MET O 11 TECHNICAL NOTE NO 100

Two Case Studies of Forecasts Produced by Different Models

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November 1977

1. Introduction

This note describes two sets of forecasts carried out during a long series of trials of different forecasting models. These trials have been carried out at weekly intervals during most of 1977. The assessment has been by synoptic assessment of forecast charts and by examination of other forms of output and statistics. In this note two examples are given with synoptic assessment. Subsequent notes will cover information obtained from other forms of output and from error statistics. The two cases chosen both showed a major change in weather type over the British Isles within three days. One is a late winter case, the other an early summer case.

Similar assessments have been carried out for the other cases run during 1977. The assessments are held on files in Met O 11. The cases presented here are fairly typical in the relative performances of the models, more general conclusions will be discussed in a subsequent note. Special comparisons of these models and some others for the GARP basic data set will appear in Carson (1977).

2. Description of experimental procedure

The following models were tested:

A. Operational split explicit 10 level model in pressure co-ordinates, covering an octagonal area north of 15N.

B. A sigma coordinate version of A.

C. A hemispheric 11 level model in sigma coordinates.

D. A hemispheric 5 level spectral model.

E. A hemispheric 5 level finite element model.

A summary of the model characteristics is given in Table 1. Model A is described in Burridge and Gadd (1977) and Gadd (1977). The extension to model B is described by Temperton (1976). Model C is a higher resolution version of the 5 level hemispheric or global model described by Corby et al (1971), the extension is described by Carson and Cullen (1977). The spectral model, D, is that discussed by Hoskins and Simmons (1975). The finite element model, E, is a velocity potential formulation of the model described in Cullen (1975), the extension is discussed in Cullen (1976).

Table 1

Summary of model characteristics

Model	A	B	C	D	E
Forecast Area	Octagon	Octagon	N Hemisphere	N Hemisphere	N Hemisphere
Vertical Coordinate	p	σ	σ	σ	σ
Resolution:					
Vertical Levels	10	10	11*	5	5
No of Grid Points	3037	3037	5176	924***	1126
Horizontal Grid Length	300 km (at 60N)	300 km (at 60N)	220 km (N45)	500 km (T42)	450 km (N22½)
Time Step	30m	30m	7½m	30m	28m
CPU Time/24hr FCST	2½m	2½m	26m	9m	8m
Integration Scheme:					
Variables Used**	h', u, v, q	θ, u, v, q	p_*, u, v, T, q	Inp_*, ζ, D, T, q	Inp_*, A, X, T, q
Space Scheme	Staggered	Staggered	Unstaggered Conservative Finite difference	Spectral	Finite element (linear) Galerkin
Time Scheme	Split explicit		Explicit	Semi-implicit	

* In this model the levels are not equally spaced.

** h' - thickness, u,v - wind components, θ - potential temperature, T - temperature, q - humidity variable, p_* - surface pressure, ζ - vorticity, D - divergence, A - stream function, X - velocity potential.

*** Number of degrees of freedom.

The initial data for the models was derived from the operational update octagon analysis for 12Z on the day in question. For the hemispheric models the data was extended to the equator using a smoothing procedure giving constant values round the equator. For model C the data had to be extended into the stratosphere. The method of carrying this out is described by Saker and Phillips (1974). The data for models D and E was derived by interpolation from model C onto the Gaussian grid used to evaluate nonlinear terms in the spectral model, this has 32 latitudes with 128 points per line. Spectral initial data was then derived using the transforms built into the spectral model. Finite element data was derived using a piecewise linear fit to the grid point values. No dynamic initialisation was used, but models C, D and E contain time filters which have a similar effect.

3. The forecasts from 17.3.77

The initial data for 12Z on the 17th March at 500 mb and the surface is shown in Figs 1 and 8, verifying analyses for 12Z on the 20th are given in Figs 2 and 9. The forecasts from models A to E at 500 mb are shown in Figs 3 to 7 and at the surface in Figs 10 to 14.

a) Actual synoptic development

At 500 mb the Atlantic sector initially contains well marked troughs at 65W and 15W and a ridge at 45W with a NW-SE orientation. Over the three day period all these features move about 15° east. The orientation of the ridge changes to NNE-SSW and cuts off the eastern trough at 0°W, a high latitude trough moves away rapidly to 15E. The flow over the UK reverses from SW to NE but the overall change at 500 mb is not very large.

Over the USA the wavelength shortens with part of a trough originally at 120W moving east to the Great Lakes. Over the Pacific a broad ridge from 130 to 160W is compressed by a trough moving east to 170W, a further trough moves about 10°

to the east over Japan. Over Eurasia the ridge initially at 30E moves east to 60E and the cut-off low to the South **relaxes** northwards from 35N. East of the ridge a trough extends southwards at 90E.

At the surface the low initially to NW of the UK moves SE into France bringing a NE flow over the UK. A ridge becomes established between Scotland and Iceland. The low initially over the W Atlantic moves a little east and intensifies. An extensive low over the western USA weakens and moves eastwards. A large high over the eastern Pacific weakens a little and depressions start propagating north-eastwards towards Alaska. A new depression intensifies at 105E associated with a strong northerly flow at 90E.

b) Model forecasts

At 500 mb all models except model E incorrectly maintain the NW/SE orientation of the Atlantic ridge, and move the eastern trough to about 10E. Model E gives a N/S ridge at 25W and a cut-off trough at 55N 0E in the correct longitude but not far south enough. No model propagates the western Atlantic trough forwards correctly. Models A and B produce shortwave features over the USA, but in the wrong phase; models C, D and E give a zonal flow. The anchored trough at 110W is present in all models.

Over the Pacific model A gives the best forecast, model B has too much amplitude in the western Pacific and model C too little in the eastern ridge. Model D produces strong shortwave features incorrectly. Model E gives reasonable amplitudes but the phases are 15° too slow. Over Eurasia only model A seems to relax the cut off low correctly, model B is next best. The others relax it eastward rather than westward. The meridional flow at 90E is best in models A and B, models C, D and E produce a more circular feature.

At the surface all models except E incorrectly move the low from NW of the UK into Norway, leaving behind a weak W to NW flow. In model E the low stagrates over the UK. The high to the NW of Scotland is placed between Iceland and Greenland by models A and B, over Greenland by model C and E, and is difficult to find in model D. The west Atlantic low is handled well by model B, in models A and C it is not deep enough and in model C it moves too far. In models D and E it hardly moves at all. All models correctly give only weak features over the USA, only models A and B attempt to produce a low over the Great Lakes. Over the Pacific models A and B forecast two of the depressions well but pressure is too high between then especially in model B. Model C is better in this respect and also develops a third low, not quite in the right place. Model D develops several features too much and is very inaccurate, model E forecasts two lows fairly well in the east Pacific but builds up pressure wrongly in the west, blocking a low over Japan from moving east. Over Eurasia the new low development at 105E is indicated in all models but is most developed by models A, B and D.

In general, all models make substantial errors. The 10-level models A and B are slightly superior to model C with A better than B. Model D produces detail which is often wrong and model E tends to get stuck, sometimes giving the right answer perhaps for the wrong reasons.

4. The forecasts from 2.6.77

The initial data for 12Z on the 2nd June at 500mb and the surface is shown in figs 15 and 21, verifying analyses for 12Z on the 5th are given in figs 16 and 22. The forecasts from models, A, C, D and E at 500mb are shown in figs 17 to 20 and at the surface in figs 23 to 26.

a) Actual synoptic development

At 500mb a strong ridge to the west of the UK retrogresses to the western Atlantic and a deep trough becomes established over the British Isles. Examination of intermediate charts shows that this happens through an amplification of a ridge initially at 50W, merging with the western part of the UK ridge and a slow breakdown of the ridge over the UK itself. Over the Pacific a broad ridge at 170E and broad trough at 140W amplify and the wavelength shortens to give a deep trough at 140W and a ridge at 170W by day 3. Over the USA, however, the reverse happens and a short wave pattern propagates into the Atlantic leaving behind a broad ridge. Finally, over Eurasia there is little change, a broad ridge at 75E and trough at 135E retrogress to 60E and 120E.

The surface developments correspond with the changes at 500mb. Over the Atlantic an anticyclone covering the UK and a weaker one at 50W merge to give a strong ridge extending from Greenland down 30W to Morocco. Over the UK a cyclonic northerly flow is established. The low over the eastern USA moves SE into the western Atlantic. Strongly meridional flows over the rest of the USA disappear and are replaced by a weak high over Canada. In the Pacific a high at 170E moves to 170W with the same intensity, but low pressure to the east of it weakens. Two depressions initially over the western Pacific move NE and weaken over Alaska and E Siberia respectively. The first reaches a maximum depth of 996mb at Day 1, the second never intensifies at all. Over Eurasia the main change is cyclonic development over Scandinavia associated with the changes in the Atlantic.

b) Model forecasts

At 500mb all models achieve the breakdown of the ridge over the UK and the retrogression associated with the west Atlantic ridge; however, all fail to amplify the new ridge and give it the pronounced NW-SE orientation required;

thus the trough to the east of the UK is not quite as strong as observed as the NW jet over the UK is not extended enough. The contour height over London should fall from 579 dm to 556 dm, the values given by the models are: A - 567, C - 564, D - 567, E - 563. The contour height at Cape Farewell rises from 543 to 575 dm, the values given by the models are: A - 570, C - 576, D - 573, E - 565. Inspection of the charts shows that model C is the best; models A and D are similar, both propagate short wave features through the ridge and fail to retain enough amplitude in the main ridge, E also does this to an even greater extent and is worse than A and D.

All the models are at fault over the USA in that a trough remains extending SSE or S from a low over Hudson's Bay instead of moving away E to leave a broad NW flow. Model D is the worst with the other similar.

Over the Pacific the phases are handled well but the amplitudes are too low, particularly in the trough at 140W. The upstream ridging over the W coast of the USA is also too weak. Model C gets the best trough amplitude. Models A and C are markedly better than models D and E is handling both the trough and the ridge. Over Eurasia the retrogression is correctly predicted but all models emphasise the trough at 105W at the expense of the secondary trough at 125W.

At the surface all models replace the high over the UK with a NW or N flow, only model C produces a cyclonic flow, models A, D and E all maintain a ridge. Models D and E produce incorrect cyclonic development over Iceland which contributes to the error over the UK.

Over the USA all models except E maintain low pressure near Hudson's Bay incorrectly. All these also have high pressure over the USA rather than Canada and model C has a spurious low over the west USA as well as the high over the east USA. Model E gives a very weak pattern which is least in error.

Over the Pacific all models give a high at 170W except model E which has it at 180W, all models have an over-intense low on the Canadian coast. The indeterminate belt of low pressure from China to Alaska is predicted, but model D overemphasises individual features.

Over Eurasia all models produce cyclonic development over Scandinavia and a high near 60E, models D and E give the least convincing pattern.

Overall the higher resolution models A and C are superior to D and E. Over the Atlantic model C is distinctly better than model A, elsewhere the models are equal with C possessing a few extra faults, eg over the west USA. Model D is somewhat better than E, their faults are opposite in that D overemphasises detail, often incorrectly, and E is too weak.

5. Conclusions

These two case studies are taken from a series of around 20 carried out between 20 February and 7 August 1977. The indications given by then are fairly typical of the rest. There is not a great deal to choose between models A, B and C though there are sometimes substantial differences in their forecasts of individual features. Model C possesses some faults not present in A and B such as problems over the Himalayas and the SW USA. Models D and E are not up to the standard of A, B and C in their present form, the obvious explanation is lack of vertical resolution.

Acknowledgements

The work described here involved co-operation from three branches of the Meteorological Office. Forecasts from the σ coordinate octagon were supplied by Dr A J Gadd, the 11 level model was supplied by Mr N J Saker. The later runs of the spectral model were carried out by Mr A Radford. The original assessment of forecasts was carried out by Mr P G Wickham, subsequently by Mr L P Steele. The suite of programs was run by Messrs G W Purvis, J W Prince and R Roskilly.

