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MET O 11 TECHNICAL NOTE NO. 185

UK/ECMWF COMPARISON EXPERIMENT

by

G. HIGGINS

Meteorological Office (Met O11
London Road
Bracknell
Berkshire
England.

FH2A

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1. INTRODUCTION

For some time, it has been noticed that marked differences have occurred in forecasts made by ECMWF and UK models. It was felt that not only were there differences in the models but that the different analysis method/starting fields may play a significant part in producing different forecasts.

It was felt useful to carry out a series of comparison experiments using the two forecast models run from not only their own analysis but also from the other model analysis. A four way comparison could then be carried out for a variety of synoptic and seasonal situations in an attempt to identify differences due to the model and differences due to the analysis.

During the Autumn of 1982, various changes were made to the UK operational suite, in the forecast and the analysis stages. Also a change to the archiving process took place during the late Autumn, the accessing of data before the change being made somewhat more difficult. Hence, it was decided to investigate cases after 1 December 1982. This meant that a number of pre-selected cases had to be dropped, the intention being to choose new cases during the coming spring and summer. However, a further complication occurred when ECMWF changed their operational forecast model from gridpoint to spectral form, making direct exchange of data between the two centres impossible using existing programs.

Consequently, only the following cases have been examined. These were chosen largely on the basis of marked differences in the subjective marking of UK and ECMWF medium range products by the medium-range forecasters in CFO.

- 5 Dec 82 - UK model 'missed' a new low development close to UK. ECMWF outlook period poor.
- 2 Jan 83 - UK model fast with a feature early in period near UK. Another new development was too deep.
- 10 Feb 83 - UK model erodes a block and rebuilds it in the wrong place, putting UK in an erroneous W'ly. ECMWF handled block much better.

The first two cases were mobile westerly types while the February case - fairly obviously - involves a slow moving blocking pattern.

2. EXPERIMENTAL DETAILS

The intention was to eliminate as much variability between models/forecasts/analysis/output as could be identified. Hence, all model runs were carried out at ECMWF using the Cray computer and ECMWF output routines. This meant that all charts were on the same scale and with the same contouring. However, ECMWF forecasts were standard global operational runs whereas those run for the UK model ran only to 30°S (except where Global reruns were carried out). Both models were run on a resolution of N48, (whereas the UK operational version run on the Cyber has resolution N60 and is global).

There were also minor differences in the sigma levels used by the two models. Consequently, a certain amount of interpolation was necessary to produce compatable formats before the forecasts could be run. Also, in order to eliminate some of the difference due to markedly different data cut-off times, the UK analysis used was the update analysis rather than the operational main run analysis.

The original model runs produced PMSL and 850mb temperature fields on one chart and 500mb heights on another. These were compared and assessed. The labelling of charts followed the convention analysis first, forecast model second. For example, a forecast run using the UK model from the ECMWF analysis was labelled ECM/UK.

Once interesting areas of differences between analyses had been identified, further investigations were carried out by writing model data dumps to tape and processing the data on the COSMOS system using the Met O 11 diagnostics package and the Met O 20 Post Processing Package.

3. CASE STUDY RESULTS

i. 2 January 1983

The feature which produced the original differences in scores between the models was a fast moving developing wave which ran from about 50°N 30°W at D2 to 62°N 25°W at D3. It deepened some 62mb during this period.

All the four model runs produced a rather fast representation of this development. The frontal analysis in the Atlantic was rather complex suggesting at least two possible shallow waves on the main Atlantic front. It seems that the models favoured representing the more eastern feature whereas reality seemed to develop the western one. The net result was that the wave moved too far east and failed to swing into the pre-existing low to reinforce it, maintaining a separate identity some ten degrees too far ENE at D3. This feature then produced an increasingly erroneous pattern over N Europe D4-5. The differences between the models concerning this feature were not particularly large in the developing stage but lead to increasing differences in the D4-5 period, all attempts being erroneous to some extent.

Another feature that was of interest was the development of a new Atlantic system which came east out of Florida at D3. Again all the model runs made some attempt at modelling this development with varying degrees of skill. Both runs from the ECMWF analysis produced a rather weak system that was somewhat fast. The ECMWF forecast from the UK analysis produced a good representation of this feature, but the UK forecast from the UK analysis produced a system that was too deep (11mb deeper than hand analysed chart), too far N and with a very poor representation of the shape of the system.

However, the major investigation of this case grew out of the marked difference in the handling of features over the Pacific and US. Attention was drawn to the Pacific area by following back a particular system in the UK/UK forecast run which was markedly too deep and out of position over Hudson's Bay at D4. It was noted that the UK/ECM run had a similar erroneously deep feature near Hudson's Bay at D4. The other two runs from ECMWF analysis had no such feature. By tracing developments back to the analysis stage, it appeared that the system was initially around 175°W and that there were differences in that region between the two analyses.

The development of the feature is shown in Figs. 1(a), 1(b), and 1(c).

As can be seen, the UK forecast run develops the low in question between D0 and D1 whereas the ECMWF forecast run treats the system as a filling feature. What can also be seen is the marked difference in position of the upper trough associated with this system. The 500mb UK chart shows an almost double trough pattern in the area of this system with almost no ridging to the East of the trough: the ECMWF chart has a simple trough and noticeable ridging to the east. By D1, the UK model has the trough and surface system still in phase and much further east than in reality. ECMWF have the trough further west ie a slower phase speed, which is correct. These differences are also noticeable at 250mb, see Figs. 2(a), 2(b), 3(a) and 3(b).

After an initial look at the case, the results were presented and discussed. It was felt that although there were definite differences between analysis fields, changes had been made to the UK assimilation and analysis suite after the date of this forecast and that these may make a difference to the UK analysis. Also it had been noticed from the CFO archive charts that quite a lot of bogussing had been carried out in the area of the feature in question, both at 12Z on the 2nd but also on previous analyses. Doubt was expressed at the accuracy of the bogussing process. It was decided to carry out two more forecast runs fron analyses where:

i. the new assimilation scheme had been used including all observations as before.

ii. all bogus observations had been removed but the original assimilation scheme was used.

It was hoped that one or other of these re-runs may produce a better forecast while removing some of the identifiable problems with the initial fields.

The two runs were carried out for three assimilation cycles viz 00Z, 06Z and 12Z on 2 January. Assessment of the forecast runs from these two experiments was carried out blind. However, the result was that neither re-run produced any major change to the erroneous evolution. The initial analyses still showed differences from ECMWF and the phase/positional error in the upper troughs was unchanged. There were minor differences in the degree of deepening of specific features but the overall evolution was still incorrect.

