MET O 11 TECHNICAL NOTE No.70

REPORT ON FINE MESH FORECASTS ON THE OCTAGON AREA

by

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1. INTRODUCTION

From May 1975 to March 1976 forecasts on the octagon area were run to 6 days once a week using a grid length of 150km instead of the operational grid length of 300km. The formulations of both the fine mesh and the operational model were identical except for the number of grid points, and both used the split semi implicit scheme described by Burridge (1975). The initial data for the fine mesh version was obtained by interpolation from the operational intialised data. The operational model was run with a time-step of 15 mins (which is half the value that stability analysis would imply was necessary) to reduce errors due to time truncation. It was decided that the same time step would suffice for the fine mesh forecasts even though the grid length was halved. The time taken for the fine mesh forecasts was therefore 4 times that of the operational forecasts (i.e. 2hrs 40mins CPU time, compared with the operational 40mins, for a 6day forecast). The early version of the program occupied 730k of core store (compared with 430k for the operational forecasts) and this was found to be too large for the COSMOS system to cope with. Special steps were therefore taken by Met.O.12 to decouple the system each Sunday and run the forecasts using the 360/195 on a stand alone basis. Subsequently, after considerable programming effort, a more efficient program was produced which reduced the core store requirement to 558k - a size which could be run under COSMOS in the normal way. The forecasts, which were assessed subjectively each week, were stored on magnetic tape together with the comparison operational runs. Late in 1975 a diagnostic program was written which computed a number of parameters such as RMS errors, phases and amplitudes of Fourier components around several different latitudes and at several different pressure levels, Hovmöller diagrams etc. Steps were taken to compute diagnostics for some of the forecasts produced earlier in the year and these are illustrated in this report. Complete diagnostics are available for a total of 14 cases. Occasionally the forecasts failed for one reason or another and these were usually <u>not</u> repeated at a later date due to the large amount of CPU time involved.

2. COLD POOLS

One of the disadvantages of the semi-implicit scheme as devised by Burridge (1975) is its tendency to produce intense cold pools. It was found during the experiment that the fine mesh octagon forecasts were even more sensitive to this than the operational forecasts. Some experiments with the operational version early in 1975 suggested that this effect was associated with the representation of the Coriolis terms in the finite difference scheme. In Burridge's original formulation: the pressure gradients contained in the external and first internal gravity wave modes were represented implicitly as the average between the values at time levels n and n+1, while the Coriolis terms were calculated explicitly with second order correction terms in the following manner

$$f v^n - \frac{f \Delta t}{2}\left(g \frac{\partial h^n}{\partial y} + f u^n\right)$$

$$-f u^n + \frac{f \Delta t}{2}\left(g \frac{\partial h^n}{\partial x} - f v^n\right)$$

The different treatment of the Coriolis and pressure gradient terms leads to a poor representation of geostrophic balance. It was thought that the second order correction terms were the cause of the problem and these were dropped from the model at the beginning of May 1975 just before the fine mesh octagon experiment was started. During the summer, however, it became clear that this change had produced severe detrimental effects elsewhere and both coarse and fine mesh forecasts were altered back to the original formulation on 21 October 1975.

A detailed investigation of a particular cold pool on 2/11/75 in the fine mesh octagon suggested that it was associated with ascent at 950mb when the lapse rate was stable. Since one sided vertical derivatives are used at 950mb, this is easily seen to be computationally unstable because the finite difference scheme is equivalent to extrapolating the lapse rate down to a fictitious 1050mb and advecting the artificially cold air implied there up to 950mb. This makes the lapse rate between 950mb and 850mb even more stable than before and exacerbates the situation in the subsequent time step. In one experiment the program was altered so that the vertical advection was set equal to that implied by the ICAO lapse rate in ascending motion at 950mb and the cold pools did not occur.

It appears from the evidence collected that the following sequence of events must arise to produce a cold pool.

(a) Ascent must occur at 950mb when the lapse rate between 950 and 850mb is appreciably stable. (This is a rather unusual event and only arises in isolated situations e.g. a cold occlusion in a still developing depression).

(b) The inconsistent representations of the Coriolis and pressure gradient terms must prevent adequate geostrophic adjustment taking place.

(c) The stability of the lower layers must increase the phase speeds of the internal gravity waves to such an extent that they break the C-F-L computational stability criterion.

It is of interest to note that on one occasion (18/1/76) the fine mesh forecast was run with a $7\frac{1}{2}$min time step (taking 5hrs 20min CPU) and the cold pools did not occur (evidently because gravity waves speeds were not sufficient to break the new stability criterion). Also, the split explicit scheme (Gadd, 1976), which was introduced operationally on 20/4/76, treats both the Coriolis and the pressure gradient terms by the same finite difference procedure. This gives a good representation of geostrophic balance and cold pools have never been observed to occur even though one sided vertical differences are still used at 950mb.

3. RESULTS OF THE FORECASTS

In assessing the forecasts it is important to bear in mind that, as described in the previous section, both the coarse mesh and fine mesh octagon results were adversely affected during the period 13 May to 21 October 1975 by the neglect of the second order correction in the Coriolis terms, and throughout the entire year the fine mesh forecasts reacted in a more sensitive way than the coarse mesh forecasts to the occurrence of spurious cold pools.

Subjectively the fine mesh forecasts were rather disappointing since they generally made the same gross errors and had the same successes as the coarse mesh operational forecasts. However, the fine mesh model was sometimes able to describe features rather better and tended to propagate them with more nearly the correct speed. One occasion illustrating this arose in the forecast from 1/6/75 when a polar low formed in a northerly airflow giving some short lived unseasonal falls of sleet in the east of Britain. The fine mesh model produced a closed low in about the right place while the operational model merely produced a weak trough. A more dramatic success of the fine mesh model occurred in the forecast from 18/1/76. Initially there was a high to the southwest of the British Isles orientated roughly east-west giving approximately westerly flow over the country (Fig. 1). 6 days later (Fig.2) the orientation of the anticyclone had changed considerably leading to a marked meridional flow over the Atlantic and northerlies over the UK. The operational forecast (Fig.3) completely failed to predict this development but the fine mesh forecast (Fig.4) made a much more convincing attempt at predicting the change of type. (The fine mesh result shown here was done with a $7\frac{1}{2}$ min time step, however the companion forecast with a 15 min time step was almost the same except for a spurious cold pool over Canada).

Figs. 5(a)-(n) show RMS errors for each of the forecasts over two areas, the entire octagon area and a 20 x 20 area surrounding the British Isles. Since the cold pools arose mainly in central Asia, in polar regions or in Canada, the 20x20 area was largely uncontaminated by them. For most occasions the RMS errors in the neighbourhood of the UK for the fine mesh octagon forecasts were smaller than for the coarse mesh forecasts at least up to about 4 days. On a few occasions the fine mesh came out a little worse than the coarse mesh (3/8/75, 31/8/75, 25/1/76), while on other occasions it was substantially better throughout most of the 6 day forecast period (27/7/75, 11/1/76, 18/1/76, 22/2/76, 29/2/76). The forecast for 18/1/76 was the only occasion when the fine mesh forecast was closer (marginally) to reality at the 6th day than it was to the coarse mesh forecast, although the forecast for 29/2/76 was also successful in this respect at 2-3 days.

A large amount of information has been computed by the diagnostic program about the spectral behaviour of the models. Although much of this has been examined, no general conclusions have been drawn except that phase speeds of the waves in the fine mesh model are a little more correct than in the coarse mesh model and the behaviour of the long waves also seems to be improved. Figs. 6 - 13 show some of the output available for a particular case (18/1/76). The amplitude spectra (Figs. 6 and 7) indicate that the fine mesh forecast handles the intermediate band of wavenumbers 6-10 rather better than the operational version. The Hovmöller diagrams for the long waves (Figs. 8,9 and 10) show that although the analyses indicate a more or less stationary pattern, both models produced a slow drift to the east with the coarse mesh model being somewhat worse in this respect. The changes in the amplitudes were also a little better in the fine mesh model. In the wavenumber band 6-10 (Figs. 11,12 and 13) both models incorrectly predicted a decline at all longitudes of the wave amplitudes by day $2\frac{1}{2}$ but the fine mesh had correctly re-established a trough ridge pattern between longitudes 240° and 0° by day 6. Both models correctly predicted an eastward propagation, the speed being about right in the fine mesh model but too fast in the operational model.

4. CONCLUSIONS

The main conclusion of the experiment is that a reduction of the grid length does not by itself cure all the problems of numerical weather prediction. Five out of the fourteen cases examined in detail gave substantially better results with a fine mesh over most of the 6 day forecast period but three were slightly worse. However, only in one case could the fine mesh version of the octagon be said to have predicted an appreciably improved synoptic development.

It is felt that research should be directed towards the use of high order finite difference schemes, space and time staggered meshes, finite element and spectral methods, all of which can improve the behaviour and transfer properties of waves in the model without suffering from the severe CPU time penalties which are involved when using a finer mesh. Nevertheless it is felt that it would be useful to repeat the experiments over a similar extended period using the split explicit model, the results of which will not be confused by the presence of spurious cold pools. It is estimated that a 150km grid length octagon computed using the split explicit method would take about 2 hours CPU for a 6 day forecast and occupy about 460k of core store.

REFERENCES

Burridge, D.M.	1975	"A split semi-implicit reformulation of the Bushby-Timpson 10-level model" Quart.J.R.Met. Soc. 101 pp 777-792.
Gadd, A.J.	1976	"A progress report on the split explicit integration scheme (March 1976)". Met.O.2b Technical Note. No.22.

