MET O 11 TECHNICAL NOTE NO. 125

FOUR-DIMENSIONAL DATA ASSIMILATION USING A DAMPED INTEGRATION SCHEME

BY

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The authors of this note have merely run the experiment and assessed the results. Its origin and construction are due to previous members of the Analysis Group and its conception is already described in two previous Met O 11 Technical Notes - Maryon (1977) and Atkins (1977).

1. Introduction

This note describes the results obtained by the Met O 11 Four-Dimensional Data Assimilation Scheme (Maryon 1977) when a damped integration scheme is used to remove spurious waves. Such a development was suggested by Maryon (1977) and the integration scheme, which damps only the external and first internal mode of the 10-level model, is described by Atkins (1977). Since these two notes describe the assimilation and integration schemes in detail, only the briefest of descriptions is given below.

The experiment was started from the 12Z operational update analysis run of 29th March 1977 using data restored from Met O 12 archive data bank tapes, and Met O 2 'DTT' tapes. Assimilation of height and wind data was carried out every 3 hours for 120 hours up to and including 12Z 3rd April 1977.

The assimilation uses a combined wind and height analysis. The height data is vertically interpolated to model levels, then horizontally interpolated to the grid points using optimum interpolation with the forecast field as background. The wind field is then adjusted by adding a geostrophic wind increment (reflecting the changes in geopotential), prior to its use as a background for the vertical and horizontal interpolation of the wind data. Quality control was used on both the height and wind data.

For the first 12 hours of assimilation the scheme was identical to that described by Maryon (1977), but after this period the normal integration was replaced by the damped scheme, and from 12Z 30th March 1977 the divergence adjustment step was dropped from the end of the wind assimilation. It was hoped that the damped integration scheme would be sufficient to control the growth of spurious waves.

During the running of the experiment, faults became apparent on two occasions, 15Z 31/3/77 and 00Z 1/4/77 when spurious winds were observed at the lower right hand boundary of the octagon. On both occasions the problem was traced to programming errors in interpolating wind to the grid points on that boundary. These were corrected and should have little impact on the results presented.

A 24 hour forecast was run from the final assimilation of 12Z 3/4/77.

2. Results of Experiment

The analyses at the main synoptic hours (00Z and 12Z) were compared subjectively with the operational initialised fields, and with the working charts of the Central Forecasting Office (CFO). The latter were regarded as the closest approximations to "truth" that were available. In the following account only the charts valid at 12Z are depicted and these only for the two models. Figures 1 to 6 contain the charts valid at these times commencing at 12Z 29/3/77, and are further subdivided as follows

(a) Surface analysis (4D)

(b) Surface analysis (Operational)

(c) 500 mb analysis (4D)

(d) 500 mb analysis (Operational)

The abbreviation 4D is used to denote the experimental assimilation scheme.

The main differences between the charts are listed and labelled 1, 2, 3 . . . . . etc, and a feature which appears on successive charts retains the same label.

2.1 1200Z 29/3/77 Figure 1

This is the synoptic situation at 1200Z 29/3/77, the start of the experiment.

2.2 1200Z 30/3/77 Figure 2

The main differences between the operational and 4D analyses at the surface were

1. The low in mid-Atlantic (4D much worse, see below)
2. The low complex over Mexico (4D better, but pressure still $\approx$ 4 mb too high)
3. The low around 24N 168W (4D better)
4. The low around 45N 175W (4D better)
5. The low around 35N 135E (4D better)
6. The low around 70N 2E (4D better, but still about 6 mb too high)

Of the above, the major discrepancy is obviously 1. This low had undergone explosive deepening as the Newfoundland 500 mb trough moved East, was reinforced

by the cold air brought down by the Greenland high, and met with a baroclinic wave moving N.E. in the relaxing Atlantic trough. This deepening had occurred since 0001Z and a check on the 0001Z charts showed that the 4D analysis had been good (better than the operational). The deepening had been greatly underforecast by both the operation 12 hour forecast run from midnight data, and a test forecast run from the 4D analysis using damped integration (Maryon 1977).

It is in these circumstances, when the background forecast is at fault, that the 4D assimilation technique might be looked on to give a better analysis to replace the background forecast. However, the 4D assimilations at 03Z, 06Z, 09Z and 12Z persistently refused to accept good observations, notably weather ships C7C and C7L, and ended with a central pressure of 985 mb. The operational initialisation gave a better position and a central value of 970 mb (975 mb before bogussing), which compares with the "true" value of 965 mb.

At 500 mb the main differences were

1. Central Atlantic trough (little to choose between two analyses)
2. Low/High pattern around 30N and 150W (4D slightly better)
3. Shape of trough near 50N 93E (4D slightly better)

These differences were all small.

2.3 1200Z 31/3/77 Figure 3

The main differences at the surface were

1. Low East Atlantic (see below)
2. Over Mexico (4D gave better shape but the operational pressure was better)
4. Low 50N 170W (4D better)
5. Low 40N 145E (4D better)
7. Low 58N 100W (4D better)
8. Low 60N 130E (4D worse, this low had filled rapidly and the 4D analysis was lagging)
9. Low over Bengal (4D better)

The main East Atlantic centre on the CFO charts was about 971 mb at 55N 18W, with further centres at 71N 7E (983 mb), 63N 7W (975 mb) and 39N 35W (1007 mb),

and the 4D analysis was slightly better. It had, however, performed unsatisfactorily for most of the previous 24 hours and the comments made in 2.2 concerning the low could be repeated here. For example at midnight it was still 7 mb too high and wind observations from C7C and C7L were rejected. Even at 0600Z it was still rejecting some good data. However from 1200Z onwards the low was treated satisfactorily.

At 500 mb the main differences were

1. East Atlantic low (4D much worse)
4. Low 70N 105W (4D much worse)
5. Trough at 180W (4D slightly worse)
6. Low 80N 90E (4D much worse)
7. Low over Morocco (4D worse)

In fact the 09 to 12Z forecast used as background was hardly altered by the analysis over the whole octagon. This behaviour was apparent at other times as well.

2.4 1200Z 1/4/77 Figure 4

The main differences at the surface were

10. High 65N 125W (4D worse)
11. High 45N 140W (4D worse)
12. Low 30N 160W (4D better)
13. Low 52N 130E (4D worse)
14. Low 40N 130E (4D worse)
15. High 55N 60E (4D worse)

At 500 mb the main differences were

5. Trought at 180W (4D worse)
6. Low at 80N 90E (4D worse)
8. Trought over Eastern seaboard of America (4D worse)
9. Low 65N 95W (4D worse)
10. High 40N 140W (4D worse)
11. Low 75N 5E (4D worse)

Here one could hardly find a feature that the 4D depicted better than the operational analysis, and it would be fair to describe the 4D chart as a bad analysis. Overall the heights were generally too high and the chart was little changed from the 09 to 12Z forecast used as background.

2.5 1200Z 2/4/77 Figure 5

At the surface the main differences were

16. High 53N 80E (4D worse, see below)
17. Low complex around 150E (4D slightly better)
18. Low pressure pattern near 43N 97E (4D pattern better but 6 mb too high)
19. Lows at 160W (4D better in North, worse in South)

The Siberian high had its pressure raised 4 mb during the 18 to 21Z forecast and was kept at this level through the subsequent analysis and forecast to 00Z. The midnight analysis raised it a further millibar, but subsequently the value was raised rapidly by the model to reach 1073 mb before the 12Z analysis partially corrected it to 1057 mb. However the "true" value was only 1046 mb.

At 500 mb almost every feature on the 4D chart was worse. Heights were generally too high, especially around the Pole, and fields were little different to the forecast values used as background to the analysis. In fact this 1200Z chart was better than the midnight analysis had been and subsequently the standard of analysis continued to improve.

2.6 1200Z 3/4/77 Figure 6

The main differences at the surface were

16. High over Siberia (4D much worse, see below)
20. Low over Lapland (4D better)
21. Low around 40N 115E (4D better)
22. Pressure near Pole (4D better)

The 3 highs near 50N at 125E, 95E and 140W were all badly treated by the 3 hourly forecasts but the last two were restored to approximately their correct values by the analyses. However the Siberian high at 125E was forecast at

over 1080 mb twice by midnight and reached 1085 mb by 03Z. Subsequently it declined somewhat, but the analysis failed to reduce it further to the correct value.

At 500 mb the main differences were

6. Low 80N 100E (4D worse)
12. Atlantic Ω block (4D worse)
13. Low 50N 145E (4D worse)
14. Low 55N 95E (4D worse)
15. Low/trough over Greece (4D worse)

These differences were, on the whole, less than those during the preceding 48 hours.

2.7 Forecast to 1200Z 4/4/77 Figure 7

A 24 hour forecast was then run from the 12Z analysis on the 3/4/77 using the operational model and the damped integration scheme just as in the previous 5 days assimilations. A subjective assessment of the forecasts indicated that each had performed realistically, the differences being consistent with the differences in the analyses. Because of this the overall forecast of the operational model was closer to the "truth".

3. Discussion

During the experiment the model suffered from three major defects

(i) In areas where the background field was different from the observations, it rejected good observations too readily; see paragraph 2.2 and 2.3.

(ii) After midnight on the 2/3/77, the Siberian high intensified rapidly and, aided by defect (i), the assimilation was unable to reduce it to a realistic level.

(iii) The 4D 500 mb analyses showed a reluctance to depart from their background values.

In any future experiment defect (i) should be remedied fairly easily by widening the acceptance criterion. However such a solution will have to be used

with care lest "bad" observations are included with a corresponding adverse effect on the analysis.

The causes of the second defect are not clear, but a careful scrutiny of figures 4 to 6 enable the following comment to be made. Whereas for the operational model the surface anticyclone was always about 4 to 5 degrees West of the upper trough, for the 4D model the two became roughly in phase, due mainly to its inability to move the upper air features with the correct speed. Thus the surface anticyclone was placed correctly under the Eastern part of the upper ridge for the operational model, but incorrectly placed under the trough for the 4D model.

This defect may or may not be related to the comments made in Section 2 concerning the apparent inability of the observations to correct the background field at 500 mb during the analysis steps (see paragraphs 2.3, 2.4 and 2.5).

4. Conclusions

Although the 4D surface analyses were often as good as or better than the operational analyses, the defects listed in the previous section are clearly serious, and any further experiments with the scheme should seek to elucidate the causes.

References

Atkins, M.J. 1977 An implicit dynamic initialisation scheme. Met O 11 Tech. Note No. 101.

Maryon, R.H. 1977 The Met O 11 four-dimensional data assimilation scheme: pilot experiment. Met O 11 Tech. Note No. 102.

Figures

Figure 1: Initial fields valid 1200Z 29/3/77

(a) Surface

(b) 500 mb

Figure 2: Analysed fields valid 1200Z 30/3/77

(a) Surface (4D)

(b) Surface (Operational)

(c) 500 mb (4D)

(d) 500 mb (Operational)

Figure 3: Analysed fields valid 1200Z 31/3/77

(a) Surface (4D)

(b) Surface (Operational)

(c) 500 mb (4D)

(d) 500 mb (Operational)

Figure 4: Analysed fields valid 1200Z 1/4/77

(a) Surface (4D)

(b) Surface (Operational)

(c) 500 mb (4D)

(d) 500 mb (Operational)

Figure 5: Analysed fields valid 1200Z 2/4/77

(a) Surface (4D)

(b) Surface (Operational)

(c) 500 mb (4D)

(d) 500 mb (Operational)

Figure 6: Analysed fields valid 1200Z 3/4/77

(a) Surface (4D)

(b) Surface (Operational)

(c) 500 mb (4D)

(d) 500 mb (Operational)

Figure 7: 24 hour forecast fields to 1200Z 4/4/77

(a) Surface (4D)

(b) Surface (Operational)

(c) 500 mb (4D)

(d) 500 mb (Operational)

SURFACE PRESSURE ISOBARS AT 4MB INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 29 / 3 / 77. VERIFICATION TIME 12 Z 29 / 3 / 77

