TECHNICAL MEMORANDUM

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Forecasting experiments using an alternative distribution of levels

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1979

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Europäisches Zentrum für mittelfristige Wettervorhersage
Centre européen pour les prévisions météorologiques à moyen

Technical Memorandum No. 3 1979

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FORECASTING EXPERIMENTS USING AN ALTERNATIVE DISTRIBUTION OF LEVELS

A.J. Simmons

1. Introduction

Most forecast experiments performed to date have used fifteen levels in the vertical, with a top full level located at $\sigma = .025$. The first such integrations with the semi-implicit scheme indicated that the time step limit was determined in this case by the strength of winds at the top most level in the polar winter stratosphere. In addition, sparsity of data renders observational analysis of a high top level difficult. Since simple model calculations reported earlier did not show any marked deterioration in forced long-wave structures to result from a lowering of the top most level from $\sigma = .025$ to a value near .05, it was decided to perform a series of forecast experiments using the full N48 model with the top level similarly lowered. This paper presents a summary of the results of these experiments.

2. Description of experiments

The currently used vertical levels are defined by

$$\sigma_{k/2} = .75s + 1.75s^3 - 1.5s^4 = f(s), \quad s = \frac{k-1}{30},$$

and have the property that $\sigma_8 = .5$. For the experiments discussed here we used

$$\sigma_{k/2} = 1.5s - 3s^2 + 5.5s^3 - 3s^4 = g(s), \quad s = \frac{k-1}{30}.$$

We again have $\sigma_8 = .5$, and since $f'(1) = g'(1) = 0$, with $f''(1) = -7.5$ and $g''(1) = -9$, we have a broadly similar boundary-layer representation. Also $g'(0) = 2f'(0)$ giving an approximate doubling

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of the value of sigma at the top level. Full-level values of sigma are compared in Table 1. In comparison with the standard distribution of levels the modified distribution has a better resolution near the tropopause, and a marginally poorer resolution at low levels.

The cases studied comprised a repeat of the Spring Experiments, using EC physics. We thus integrated 8 cases from February 1976 (with 7 included in the ensemble-mean verification to day 10) and 5 from August 1975 (with 4 used for ensemble means). Initial data for the modified sigma levels was obtained by cubic-spline interpolation from the standard 15-level data. A further forecast from 16 January 1979 (using linear diffusion) has also beeen performed.

TABLE 1

k	Standard σ_k	Modified σ_k
1	.025	.047
2	.077	.125
3	.132	.190
4	.193	.248
5	.260	.304
6	.334	.364
7	.415	.428
8	.500	.500
9	.589	.578
10	.678	.661
11	.765	.746
12	.845	.829
13	.914	.903
14	.967	.961
15	.996	.995

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3. Timesteps

It was attempted to run all February cases with a 20 minute timestep and all August cases with a 15 minute timestep. One February and one August case were unstable with these timesteps, and they were successfully completed with timesteps of 15 and 12 minutes respectively. These figures represent some improvement in timestep over the standard distribution of levels for which some other February and August cases were also unstable with timesteps of 20 and 15 minutes respectively.

Using the standard distribution of levels, all February cases were stable with a 15 minute timestep. Thus, although a fine tuning of the timestep has not been performed, it appears that use of the lower top level can generally result in an increase in timestep by an amount less than 30 %. The precise figure may well be substantially smaller.

4. Ensemble-Mean Errors

The ensemble-mean of the r.m.s. error of the 500 mb height field is shown in Fig. 1 for the February cases. For the total field there is evidently very little difference between results for the two distributions of levels, particularly before day 6, when the total error curves cross the climatological norm. Overall the standard distribution of levels gives a marginally lower error, this being most marked for wavenumbers 1 - 3. Similar results are found using other measures of error.

Mean differences from observation for the 500 mb height at day 10 are compared in Fig 2. Overall patterns are clearly similar, although there are substantial differences in the amplitude of the error in the Atlantic sector. It is unclear at present whether these represent true systematic differences between the two resolutions or whether they are simply a feature of these particular seven cases.

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Corresponding results for August are shown in Figures 3 and 4. Root-mean square errors are particularly close in these cases. Differences in the amplitude of the mean error at day 10 (Fig. 4) are much as found for February, although over much of the map the error appears to be lower for the modified vertical resolution.

5. Individual cases

R.m.s. errors for the 500 mb height field are shown in Figs. 5 and 6 for forecasts from 9 February and 12 February respectively. These represent cases for which this and most other objective measures indicate respectively the best and worst performance of the modified resolution in comparison with the standard resolution up to the time of crossing of the climatological norm. Of the other six February cases, three gave almost identical objective verifications, while the other three favoured the standard resolution. In two of the latter, differences in r.m.s. error were almost as large as indicated in Fig. 6. In contrast, all August cases gave very similar objective scores.

Synoptic maps are presented in Figs. 7,8 and 9 for two cases. Figs. 7a) and b) are day 6 500 mb forecasts from 25 August, while Fig. 7c) is the corresponding NMC analysis. The two forecasts are evidently particularly close at this time, and differences between the two are certainly much less than differences between one (or other) of the forecasts and the analysis.

A similar result is shown in Fig. 8 for the day 6 forecasts from 15 February. At this time the r.m.s. error of the forecast using the standard vertical resolution (Fig. 8a) is lower than that from the modified resolution by an amount similar to that shown in Fig. 6 for day 6 of the integration from 12 February. It is difficult to account for this difference synoptically.

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Much larger differences become apparent at later days. Fig. 9 presents day 9 forecasts of the 1000 mb height, again for 15 February initial conditions. Examination of the Pacific sector reveals a marked difference in development.

A brief study has also been made of 50 mb charts. Although this level is generally close to the top of the model with modified vertical resolution, little synoptic difference is again found for forecasts of a few days. A result of interest is that both models capture an observed change from an elongated circumpolar vortex to a pronounced asymmetric vortex, centred significantly away from the pole, over an 8-day period commencing 16 January 1979, although marked differences were found in the detail of the flow pattern. Objective tropospheric verification of these forecasts again showed slightly better scores for the standard vertical resolution up to day 7, although height errors become larger at day 8.

6. Conclusions

These results indicate that up to the current limit of useful predictability there is little difference in the quality of forecasts between the two different vertical resolutions. Objective measures appear to favour marginally the use of the resolution with a top level at $\sigma = .025$, although this requires a somewhat shorter timestep. Use of the lower top level would reduce the requirement for stratospheric analysis, and the choice of resolution must in part depend on the quality of our stratospheric analyses.