SURFACE PRESSURE ANALYSIS 12Z 18/01/76

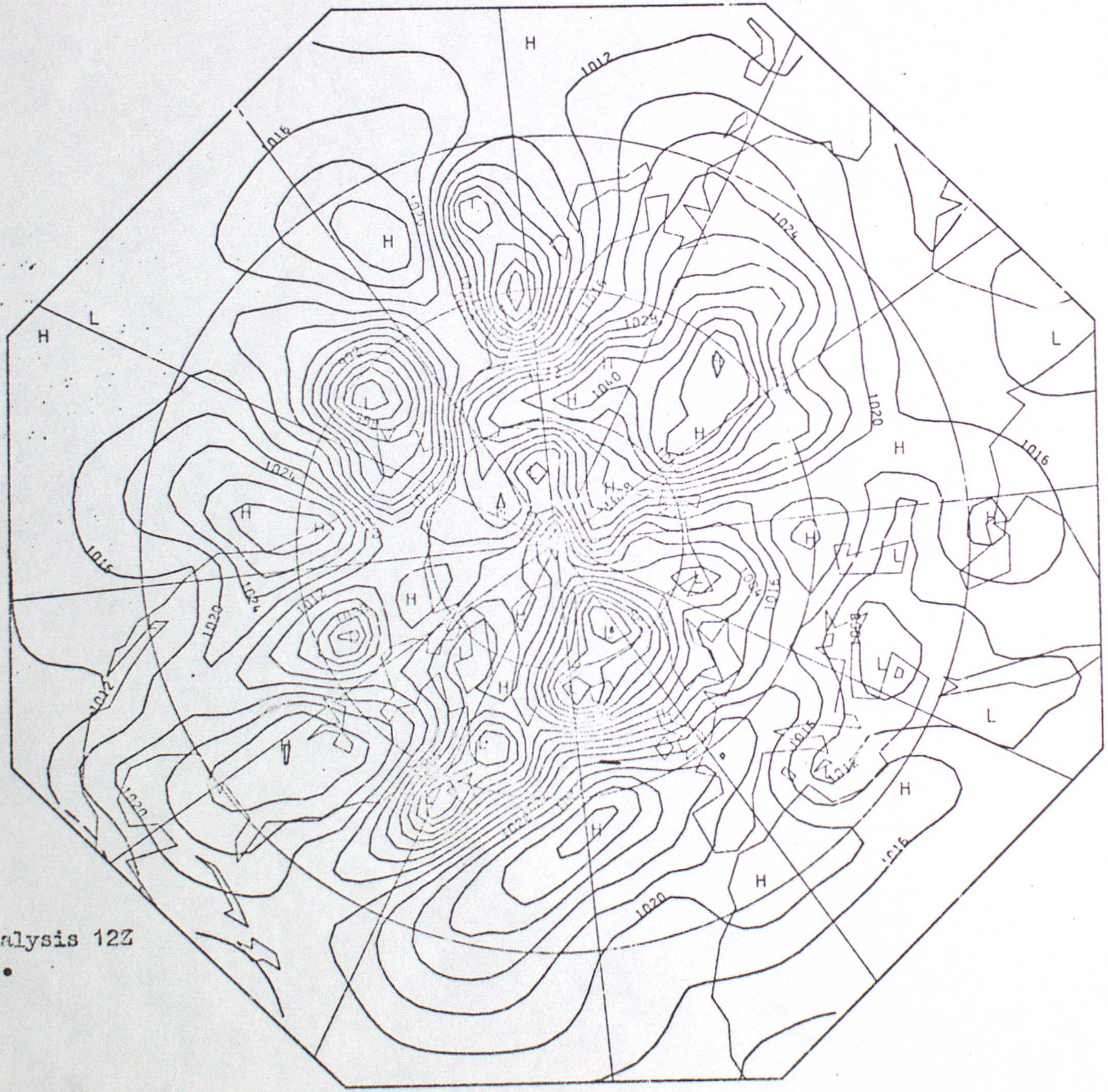


Fig.1 -
Initial Analysis 12Z
18.1.76.

SURFACE PRESSURE ANALYSIS   12Z 24/01/76

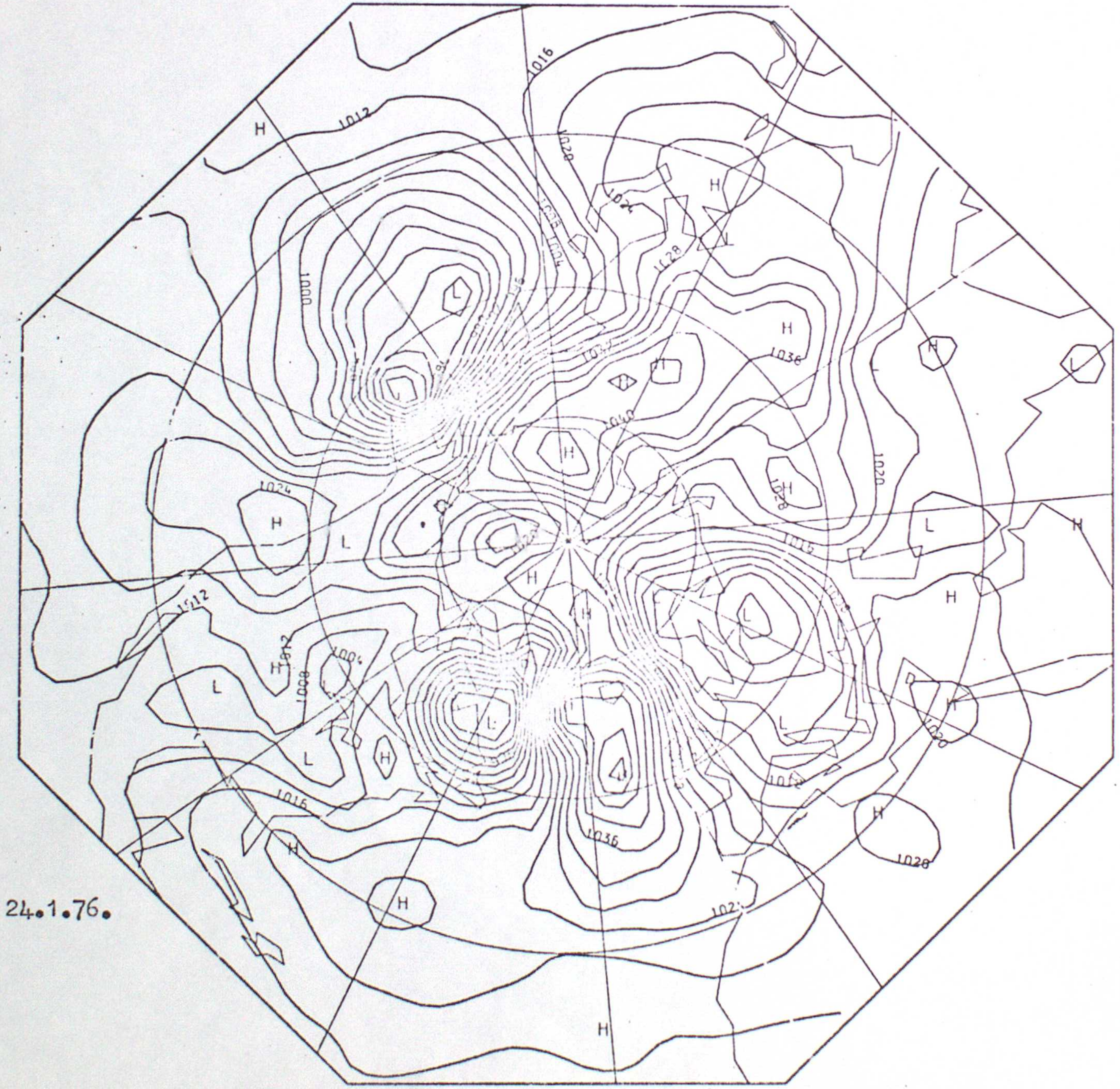
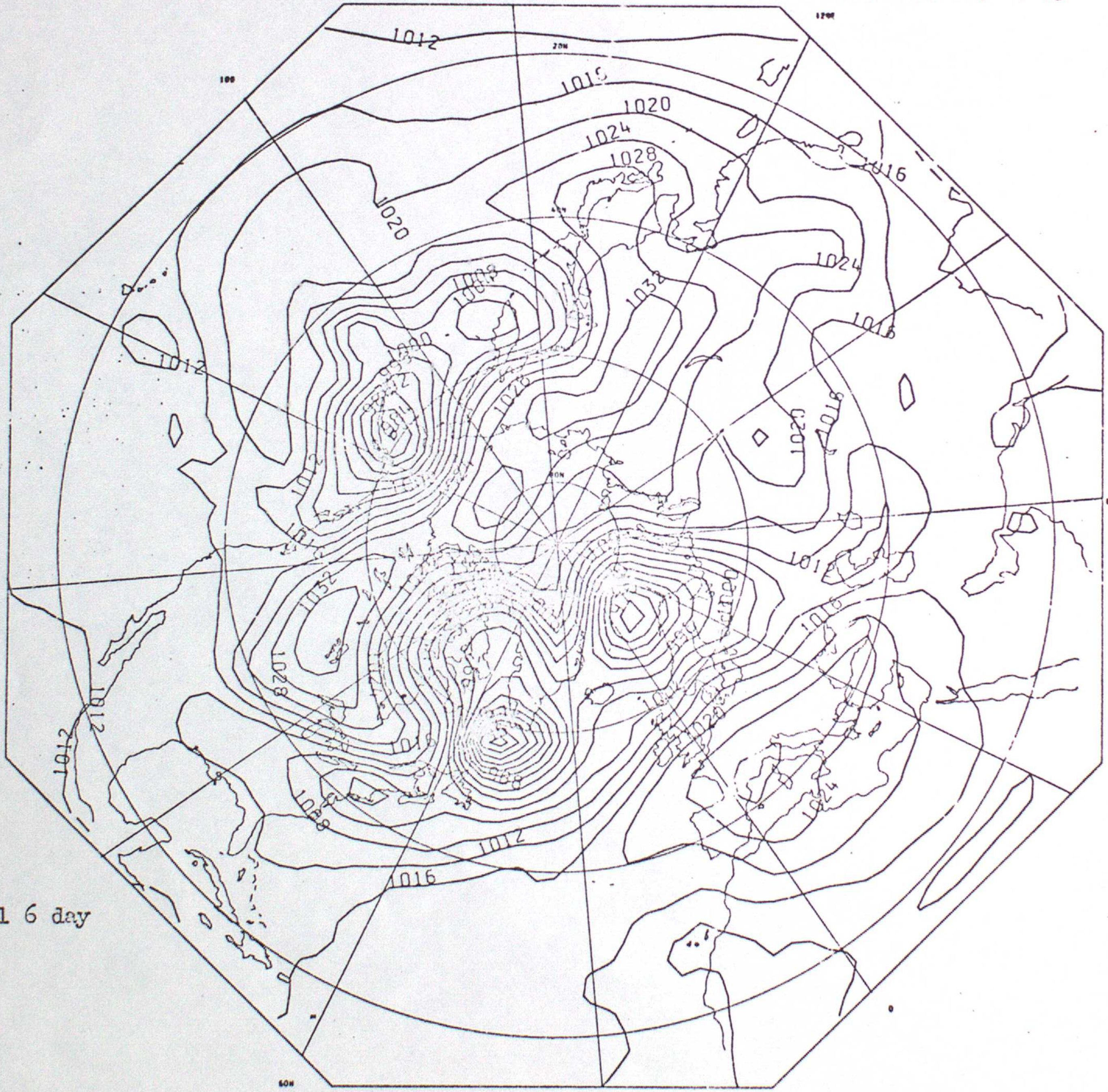


Fig.2 -
Analysis 12Z 24.1.76.