SE VERSION

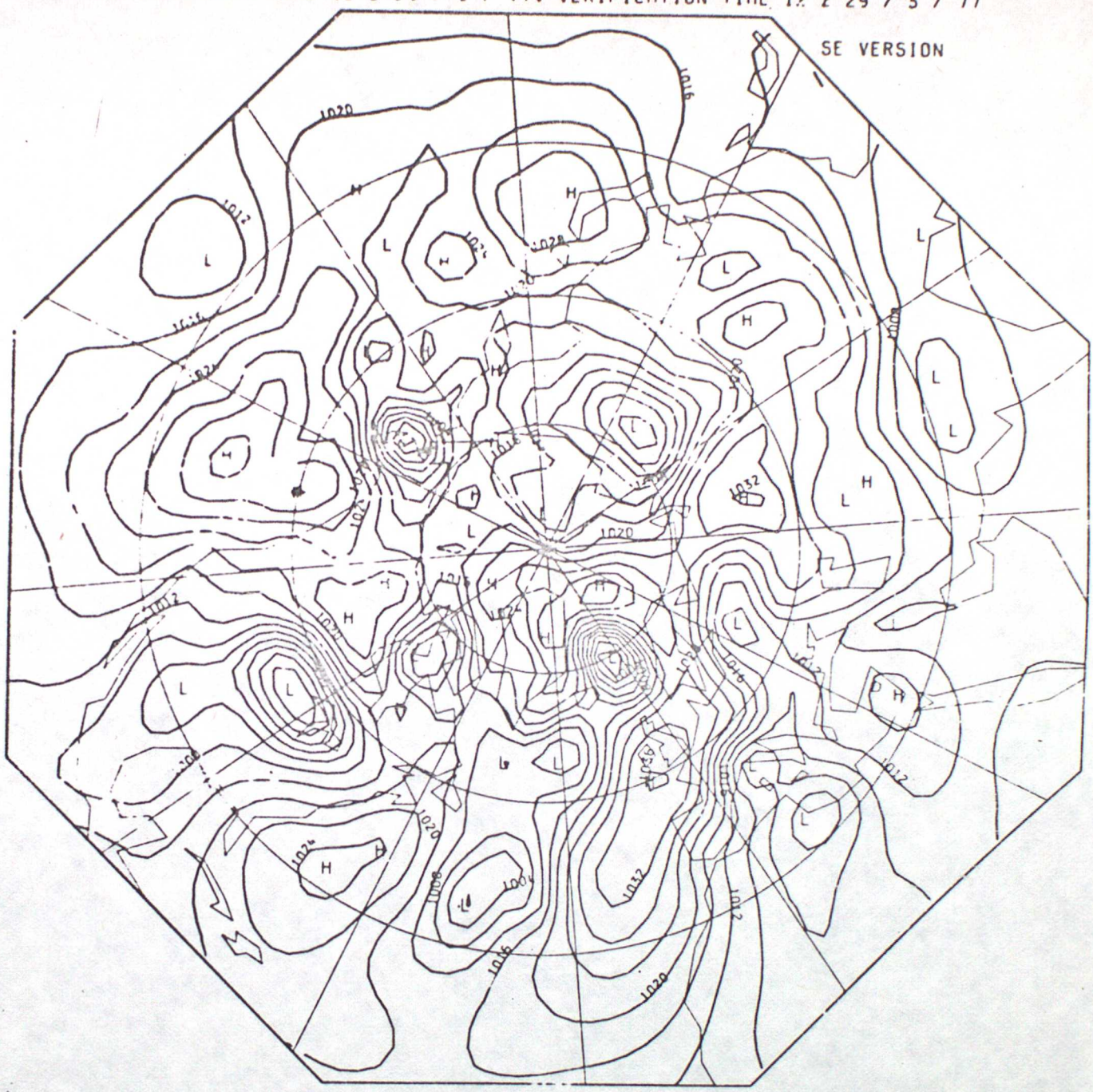


FIG 1(a) INITIAL

500 MB CONTOURS CONTOUR LINES AT 6 DECAMETER INTERVALS

0 HR. FORECAST. DATA TIME 12 Z 29 / 3 / 77. VERIFICATION TIME 12 Z 29 / 3 / 77

SE VERSION

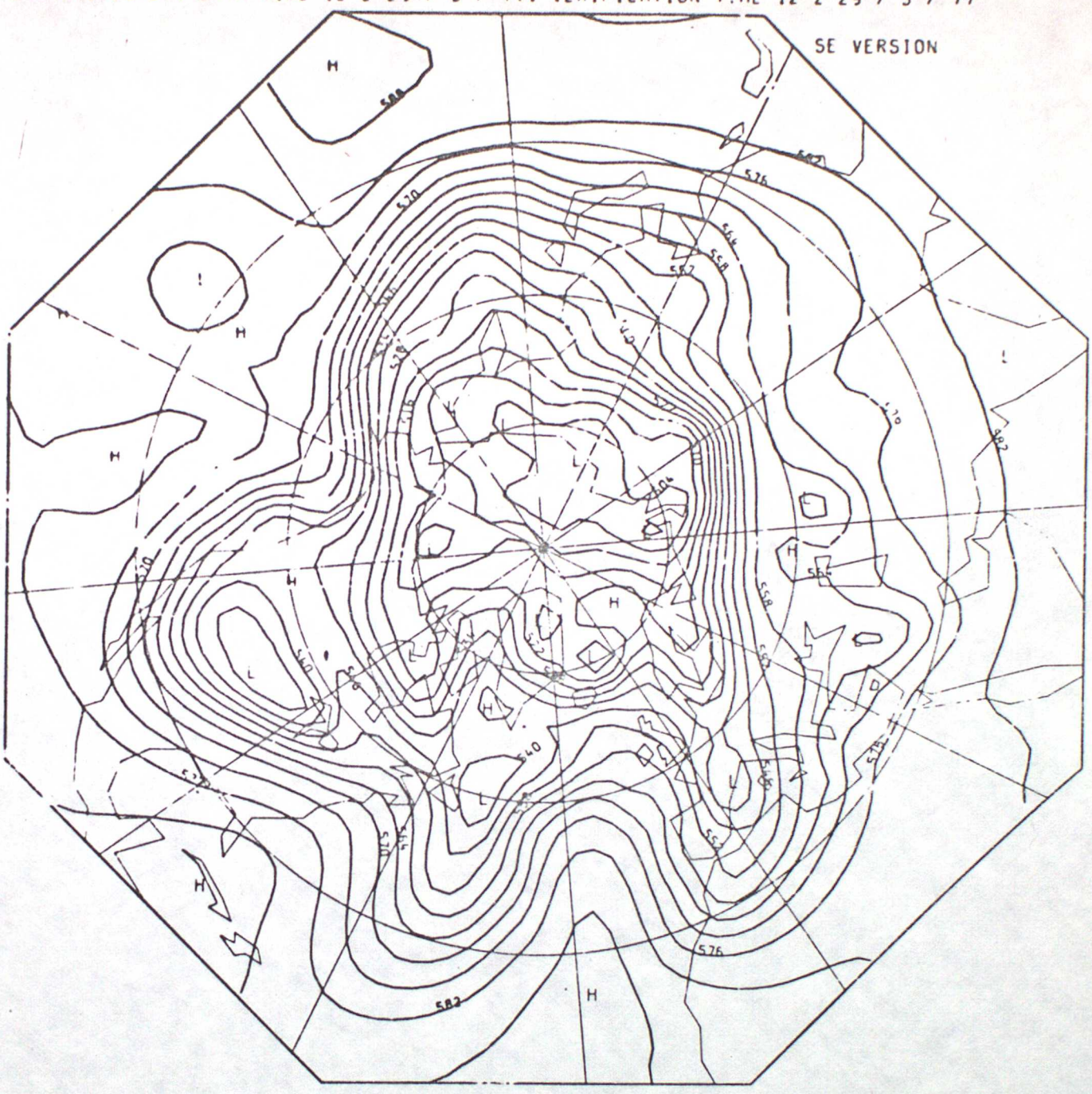
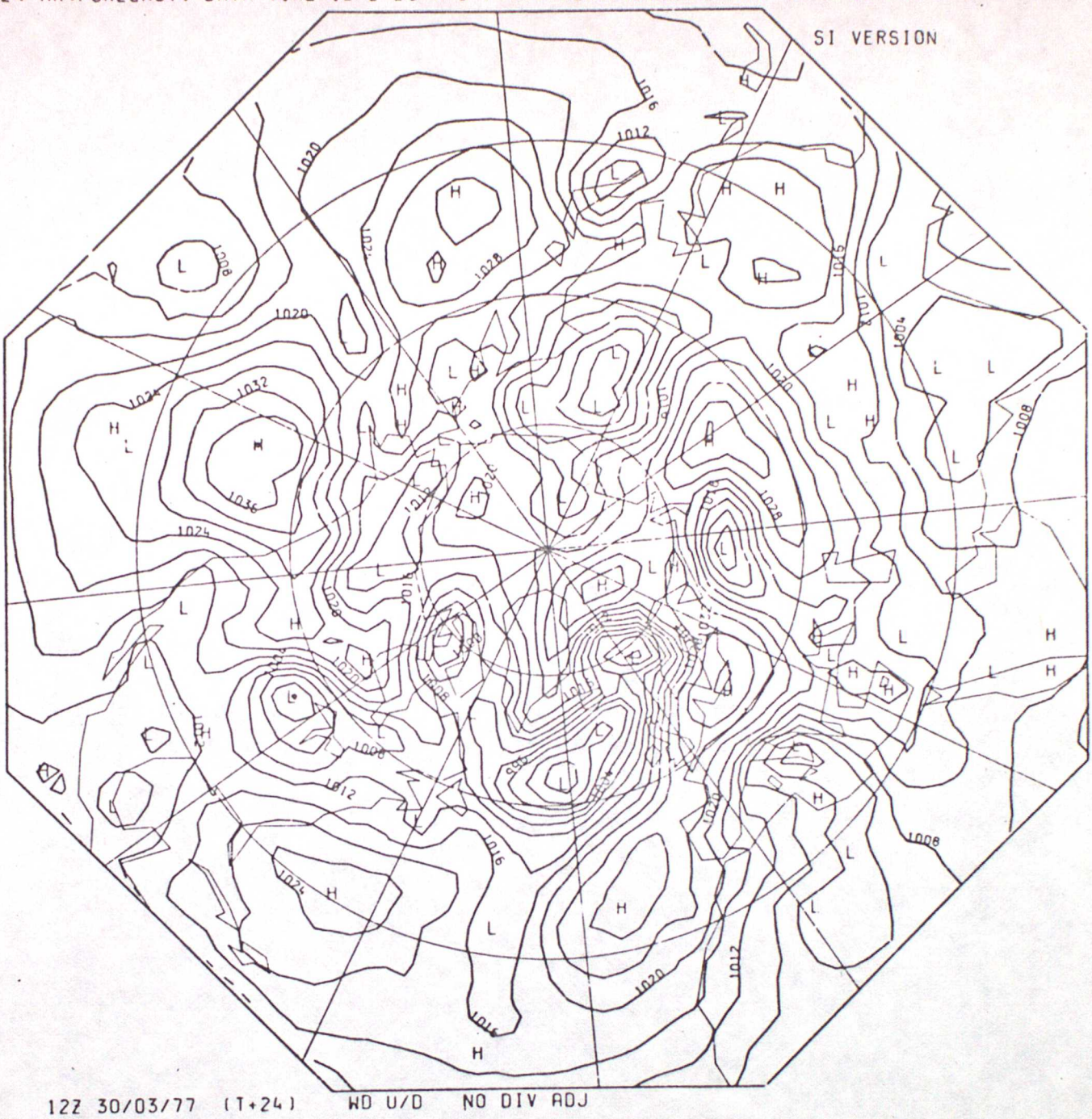


FIG 1 (b) INITIAL

SURFACE PRESSURE ISOBARS AT 4MB INTERVALS

24 HR.FORECAST. DATA TIME 12 Z 29 / 3 / 77. VERIFICATION TIME 12 Z 30 / 3 / 77

SI VERSION



12Z 30/03/77 (T+24) WD U/D NO DIV ADJ

FIG 2(a) 4-D

SURFACE PRESSURE ISOBARS AT 4MB INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 30 / 3 / 77 VERIFICATION TIME 12 Z 30 / 3 / 77

