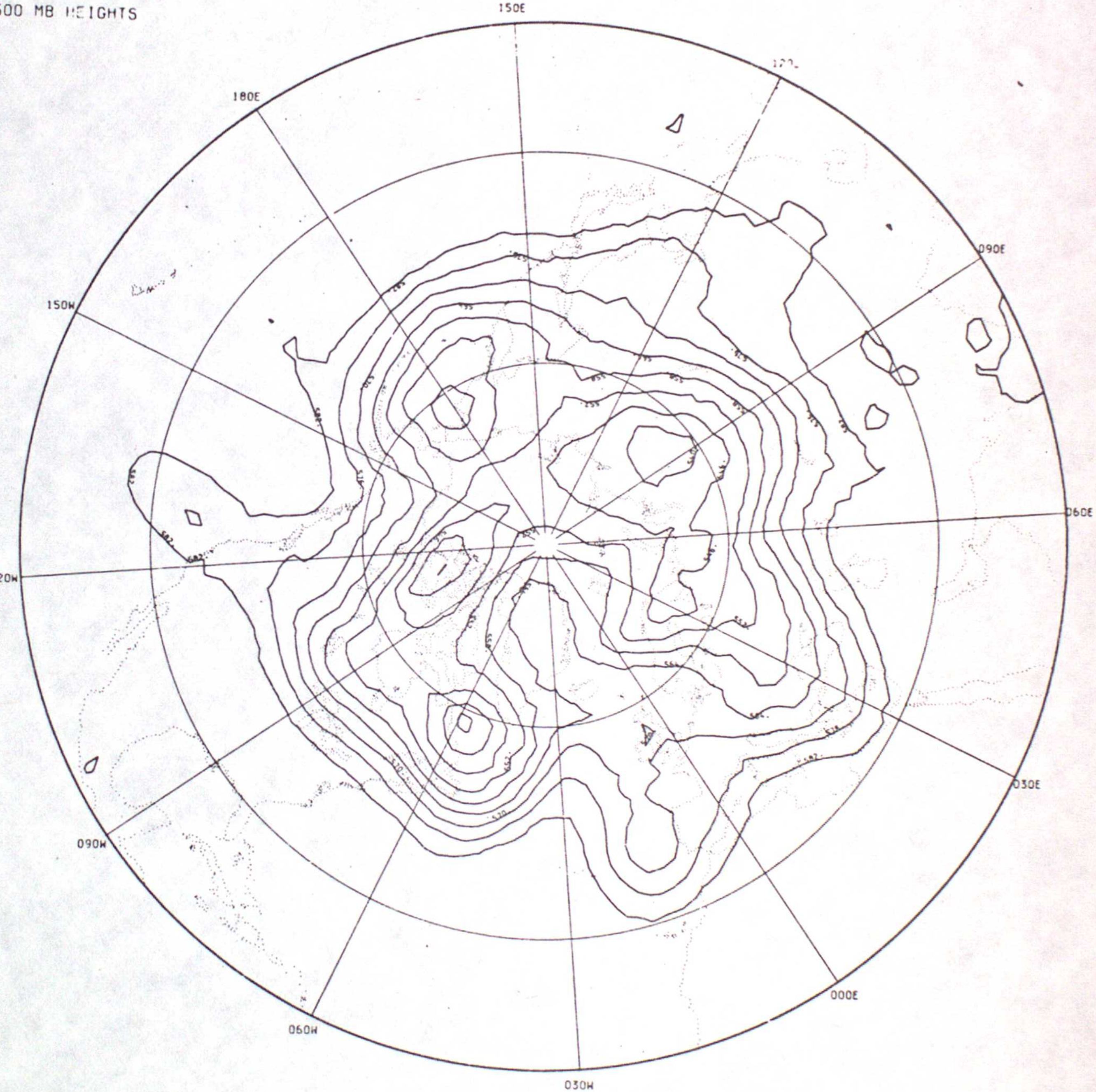


FIG 4.4

5 DAY FCST.DAY 0= 12Z AUGUST 14TH 1977

MEAN OF WAVE NOS 3 - 5 AT LATITUDE = 49

CONTOUR INTERVAL = 2.0   LONGITUDE (°EAST)   EXPERIMENT NO = 0

FIG 4.5

8/77
Waves
...tial
...level

OP F/C
DATA TIME 12Z 14/8/77

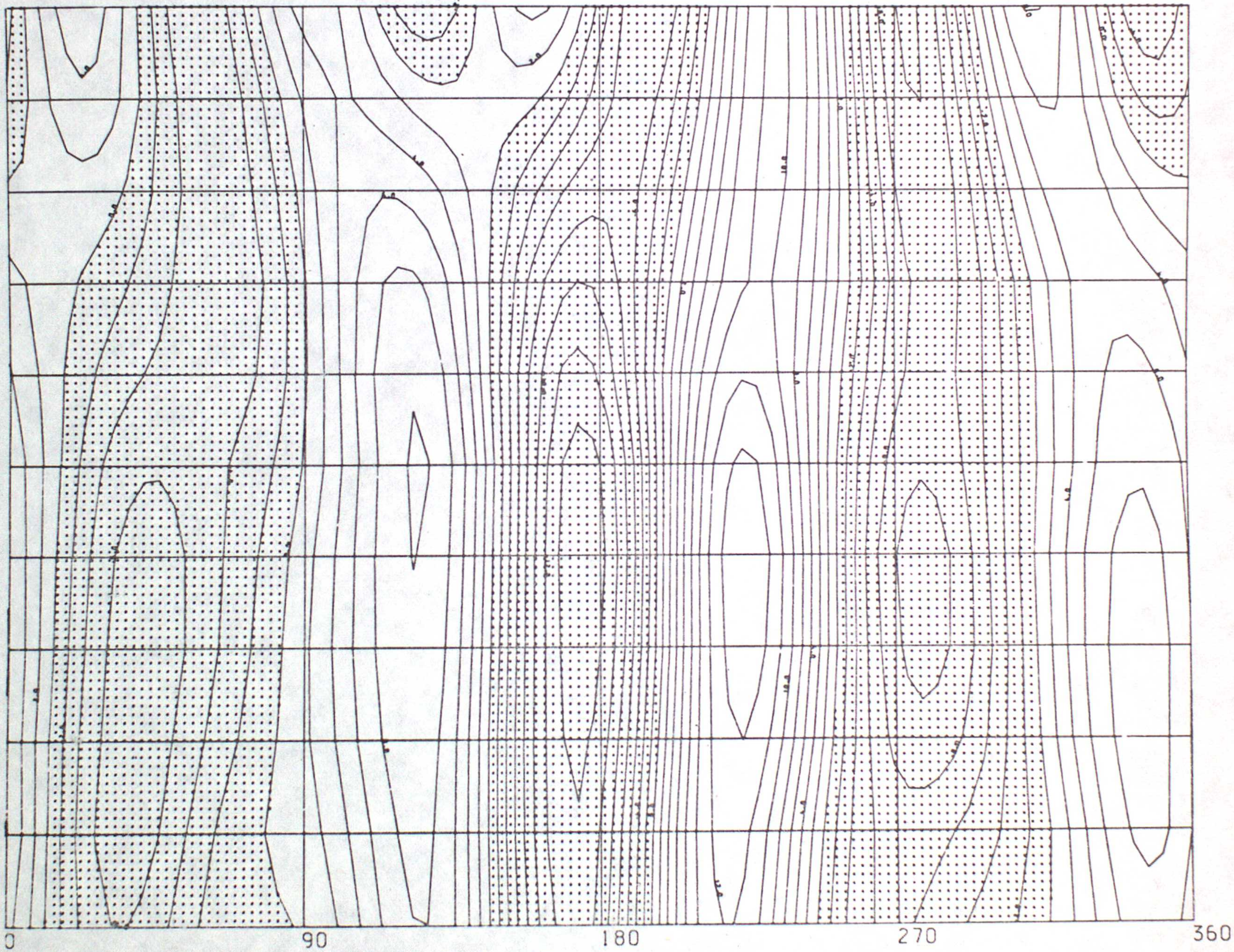
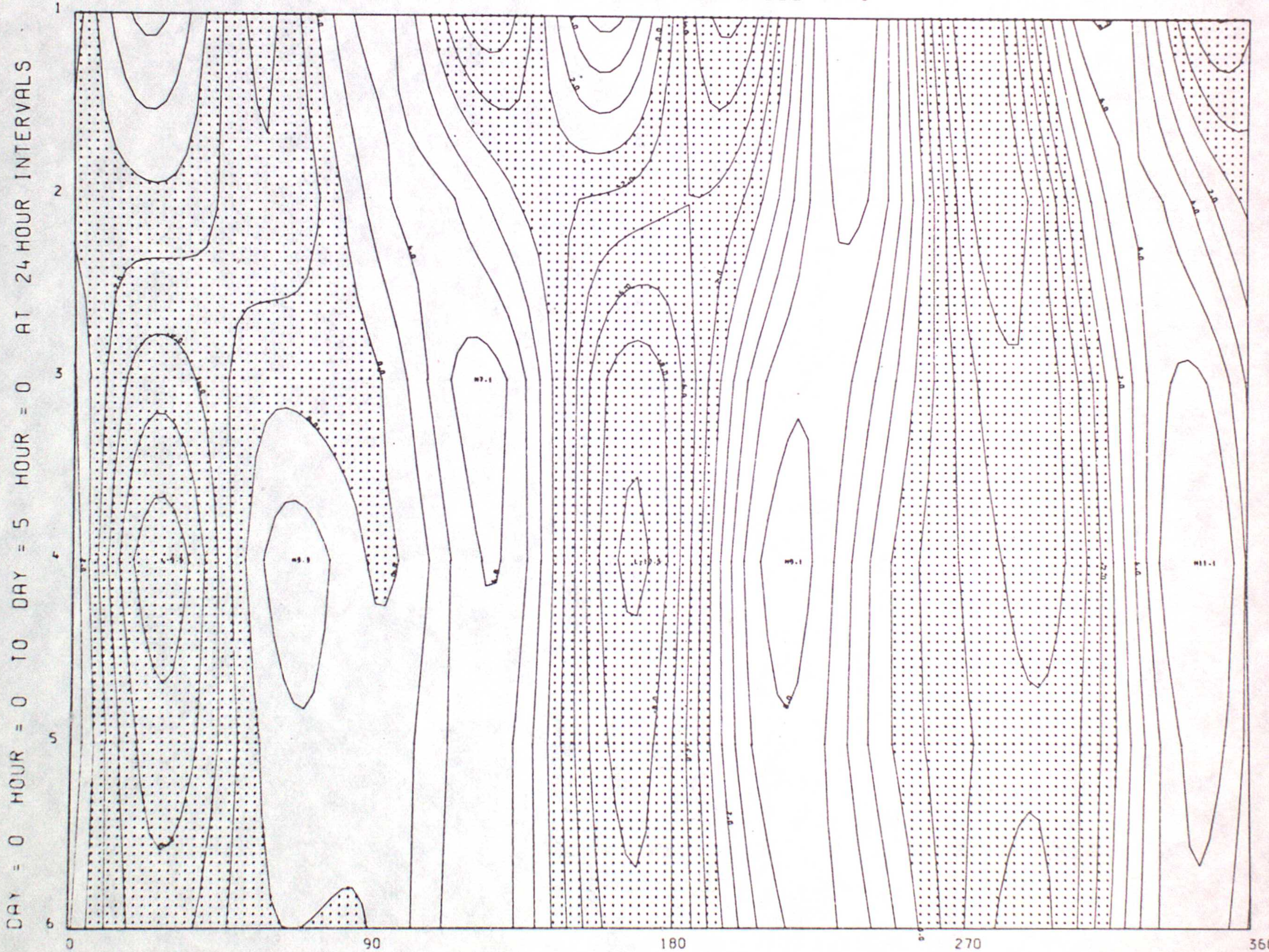