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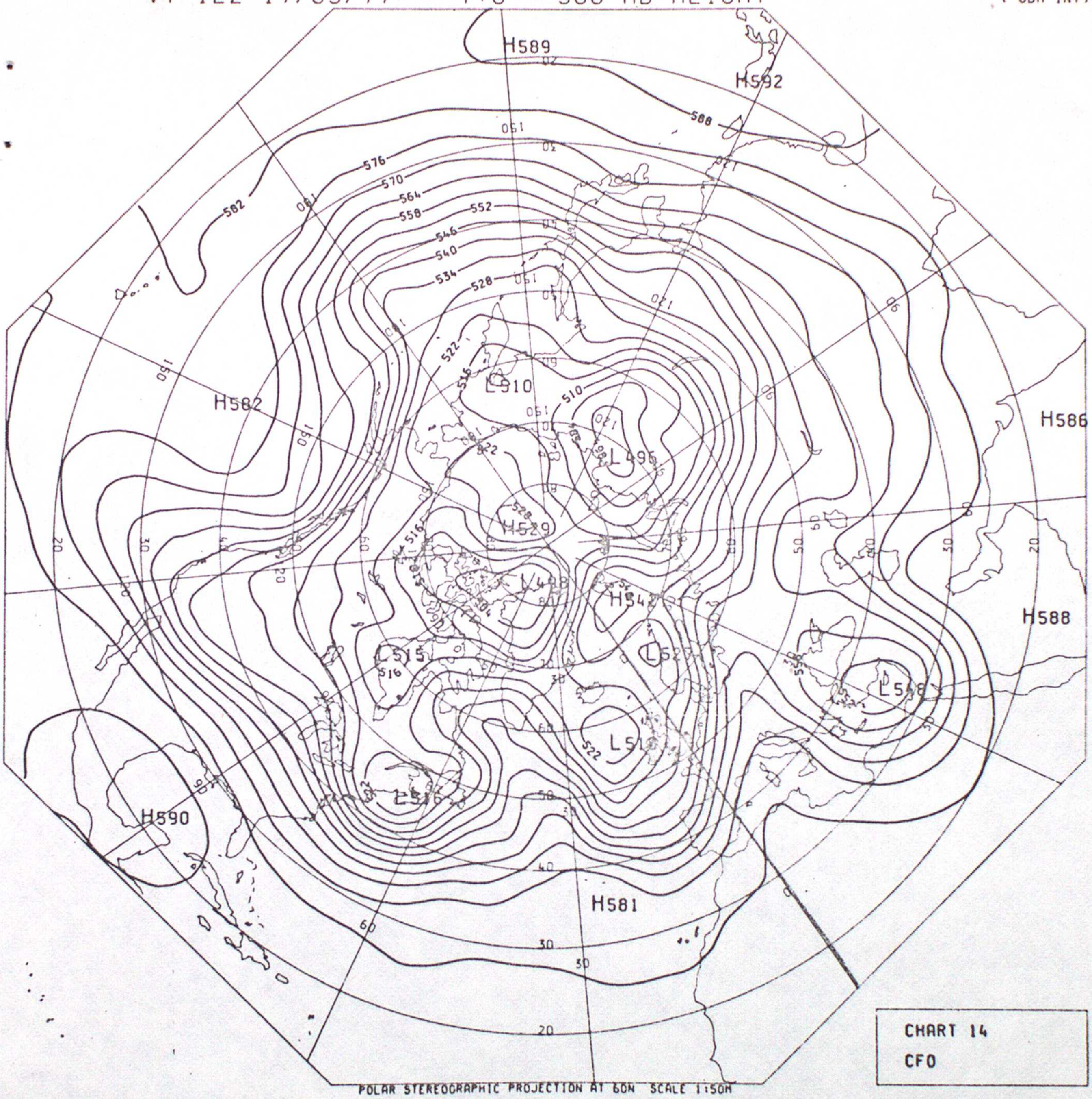
List of figures:

ACTUAL 500MB DAY 0

VT 12Z 17/03/77 T+0 500 MB HEIGHT (6DM INT)



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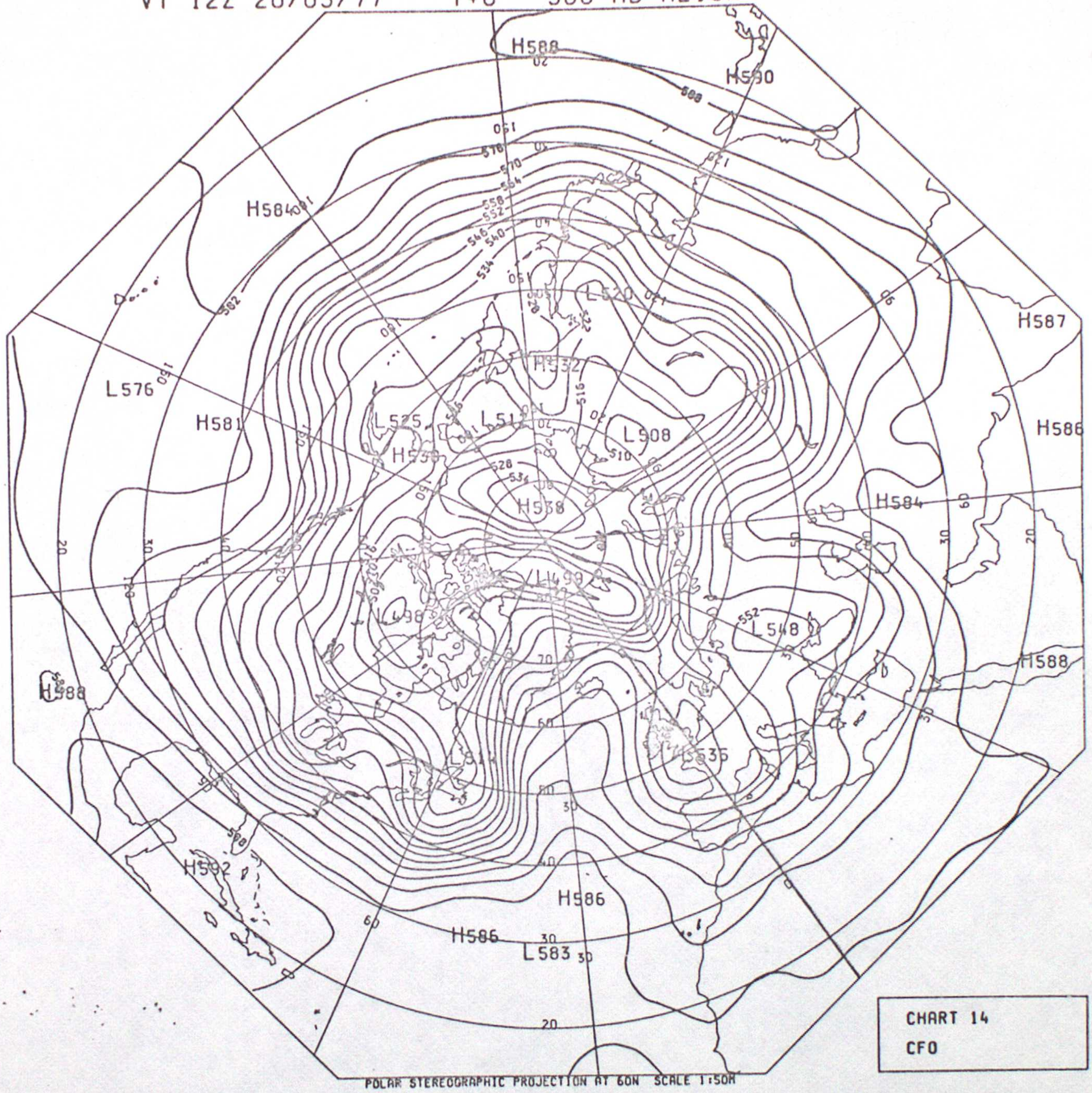

POLAR STEREOGRAPHIC PROJECTION AT 60N SCALE 1:50M

CHART 14
CFO

10 LEVEL p MODEL 500MB DAY3

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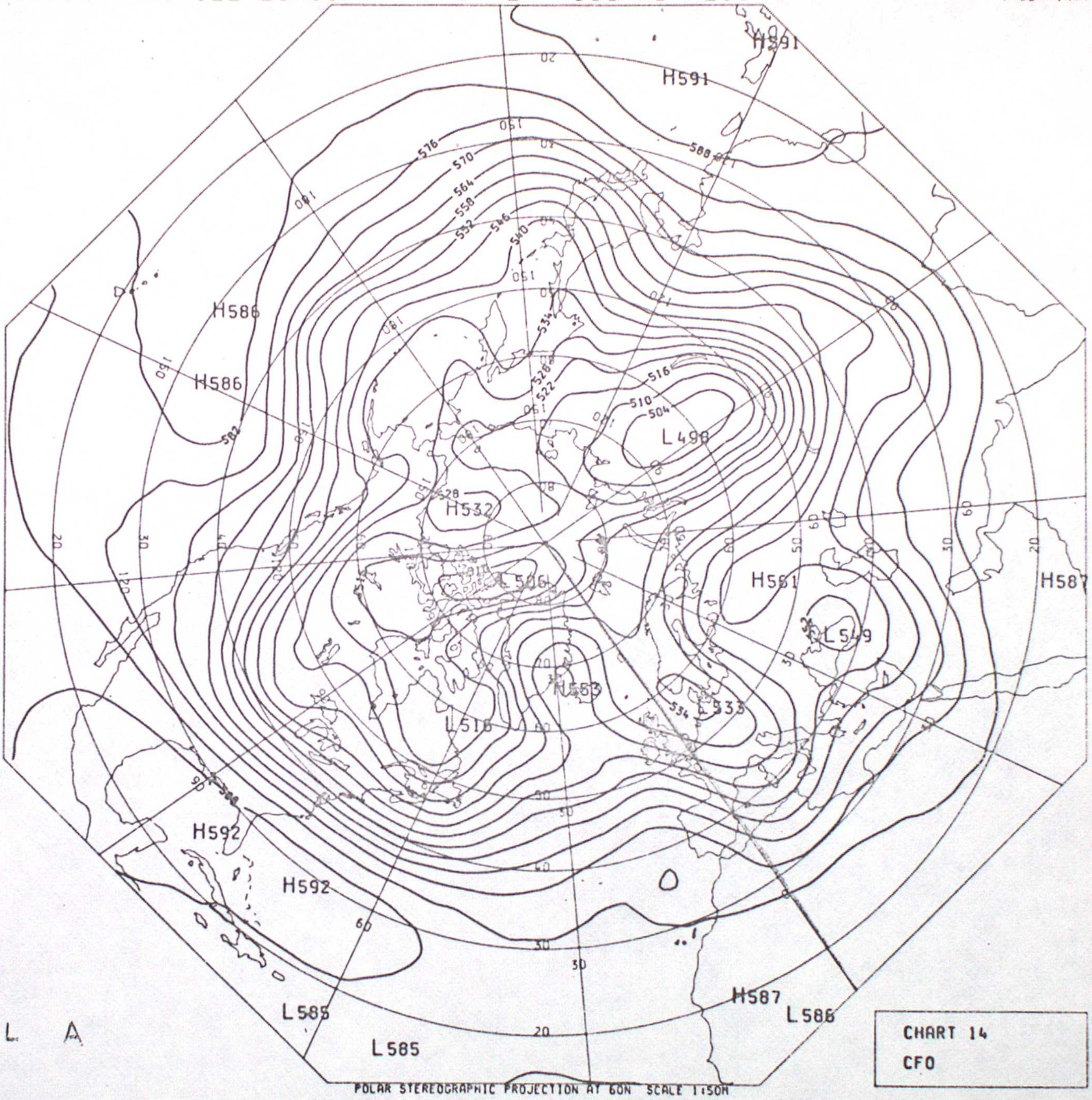


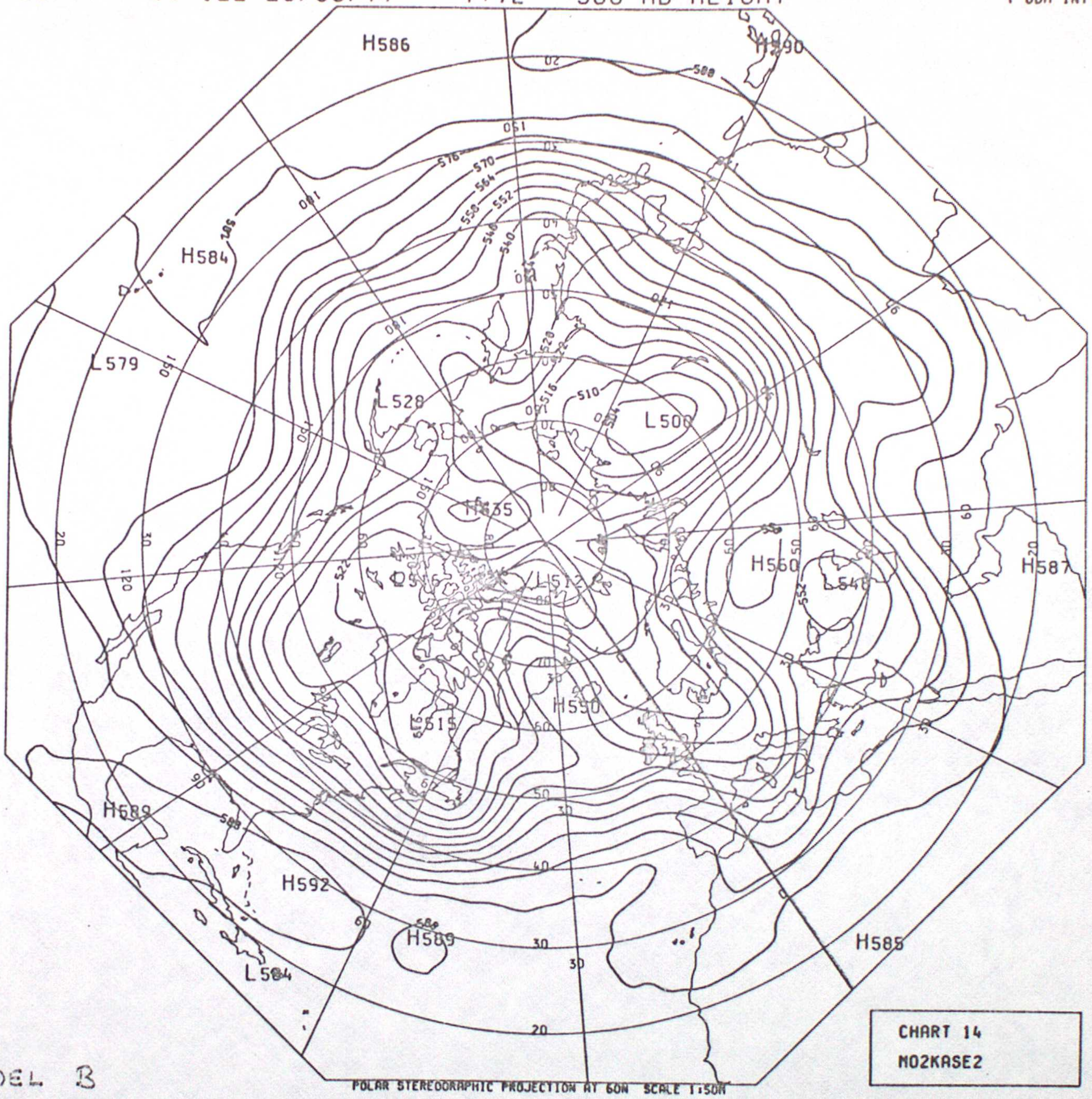
POLAR STEREOGRAPHIC PROJECTION AT 60N SCALE 1:50M