SE VERSION

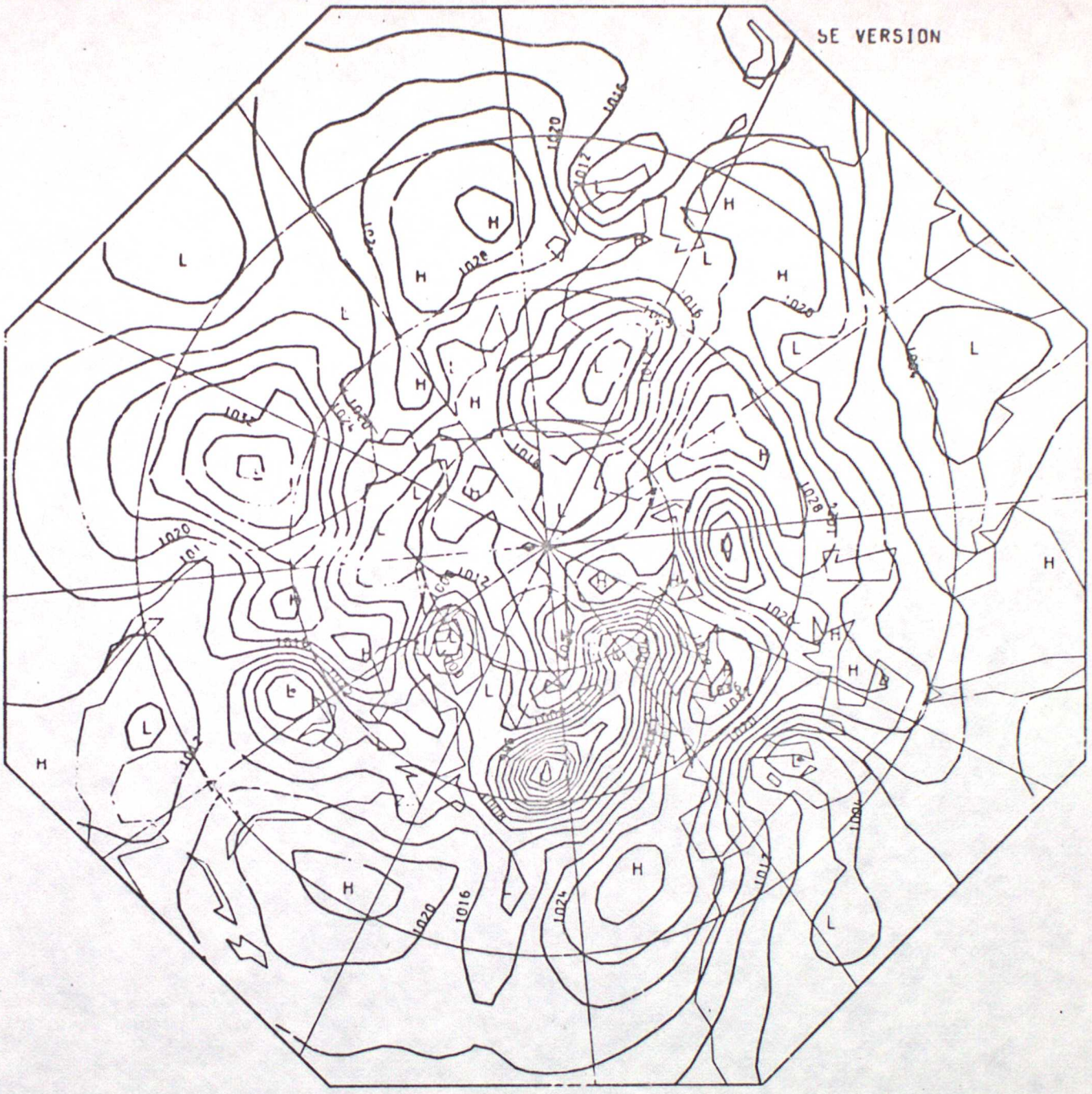
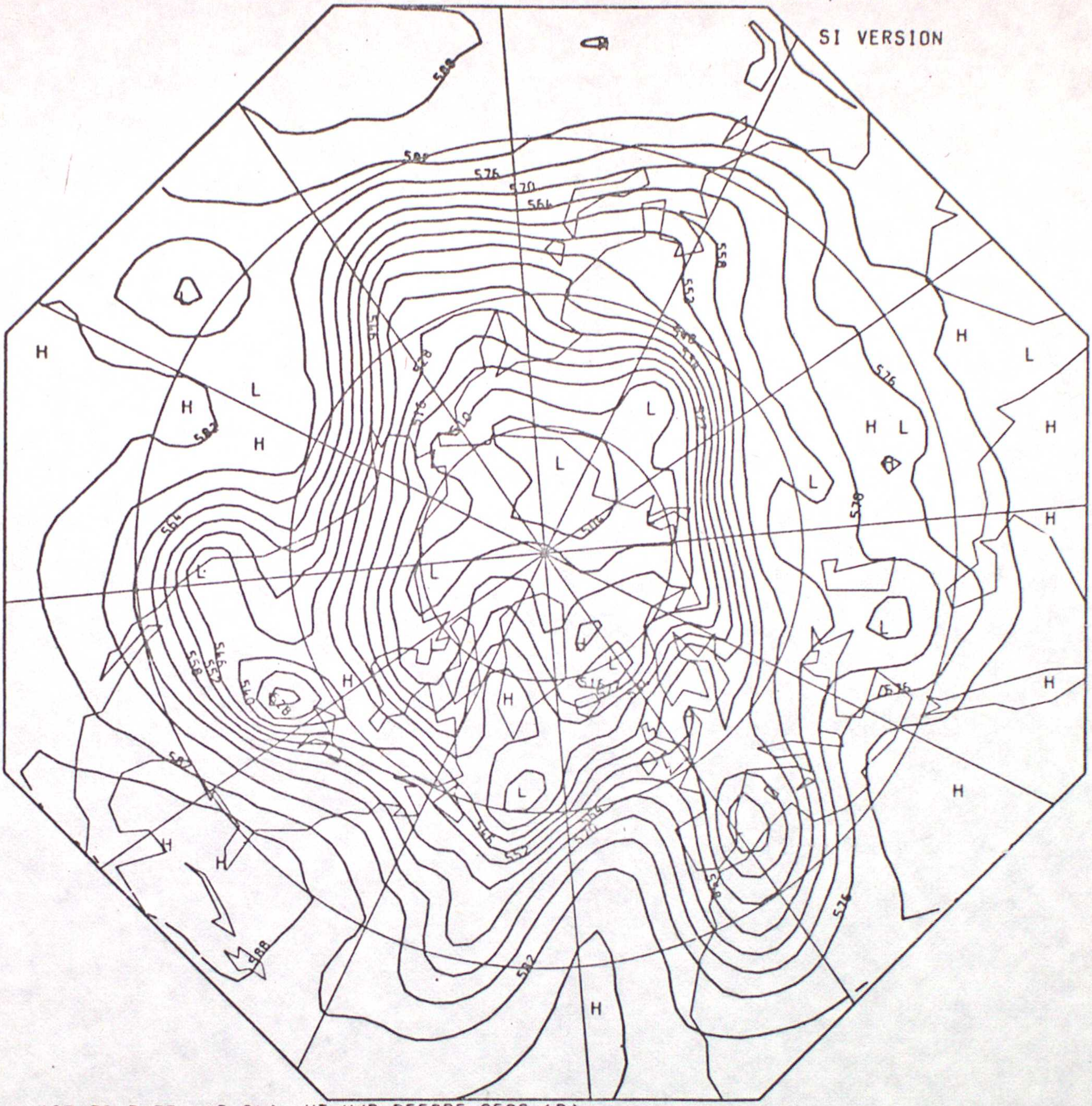


FIG 2(b) OPER.

500 MB CONTOURS CONTOUR LINES AT 6 DECAMETER INTERVALS

24 HR.FORECAST. DATA TIME 12 Z 29 / 3 / 77. VERIFICATION TIME 12 Z 30 / 3 / 77

SI VERSION



12Z 30/3/77 (T+24) HT U/D BEFORE GEOS (B)

FIG 2(c) 4-D

500 MB CONTOURS CONTOUR LINES AT 6 DECAMETER INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 30 / 3 / 77. VERIFICATION TIME 12 Z 30 / 3 / 77

SE VERSION

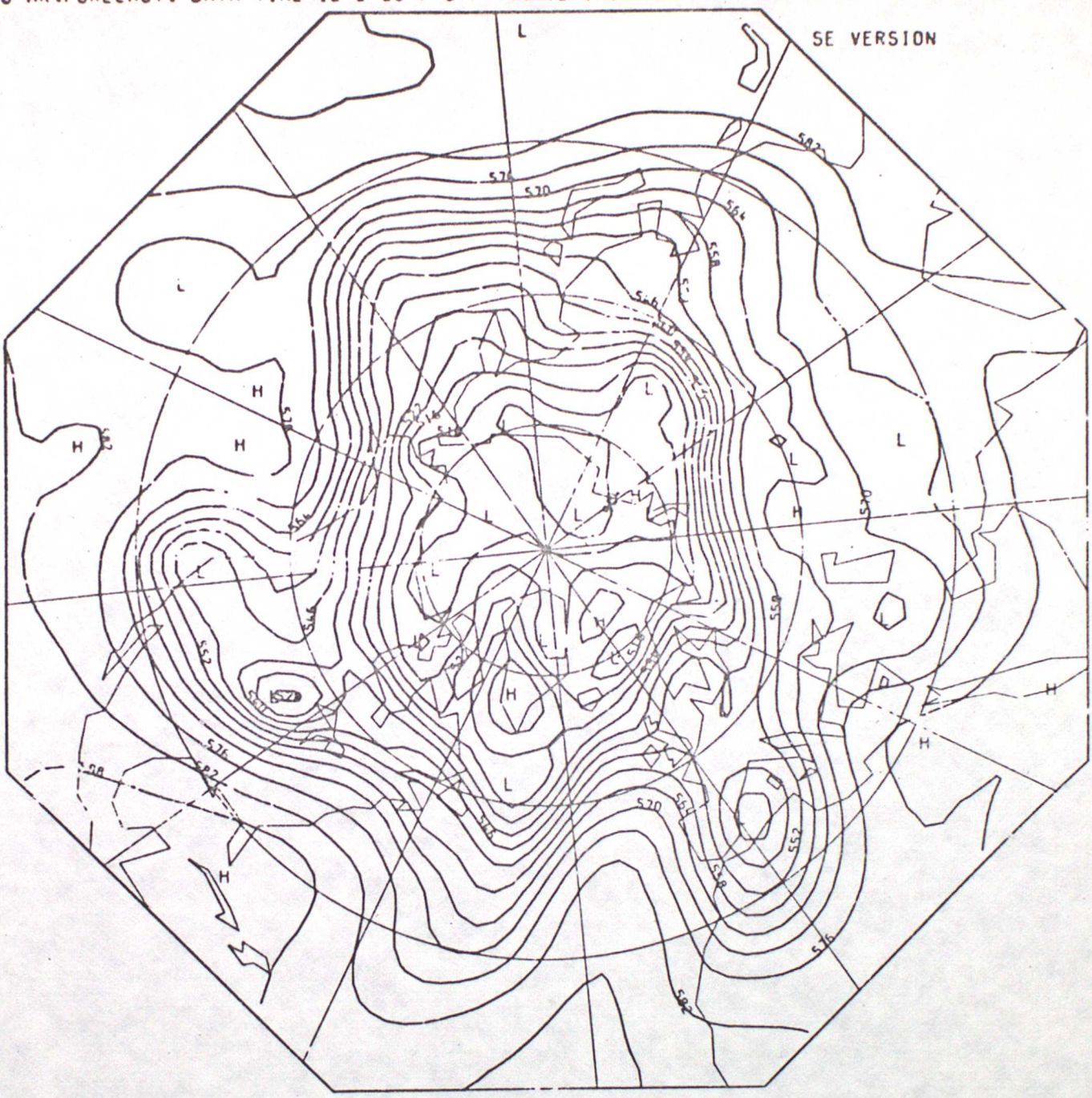
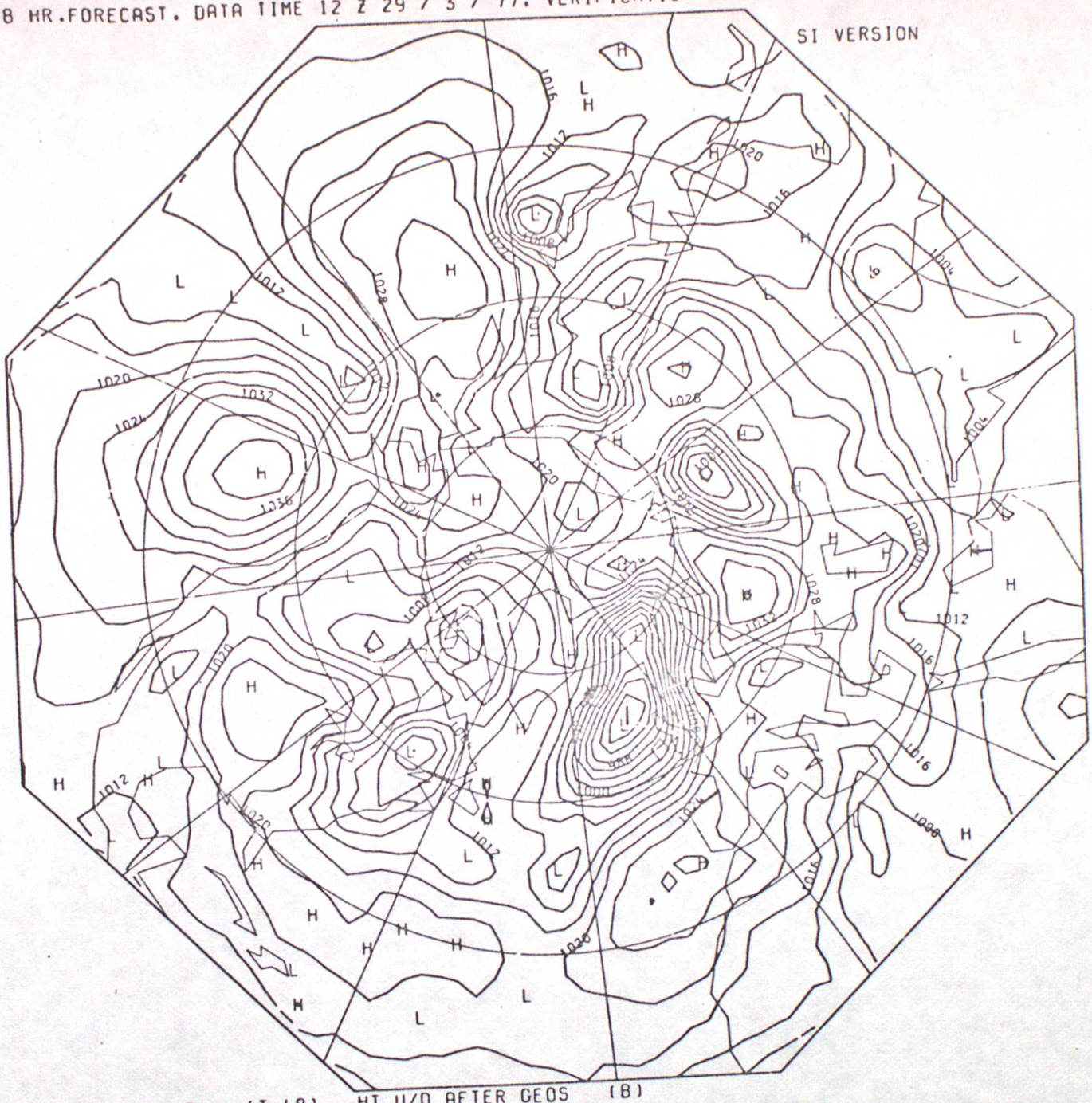


FIG 2(d) OPER.