FIG 4.6 WAVE GROUP 3 TO 5
BASED ON 80 PTS AT 50N

5 DAY FCST.DAY 0= 12Z AUGUST 14TH 1977

MEAN OF WAVE NOS 3 - 5 AT LATITUDE = 49



CONTOUR INTERVAL = 2.0

EXPERIMENT NO = 0

FIG 4.7

?/8/77
5 Wave
C 11 level

COMPARISON OPER UPDATE F/C & ACTUAL 500MB HT   VERIFYING TIME 12Z 17/8/77

ERROR (F'CAST-ACTUAL)   T+72 FORECAST FIELD

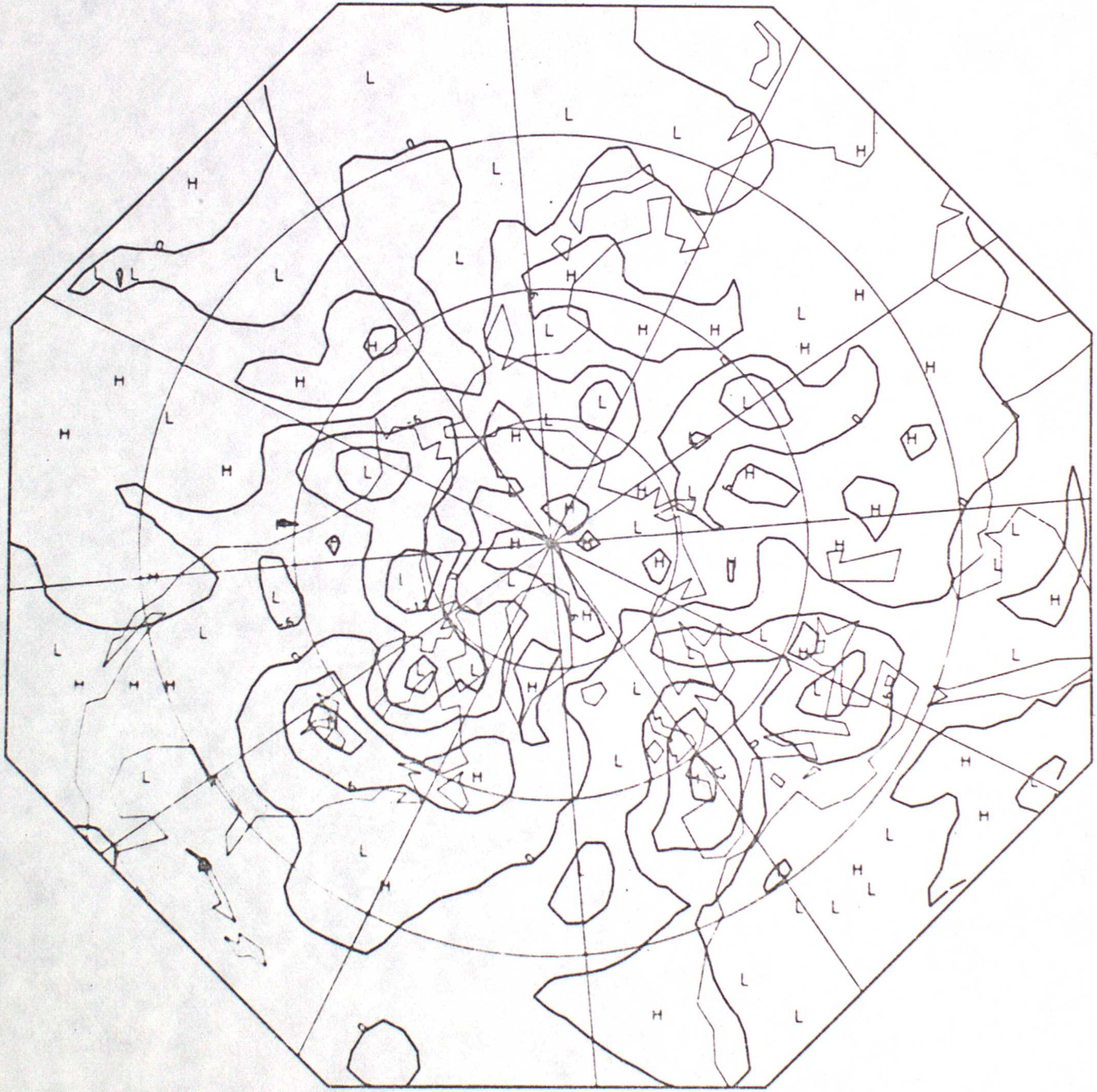


FIG 4.8

INTERVAL=6

72hr 500 error
DT 14/8/77 12Z
11 level

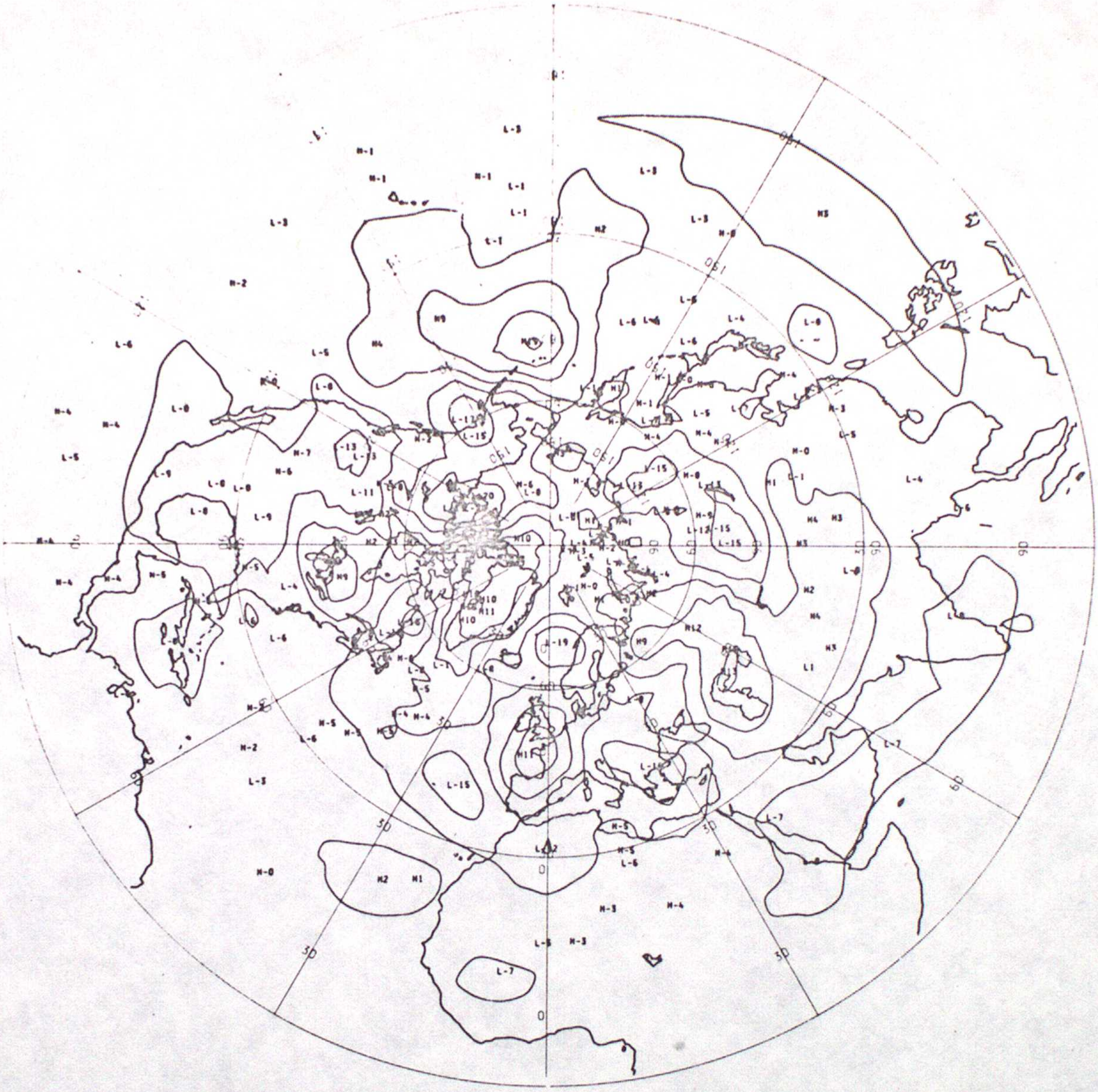


FIG 4.9 DIFFERENCE IN PRESSURE LEVEL =500.0 FOR EXH 0 - EXH 0 D 3H 0
CONTOUR INTERVAL = 6.00

500 MB CONTOURS   CONTOUR LINES AT 6 DECAMETER INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 24 / 11 / 77. VERIFICATION TIME 12 Z 24 / 11 / 77

SE VERSION

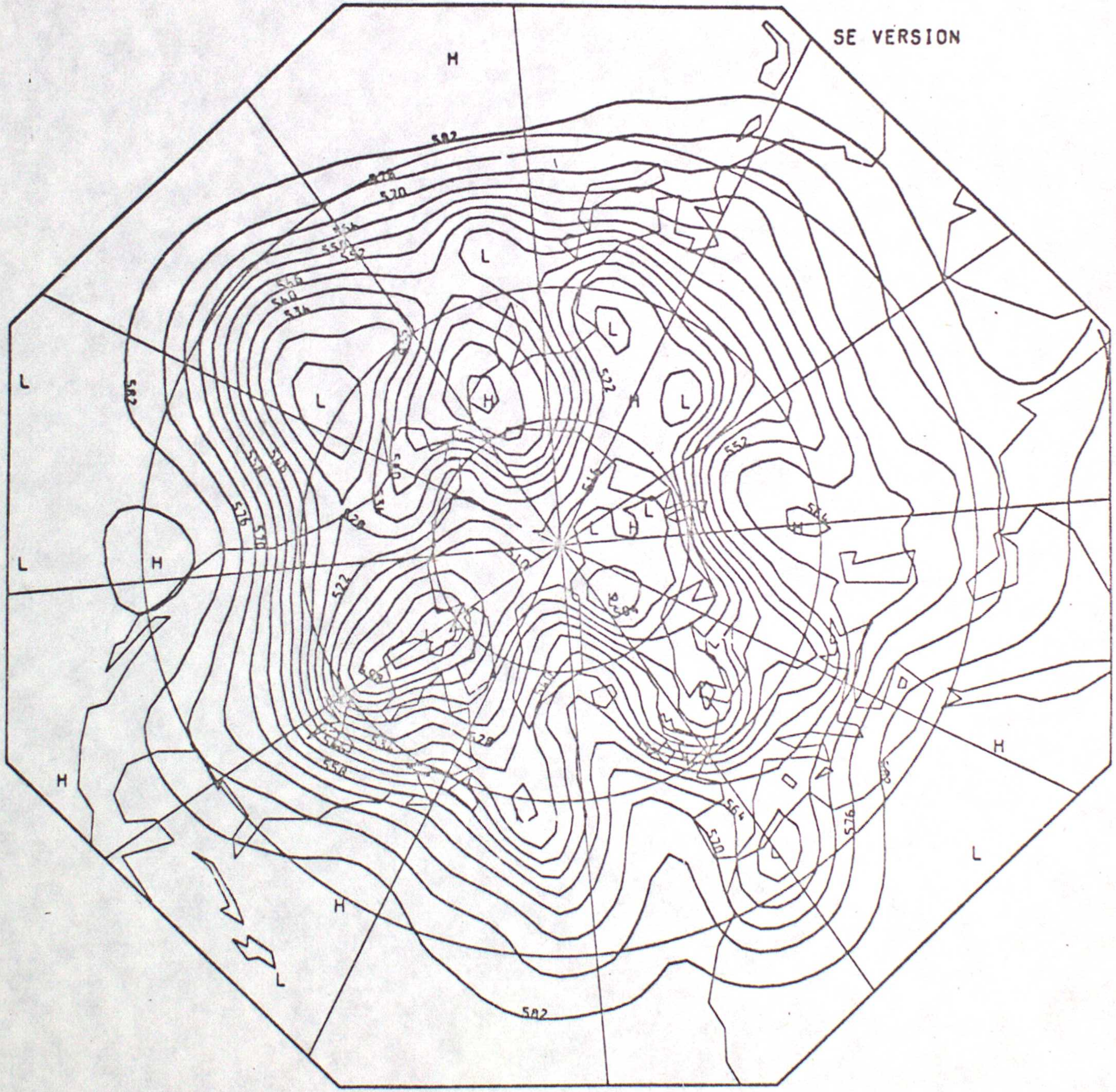
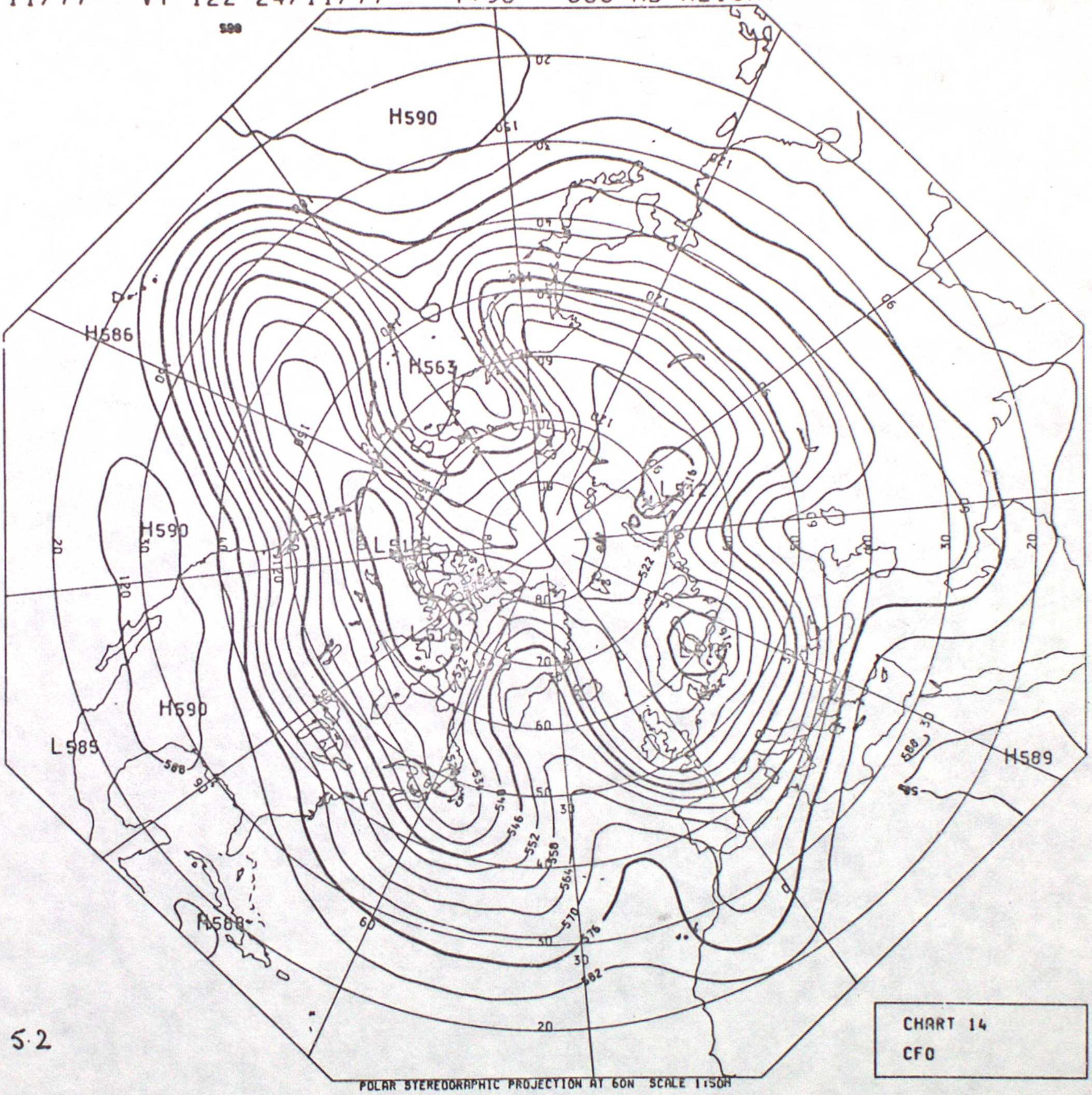


FIG. 5.1

6-Day F/C
20-11-77

DT 12Z 20/11/77 VT 12Z 24/11/77 T+96 500 MB HEIGHT (6DM INT)