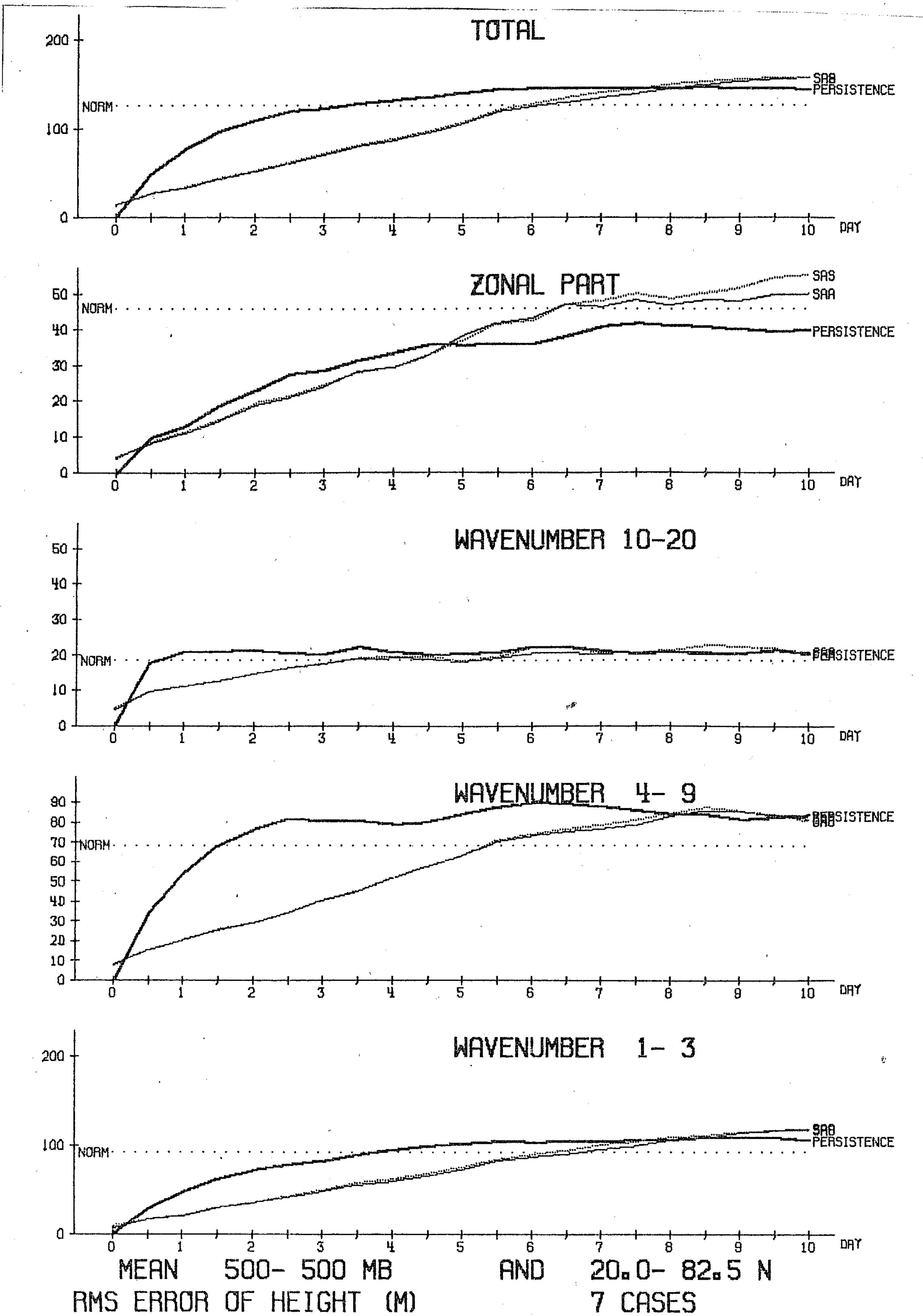

Fig. 1 : Ensemble-mean root-mean square 500 mb height error for February cases. The light solid curves denote results for the standard distribution of vertical levels.

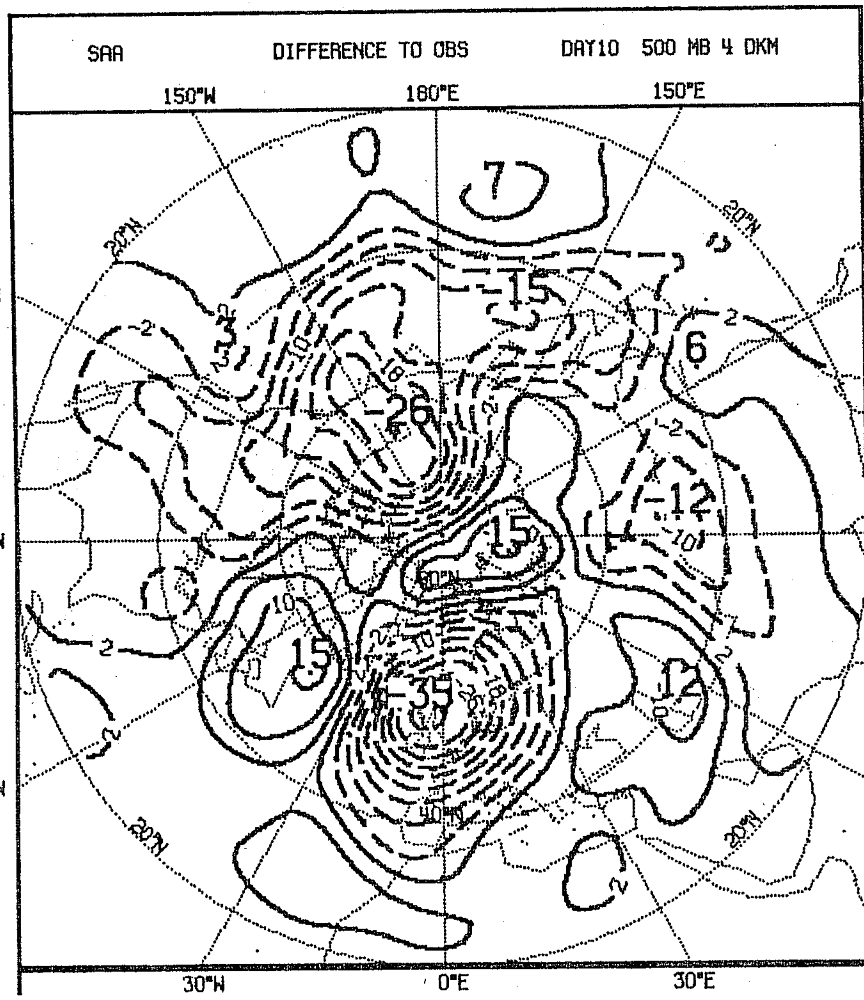

Fig.2a)

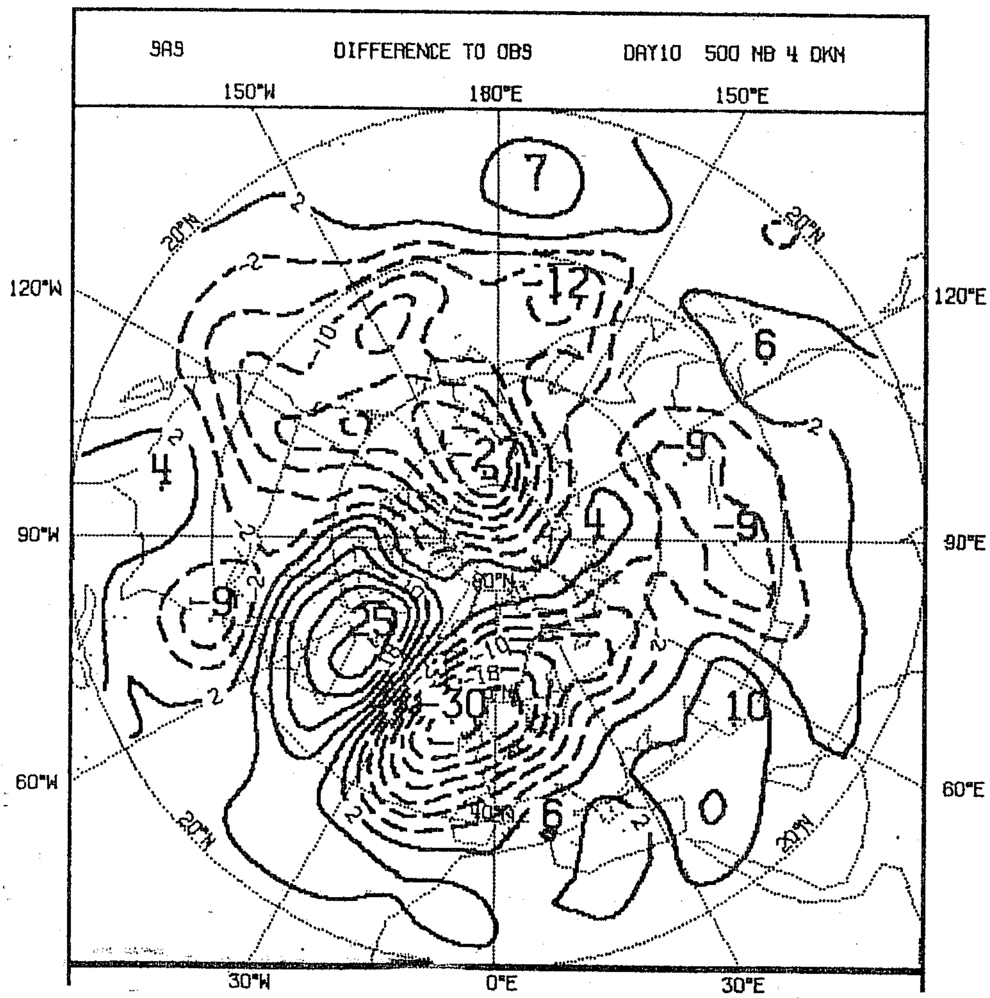

Fig. 2b)

Fig. 2 : Mean differences from observations for the 500 mb height at day 10 fo[r] February cases.
a) Standard resolution,
b) Modified resolution