SURFACE PRESSURE ISOBARS AT 4MB INTERVALS

48 HR.FORECAST. DATA TIME 12 Z 29 / 3 / 77. VERIFICATION TIME 12 Z 31 / 3 / 77

SI VERSION



12Z 31/3/77 (T+48) HT U/D AFTER GEOS (B)

FIG 3(a) 4-D

SURFACE PRESSURE ISOBARS AT 4MB INTERVALS

0 HR. FORECAST. DATA TIME 12 Z 31 / 3 / 77. VERIFICATION TIME 12 Z 31 / 3 / 77

SE VERSION

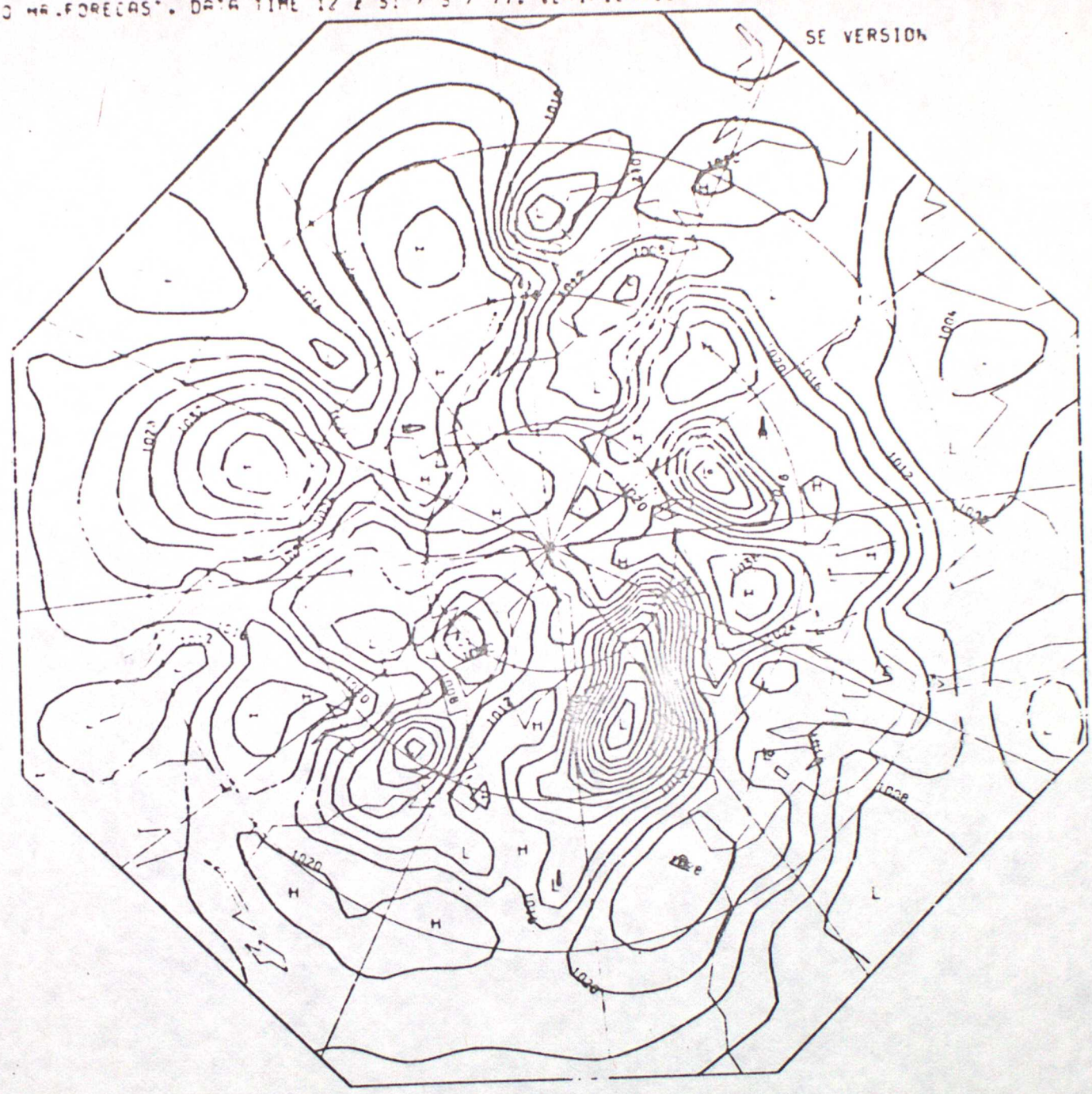
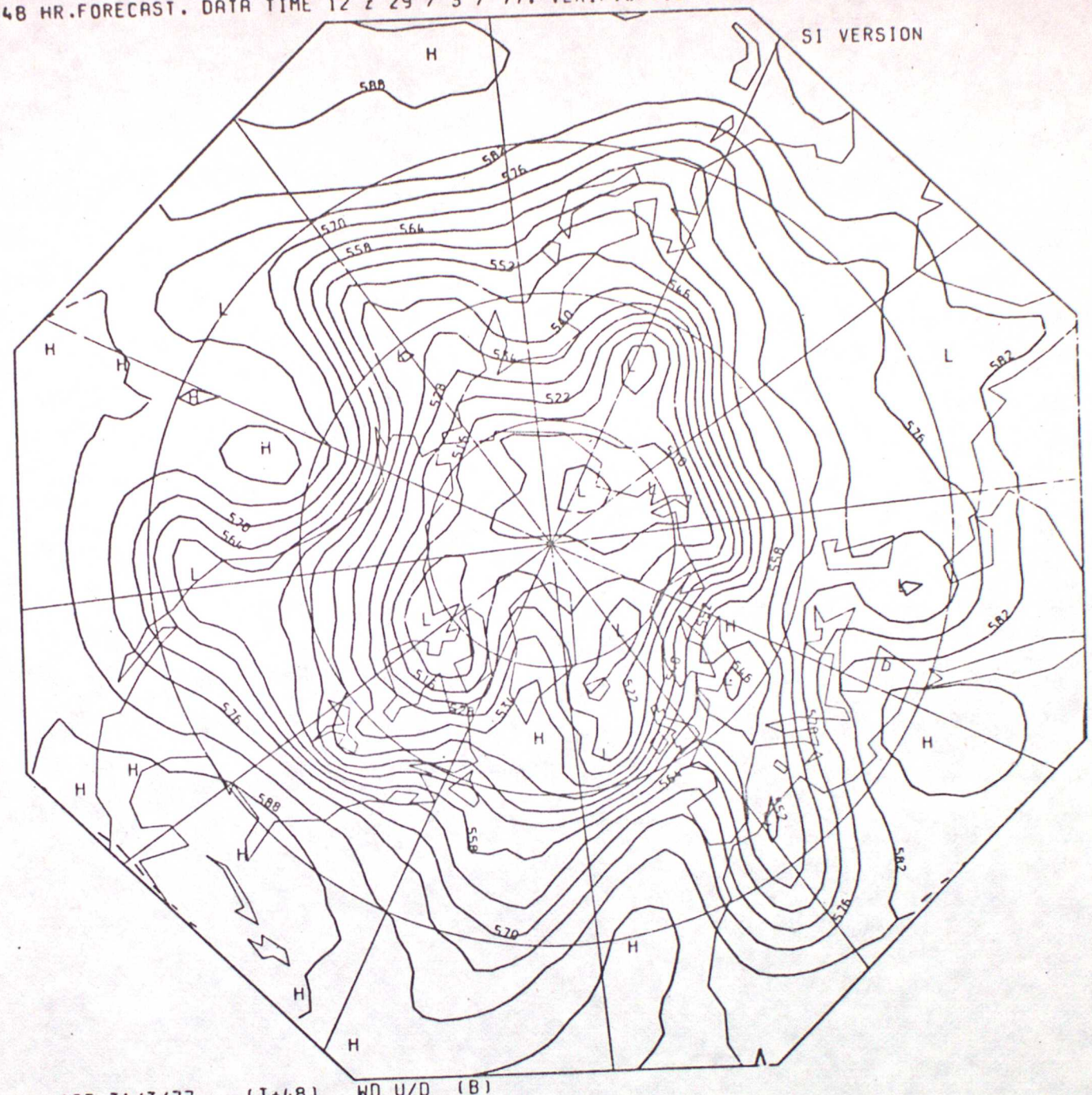


FIG 3(b) OPER

500 MB CONTOURS CONTOUR LINES AT 6 DECAMETER INTERVALS

48 HR.FORECAST. DATA TIME 12 Z 29 / 3 / 77. VERIFICATION TIME 12 Z 31 / 3 / 77

S1 VERSION



12Z 31/3/77 (T+48) WD U/D (B)

FIG 3(c) 4-3

500 MB CONTOURS CONTOUR LINES AT 6 DECAMETER INTERVALS

C HR.FORECAST. DATA TIME 12 Z 31 / 3 / 77. VERIFICATION TIME 12 Z 31 / 3 / 77

SE VERSION

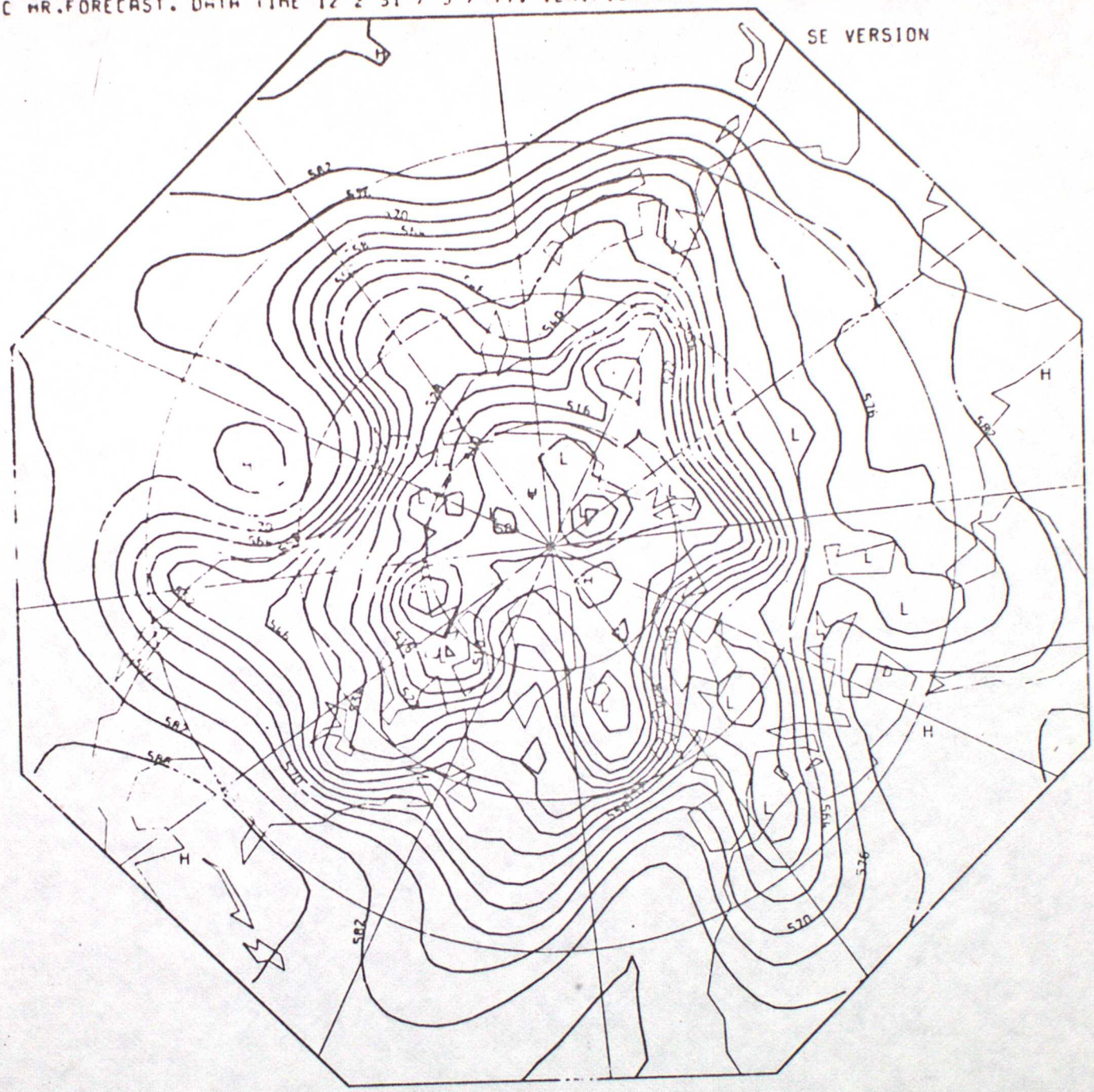
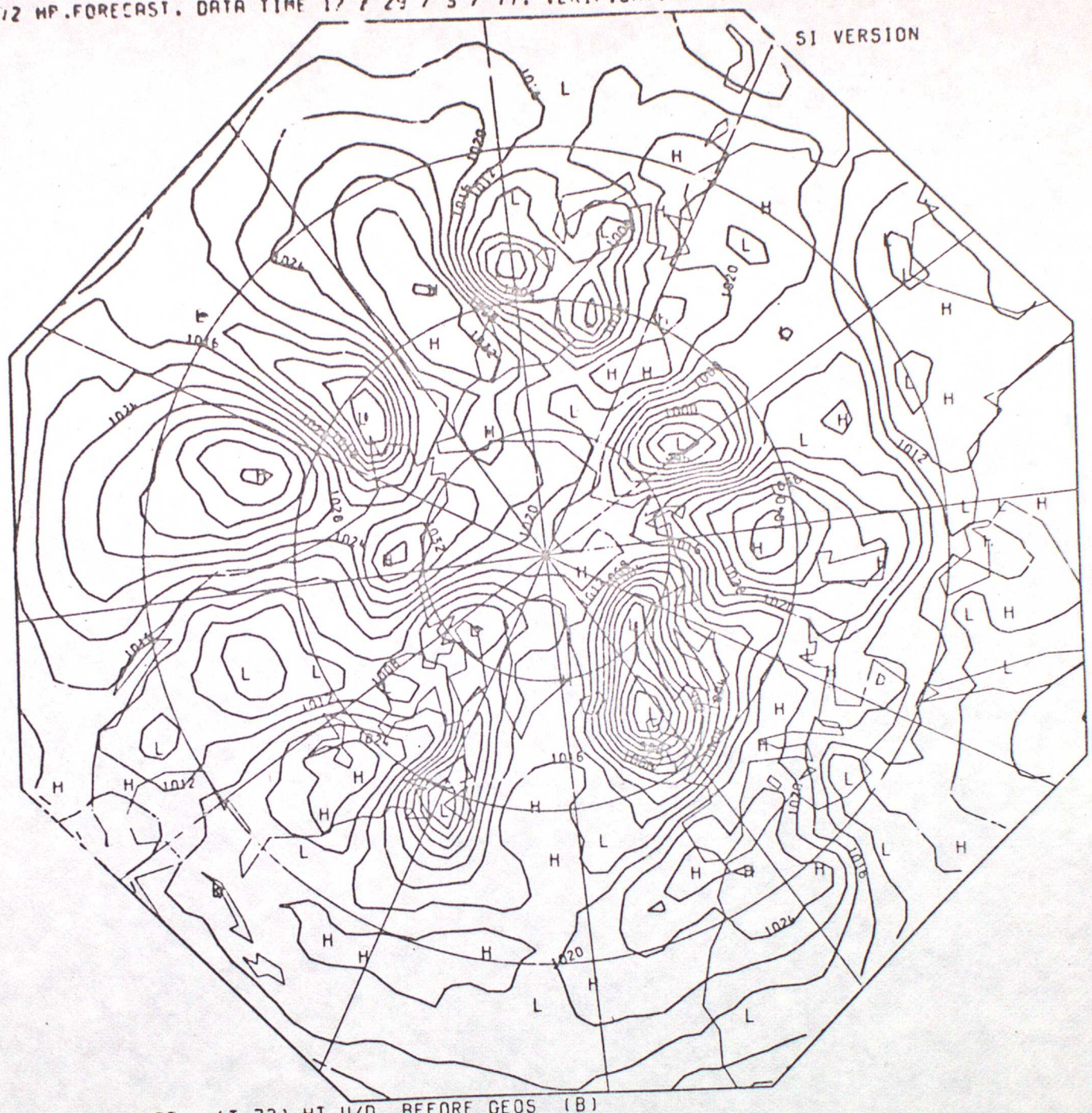