POLAR STEREOGRAPHIC PROJECTION AT 60N SCALE 1:50M

FIG 5.2

D.T 20

DT 12Z 20/11/77 VT 12Z 24/11/77 T+96 500 MB HEIGHT

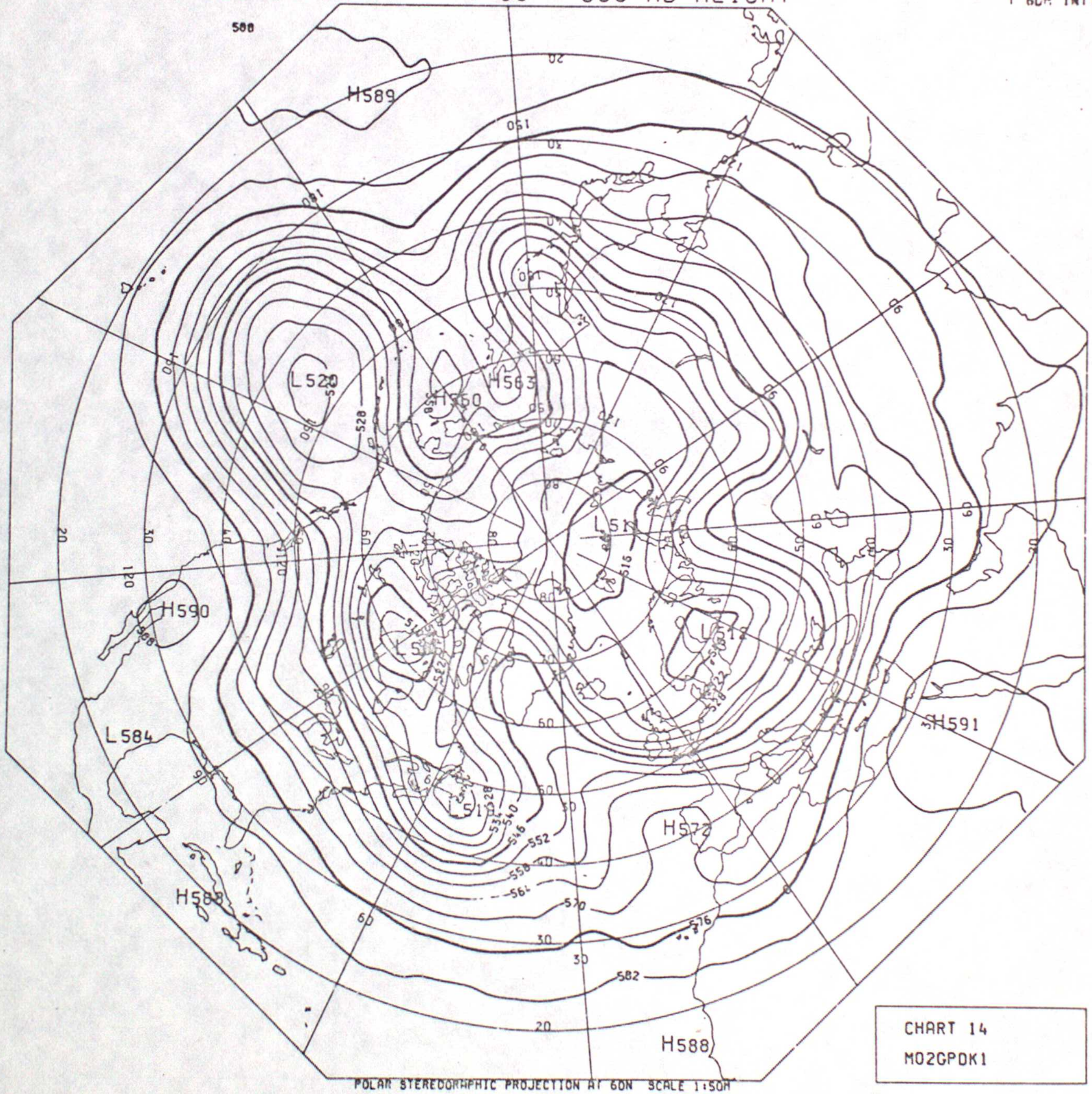


FIG 3.3

EXPERIMENT TIME = D004H00 500 MB HEIGHTS
CONTOUR INTERVAL = 6.00 DEKAMETRES

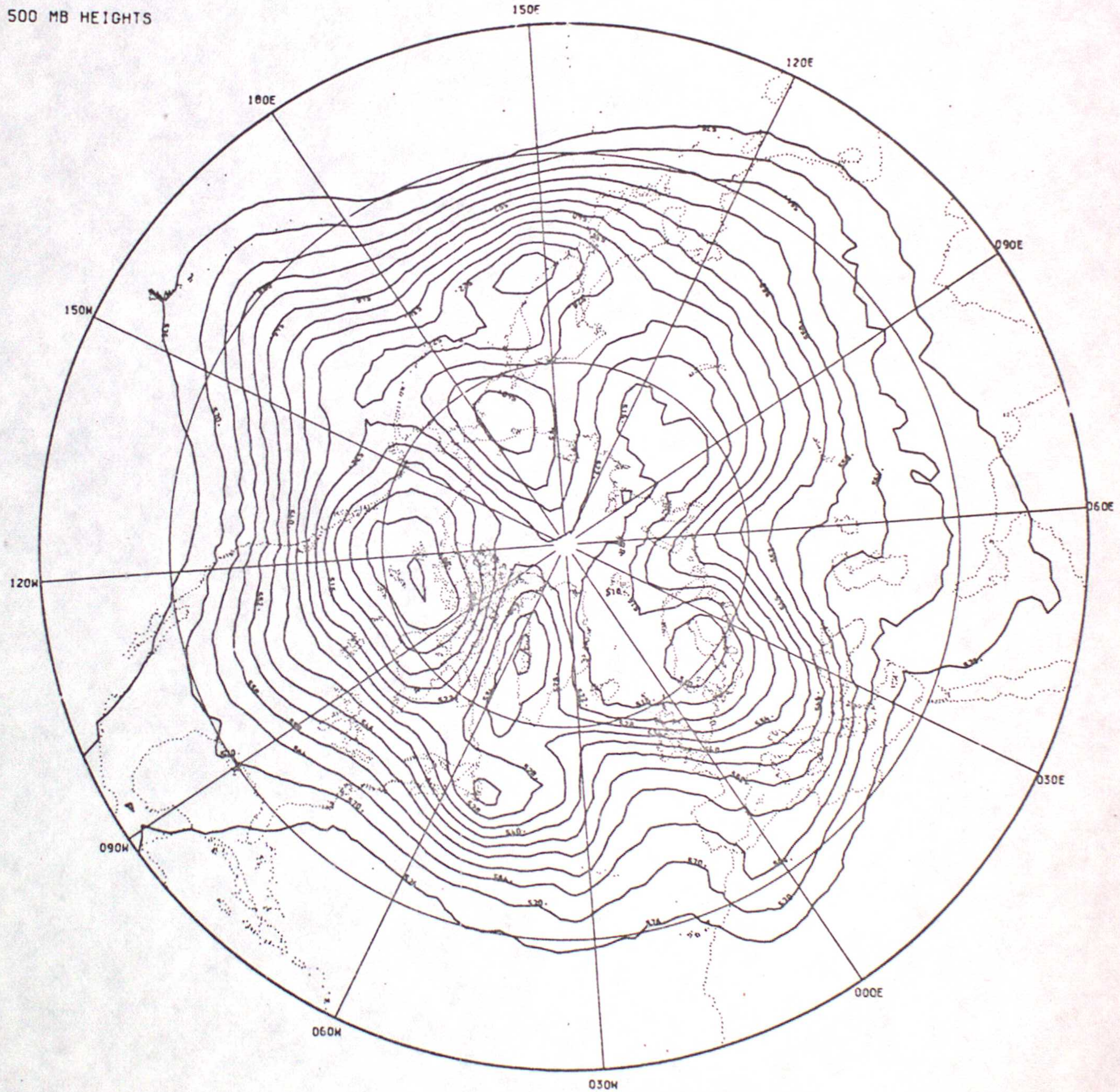


FIG 5.4

EXPERIMENT   TIME = 0004H00   500 MB HEIGHTS
CONTOUR INTERVAL = 6.00 DEKAMETRES

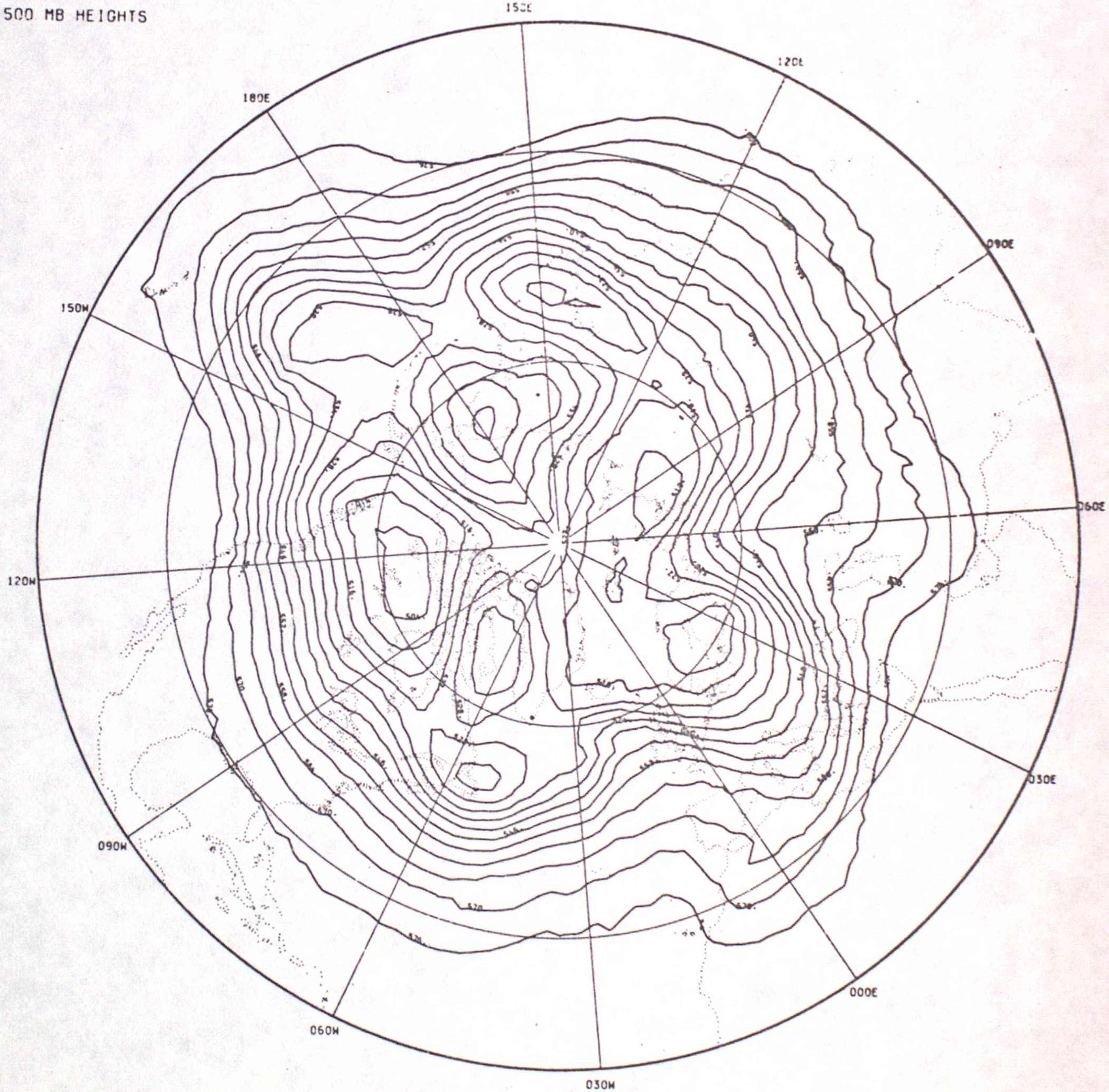


FIG 5.45

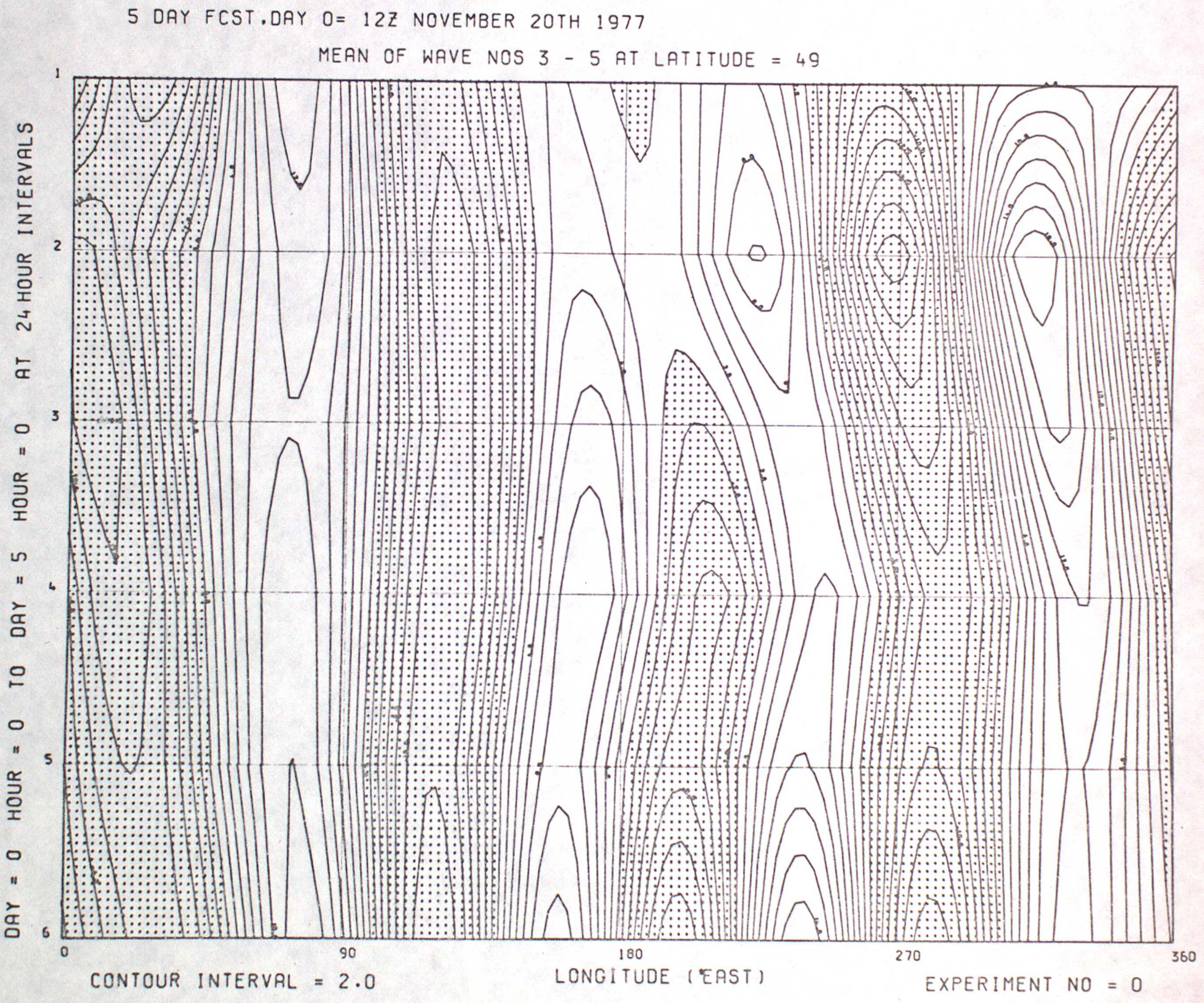
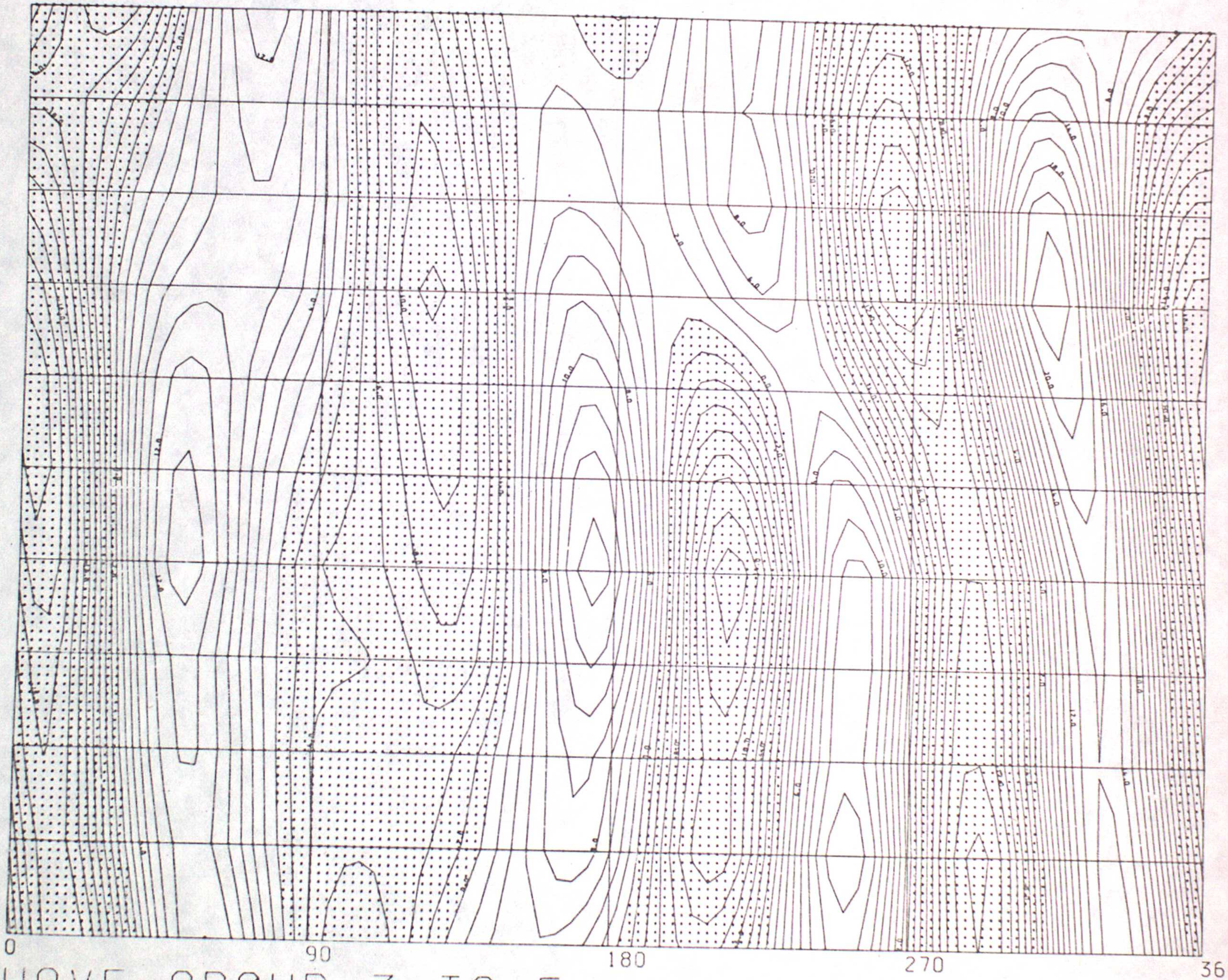