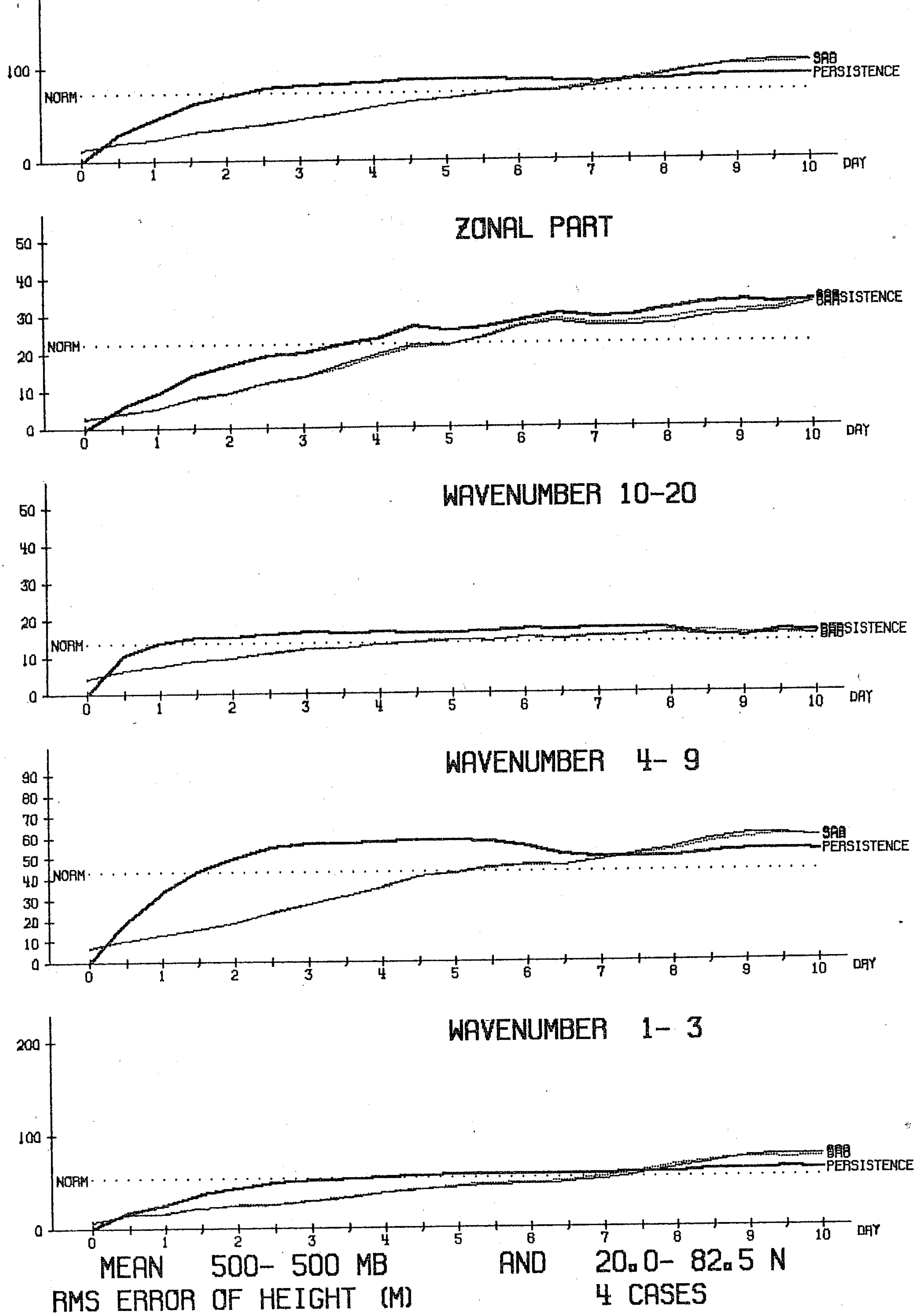

Fig. 3 : As Fig. 1, but for August cases.

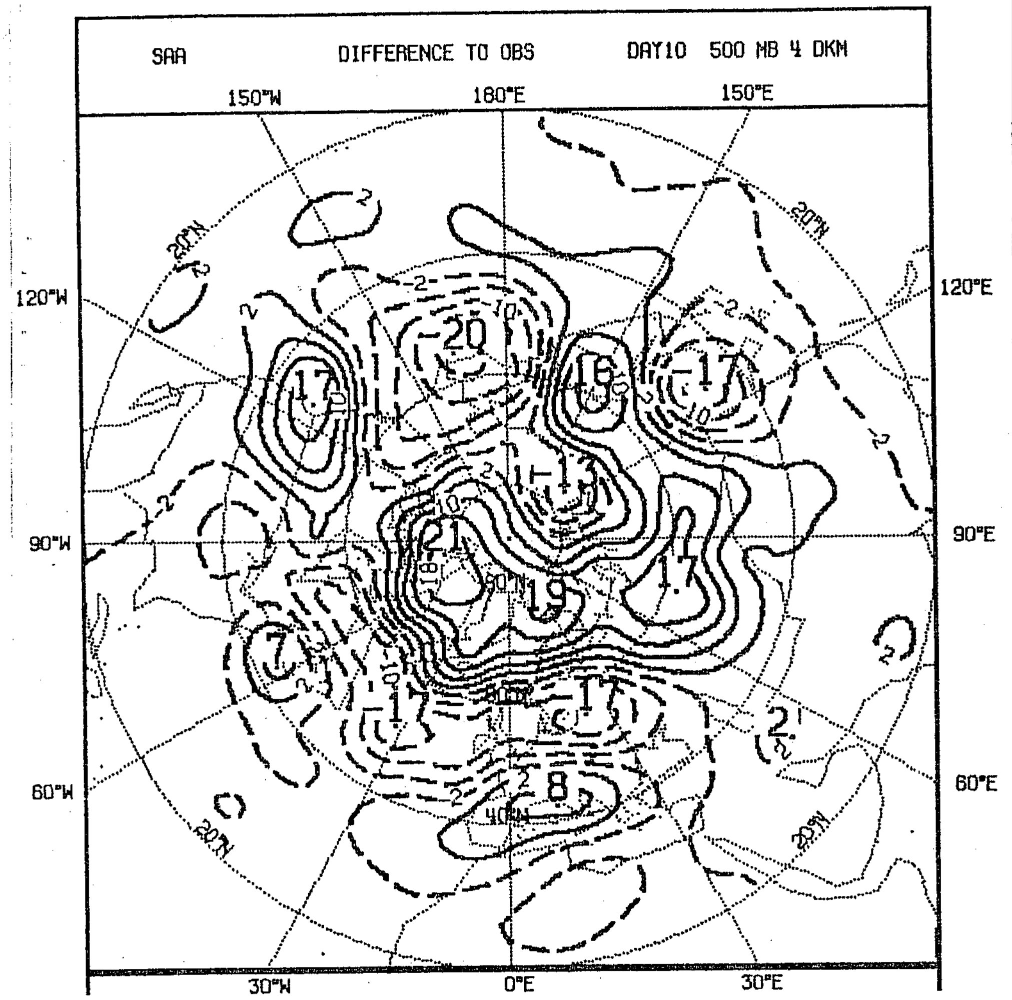

Fig. 4a)

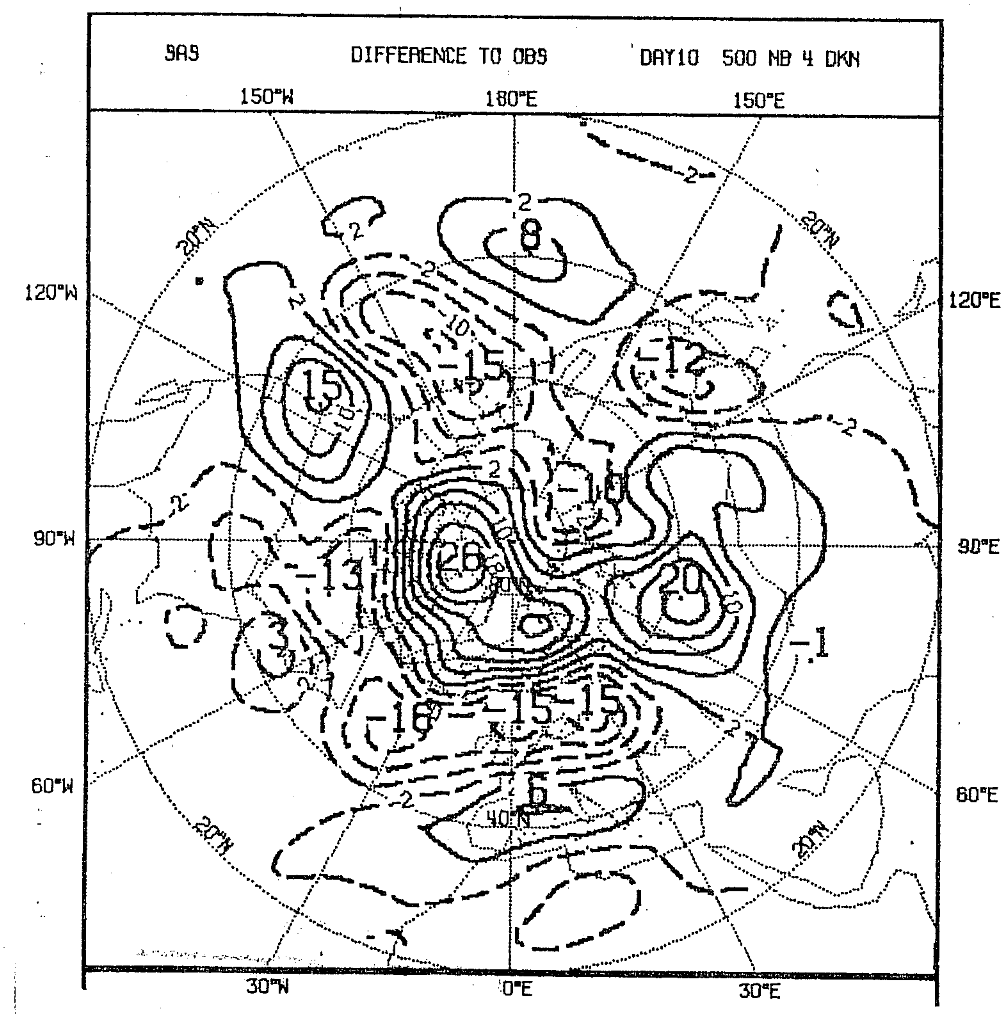

Fig. 4b)

