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Six Case Studies with the 11-level spectral model

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1. INTRODUCTION

This note describes an experiment to compare an 11-level spectral model with an 11-level finite-difference model. The comparison is over six 'special cases' selected from 54 cases that were run during the Met O 11 model comparison experiment which spanned the period from February 1977 to May 1978, the results of which have been described by Cullen (1978a).

One of the models used in the long experiment was a 5-level spectral model, the code of which was supplied by the UK Universities Atmospheric Modelling Group of Reading University; a full description of the model is given by Hoskins and Simmons (1975). An 11-level version has since been developed within Met O 11. When the model was first run its size prohibited execution on the IBM 360/195 computer (which has since been enhanced), which meant that the forecasts had to be run on the CRAY-1 computer at the European Centre for Medium Range Weather Forecasts. The finite-difference model with which the spectral model is being compared is the Met O 20 11-level general circulation model. The main characteristics of the two models are listed in Table 1.

The initial dataset for the spectral model is in grid-point form and is interpolated in the horizontal from the initialisation of the Met O 20 11-level model. The vertical σ-levels are identical in both models. No further balancing of the fields is performed by the spectral model.

The results of this experiment will be presented in identical fashion to those of Cullen (1978b) who compared three models over the same six special cases. One of the models used was the Met O 20 11-level model and was designated the identifying letter C. This will be used in this note also, and the letter S will be used to identify the 11-level spectral model. None of the charts presented in this note will coincide with any presented by Cullen, so for a fuller assimilation of the results it will be beneficial for the reader to have Cullen's note at hand.

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) of 1000 mb height at day 2 and 500 mb height at day 3.

c) Hovmoeller diagrams of the 500mb height at 50°N for wavenumber groups 1-2, 3-5, 6-10, 11-16.

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

In some of the cases the objective diagnostics (d) were not available.

The six cases 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 first three cases were performed with an extended octagon analysis for C (see Cullen (1978a)) and the last three with the merged analysis. The synoptic assessments are based on those made from a complete study of all the charts from the cases concerned, not just those presented here. They concentrate on the changes over the British Isles and the Atlantic; features elsewhere are discussed more briefly.

TABLE 1

A summary of the model characteristics

MODEL	C	S
FORECAST AREA	N.HEMISPHERE	N.HEMISPHERE
VERTICAL CO-ORDINATE SYSTEM	σ	σ
NUMBER OF VERTICAL LEVELS	11	11
HORIZONTAL RESOLUTION	220 km	T42 (500 km)
TIME STEP	$7\frac{1}{2}$ min	15 min
CPU TIME PER 24 HR F/C	26 min (360/195)	8 min (CRAY - 1)
INTEGRATION SCHEME	EXPLICIT UNSTAGGERED FINITE DIFFERENCE	SEMI-IMPLICIT SPECTRAL GALERKIN

Also note that the non-adiabatic processes (the 'physics') are identical in the two models.

2. 20th FEBRUARY 1977

a) Synoptic Assessment

Fig 2.1 shows the 500 mb chart at day 4. Figs 2.2 and 2.3 show the forecasts produced by models C and S. 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. Both models keep pressure too low over the UK - model C is slightly worse in this respect. Compounding the error is the fact that (in both models) the surface depression is off north-east Scotland instead of being in the south-west approaches thus resulting in north-westerlies over the UK rather than southerlies. Neither model amplifies the mid-Atlantic ridge sufficiently although S fares better than C, especially at the surface. Neither model handles the low pressure to the west of Greenland successfully, but S makes a better attempt at developing the trough over the central USA. The trough over North Africa on day 3 is lagging in both models. By day 4 model C has become almost zonal from Newfoundland to central Europe while S retains a fair amount of meridionality over the east Atlantic.

Over the east Pacific a shortened wavelength develops by day 3 with a weak ridge at 120°W and a sharp ridge at 155°W. The rest of the Pacific is zonal as is much of Asia. Model S handles the ridge-trough-ridge development better than C, but although the leading ridge (at 120°W) is correctly positioned, the following trough and ridge are 15° too far west resulting in the features being not sharp enough. Over the rest of the Pacific S produces a good forecast while in C the broad trough near Japan is 10° too fast on day 3.

b) Hovmoeller Diagrams

Fig 2.4 shows the actual Hovmoeller diagram for wavenumbers 1 to 3 and figs 2.5 and 2.6 show the forecasts produced by C and S.

In wavegroup 1-3 both models correctly forecast the development of the ridge-trough-ridge system between 0° and 150°W - however S keeps the trough stationary and C retrogresses it while in fact it should have progressed. S wrongly develops a trough at 40°E from day 3 onwards. The amplitude in S is generally not high enough but in some features (such as the ridge at 30°W) it is too high. S would seem to be gaining energy in the long waves as the forecast progresses. The amplitude in model C is generally good.

In wavegroup 4-5, neither model shows enough progression although S is possibly better than C. After day 2 progression practically ceases altogether. Developments are forecast incorrectly by both models. For the first two days both models give good amplitudes although lacking somewhat in the region 0-90°E. S shows a marked drop in amplitude on day 3 but then recovers too much on days 4 and 5. C also has excessive amplitudes towards the end of the period.

In wavegroup 6-10 the phase speeds in both models are too fast. Beyond 2 or 3 days the energy in C is weak and too evenly distributed rather than being concentrated around 30°E to 90°W. S has better amplitudes than C but concentrated in the wrong places. Neither model has sufficient amplitude in the strong ridge-trough-ridge system at day 2 between 140° and 180°E.

In wavegroup 11-16 S has good amplitudes on day 2 between 140° and 180°E - the amplitudes in C are far too weak. The high amplitude perturbations on day 3 between 60°W and 60°E are not picked up by either model.

c) <u>Error Fields</u>

Figs 2.7 and 2.8 show the 1000 mb error fields from models C and S at day 2. There are marked similarities in the patterns from the two models - both show large negative errors to the north of the UK and over north-western Canada, and large positive errors over most of the USA and in the west Pacific. The magnitudes of the errors are similar. The main difference between the models occurs over the Atlantic. C has a negative anomaly stretching from a centre near Newfoundland to one north of the UK, while S has a generally higher pressure than C between Newfoundland and Iceland with a 'ridge' of positive anomaly in the west Atlantic. There is quite a strong area of negative error near the Aleutians in model C, but this is relatively weak in S.

At 500 mb on day 3 C has greater errors over Europe than S but of the same sign. S has a more widespread and greater magnitude positive error over eastern Asia and the west Pacific, while C has greater errors over the east Pacific and western USA. The main difference, as at 1000 mb, is over the Atlantic and north-east Canada. S shows positive errors while C has negative errors. S also has a strong area of negative errors to the north-west of the Great Lakes.

In general the signs and positions of the errors are very similar apart from the main difference over the Atlantic and Canada.

d) Objective Scores

Table 2 gives the rms errors for this case. The breakdown of error by wavenumber nor the height change correlations were available for this forecast.

Table 2

500 mb error

Parameter	Model	Time (Days) 1	2	3	4	5
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
RMS forecast error	S	6.7	9.8	10.3	10.9	12.7
RMS persistence error		7.8	12.9	13.8	14.7	15.2
Forecast error/persistence error x 100%		86	76	75	74	84

Table 2 (contd)

1000 mb error

Parameter	Model	Time (Days) 1	2	3	4	5
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
RMS forecast error	S	7.2	8.4	9.2	9.6	10.5
RMS persistence error		6.1	10.5	11.1	10.6	10.3
Forecast error/persistence error x 100%		118	80	83	91	102

e) Summary

The synoptic assessment points to the forecast from model S being more useful than that from model C in most areas. C soon becomes more or less zonal in the Atlantic while S retains some meridionality albeit inaccurate. From the Hovmoeller diagrams S appears to gain too much energy in the longer waves towards the end of the forecast and neither model forecasts new developments successfully - S has no significant advantage over C. The error fields show that both models make more or less the same mistakes to about the same extent apart from one main difference - that of the Atlantic area. S forecasts too high pressure while C is too low. The rms errors show that at 500 mb C is better at the beginning of the forecast while S is better on days 4 and 5. At 1000 mb C is better than S throughout. Of particular note here is the high value of rms error on day 1 in both models but more especially in S. The figure (with respect to the persistence error) drops markedly on day 2. This feature occurs in all of the cases and is thought to be due to the initialisation procedure. Another feature of the forecast from model S that re-appears in other cases is the tendency for large-scale troughs to lag in southern latitudes resulting in a south-west to north-east orientation. This effect can be seen on the day 4 500 mb chart between 0° and 30°W, near 160°W and near 40°E.

3. <u>8th MAY 1977</u>

a) <u>Synoptic Assessment</u>

Fig 3.1 shows the 500 mb chart at day 3. Figs 3.2 and 3.3 show the forecasts produced by models C and S. 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. Up to day 3 both models perform quite well. S has a better surface pattern near the UK than C. By day 4 however the UK trough is 10° too far west in both models, although the shape in S is better than in C. The mid-Atlantic ridge is also slow in both models. At day 5 S is slightly better than C.

Over the eastern USA a trough is almost stationary with secondary troughs breaking away on day 2 and day 5. The depth of the stationary trough and associated surface depression is consistently too high in S and too low in C. Both models forecast the breakaway on day 2 but only S makes an attempt at forecasting the development on day 5.

Over the western USA a large trough remains stationary throughout the period. Both models treat it similarly - up to day 3 the forecasts are not too bad but thereafter they split the large trough into two weaker ones.

A trough in the west Pacific moves east through 30° to 180°W by day 5. This movement is too slow in both models - C is slightly worse for speed although it has a better amplitude than in S. In general neither model treats the Pacific very well.

b) <u>Hovmoeller Diagrams</u>

Fig 3.4 shows the actual Hovmoeller diagram for wavegroup 1 to 2 and figs 3.5 and 3.6 show the forecasts produced by C and S.

In wavegroup 1-2 S shows a marked retrogression of 150° instead of a progression of 20° over the 5 days thus being almost in phase again on day 5. Most of the retrogression takes place after day 2 when the perturbations are very weak. The amplitude recovers somewhat by day 5 but not sufficiently. C also loses amplitude after day 2 although not as badly as in S. C also retrogresses slightly for the first two days but progresses thereafter.

In wavegroup 3-5 C treats the phase speeds slightly better than S (see for example 30° - 90°E and 0° - 60°W), although neither model is bad. Both models correctly lose amplitude by day 3 and regain some by day 5, although these changes are not always in the correct places. The same (small) mistakes are made by both models.

In wavegroup 6-10 the speeds in S are generally 10° too slow while C is about right. Both models are too intense between 90°W through 0° to 90°E and not intense enough over the other half of the hemisphere.

In the short waves (11-16), S has lost most of the amplitude by day 5 and is too intense on day 2 between 90°E and 180°E. C is generally better.

c) Error Fields

Figs 3.7 and 3.8 show the 1000 mb error fields at day 2 from the two models. Both show a large negative anomaly over Siberia, with C being worse than S. Both models have positive anomalies across the Atlantic and over central USA and in this case S is worse than C. Both models have similar positive anomalies near the Aleutians, and in general the patterns are very similar in both models.

At 500 mb on day 3 both models show a spurious easterly gradient across the UK which is much stronger in C than in S. Over the west Atlantic and over the central Pacific S has higher positive errors than C. Model C shows extensive negative errors across northern Russia and over Japan, these also appear to a lesser extent in S.

d) Objective Scores

Table 3 gives the rms errors for this case. The breakdown of error by wavenumber and the height change correlations were not available for this forecast.

Table 3

500 mb error

Parameter	Model	Time (Days) 1	2	3	4	5
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
RMS forecast error	S	4.2	5.9	7.1	8.2	8.4
RMS persistence error		5.7	9.2	10.6	11.1	12.0
Forecast error/persistence error x 100%		64	64	67	74	70

1000 mb error

Parameter	Model	Time (Days) 1	2	3	4	5
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
RMS forecast error	S	4.6	5.1	5.3	6.5	7.0
RMS persistence error		4.2	6.3	6.9	7.0	6.9
Forecast error/persistence error x 100%		110	81	77	93	101

e) Summary

From the synoptic assessment it can be seen that both models perform quite well in the Atlantic region up to day 3. Thereafter the major features are moved too slowly especially in S; but S does well on day 5 in producing a new breakaway low from the trough over the eastern USA where C fails to do so. The Hovmoeller diagrams show C to have given the better forecast, especially in the very long waves (1 and 2) where S retrogresses markedly rather than progressing.

It is difficult to pick up this mistake when looking at the 500 mb charts alone. In the baroclinic and short wavegroups C handles the phase speeds and the amplitudes slightly better than S. The error fields at days 2 and 3 imply that the two models make the same mistakes for the most part, with C probably being slightly the better of the two. The RMS errors also show that C is slightly better throughout the forecast, although the differences at 500 mb are not great.

4. 14th AUGUST 1977

a) Synoptic Assessment

Fig 4.1 shows the 500 mb chart at day 4. Figs 4.2 and 4.3 show the forecasts produced by models C and S. A sharp trough to the west of the UK moves eastwards. An upper cold pool and surface low forms in the south-west approaches on day 2 and moves across southern England giving a great deal of rain. An anticyclone to the north of Scotland persists for most of the period and a deep depression moves into the NW Atlantic from SE Canada. Both models fail to forecast the closed circulation of the upper low. The ridge over the UK is moved too slowly eastwards so that, on day 3, instead of being at 15°E it is at 5°E in S and 5°W in C. The surface depression is too far south of the UK on day 3, especially in C. The NW Atlantic depression is forecast quite well by both models, except that in S it is not deep enough while in C it is too deep.

Over the USA and Pacific there is a large amplitude pattern with a ridge at 140°W at day 3 and troughs either side. The two models produce very similar forecasts here. Neither has enough amplitude in the pattern, and by day 5 both models are zonal between 180°W and 60°W instead of having a large amplitude ridge at 150°W.

A cold upper vortex covering much of Eurasia is treated similarly by the two models. Both maintain the trough but neither splits it into two separate centres.

b) Hovmoeller Diagrams

Fig 4.4 shows the actual Hovmoeller diagram for wavegroup 6-10 and figs 4.5 and 4.6 show the forecasts produced by models C and S.

In wavegroup 1-2 C has excessive amplitude at 150°W and S at 80°E. Neither model handles the phases properly.

In wavegroup 3-5 both models forecast the phase speeds quite well except between 0° and 90°E where neither model is progressive after day 2. S wrongly develops a trough at 100°W from day 2 onwards. Both models lack amplitude between 60°W and 180°W - S is slightly worse in this respect.

In wavegroup 6-10 both models are slow between 0° and 90°E especially S. Changes occurring between 90°W and 180°W during days 2 and 3 are badly forecast by both models, and the amplitudes in this region after day 2 are far too weak.

In wavegroup 11-16 C has very little amplitude after day 2. S gives better amplitudes than C in general.

c) Error Fields

Figs 4.7 and 4.8 show the 1000 mb errors at day 2. Both models show very similar magnitude errors in about the same places. One of the main areas is near the UK where both models show a positive anomaly near the south-west of the UK and negative anomalies to the west of Iberia and near Iceland. The general level of pressure in these regions is lower in S than in C. Errors over Canada are generally negative while over the USA the errors are positive. There is an anomalous westerly gradient south-east of the Aleutians. Both models show positive errors over the pole.

At 500 mb on day 3 the same errors are produced by both models. There are positive errors to the south of the UK, near the Caspian Sea, in the Central Pacific, near the Great Lakes and over the pole, although in C this error is centred over western Greenland. There are negative errors to the north of the UK, in the Atlantic, over eastern Europe and Alaska.

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	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
RMS forecast error	S	3.4	5.1	7.0	8.3	9.3
RMS persistence error		3.6	6.1	7.4	7.8	8.6
Forecast error/persistence error x 100%		94	84	95	106	108
Height change correlation (%)	C	74	76	68	64	64
Height change correlation (%)	S	69	66	59	51	51

1000 mb error

Parameter	Model	Time (Days) 1	2	3	4	5
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
RMS forecast error	S	4.0	4.6	5.3	5.9	6.0
RMS persistence error		2.6	3.9	4.0	4.5	4.7
Forecast error/persistence error x 100%		154	118	133	131	128
Height change correlation (%)	C	58	55	45	48	47
Height change correlation (%)	S	47	49	44	44	43

e) Summary

From both the synoptic assessment and the error fields it can be seen that the two models made more or less the same mistakes. Near the UK, neither model moved the ridge eastwards quickly enough resulting in the active surface depression travelling too far south. Neither model impresses greatly in the Hovmoeller diagrams, with major errors in amplitude and phase speeds occurring in all scales of motion. The objective RMS errors and height change correlation coefficients show C to be considerably better than S both at 500 mb and 1000 mb. In particular at 1000 mb both models have very bad scores with respect to persistence and the correlation coefficients are also very low. This would seem to be more as a result of the persistence errors being exceptionally low than anything else. Note again the exceptionally high error on day 1 in model S (see 2(e)).

5. 20th NOVEMBER 1977

a) Synoptic Assessment

Fig 5.1 shows the 500 mb chart at day 3 and figs 5.2 and 5.3 show the forecasts produced by models C and S. The pattern is dominated throughout the period by two blocks - an omega block over the Atlantic and a diffluent block over the North Pacific. The main flows are from Gibraltar to Japan and in low latitude across the Pacific and USA with the jet exit near the Great Lakes. This latter flow extends 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 eastwards close to northern Scotland, and subsequently reinforcing the eastern trough over Europe. The small amplitude ridge in northern latitudes phases in with the blocking ridge at 25°W 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 western Atlantic. Little change takes place in the Pacific block. An oscillation develops in the jet near the Caspian Sea.

S handles the changes near the UK better than C but neither model produces a convincing forecast. There is insufficient amplitude in the trough moving quickly round the Atlantic ridge resulting in the inability to forecast the deep surface low that moves across northern Scotland. The main difference between the two models occurs in the way in which they handle the ridge in northern latitudes. S correctly phases in the ridge with the main blocking ridge on day 4 whereas C keeps it to the west of Greenland while moving the main ridge too far east into the UK. By day 5 S correctly has the ridge to the west of the UK, although it lacks amplitude, while C has a flat ridge to the east of the UK with a strong westerly flow across the country.

In the Pacific both models correctly cut off the upper high but the amplitude is lacking on day 3; S has better amplitudes than C. At the surface on day 3 in both models the low to the north of Japan is too deep while the low at 150°W is too shallow.

b. Hovmoeller Diagrams

Fig 5.4 shows the actual Hovmoeller diagram for waves 6 to 10 and figs 5.5 and 5.6 show the forecasts produced by models C and S.

In wavegroup 1-2 the large trough centred near 180°E is well forecast up to day 3. Then both models proceed (wrongly) to retrogress its eastern flank. C correctly progresses the westward flank but S retrogresses it. Both models (especially C) retain too much amplitude in the trough. The amplitude in the ridge is better in C. Model C has a high amplitude perturbation on day 1.

In wavegroup 3-5 the phases in S are generally better than in C especially in the region 0° - 90°W and in the treatment of the ridge at 70°E. C wrongly splits the trough at 120°E and also suffers a marked loss of amplitude. The amplitudes in S are very good while in C they are too weak especially between 90° and 270°E.

In wavegroup 6-10 the phases and amplitudes are well forecast in both models.

In the short waves (11-16) S tends to lack amplitude while C gives good amplitudes.

c) Error Fields

Figures 5.7 and 5.8 show the 1000 mb errors at day 2. C has large negative errors over the UK while S is correct, but S has positive errors near Iceland and over the Mediterranean while C is correct. Both models have positive errors to the south-east of Newfoundland and over the south-west USA. S extends this area through western USA into western Canada where C has negative errors. Both models have negative errors near the Aleutians and Kamchatka, and positive errors in the central Pacific, where S is worse than C.

At 500 mb on day 3 both models have positive errors to the north-west of the UK, over the North Pole, Baffin Island, central USA, eastern Russia and the central Pacific. However, apart from these areas both models show predominantly negative errors which are large and extensive in places. These areas include Europe, Greenland, the west Atlantic, Alaska and Kamchatka. The level of errors tends to be greater in C, but, as at 1000 mb, S has a larger positive error in the Pacific.

d) Objective Scores

Table 5 gives the rms errors and height change correlation coefficients for this case, also the breakdown of rms error by wavenumber for 500 mb.

Table 5

500 mb error

Parameter	Model	Time (Days) 1	2	3	4	5
RMS forecast error	C	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
RMS forecast error	S	5.2	6.3	7.8	8.5	10.8
RMS persistence error		7.5	10.9	12.0	13.7	15.2
Forecast error/persistence error x 100%		69	58	65	62	71
Height change correlation (%)	C	76	84	79	75	69
Height change correlation (%)	S	75	82	82	82	79

1000 mb error

Parameter	Model	Time (Days) 1	2	3	4	5
RMS forecast error	C	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
RMS forecast error	S	5.5	5.9	6.8	6.9	8.0
RMS persistence error		6.1	7.6	7.4	8.8	10.4
Forecast error/persistence error x 100%		90	78	92	78	77
Height change correlation (%)	C	74	77	68	61	62
Height change correlation (%)	S	70	76	67	71	68

500 mb error by wavenumber (from 30°N to pole)

(Figures expressed as forecast error/persistence error x 100%)

		Model	Day 1	Day 2	Day 3	Day 4	Day 5
	Mean	C	200	205	133	139	168
		S	165	113	122	114	162
Wavegroup	1-2	C	94	59	63	56	73
		S	72	64	63	55	67
	3-5	C	38	47	70	86	83
		S	56	47	59	57	56
	6-10	C	31	42	51	56	51
		S	52	48	51	51	54
	11-16	C	71	81	73	81	93
		S	98	102	97	112	73

e) Summary

The synoptic assessment shows S to be slightly better than C, especially over the Atlantic and the UK. Neither model treats the breakdown and re-establishment of the northerlies over the UK particularly well, but S ends up with a better-looking situation than C. Over the rest of the hemisphere the models behave very similarly. S produces a good forecast for waves 3-10 while C handles waves 6-16 well. Neither model correctly forecasts the predominantly wavenumber 1 pattern in the long waves. The error fields show similar errors in both models with the main exception being near the UK where the general level of pressure is higher in S than in C. Both models have strong negative biases at 500 mb that grow throughout the forecast period. This feature appears in all six of the cases but is particularly noticeable here. It is thought to be due to the physics package (which is common to both models) causing a general cooling of the atmosphere. The rms errors and correlation coefficients at 500 mb show S to be the better of the two forecasts especially from day 3 onwards. At 1000 mb C is better for days 1-3, thereafter S is better. On day 3 at 1000 mb S shows a marked increase in "percentage persistence error" corresponding to a fall in the rms persistence error. The initialisation problem shows up again on day 1 in both models. It also appears in the statistics obtained from the breakdown of error by wavenumber, mainly in wavegroup 1-2. These statistics show S to be superior to C in the longer waves and especially in the zonal mean field, where C makes serious errors. In the short waves (11-16) S is worse than C except on day 5.

This is the only one of the six cases in which the objective scores show S to give a better forecast than C.

6. 1st JANUARY 1978

a) Synoptic Assessment

Fig 6.1 shows the 500 mb chart at day 4 and figs 6.2 and 6.3 show the forecasts produced by models C and S. 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 onwards the ridge continues to develop and move across the UK and by day 5 it is east of the UK with the large troughs over Europe and the mid-Atlantic. Both models give the ridge insufficient amplitude at 500 mb and fail to move it quickly enough from day 3 onwards; S does push it through on day 5 but lags badly in southern latitudes. The surface anticyclone tends to be too weak in C and too strong in S. The trough that moves quickly across the UK and intensifies over Europe is treated well by C up to day 3 - thereafter it lacks amplitude. The position is consistently 10° too far west in S but the amplitude is treated rather better than by C.

S handles the low pressure in the Atlantic rather better than C - C fails to move the centre from the west of Greenland whereas S correctly transfers it to the north-east of Iceland by day 5 but it isn't deep enough.

Over the Pacific and particularly over western Canada C performs much better than S. The large amplitude block over western Canada is well forecast by C, but S fails to retrogress the ridge and also loses the cut-off circulation by day 3; by day 5 the pattern is almost 180° out of phase.

b) Hovmoeller Diagrams

Fig 6.4 shows the actual Hovmoeller diagram for waves 1 and 2, and figs 6.5 and 6.6 show the forecasts produced by models C and S.

In wavegroup 1-2 model S fails to intensify the trough at 150°E on day 1 and thereafter both models incorrectly lose amplitude. Both models give insufficient amplitude to the ridge at 30°E with S worse than C. However S handles the trough at 80°W on day 2 better than C, which is one day late with the development.

In wavegroup 3-5 both models incorrectly retrogress the trough at 40°E and neither is sufficiently progressive at 90°W although C is better than S. In the region from 120°W to 180°W C is much more convincing than S which fails to develop the weak trough at 130°W from day 3.

In wavegroup 6-10 both models show good phase speeds. The amplitudes in C are good but in S they are too high towards the end of the period.

Both models show very similar behaviour in wavegroup 11-16.

c) Error Fields

Figs 6.7 and 6.8 show the 1000 mb error fields at day 2. S shows considerable positive errors to the west and to the east of the UK, while in C the emphasis is on the negative errors to the north and south. Both models have a large area of negative errors over western Russia. S has very high positive errors over the west Pacific with very high negative errors to the north over the Bering Strait leading to an anomalous westerly flow; the corresponding errors in C are displaced to the west slightly and are not so great, although there is a very high positive error near the pole. The errors over North America are similarly positioned but the intensity is greater in S.

At 500 mb on day 3 both models have strong negative errors near the UK but in different positions - in S the error is centred to the south-east giving rise to an anomalous north-easterly flow over the UK, while in C the centre is to the north-west resulting in an anomalous south-westerly flow. Both models show strong negative errors near the North Cape and north of the Caspian Sea, and high positive errors over the Atlantic and southern Greenland. Both models have extensive negative errors over North America but the errors in C are of about twice the magnitude of those in S, while the positive errors in S over the north-west Pacific are much worse than those in C. S has very high positive errors over western Canada and high negative errors near the Aleutians. C has very high positive errors near the pole compared with S.

d) Objective Scores

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

Table 6.