FIG 5.6

0/11/77
5 Waves
Actual
Level

OP F/C
DATA TIME 12Z 20/11/77



20/11/77
3-5 Waves
10 level
F/C

FIG 5.7

WAVE GROUP 3 TO 5
BASED ON 80 PTS AT 50N

5 DAY FCST. DAY 0= 12Z NOVEMBER 20TH 1977

MEAN OF WAVE NOS 3 - 5 AT LATITUDE = 49

CONTOUR INTERVAL = 2.0

EXPERIMENT NO = 0

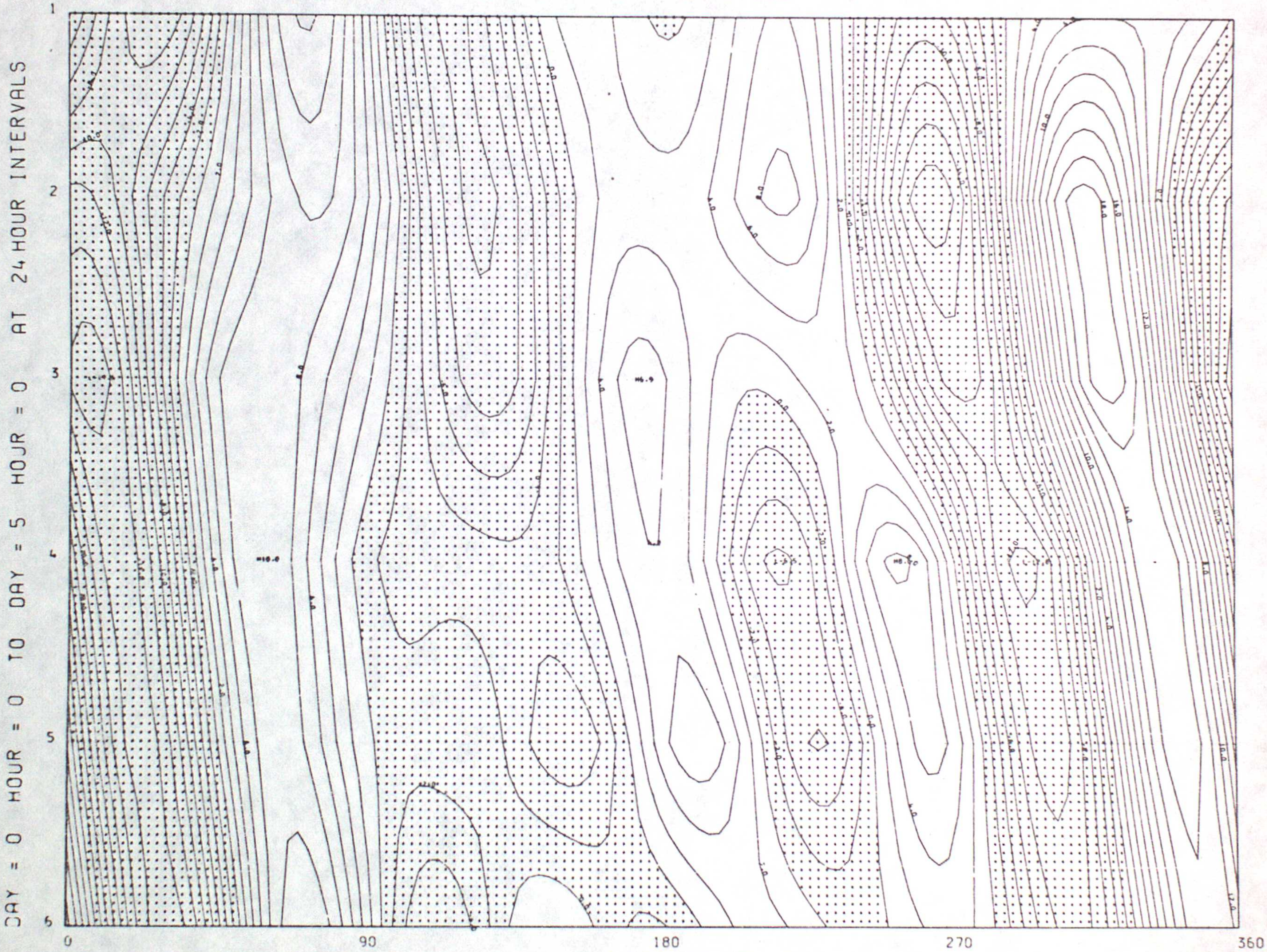
FIG 5.8

…0/11/77
– 5 waves
level standard
F/C

11-77
Waves
merged
F/C

5 DAY FCST.DAY 0 = 12Z NOVEMBER 20TH 1977 MERGED VERSION

MEAN OF WAVE NOS 3 - 5 AT LATITUDE = 49



CONTOUR INTERVAL = 2.0

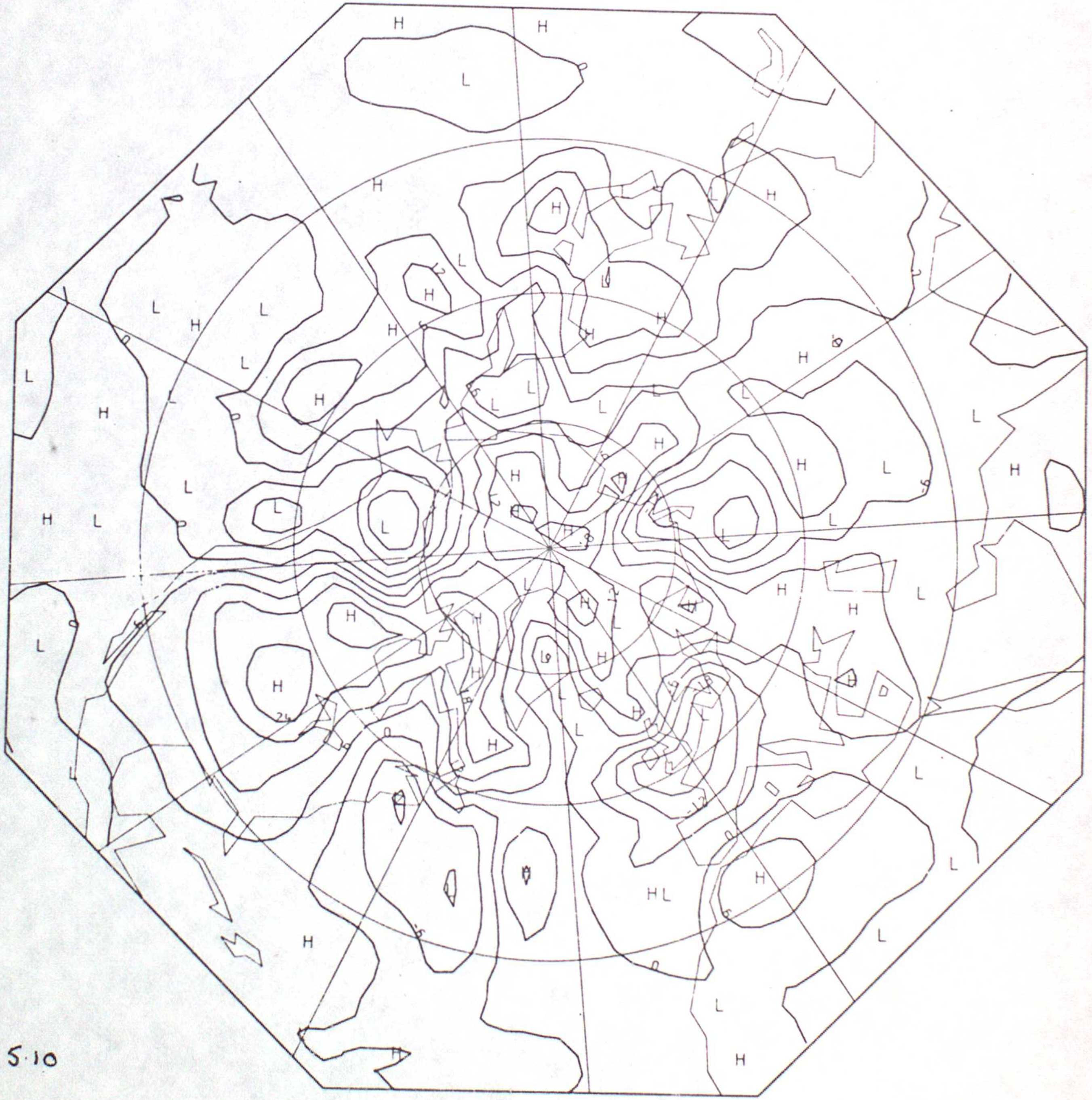
EXPERIMENT NO = 0

FIG 5.9

COMPARISON OPER UPDATE F/C & ACTUAL 500MB HT ERROR (F'CAST-ACTUAL) T+72 FORECAST FIELD

VERIFYING TIME 12Z 23/11/77

72hr
500mb error
T 20/11/77 12Z
0 level



INTERVAL=6

FIG 5.10

72hr 500mb error
DT 20/11/77 12Z
11level

FIG 5.11 DIFFERENCE IN PRESSURE LEVEL=500.0 FOR EXH 0 - EXH 0 D 3H 0 D 3H 0
CONTOUR INTERVAL = 6.00

DT 20/11/77 12Z
(Merged Analysis) 11 level
Date run 12/12/77

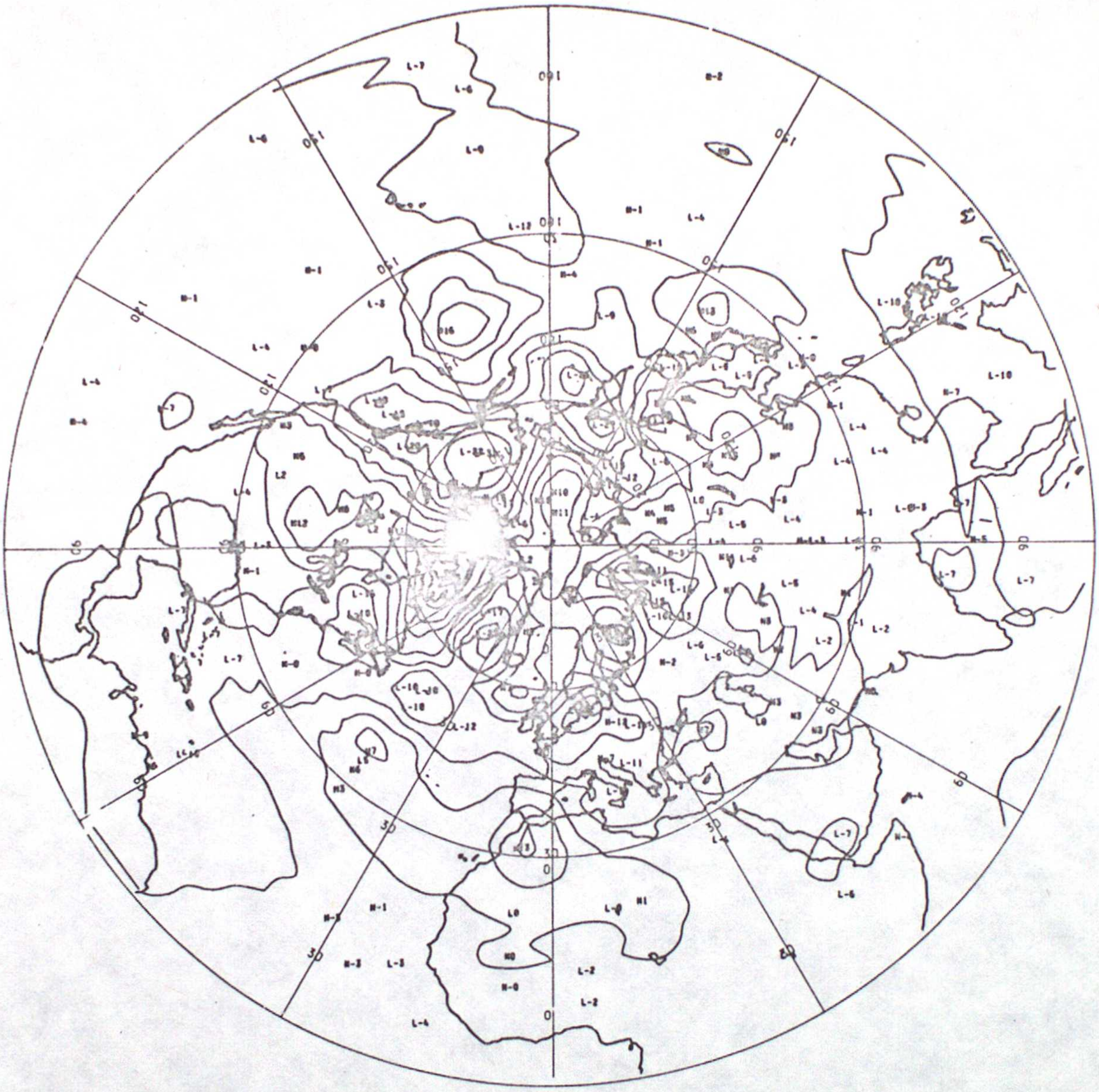


FIG 5.12

DIFFERENCE IN PRESSURE LEVEL=500.0 FOR EXH 0 - EXH 0 D 3H 0 D 3H 0
CONTOUR INTERVAL = 6.00

500 MB CONTOURS.   CONTOUR LINES AT 6 DECAMETER INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 4 / 1 / 78. VERIFICATION TIME 12 Z 4 / 1 / 78

SE VERSION

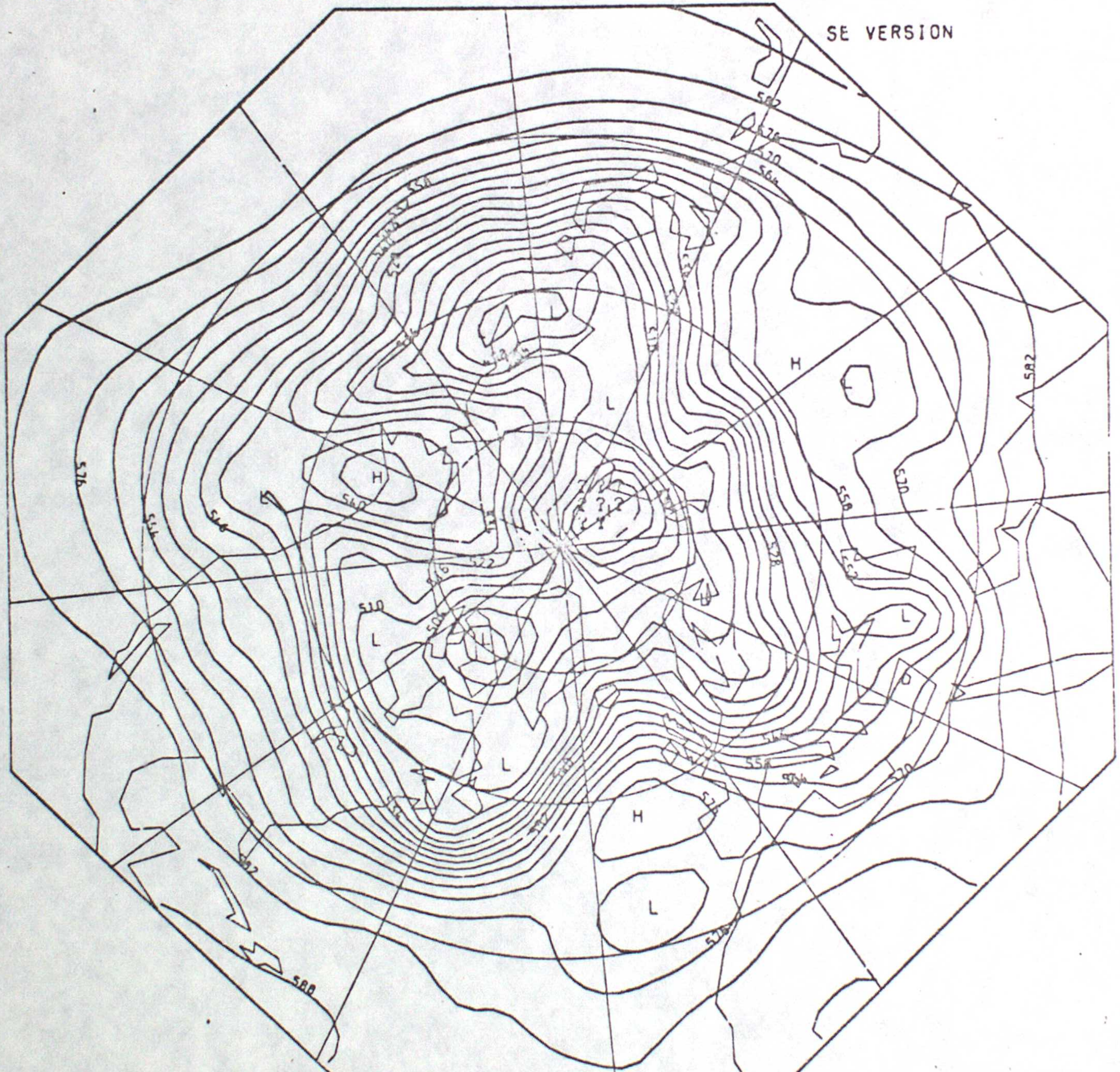


FIG. 6.1

DT 12Z 01/01/78   VT 12Z 04/01/78   T+72   0500 MB HEIGHT   (6DM INT)

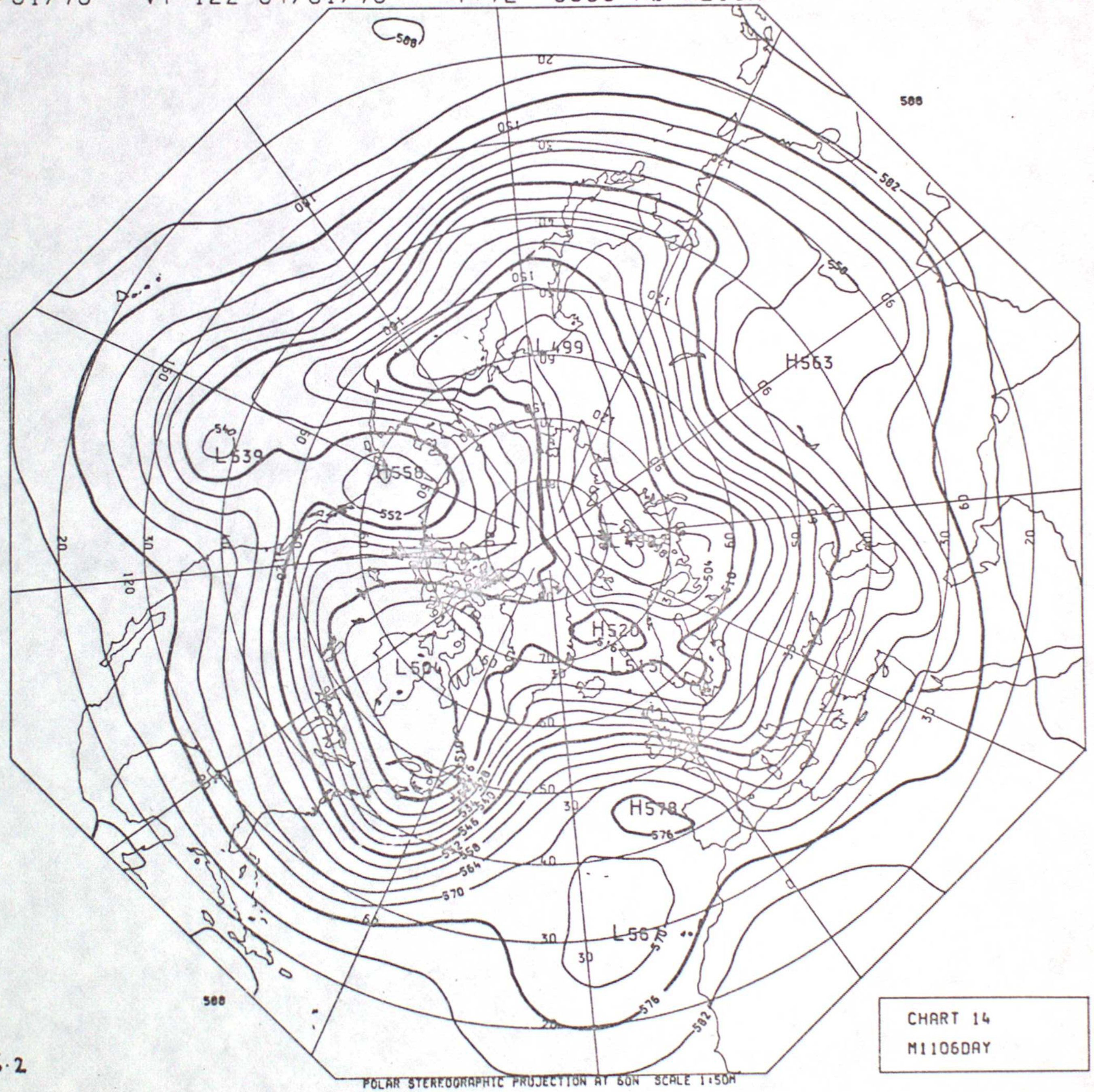


CHART 14
M1106DAY

Fig 6.2

DT .1.1.78

DT 12Z 01/01/78 VT 12Z 04/01/78 T+72 500 MB HEIGHT (60M INT)