FIG 3(d) OPER.

SURFACE PRESSURE ISOBARS AT 4MB INTERVALS

12 HR.FORECAST. DATA TIME 12 Z 29 / 3 / 77. VERIFICATION TIME 12 Z 1 / 4 / 77

SI VERSION



12Z 01/4/77 (T+72) HT U/D BEFORE GEOS (B)

FIG 4(a) 4-D

SURFACE PRESSURE ISOBARS AT 4MB INTERVALS

0 HR. FORECAST. DATA TIME 12 Z 1 / 4 / 77. VERIFICATION TIME 12 Z 1 / 4 / 77

SE VERSION

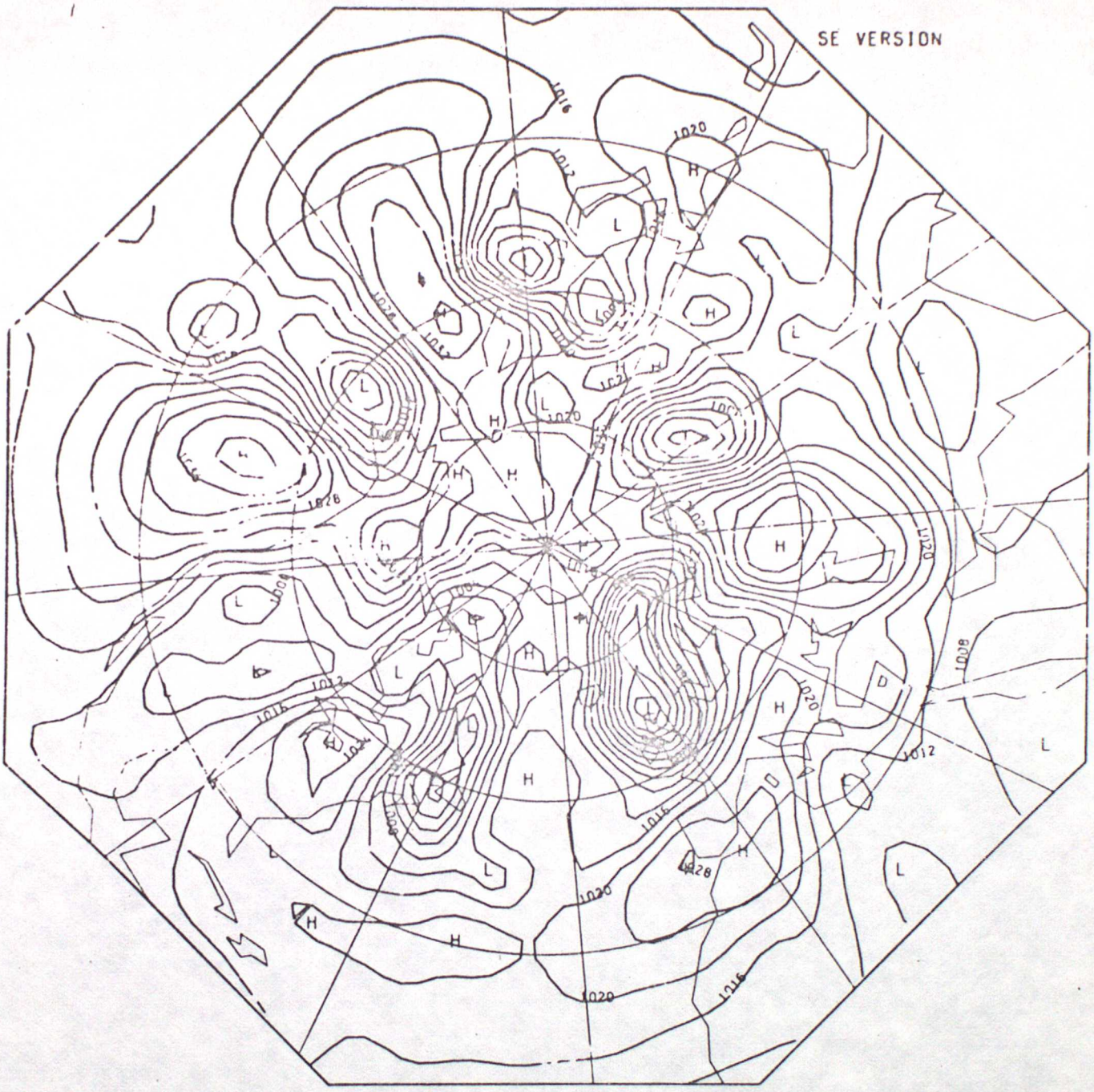


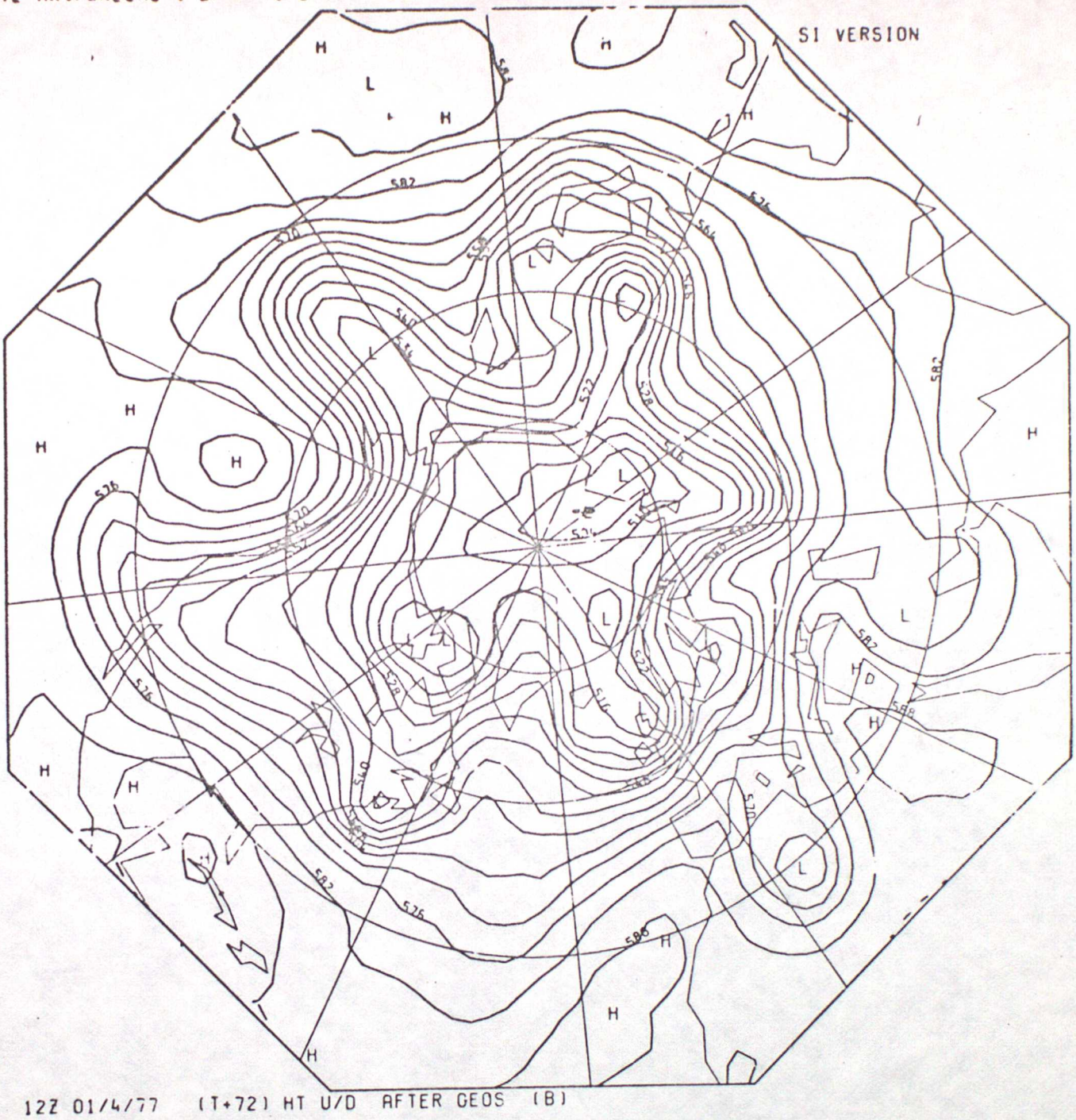
FIG 4(b)

OPER.

500 MB CONTOURS CONTOUR LINES AT 6 DECAMETER INTERVAL

72 HR.FORECAST. DATA TIME 12 Z 29 / 3 / 77. VERIFICATION TIME 12 Z 1 / 4 / 77

S1 VERSION



12Z 01/4/77 (T+72) HT U/D AFTER GEOS (B)

FIG 4 (B)