500 mb error

Parameter	Model	1	2	3	4	5
		Time (Days)				
RMS forecast error	C	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
RMS forecast error	S	5.1	6.9	9.2	12.3	13.7
RMS persistence error		7.0	9.8	11.1	10.2	10.6
Forecast error/persistence error x 100%		73	70	83	121	129
Height change correlation (%)	C	88	83	76	65	52
Height change correlation (%)	S	77	74	57	36	29

1000 mb error

Parameter	Model	1	2	3	4	5
		Time (Days)				
RMS forecast error	C	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
RMS forecast error	S	5.1	6.1	8.5	9.3	9.6
RMS persistence error		5.6	7.5	8.5	8.2	8.0
Forecast error/persistence error x 100%		91	81	100	113	120
Height change correlation (%)	C	84	79	71	65	63
Height change correlation (%)	S	70	73	60	53	51

500 mb error by wavenumber (from 30°N to pole)

(Figures expressed as forecast error/persistence error x 100%)

		Model	Day 1	Day 2	Day 3	Day 4	Day 5
	Mean	C	191	123	90	116	146
		S	262	80	42	59	110
Wavegroup	1–2	C	47	52	81	108	128
		S	70	69	104	115	130
	3–5	C	39	56	78	92	99
		S	61	74	104	140	141
	6–10	C	33	57	54	89	76
		S	49	63	68	132	107
	11–16	C	53	65	74	113	82
		S	63	70	110	145	109

e) Summary

In the Atlantic area S produced a better forecast than C whereas in the Pacific C was the better of the two models. S treated the Atlantic low better than C but produced a poor forecast over the eastern Pacific and western Canada. On day 5 the trough over Europe in S lags markedly in the south corresponding to the situation mentioned in section 2(e). The Hovmoeller diagrams show up the poor forecast by S between 120°W and 180°W in wavegroup 3-5, and the rms errors by wavenumber groups show S to be worse than C for all waves except the zonal mean. The error fields show once again that the two models make more or less the same mistakes, and that the magnitude of the errors is greater in S than in C. As in the previous case (see section 5(e)) the general level of pressure in the area of the UK on day 2 is higher in S than in C. The bias at 500 mb is again negative in both models. Model S comes out worse from all the objective scores, and in particular the value of 29% for the height change correlation coefficient at 500 mb on day 5 is very poor indeed.

7. 9th APRIL 1978

a) Synoptic Assessment

Fig 7.1 shows the 500 mb chart at day 3 and figs 7.2 and 7.3 show the forecasts produced by models C and S. Initially there is a large amplitude 500 mb trough over the UK and Iberia with a strong 500 mb ridge over the Atlantic. During the period these move slowly east but the ridge axis remains west of Ireland and consequently cold surface northerlies are maintained over the UK. To the west of the Atlantic ridge there is a depression over Newfoundland from which a sharp 500 mb trough extends southward, and these also move slowly east during the period. The depression deepens a little after day 4 as the next 500 mb trough moves from Canada into the old Newfoundland trough. As a result the Atlantic ridge is accentuated towards the end of the period. C gives a much better forecast in the Atlantic than S. Although the ridge loses amplitude it is still sufficient to give the strong surface northerlies over the UK on day 5; S swings the ridge south-eastwards into the country and lacks amplitude in the trough to the east resulting in only a weak anticyclonic northerly flow over the UK.

Over the Pacific a 500 mb trough off the west coast of Canada moves east and merges with the Canadian low on day 3. A ridge becomes established at 50°E ahead of the European trough. C is better than S at forecasting these developments. Over Canada S fails to intensify the trough moving east so that on day 3 there is a broad ridge to the west of the Great Lakes instead of a broad trough. The European ridge is far too mobile in S and by day 5 it is 30° too far east, while in C it is 10° too far west.

b) Hovmoeller Diagrams

Fig 7.4 shows the actual Hovmoeller diagram for wavenumbers 3-5, and figs 7.5 and 7.6 show the forecasts produced by models C and S.

In wavegroup 1-2 C forecasts the phases quite well but doesn't retain enough amplitude after day 2. S is not as good as C as regards the phases and the amplitudes are even worse.

In wavegroup 3-5 S does not show enough retrogression between 90°W and 180°W - C is better except on day 5. In S the ridge at 60°E is not strong enough as well as being too far east - once again C is better. The amplitudes in general are better in C than in S.

In wavegroup 6-10 S is too progressive. New developments are poorly handled by both models, especially S. The amplitudes are better in C than in S.

In wavegroup 11-16 S is slightly better in that it shows a concentration of amplitude in the area 120°W to 30°E, insufficient though it is.

c) Error Fields

Figs 7.7 and 7.8 show the 1000 mb error fields at day 2. Both models show a high positive error over North America, the area being more extensive in S than in C. In S this area extends eastwards in a band across the Atlantic to Western Europe while in C the Atlantic has small negative errors with a larger negative error covering the UK. Both models have positive errors over north-west Russia and in the Pacific. S has an area of high positive error over south-east Asia while in C there are only small errors. At 500 mb the only area where the models completely disagree is over the UK where S has positive errors and C negative. Both models have strong negative errors over the Great Lakes, the Aleutians, NE Asia, SE Asia, Scandinavia and NE Canada. There are positive errors in the western Atlantic, Japan, central North America and the central Pacific. The errors tend to be greater in S than in C. Both models show an extensive negative bias at 500 mb.

d) Objective Scores

Table 7 gives the rms errors and height change correlation coefficients for this case, also the breakdown of rms error by wavenumber groups for 500 mb.

Table 7

500 mb error

Note that the values of rms errors at 500 mb for model C given here are corrected values from those given in Table 7 of Cullen (1978b). Also included here are the corrected values for model A (the operational 10 level model) which were also in error in Cullen (1978b).

Parameter	Model	Time (Days)				
		1	2	3	4	5
RMS forecast error	A	2.8	4.5	6.2	7.6	8.7
RMS persistence error		6.5	9.2	11.0	12.8	13.9
Forecast error/persistence error x 100%		43	49	56	59	63
RMS forecast error	C	3.8	5.5	7.2	8.5	9.1
RMS persistence error		6.6	9.7	11.9	13.7	14.7
Forecast error/persistence error x 100%		58	57	61	62	62
RMS forecast error	S	4.4	6.7	9.5	11.4	12.6
RMS persistence error		6.2	9.4	11.7	13.6	14.6
Forecast error/persistence error x 100%		71	71	81	84	86
Height change correlation (%)	C	83	85	85	83	83
Height change correlation (%)	S	75	73	69	66	67

1000 mb error

Parameter	Model	1	2	3	4	5
RMS forecast error	C	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
RMS forecast error	S	4.3	5.8	7.1	7.8	9.0
RMS persistence error		4.3	6.7	8.3	8.9	9.6
Forecast error/persistence error x 100%		100	87	86	88	94
Height change correlation (%)	C	78	82	79	73	72
Height change correlation (%)	S	65	63	59	57	52

(Columns 1–5: Time (Days))

500 mb error by wavenumber (from 30°N to pole)

(Figures expressed as forecast error/persistence error x 100%)

		Model	Day 1	Day 2	Day 3	Day 4	Day 5
	Mean	C	93	100	137	147	165
		S	151	131	172	186	223
Wavegroup	1-2	C	93	88	62	52	41
		S	89	73	75	73	58
	3-5	C	53	40	41	48	51
		S	72	72	67	68	75
	6-10	C	33	39	51	44	41
		S	44	52	71	65	54
	11-16	C	53	62	79	114	68
		S	70	90	90	167	87

e) Summary

In all departments and over most of the hemisphere model C is assessed to be better than S. Loss of amplitude and excessive mobility seem to be the main faults in the performance of S. These are shown up both in the synoptic charts and in the Hovmoeller diagrams. The rms errors for wavenumber groups show S to be inferior at all scales except in wavegroup 1-2 on days 1 and 2. Cullen (1978b) has suggested that the poor performance of C in wavegroup 1-2 early in the forecast may be due to some initialisation problem. If this is the case, it is unclear as to why the problem has not been passed on to S. The error fields are similar again although near the UK the level of pressure is higher in S than in C as was noticed in the two previous cases. At 500 mb both models again show an extensive negative bias. The rms statistics and the correlation coefficient show C to be superior to S at all times during the forecast.

8. GENERAL DISCUSSION

Over the six cases as a whole the general behaviour of the two models was very similar, although differences can be found in every case. Synoptically C was markedly better than S in only one case (9th April 1978); on this occasion S was excessively mobile and had insufficient amplitude in the wave pattern, while C retained meriodionality up to day 5. However the opposite occurred in the case of 20th February 1977 when C became zonal and S retained meridionality. The objective scores showed C to be better than S in most cases, especially at 1000 mb, where both models suffered from consistently large errors (with respect to persistence) on day 1. This is thought to be due to some problems in the initialisation of the models. As a consequence of the method of forming the initial dataset for S (described in section 1) any imbalances present in C may be magnified in S through the interpolation procedure. This might also explain the relatively poor statistical performances of S with respect to C. On only one occasion did S have more skill than C and that was the case of 20th November 1977, although on days 4 and 5 of the case of 20th February 1977 S also showed some superiority at 500 mb. The Hovmoeller diagrams showed that both models are poor at picking up new developments after day 3.

A particular characteristic of S that seemed to run through the six cases was the reluctance to move large amplitude troughs quickly enough in southern latitudes; this results in a SW-NE orientation of the troughs which in turn results in a poleward flux of zonal momentum. This feature can best be seen in the cases of 20th February 1977, 1st January 1978 and 9th April 1978, but also occurs to a lesser extent in the other three cases.

A characteristic common to both models was the strong negative bias occurring in the error field at 500 mb that grew in magnitude as the forecast proceeded. This is almost certainly due to the 'physics package' (which is common to both models) having a marked cooling effect. The error fields on day 2 at 1000 mb showed that the same errors were being made by both models, with the magnitude usually greater in S than in C. In the last three cases the general level of pressure in the area of the UK in model C appeared to be lower with respect to S than in the first three cases. As mentioned in section 1 model C was set up using a merged analysis for these cases, but there is no obvious reason for the relative fall in pressure.

As far as the spectral model is concerned an important point to have arisen from this study is the consistently poor objective assessment, especially at 1000 mb on day 1. An experiment is being planned to assess the way in which the initialisation procedure for the spectral model influences its subsequent performance.

Acknowledgements

The results from the Met O 20 11 level model were obtained by G W Purvis, J W Prince and D R Roskilly.

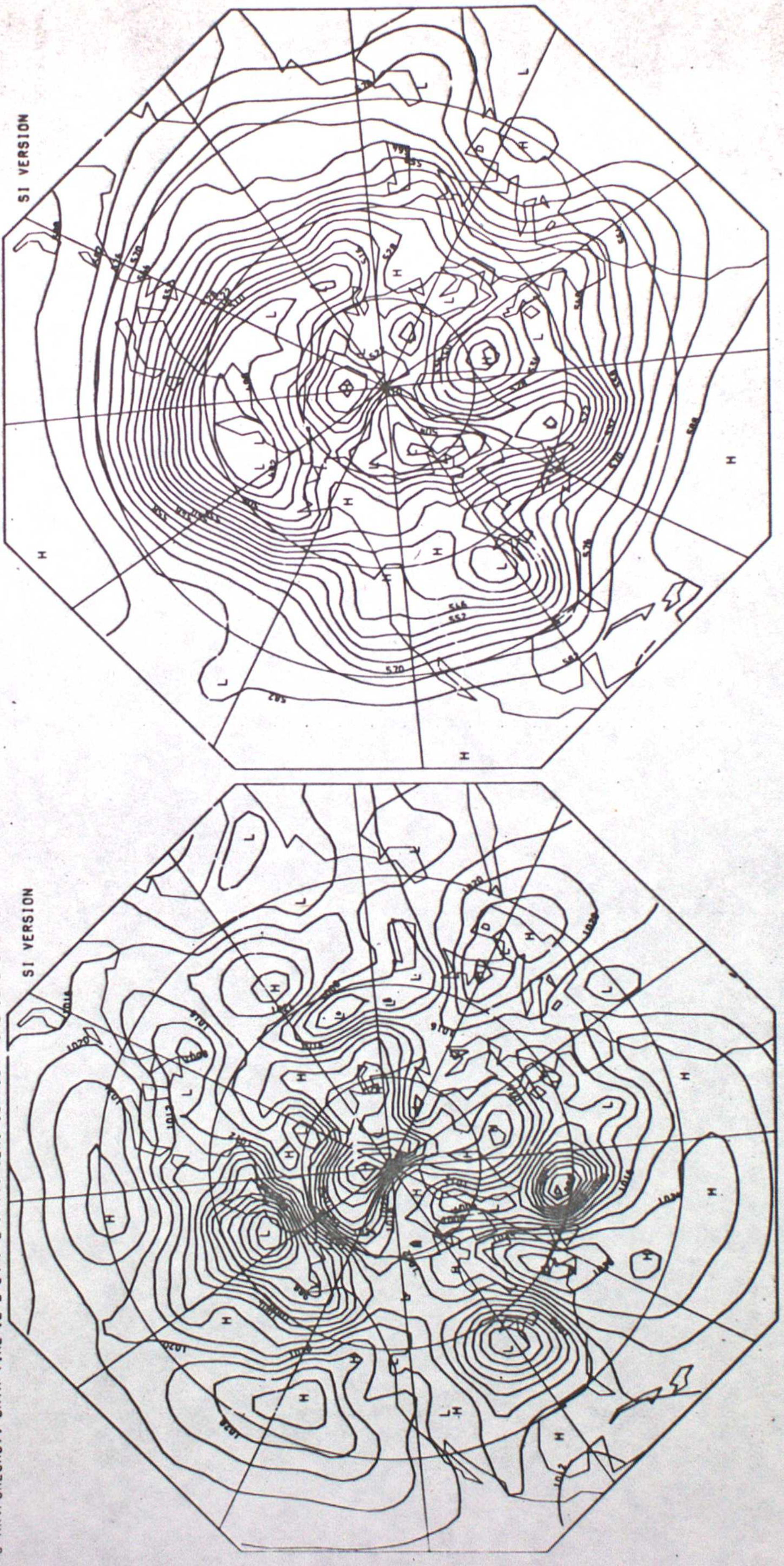
References

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 (1978a).

Cullen, M.J.P. "Six case studies from the forecast model intercomparison experiment, February 1977 to May 1978" Met O 11 Tech Note No. 113 (1978b)

Hoskins, B.J. and Simmons, A.J. "A multi-layer spectral model and the semi-implicit method" Q.J.R. Met.Soc. 101 pp 637-655 (1975)

FIG. 2.1



500 MB CONTOURS CONTOUR LINES AT 6 DECAMETER INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 24 / 2 / 77. VERIFICATION TIME 12 Z 24 / 2 / 77

SI VERSION

SURFACE PRESSURE ISOBARS AT 4MB INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 24 / 2 / 77. VERIFICATION TIME 12 Z 24 / 2 / 77

SI VERSION

FIG. 2.2

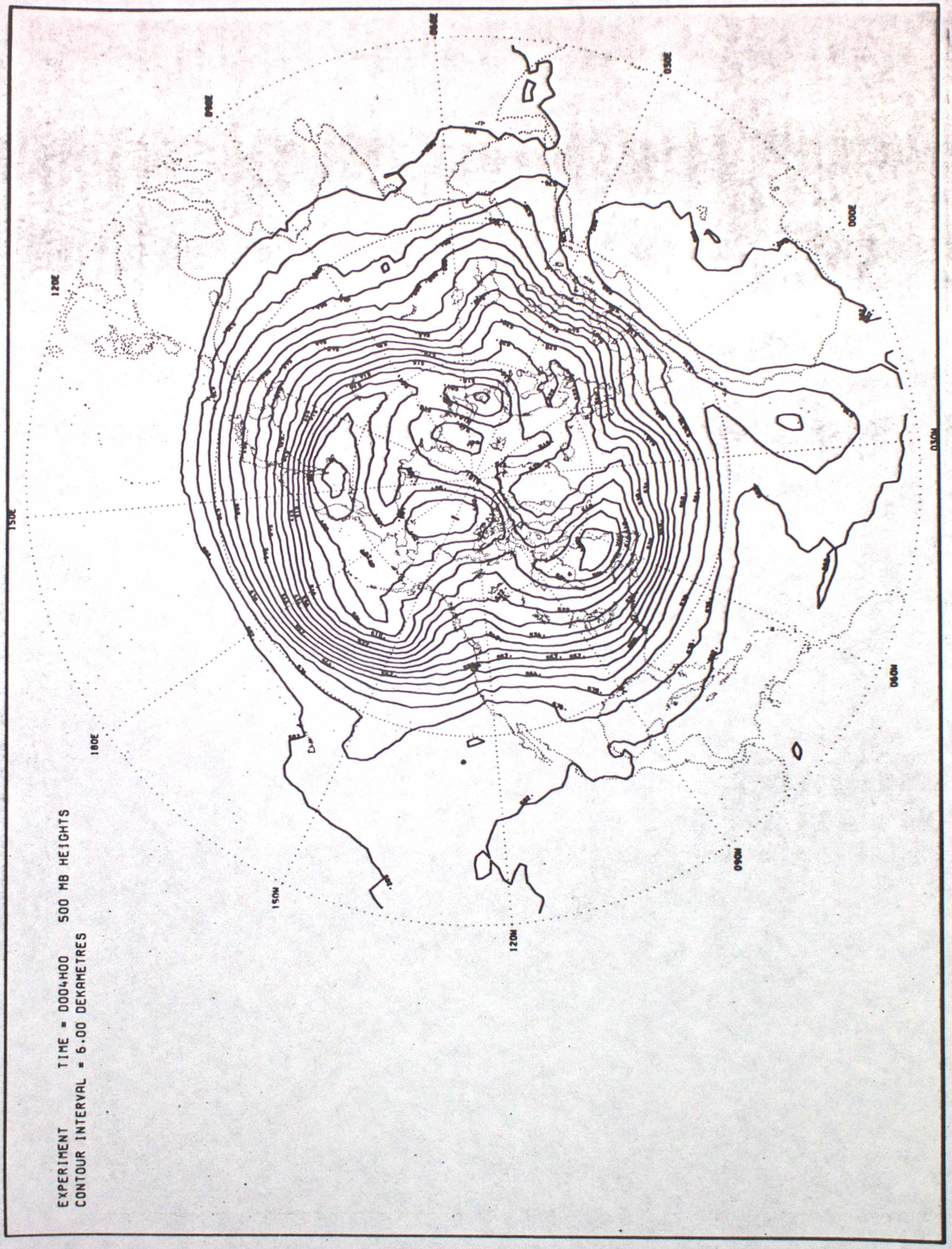
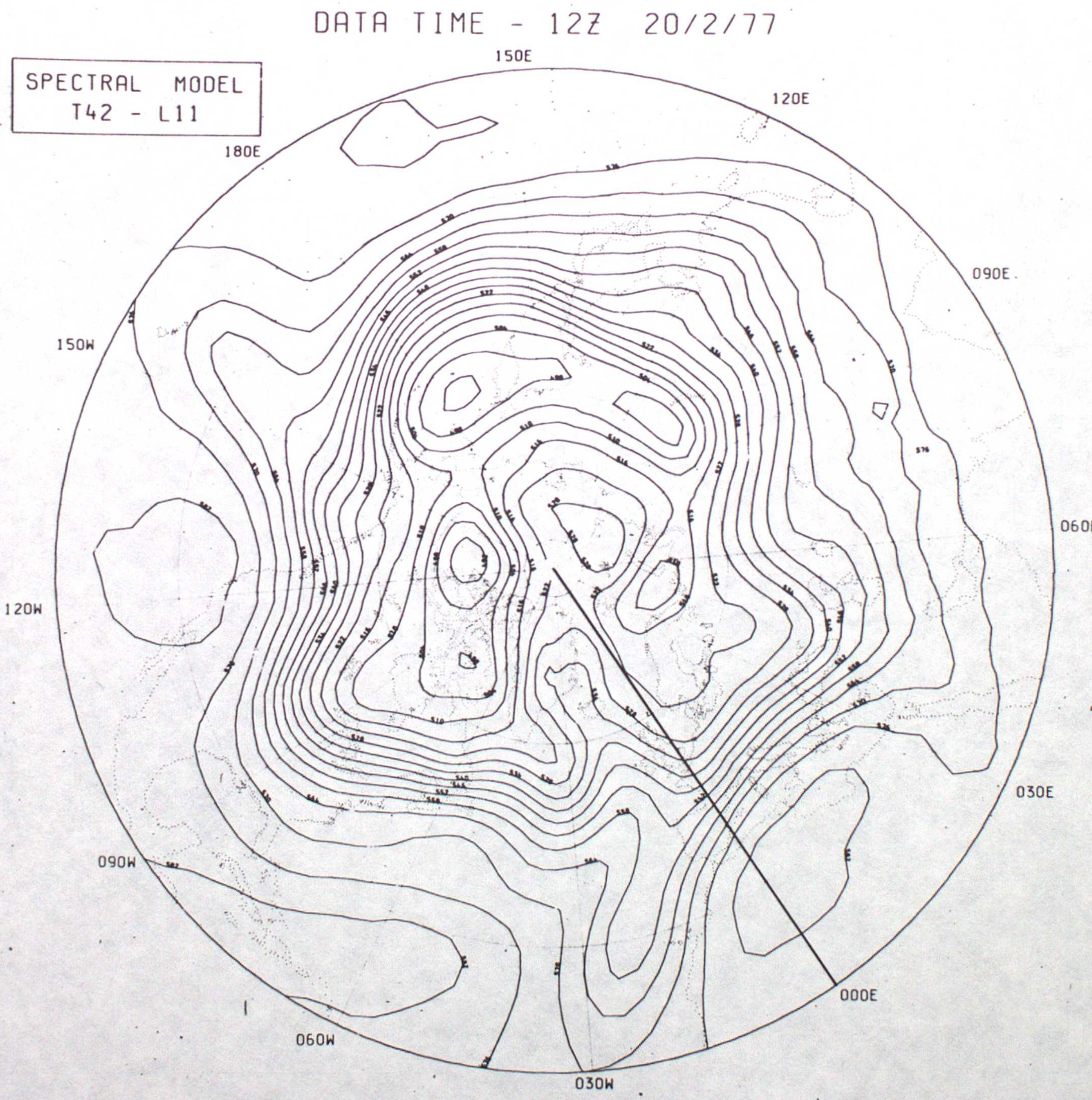

EXPERIMENT TIME = D004H00 500 MB HEIGHTS
CONTOUR INTERVAL = 6.00 DEKAMETRES
150E
120E
180E
150W
120W
090W
060W
030W
000E
030E
060E
090E

FIG. 2.3.