SURFACE PRESSURE FIELD
144HR.FORECAST. DATA TIME 12 Z 18 / 1 / 76. VERIFICATION TIME 12 Z 24 / 1 / 76

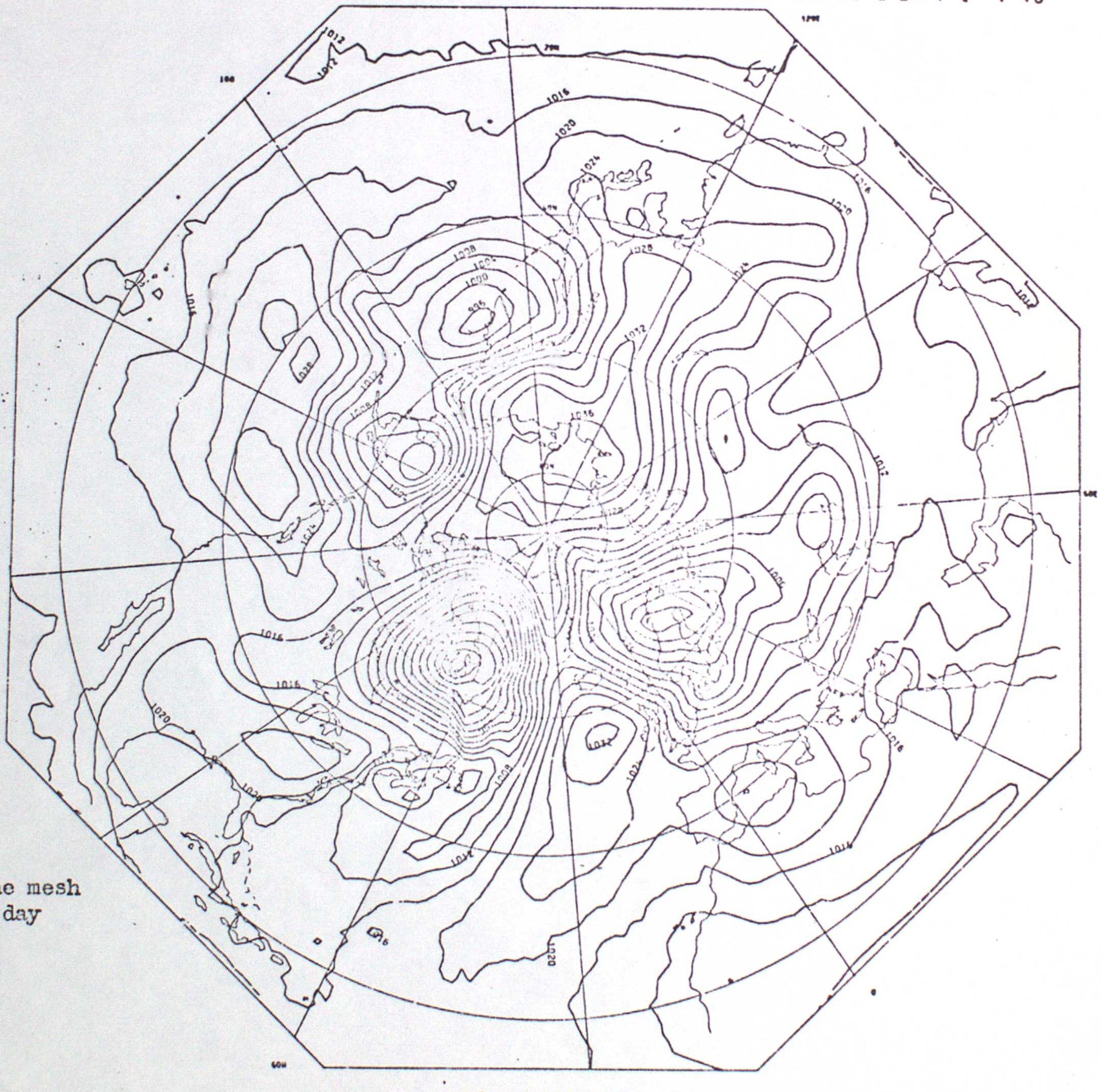


300 KM OCTAGON

Fig.3 -
Operational 6 day
fórecast.

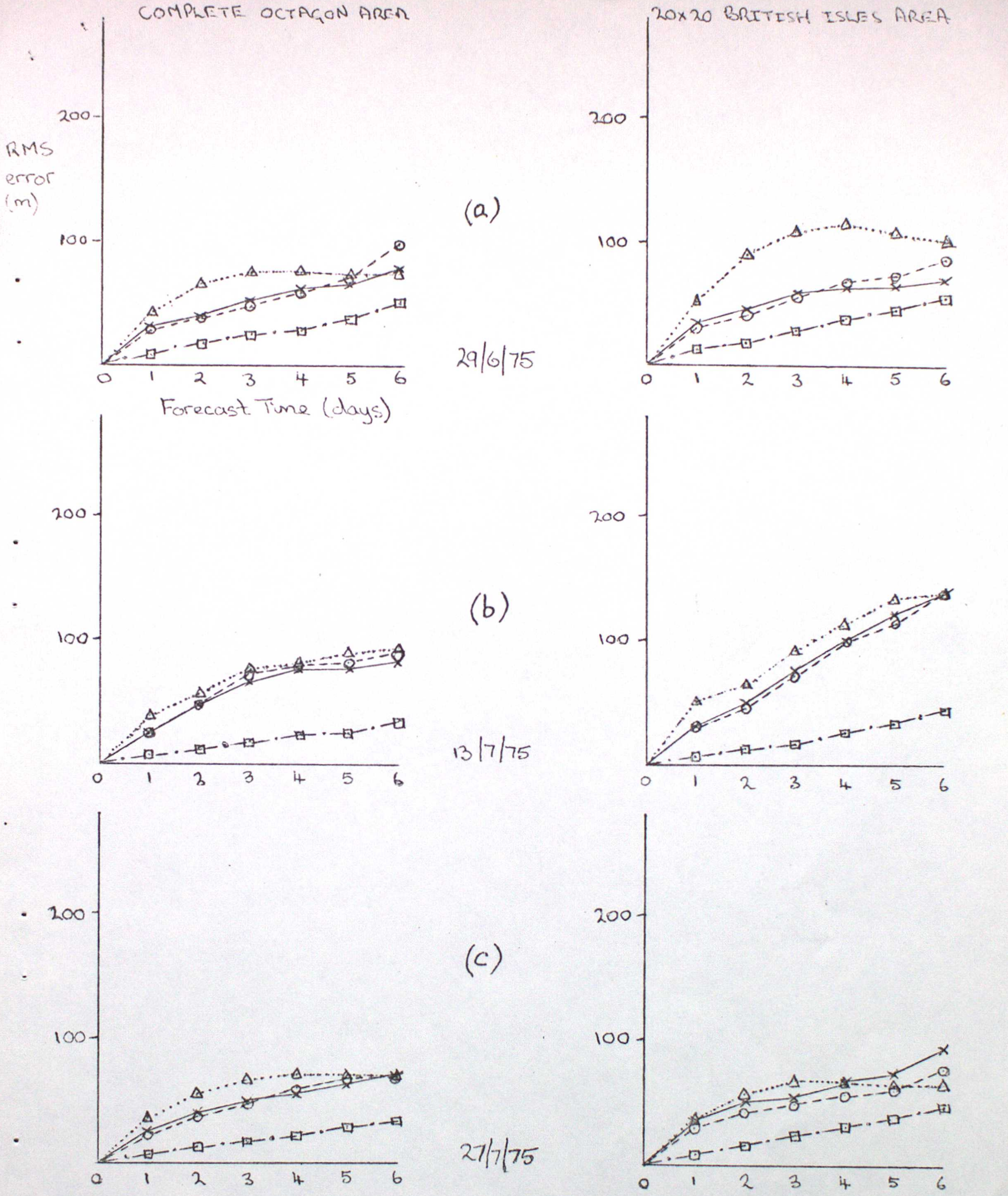
SURFACE PRESSURE FIELD

144HR.FORECAST. DATA TIME 12 Z 18 / 1 / 76. VERIFICATION TIME 12 Z 24 / 1 / 76



150 KM OCTAGON

Fig.4. - Fine mesh Octagon 6 day forecast.