As a result of a further presentation and subsequent discussion, suggestions were made concerning continued investigation. No wind charts had been presented during the previous investigations and it was felt that perhaps they may cast some light on the problem, particularly at levels around the jet. Consequently, efforts were concentrated on programs to draw winds, isotachs etc rather than height fields.

In due course, combined charts showing heights, winds and isotachs were produced enabling a fairly detailed investigation of the jet structure to be undertaken. Also cross-sections were produced through the jet-stream in the problem area. In addition, actual data were extracted and the fit of the analyses to the data compared.

Some general criticisms of the UK analyses can be made in the face of ECMWF analyses. The winds seemed to be better balanced with the heights in ECMWF than in the UK and the flow around troughs was noticeably smoother. UK trough axes seemed to be fragmented rather than single, smooth features as in ECMWF. The particular trough in question was in a slightly different position in the two analyses; the hand drawn analysis showed that there was doubt as to the precise position of the trough due to lack of data. In two areas of difference, the UK model had more precisely fitted the data but the winds/heights in those areas were apparently unbalanced. In both cases, the extra information in the UK initial fields was lost by D1; in fact ECMWF produced better fields in these regions at D2 having started from a field which fitted the data less precisely but was apparently smooth and well balanced.

The area of the jet exit was also analysed - and forecast - differently. ECM analysed the jet core at 30°N, at the 250mb level and with a speed of 50-55 ms^{-1}. The UK model put it at $28\frac{1}{2}^{\circ}$N, at the 300mb level with a speed of 55-60 ms^{-1}. The evidence from the actual data favours the position/level of ECMWF but the greater speed of UK. ECMWF also had a better representation of the jet flow through the trough in question.

By D1, the actual jet propogates forward and ECMWF models this quite well. However, the UK model does not propogate the jet core east; indeed the 60 ms^{-1} and 70 ms^{-1} isotachs both retrogress unrealistically. The result of this error, in simple terms, is that the surface low of this problem feature is maintained in an area of diffluence at the jet exit in the UK model. This does not happen in the ECMWF forecast, the jet pushing quickly East, the surface low being left well to the rear of the diffluent region. Hence one model deepens the feature while the other does not.

A similar look at the forecast run from the analysis with bogus observations removed showed the same problems of imbalance, and tight fit of data. The jet core was positioned even further south (at 27°N) at the same level as the original run. One particular area, where data suggested winds of around 60 ms^{-1} was fitted but the information was spread downwind away from the observation position and by D1, the area of strong winds was lost. It is interesting to surmise by what point in the 24 hour period that information is lost and why.

One other area of difference between analyses was in potential temperature fields. Cross-sections revealed rather spurious patterns from the UK model analysis and it was felt that these may have been due to bogussing. However, the patterns were still present in the analysis run with bogus data removed. Indeed, temperature fit was poorer in certain areas with bogus data removed so the concept of bogussing was exonerated.

A final, though significant, point is that the analyses of 250mb winds and heights for the two forecast runs from opposite centre analyses (ECM/UK, UK/ECM) exhibit the features of the analysis and not the forecast model. So, at D1, the ECMWF forecast run from the UK analysis shows the same erroneous retrogression of the jet core and the same phase error in the upper trough position as the UK/UK run.

(N.B. A <u>global</u> run of the operational forecast from the same 12Z data showed the same basic error of phase over US).

<u>Summary for 2 Jan 83 Case</u>

i. Although the original reason for picking the case involved differences in markings between UK and ECMWF models close to UK, the intercomparison runs showed very similar erroneous evolution of this feature.

ii. Differences were evident in an area of the Pacific where Aireps were the major source of data. While the UK analysis suite more precisely fitted the data, this information was lost by D1.

iii. The two forecasts run from the UK analysis had the same error while the two run from ECMWF analysis shared a more correct evolution.

iv. Bogussing was not responsible for the error and in fact improved the temperature structure in places.

v. A subsequent change to the assimilation/analysis suite (involving divergence damping) made no difference to the erroneous evolution. (iv) and (v) together suggest that there may have been something wrong with the analysis of the feature in question within the background field.

3. ii. 5 December 82

This case was originally selected because of marked differences in the scores (UK cf ECM) in the medium-range forecaster's assessment book. However, when the intercomparison forecast runs were assessed, only very small differences between the forecasts were noted.

Differences in forecast evolution were again broadly linked by analysis rather than forecast model. All combinations of analysis and forecast model went wrong with varying error in the detail. Hence, after D3, there was a closer resemblance between model runs than there was with reality. However, the behaviour of one particular feature appears to contradict the analysis link. A large low centre slowly filled over the NW Russian 'coast', with a central pressure of ≏984 mb by D5. The ECMWF model run from their own analysis filled the low (somewhat out of position) to 990 mb while the UK model run from its own analysis only filled the low to 978 mb, (similarly out of position).

There seemed to be therefore a tendency for ECMWF model to "overfill" this low while the UK model "underfilled" it. When ECMWF model was run from the UK analysis, the overfilling was exacerbated to 998 mb; with UK model run from ECMWF analysis, the underfilling - or holding the centre too deep - was also exacerbated, the low being 968 mb at D5.

The problem of lows not filling quickly enough has been noted in both models on many occasions in the past. In this particular case, ECMWF seem to have handled the low rather better. It is hoped to address the problem of the failure of lows to fill quickly enough within Met O 11 in the coming months.

3. iii. 10 February 83

The main purpose of this comparison was to investigate why the UK operational forecast (from initial data 12Z on 10 February 83) predicted a change in UK weather to a mobile westerly, the high having slipped erroneously south. When the cross comparison runs were completed, the re-run UK forecast from the UK analysis obviously agreed much more with the correct evolution than with the operational run. This discrepancy was further checked by re-running the operational global version of the model from the same update analysis as that used for the Cray run. The result was similar to the original main run. It seems likely therefore that there is something 'wrong' or different in the global version and this is to be further investigated. However, various other aspects of the differences between forecast models and analyses have been noted.

Similarities in Forecast Model

1. A low over Venice (D1) does not correctly fill in either UK forecast - in fact, the feature deepens instead and moves too far NE (D3). By D4, the feature is much too deep and elongated with an erroneously strong gradient on the Eastern flank of the low. See FIGS 4(c) and 4(d).

This may be thought of as a failure to fill a 'land' feature, an aspect of the UK model which has been noted before.

The same feature in the two ECMWF forecasts both fills and moves in good agreement with reality.

2. A low that crosses Greenland D3 and then moves east with only weak development over deepens in both UK forecasts, though the final shape is different.

The two ECMWF forecasts of this feature are considerably slower than reality and also too deep. See FIGS 4(d), 4(e), and 4(f).

So both models handle the feature incorrectly though with different errors.