MODEL A

CHART 14
CFO

10 LEVEL σ MODEL 500MB DAY3

12Z 17/03/77 VT 12Z 20/03/77 T+72 500 MB HEIGHT (60M INT) UPDATE



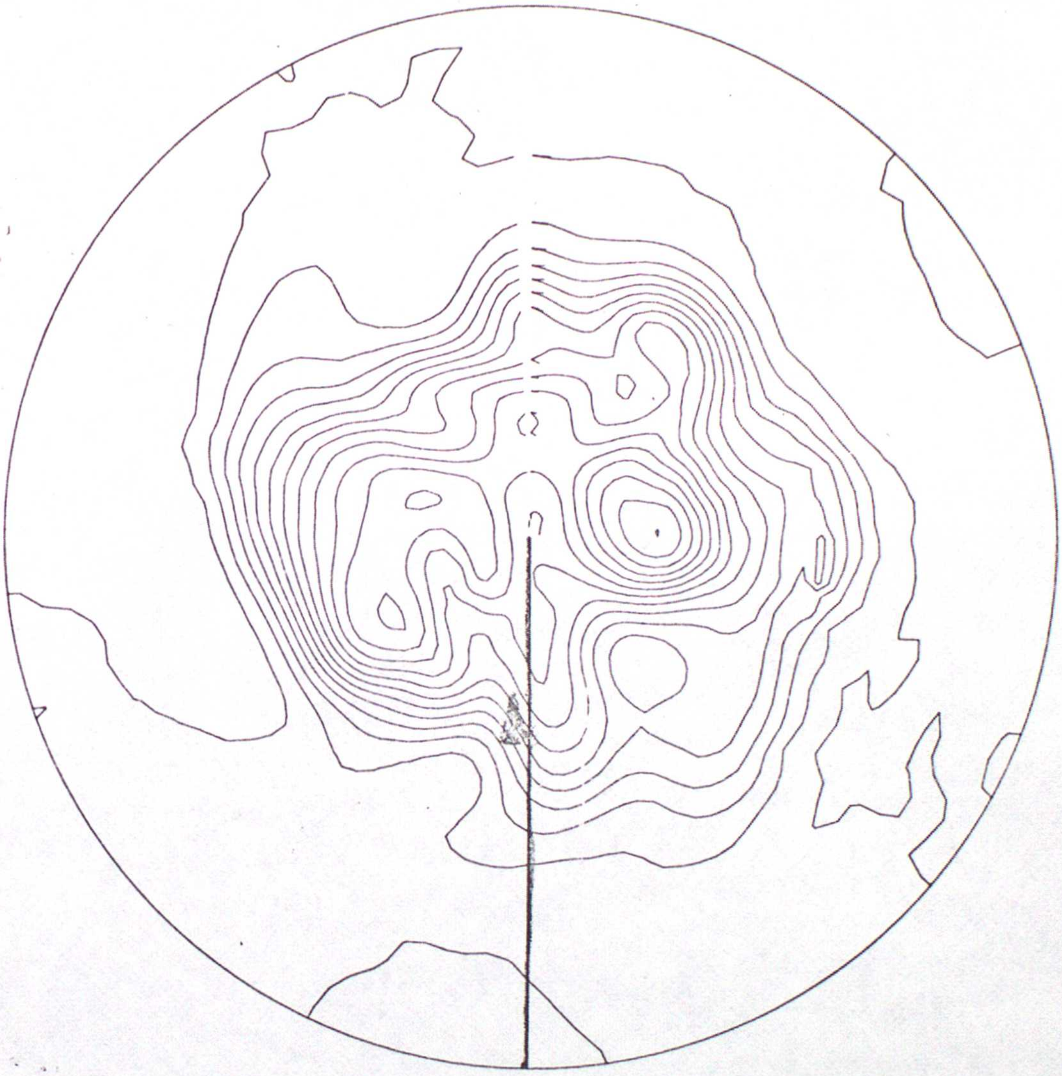
POLAR STEREOGRAPHIC PROJECTION AT 60N SCALE 1:50M

CHART 14
MO2KASE2

MODEL B

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

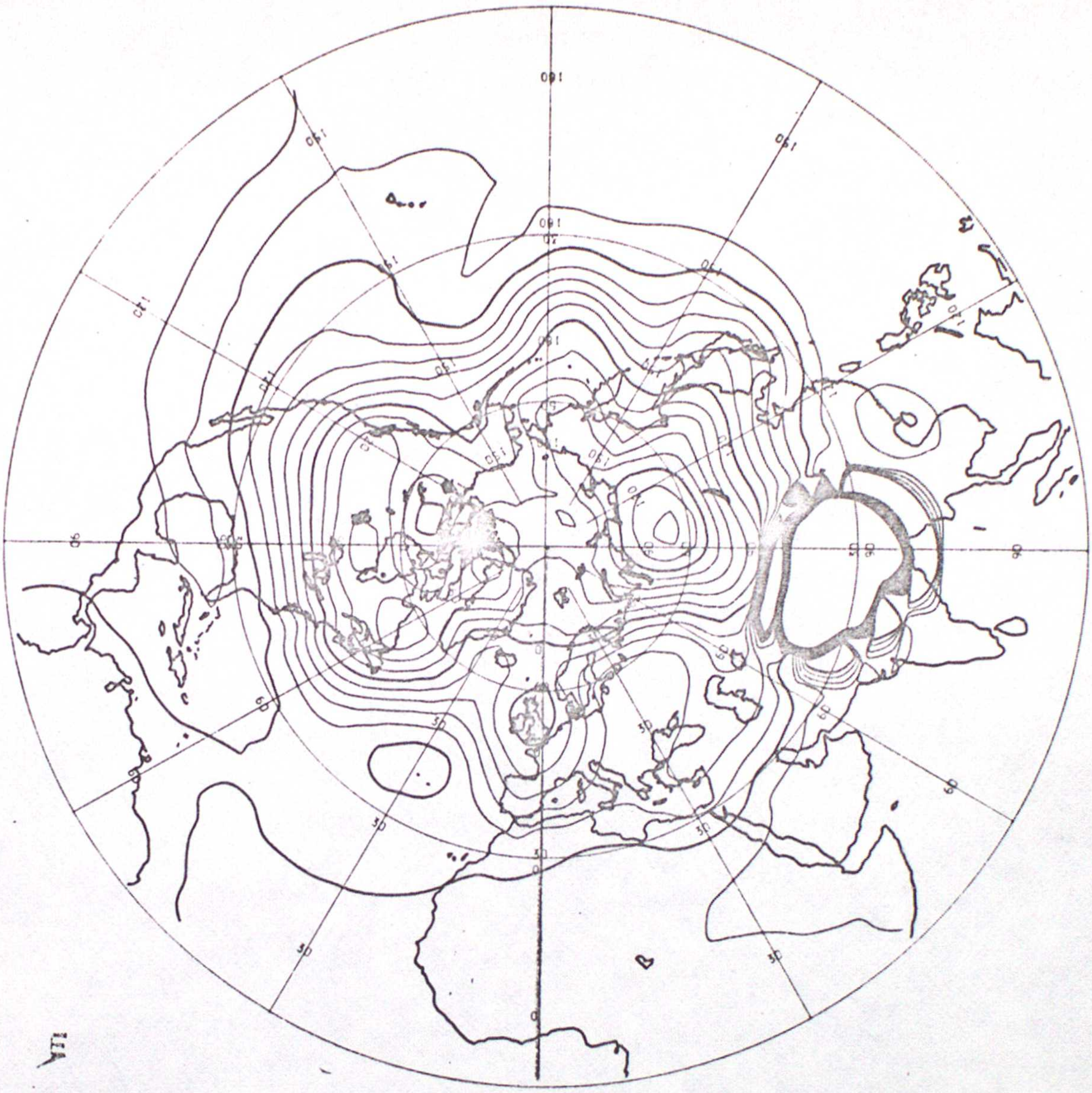
11 LEVEL MODEL
500 MB
DAY 3
MODEL C



500 MB HEIGHT DAY 3

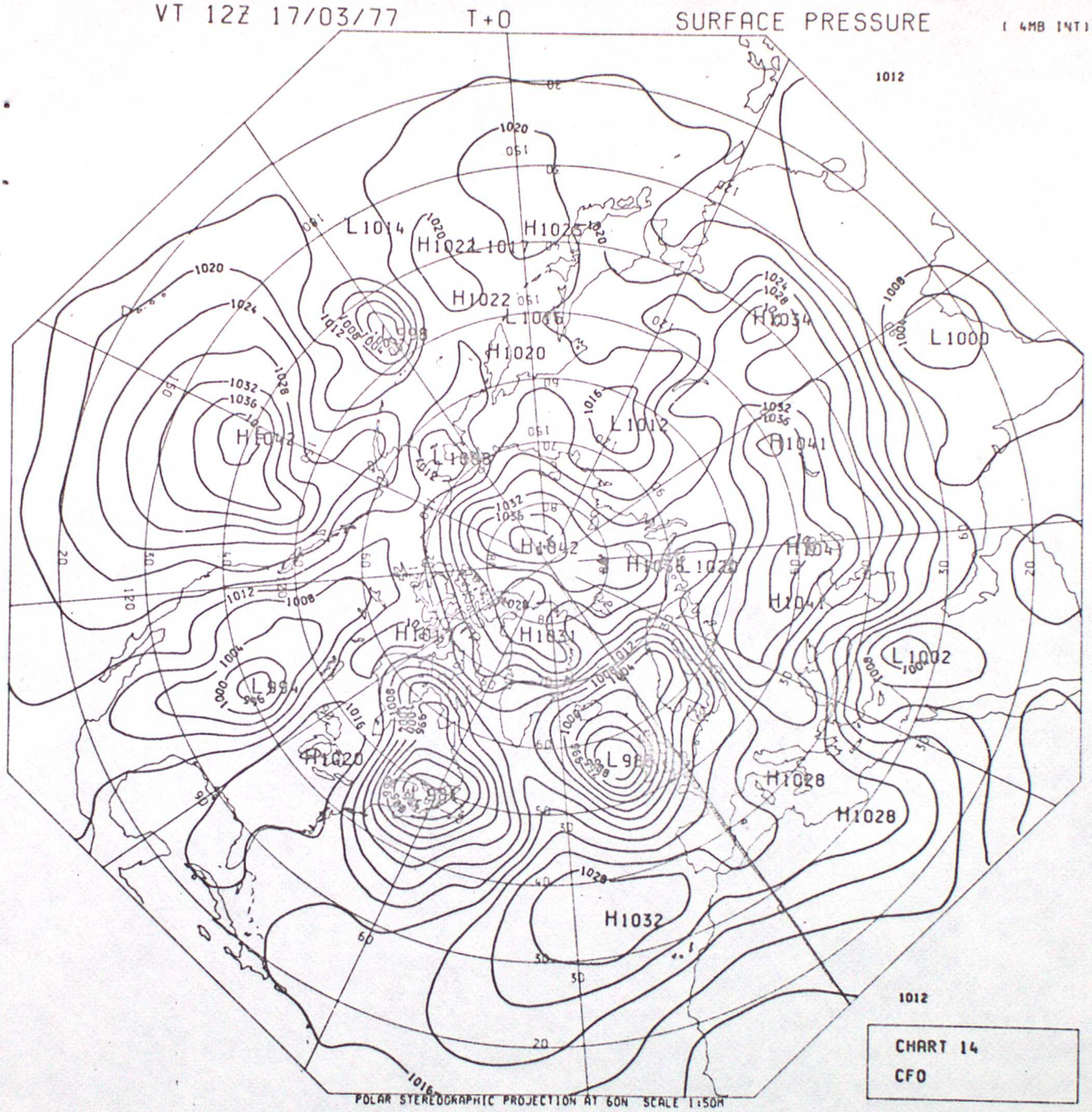
MODEL D SPECTRAL MODEL

H DAY 3 F.E.FORECAST FROM 17 3 77 500MB VP



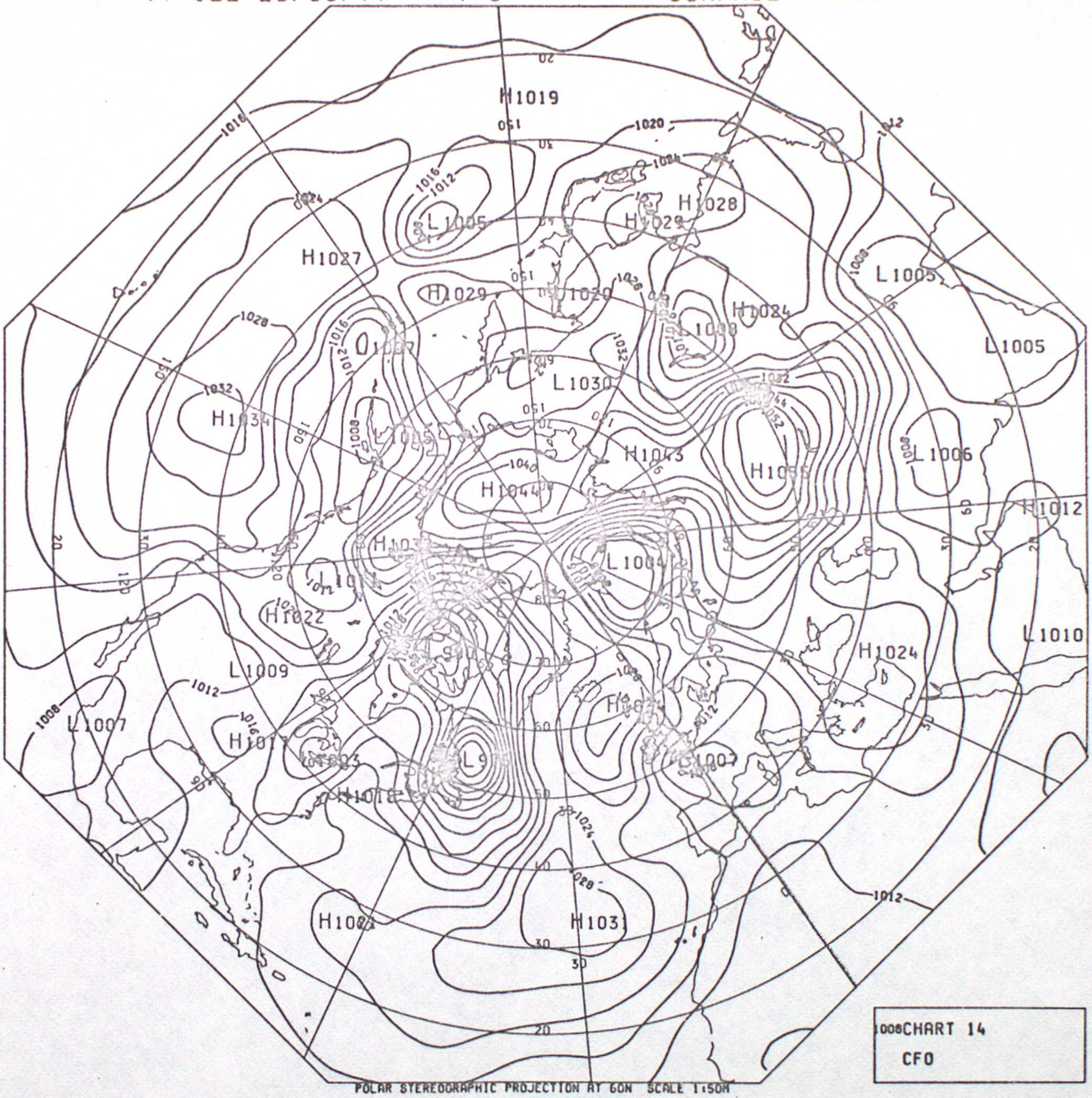
MODEL E

ACTUAL SURFACE PRESSURE DAY 0



ACTUAL SURFACE PRESSURE DAY3

VT 12Z 20/03/77 T+0 SURFACE PRESSURE (4MB INT)