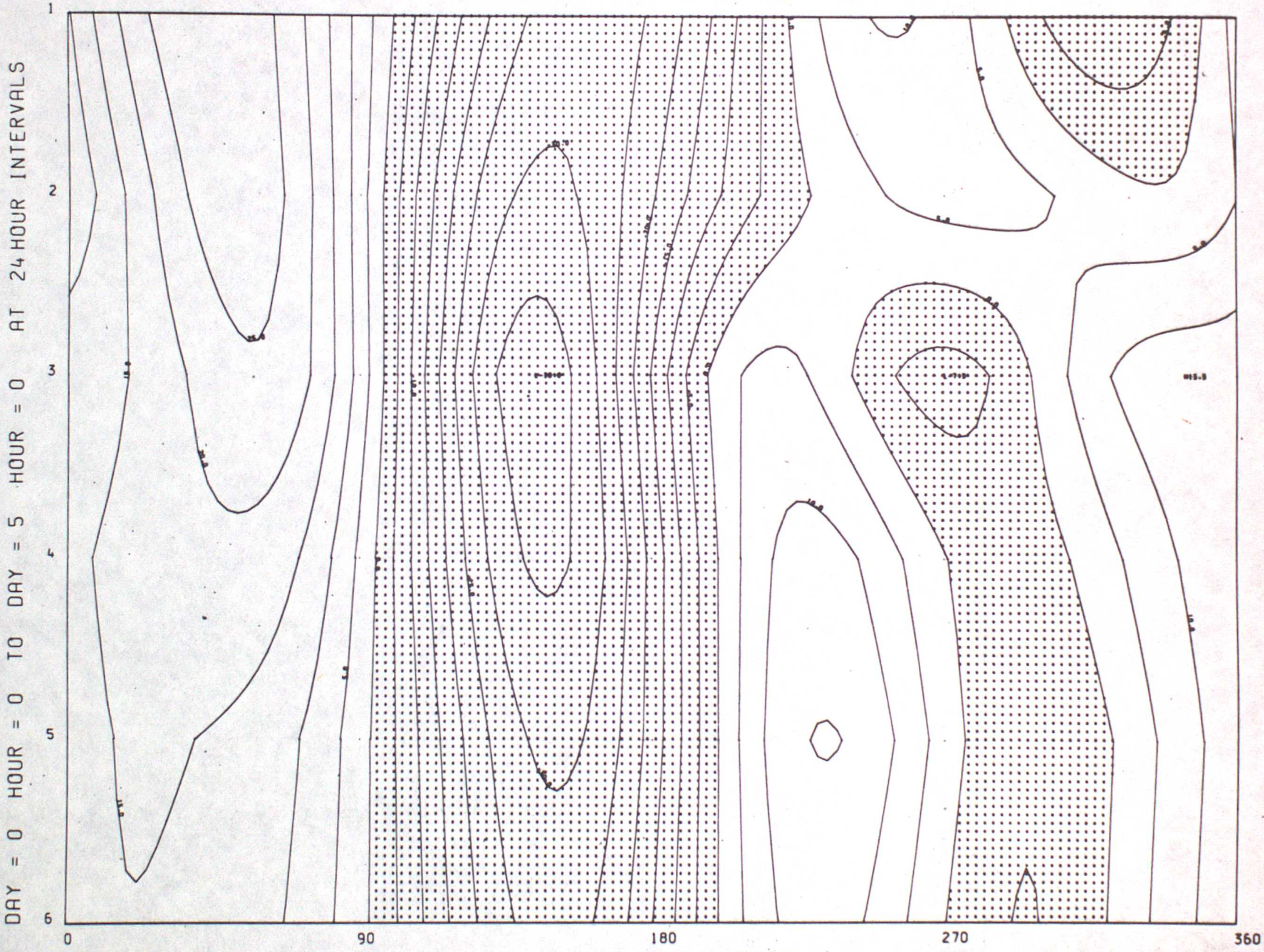


500MB CONTOURS AT DAY 4.00

6 DAY FCST.DAY 0= 12Z FEB 20TH

00000700

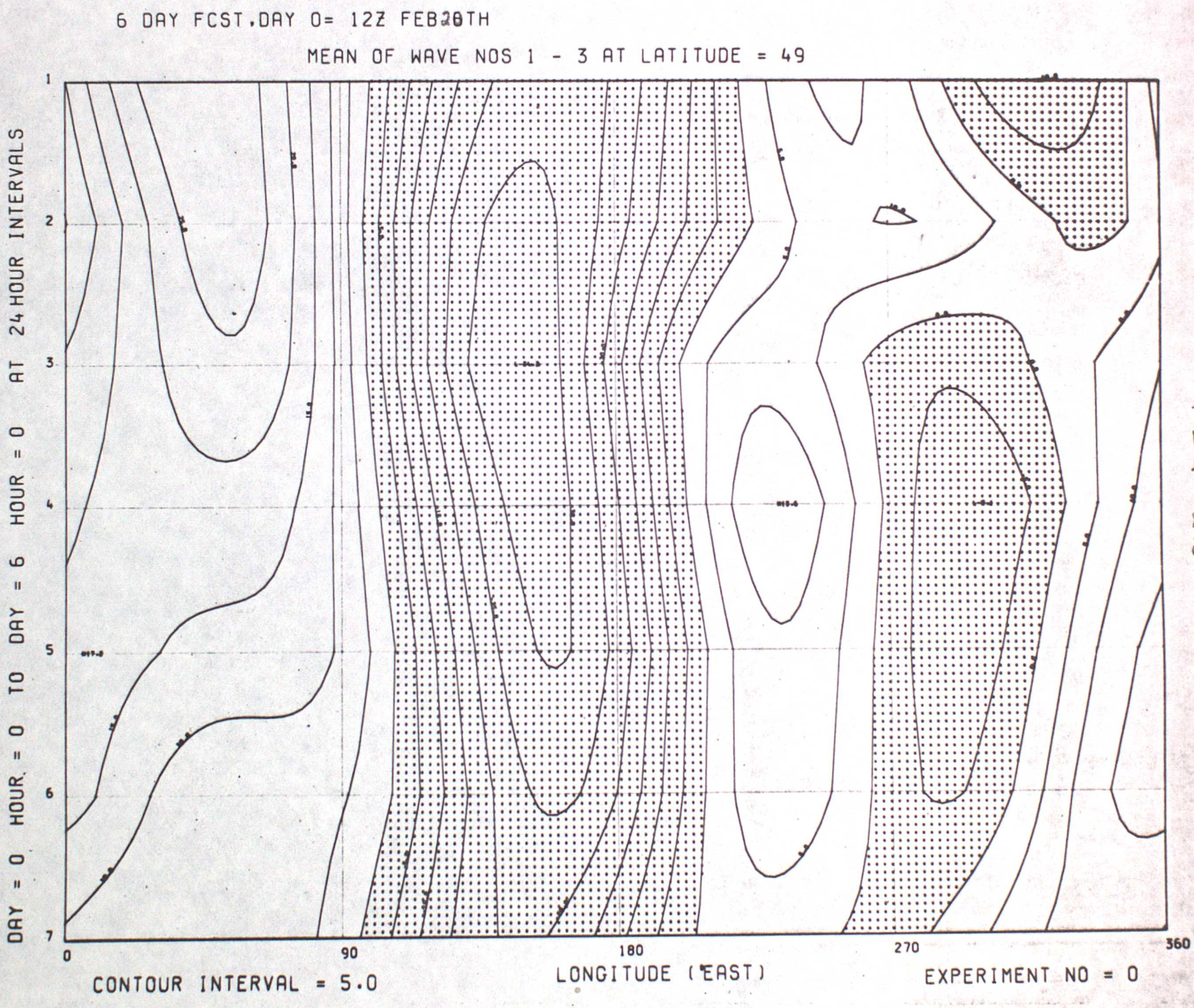
MEAN OF WAVE NOS 1 - 3 AT LATITUDE = 49



CONTOUR INTERVAL = 5.0

EXPERIMENT NO = 0

FIG. 2.4



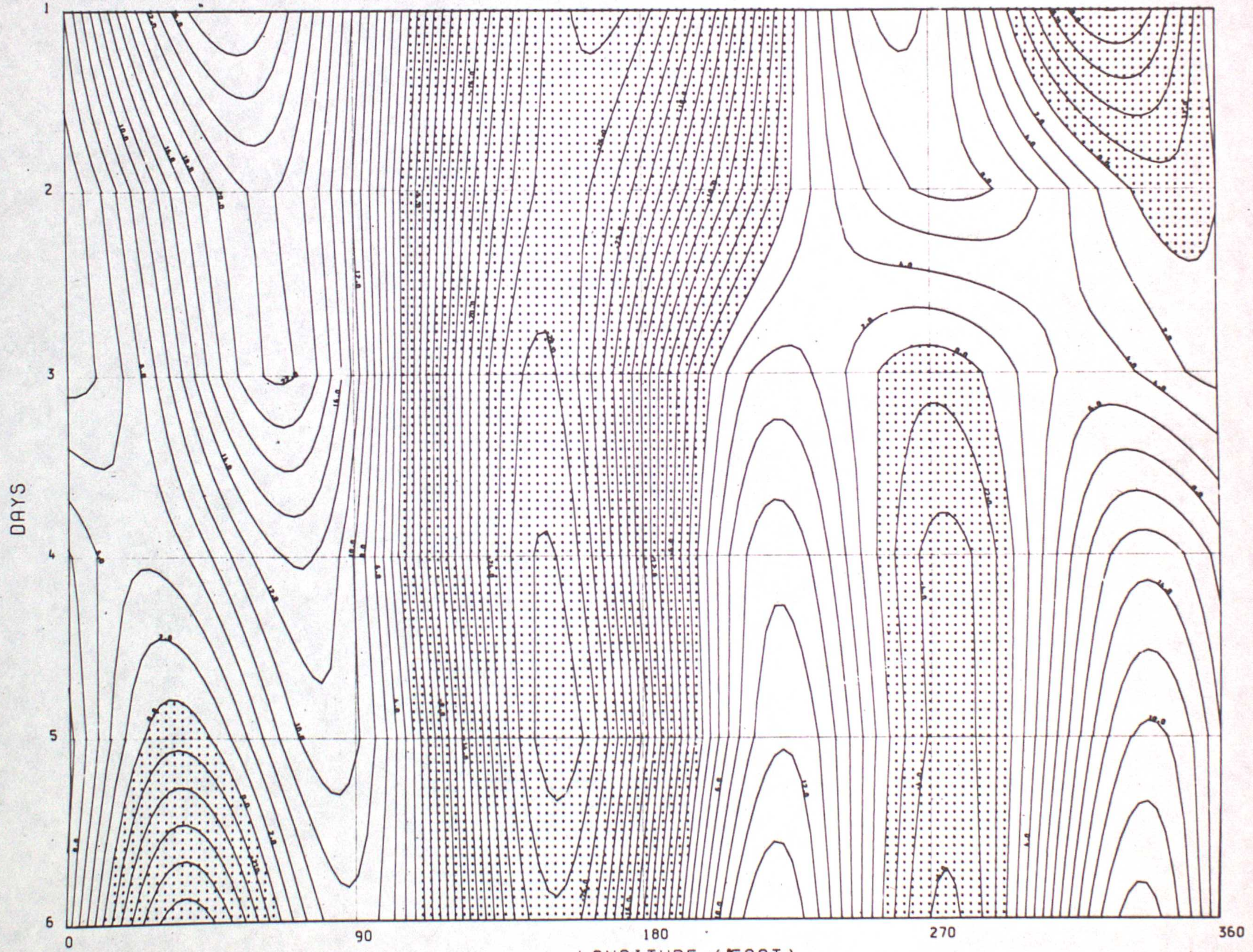
6 DAY FCST.DAY 0= 12Z FEB20TH
MEAN OF WAVE NOS 1 - 3 AT LATITUDE = 49
DAY = 0 HOUR = 0 TO DAY = 6 HOUR = 0 AT 24 HOUR INTERVALS
1
2
3
4
5
6
7
0
90
180
270
360
LONGITUDE (EAST)
CONTOUR INTERVAL = 5.0
EXPERIMENT NO = 0

FIG. 2.5

SPECTRAL MODEL

T42-L11   5 - DAY FORECAST FROM 12Z 20/2/77

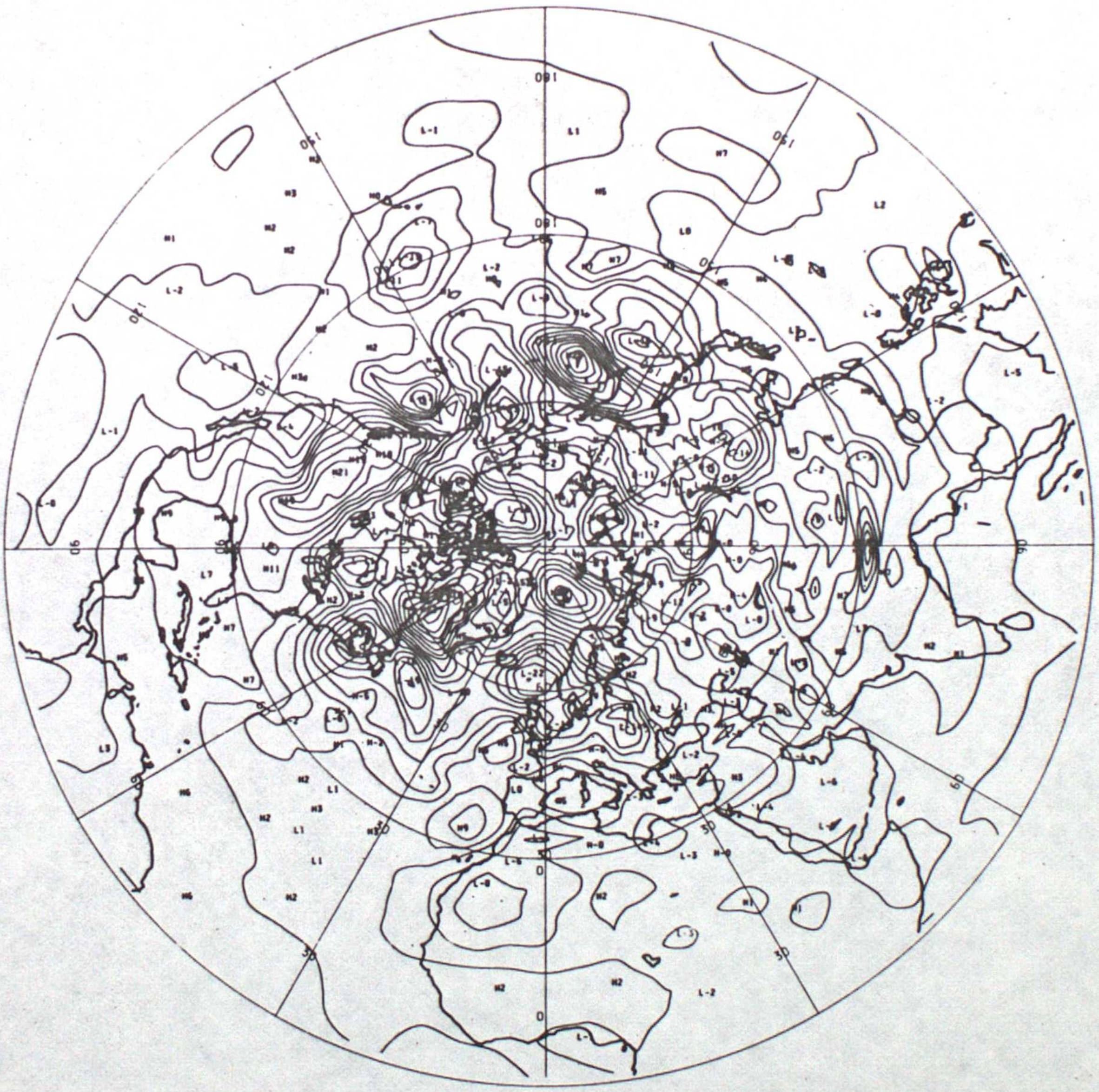
MEAN OF WAVE NOS 1 - 3 AT GAUSSIAN LATITUDE 15



CONTOUR INTERVAL = 2.0

FIG. 2.6

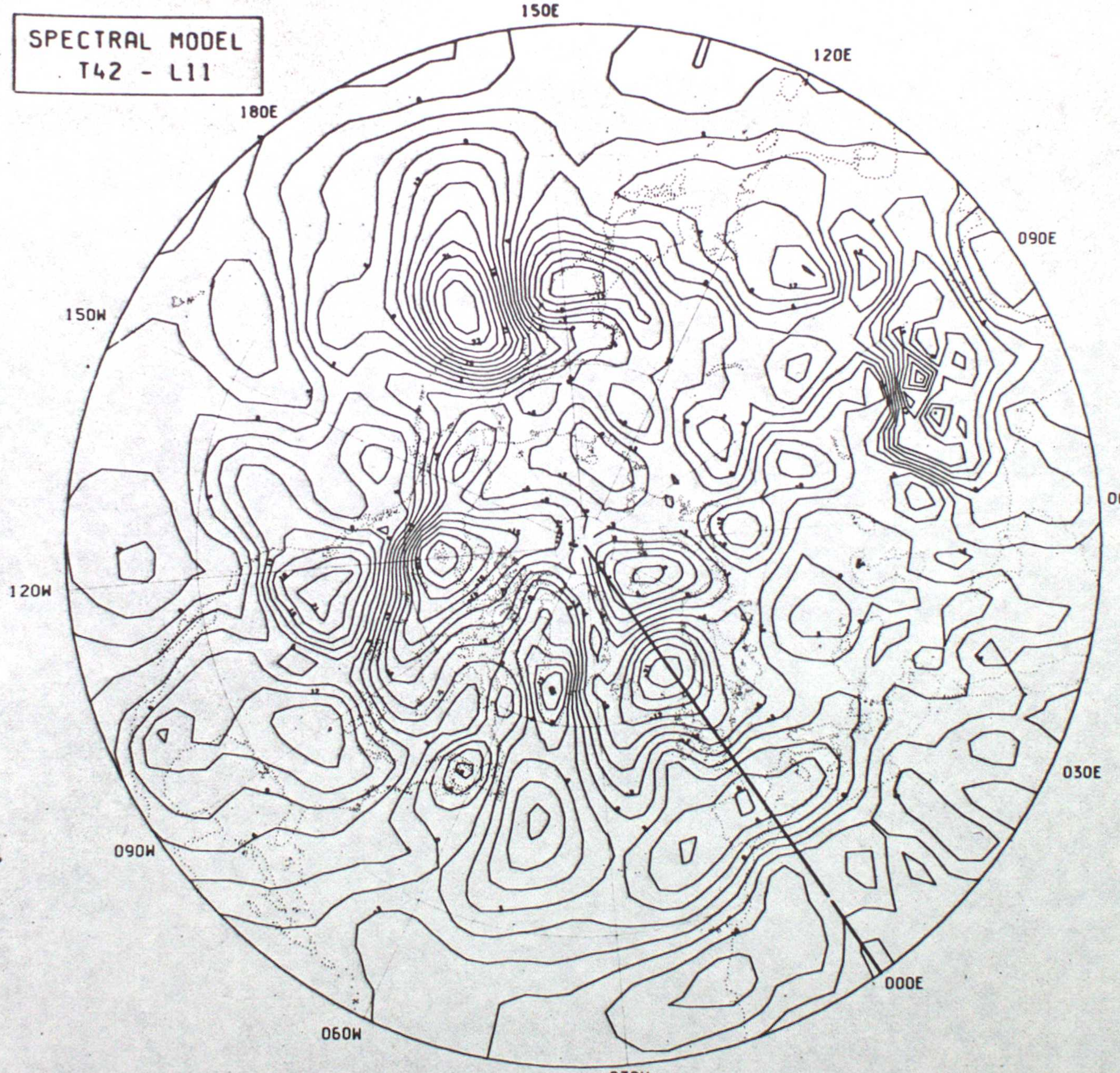
FIG. 2.7



DIFFERENCE IN PRESSURE LEVEL =999.0 FOR EXH 0 - EXH 0 D 2H 0
CONTOUR INTERVAL = 3.00

FIG. 2.8

DATA TIME - 12Z 22/2/77



1000MB HEIGHT DIFFERENCES (F/C - ACTUAL) DAY 2

FIG. 3.1

500 MB CONTOURS CONTOUR LINES AT 6 DECAMETER INTERVALS

O HR.FORECAST. DATA TIME 12 Z 11 / 5 / 77. VERIFICATION TIME 12 Z 11 / 5 / 77

SE VERSION

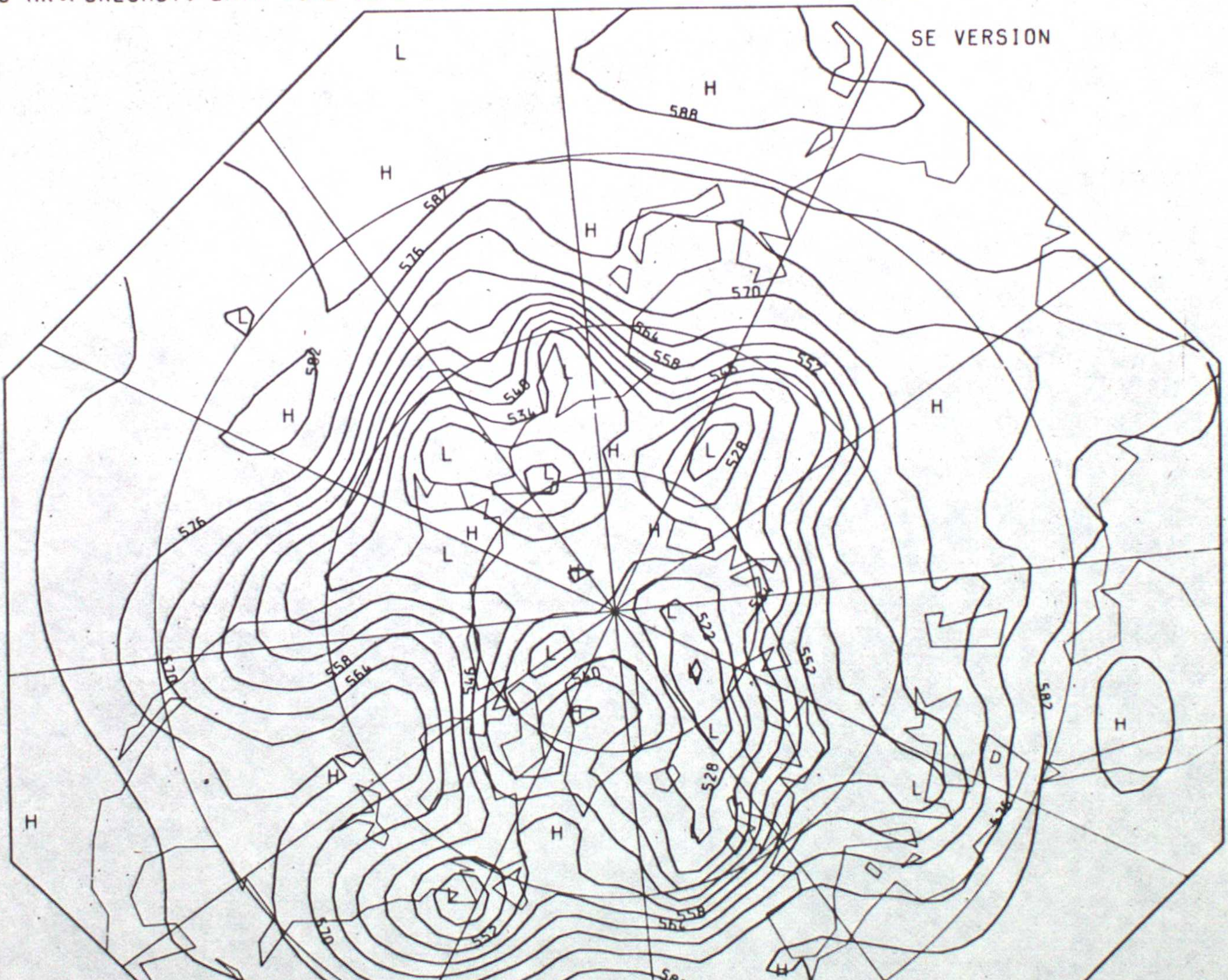


FIG. 3.2

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

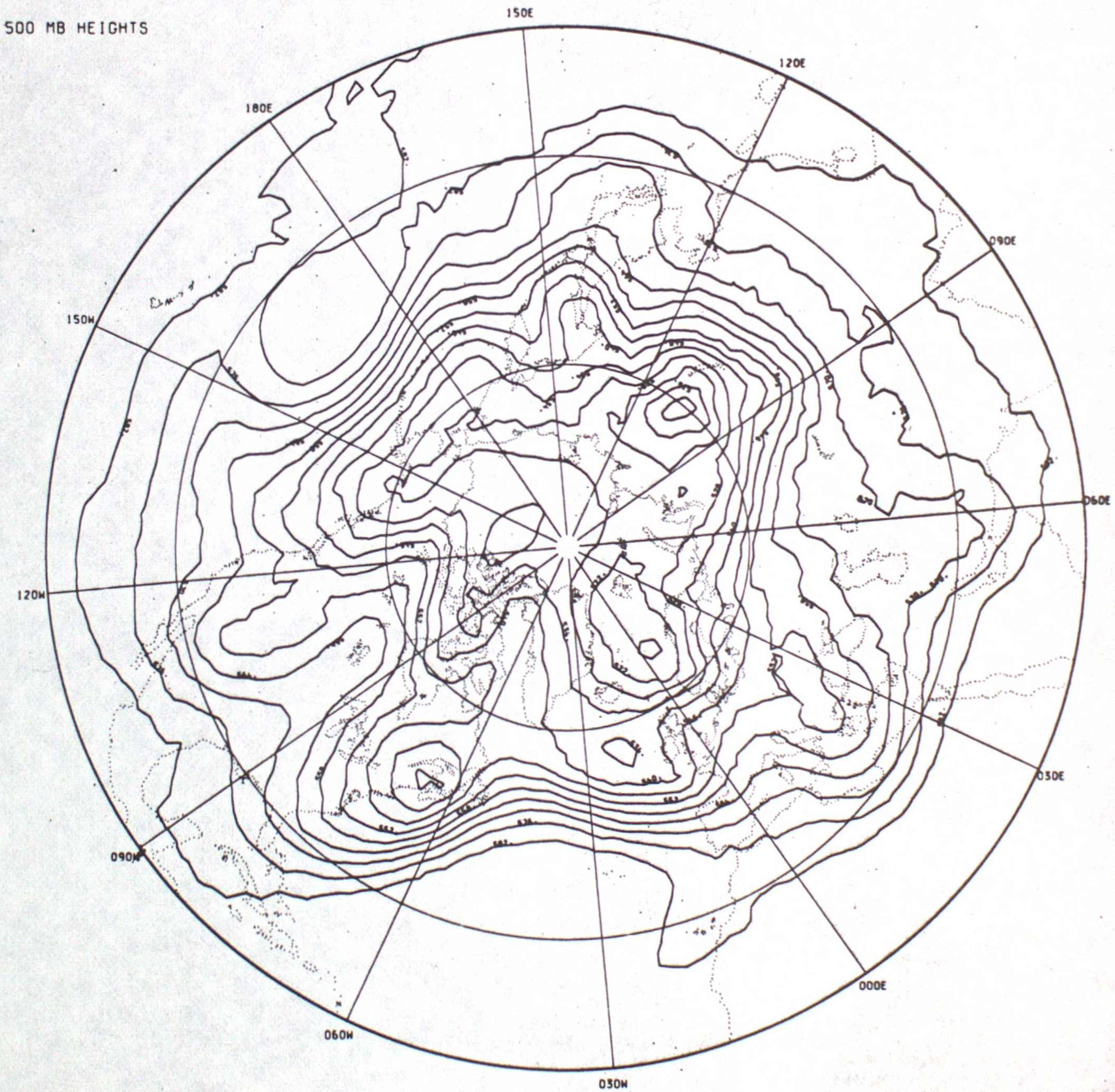
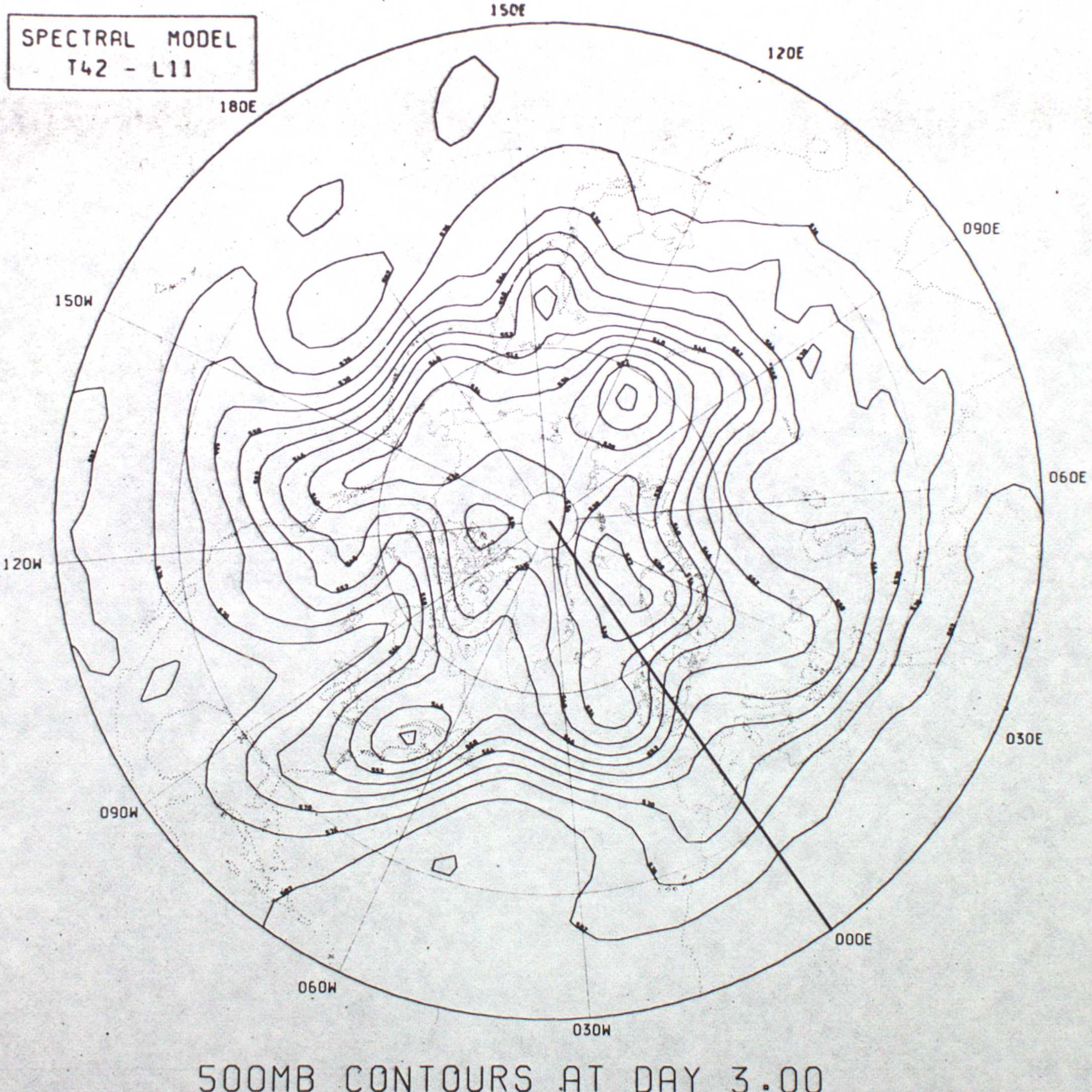