3. The forecast position of the Atlantic low at D3 is at 45°N for the UK forecasts and only 42°N for the ECMWF versions. This reflects the greater deepening of the feature (at this stage) of the UK model and hence, a greater turning of the low centre. See FIG 4(d).

4. The ECMWF forecasts favour a split high centre, one (almost correctly) to the E of UK and one (incorrectly) to the SW of UK. See FIG 4(f).

The UK model tends to keep only one centre; in one case, it puts it over UK (UK analysis), which is too far SSW and in the other it is much too far SW, favouring the incorrect second high of the ECMWF model (ECMWF Analysis). There are differences here between Global and 30°S versions of the ECM/UK forecasts.

5. The ECMWF model runs have a more meridional tendency in the Atlantic trough which helps to rebuild the block at D5. This is evident in the flow direction (at 500mb, 250mb and surface) over Newfoundland ie to the rear of the trough. See FIGS 4(f) and 5.

Similarities by Analysis

1. The two forecasts from the ECMWF analysis transfer part of the block "correctly" NE/E of UK but incorrectly maintain a large Azores high at 35°N (ECM/ECM) and 43°N (ECM/UK). The forecasts from the UK analysis put the single high over UK (UK/UK) and just east of UK (UK/ECM) with only a weak ridge SW. This is still incorrect but, in one respect, better than ECMWF.

2. Both runs from UK analysis pick up a low 'South of Florida' at D3 quite well. This develops in a most realistic manner in UK/UK version but fails to develop in UK/ECM. At 500mb the trough is present in UK/UK but missing from UK/ECM.

The runs from ECMWF analysis barely have a feature at all at D3, (though arguably some sort of a very weak wave runs up the cold front of the preceeding system).

Features Affecting the Block

The major system affecting the maintenance of the block is a system which comes east from America at D1. The low deepens D1-D2 then more markedly D2-4 with significant erosion of the Atlantic high D3/4 as the system troughs southwards. The upper trough has a closed centre D3 with strong flow right round the base of the trough, particularly to the rear of the trough. This results in the extension of the trough SSE, the axis N/S at 42°W D4 and roughly NNW/SSE at 35°W by D5. A new surface low develops in the base of this trough by D5, the original main low filling rapidly to the south of Greenland.

None of the forecast runs handles this process or evolution correctly. The UK/UK run gives the best representation of the deepening of the system to D4, particularly when compared with CFO hand analysed charts ie observations. ECM/UK is also better than the versions of ECMWF model which are both very slow and weak with development of the low to D3. However, at D5, all the versions overdeveloped the low, the feature moving too far NE and continuing to deepen. The ECM/ECM version produces the deepest low. See FIGS 4(a) - 4(f).

The upper trough extension was not modelled at all, flow to the rear of the trough being weak. The main flow was maintained at high latitudes with no splitting to the south of the block. In response to this incorrect upper air evolution, none of the models predicted the new low in the base of the upper trough. The failure of all model runs to predict the correct handling of the Atlantic system would seem to be a major reason for the failure to correctly predict the handling of the block.

Another important factor affecting the block was the handling of the Iberian low. In reality, the upper vortex was due south of the high by D5; the models allowed it to drift away eastwards, especially the UK forecast model from UK analysis where the vortex was allowed some 15°E of reality. This combination also produced the most erroneously deep surface low (983mb cf 1007mb in reality). ECMWF forecast model versions were notably better than the UK in the handling of this feature. See FIGS 5 and 4(f).

At a presentation of this case, two questions were posed:

i. How long was the block maintained without the split jet having been predicted?

ii. How close to the event was the correct evolution of the Atlantic system/Block actually predicted?

Both these questions can be answered for the ECMWF operational run (ECM/ECM) using their verification charts out to D10.

In fact ECMWF maintained the block to D8 allowing it to move erroneously ten degrees east; it had collapsed however by D10 (20th). Despite very serious errors in the Atlantic (and elsewhere), there was a weak split in the 500mb flow at 15°W at D7 and D8: thereafter, the gross errors broke down the incorrectly positioned block. In reality the block was maintained in position over UK until 21st when it moved East and broke down over Europe 25th/26th.

To answer the second question, forecasts starting from DT 12Z on 11th and 12th February show improved troughing of the Atlantic low on 15th and both forecasts produce the new low on the 16th, a day late. It is not until the D2 forecast from the run commencing 12Z on the 13th that the Atlantic system extends and splits correctly on the 15th. However, this forecast goes badly wrong after D7 (20th) and collapses the block much too soon due to other errors. It is interesting to note that the D10 forecast (surface pressure) pattern from 12Z on 12th (22nd) maintained a well positioned block whereas the sequence from 12Z on 13th, while improving one aspect of the evolution, allowed the block to collapse. Clearly, the correct building and maintenance of a blocking pattern within the model depends critically on some aspect of data being input at the analysis stage. It was also found that the UK operational forecast from DT 12Z on 11th produced and maintained a good block, despite the Iberian low again slipping erroneously East and failing to fill.

A global version of the ECM/UK combination was run on the Cray to eradicate differences due to the boundary at 30°S. However, although some aspects of the forecast were slightly changed, the evolution and handling of the block were still incorrect.

As a further approach to the investigation, an analysis of the 500mb heights was carried out for each model/analysis combination, looking only at wave numbers 0 to 3. These analyses were available day by day. It was evident that:-

i. forecasts run from the ECMWF analysis were superior, to those run from the UK analysis, in re-establishing the block.

ii. In each case, the ECMWF forecast model was superior to the UK model in re-establishing the block. See FIGS 6(a) - 6(c).

At the presentation of these results, it was suggested that this dual effect may come from the feedback of the forecast model on the analysis through the background field. There was also considerable comment about the mishandling of the low over Iberia. It was felt that this may be the major factor in the mishandling of blocks (in general) by the UK model, the tendency being towards zonality which sweeps the lows away eastwards. This has the effect of removing the balancing Easterly flow on the S side of the high and hence to the collapse of the block.

Summary for 10 Feb 83 Case

1. All model/analysis combinations gave reasonable predictions to D3 but failed thereafter to predict the trough extension, which played a major part in the re-establishment of the block, D4-5.

2. ECMWF was superior to UK, in both analysis and forecast model, in handling the block. However, ECMWF had more serious errors upwind.

3. The low system of the block tended to drift east D3-5. ECMWF was superior to the UK model in handling this feature, the UK model allowing the system to move some fifteen degrees east of reality.

4. The UK model failed to fill a system over E Europe, a feature of the model noted before.

5. The tendency for the UK model to break down blocking patterns may be closely linked with a mishandling of long waves and a tendency to excessive westerlies evident in long runs of the model.