Fig. 4 : As Fig 2, but for August cas

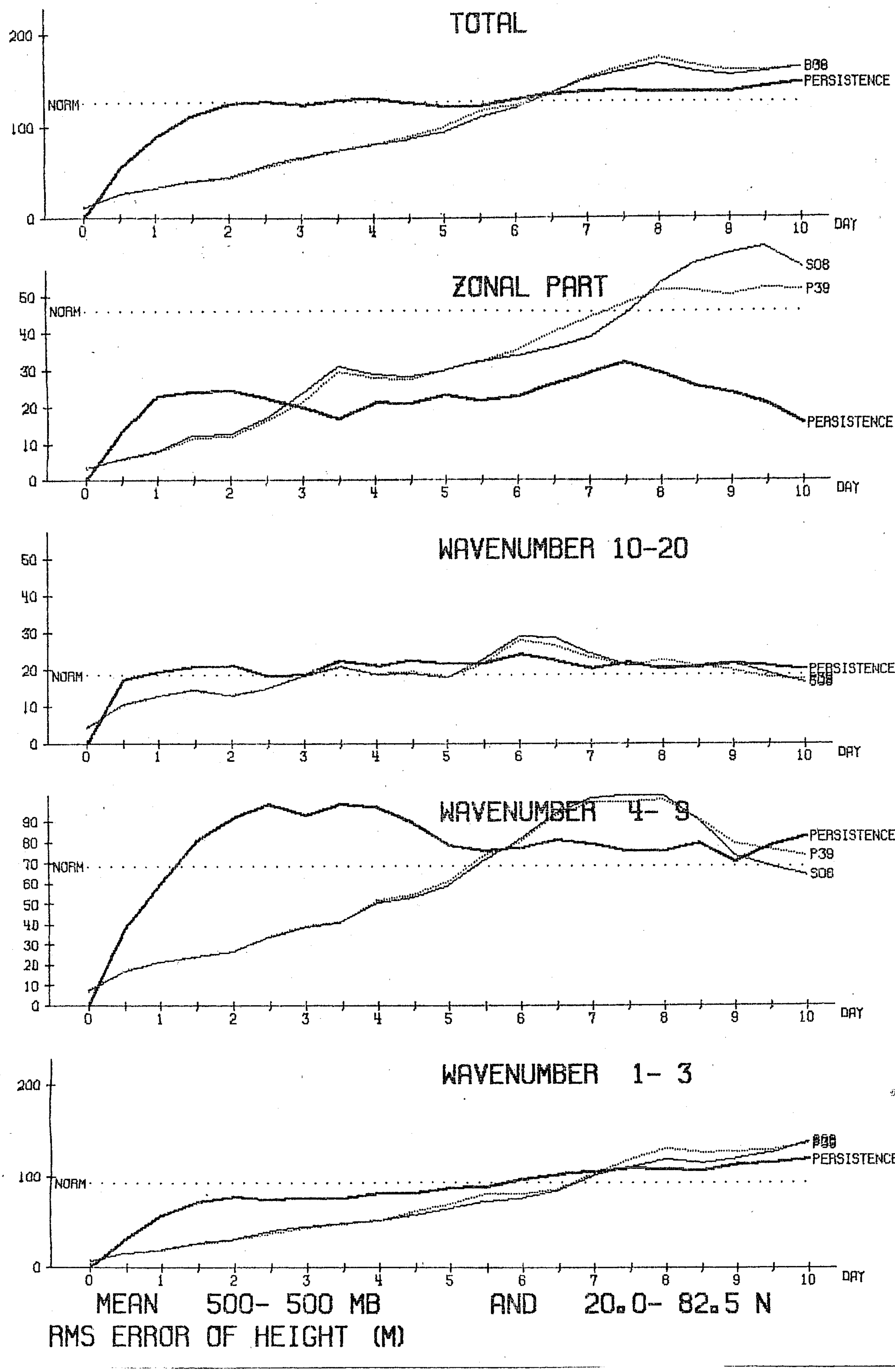

Fig. 5 : Root-mean square 500 mb height error for the forecasts from 9 February. The light solid curves here denote results for the modi

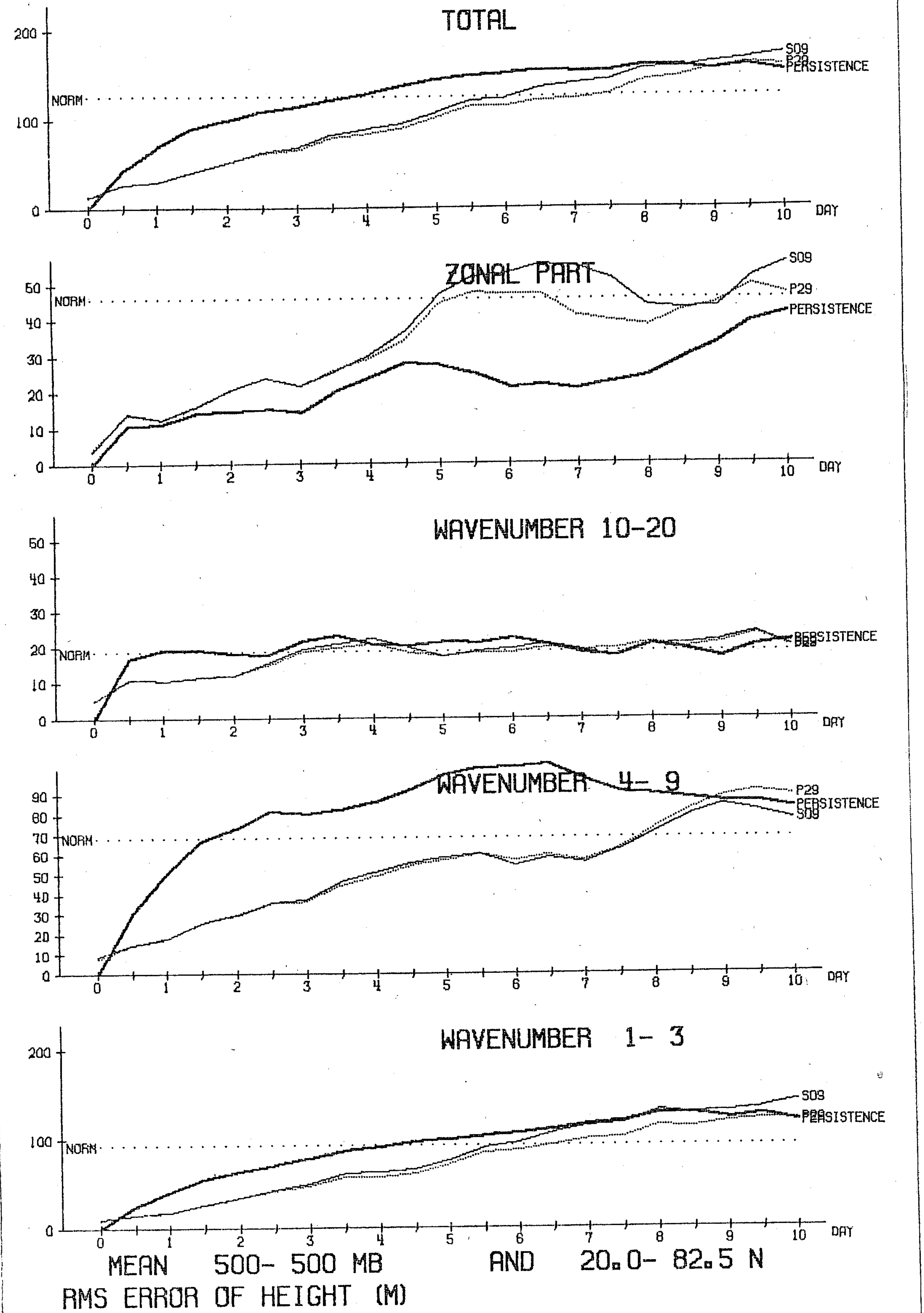

Fig. 6 : As Fig. 5, but for 12 February.