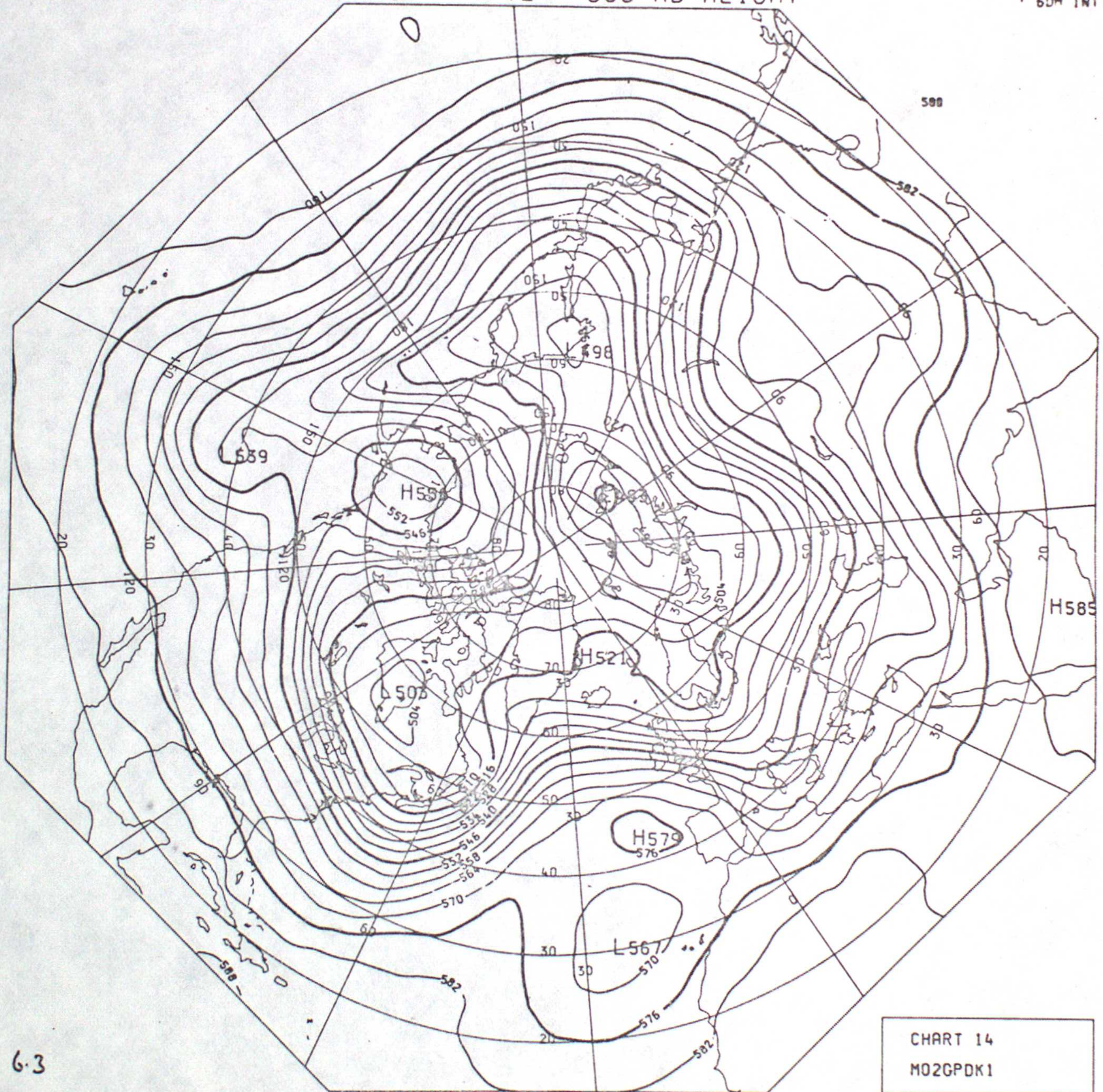


CHART 14
M02GPDK1

FIG 6.3

EXPERIMENT TIME = 0003H00 500 MB HEIGHTS
CONTOUR INTERVAL = 6.00 DEKAMETRES

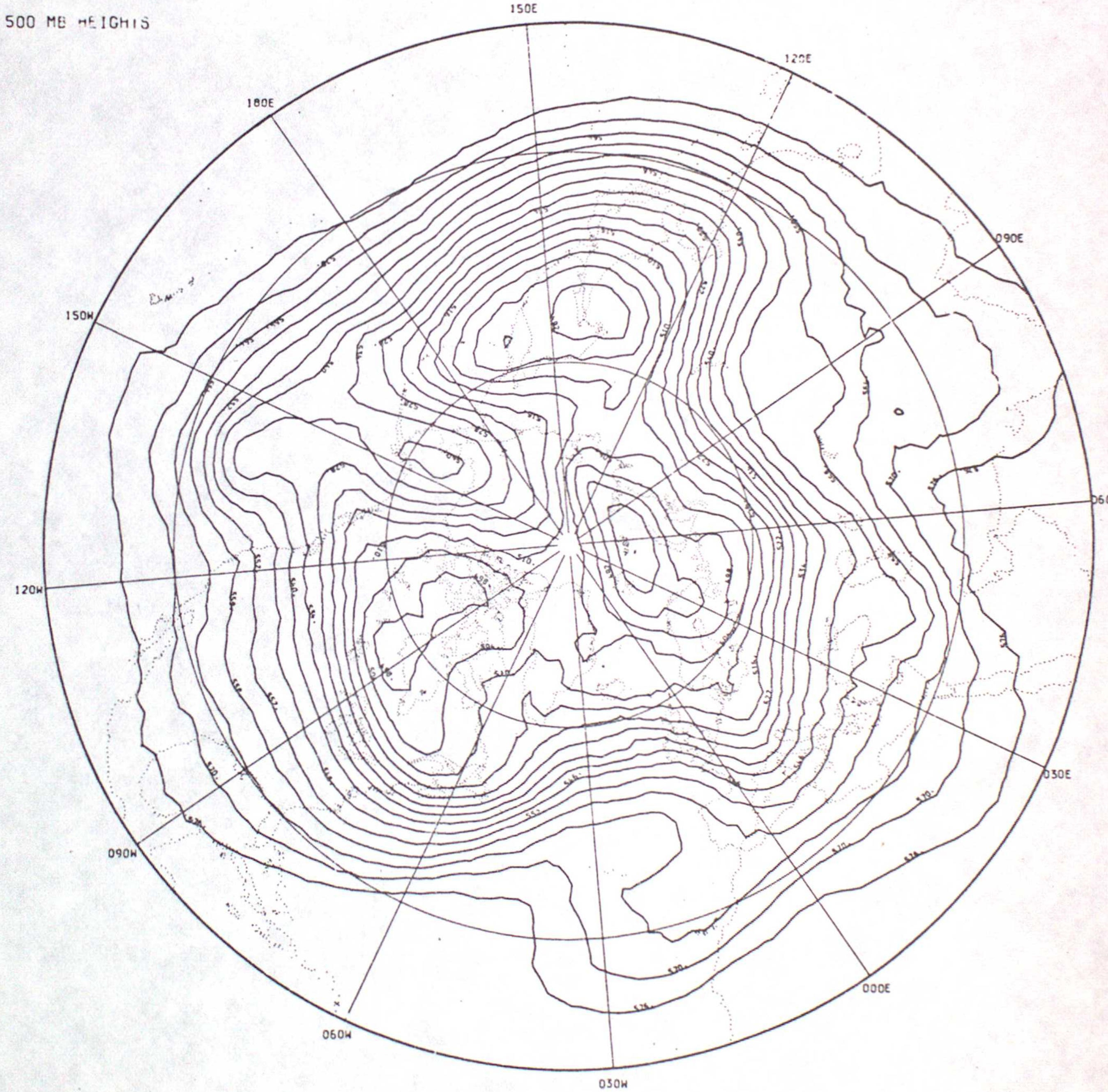


FIG 6.4

EXPERIMENT TIME = D003H00 500 MB HEIGHTS
CONTOUR INTERVAL = 6.00 DEKAMETRES

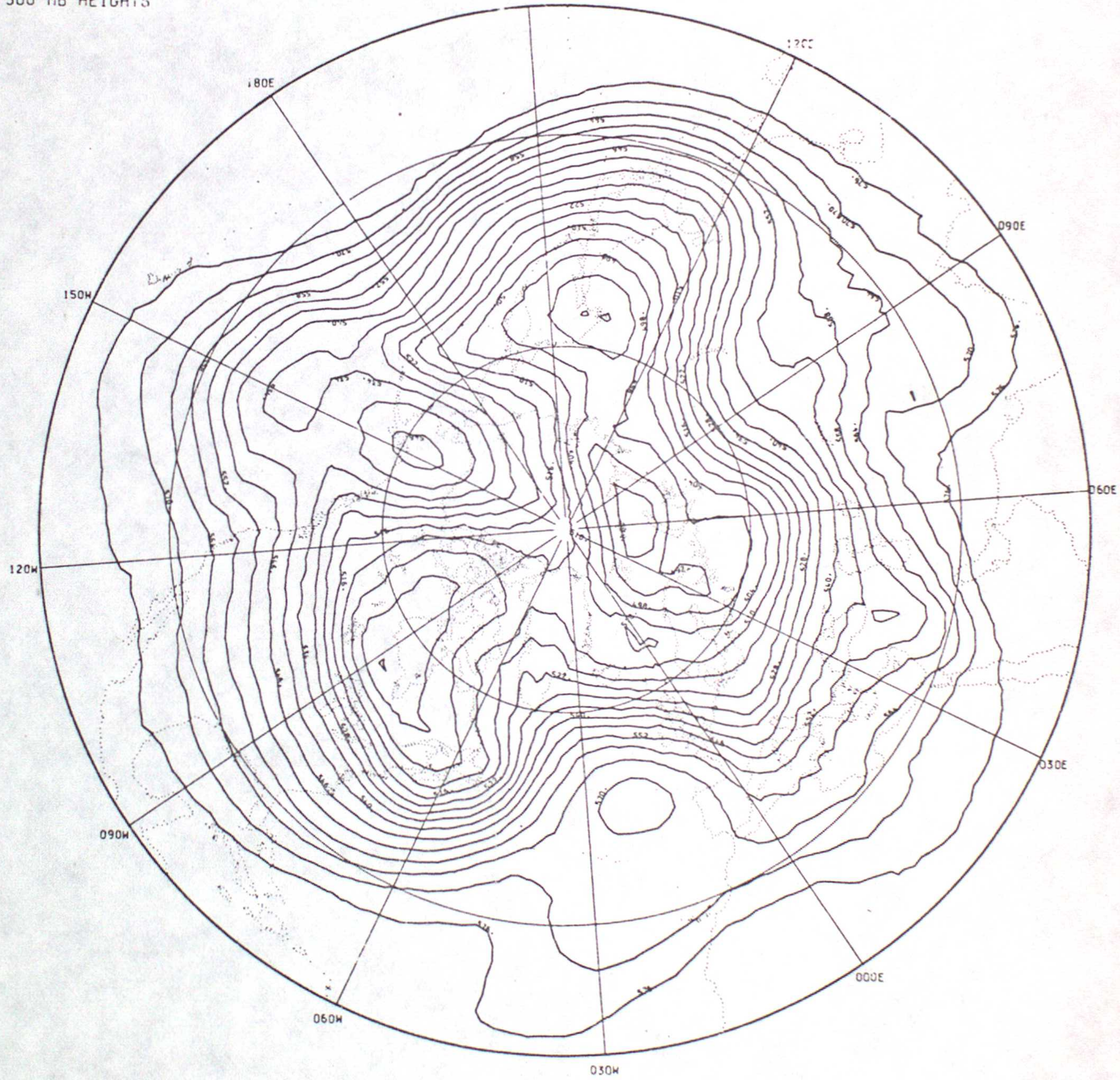
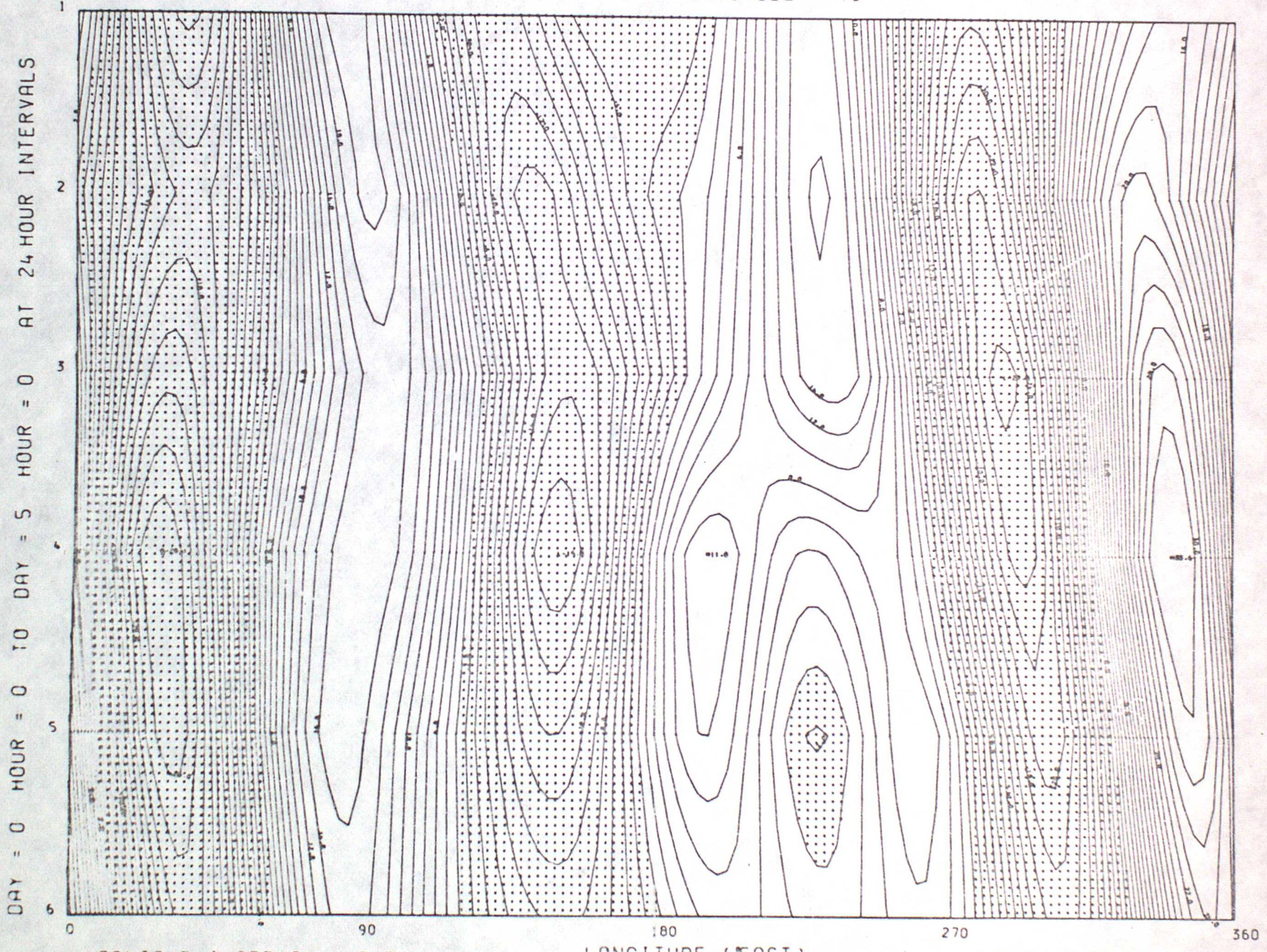