POLAR STEREOGRAPHIC PROJECTION AT 60N SCALE 1:50M

CHART 14
CFO

10 LEVEL p MODEL SURFACE PRESSURE DAY3

DT 12Z 17/03/77 VT 12Z 20/03/77 T+72 SURFACE PRESSURE : 4MB INT

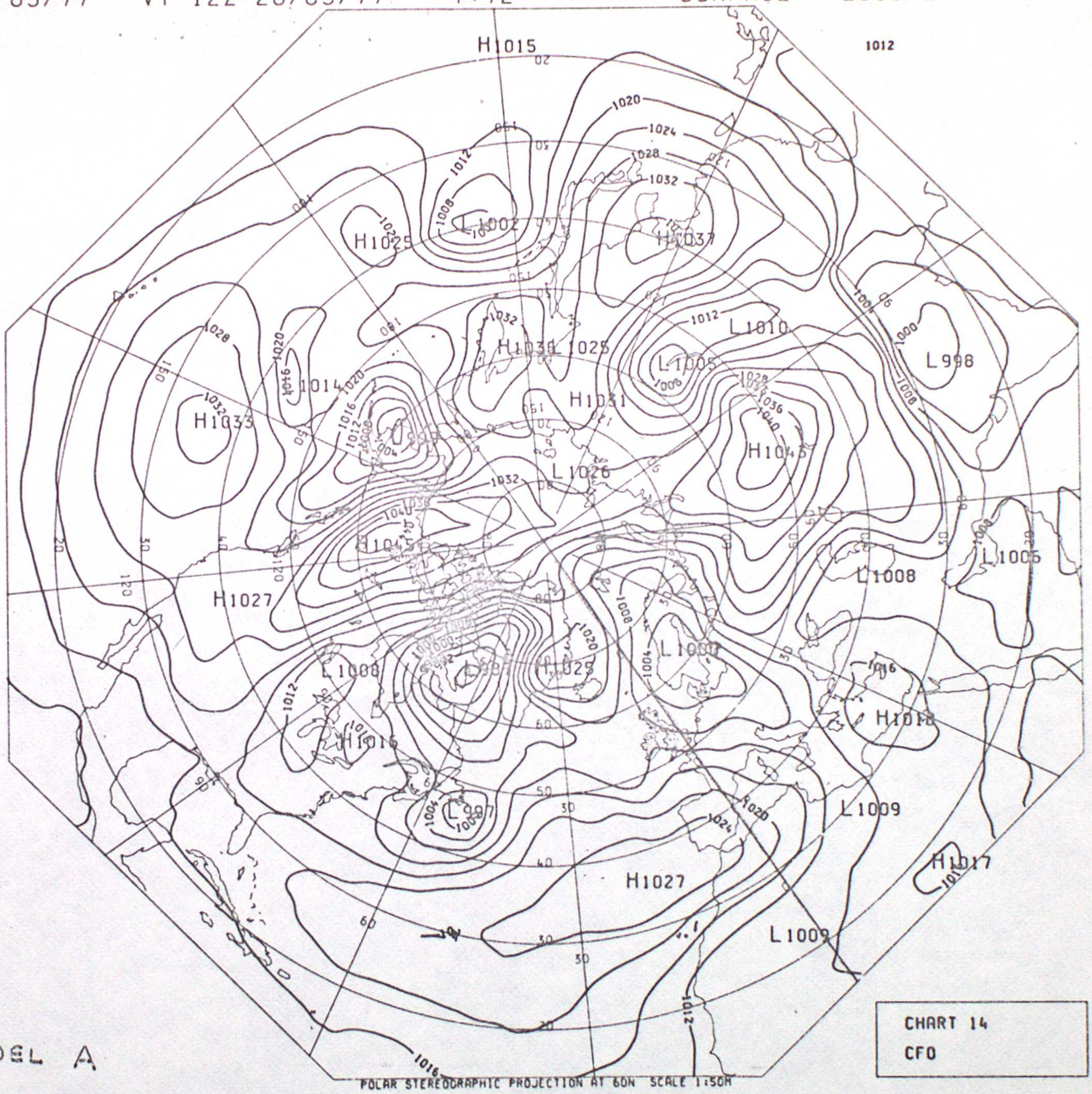


CHART 14
CFO

MODEL A

10 LEVEL σ MODEL SURFACE PRESSURE DAY3

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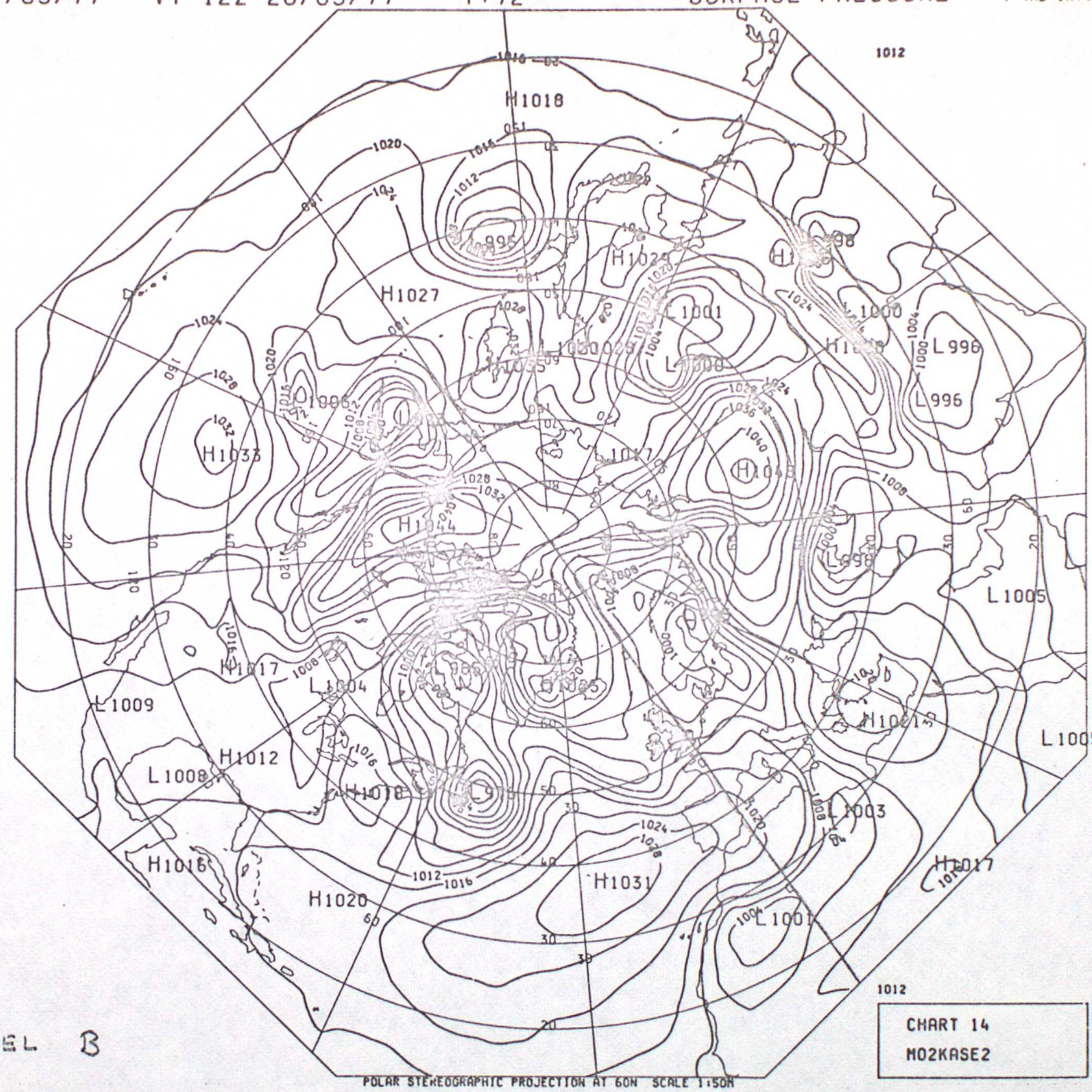