4-D

500 MB CONTOURS CONTOUR LINES AT 6 DECAMETER INTERVALS

0 HR. FORECAST. DATA TIME 12 Z 1 / 4 / 77. VERIFICATION TIME 12 Z 1 / 4 / 77

SE VERSION

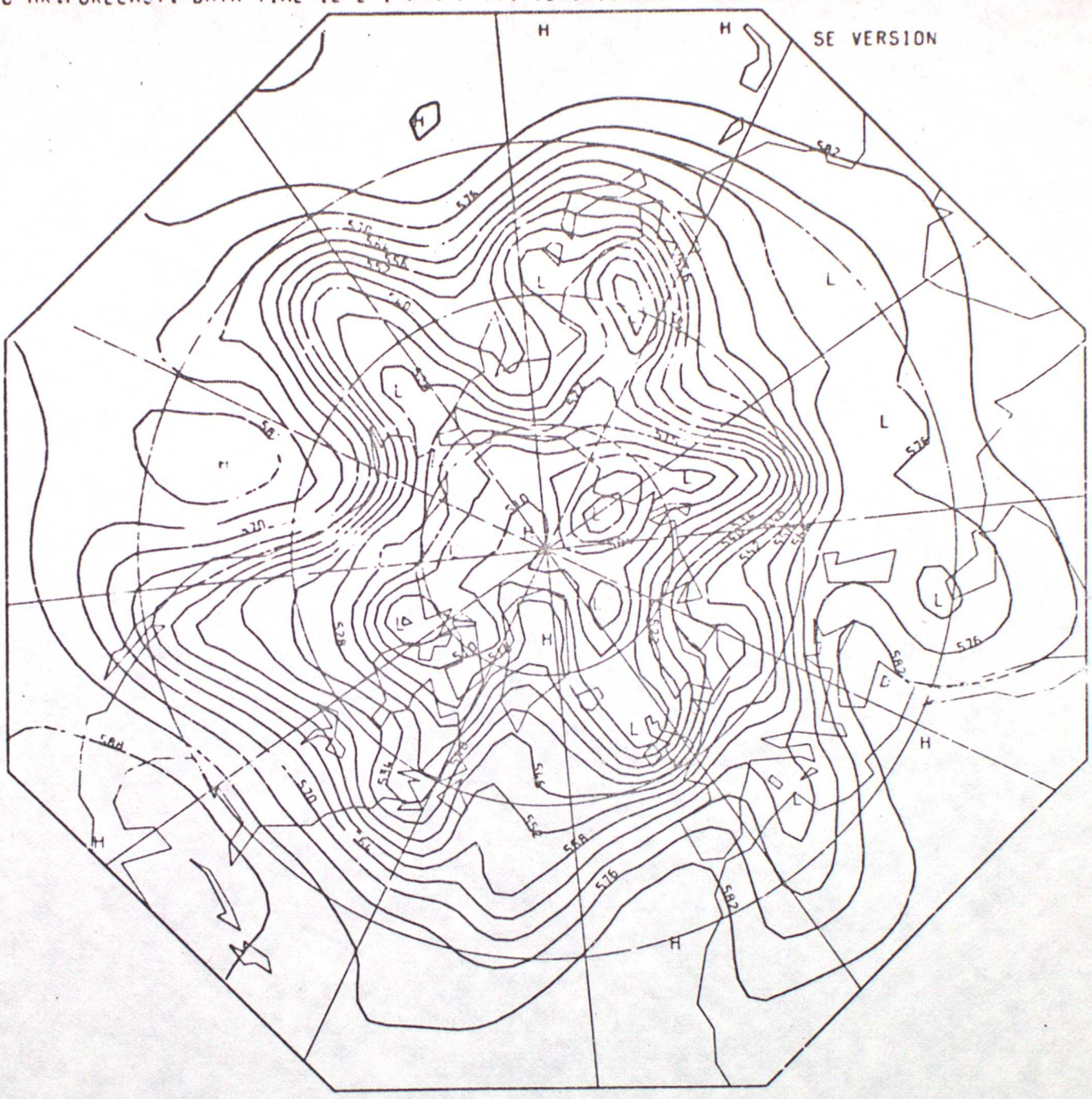
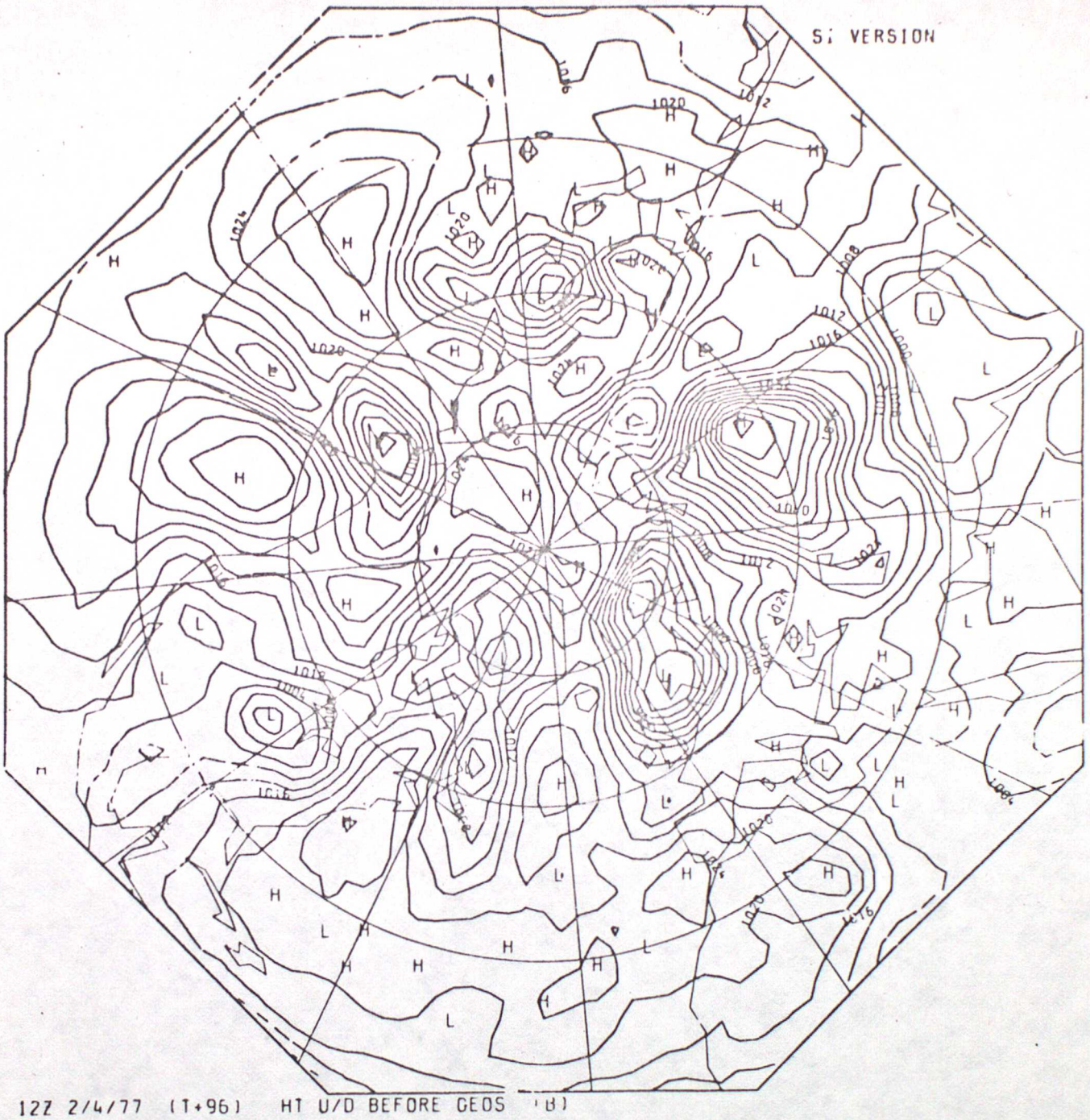


FIG 4 (d) OPER

SURFACE PRESSURE ISOBARS AT 4MB INTERVALS

96 HR.FORECAST. DATA TIME 12 Z 29 / 3 / 77. VERIFICATION TIME 12 Z 2 / 4 / 77

S. VERSION



12Z 2/4/77 (T+96) HT U/D BEFORE GEOS (B)

FIG 5(a) 4->

SURFACE PRESSURE ISOBARS AT 4MB INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 2 / 4 / 77. VERIFICATION TIME 12 Z 2 / 4 / 77

SE VERSION

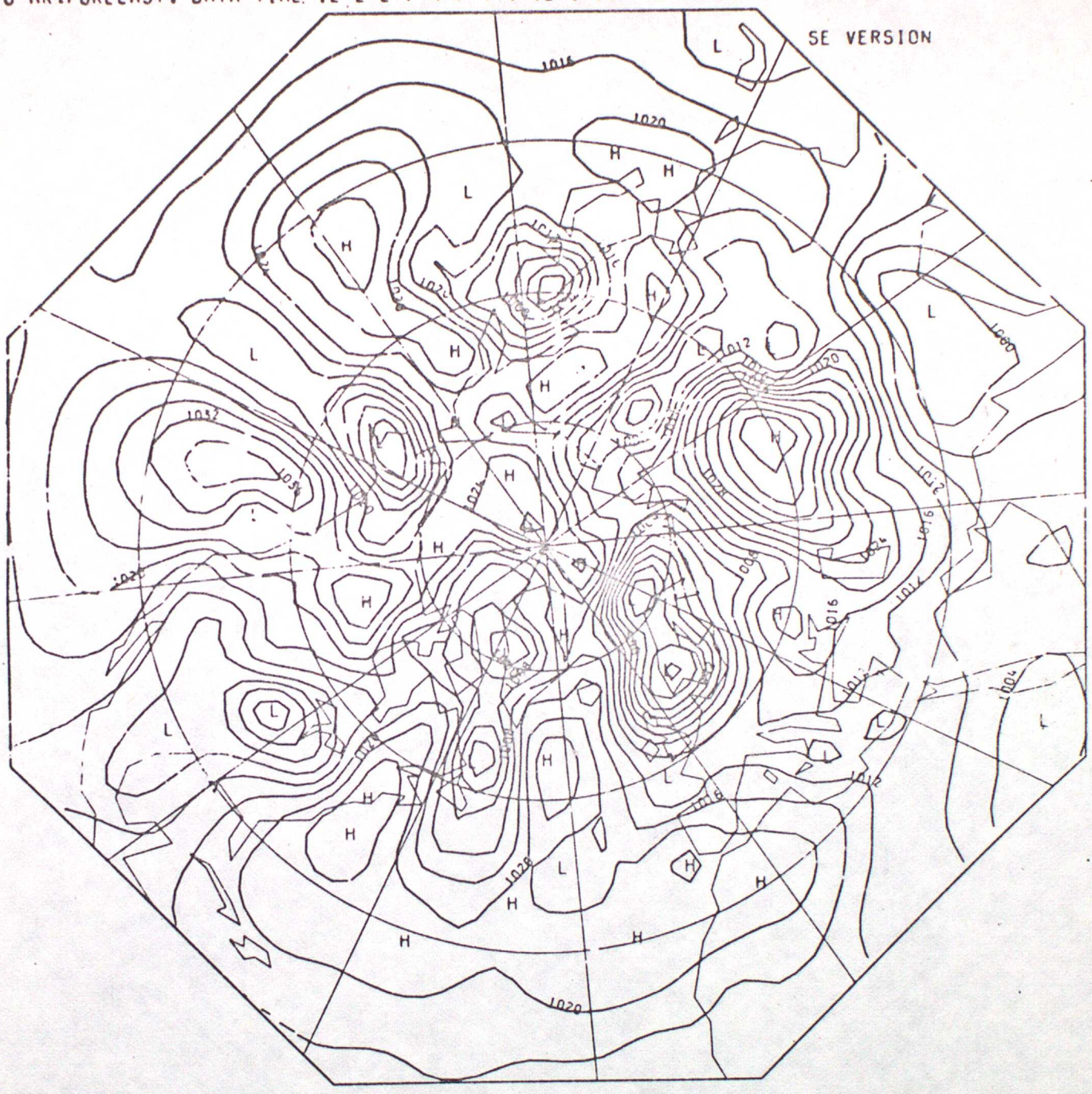


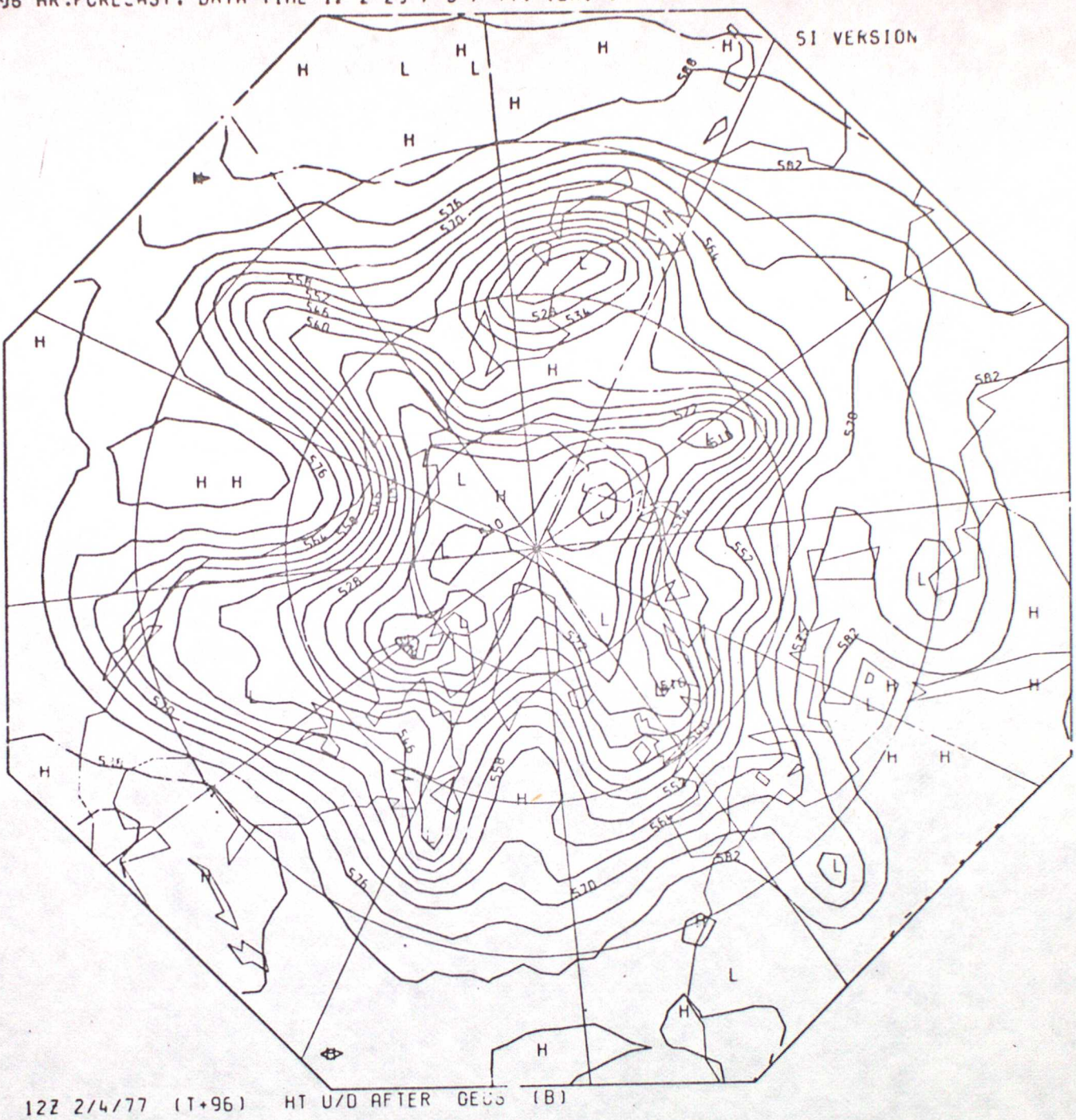
FIG 5(b)