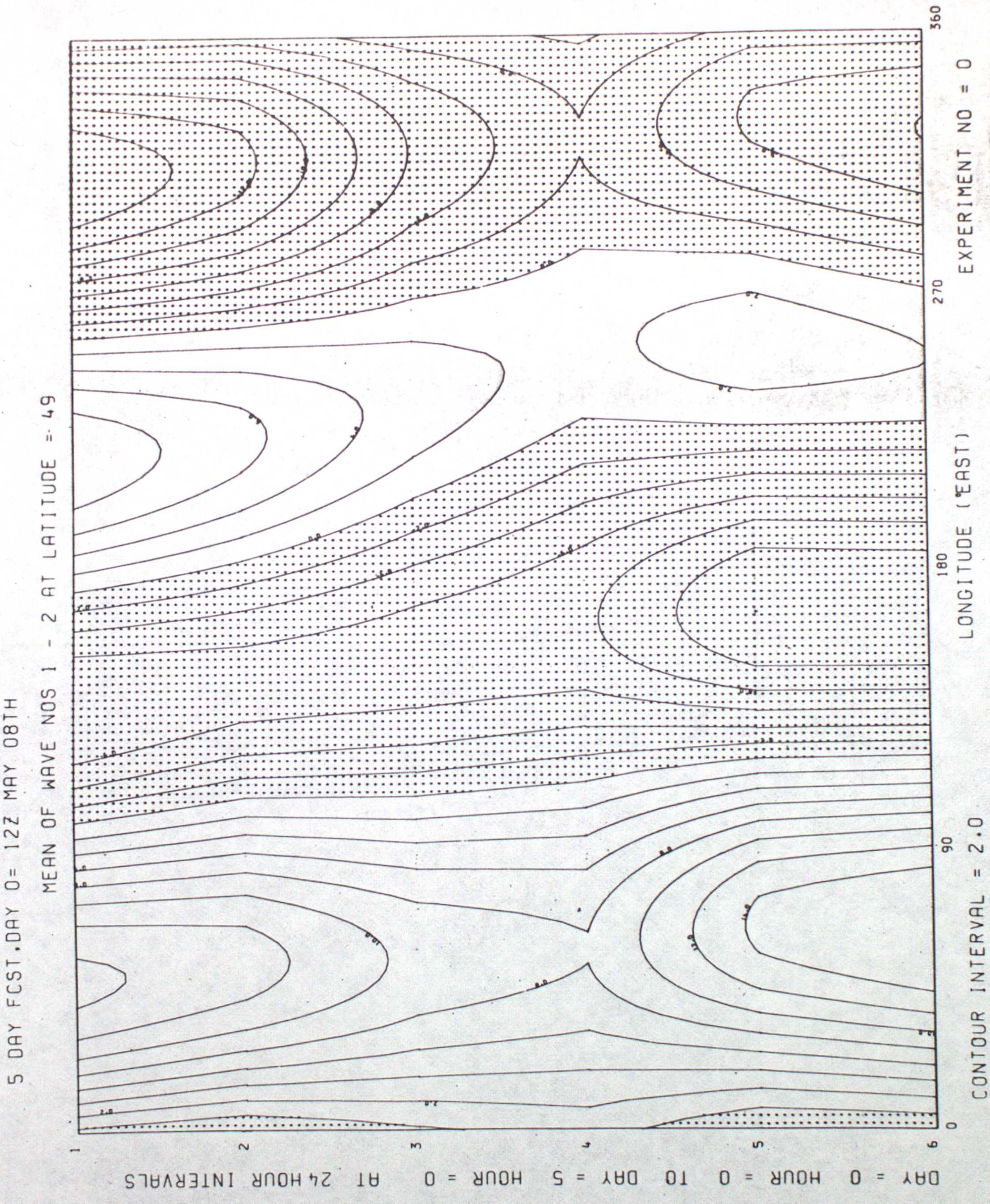
FIG. 3.3

DATA TIME - 12Z 8/5/77



500MB CONTOURS AT DAY 3.00

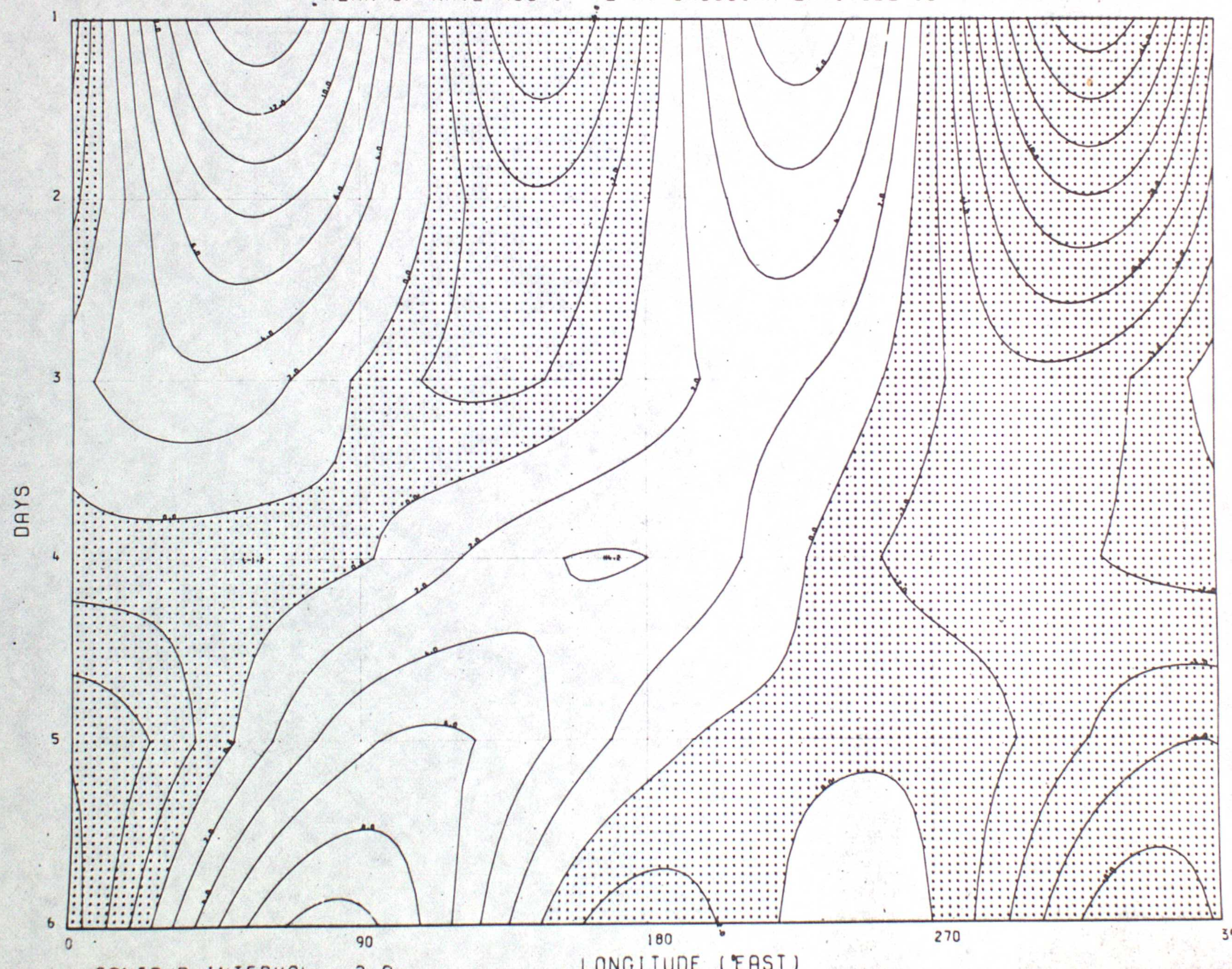
FIG. 3.4


5 DAY FCST.DAY 0= 12Z MAY 08TH
MEAN OF WAVE NOS 1 - 2 AT LATITUDE = 49
CONTOUR INTERVAL = 2.0
LONGITUDE (°EAST)
EXPERIMENT NO = 0
0
90
180
270
360
1
2
3
4
5
6
DAY = 0 HOUR = 0 TO DAY = 5 HOUR = 0 AT 24HOUR INTERVALS

SPECTRAL MODEL

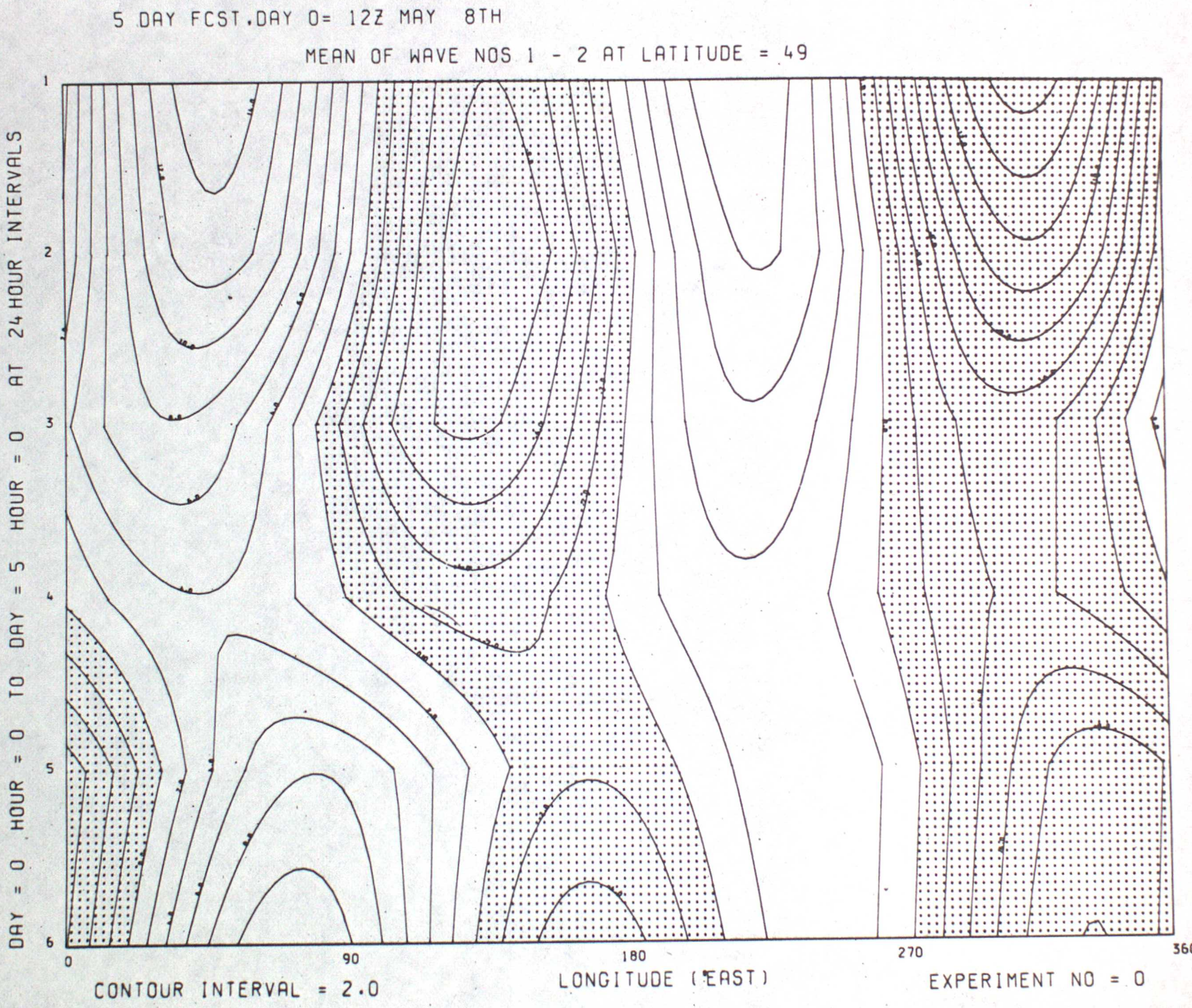
T42-L11 5 - DAY FORECAST FROM 12Z 8/5/77

MEAN OF WAVE NOS 1 - 2 AT GAUSSIAN LATITUDE 15



CONTOUR INTERVAL = 2.0

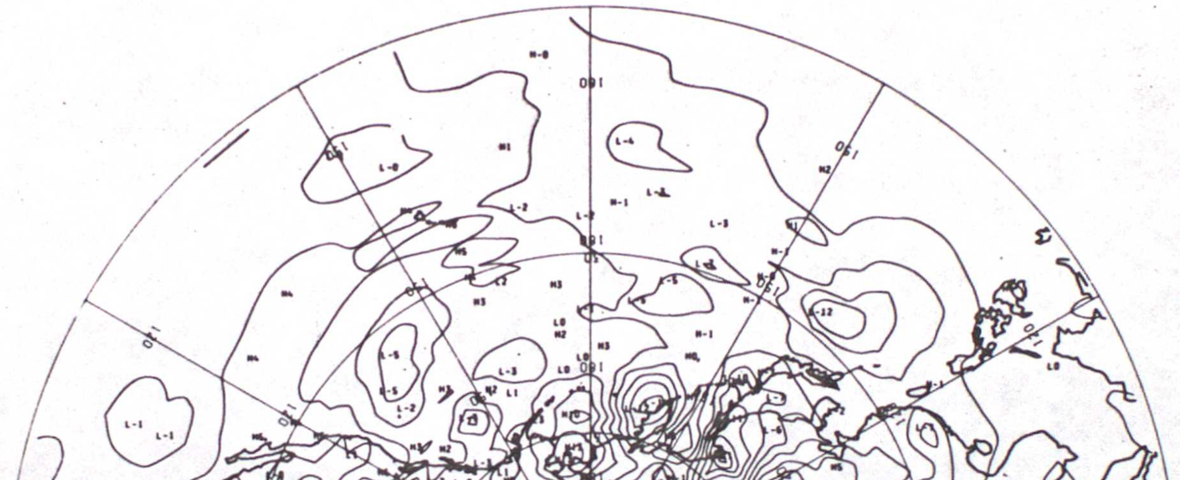
FIG. 3.6



5 DAY FCST.DAY 0= 12Z MAY 8TH
MEAN OF WAVE NOS 1 - 2 AT LATITUDE = 49
DAY = 0 HOUR = 0 TO DAY = 5 HOUR = 0 AT 24 HOUR INTERVALS
1
2
3
4
5
6
0
90
180
270
360
CONTOUR INTERVAL = 2.0
LONGITUDE (EAST)
EXPERIMENT NO = 0

FIG. 3.5

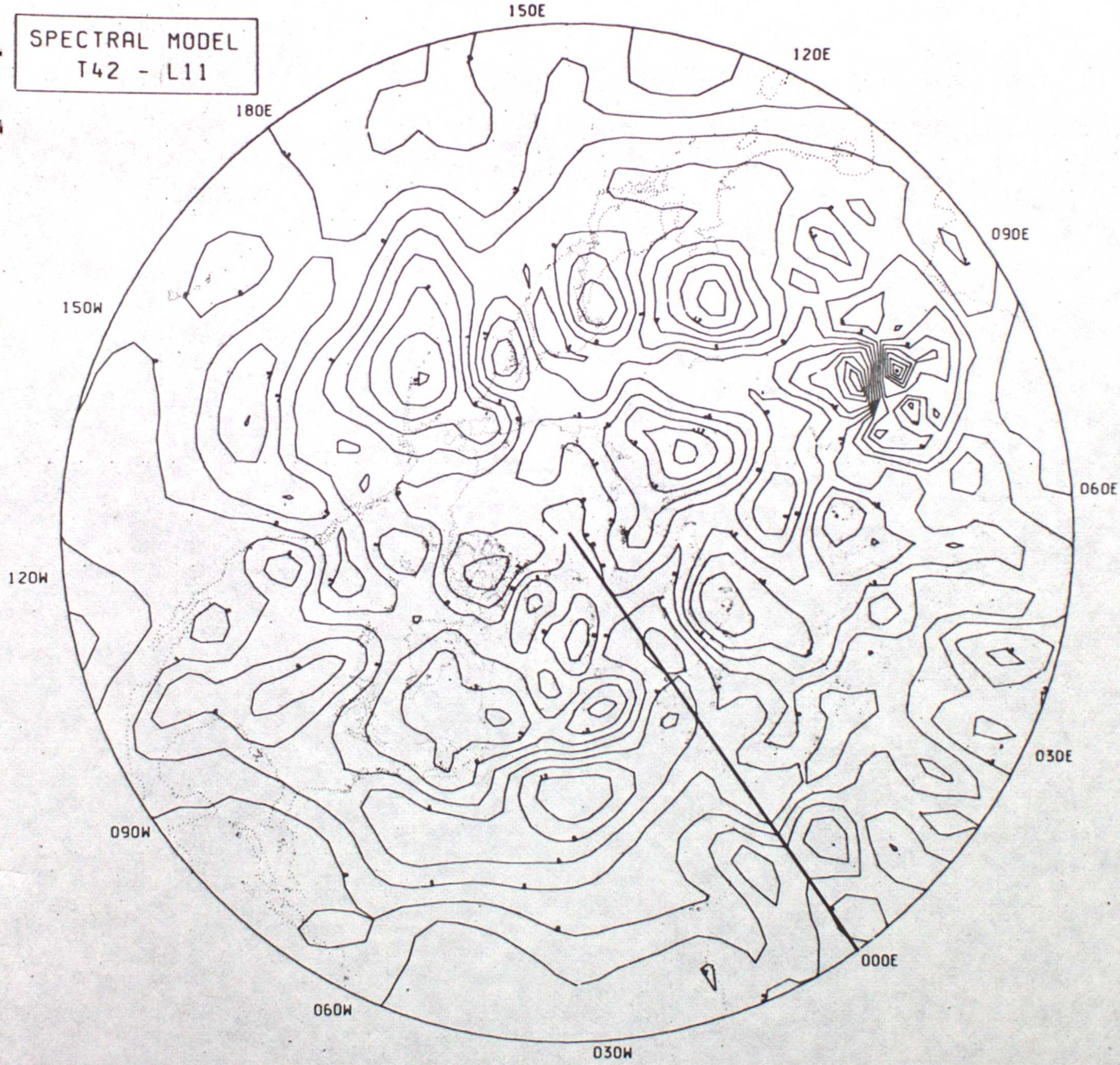
FIG. 3.7



DIFFERENCE IN PRESSURE LEVEL =999.0 FOR EXH 0 - EXH 0 D 2H 0
CONTOUR INTERVAL = 3.00

FIG. 3.8

DATA TIME - 12Z 10/5/77



1000MB HEIGHT DIFFERENCES (F/C - ACTUAL) DAY 2

FIG. 4.1

500 MB CONTOURS   CONTOUR LINES AT 6 DECAMETER INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 18 / 8 / 77. VERIFICATION TIME 12 Z 18 / 8 / 77