POLAR STEREOGRAPHIC PROJECTION AT 60N SCALE 1:50M

MODEL B

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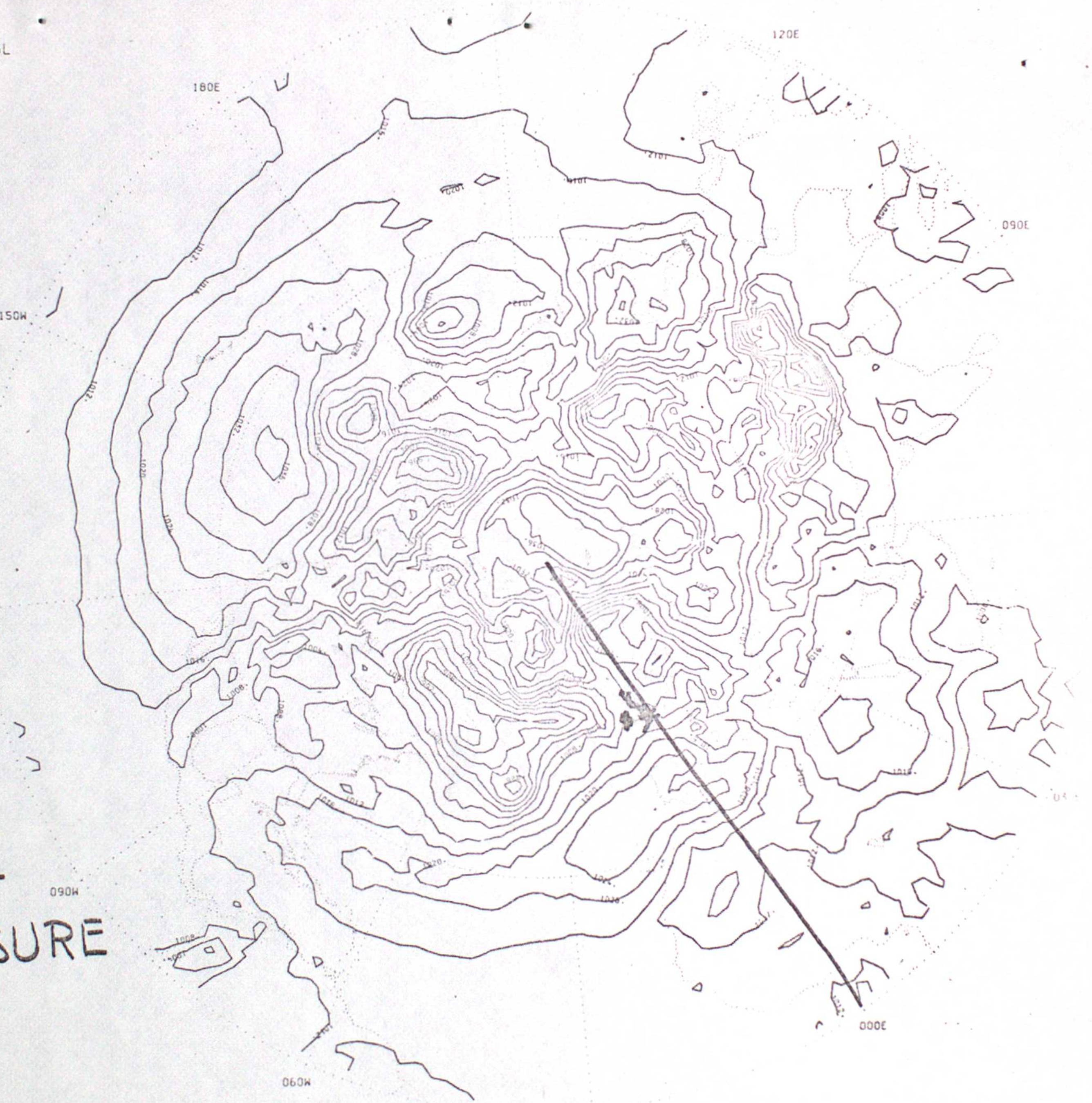
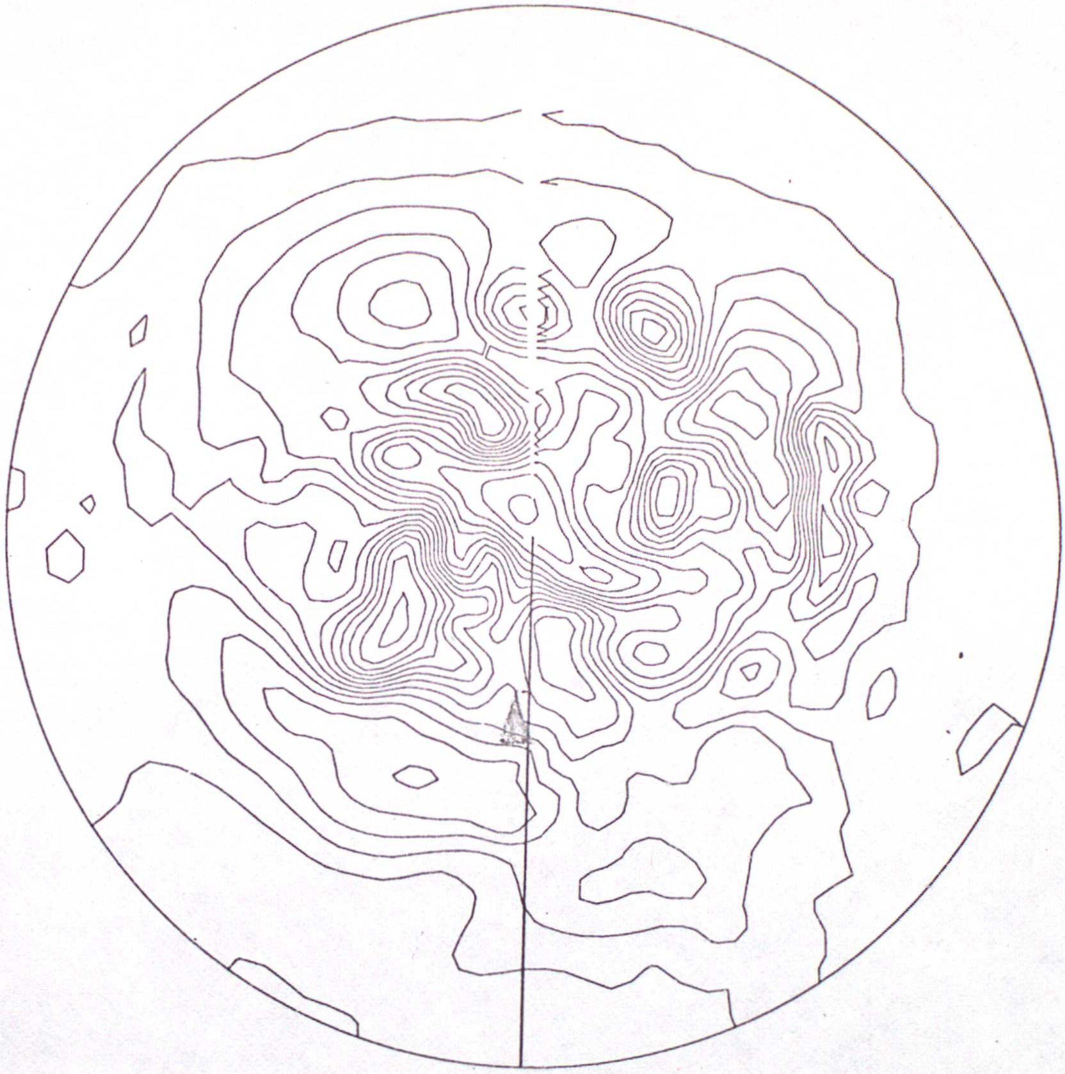


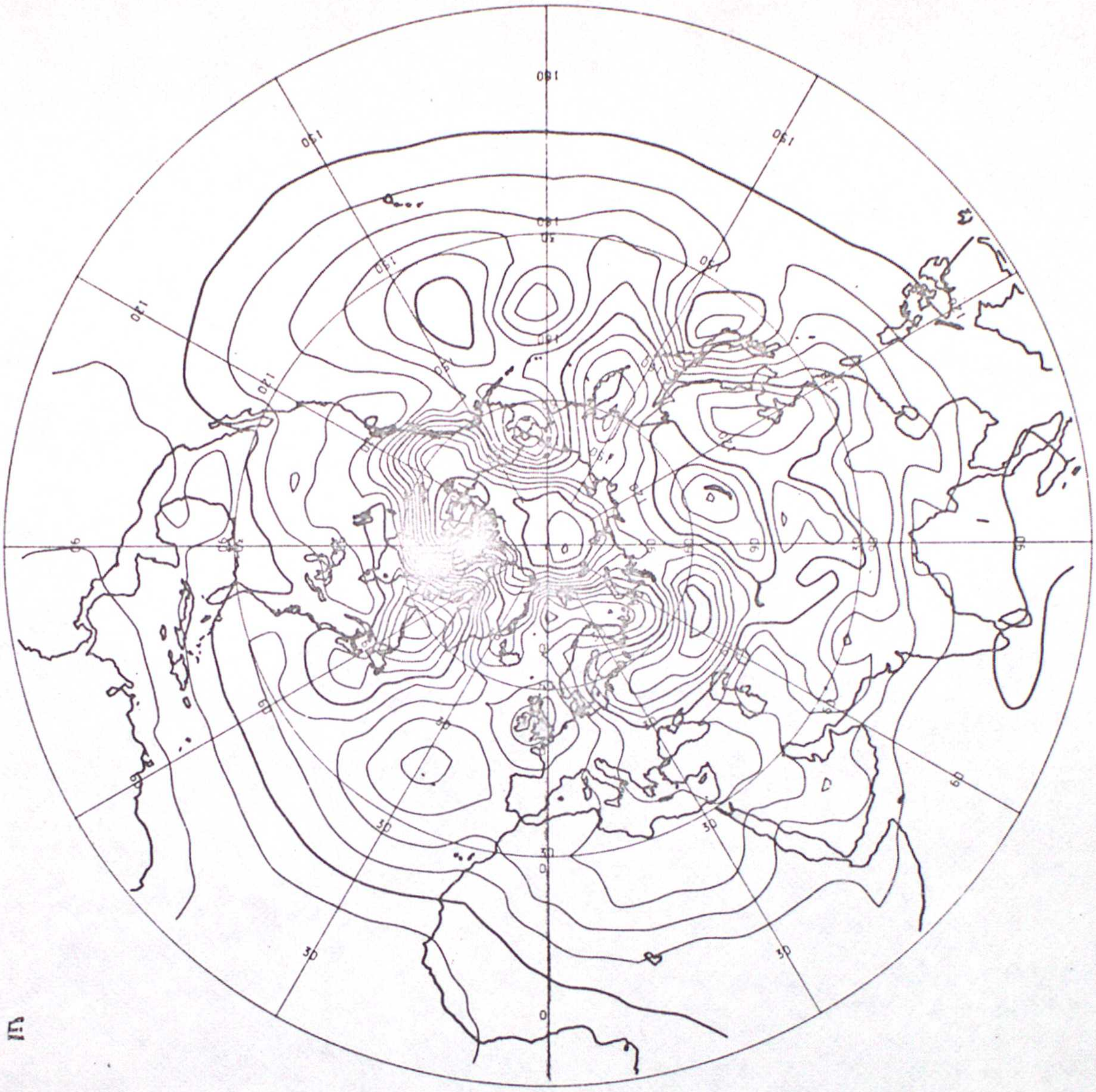
11 LEVEL MODEL
SURFACE PRESSURE
DAY 3
MODEL C



SURFACE PRESSURE AT DAY 3

MODEL D SPECTRAL MODEL

H DAY 3 F.E.FORECAST FROM 17 3 77 PMSL VP



MODEL E

500 MB CONTOURS CONTOUR LINES AT 6 DECAMETER INTERVALS

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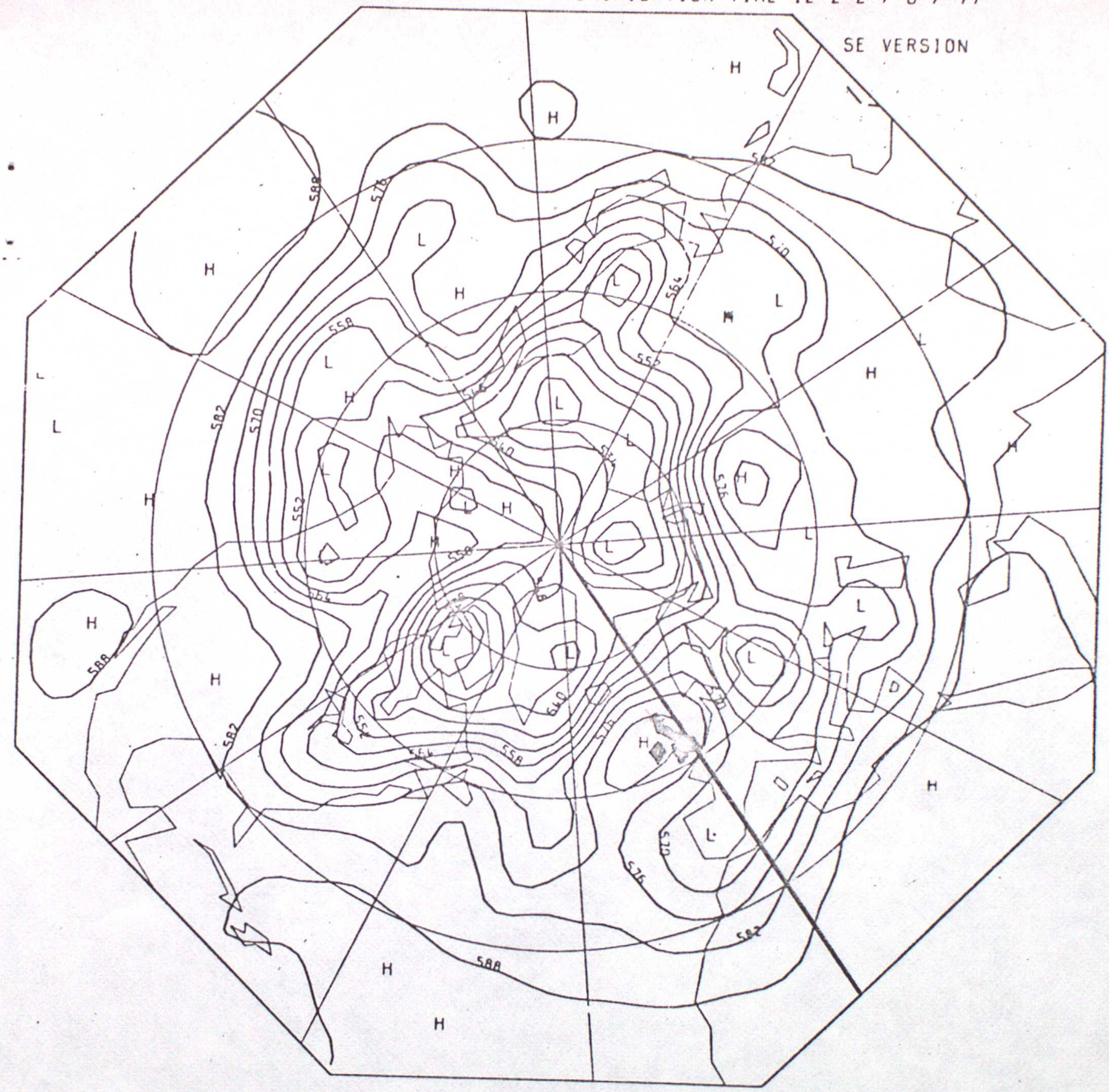

ACTUAL 500mb DAY 0

500 MB CONTOURS CONTOUR LINES AT 6 DECAMETER INTERVALS

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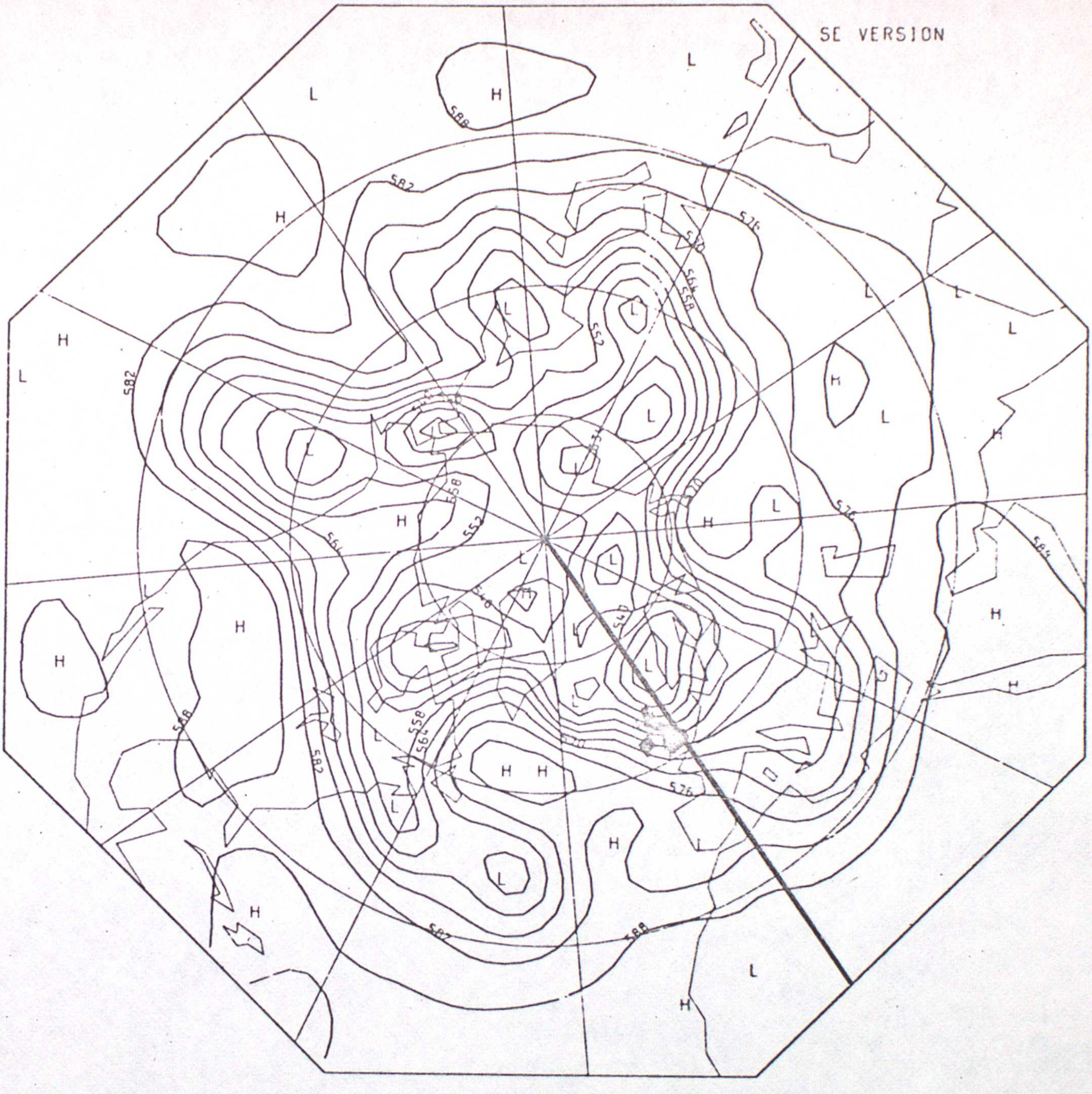