FIG 1(a). PMSL(mb), showing surface developments, DO 2JAN83 12z above, D1 3JAN83 12z below.

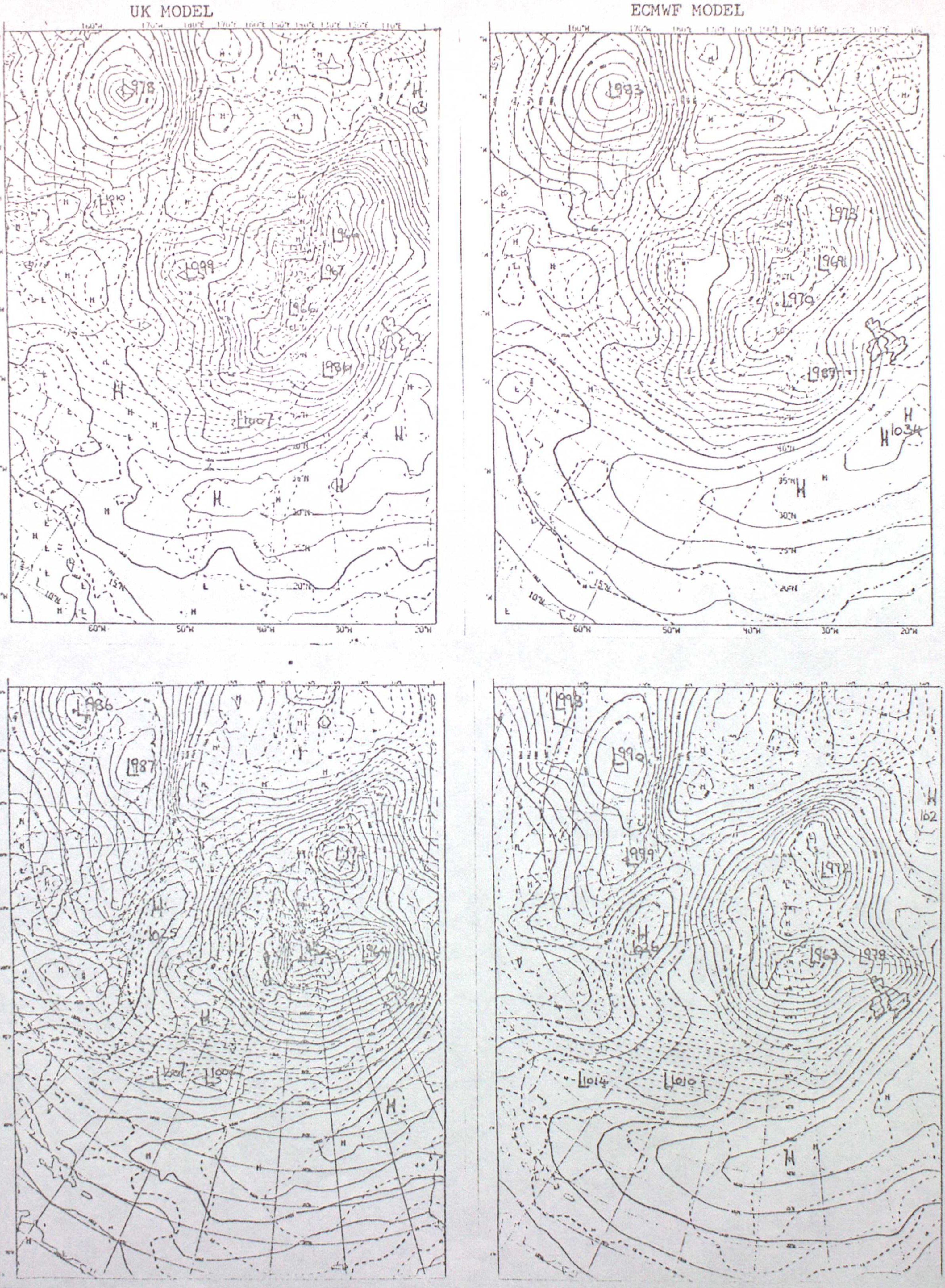


FIG 1(b). PMSL(mb), showing surface developments, D2 4JAN83 12z above, D3 5JAN83 12z below.