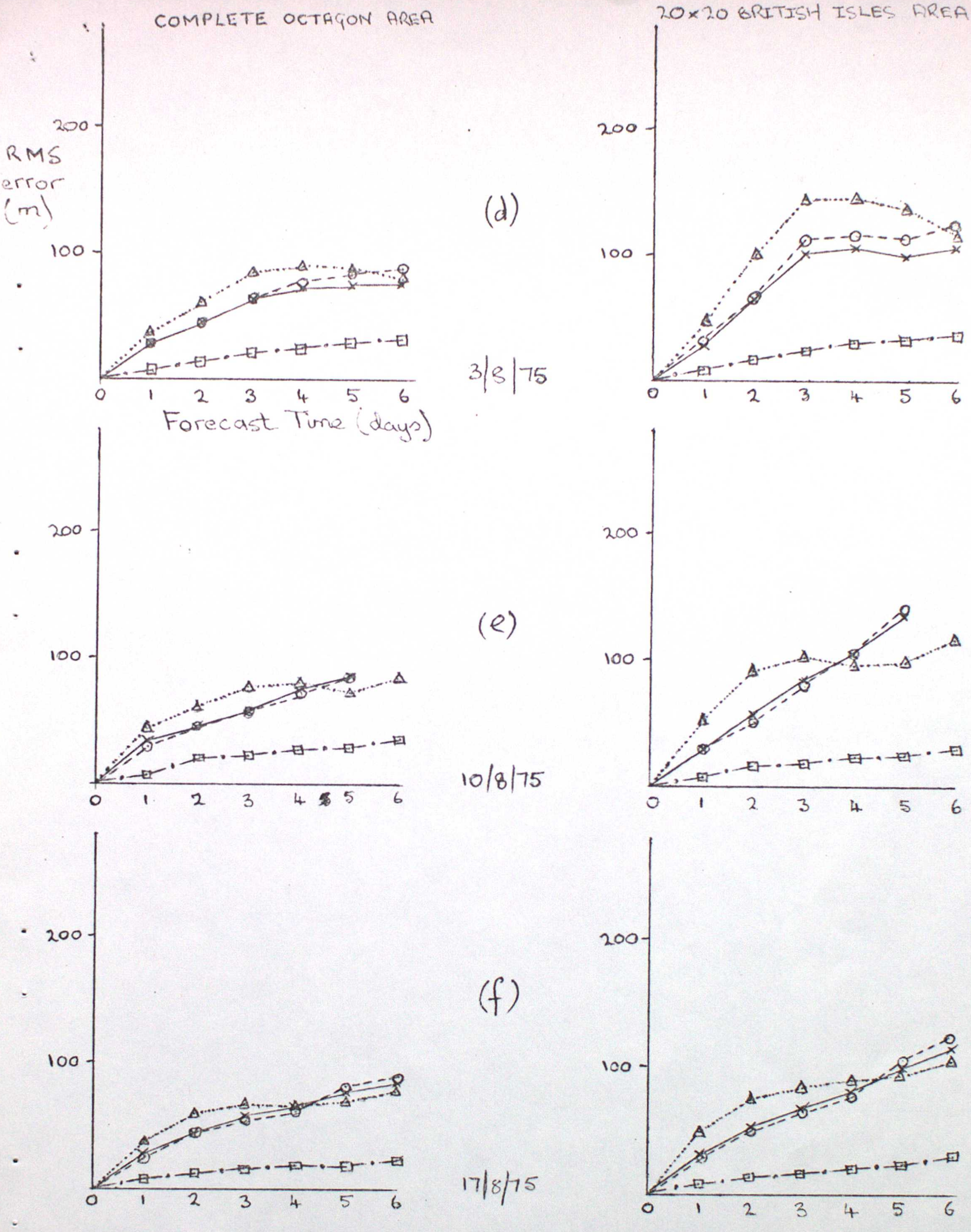
Δ·········Δ RMS PERSISTENCE ERROR

FIG. 5.

×———× RMS COARSE MESH ERROR

○- - - - - -○ RMS FINE MESH ERROR

□—·—□ RMS DIFFERENCE BETWEEN COARSE AND FINE MESH.



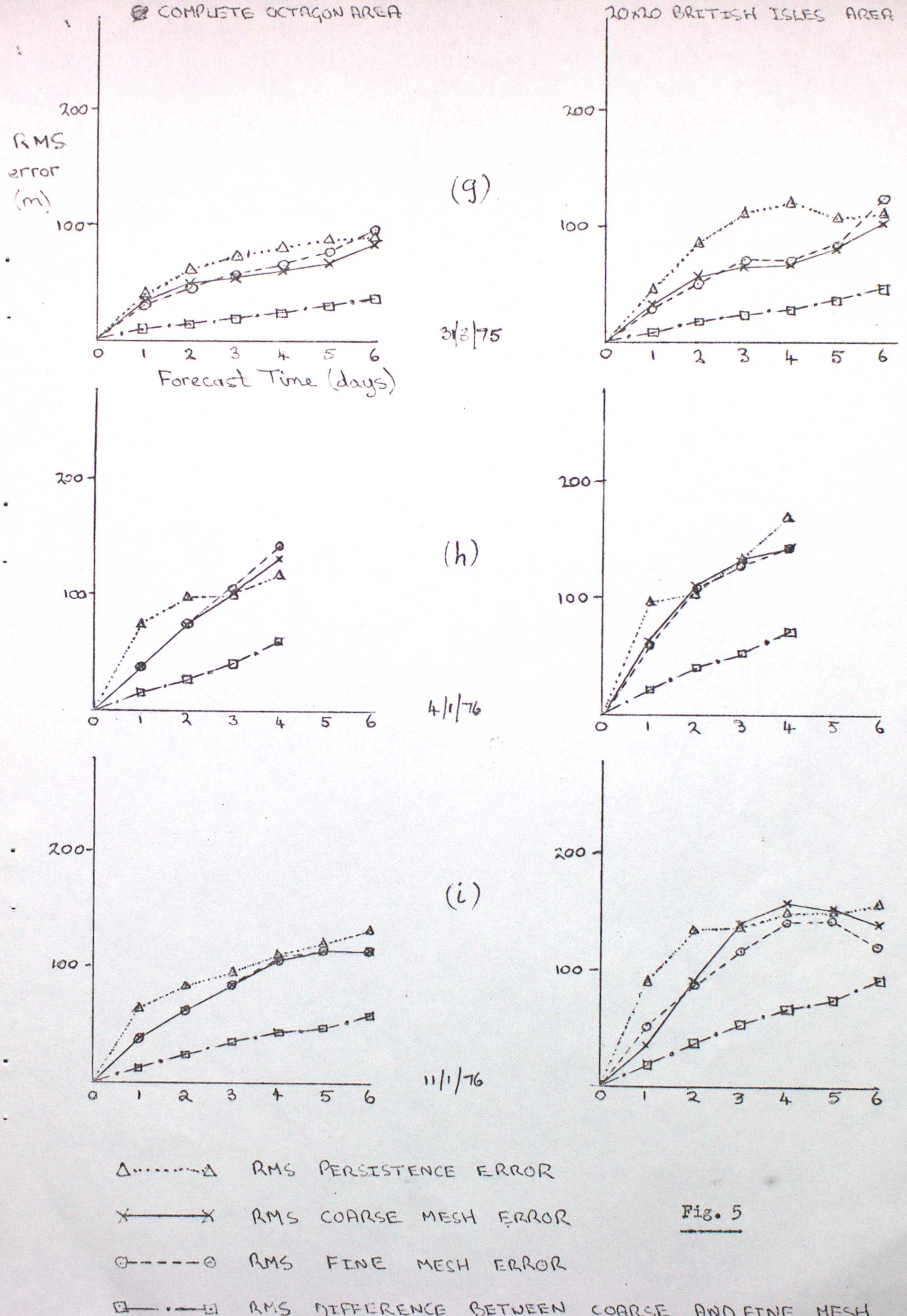
Δ······Δ RMS PERSISTENCE ERROR

×——× RMS COARSE MESH ERROR

⊙- - -⊙ RMS FINE MESH ERROR

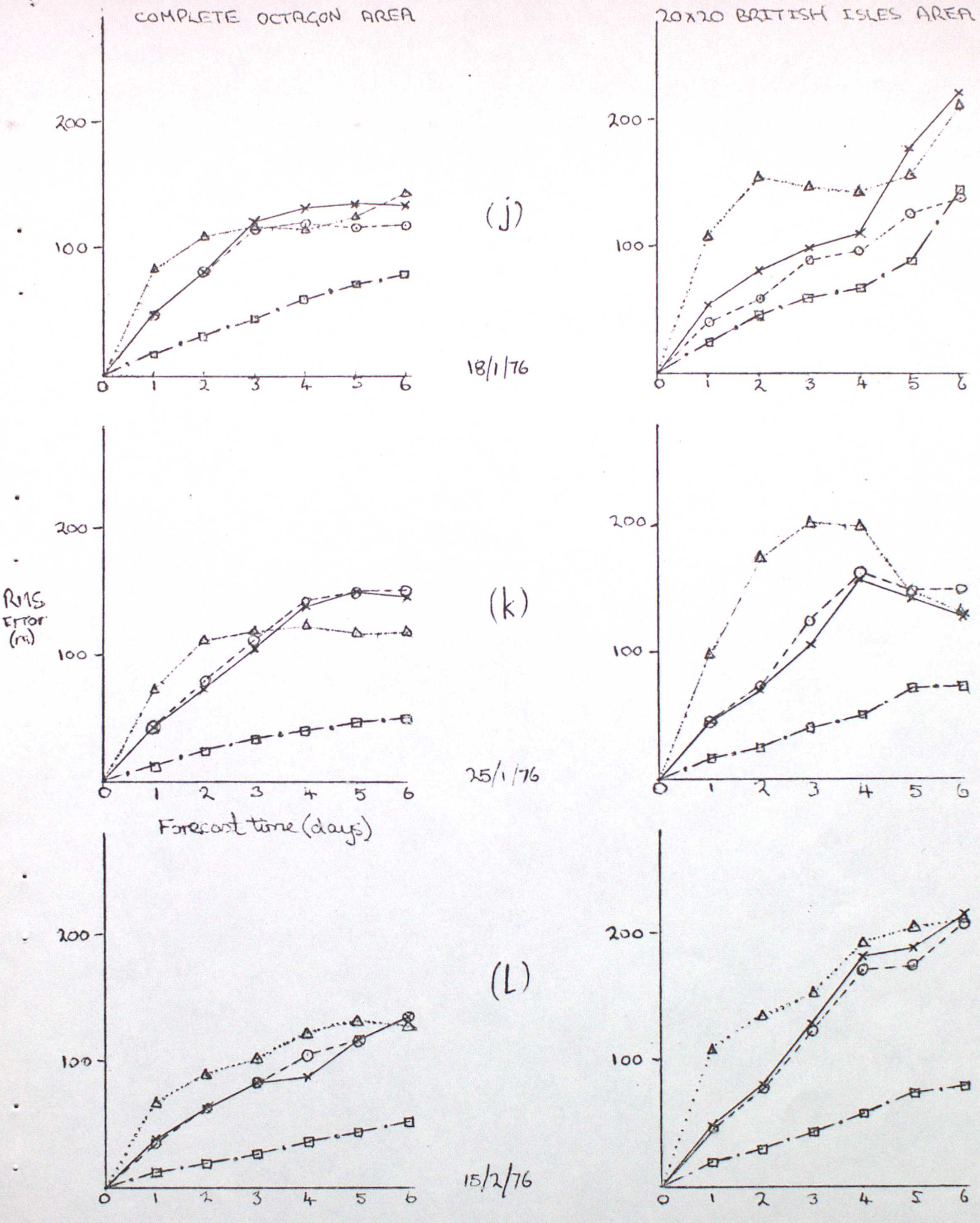
⊡—·—⊡ RMS DIFFERENCE BETWEEN COARSE AND FINE MESH.