SE VERSION

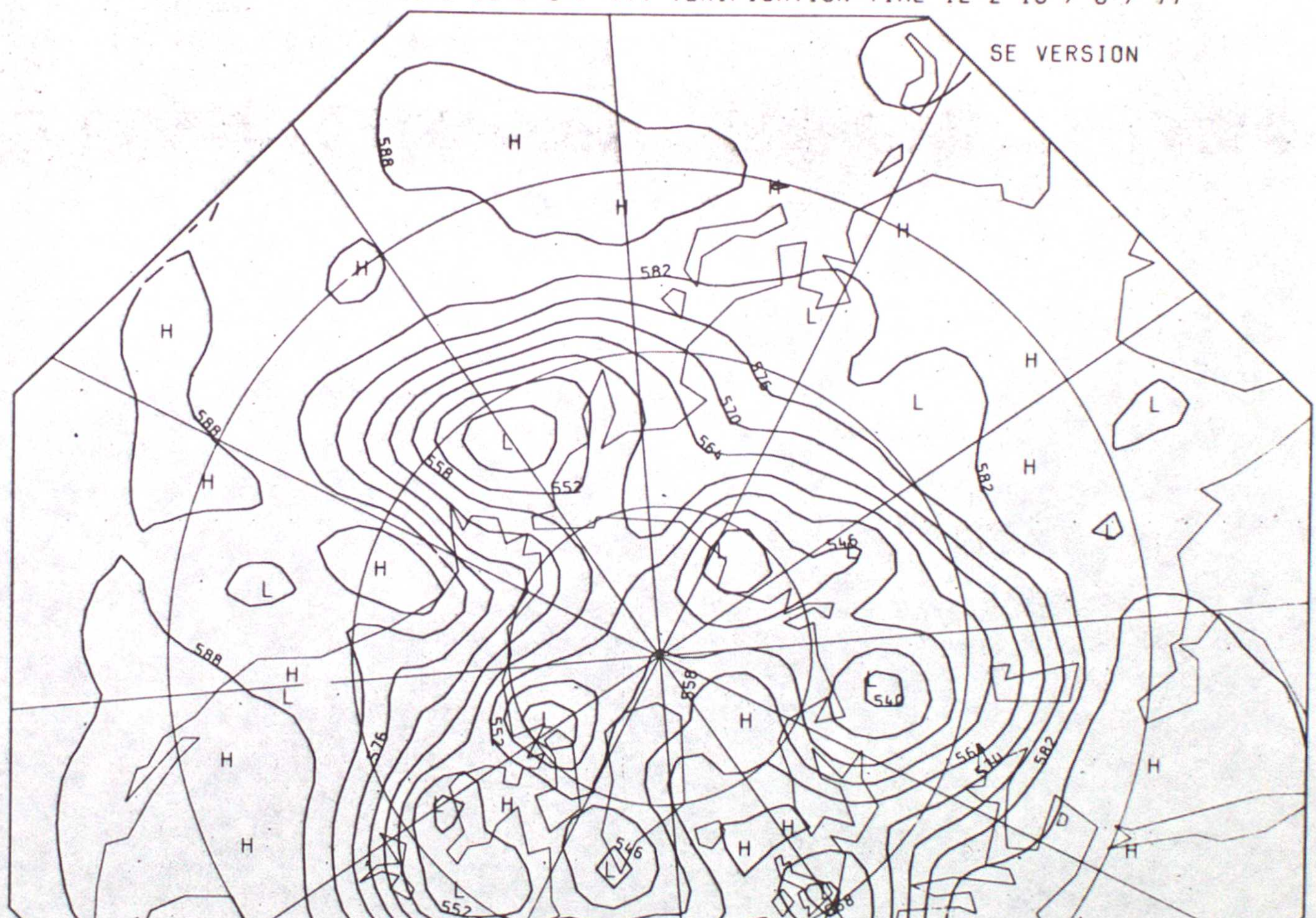


FIG. 4.2

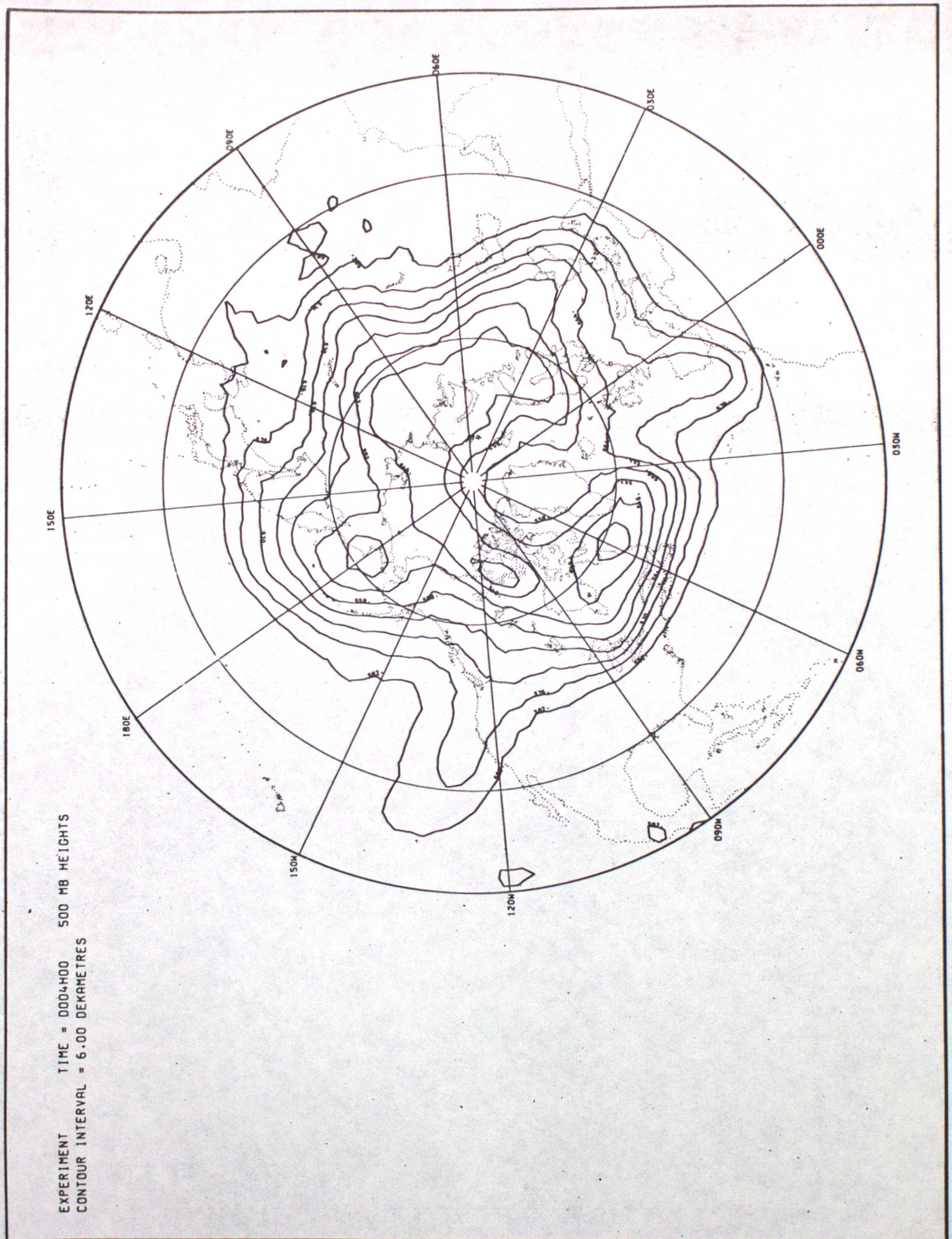
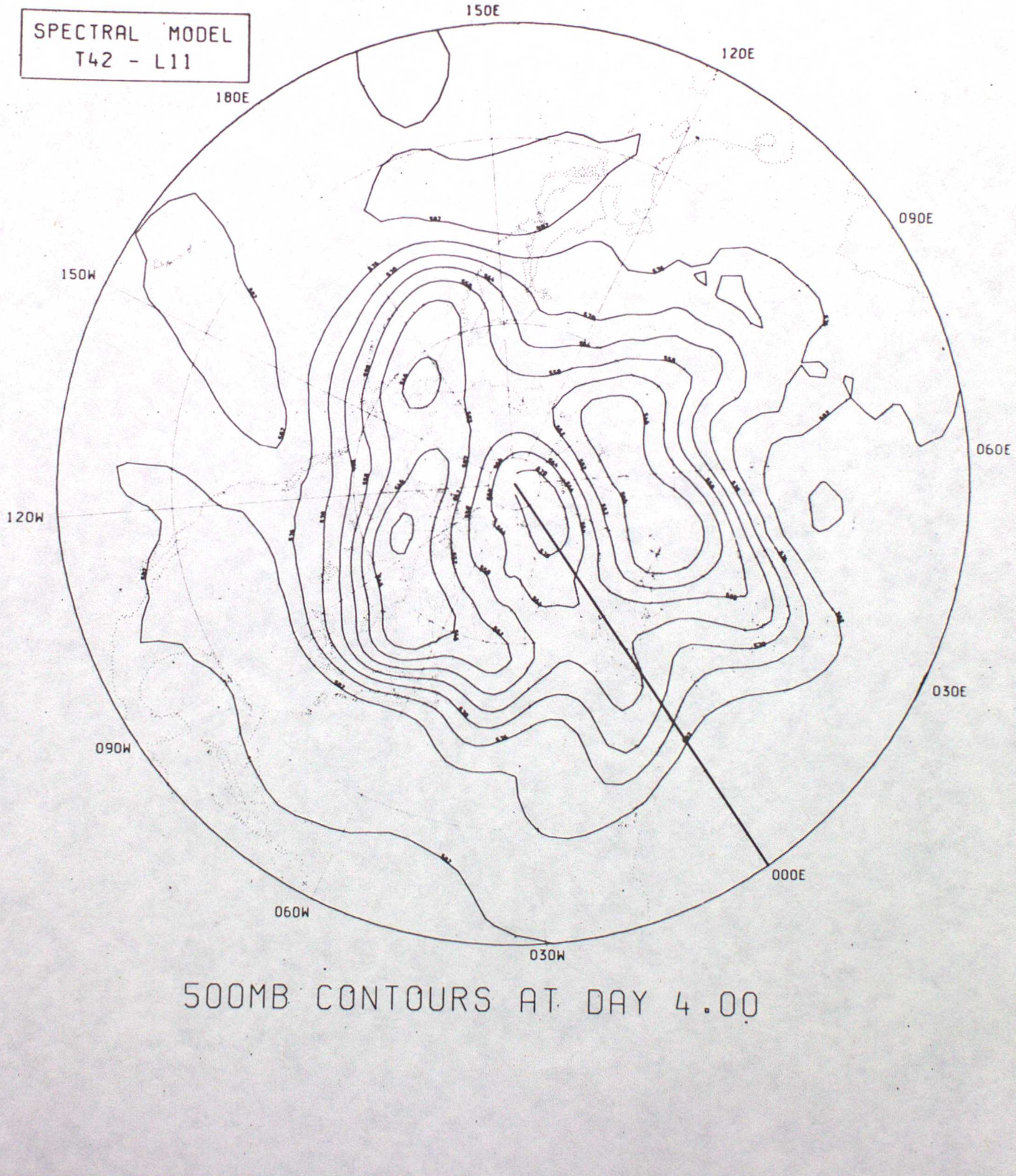

EXPERIMENT TIME = D004H00 500 MB HEIGHTS
CONTOUR INTERVAL = 6.00 DEKAMETRES
060E
030E
000E
030W
060W
090W
120W
150W
180E
150E
120E
090E

FIG. 4.3

DATA TIME - 12Z 14/8/77

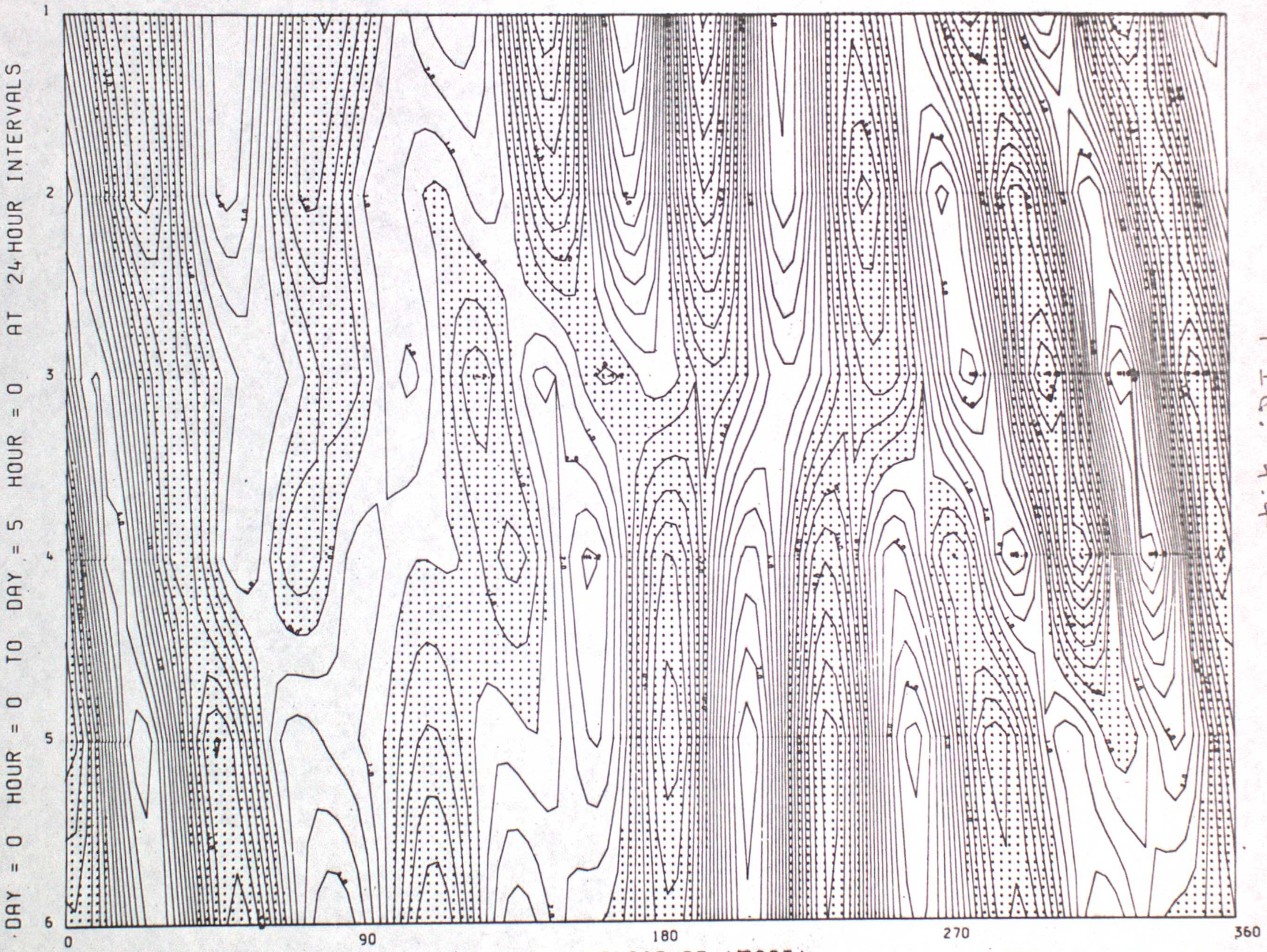
SPECTRAL MODEL
T42 - L11



500MB CONTOURS AT DAY 4.00

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

MEAN OF WAVE NOS 6 - 10 AT LATITUDE = 49



CONTOUR INTERVAL = 1.0

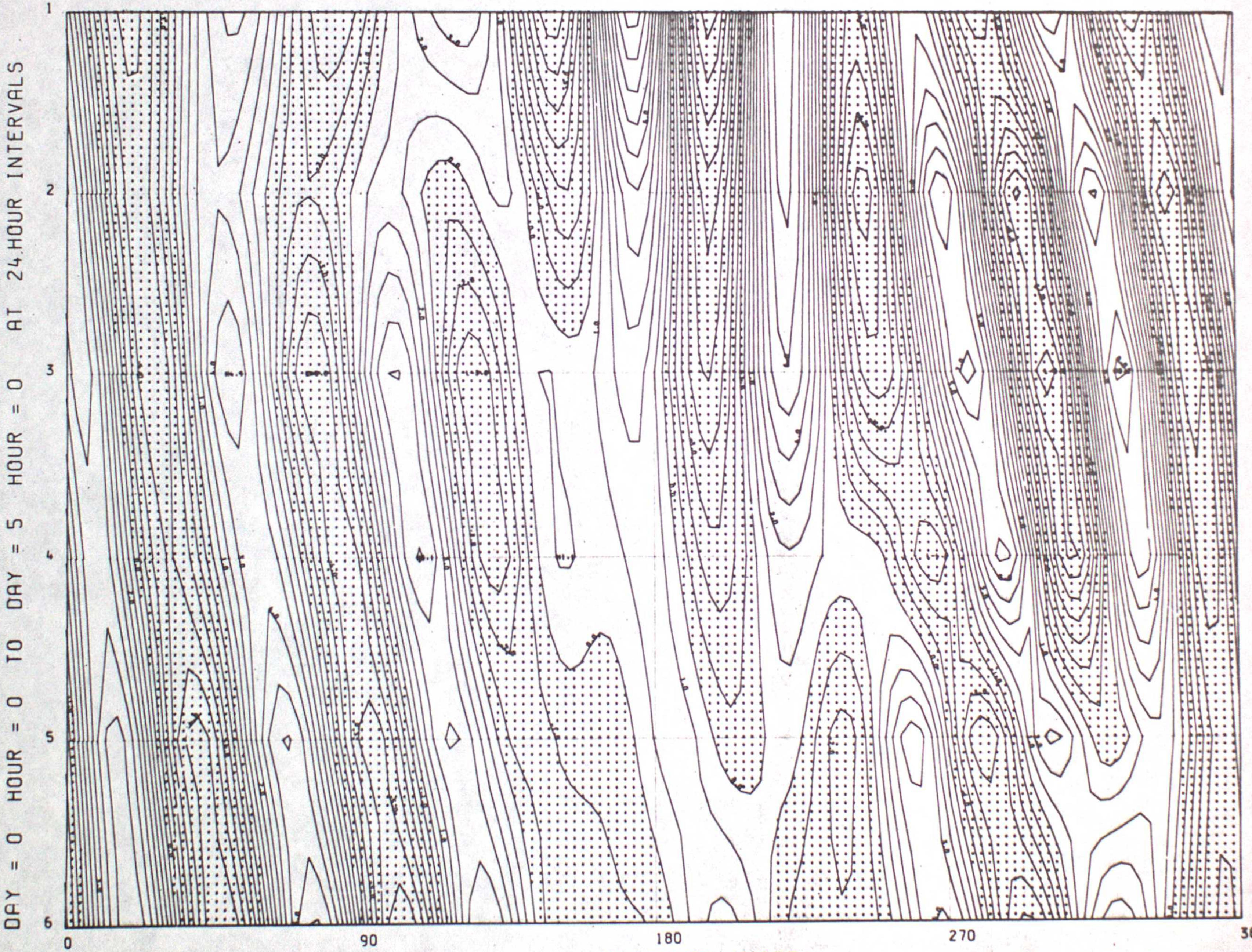
EXPERIMENT NO = 0

FIG. 4.4

FIG. 4.5

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

MEAN OF WAVE NOS 6 - 10 AT LATITUDE = 49



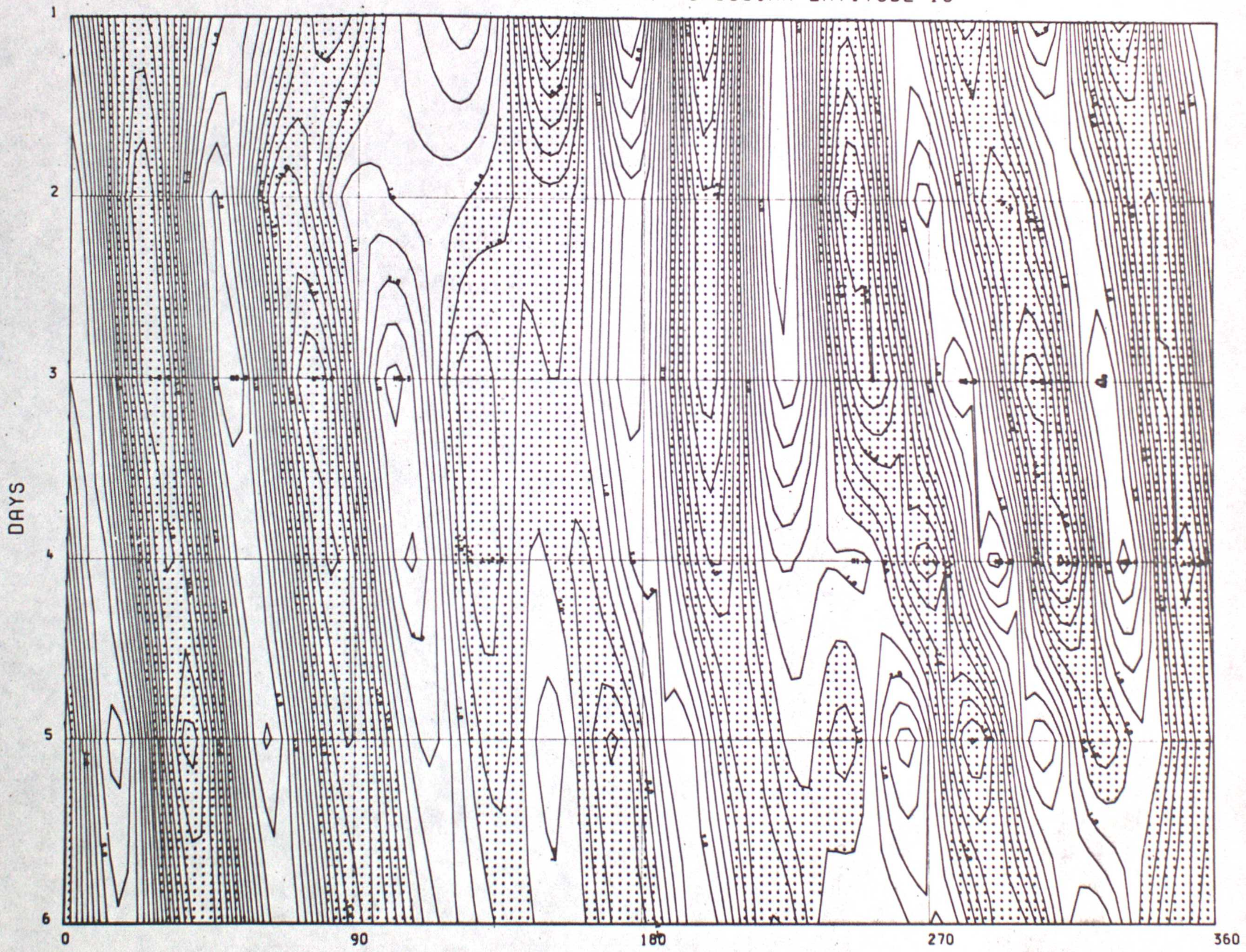
CONTOUR INTERVAL = 1.0

EXPERIMENT NO = 0

SPECTRAL. MODEL

T42-L11 5 - DAY FORECAST FROM 12Z 14/8/77

MEAN OF WAVE NOS 6 - 10 AT GAUSSIAN LATITUDE 15



CONTOUR INTERVAL = 1.0

FIG. 4.6

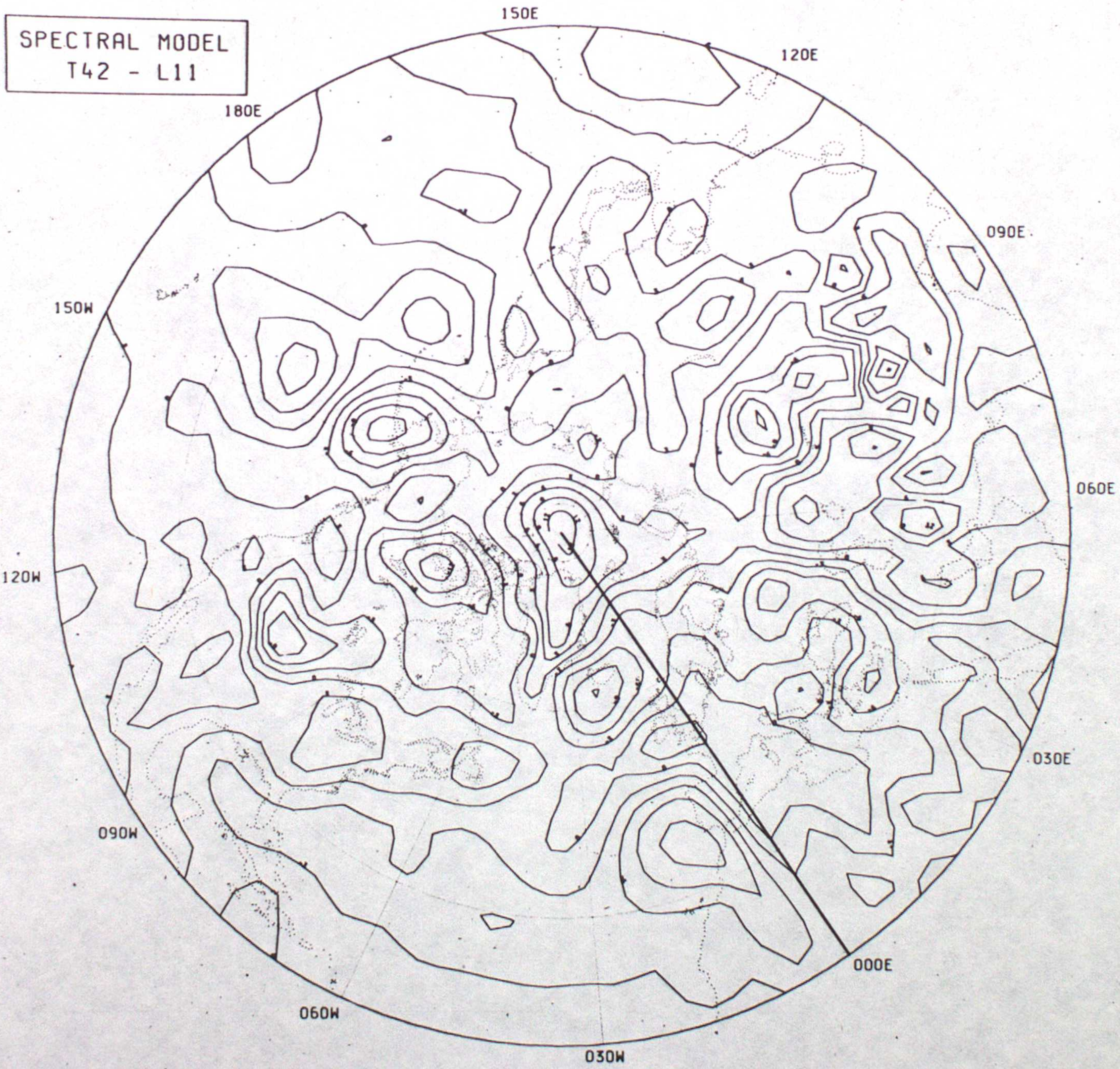
FIG. 4.7

DIFFERENCE IN PRESSURE LEVEL =999.0 FOR EXH 0 - EXH 0 D 2H 0
CONTOUR INTERVAL = 6.00

FIG. 4.8

DATA TIME - 12Z 16/8/77

SPECTRAL MODEL
T42 - L11



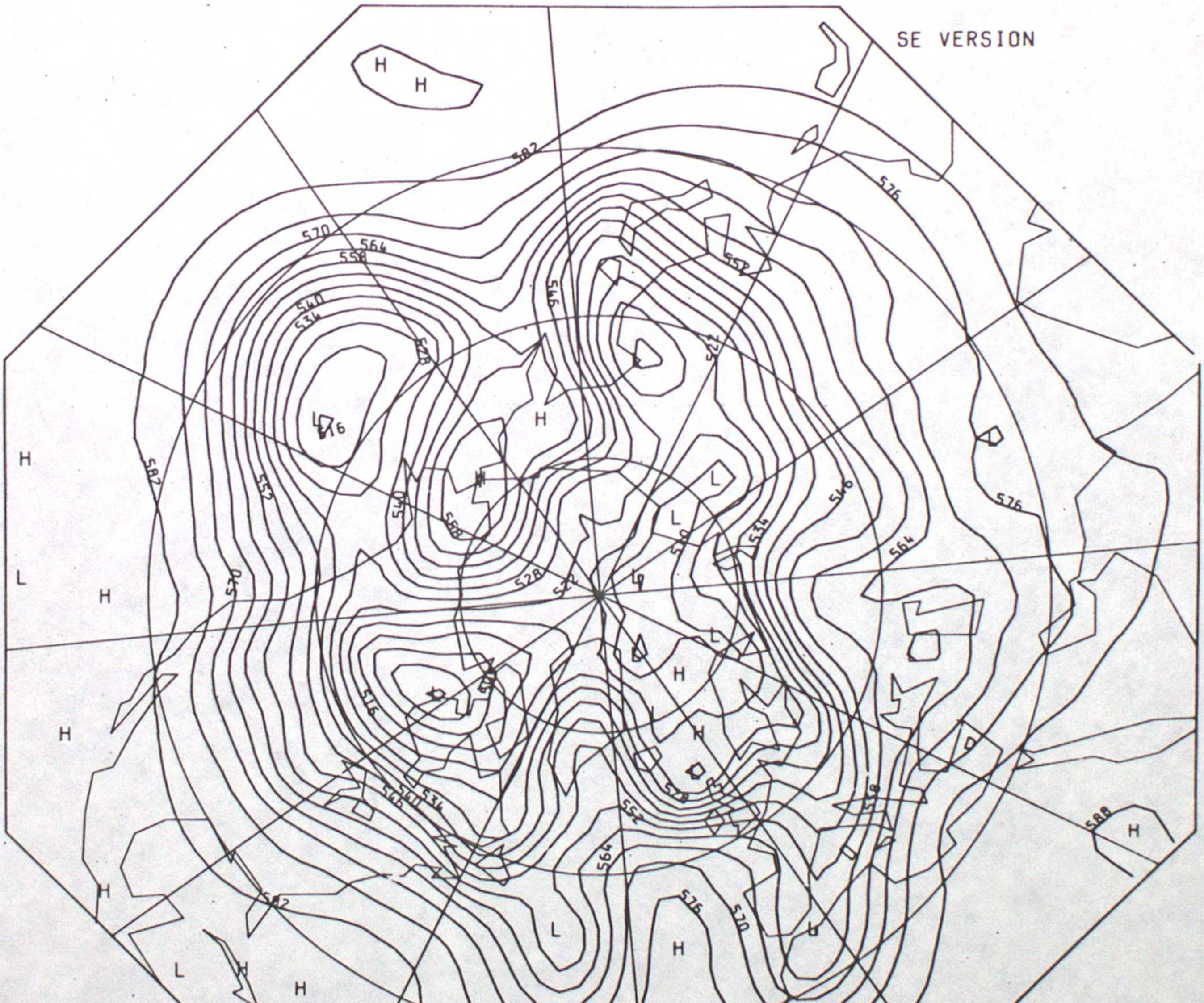
1000MB HEIGHT DIFFERENCES (F/C - ACTUAL) DAY 2