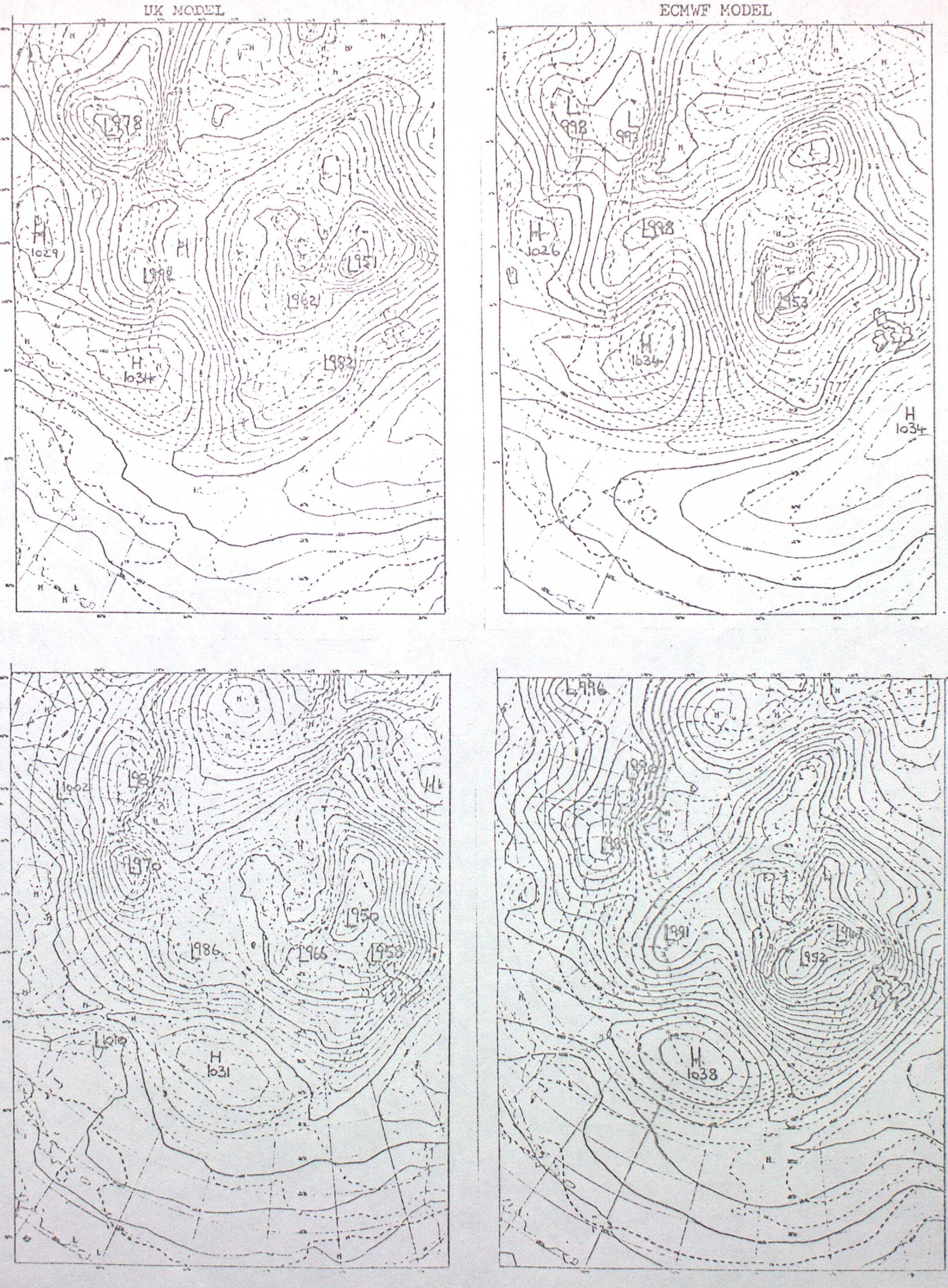


FIG 1(c). PMSL(mb), showing surface developments, D4 6JAN83 12z above, D5 7JAN83 12z below.

UK MODEL | ECMWF MODEL

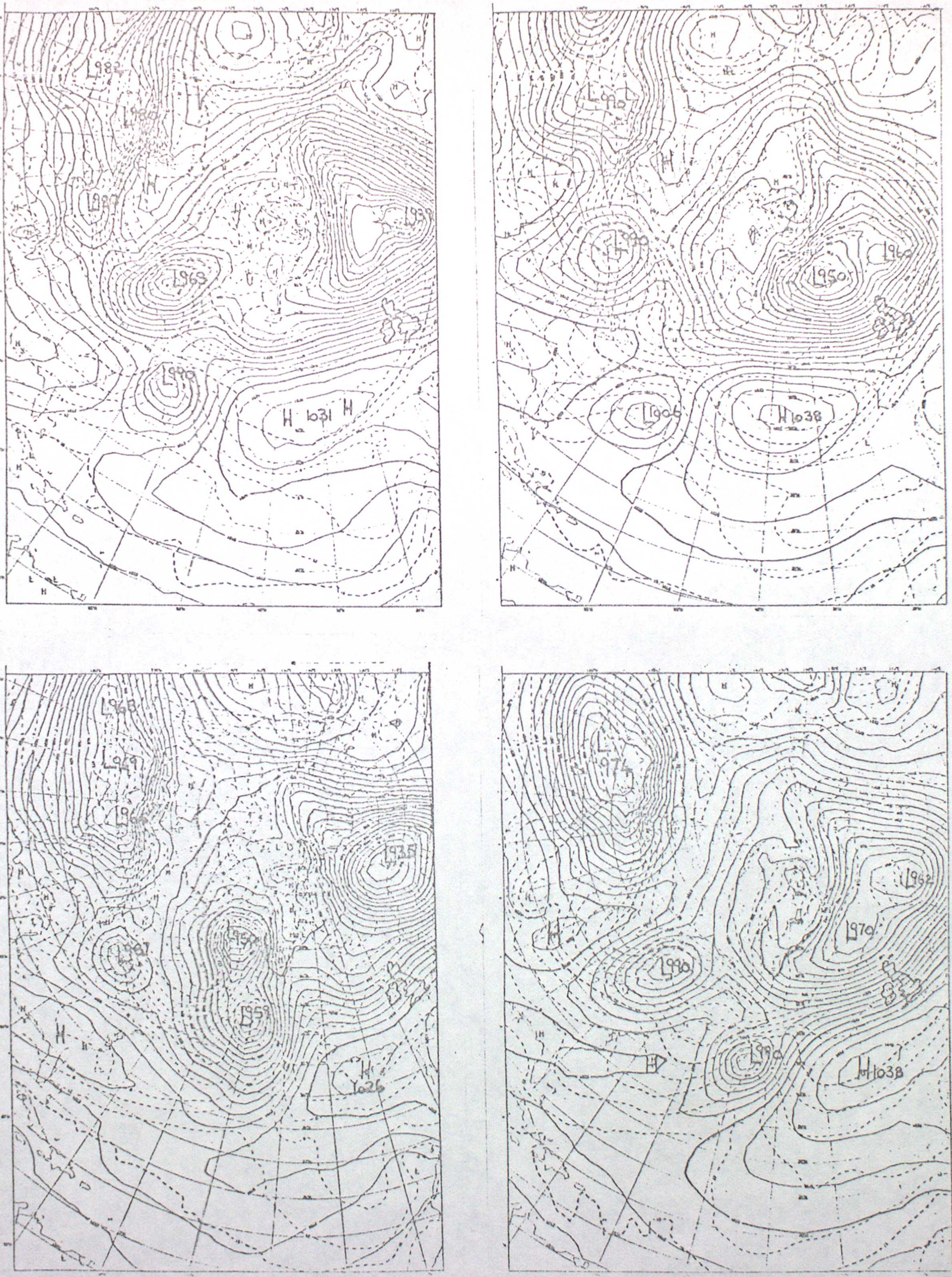


FIG 2(a). PMSL(mb) and 500mb Heights(geopotential m) for DO,

2JAN83 12z.

Pacific region.