Fig.5.



COMPLETE OCTAGON AREA
20x20 BRITISH ISLES AREA
RMS error (m)
200
100
0 1 2 3 4 5 6
Forecast Time (days)
(g)
31/8/75
(h)
4/1/76
(i)
11/1/76
RMS PERSISTENCE ERROR
RMS COARSE MESH ERROR
RMS FINE MESH ERROR
RMS DIFFERENCE BETWEEN COARSE AND FINE MESH

Fig. 5



RMS PERSISTENCE ERROR

RMS COARSE MESH ERROR

RMS FINE MESH ERROR

RMS DIFFERENCE BETWEEN COARSE AND FINE MESH

Fig. 5.

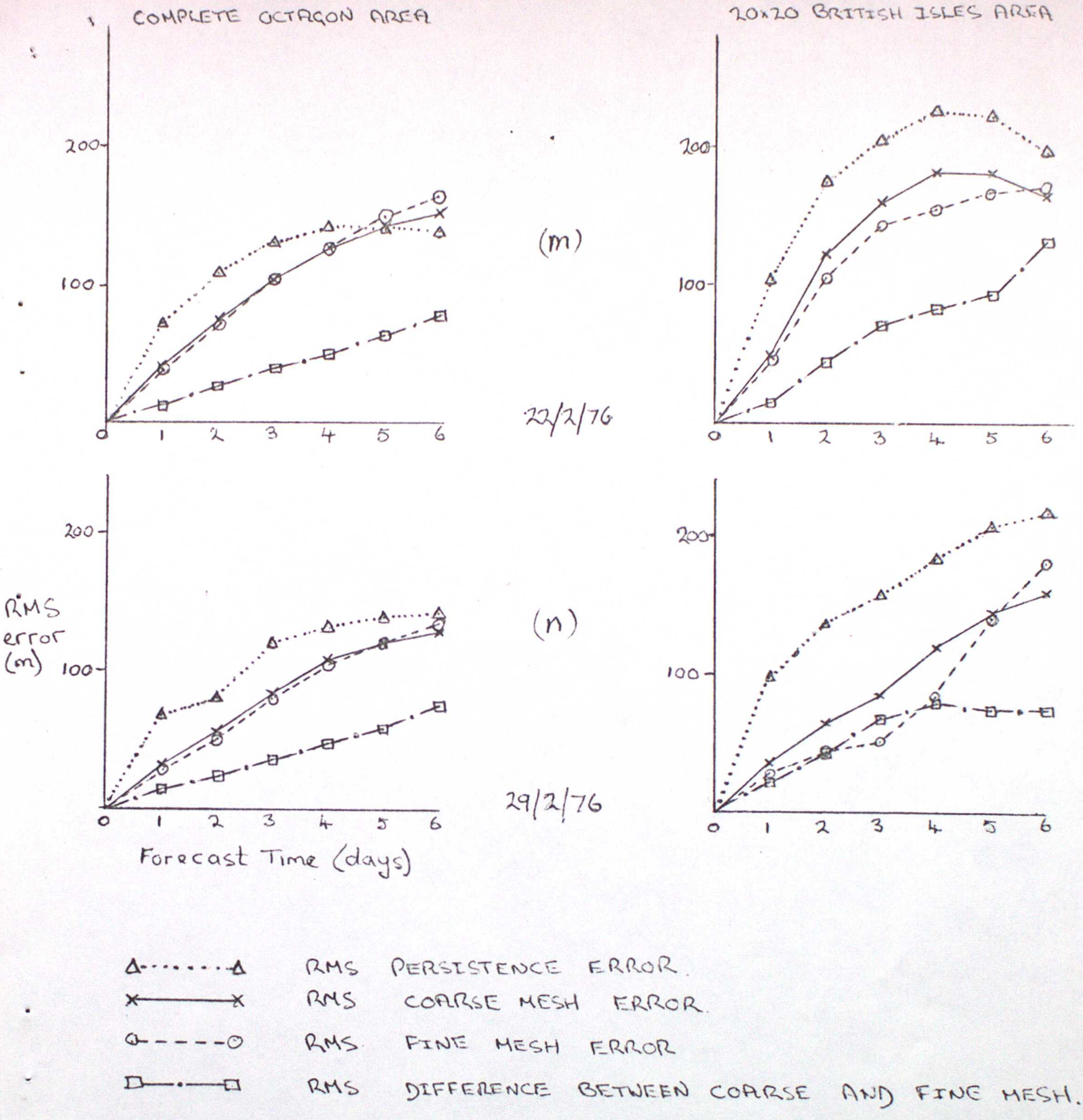

COMPLETE OCTAGON AREA
20x20 BRITISH ISLES AREA
200
100
0
1
2
3
4
5
6
(m)
22/2/76
(n)
29/2/76
RMS error (m)
Forecast Time (days)
RMS PERSISTENCE ERROR
RMS COARSE MESH ERROR
RMS FINE MESH ERROR
RMS DIFFERENCE BETWEEN COARSE AND FINE MESH.

Fig. 5.

PLOT OF SPECTRA

VERIFYING ANALYSES

DATA STARTS ON 12Z 18/1/76

FOR 500MB

BASED ON 80 POINTS AT 50.0 DEGS N

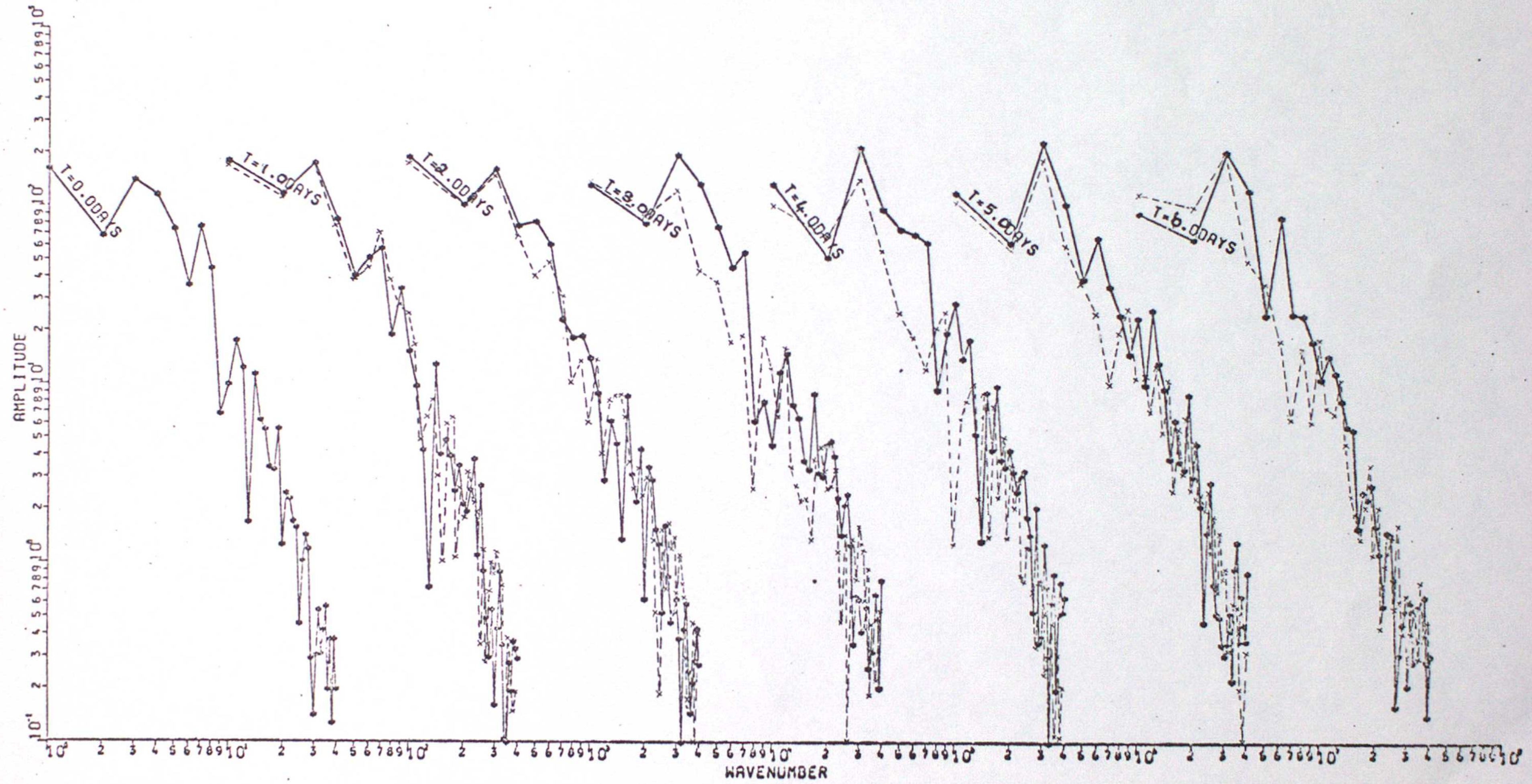


Fig. 6 Amplitude spectra. Full line - Actual
Pecked line - Coarse Mesh.