FIG. 5.1

500 MB CONTOURS   CONTOUR LINES AT 6 DECAMETER INTERVALS

O HR.FORECAST. DATA TIME 12 Z 23 / 11 / 77. VERIFICATION TIME 12 Z 23 / 11 / 77

SE VERSION



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

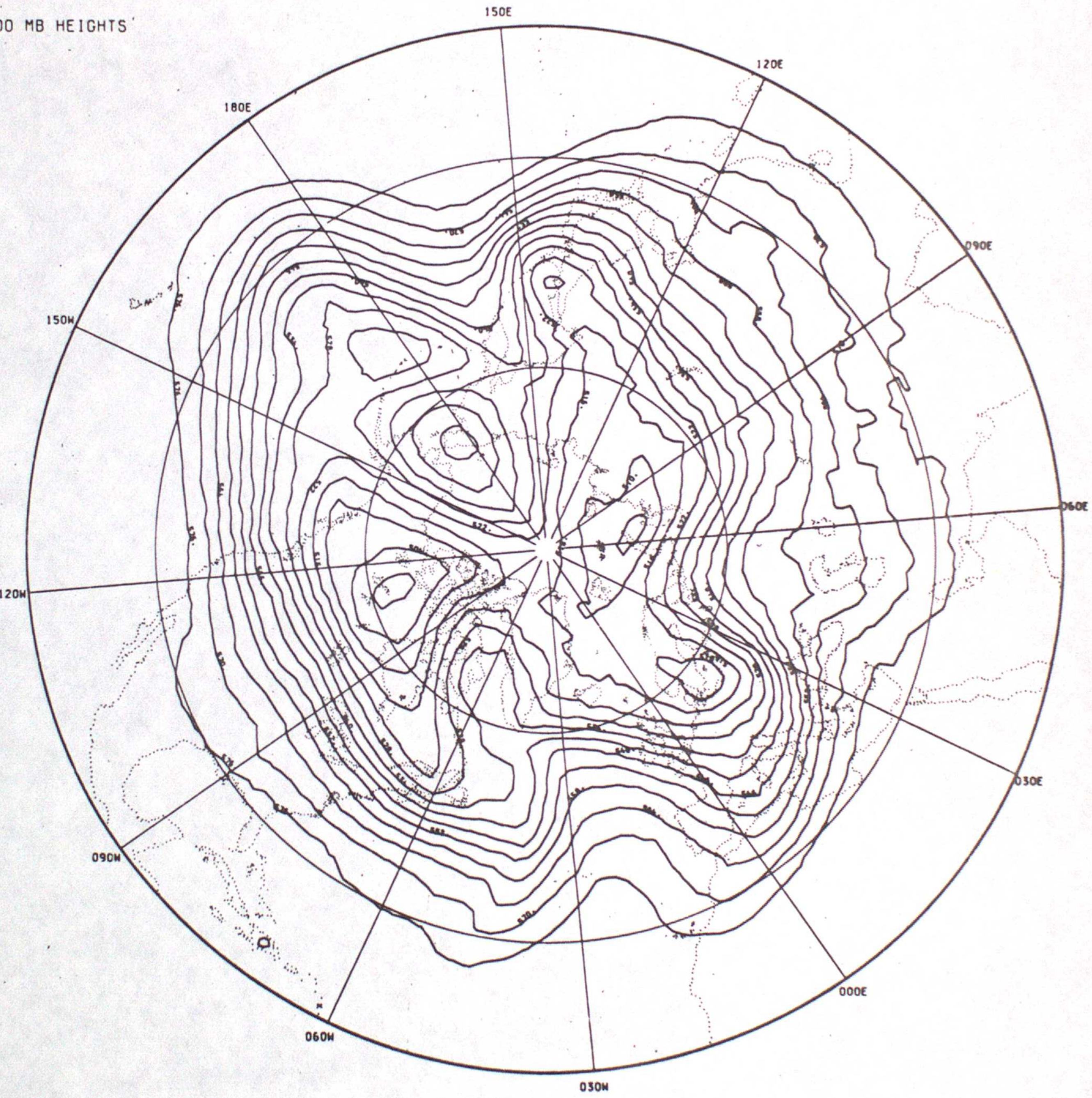
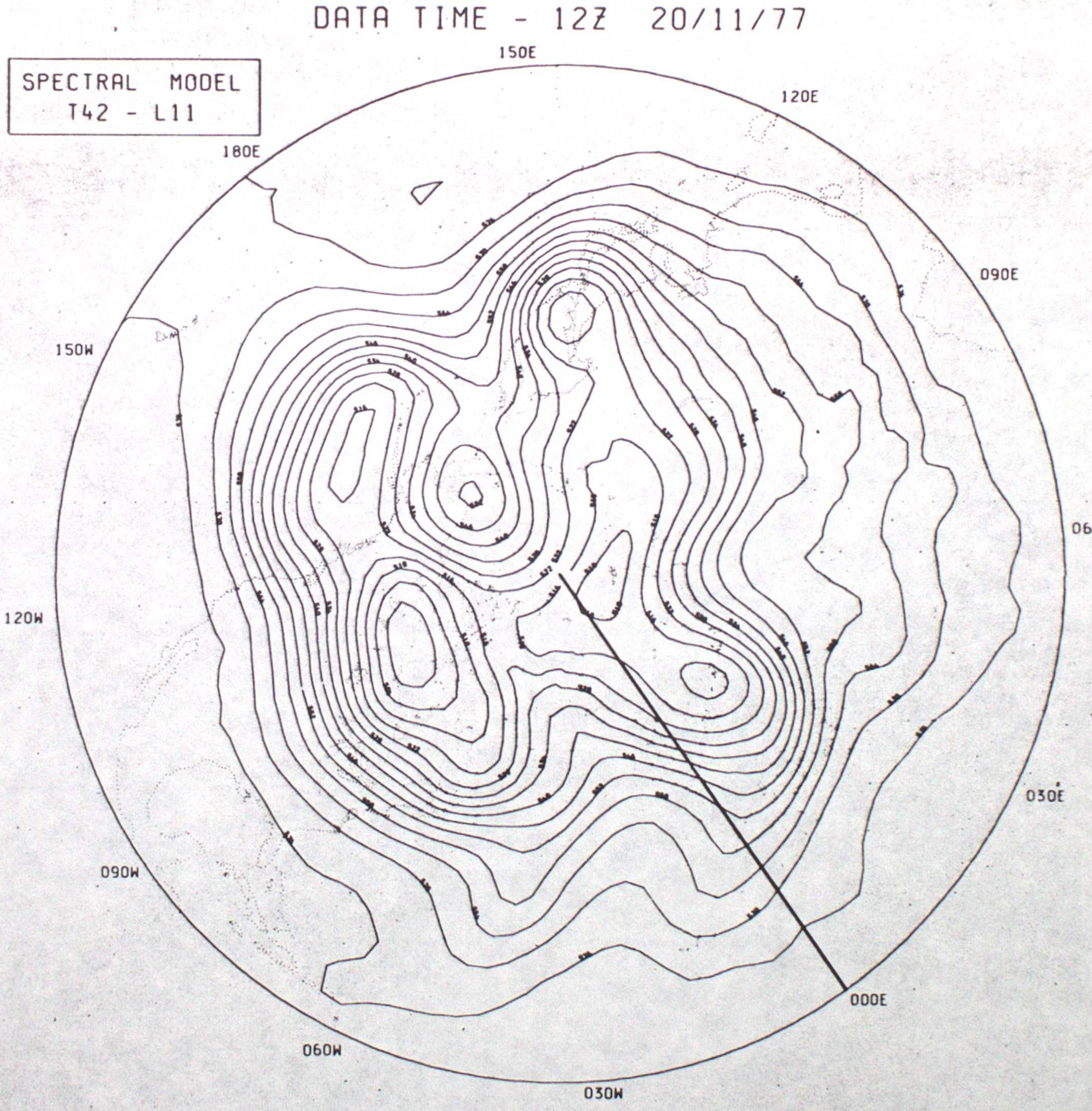


FIG. 5.2

FIG. 5.3

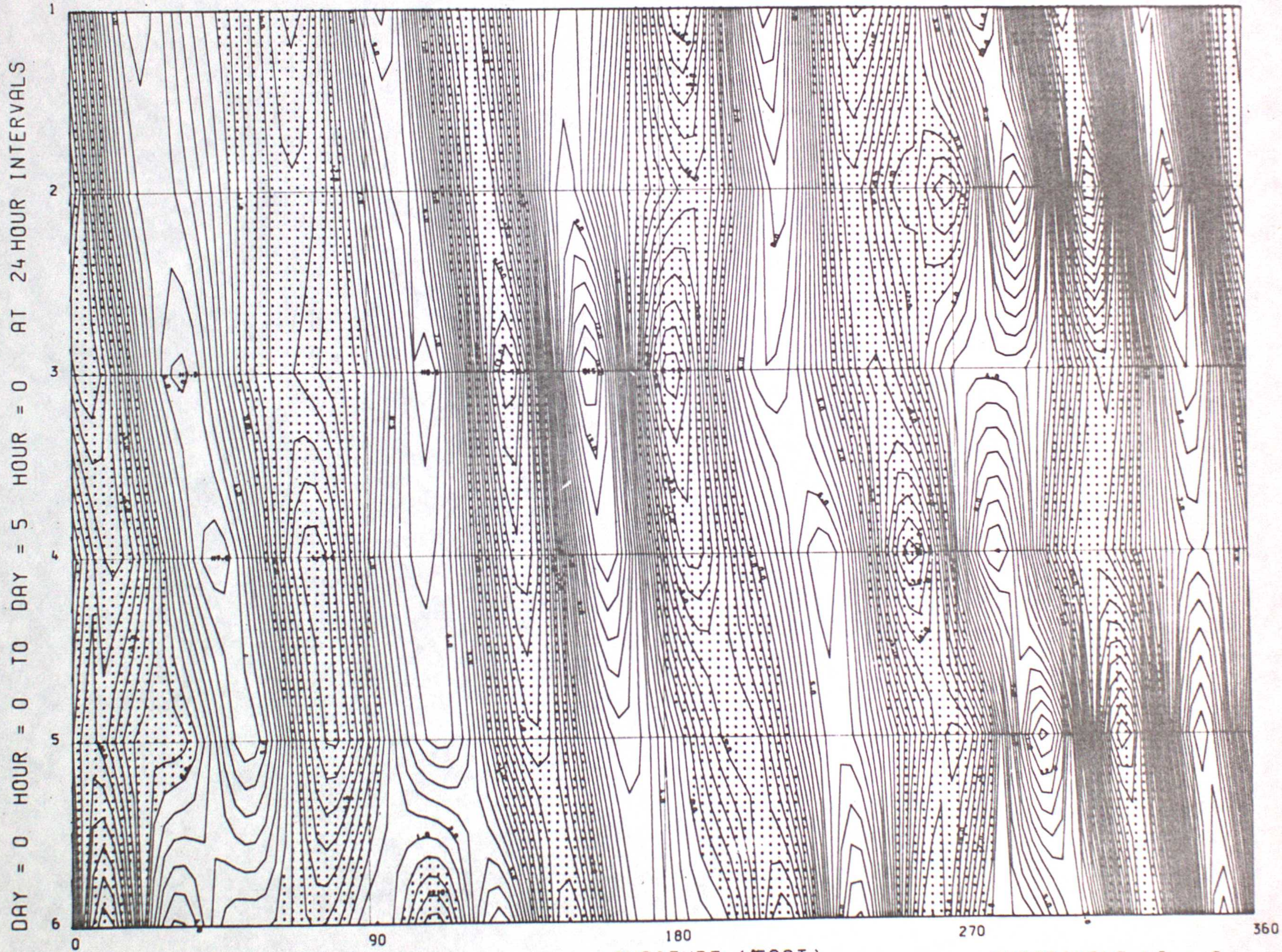


500MB CONTOURS AT DAY 3.00

FIG. 5.4

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

MEAN OF WAVE NOS 6 - 10 AT LATITUDE = 49



CONTOUR INTERVAL = 1.0

EXPERIMENT NO = 0

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

MEAN OF WAVE NOS 6 - 10 AT LATITUDE = 49

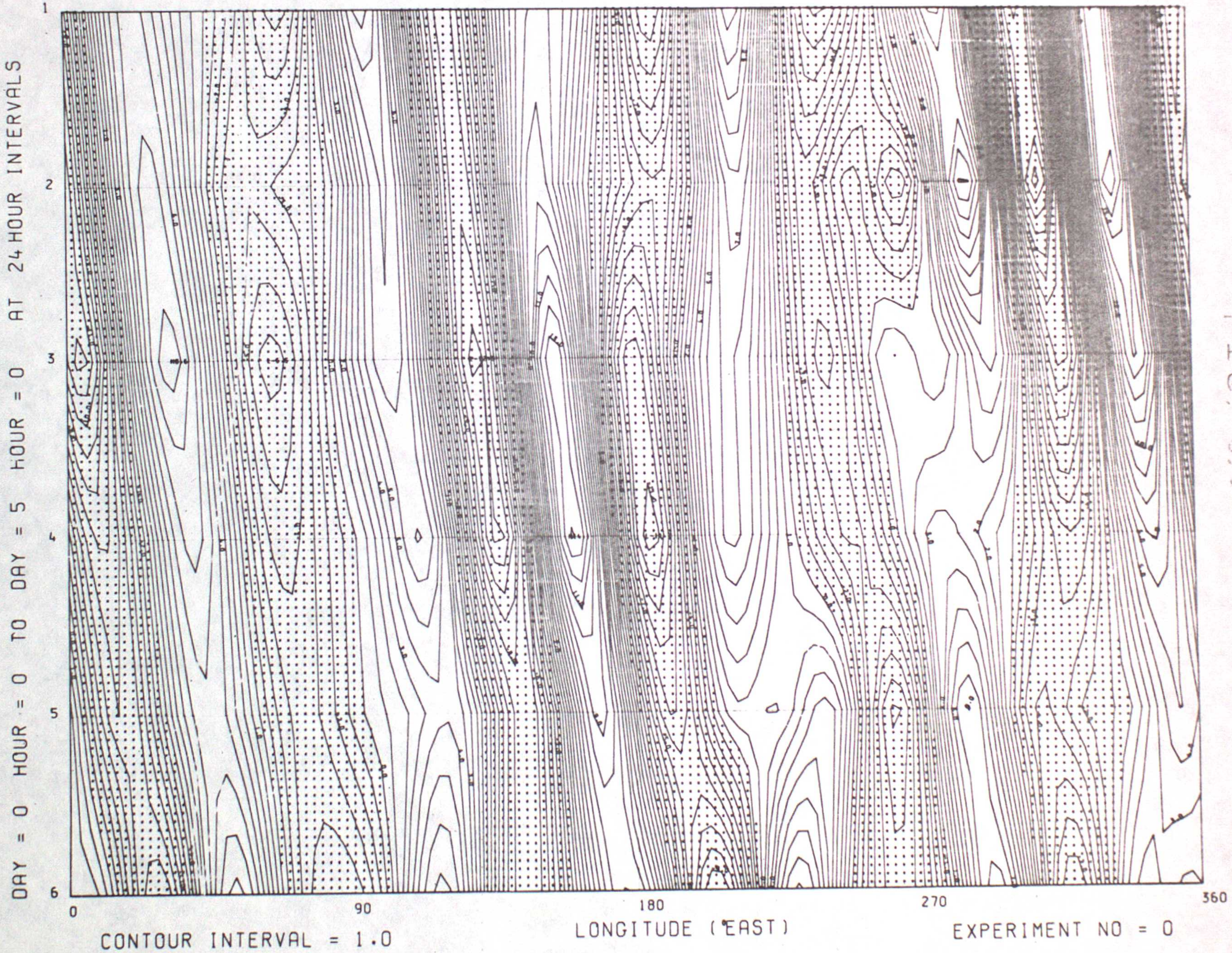


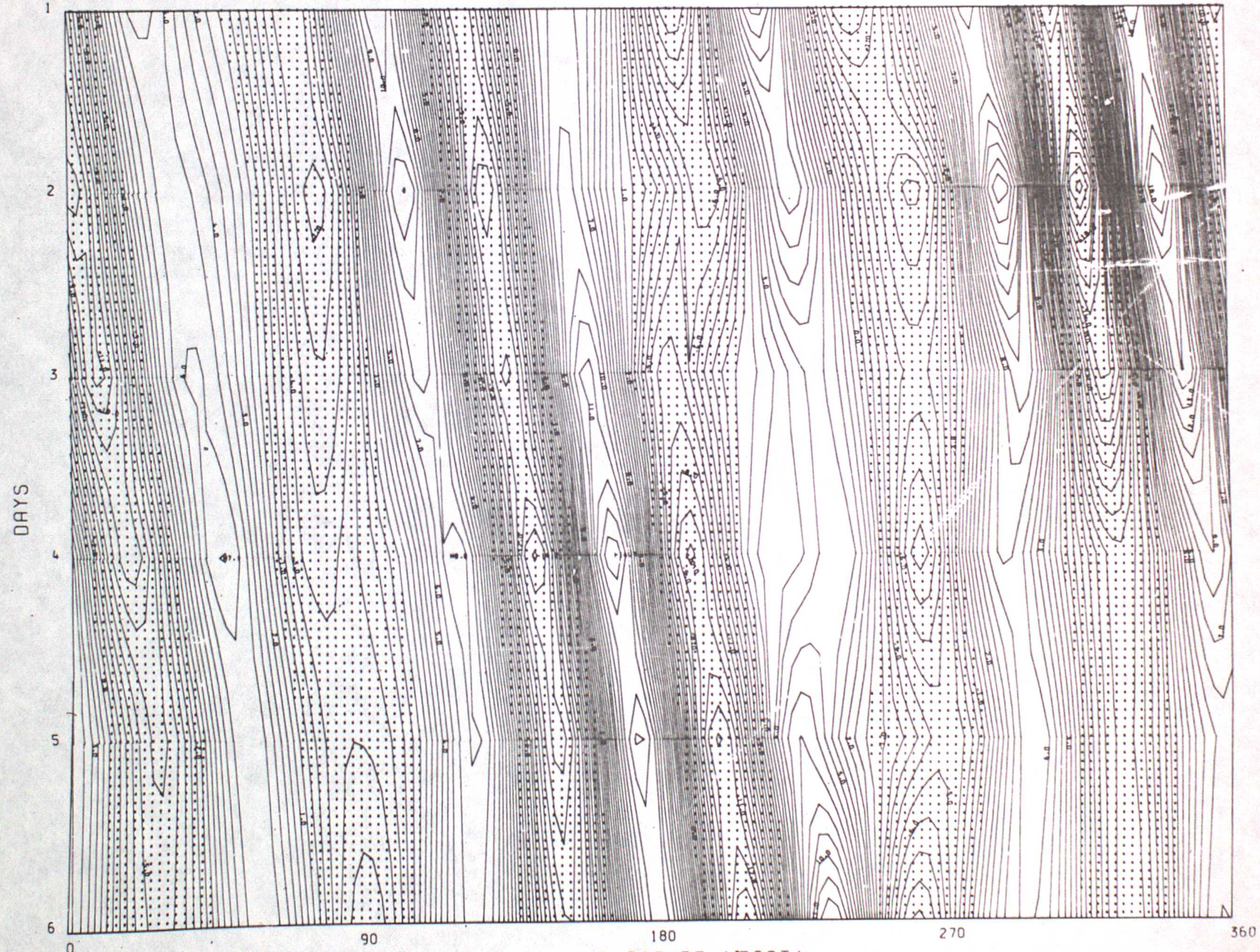
FIG. 5.5

FIG. 5.6

SPECTRAL MODEL

T42-L11 5 - DAY FORECAST FROM 12Z 20/11/77

MEAN OF WAVE NOS 6 - 10 AT GAUSSIAN LATITUDE 15



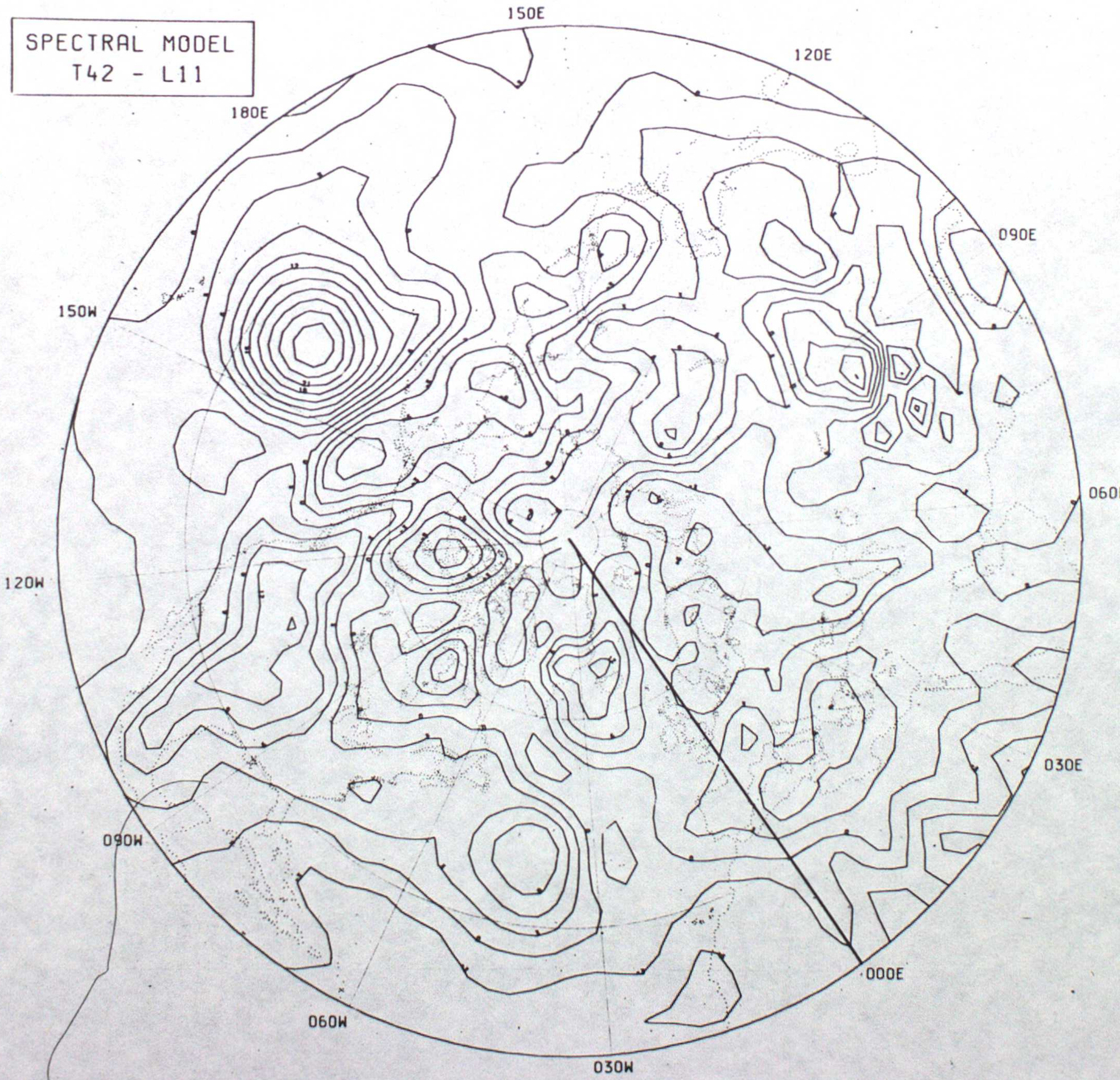
CONTOUR INTERVAL = 1.0

FIG. 5.7

DIFFERENCE IN PRESSURE LEVEL=999.0 FOR EXH 0 - EXH 0 D 2H 0 D 2H 0
CONTOUR INTERVAL = 6.00

FIG. 5.8

DATA TIME - 12Z 22/11/77



1000MB HEIGHT DIFFERENCES (F/C - ACTUAL) DAY 2

FIG. 6.1

500 MB CONTOURS, CONTOUR LINES AT 6 DECAMETER INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 5 / 1 / 78. VERIFICATION TIME 12 Z 5 / 1 / 78