OPER

SCC MB CONTOURS CONTOUR LINES AT 6 DECAMETER INTERVALS

96 HR.FORECAST. DATA TIME 12 Z 29 / 3 / 77. VERIFICATION TIME 12 Z 2 / 4 / 77

SI VERSION



12Z 2/4/77 (T+96) HT U/D AFTER GEOS (B)

FIG 5(c)

4-D

500 MB CONTOURS CONTOUR LINES AT 6 DECAMETER INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 2 / 4 / 77. VERIFICATION TIME 12 Z 2 / 4 / 77

SE VERSION

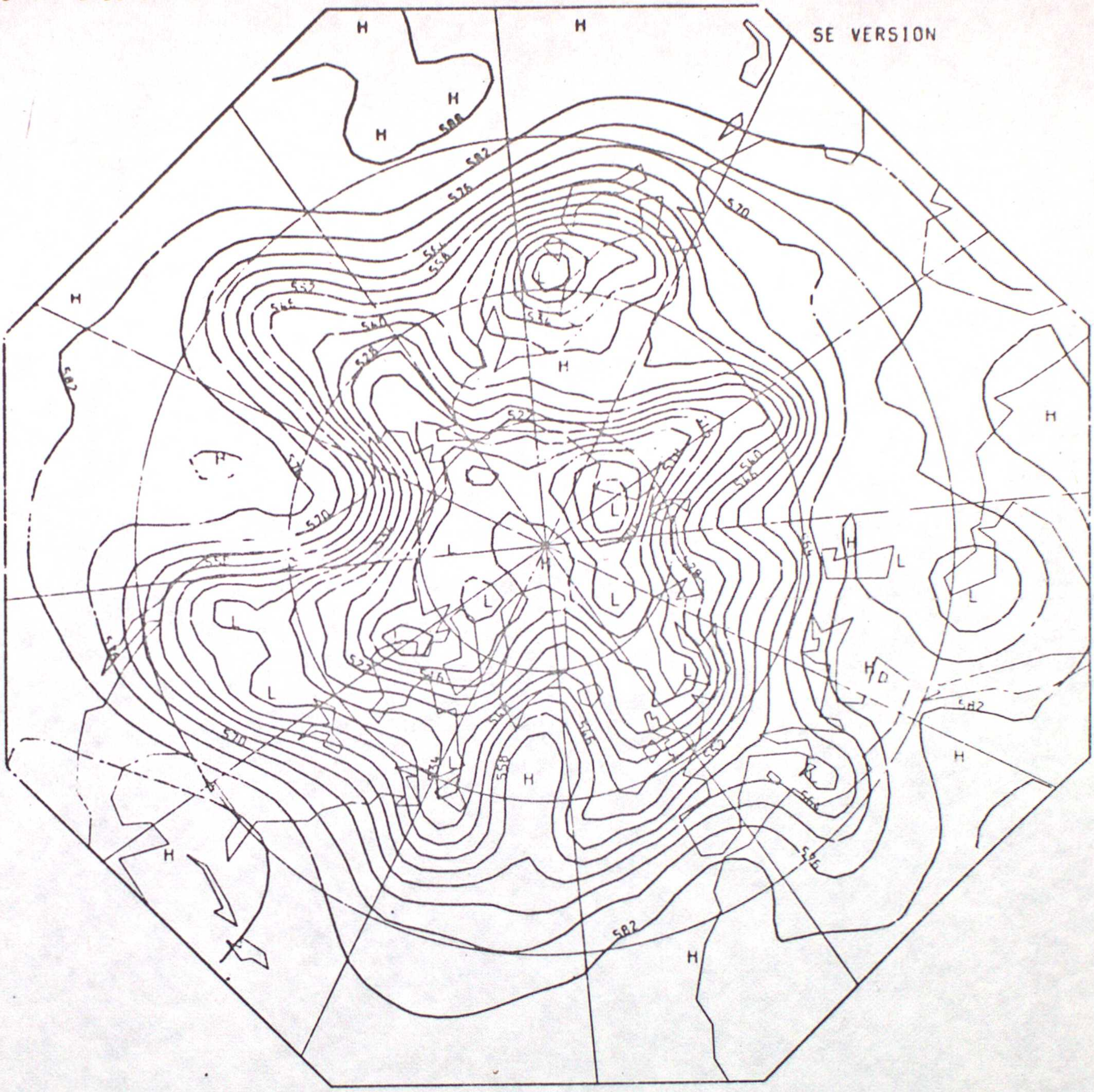


FIG 5(d) OPER

12Z HR.FORECAST. DATA TIME 12 Z 29 / 3 / 77. VERIFICATION TIME 12 Z 3 / 4 / 77

SI VERSION

12Z 3/4/77 (T+120) WD U/D (B)

FIG 6 (a) 4-D

SURFACE PRESSURE ISOBARS AT 4MB INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 3 / 4 / 77. VERIFICATION TIME 12 Z 3 / 4 / 77

SE VERSION

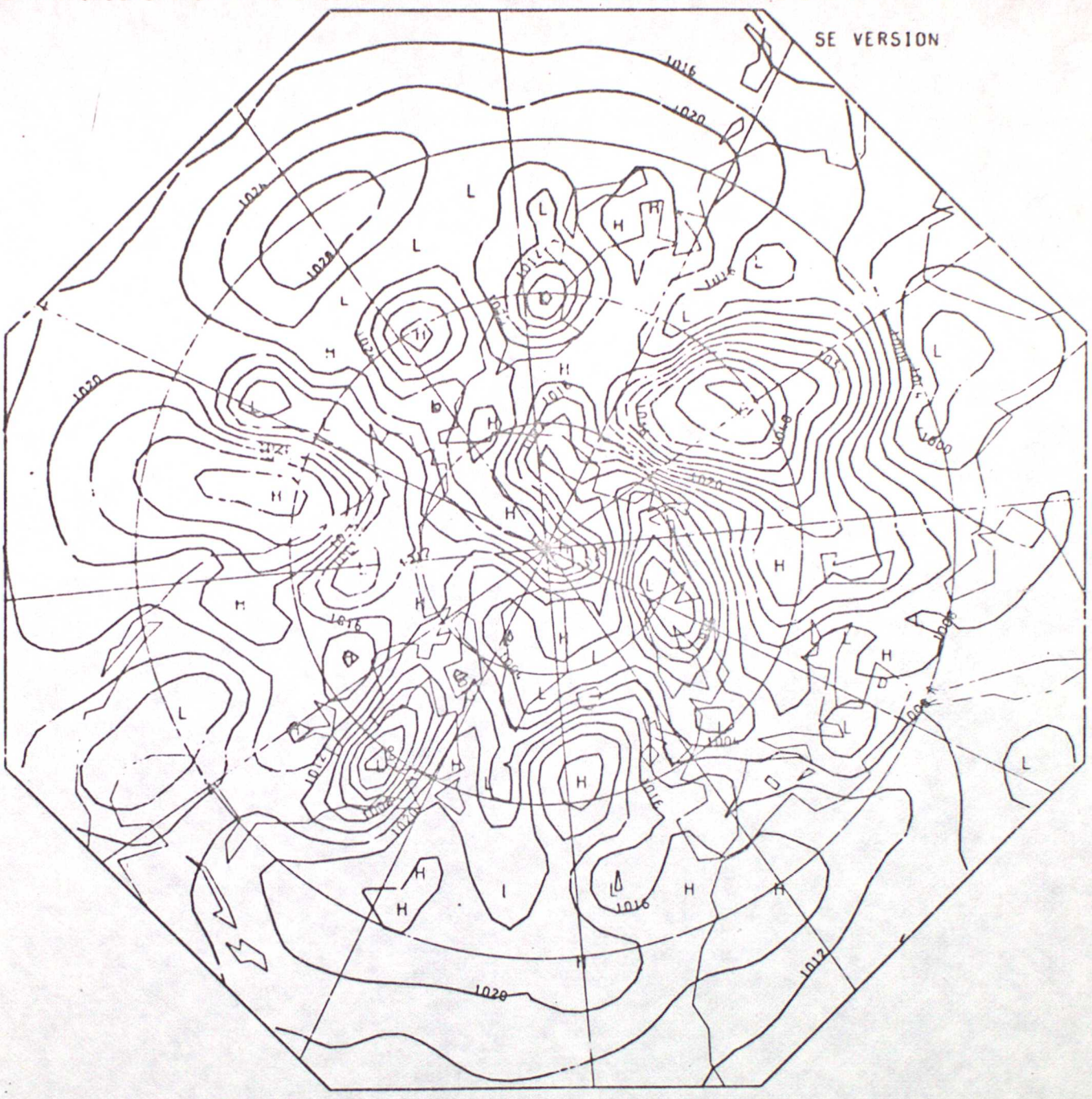
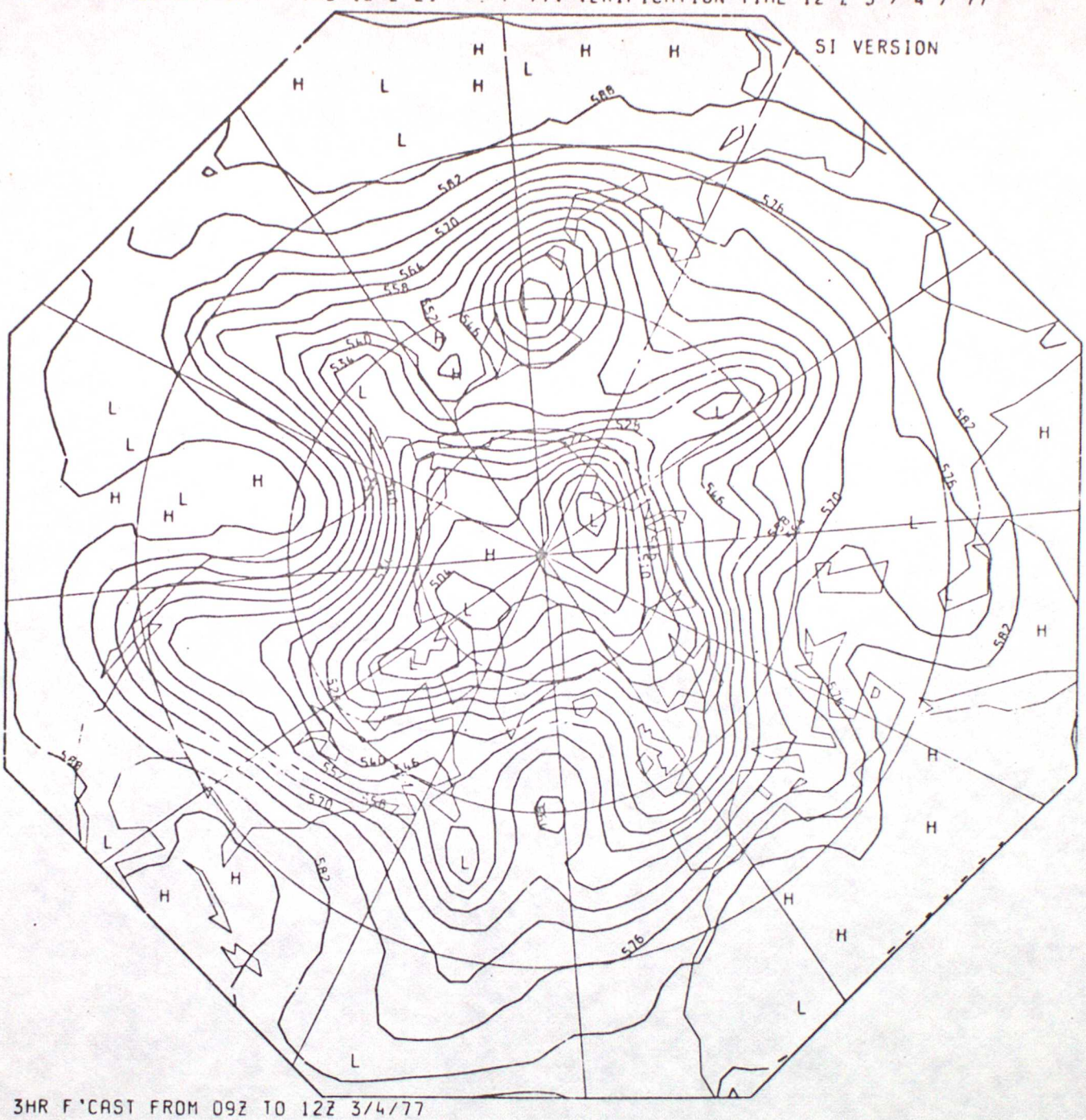