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Please amend Fig. 7 to read

Pecked line - FINE mesh.

Met.O.11
12.7.76.

PLOT OF SPECTRA

VERIFYING ANALYSES

DATA STARTS ON 12Z 18/1/76

FOR 500MB

BASED ON 80 POINTS AT 50.0 DEGS N

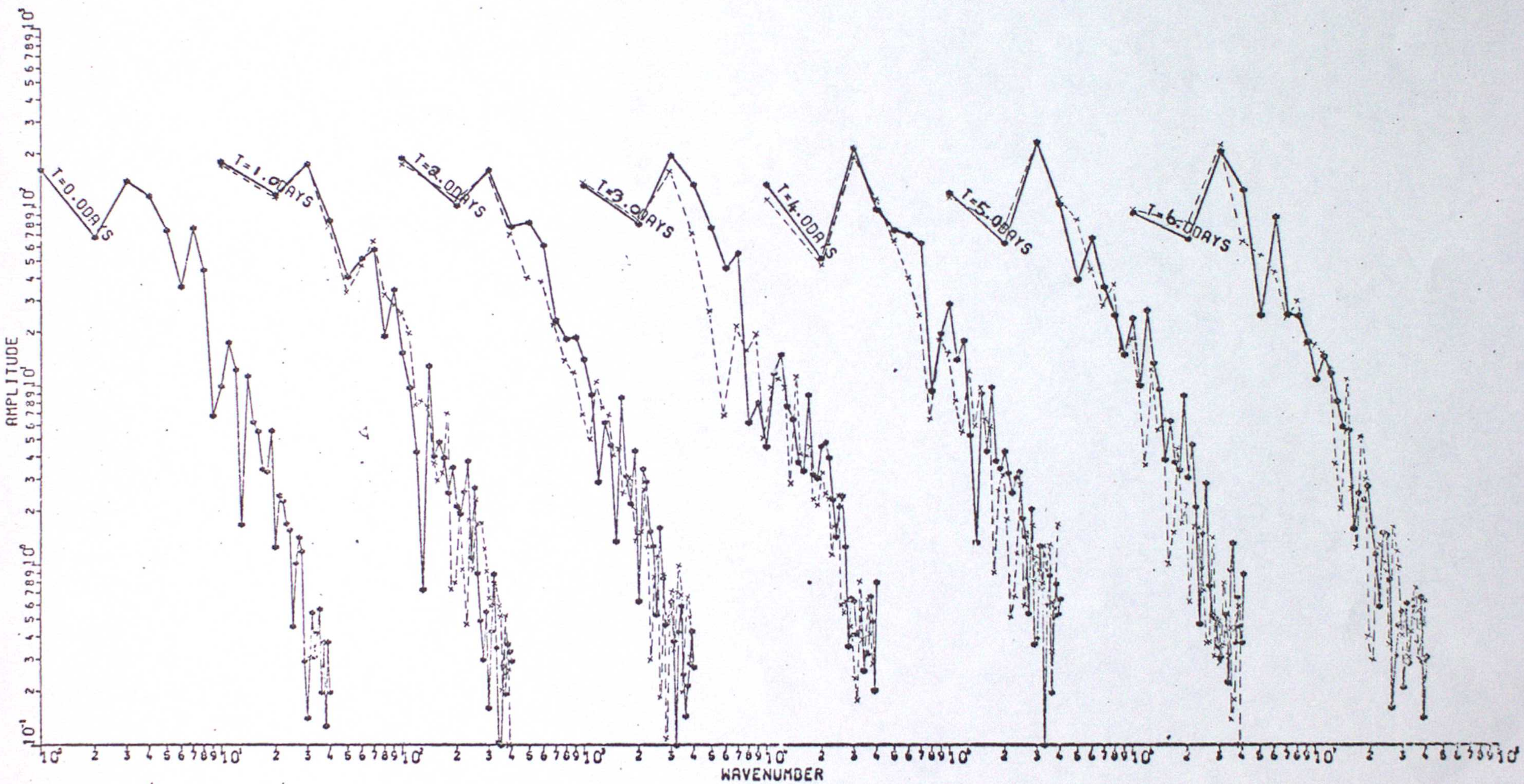


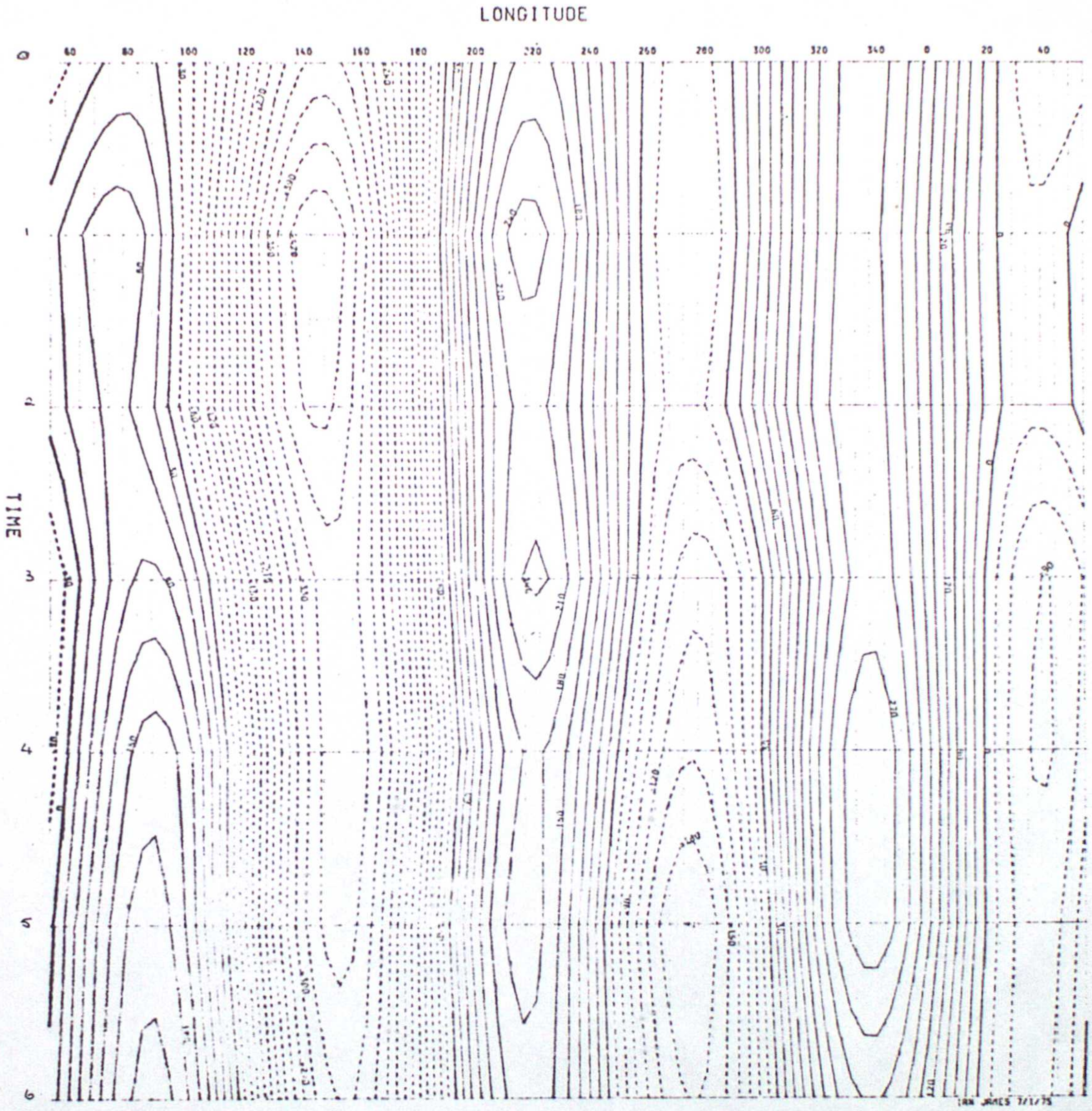
Fig. 7 Amplitude spectra. Full line - Actual