SE VERSION

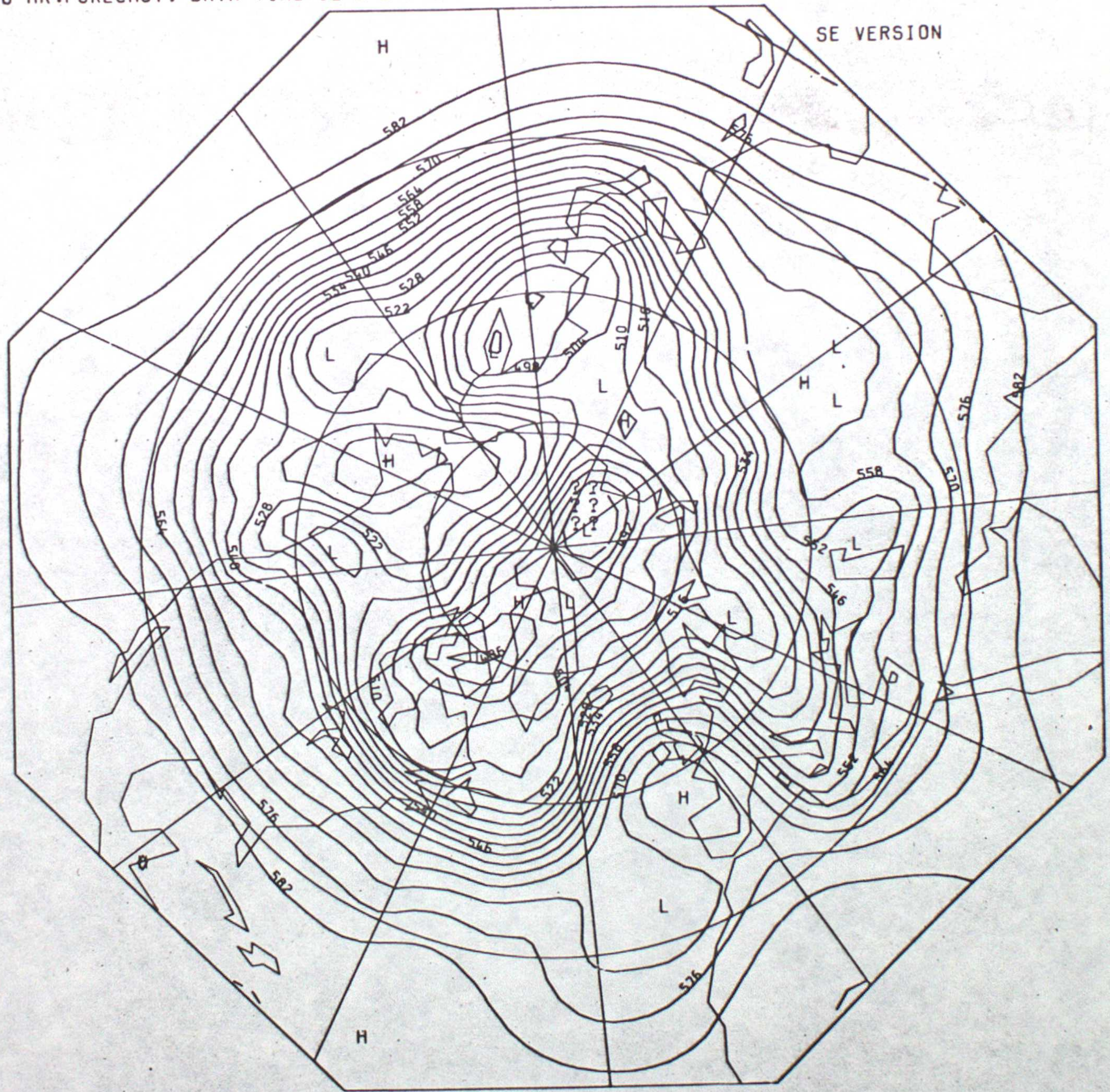


FIG. 6.2

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

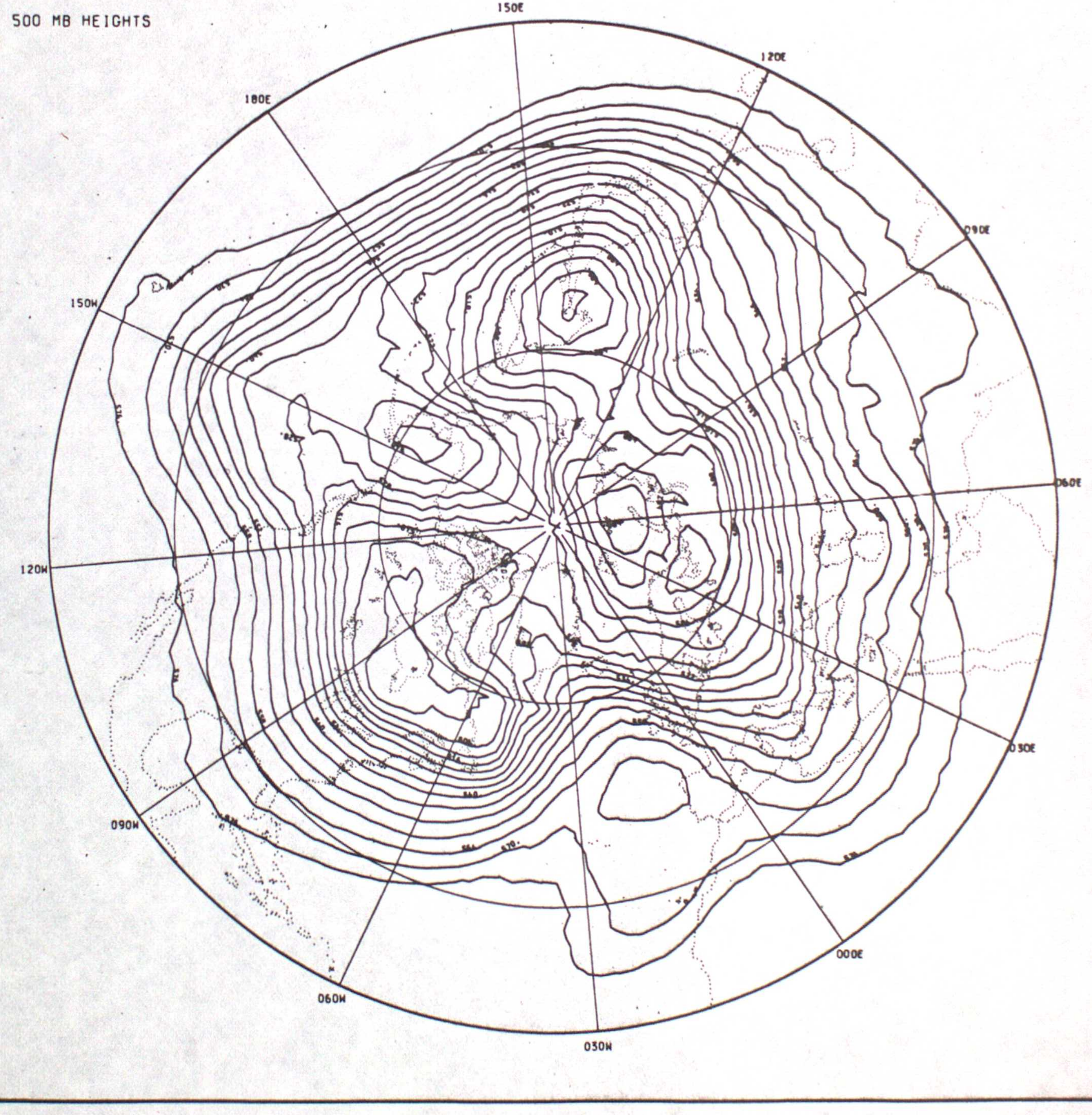
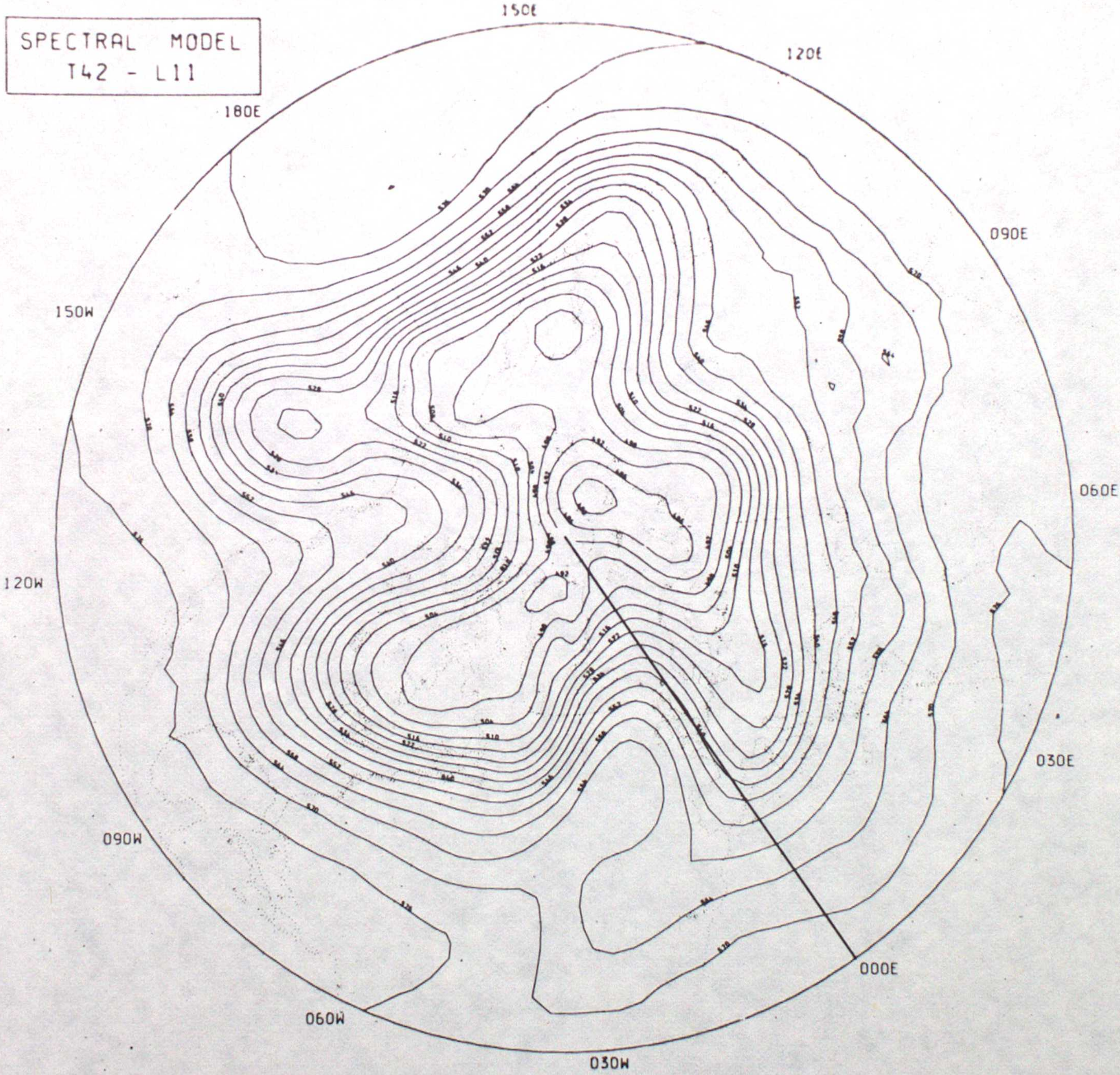


FIG. 6.3

DATA TIME - 12Z 1/1/78

SPECTRAL MODEL
T42 - L11



500MB CONTOURS AT DAY 4.00

FIG. 6.4

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

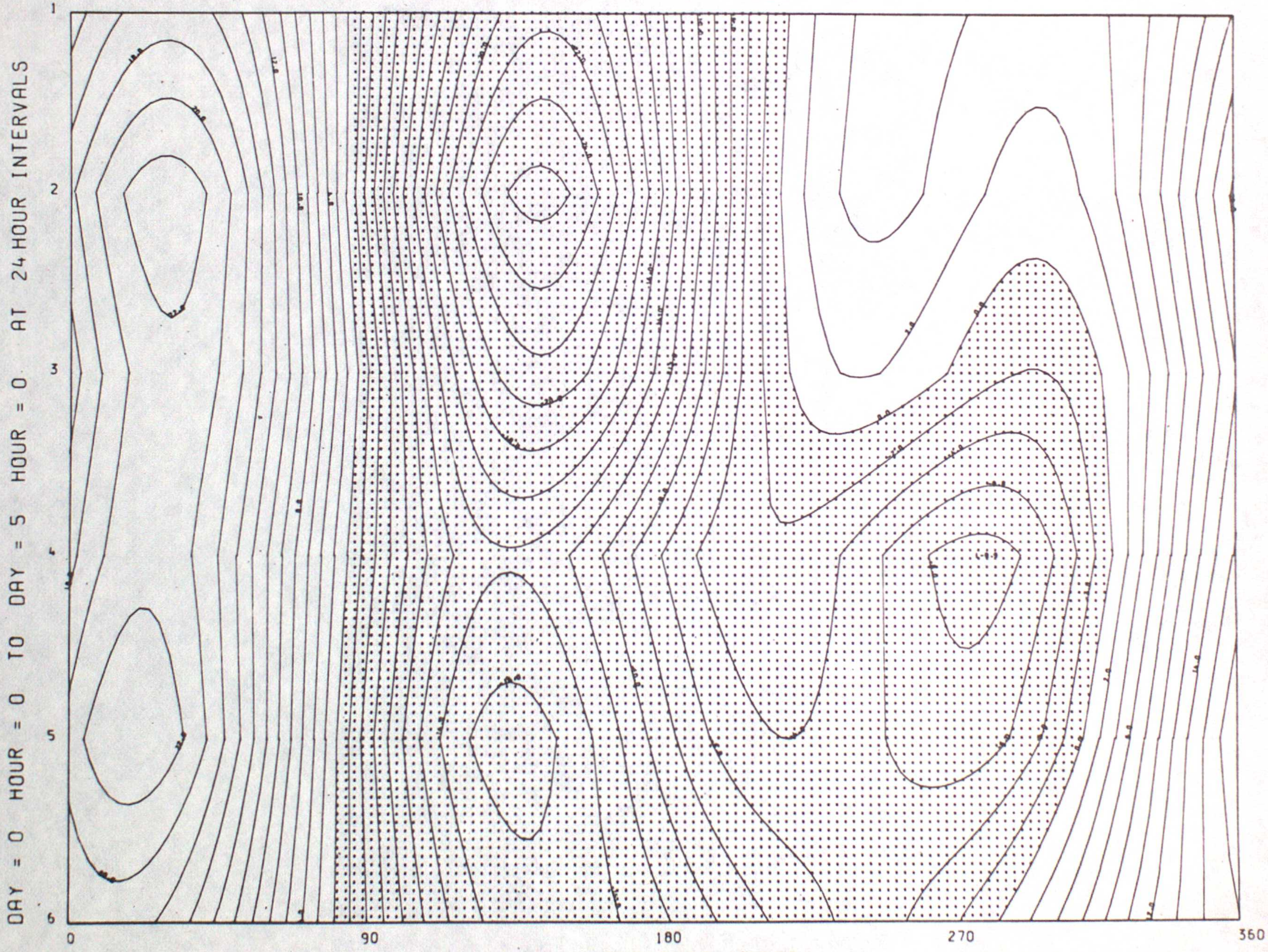
MEAN OF WAVE NOS 1 - 2 AT LATITUDE = 49

CONTOUR INTERVAL = 2.0

EXPERIMENT NO = 0

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

MEAN OF WAVE NOS 1 - 2 AT LATITUDE = 49



CONTOUR INTERVAL = 2.0

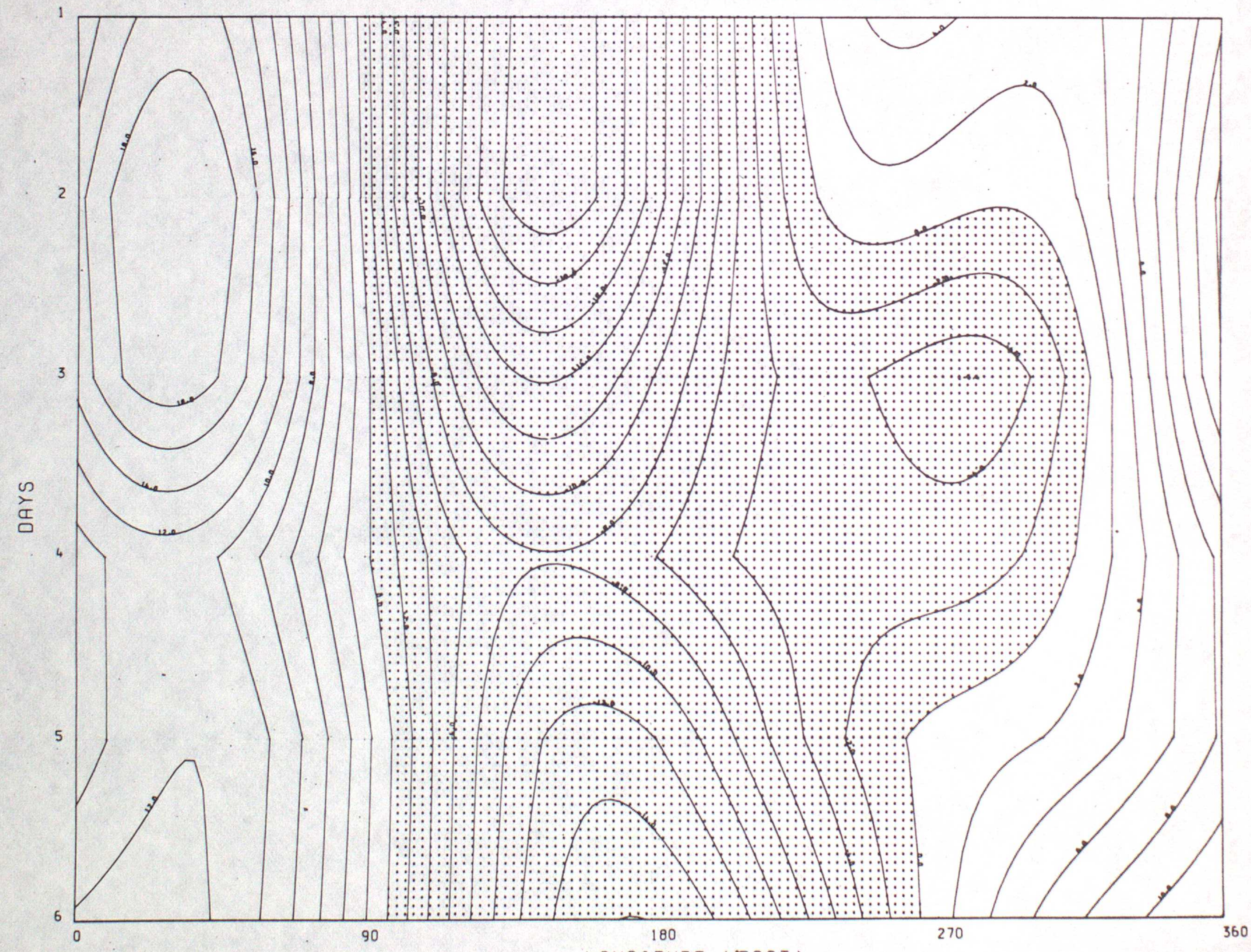
EXPERIMENT NO = 0

FIG. 65

SPECTRAL MODEL

T42-L11 5 - DAY FORECAST FROM 12Z 1/1/78

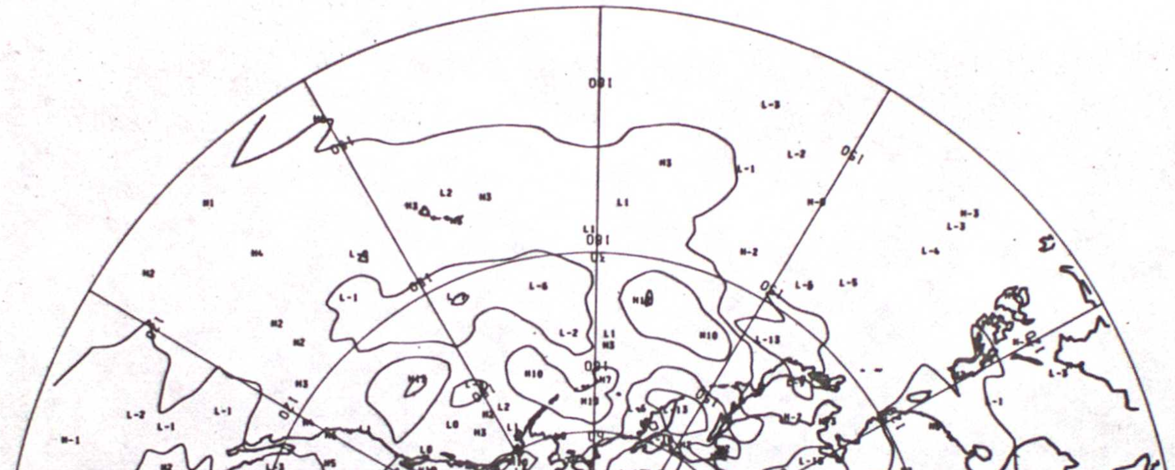
MEAN OF WAVE NOS 1 - 2 AT GAUSSIAN LATITUDE 15