UK MODEL | ECMWF MODEL

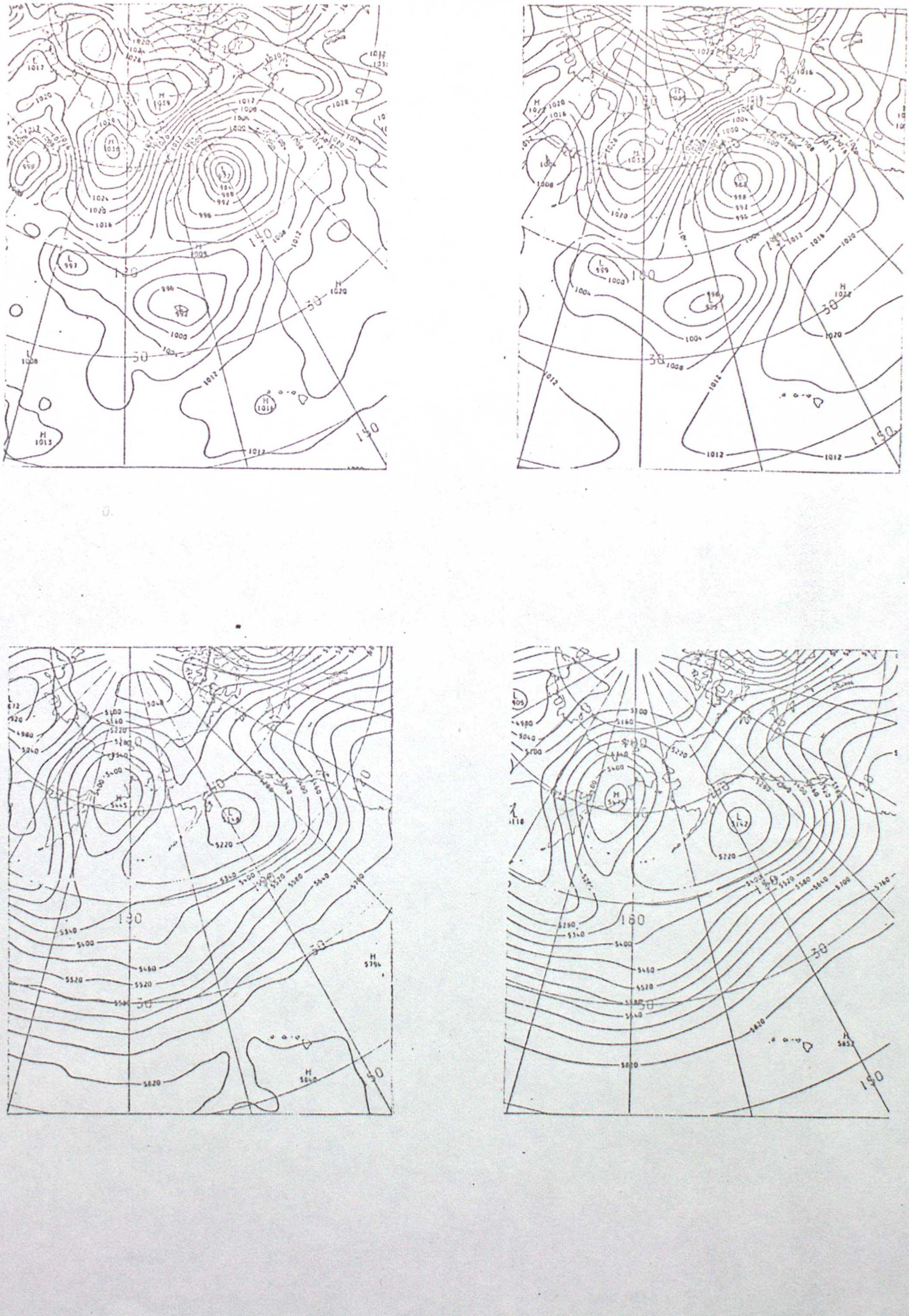
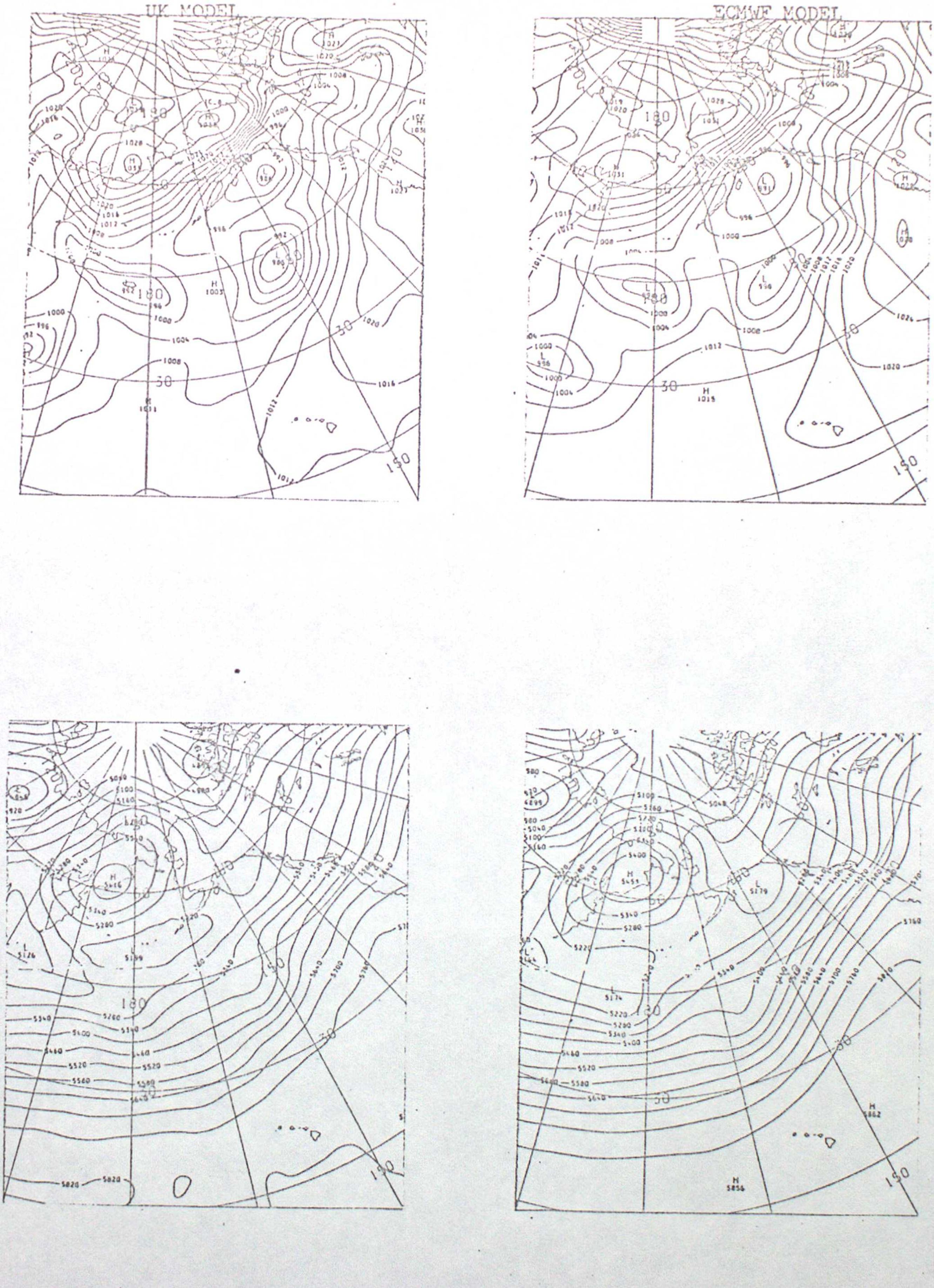