Pecked line - ~~Coarse~~ FINE Mesh

HOVMOELLER DIAGRAM FOR WAVENUMBERS 1 TO 3

DATA TIME IS 12Z 18/1/76

BASED ON 80 POINTS AT 50.0°N



VERIFYING ANALYSES

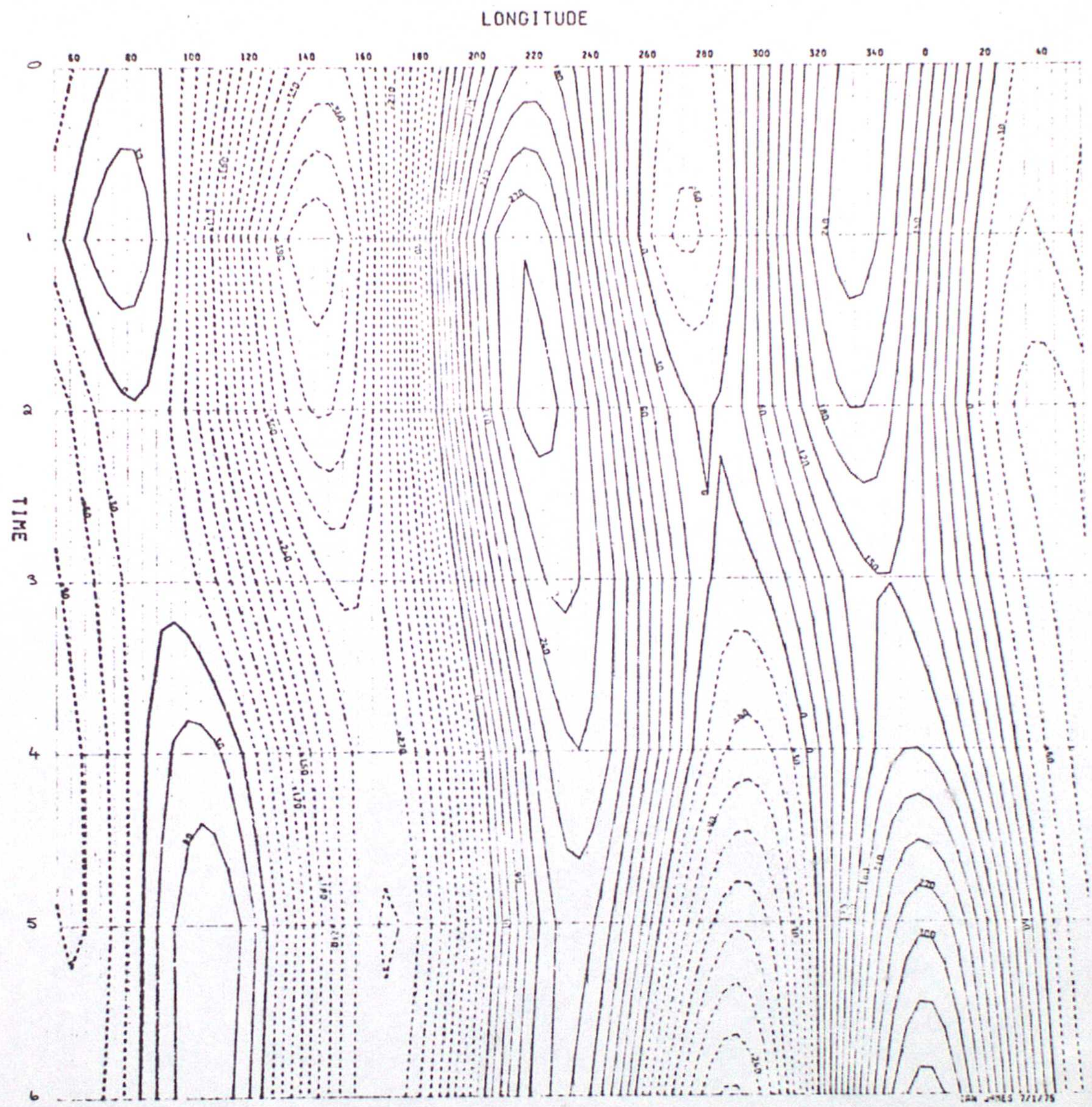
CONTOUR INTERVAL IS 30.0 M

Fig. 8 Hovmöller diagram 12Z 18/1/76 - 12Z 24/1/76 (real atmosphere)

HOVMOELLER DIAGRAM FOR WAVENUMBERS 1 TO 3

DATA TIME IS 12Z 18/1/76

BASED ON 80 POINTS AT 50.0°N



500 MB. HEIGHTS

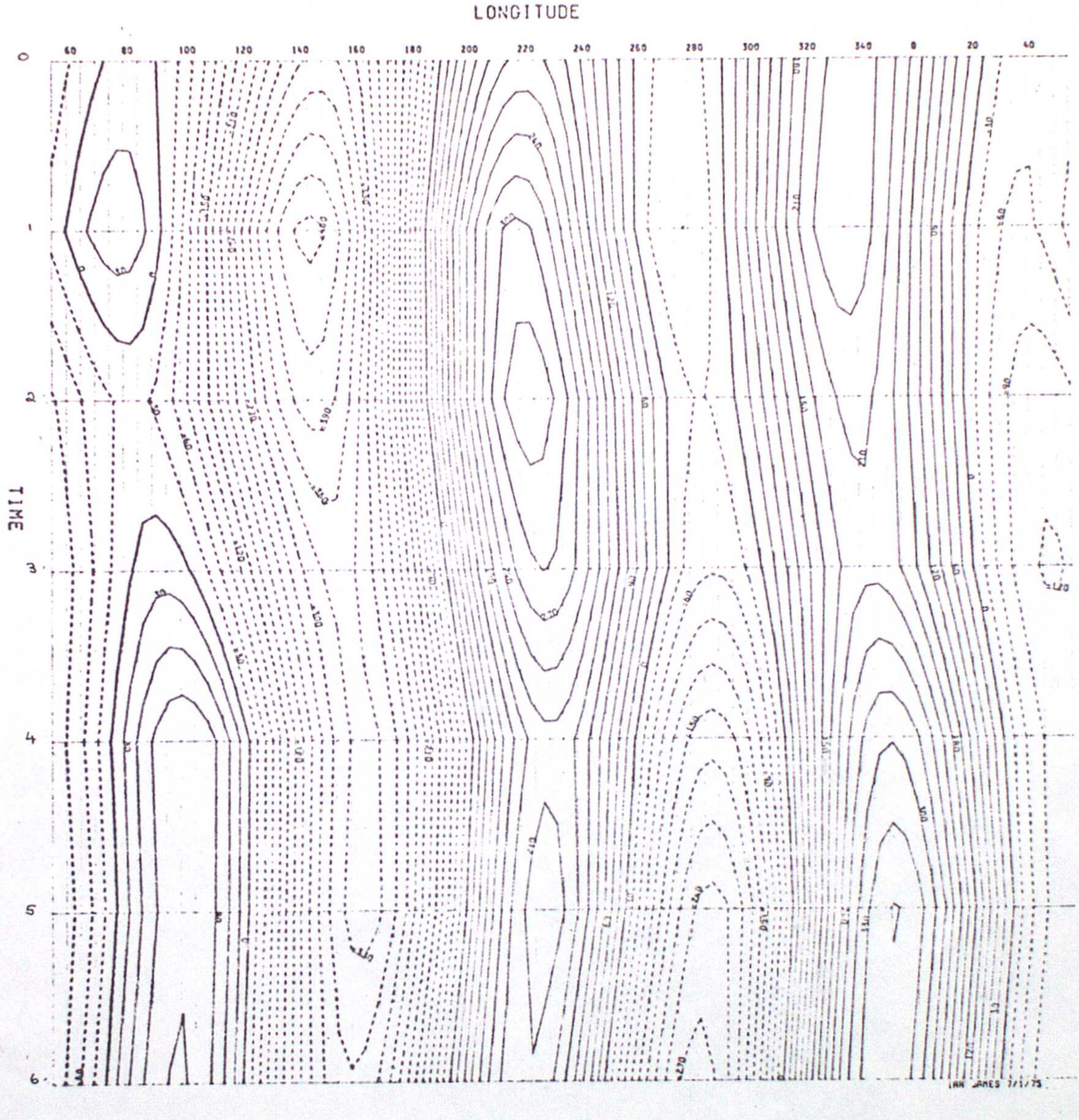
CONTOUR INTERVAL IS 30.0 M

Fig. 9. Hovmöller diagram 12Z 18/1/76 - 12Z 24/1/76 (Coarse mesh)

HOVMOELLER DIAGRAM FOR WAVENUMBERS 1 TO 3

DATA TIME IS 12Z 18/1/76

BASED ON 80 POINTS AT 50.0°N



500 MB. HEIGHTS

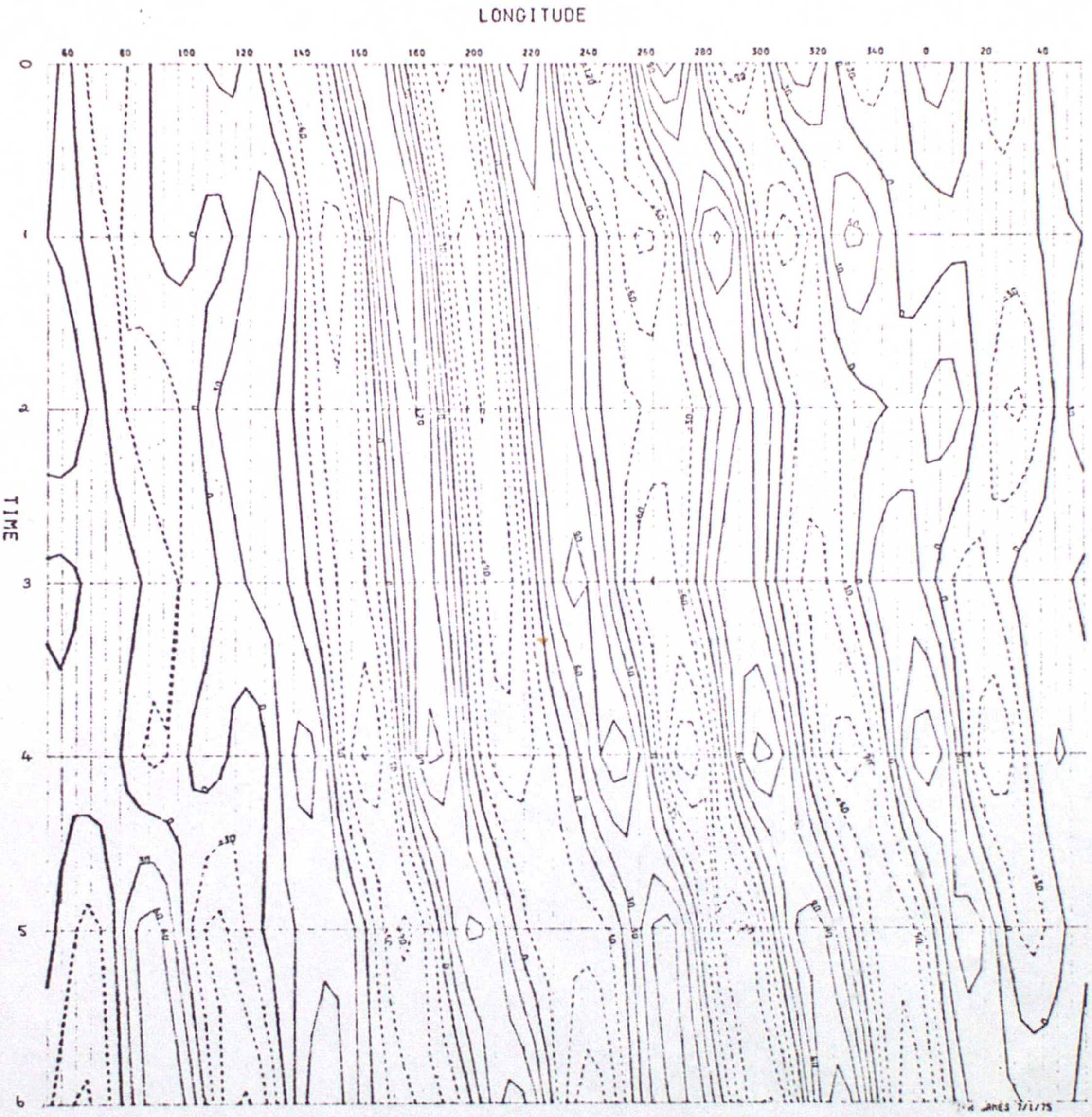
CONTOUR INTERVAL IS 30.0 M

Fig. 10 Hovmöller diagram 12Z 18/1/76 - 12Z 24/1/76 (Fine Mesh)