FIG 6.5

5 DAY FCST.DAY 0= 12Z JANUARY 01ST 1978

MEAN OF WAVE NOS 3 - 5 AT LATITUDE = 49



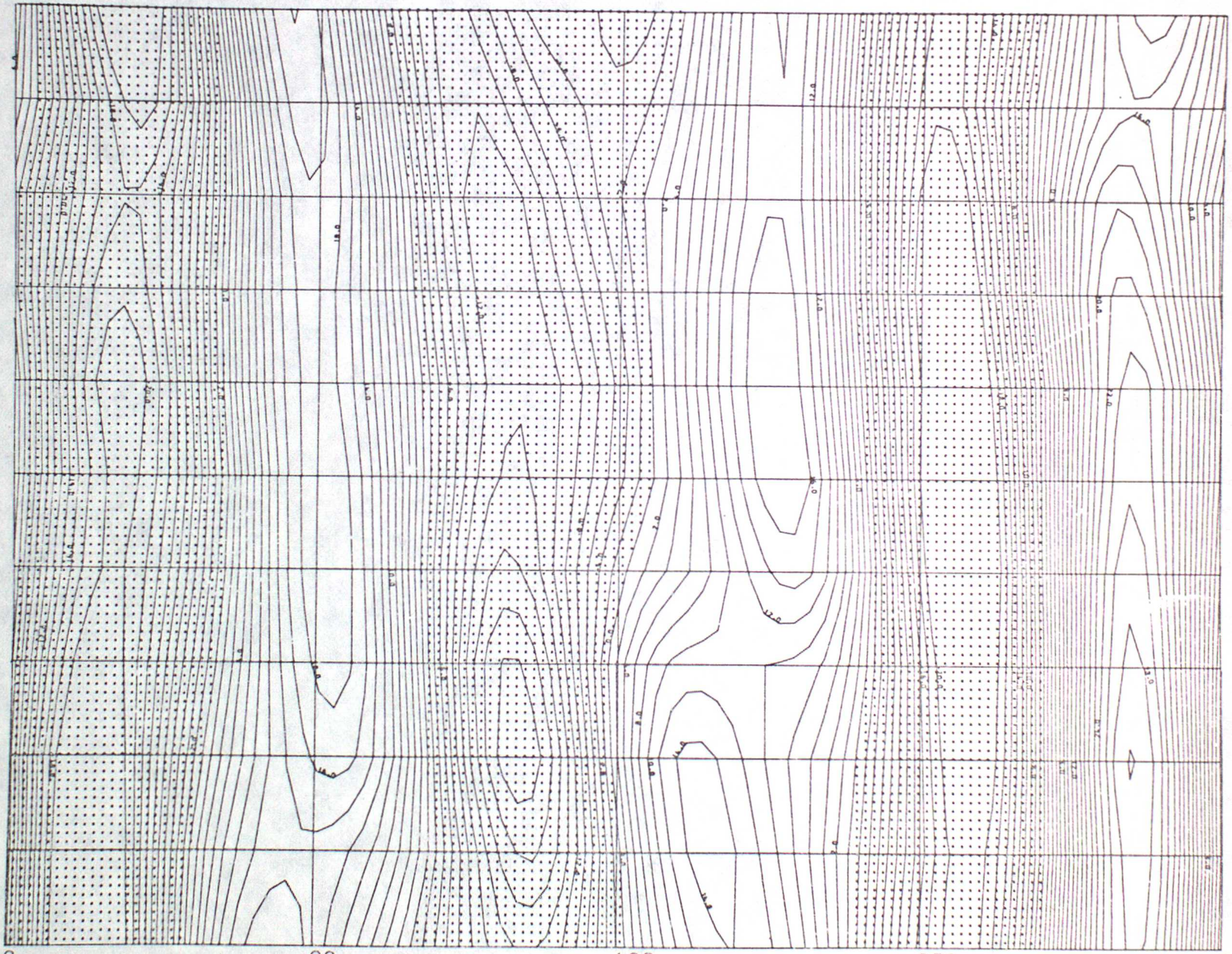
CONTOUR INTERVAL = 2.0

LONGITUDE (°EAST)

EXPERIMENT NO = 0

FIG 6.6

GP F/C
DATA TIME 12Z 1/1/78



WAVE GROUP 3 TO 5
BASED ON 80 PTS AT 50N

Fig 6.7

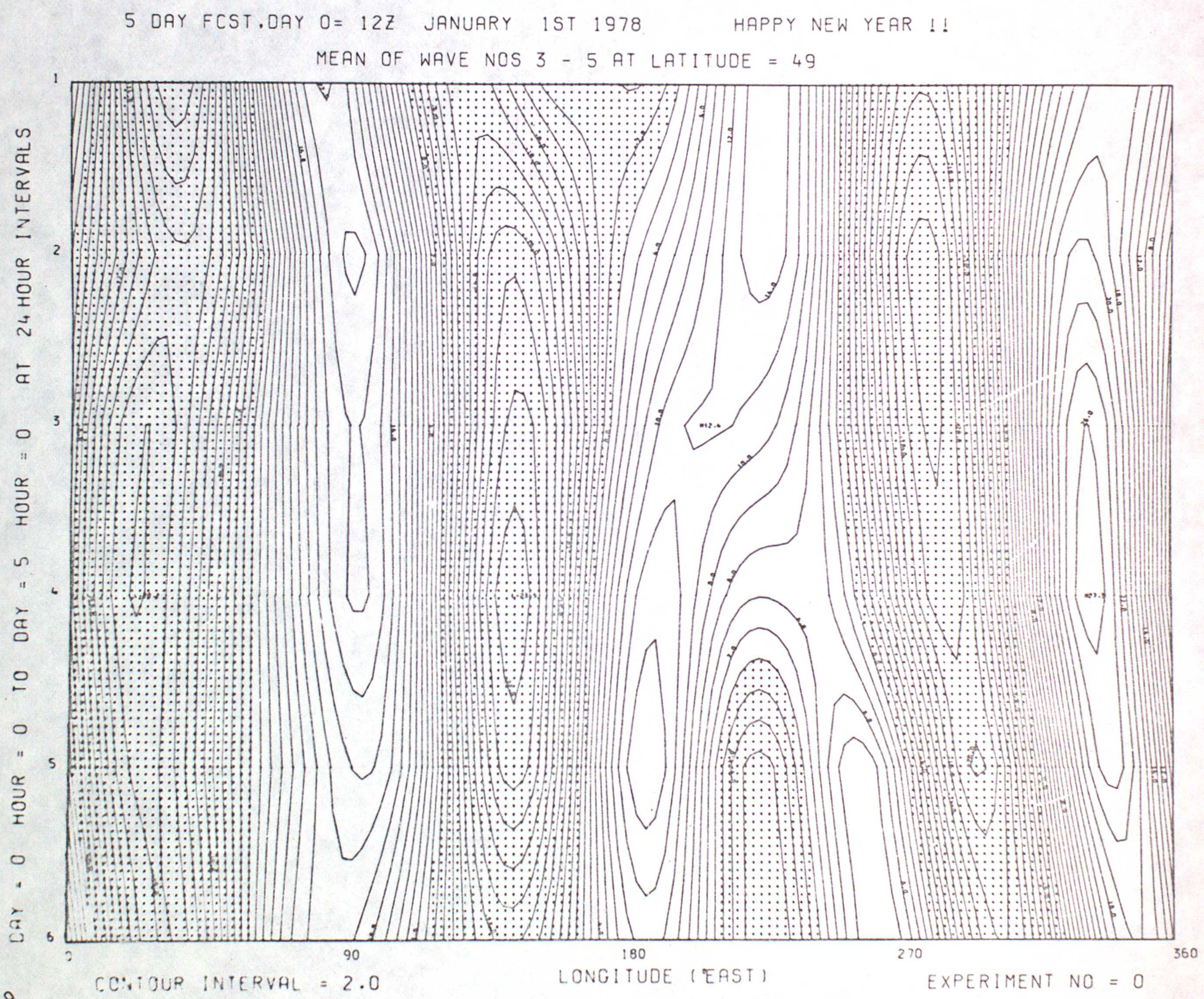


FIG. 6.8

/78
5 waves
el standard
F/C

5 DAY FCST.DAY 0 = 12Z JANUARY 1ST 1978 MERGED VERSION

MEAN OF WAVE NOS 3 - 5 AT LATITUDE = 49

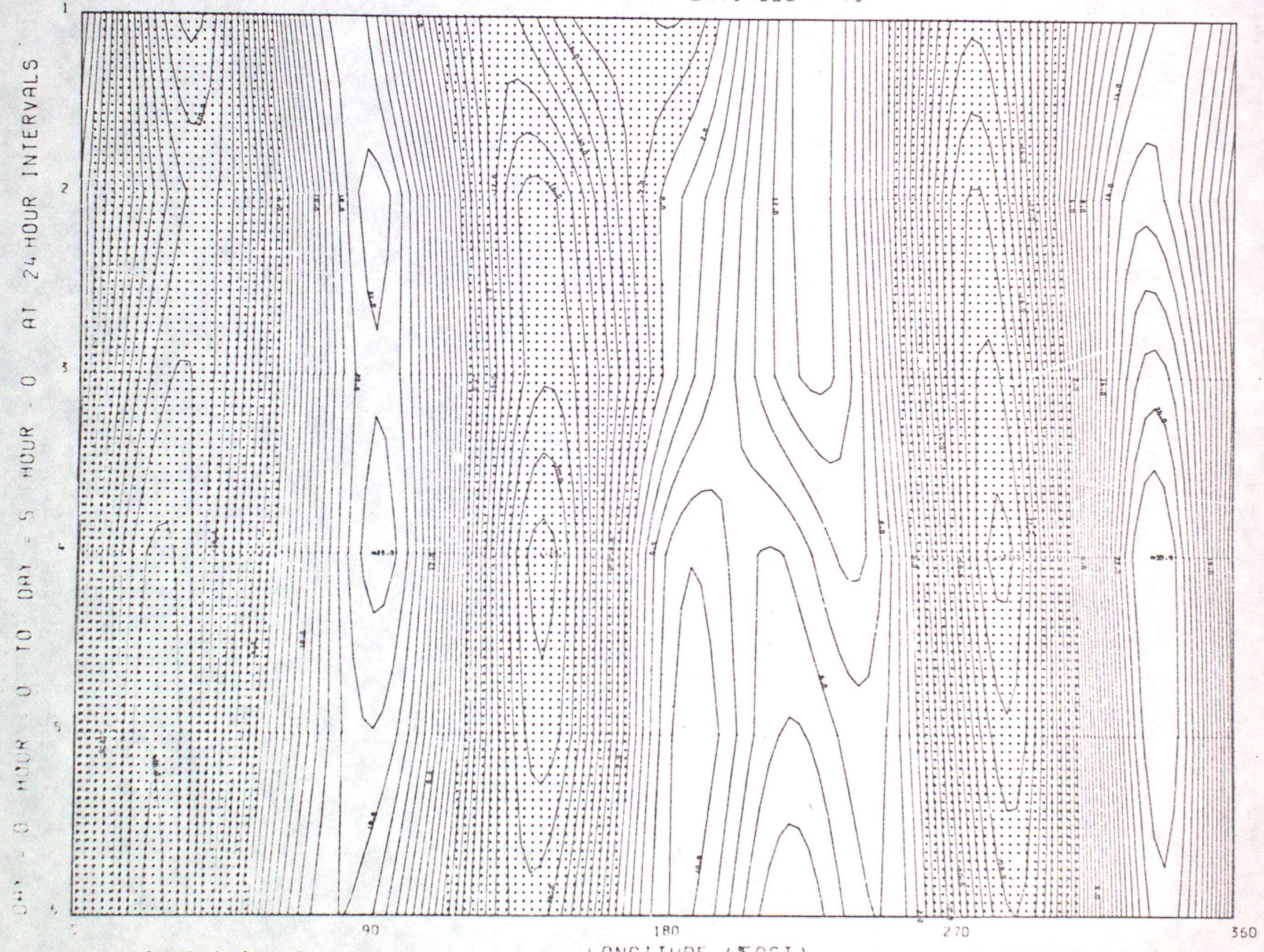
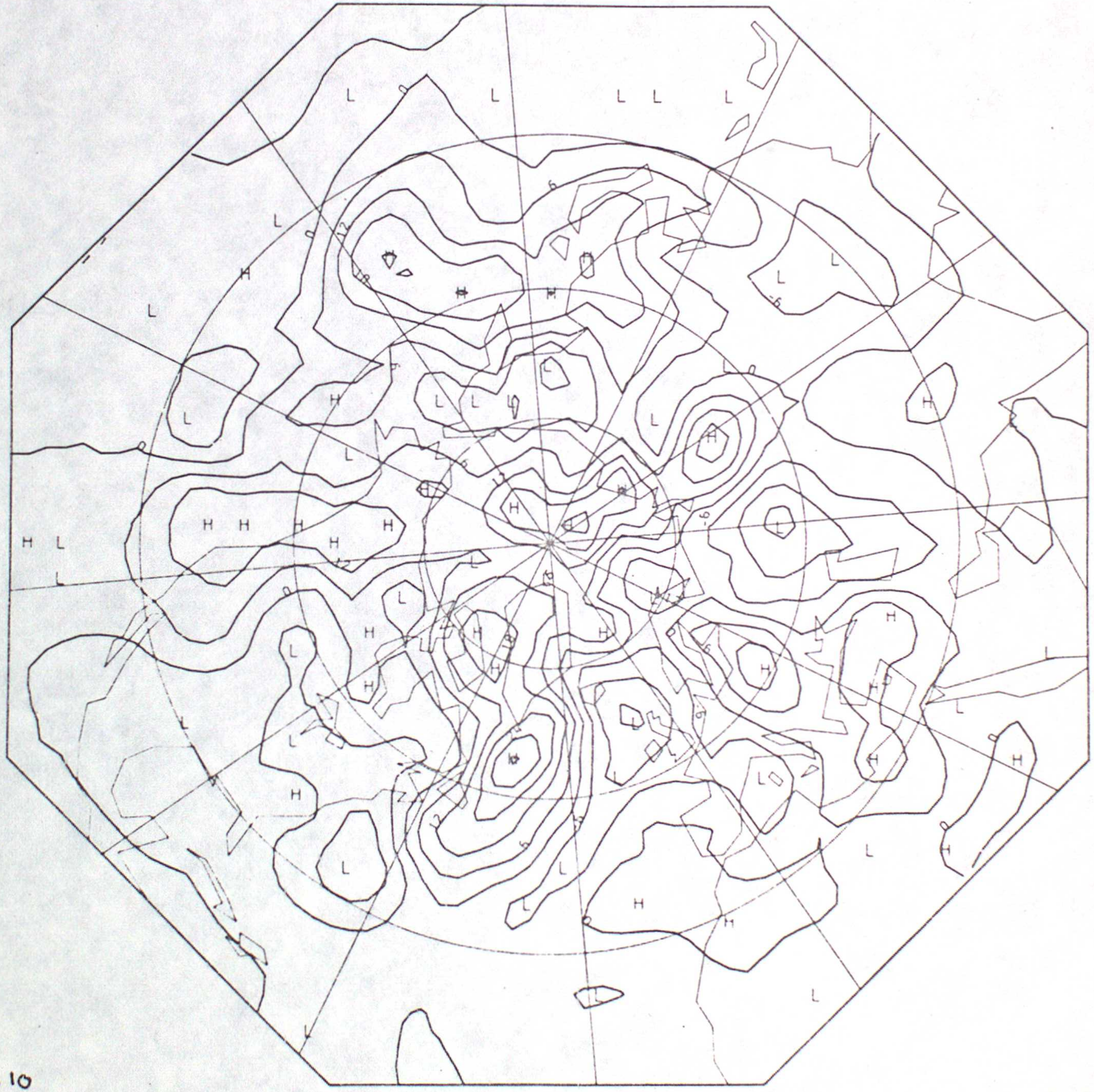


FIG 6.9

COMPARISON OPER UPDATE F/C & ACTUAL 500MB HT   VERIFYING TIME 12Z 4/1/78

ERROR (F'CAST-ACTUAL) T+72 FORECAST FIELD



INTERVAL=6

FIG 6.10

72hr 500mb error
DT 1/1/78 12Z
11 level

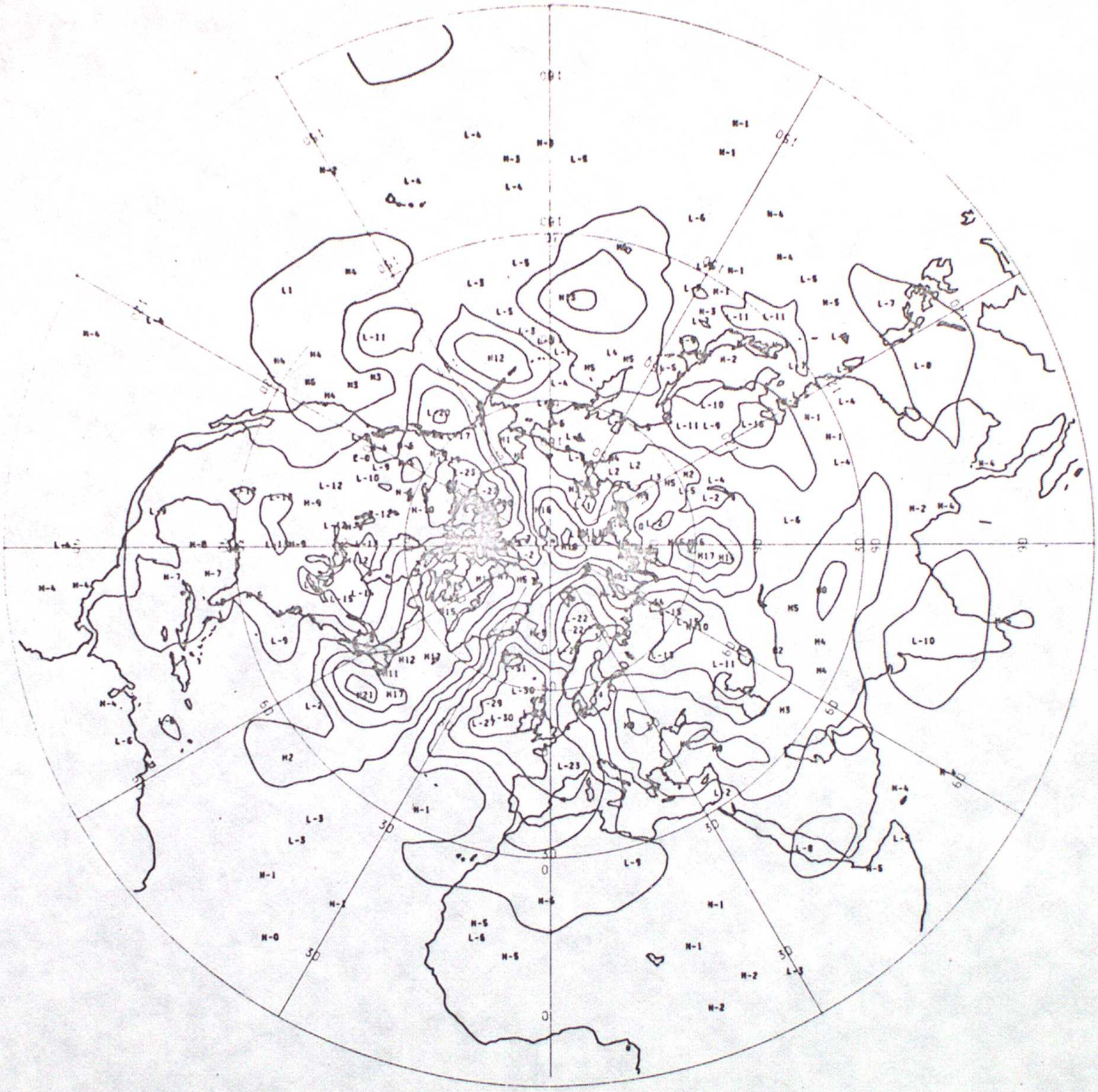


FIG 6.11 DIFFERENCE IN PRESSURE LEVEL=500.0 FOR EXH 0 - EXH 0 D 3H 0 D 3H 0
CONTOUR INTERVAL = 6.00

72hr 500mb error
DT 1/1/78 12Z
(Merged Analysis)
11 level

FIG 6.12 DIFFERENCE IN PRESSURE LEVEL=500.0 FOR EXH 0 - EXH 0 D 3H 0 D 3H 0
CONTOUR INTERVAL = 6.00

500 MB CONTOURS   CONTOUR LINES AT 6 DECAMETER INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 13 / 4 / 78. VERIFICATION TIME 12 Z 13 / 4 / 78