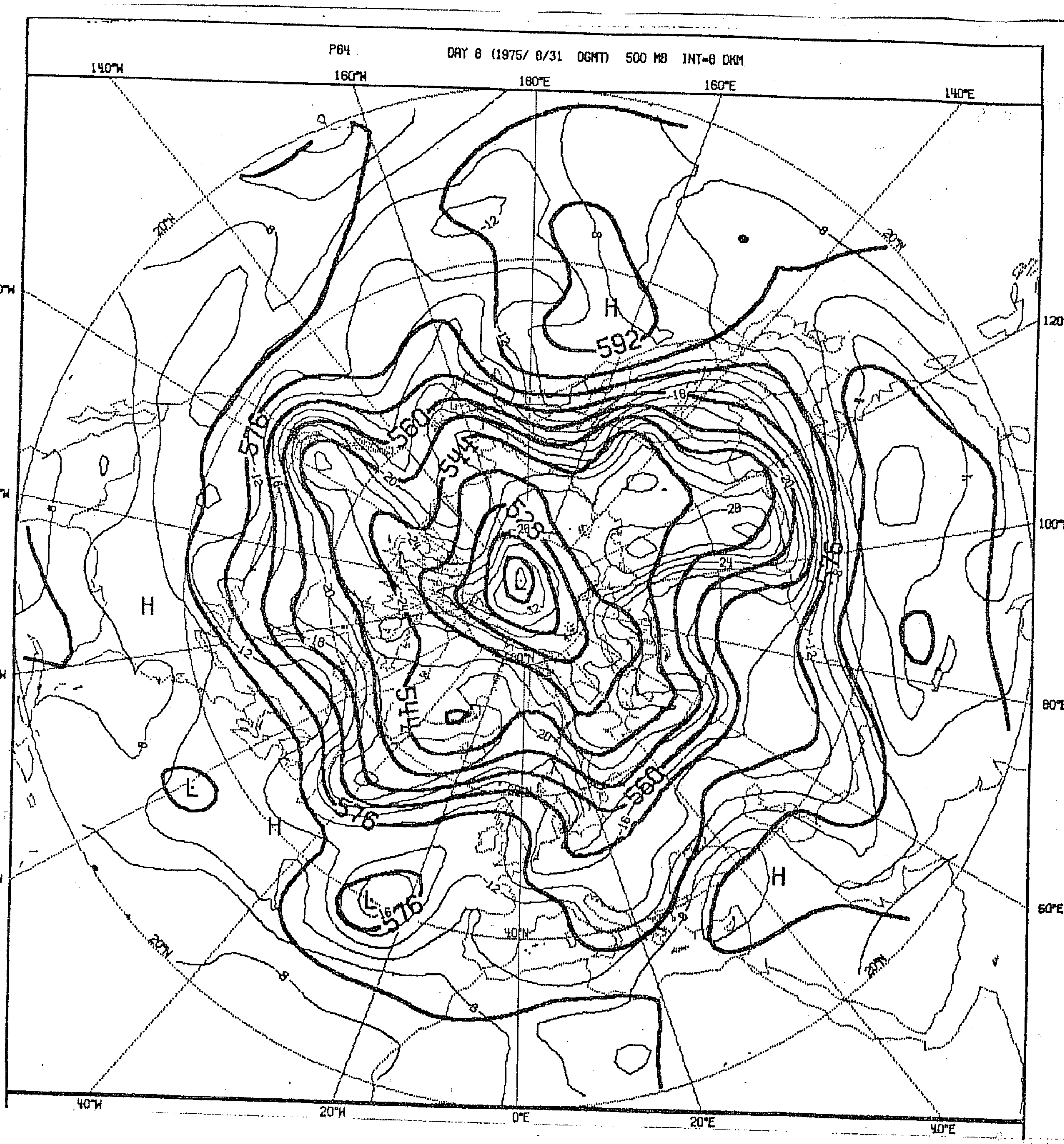

Fig. 7a : 500 mb charts for 31 August
6 day forecast using standard levels.

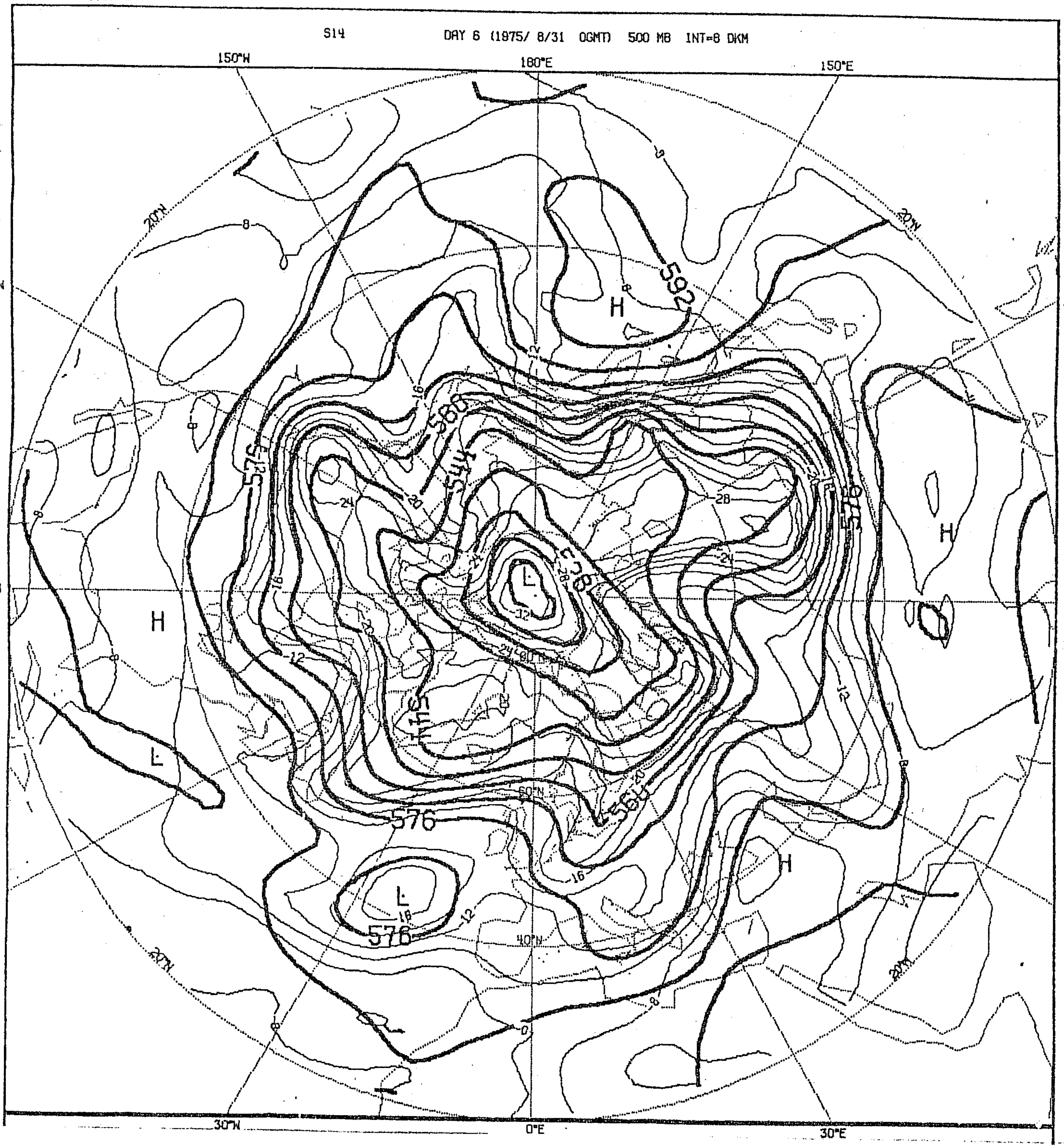

Fig. 7b) : 500 mb charts for 31 August .

6 day forecast using modified levels .