ACTUAL 500mb DAY 3

10 LEVEL MODEL 500mb DAY 3

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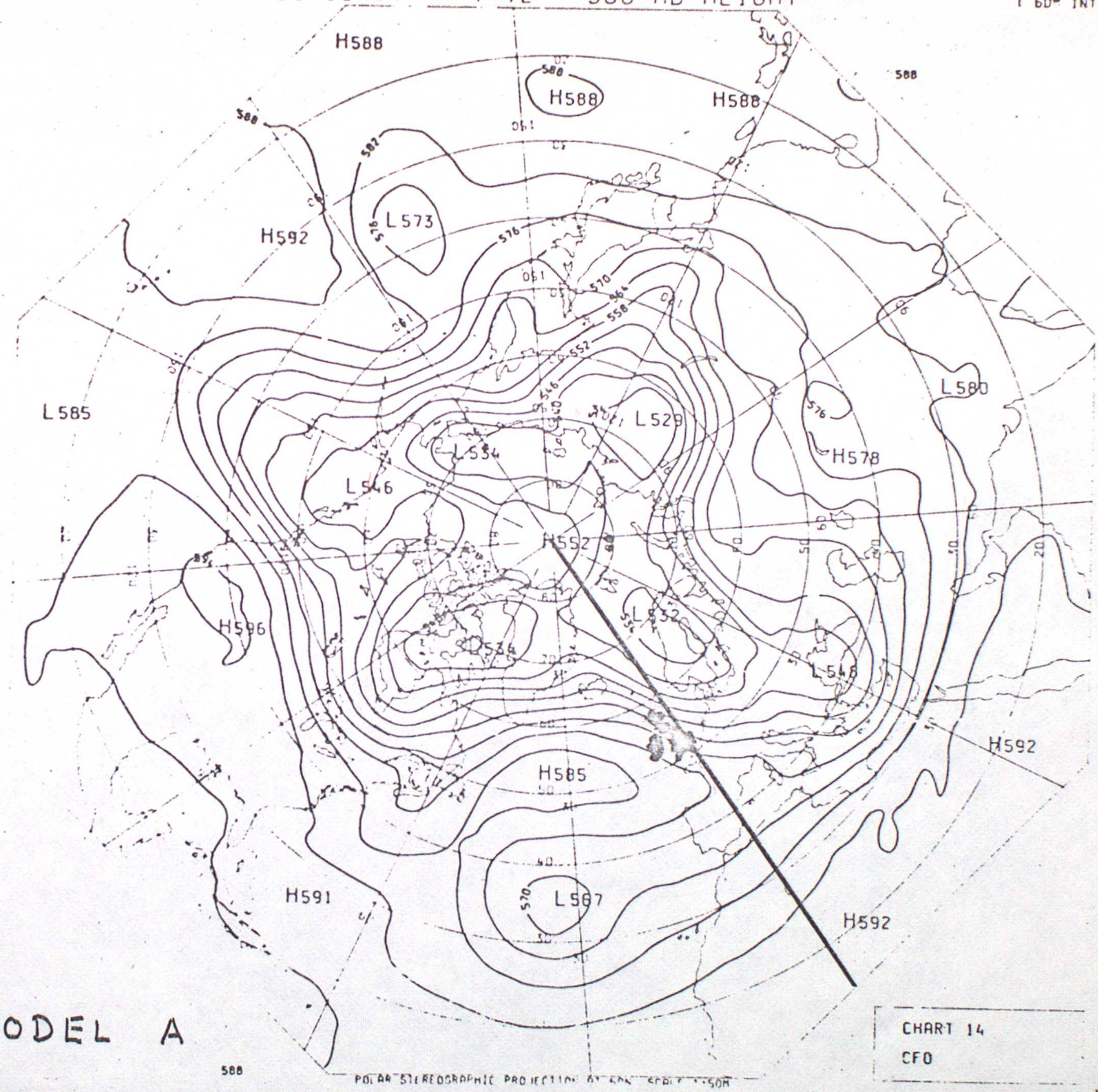
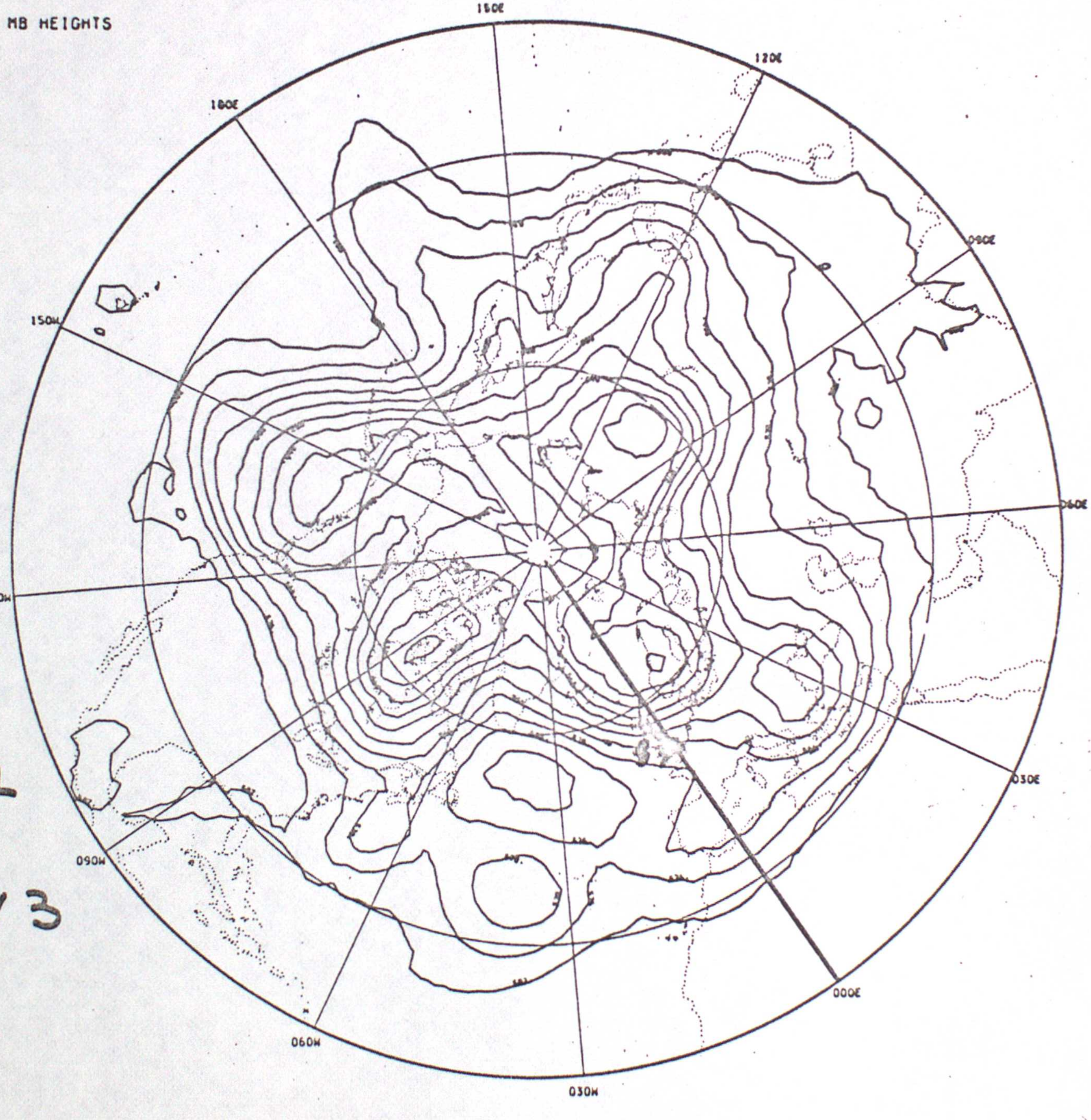