SE VERSION

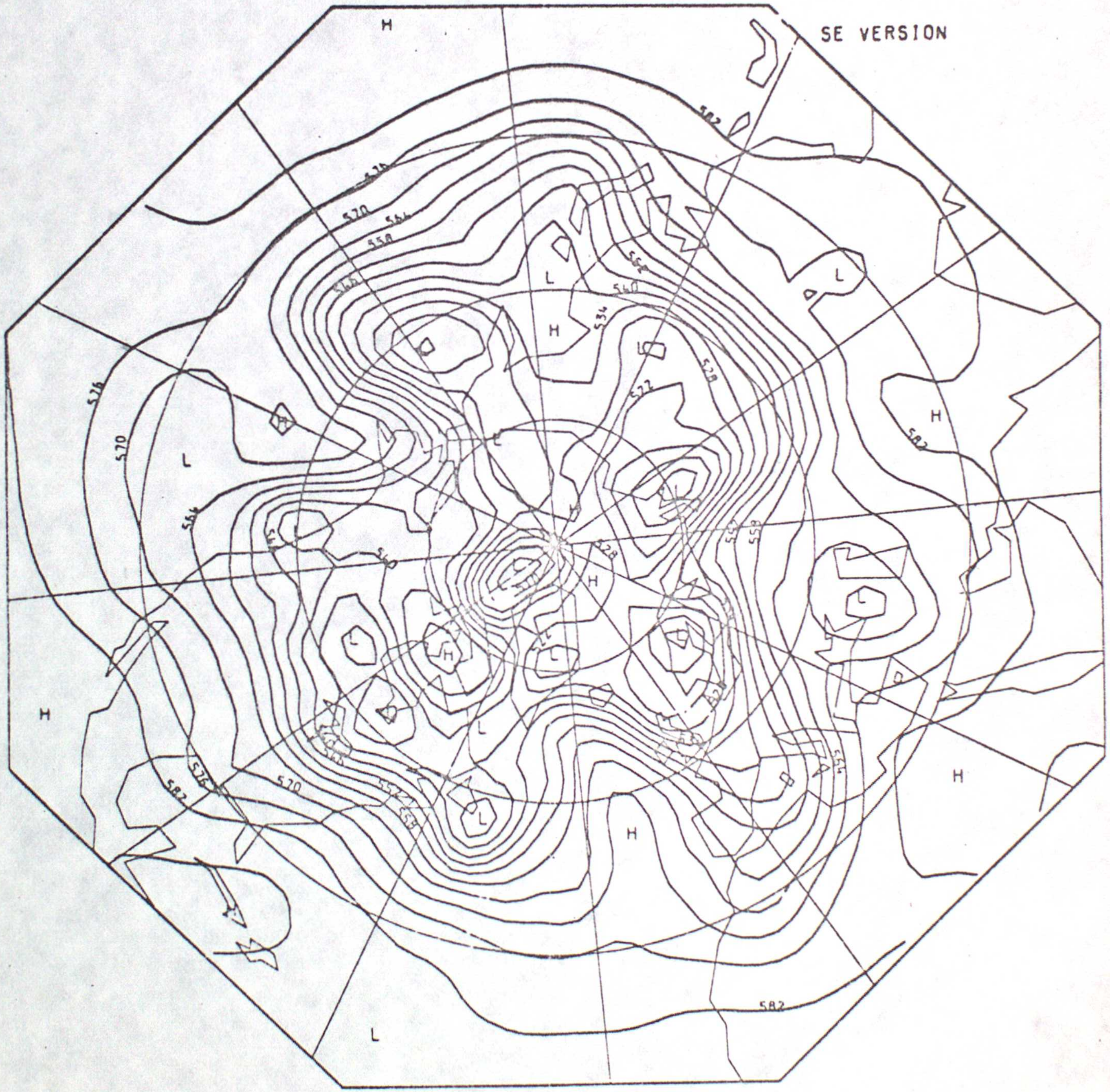


FIG. B.1

DT. 9.4.7

DT 12Z 09/04/78   VT 12Z 13/04/78   T+96   0500 MB HEIGHT

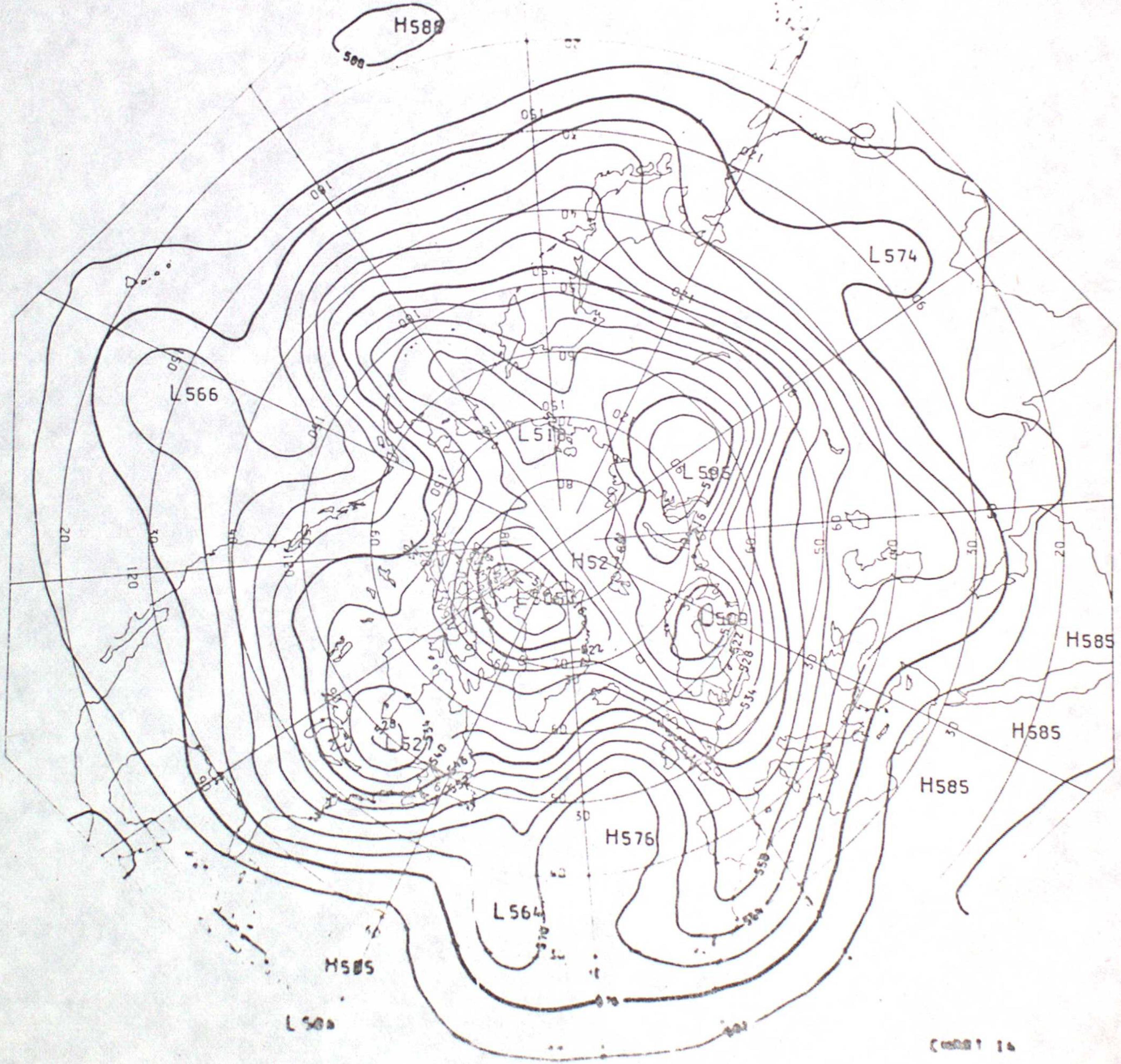


Fig 7.2

DT 12Z 09/04/78 VT 12Z 13/04/78 T+96 500 MB HEIGHT

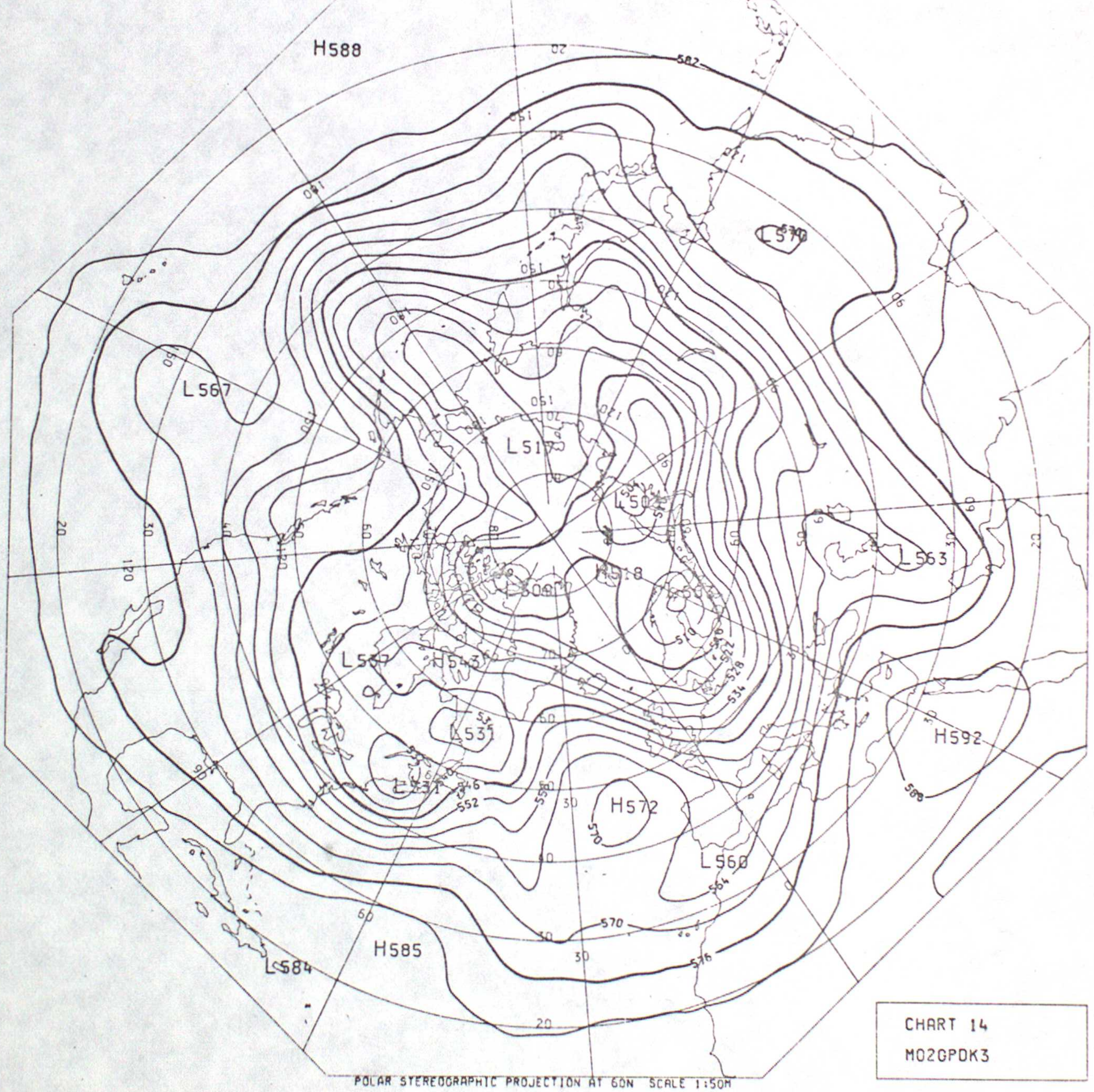


FIG 7.3

(m)
DT 9.478

EXPERIMENT TIME = 0004H00 500 MB HEIGHTS
CONTOUR INTERVAL = 6.00 DEKAMETRES

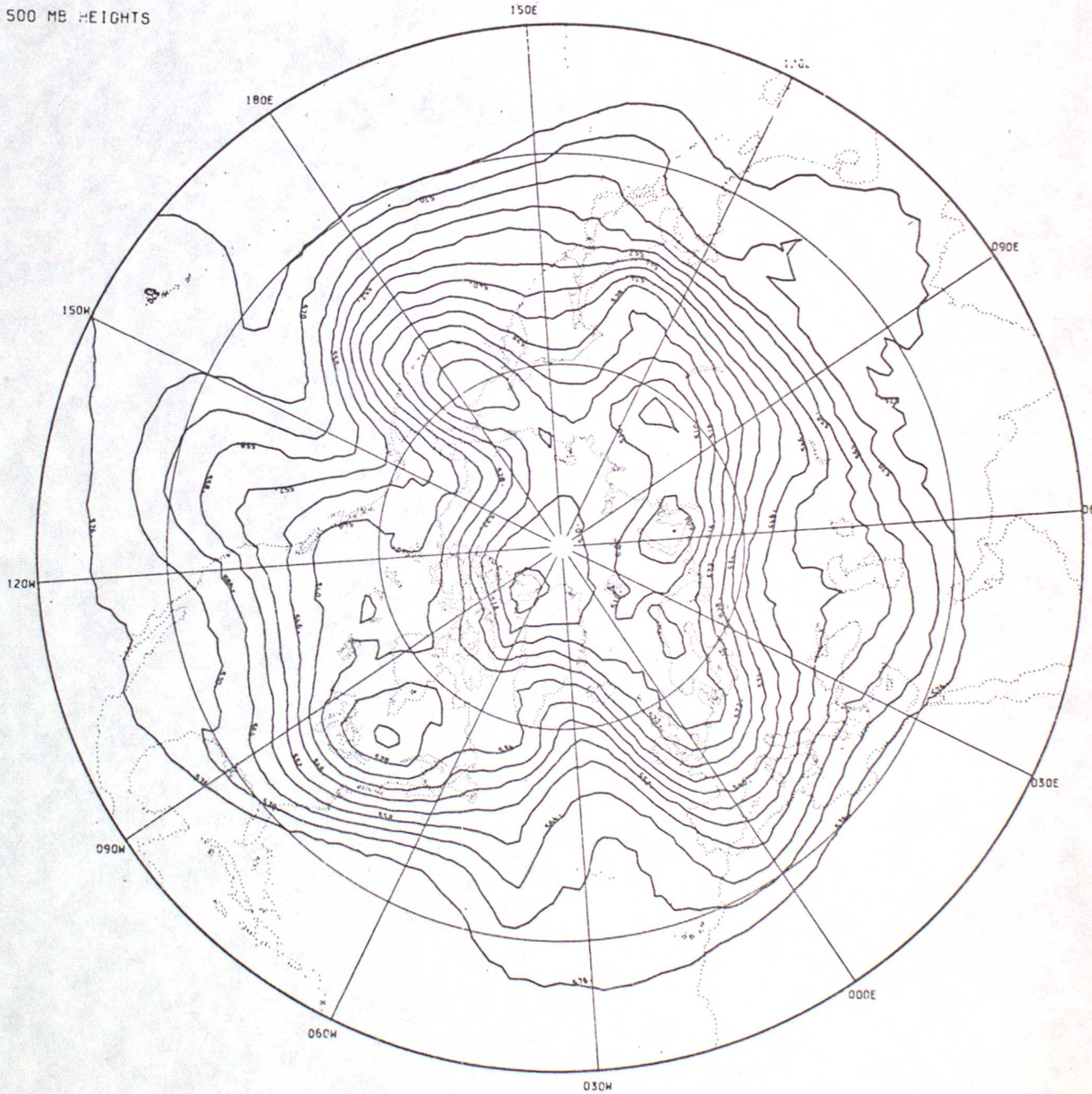


FIG. 7.4

6 DAY FCST.DAY 0= 12Z APR 09TH

MEAN OF WAVE NOS 1 - 2 AT LATITUDE = 49

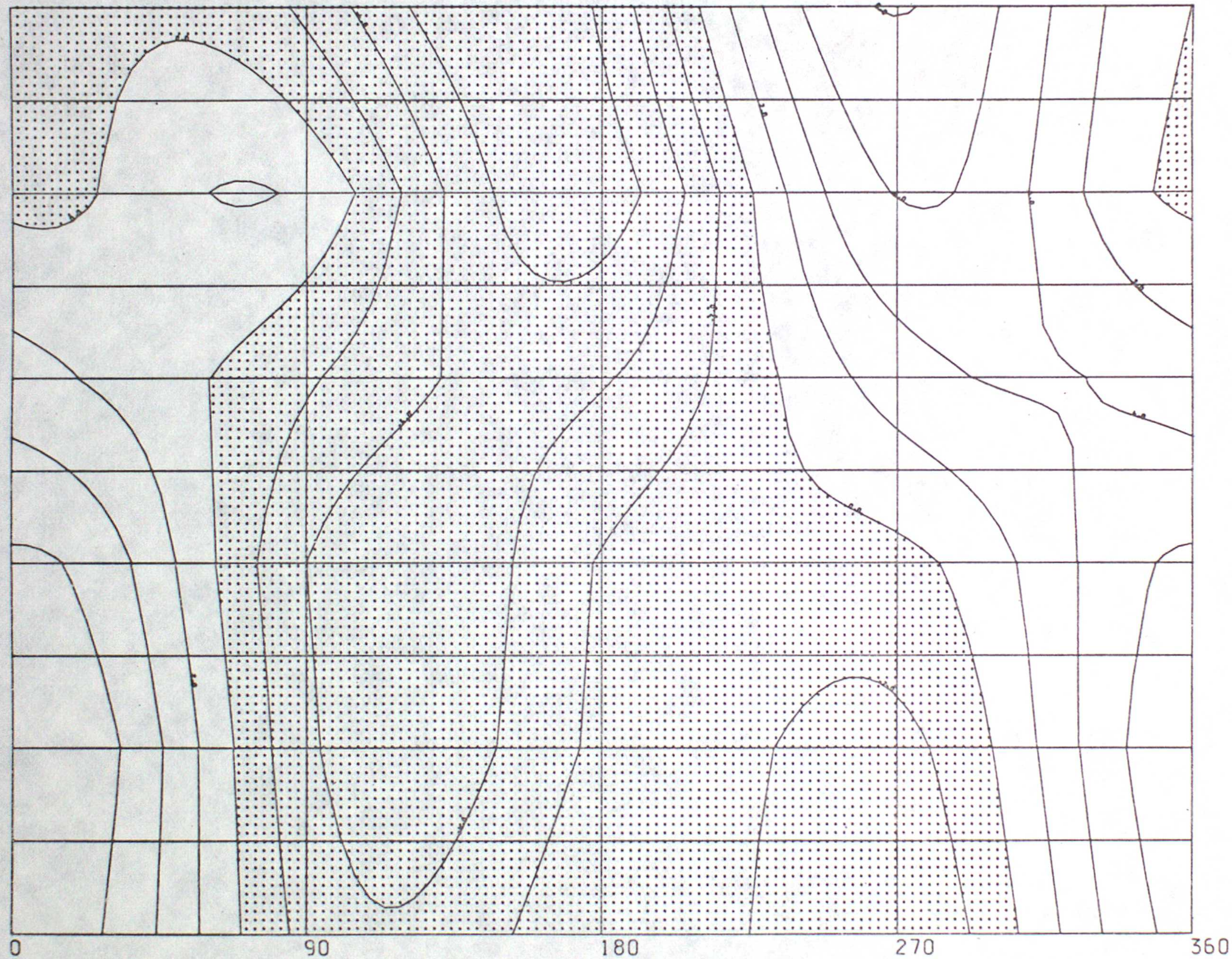
CONTOUR INTERVAL = 2.0

EXPERIMENT NO = 0

FIG 7.5

OP F/C
DATA TIME 12Z 9/4/78

9/4/78

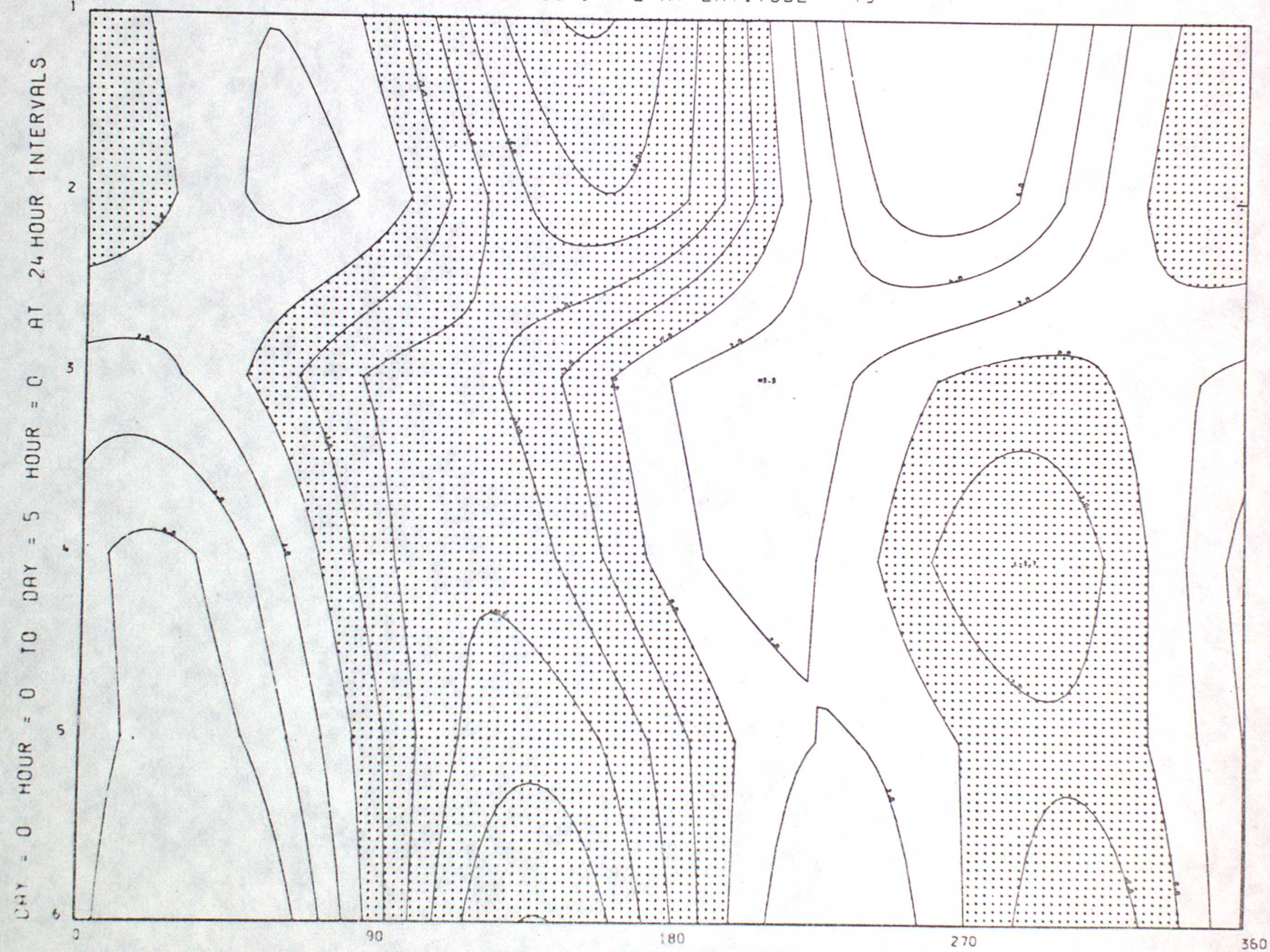