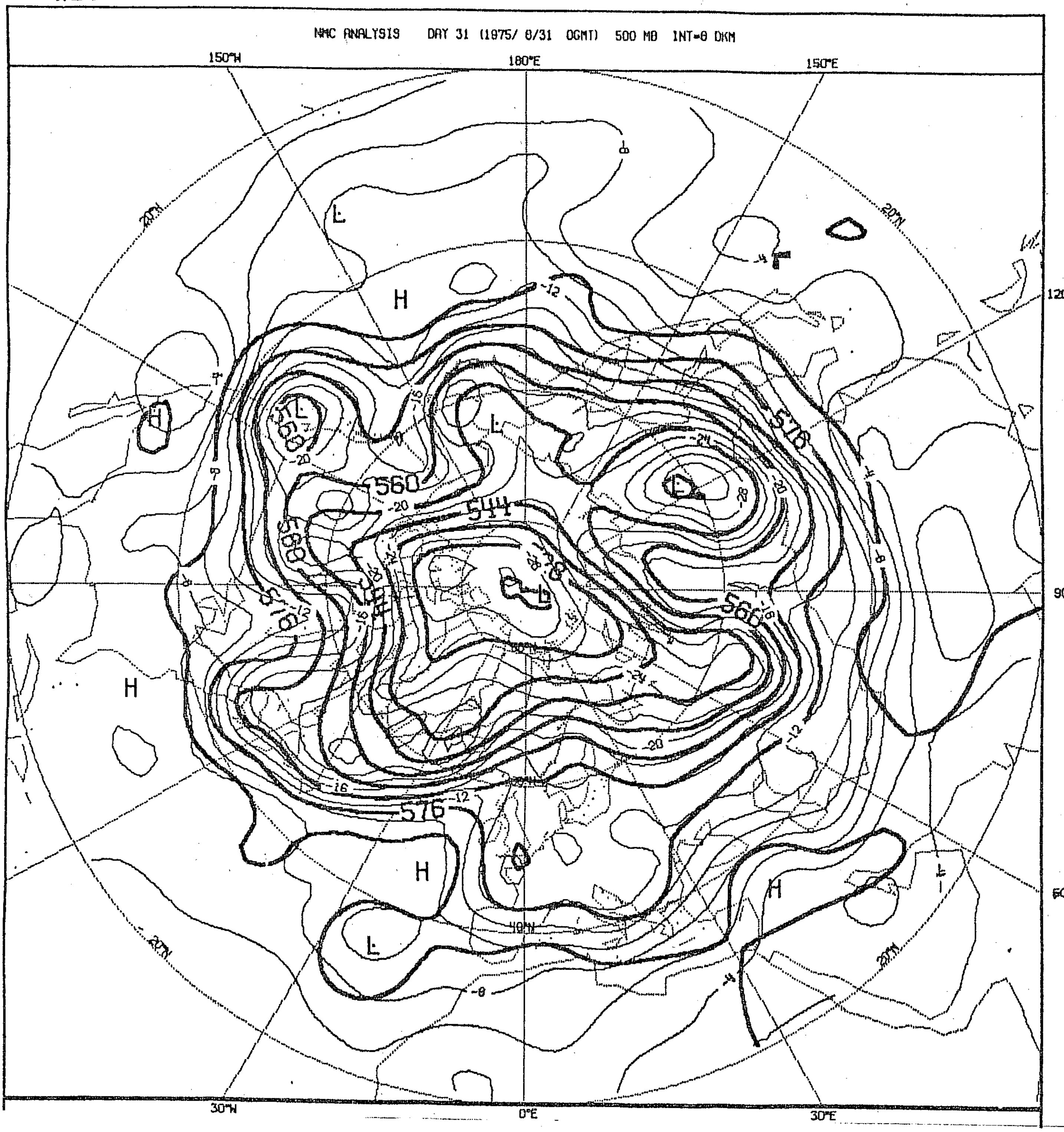

Fig. 7c) : 500 mb charts for 31 August.

NMC Analysis.

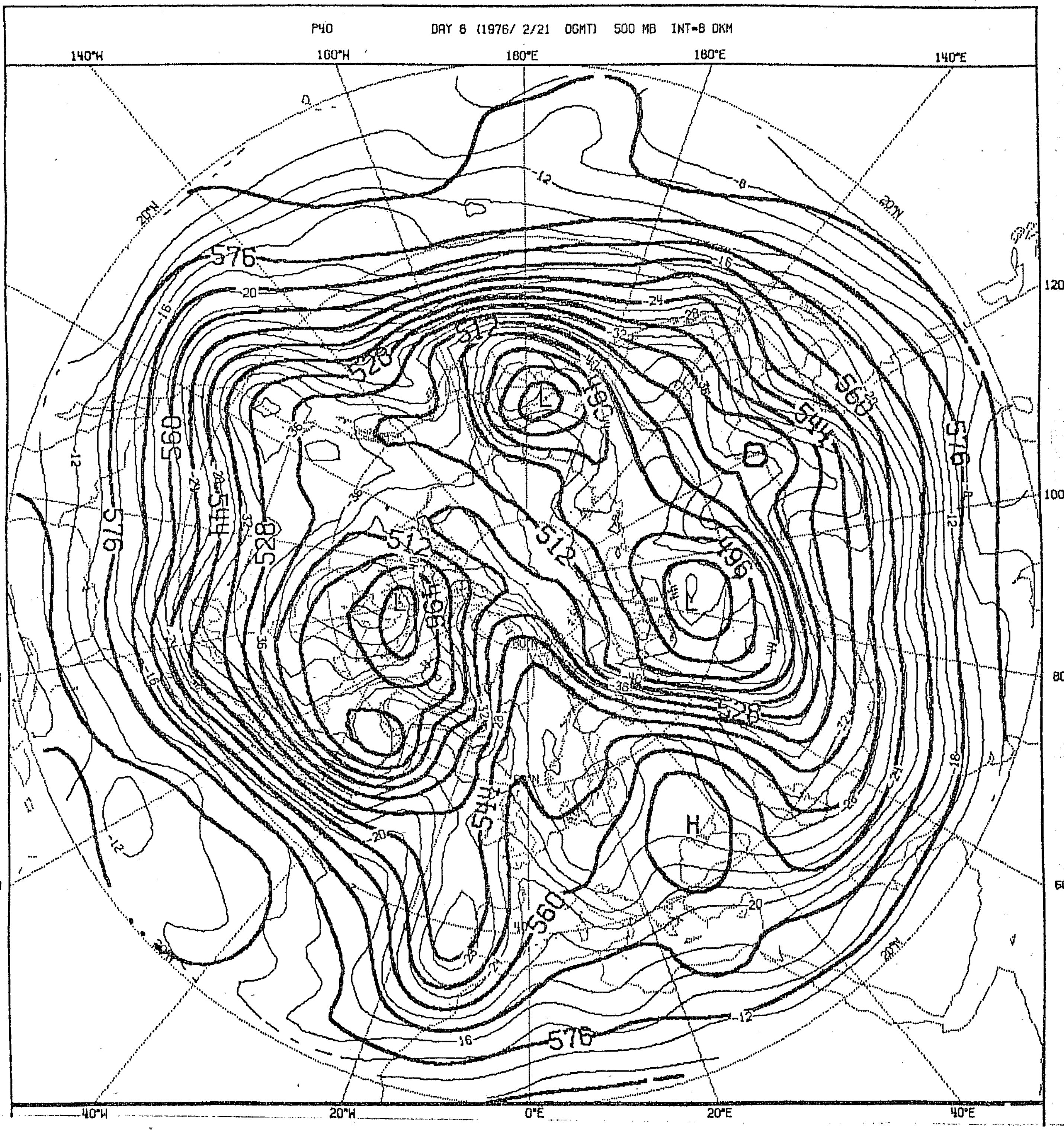

Fig. 8a) : As Fig. 7a, but for 21 February .