FIG 2(b). PMSL(mb) and 500mb Heights(geopotential m) for D1,

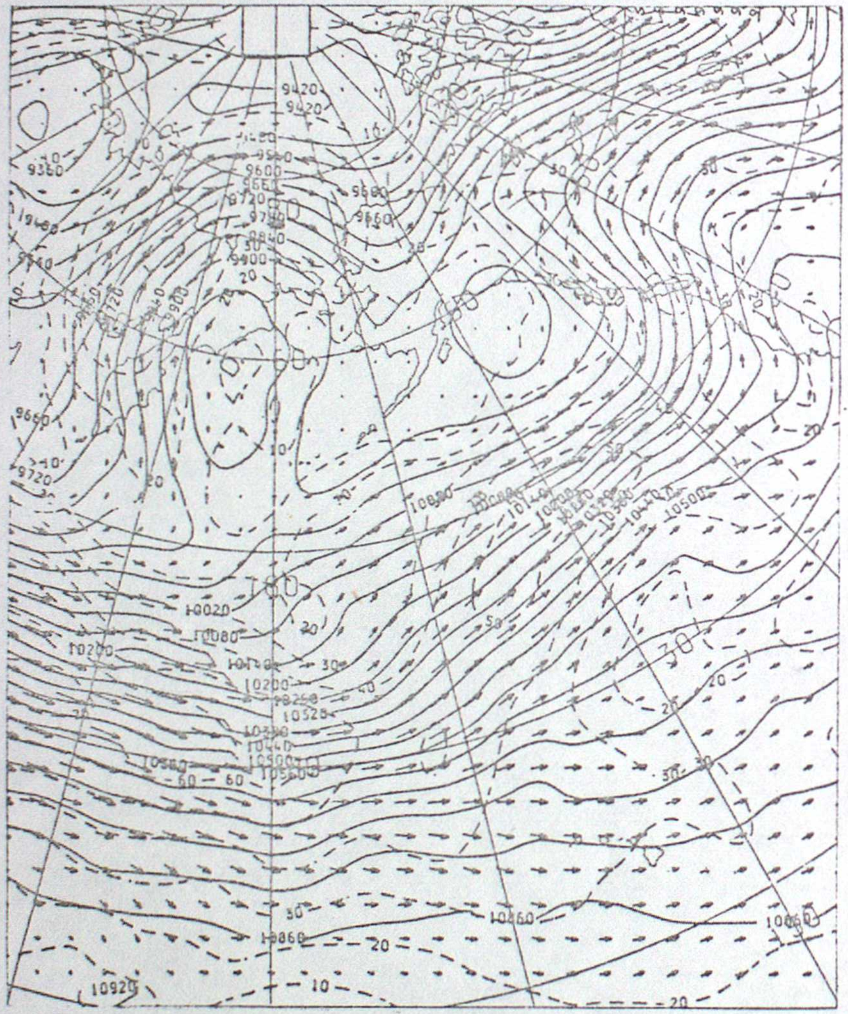
3JAN83 12z.

Pacific region.

UK MODEL | ECMWF MODEL



UK MODEL



ECMWF MODEL

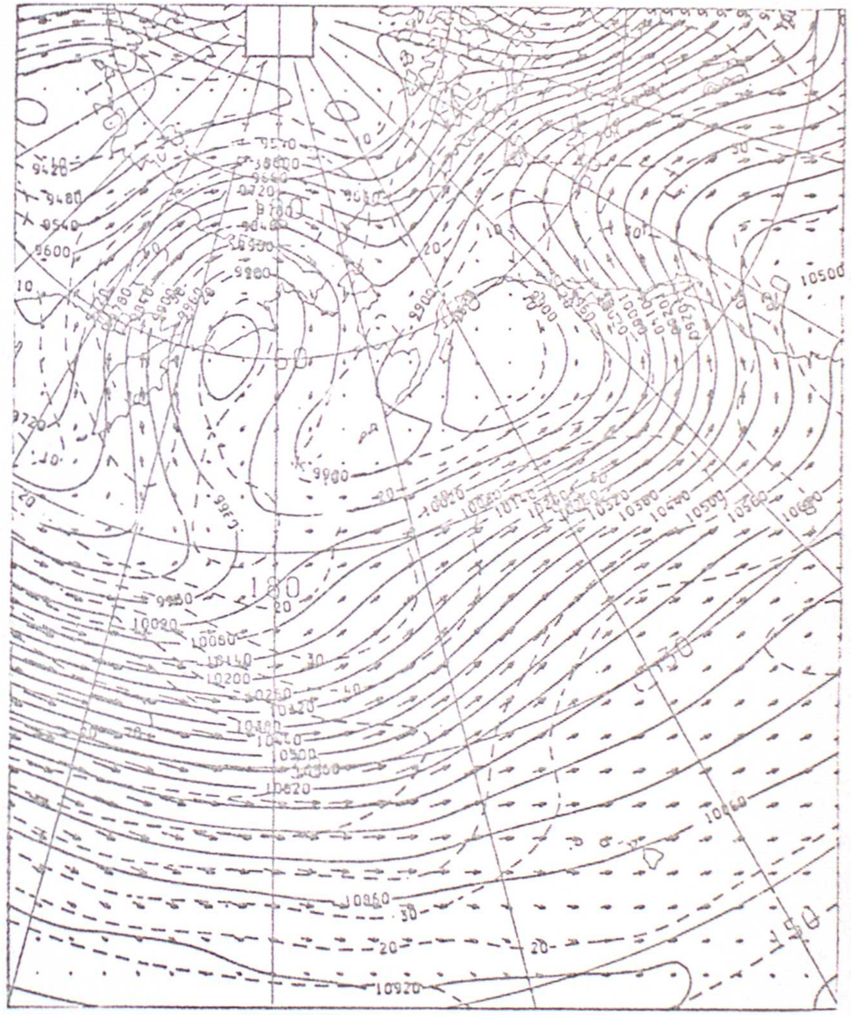


FIG 3(a). 250mb Winds, Heights and Isotachs for DO, 2JAN83 12z.