WAVE GROUP 1 TO 2
BASED ON 80 PTS AT 50N

FIG 7.6

5 DAY F'CAST.   DAY 0 = 12Z 9TH APRIL 1978   MERGED VERSION

MEAN OF WAVE NOS 1 - 2 AT LATITUDE = 49



CONTOUR INTERVAL = 2.0   LONGITUDE (EAST)   EXPERIMENT NO = 0

FIG 7.87

/4/78
2 waves
level
merged F/C

COMPARISON OPER UPDATE F/C & ACTUAL 500MB HT VERIFYING TIME 12Z 12/4/78
ERROR (F'CAST-ACTUAL) T+72 FORECAST FIELD

2hr
00 mb
error
9/4/78 12z
0level

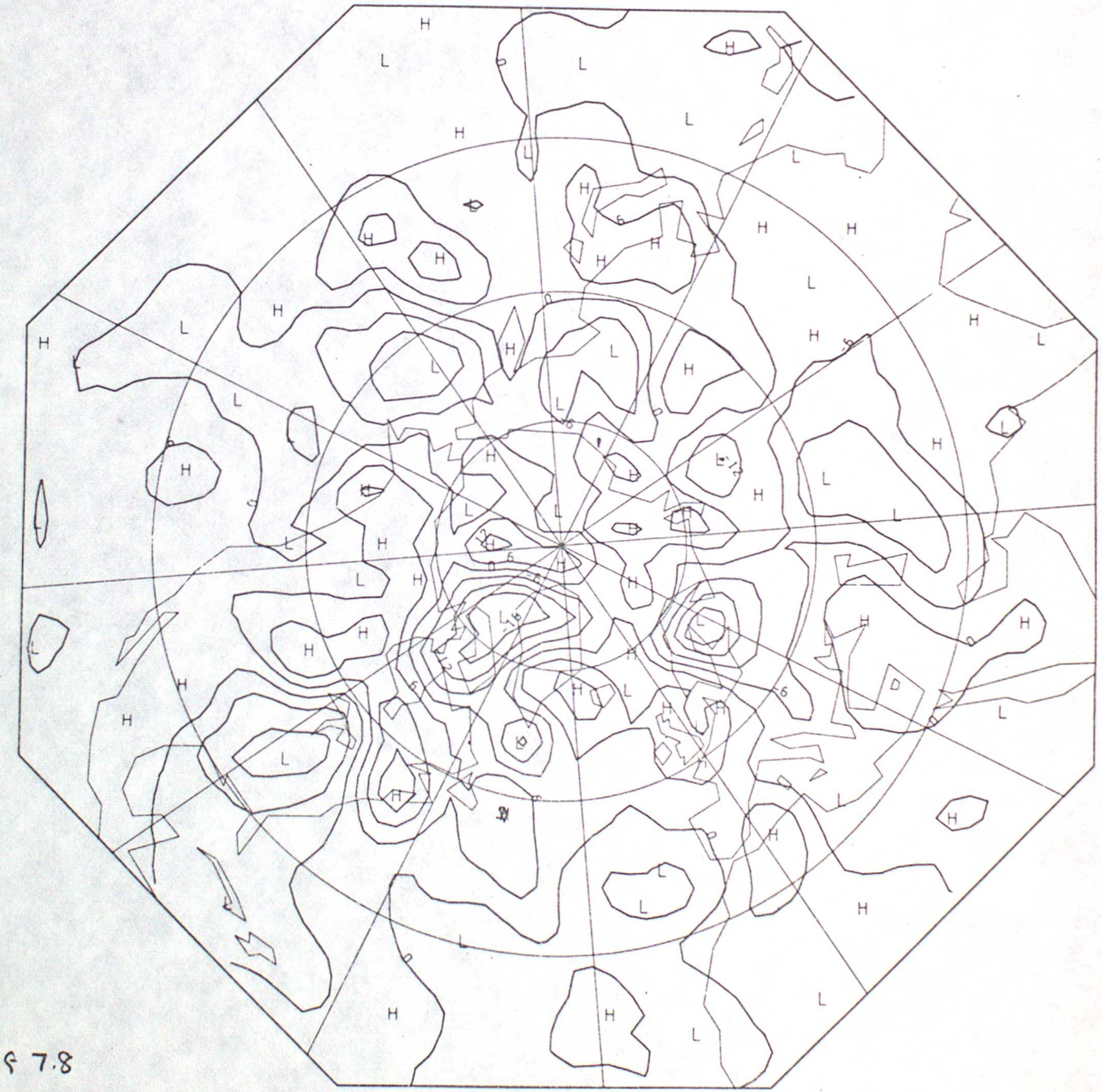


Fig 7.8

INTERVAL=6

72hr 500mb error
DT 9/4/78 12Z
11 level

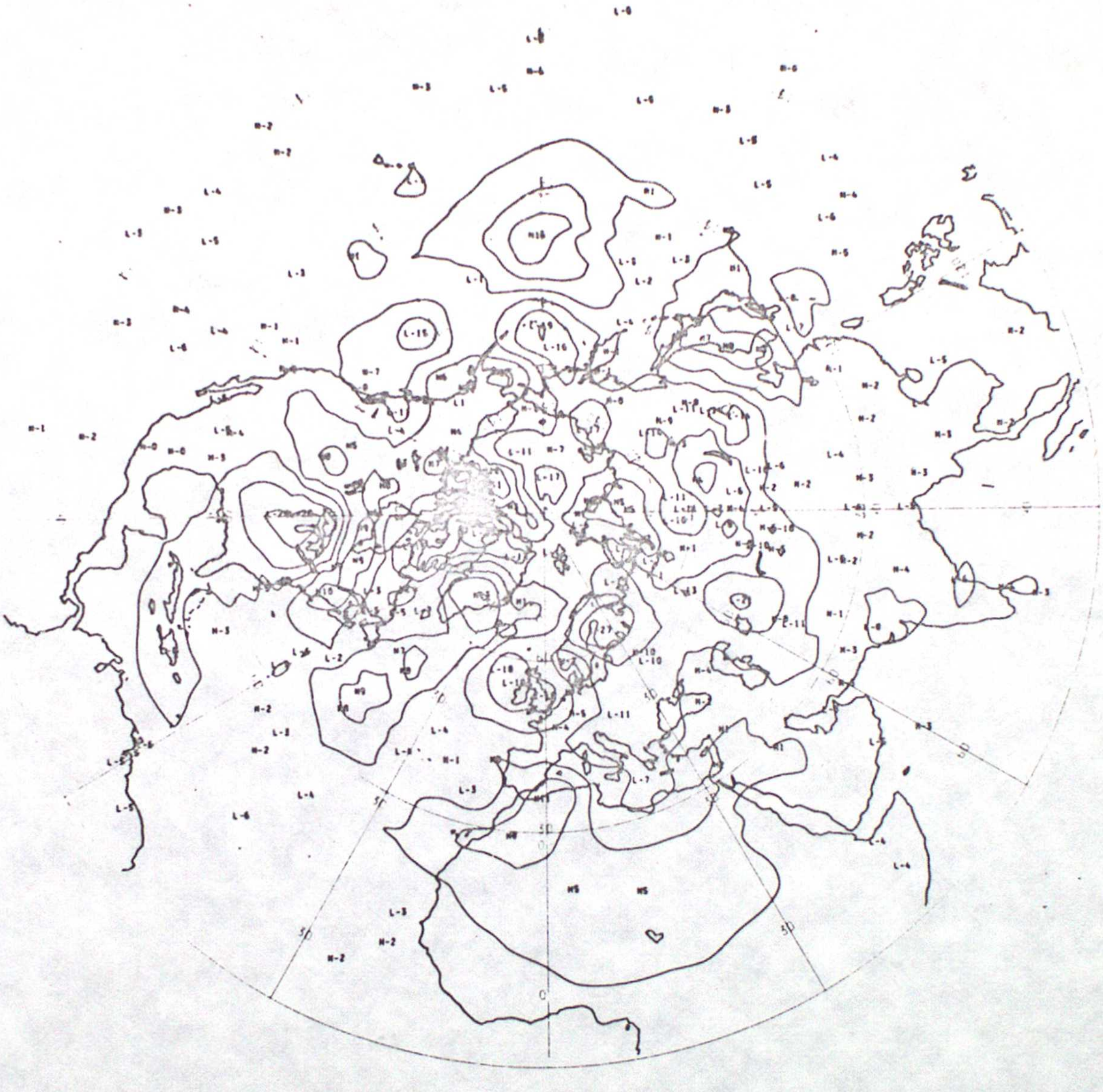


FIG 7.9 DIFFERENCE IN PRESSURE LEVEL=500.0 FOR EXH 0 - EXH 0 D 3H 0 D 3H 0
CONTOUR INTERVAL = 6.00