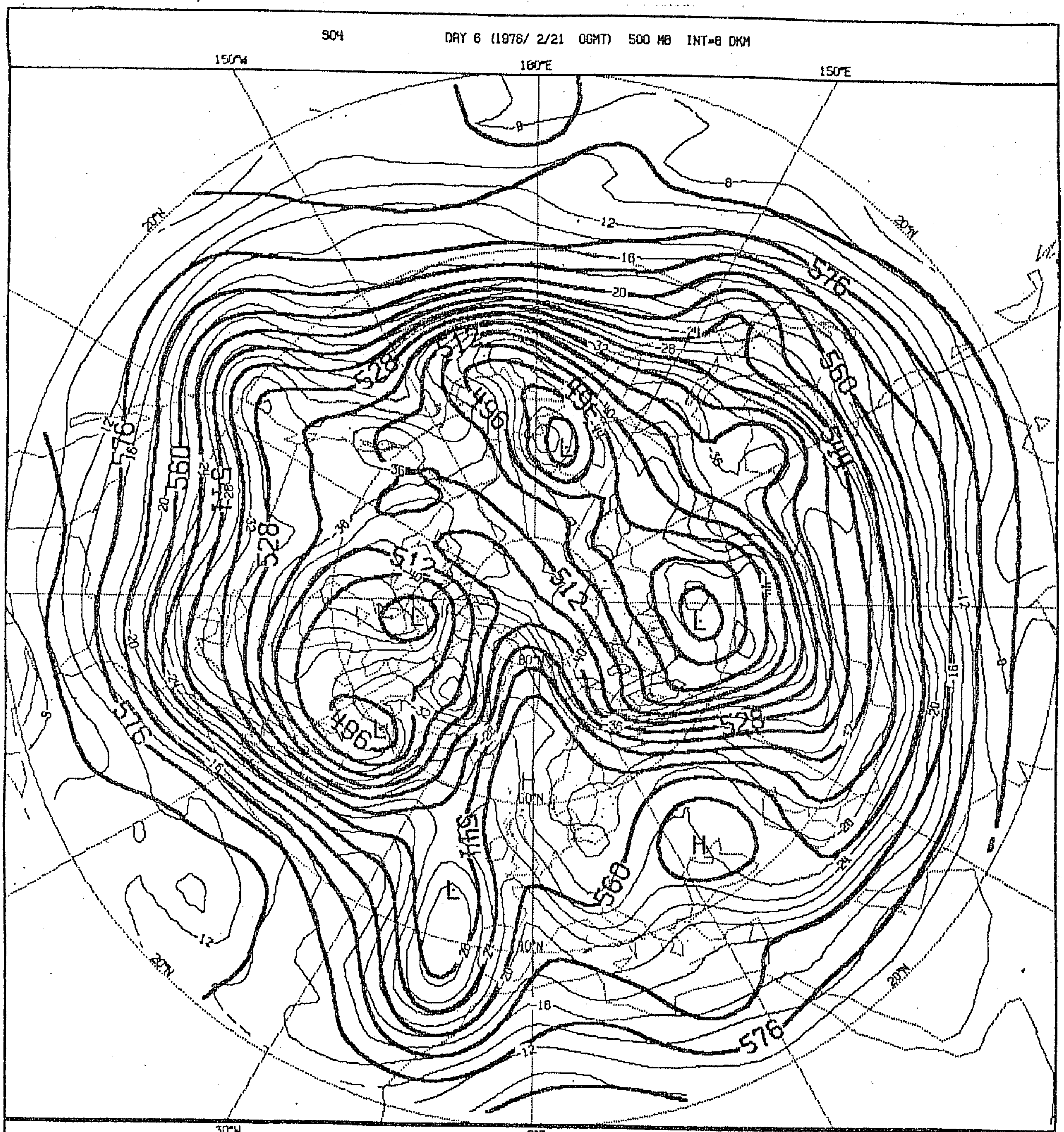

Fig. 8b) : As Fig. 7b, but for 21 February.

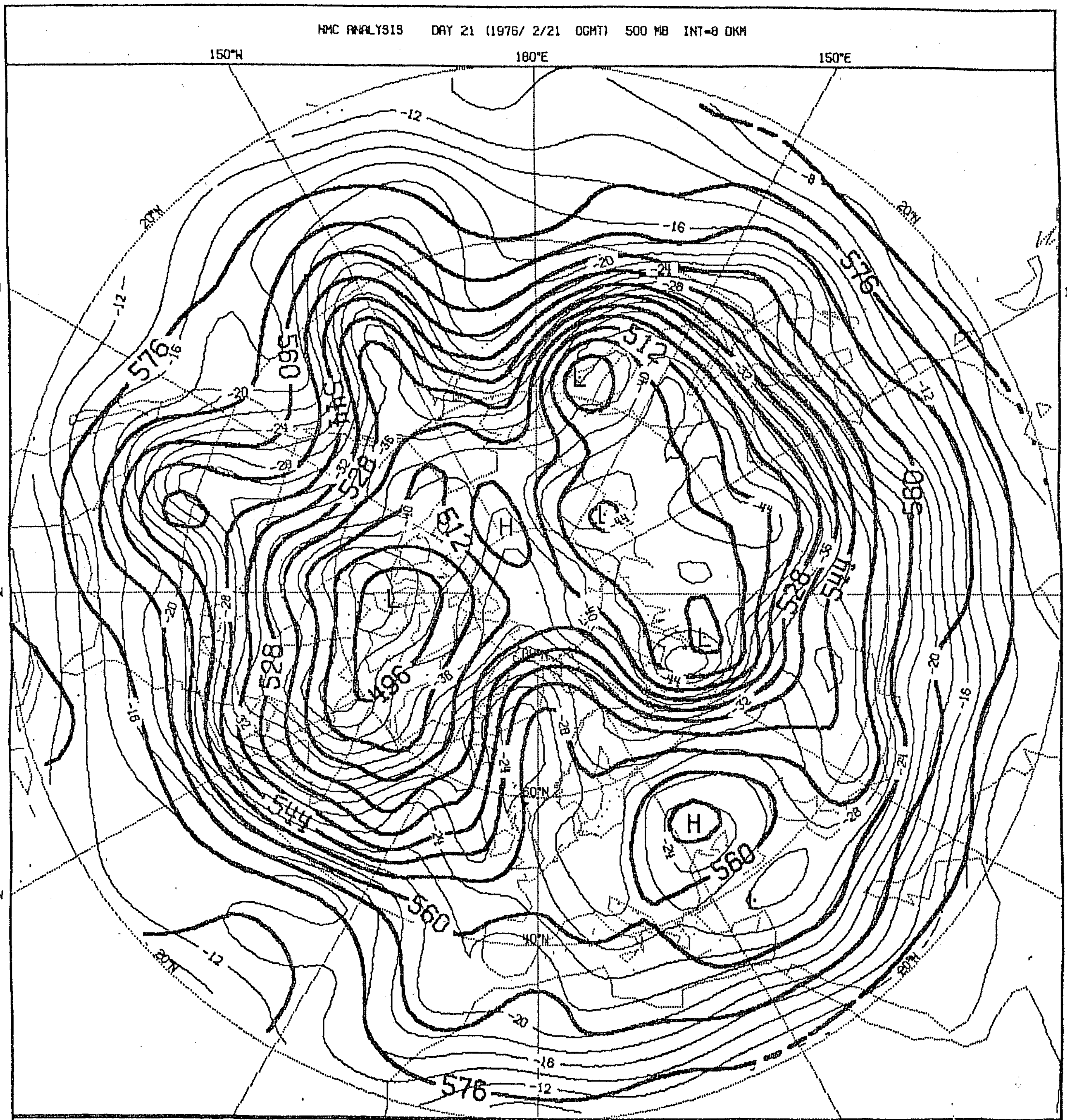

Fig. 8c) : As Fig. 7c, but for 21 February.

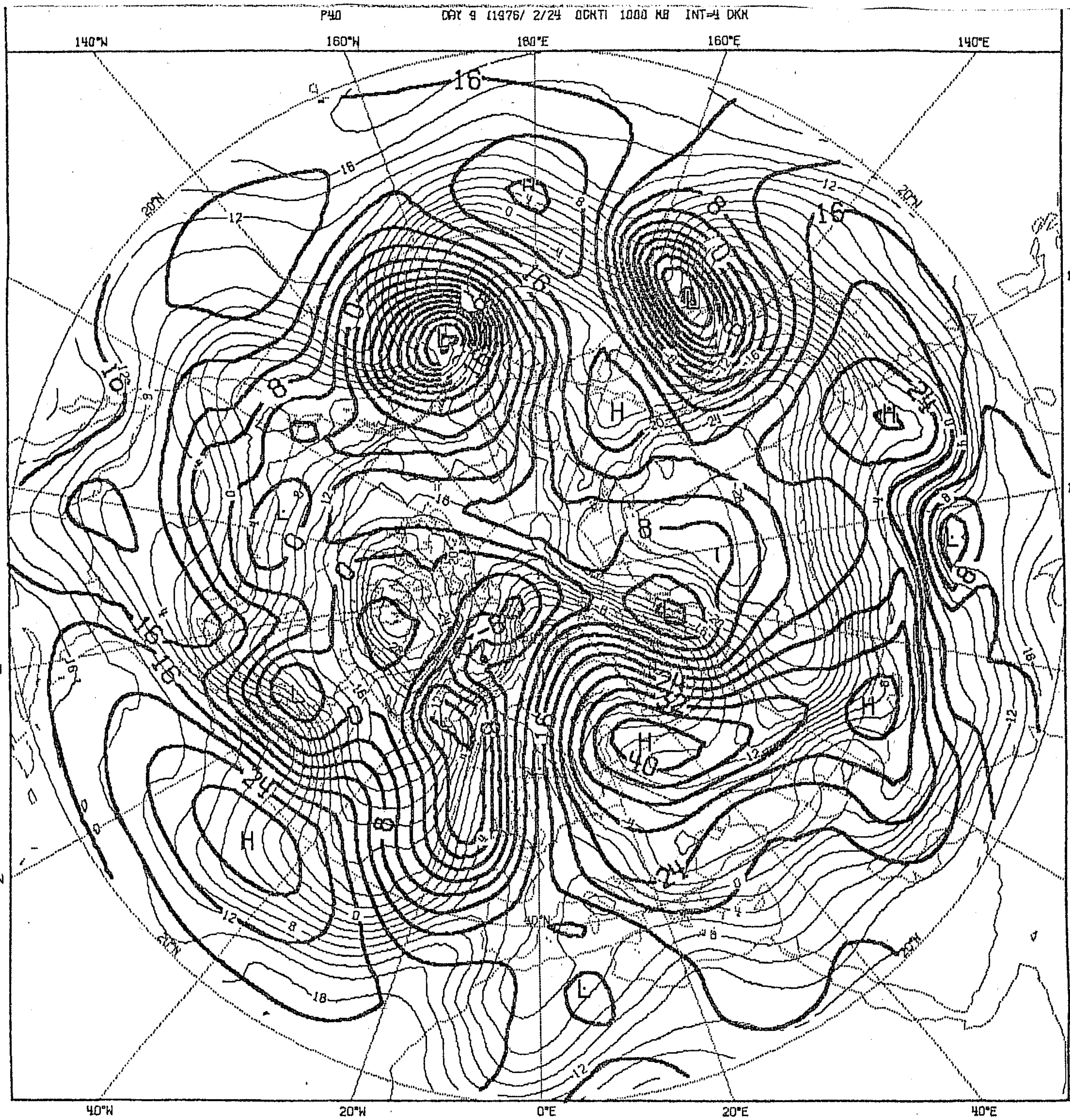

Fig. 9a) 1000 mb height for 24 February.
9 day forecast using standard levels.