CONTOUR INTERVAL = 2.0

FIG. 6.6

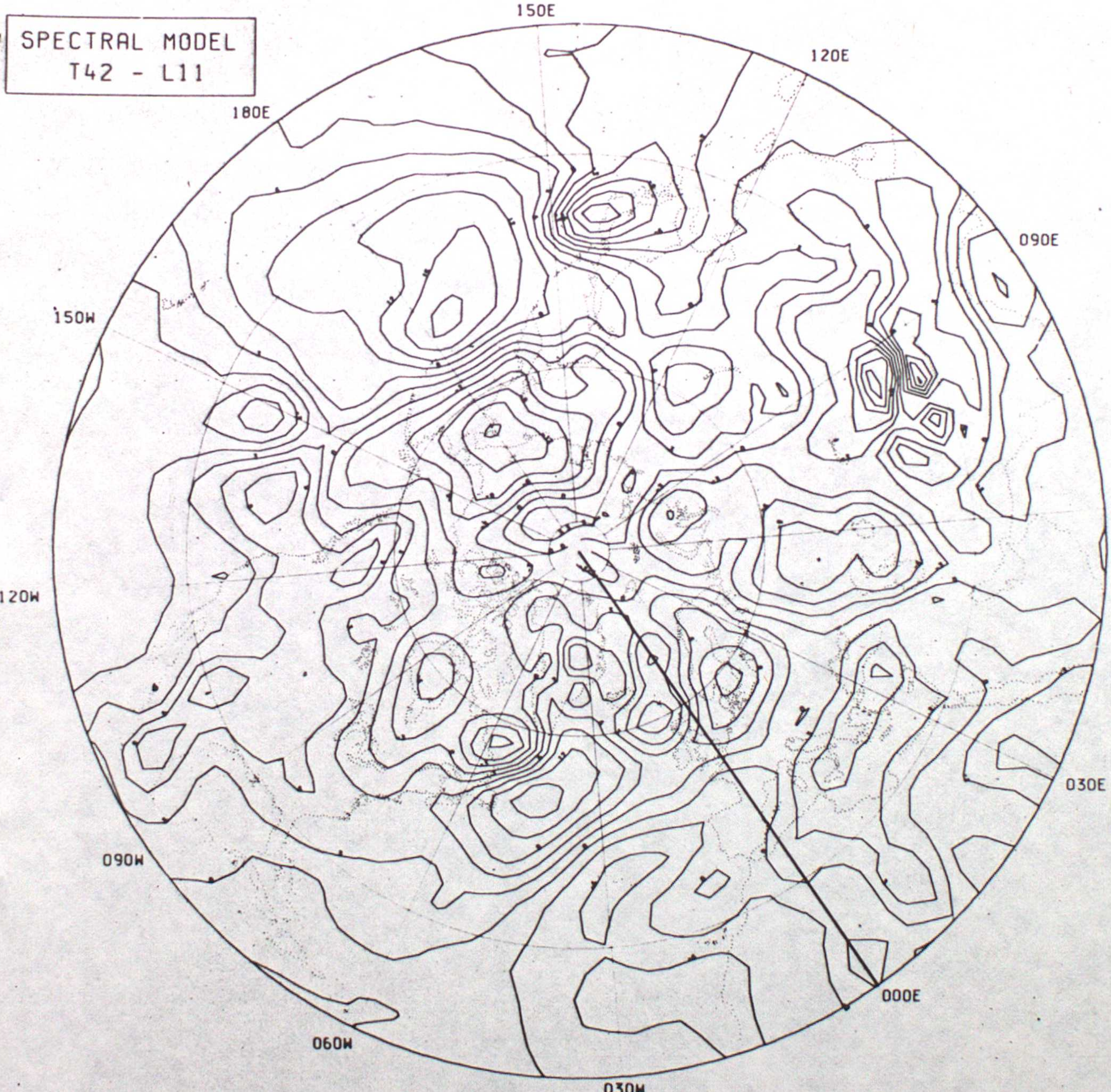
FIG. 6.7



DIFFERENCE IN PRESSURE LEVEL=999.0 FOR EXH 0 - EXH 0 D 2M D D 2M D
CONTOUR INTERVAL = 6.00

FIG. 6.8

DATA TIME - 12Z 3/1/78



1000MB HEIGHT DIFFERENCES (F/C - ACTUAL) DAY 2

FIG. 7.1

500 MB CONTOURS CONTOUR LINES AT 6 DECAMETER INTERVALS

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

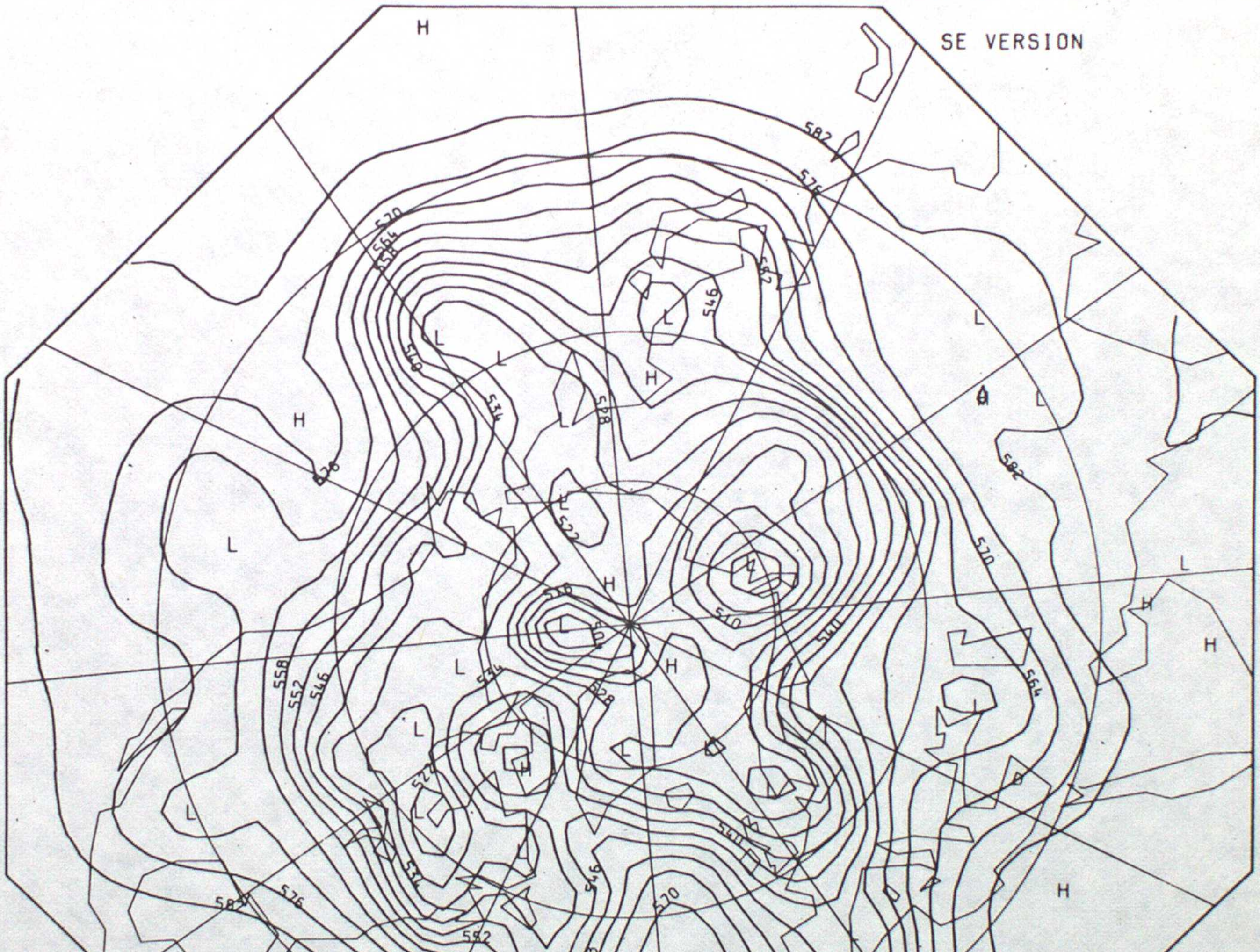


FIG. 7.2

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

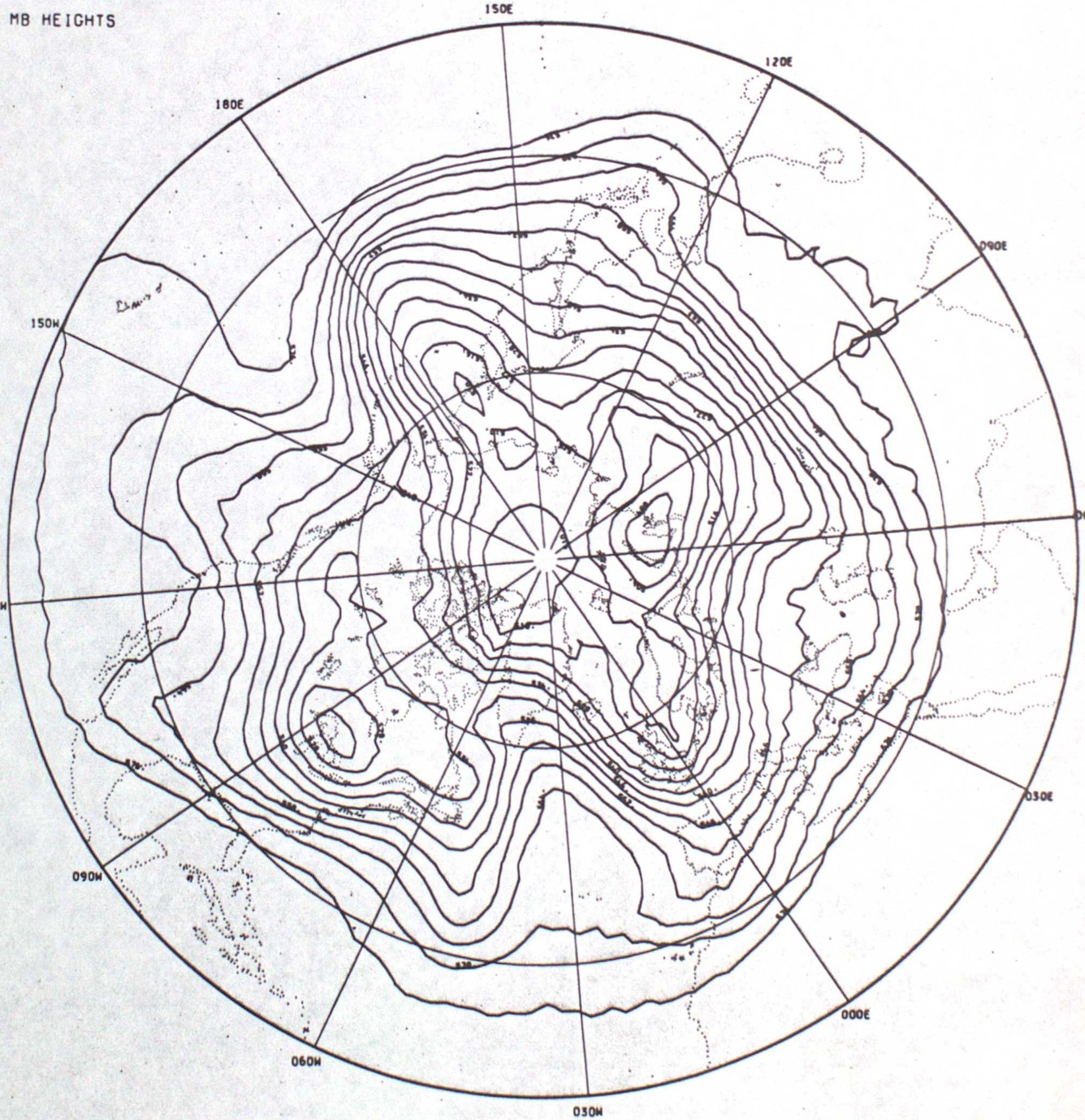
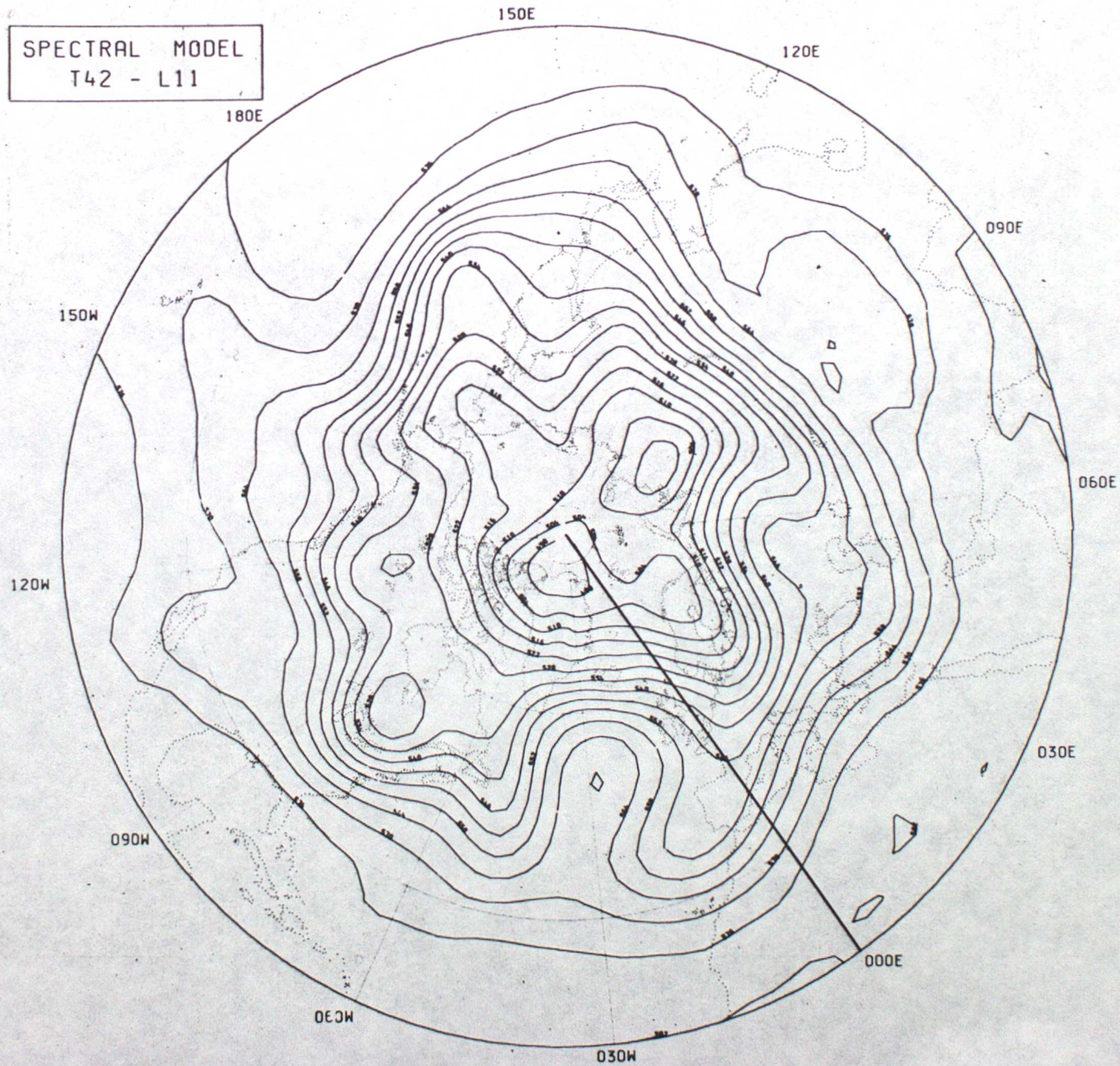


FIG. 7.3

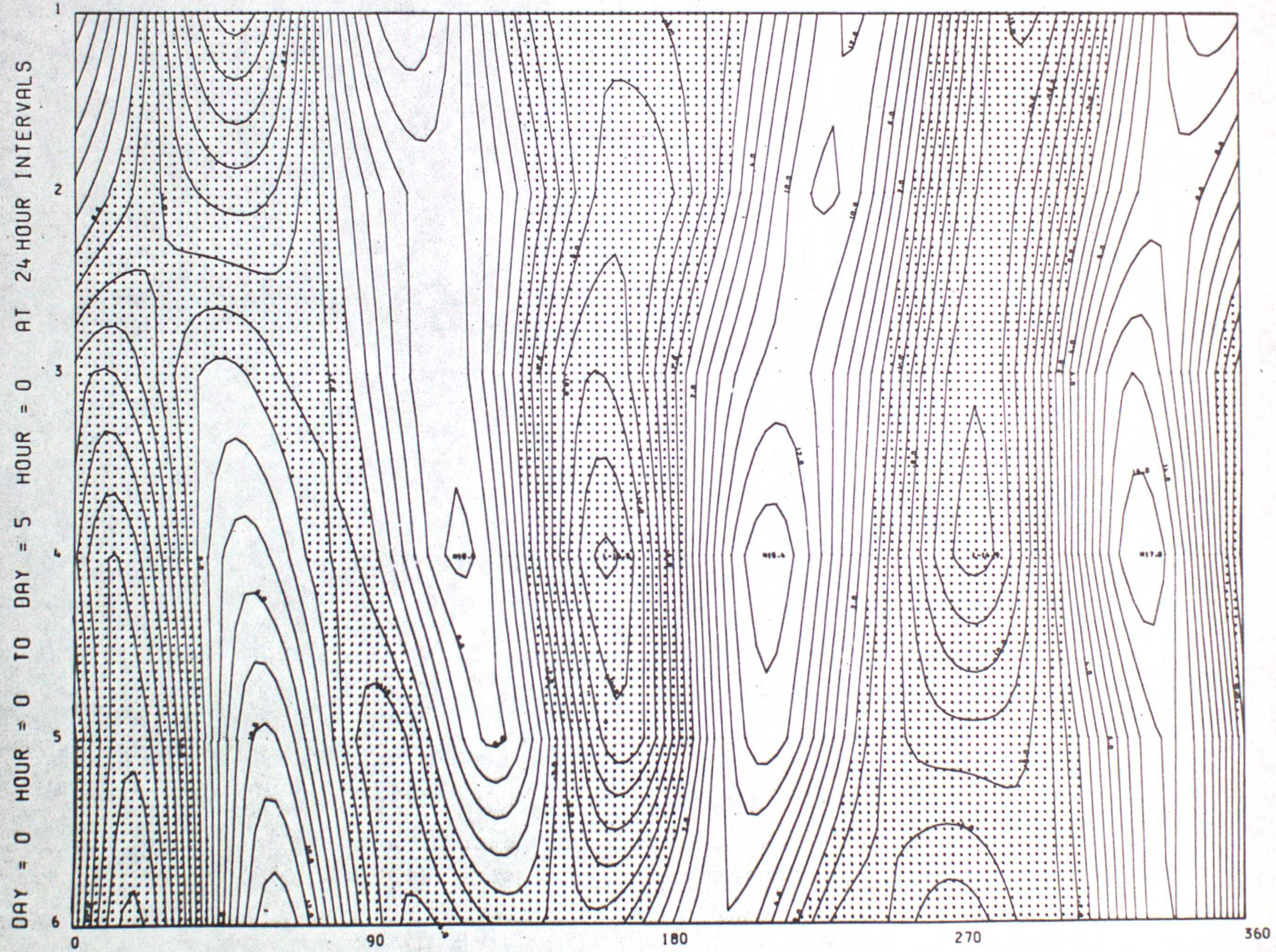
DATA TIME - 12Z 9/4/78



500MB CONTOURS AT DAY 3.00

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

MEAN OF WAVE NOS 3 - 5 AT LATITUDE = 49



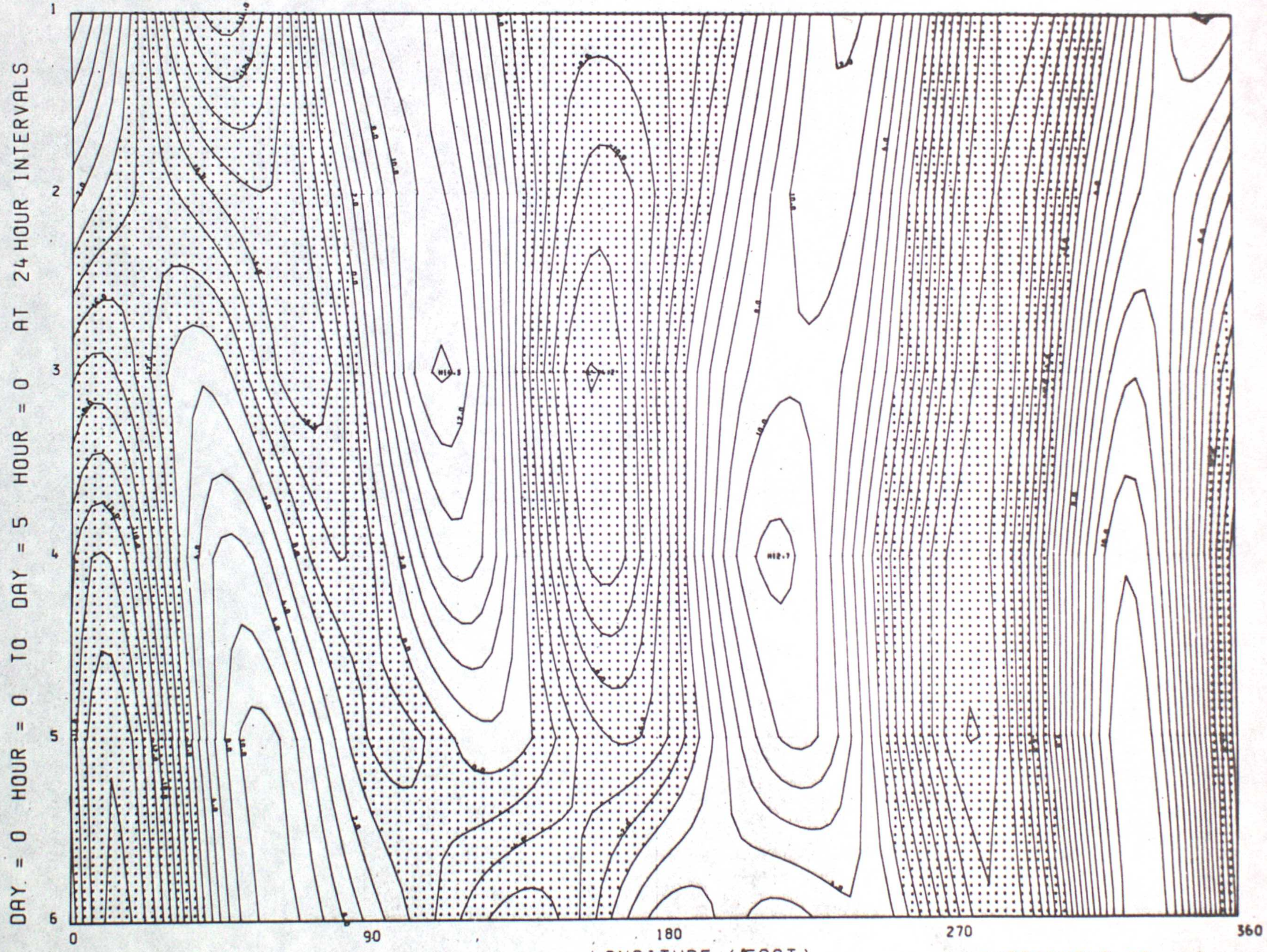
CONTOUR INTERVAL = 2.0

EXPERIMENT NO = 0

FIG. 7.4

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

MEAN OF WAVE NOS 3 - 5 AT LATITUDE = 49



CONTOUR INTERVAL = 2.0

EXPERIMENT NO = 0

FIG. 7.5

SPECTRAL MODEL

T42-L11 5 - DAY FORECAST FROM 12Z 9/4/78

MEAN OF WAVE NOS 3 - 5 AT GAUSSIAN LATITUDE 15

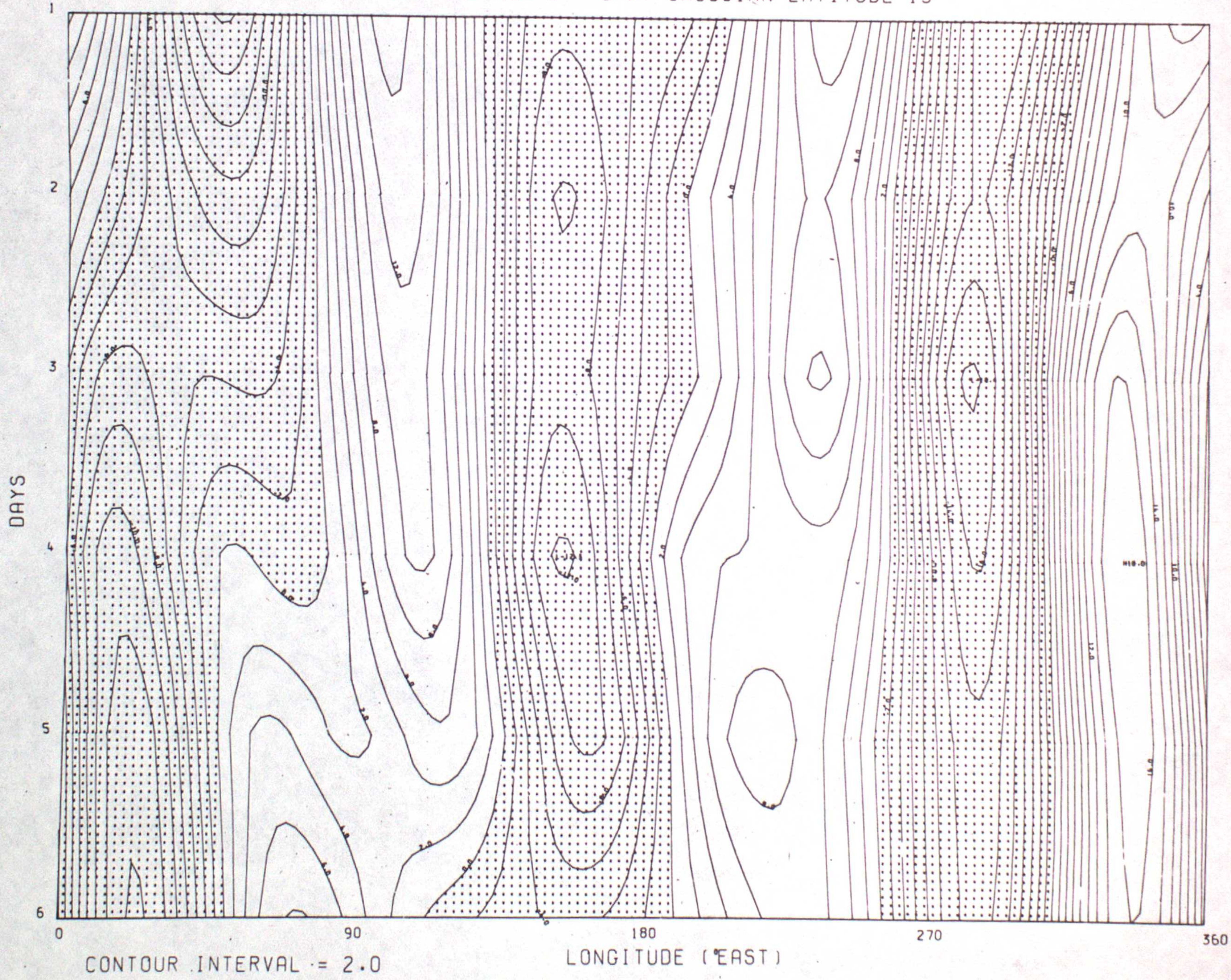


FIG. 7.6

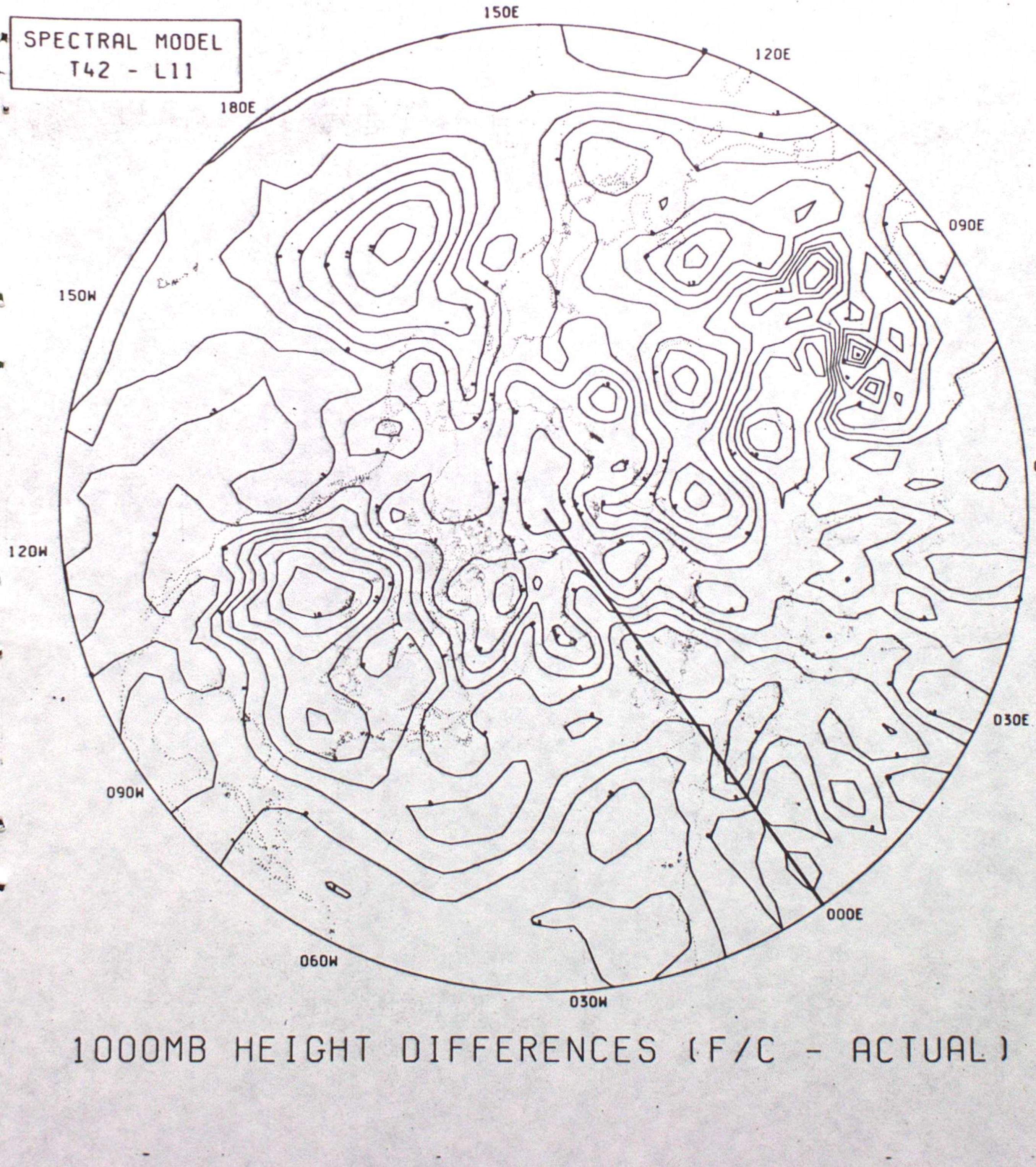
FIG. 7.7

DIFFERENCE IN PRESSURE LEVEL=999.0 FOR EXH 0 - EXH 0 D 2H 0 D 2H 0
CONTOUR INTERVAL = 6.00

FIG. 7.8

DATA TIME - 12Z 11/4/78

SPECTRAL MODEL
T42 - L11



1000MB HEIGHT DIFFERENCES (F/C - ACTUAL) DAY 2