FIG 6(b) OPER

500 MB CONTOURS CONTOUR LINES AT 6 DECAMETER INTERVALS

120 HR. FORECAST. DAT. TIME 12 Z 29 / 3 / 77. VERIFICATION TIME 12 Z 3 / 4 / 77

SI VERSION



3HR F'CAST FROM 09Z TO 12Z 3/4/77

FIG 6 (C)

4-D

500 MB CONTOURS CONTOUR LINES AT 6 DECAMETER INTERVALS

0 HR.FORECAST. DATA TIME 12 Z 3 / 4 / 77. VERIFICATION TIME 12 Z 3 / 4 / 77

SE VERSION

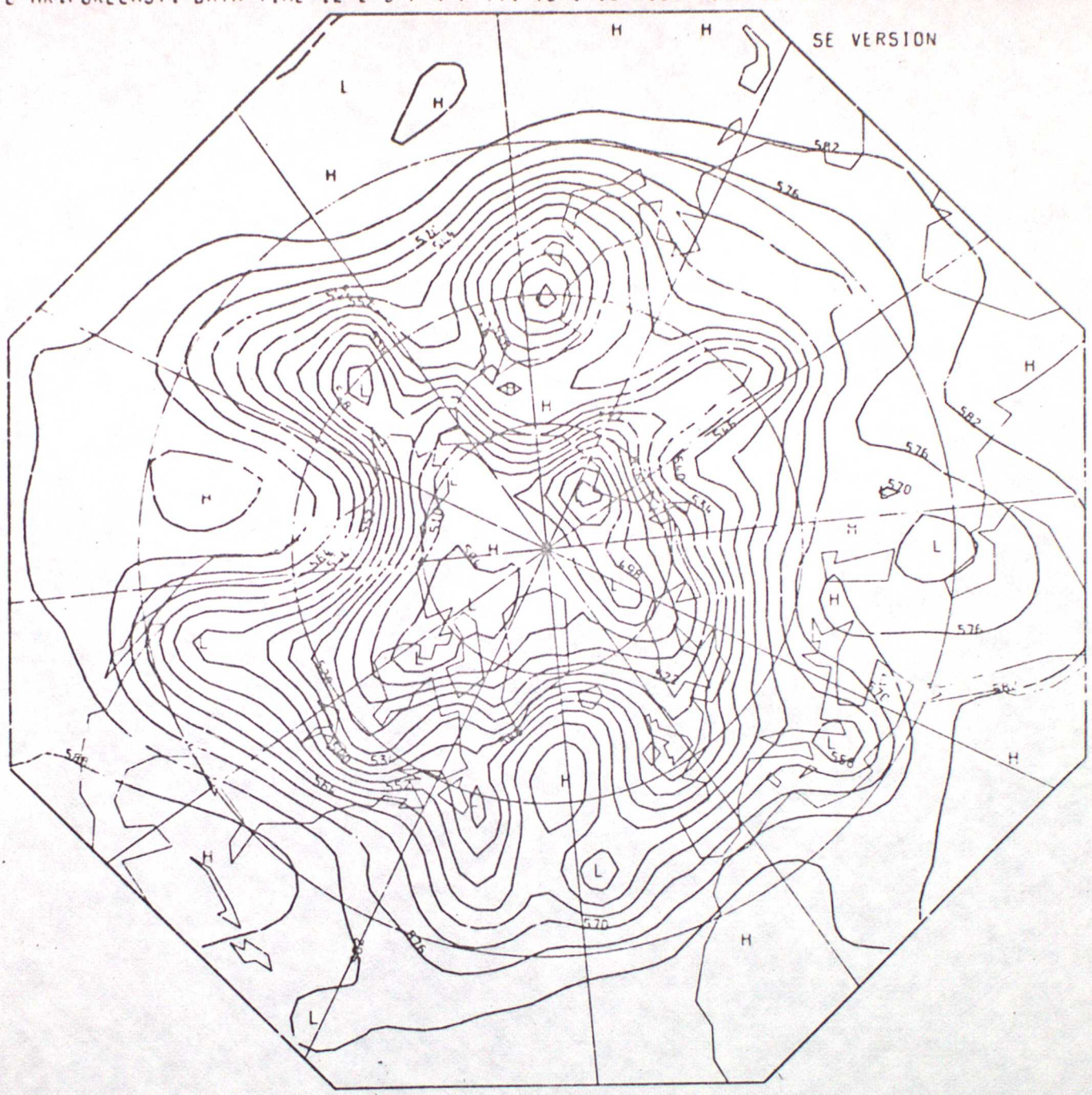


FIG 6(d)

OPER

. SURFACE PRESSURE ISOBARS AT 4MB INTERVALS

144 HR.FORECAST. DATA TIME 12 Z 29 / 3 / 77. VERIFICATION TIME 12 Z 4 / 4 / 77

SI VERSION

24HR F'CAST FROM 12Z 3/4/77 TO 12Z 4/4/77

FIG 7 (a)

4-D

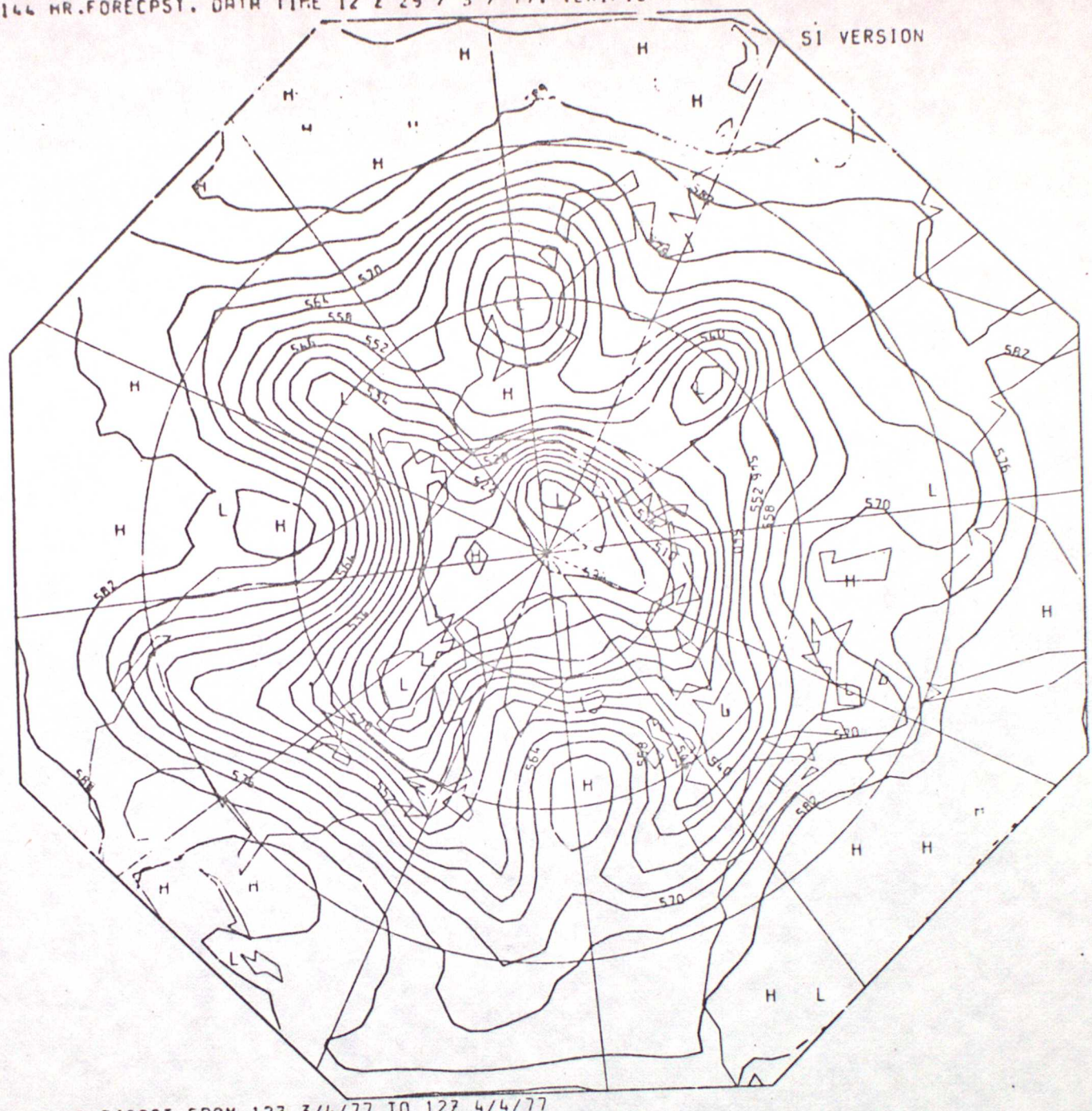
DT 12Z 03/04/77 VT 12Z 04/04/77 T+24 SURFACE PRESSURE

FIG 7(b) OPER

500 MB CONTOURS CONTOUR LINES AT 6 DECAMETER INTERVALS

144 HR.FORECAST. DATA TIME 12 Z 29 / 3 / 77. VERIFICATION TIME 12 Z 4 / 4 / 77

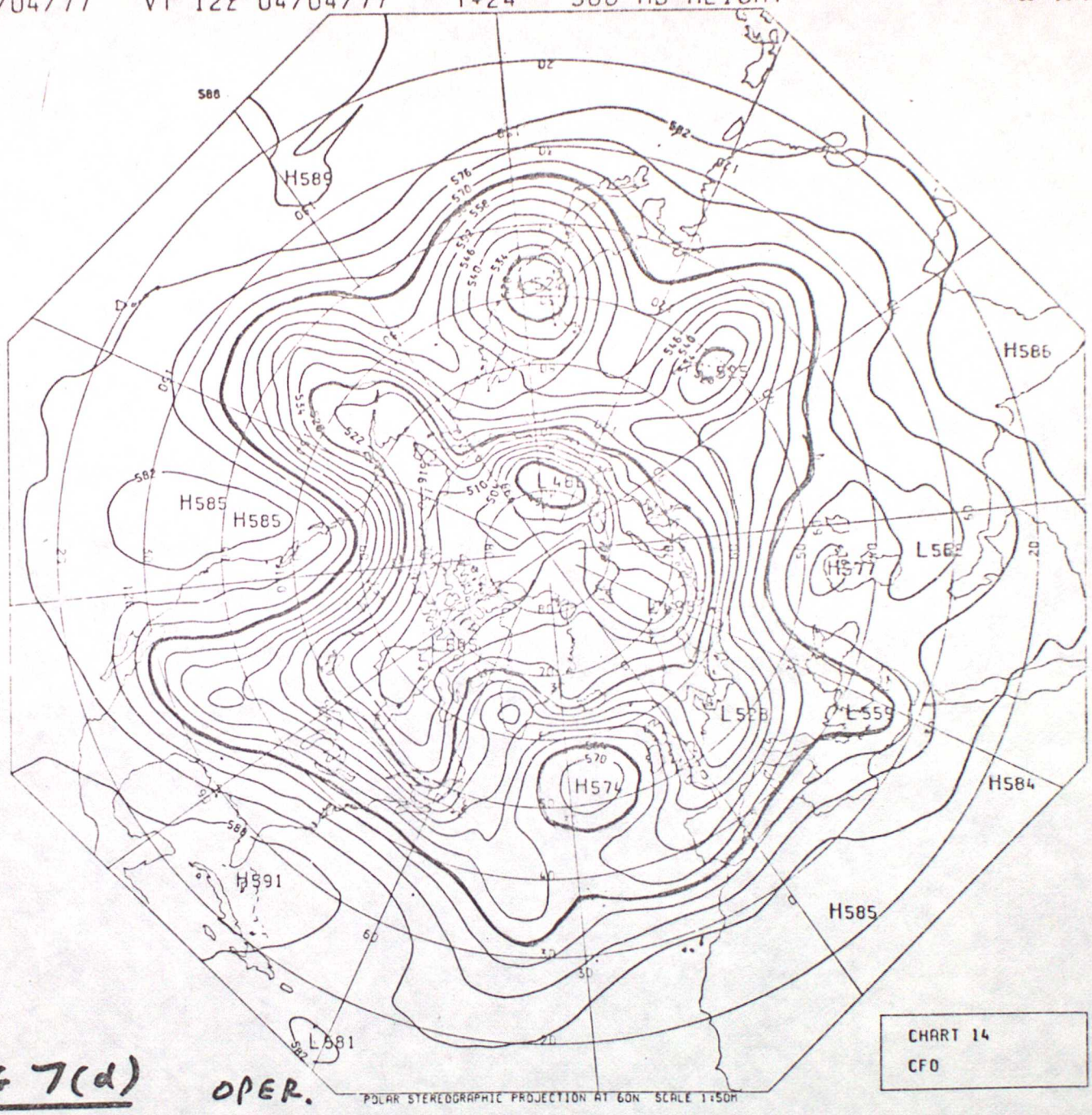
SI VERSION



24HR F'CAST FROM 12Z 3/4/77 TO 12Z 4/4/77

FIG 7(c) 4-D

DT 12Z 03/04/77 VT 12Z 04/04/77 T+24 500 MB HEIGHT



POLAR STEREOGRAPHIC PROJECTION AT 60N SCALE 1:50M

FIG 7(d) OPER.