MODEL A

CHART 14
CFO

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



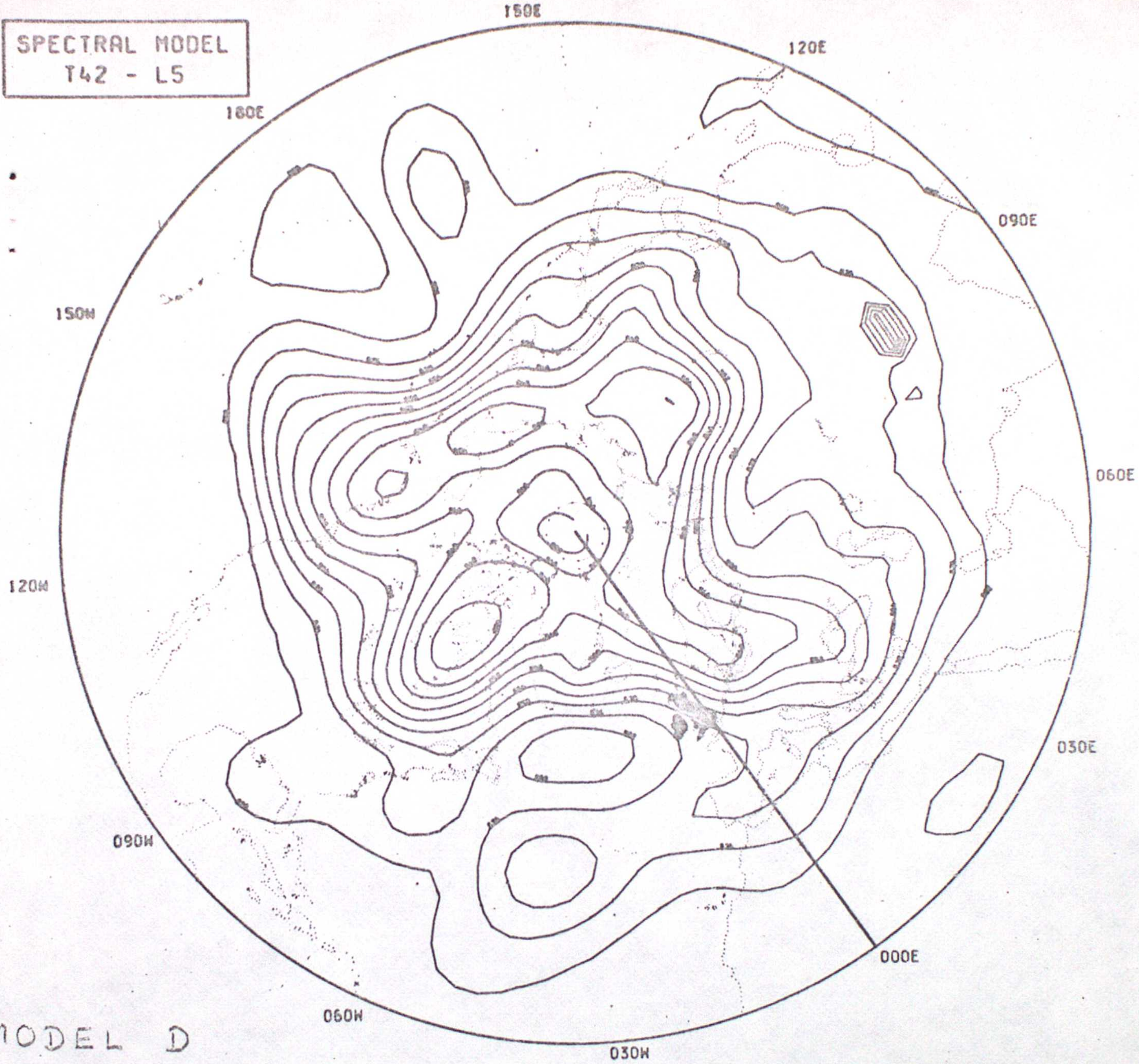
11 LEVEL MODEL

500mb DAY 3

MODEL C

DATA TIME - 12Z 2/6/77

SPECTRAL MODEL
T42 - L5



MODEL D

500MB CONTOURS AT DAY 3.00

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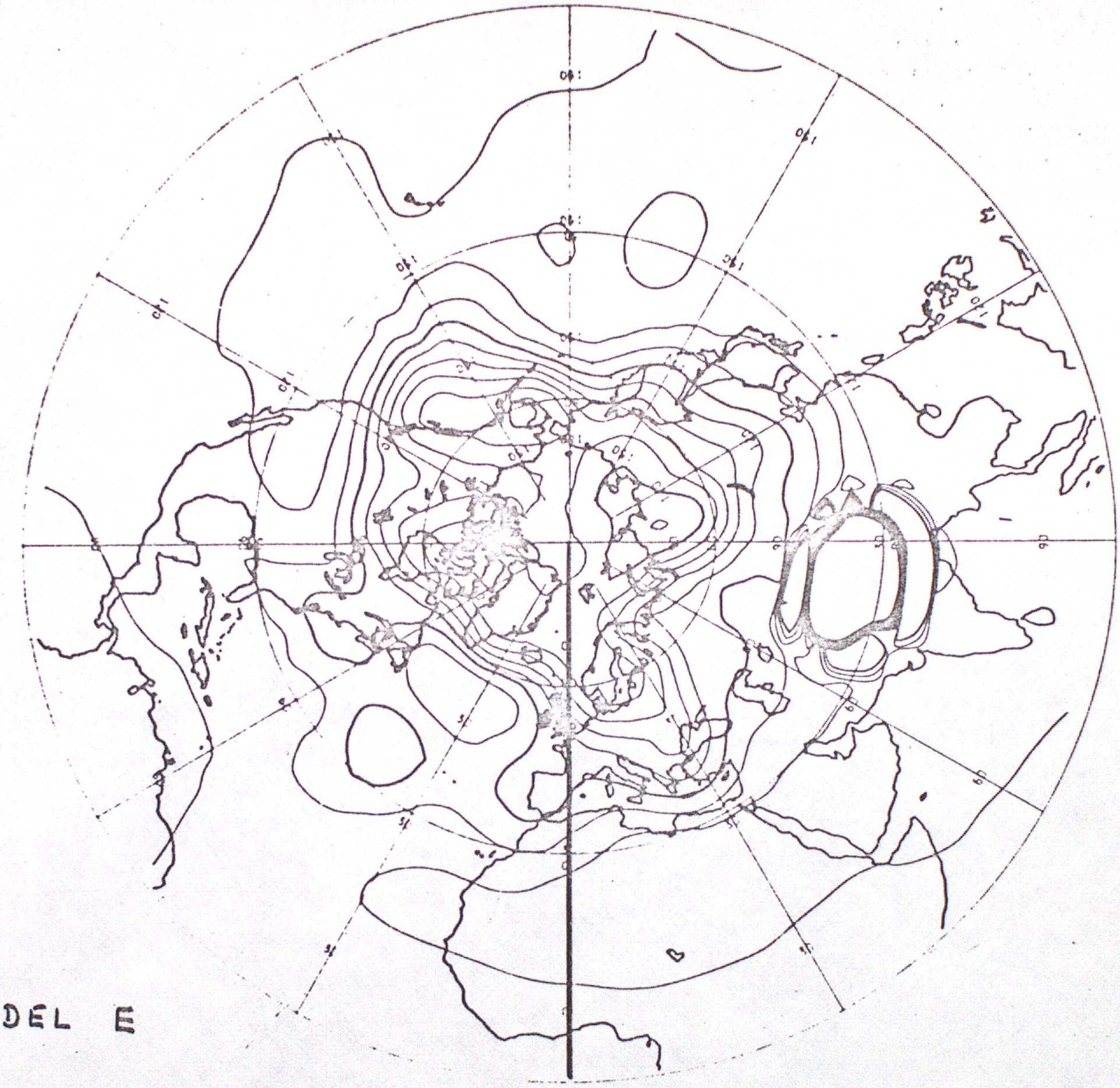
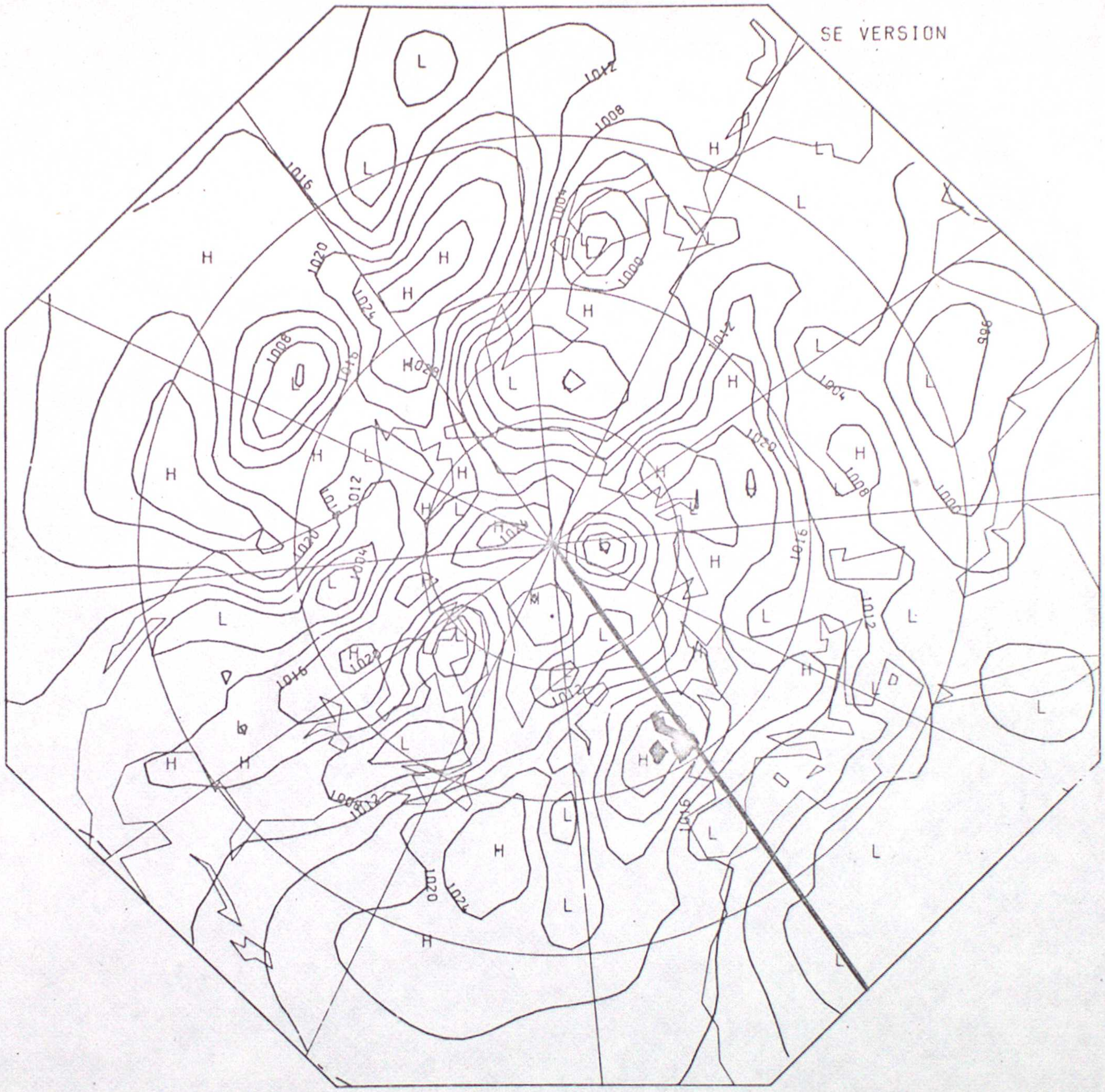


MODEL E

SURFACE PRESSURE ISOBARS AT 4MB INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 2 / 6 / 77. VERIFICATION TIME 12 Z 2 / 6 / 77

SE VERSION



ACTUAL SURFACE PRESSURE DAY 0

SURFACE PRESSURE ISOBARS AT 4MB INTERVALS

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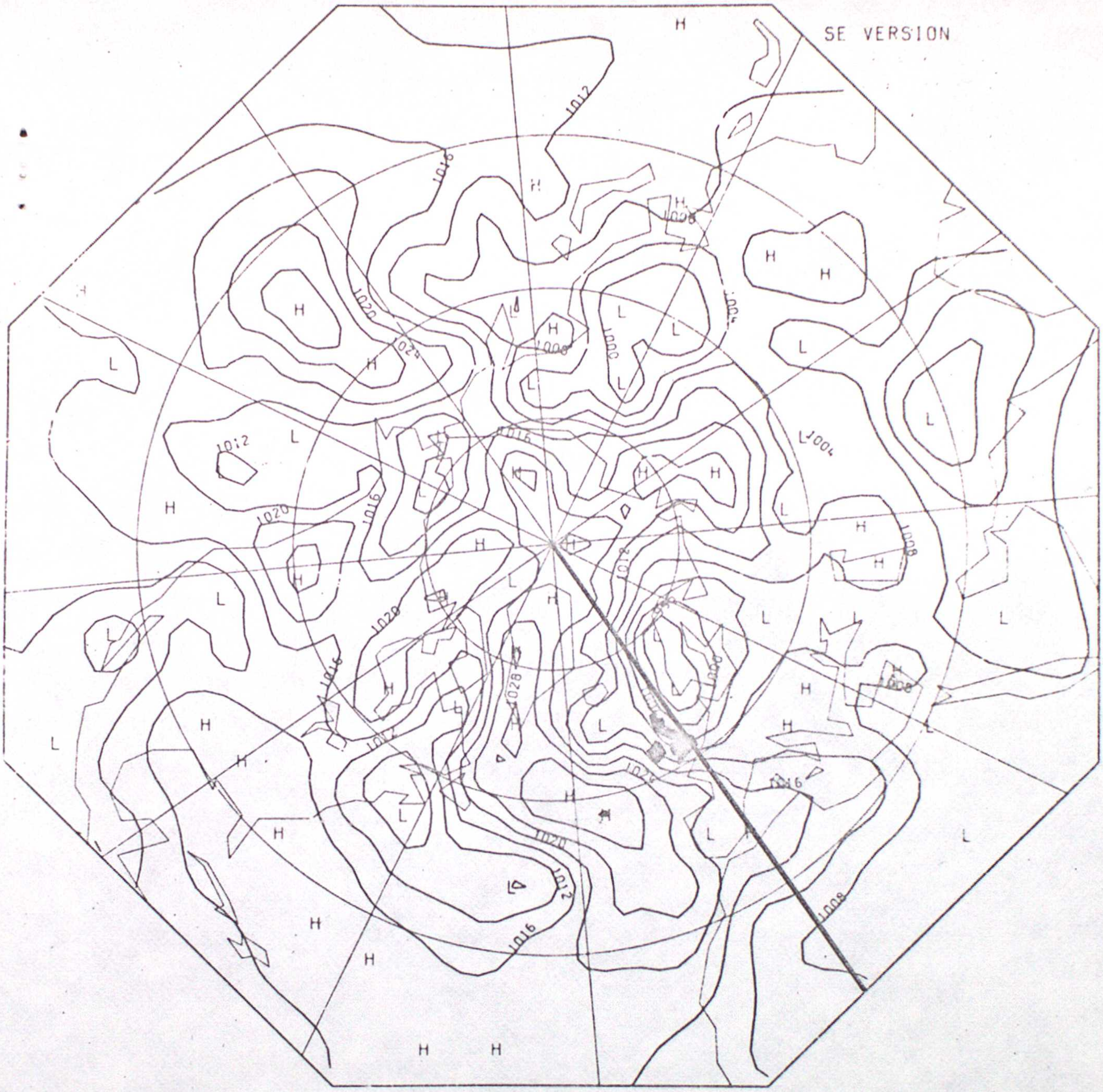
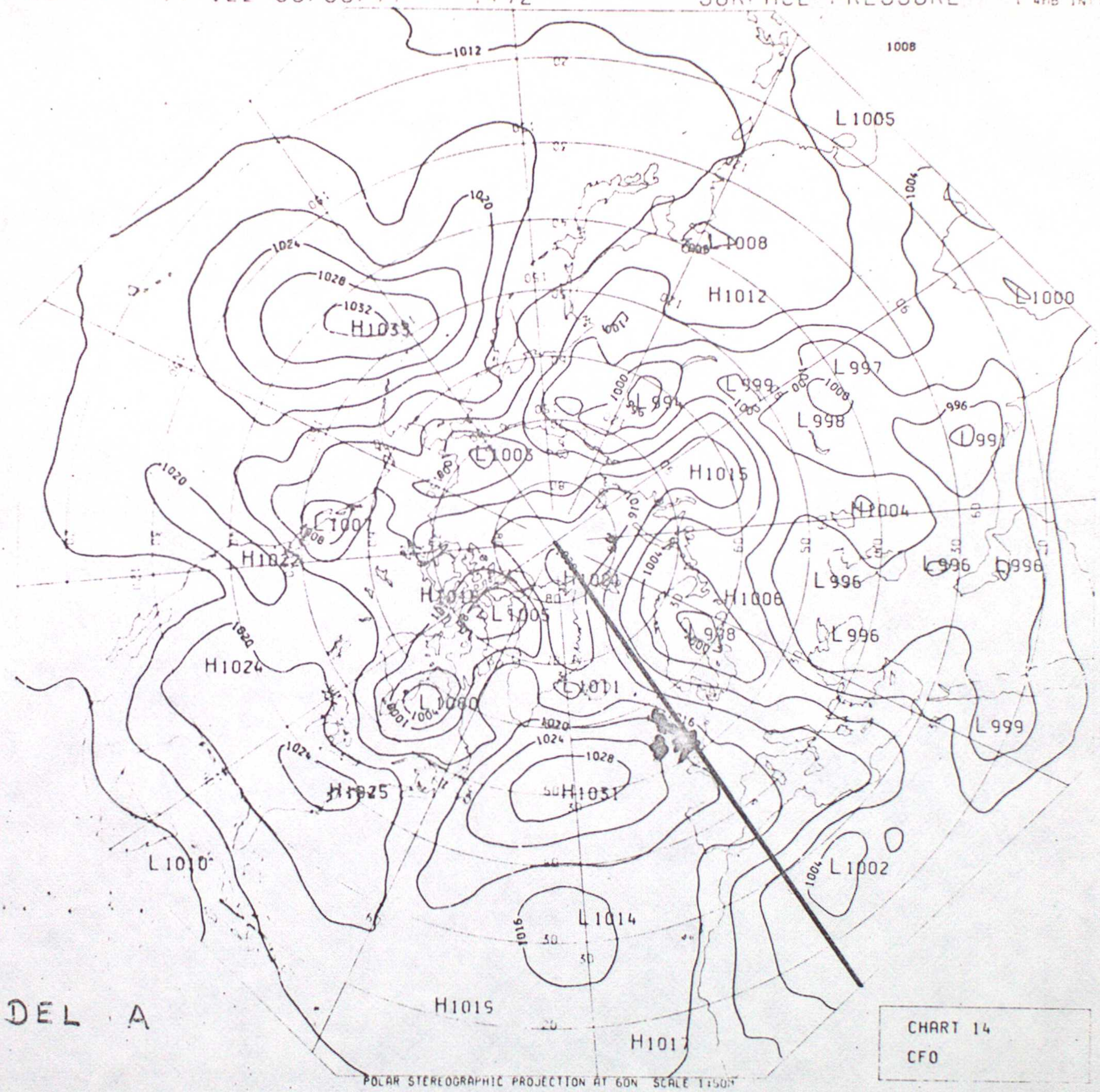