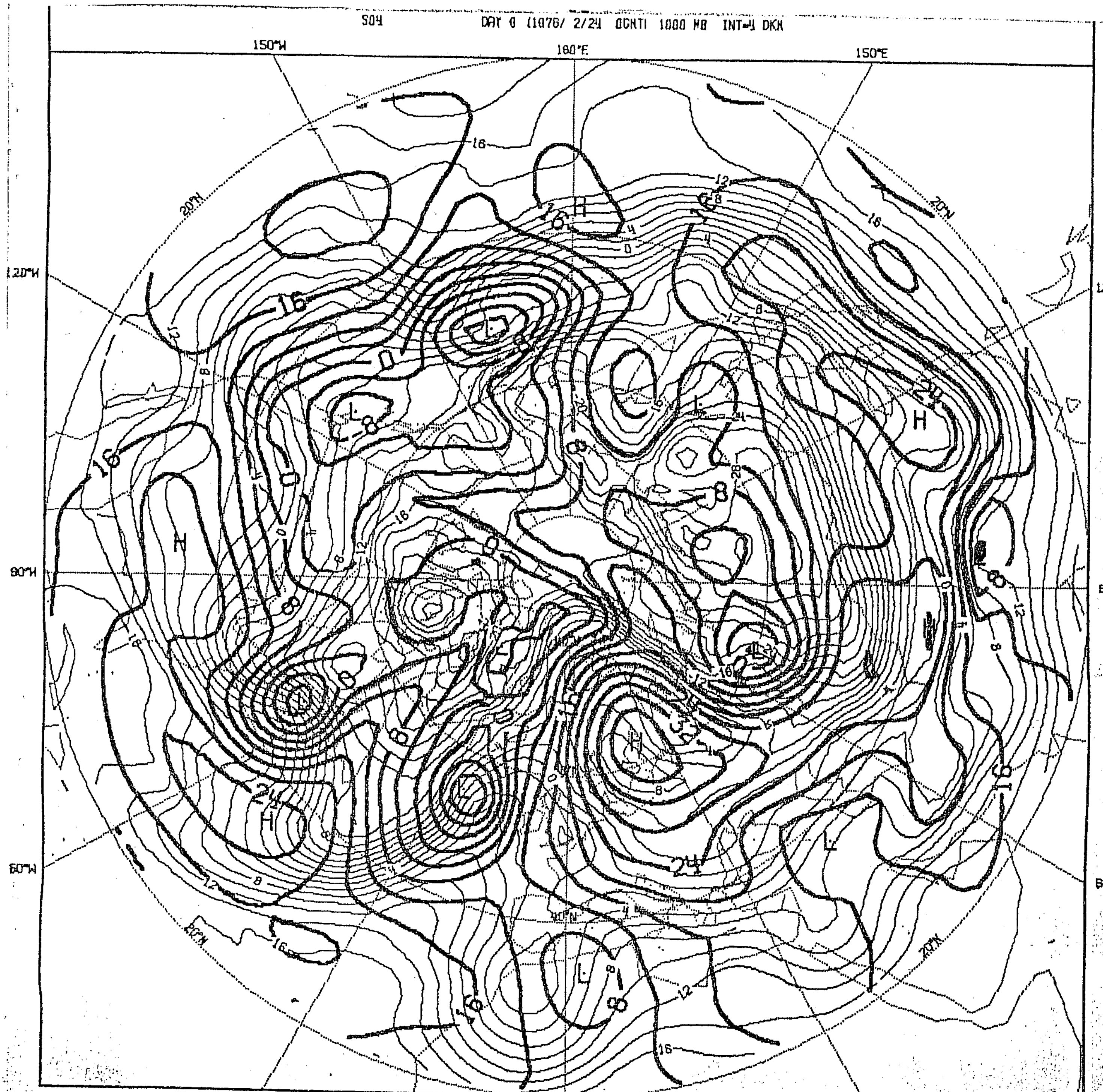

Fig. 9b) : 1000 mb height for 24 February.

9 day forecast using modified levels.

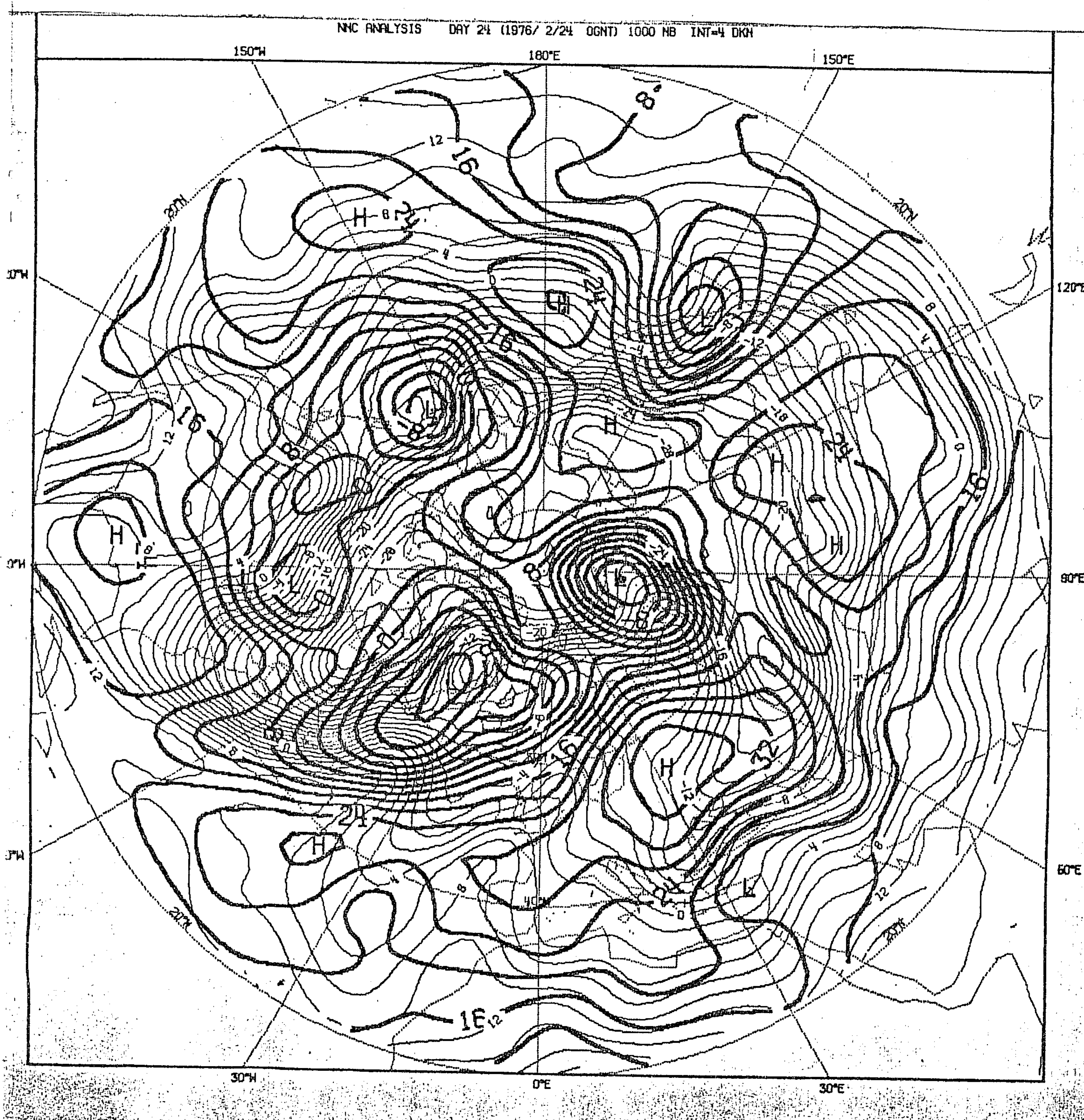

Fig. 9c) : 1000 mb height for 24 February.
NMC Analysis.