HOVMOELLER DIAGRAM FOR WAVENUMBERS 6 TO 10

DATA TIME IS 12Z 18/1/76

BASED ON 80 POINTS AT 50.0°N



VERIFYING ANALYSES

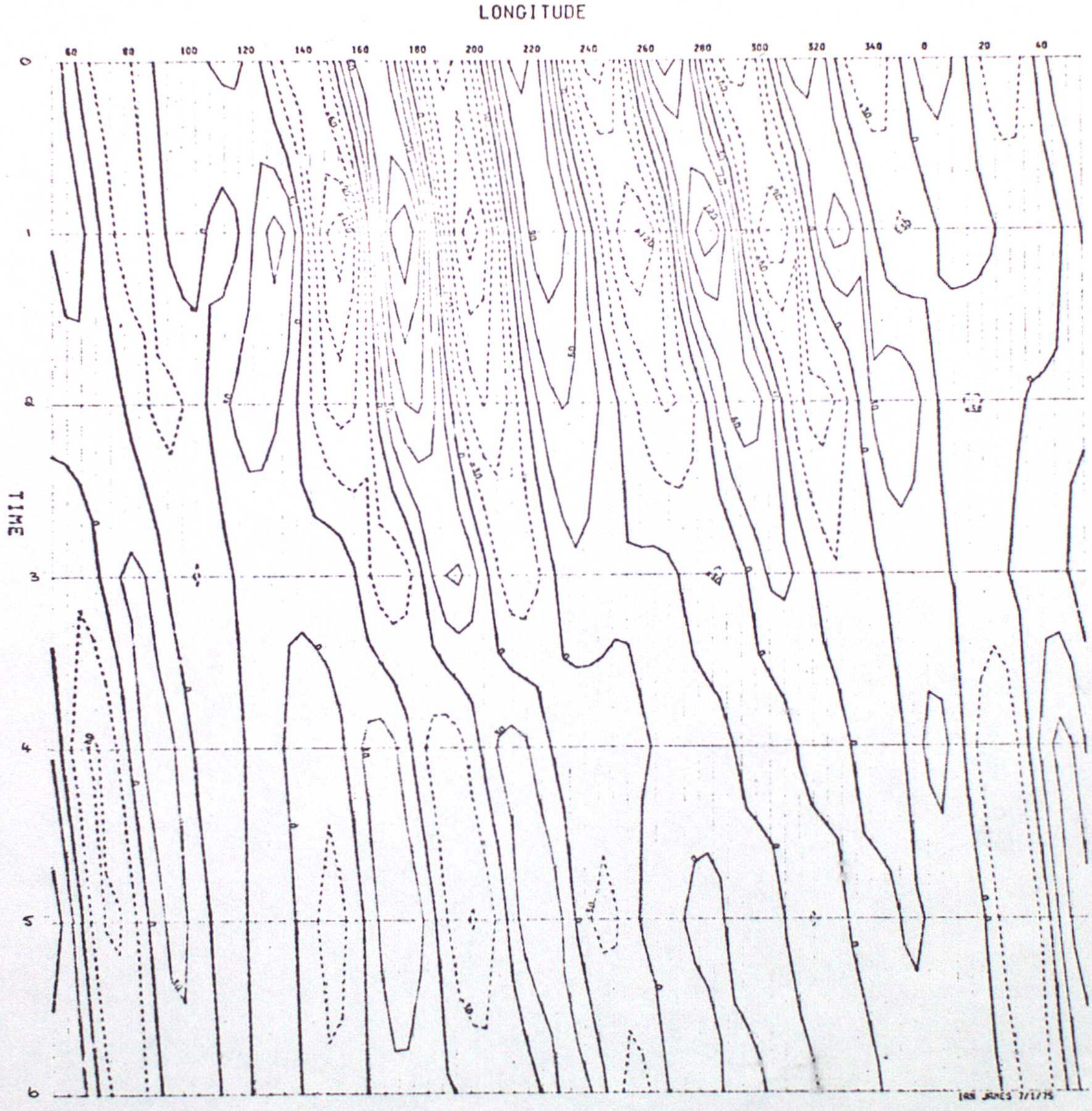
CONTOUR INTERVAL IS 30.0 M

Fig.11 Hovmöller diagram 12Z 18/1/76 - 12Z 24/1/76 (real atmosphere)

HOVMOELLER DIAGRAM FOR WAVENUMBERS 6 TO 10

DATA TIME IS 12Z 18/1/76

BASED ON 80 POINTS AT 50.0°N



500 MB. HEIGHTS

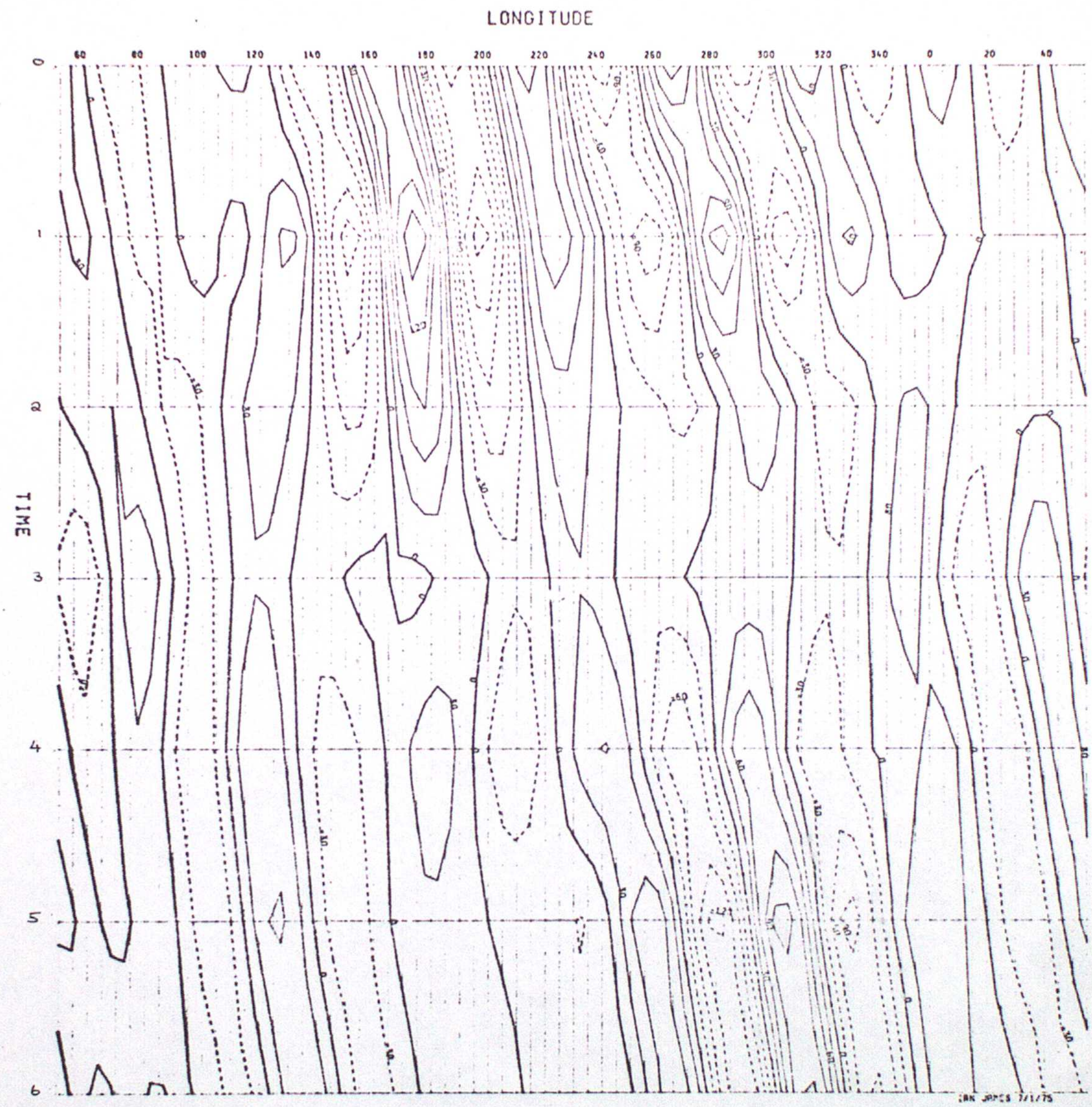
CONTOUR INTERVAL IS 30.0 M

Fig.12 Hovmöller diagram 12Z 18/1/76 - 12Z 24/1/76 (Coarse Mesh)

HOVMOELLER DIAGRAM FOR WAVENUMBERS 6 TO 10

DATA TIME IS 12Z 18/1/76

BASED ON 80 POINTS AT 50.0°N



500 MB. HEIGHTS

CONTOUR INTERVAL IS 30.0 M

Fig. 13 Hovmöller diagram 12Z 18/1/76 - 12Z 24/1/76 (Fine Mesh)