ACTUAL SURFACE PRESSURE DAY 3

10 LEVEL MODEL SURFACE PRESSURE DAY 3

DT 12Z 02/06/77 VT 12Z 05/06/77 T+72 SURFACE PRESSURE (4MB INT)



MODEL A

POLAR STEREOGRAPHIC PROJECTION AT 60N SCALE 1:50M

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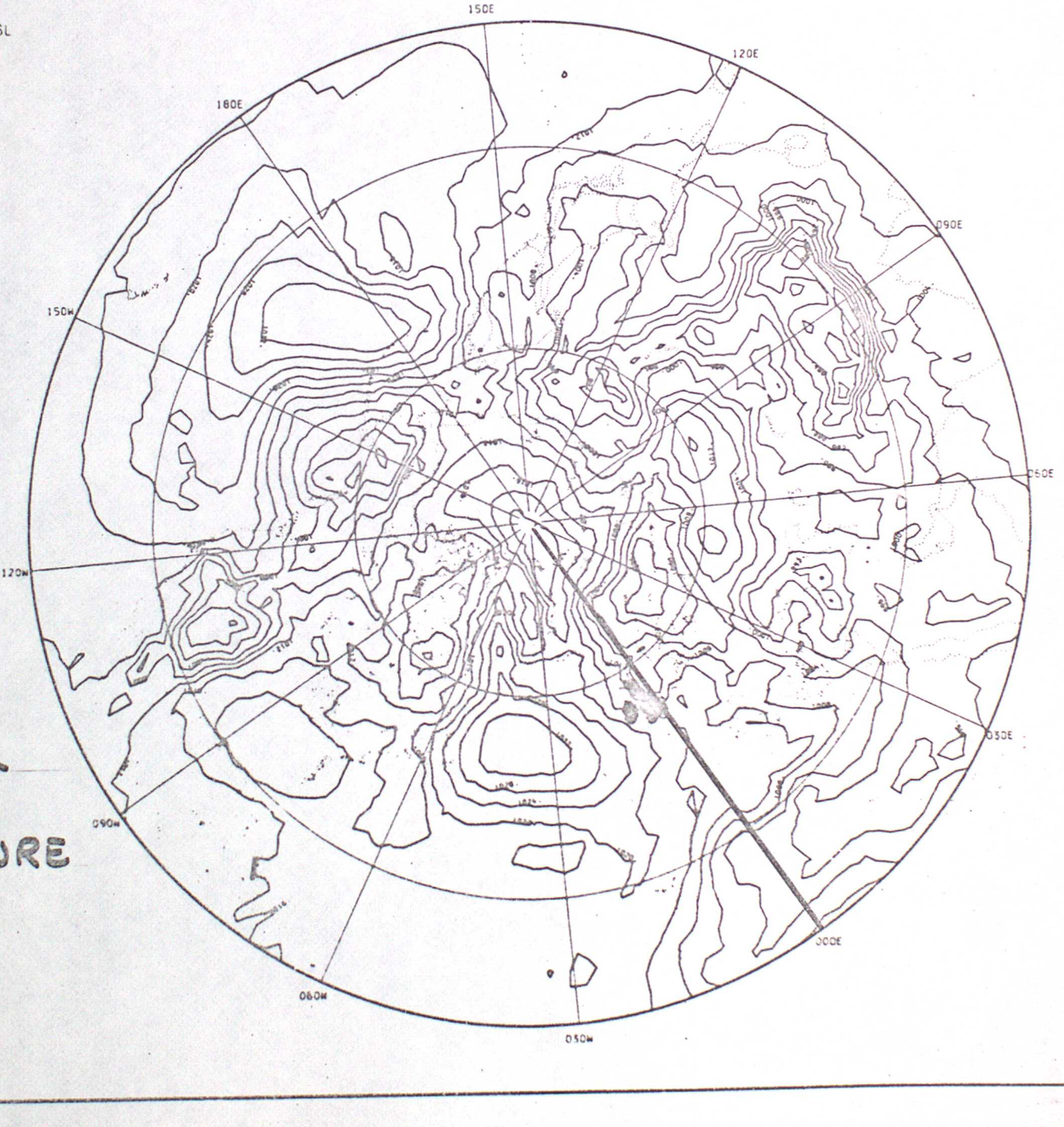


11 LEVEL MODEL

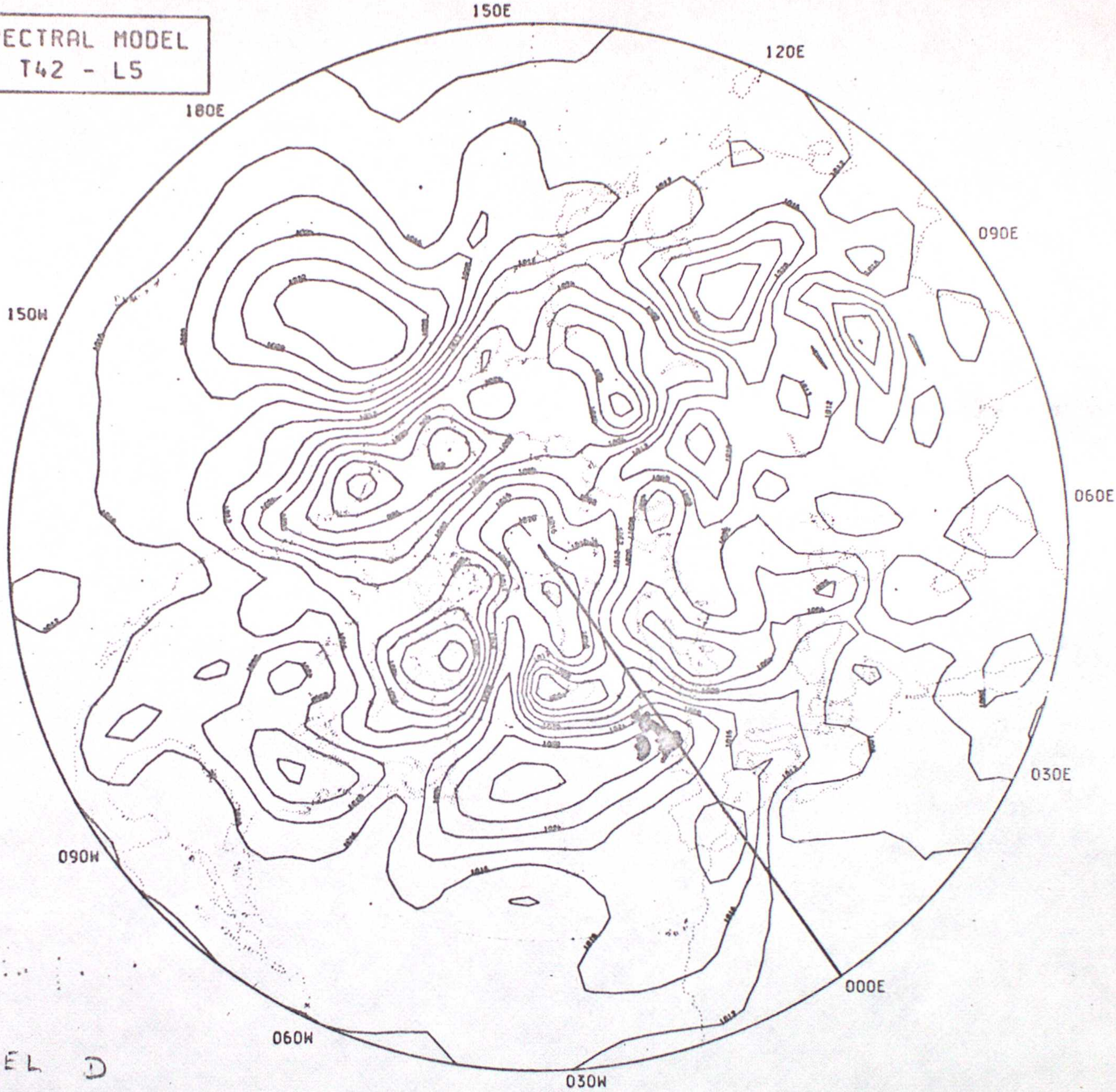
SURFACE PRESSURE

DAY 3

MODEL C

DATA TIME - 12Z 2/6/77

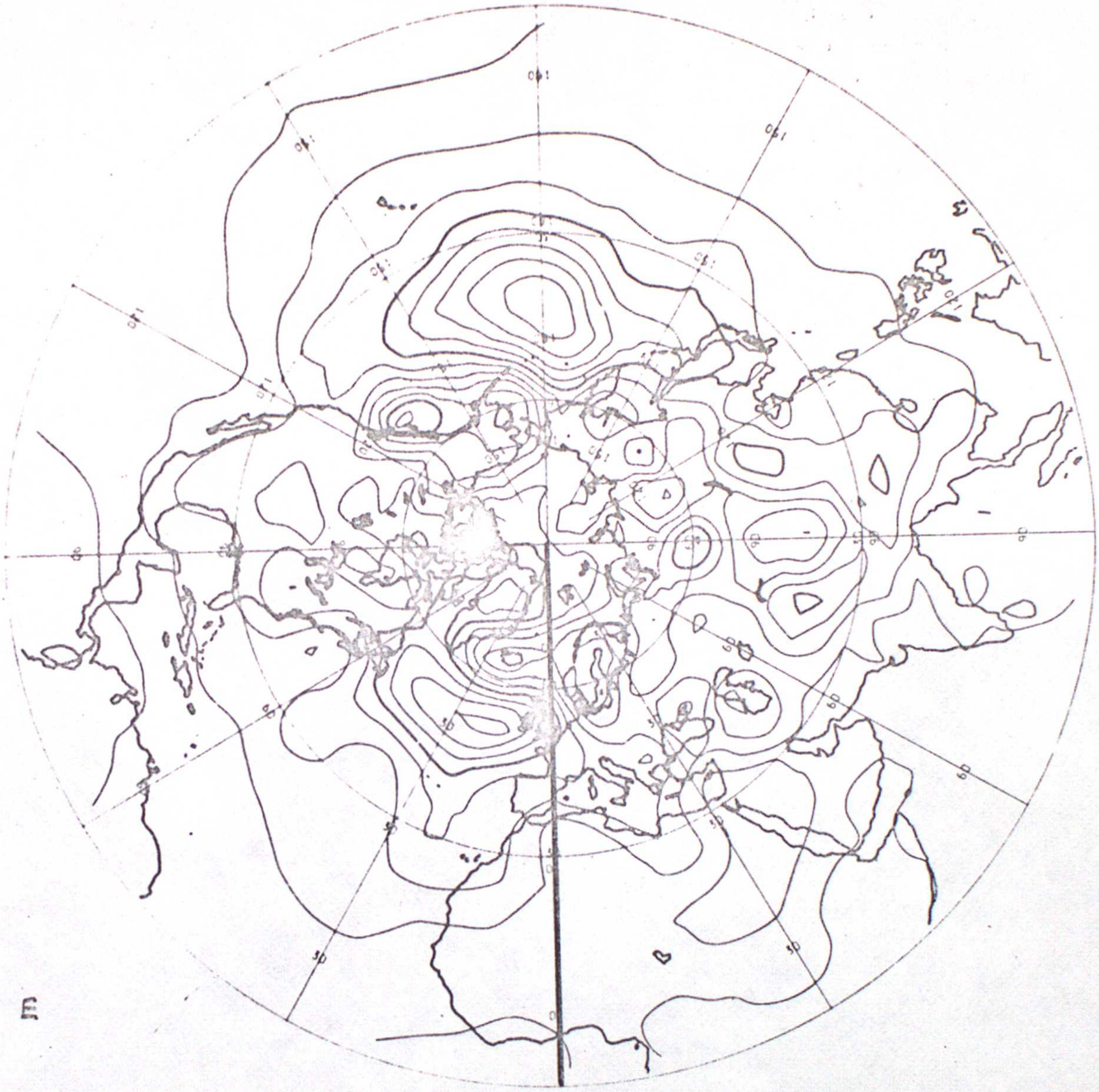
SPECTRAL MODEL
T42 - L5



MODEL D

SURFACE PRESSURE AT DAY 3.00

H DAY 3 F.E.FORECAST FROM 2 6 77 PMSL VP



MODEL E