UK MODEL

ECMWF MODEL

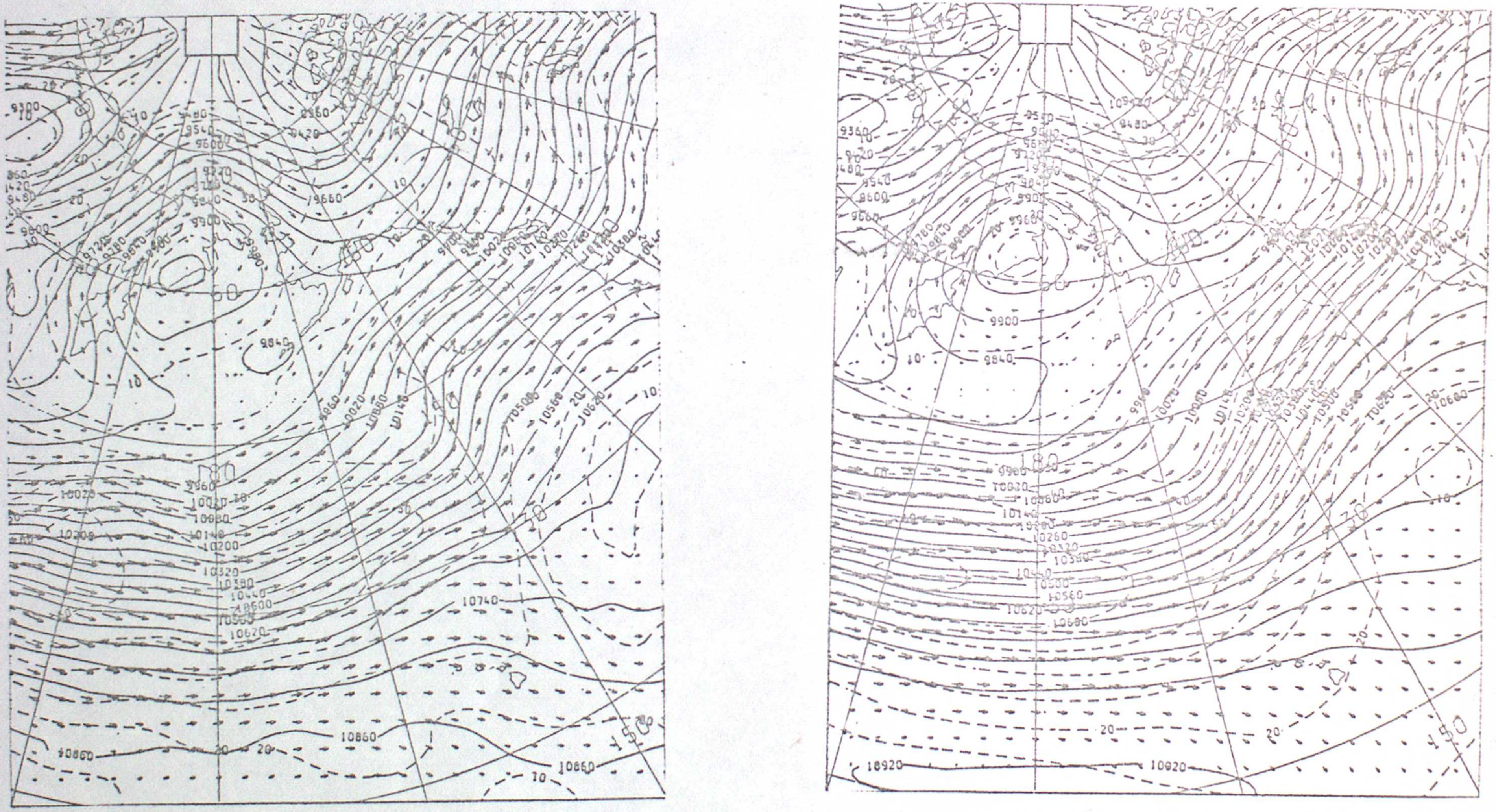
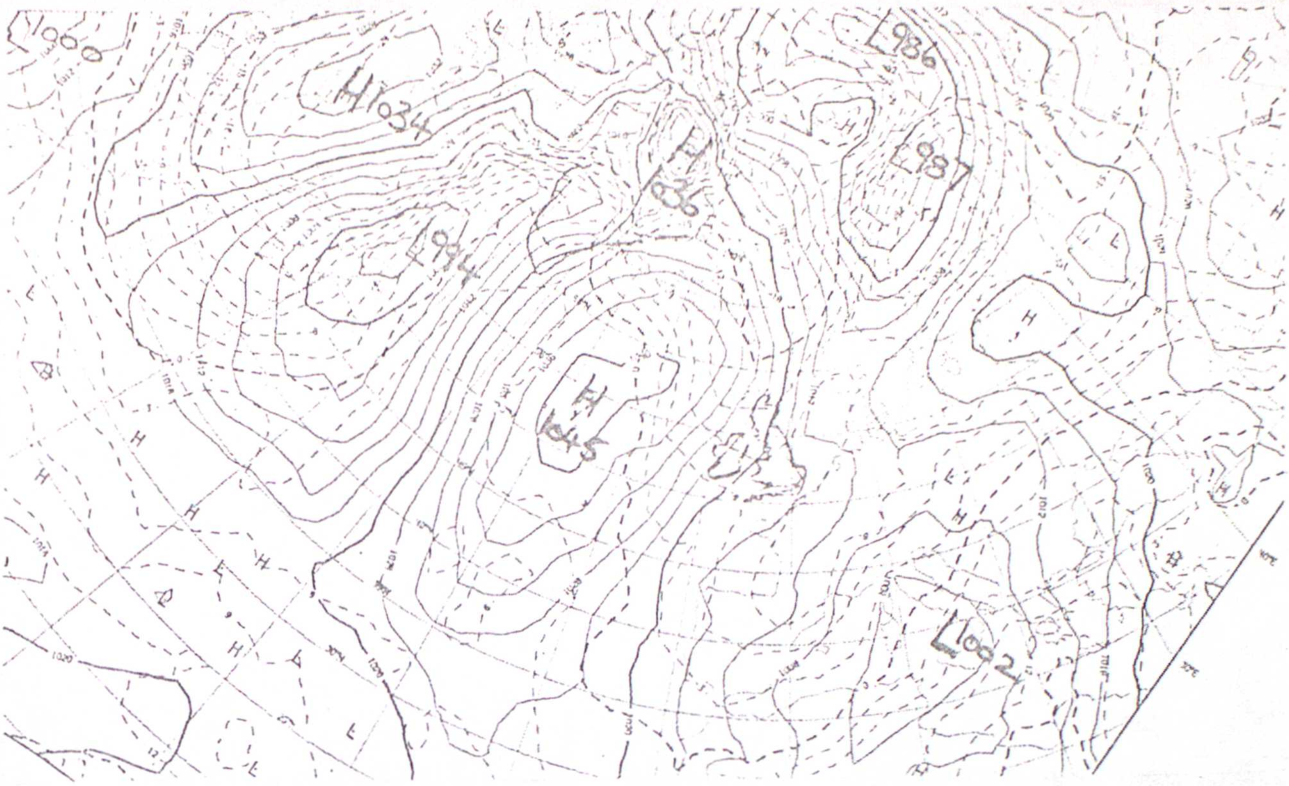


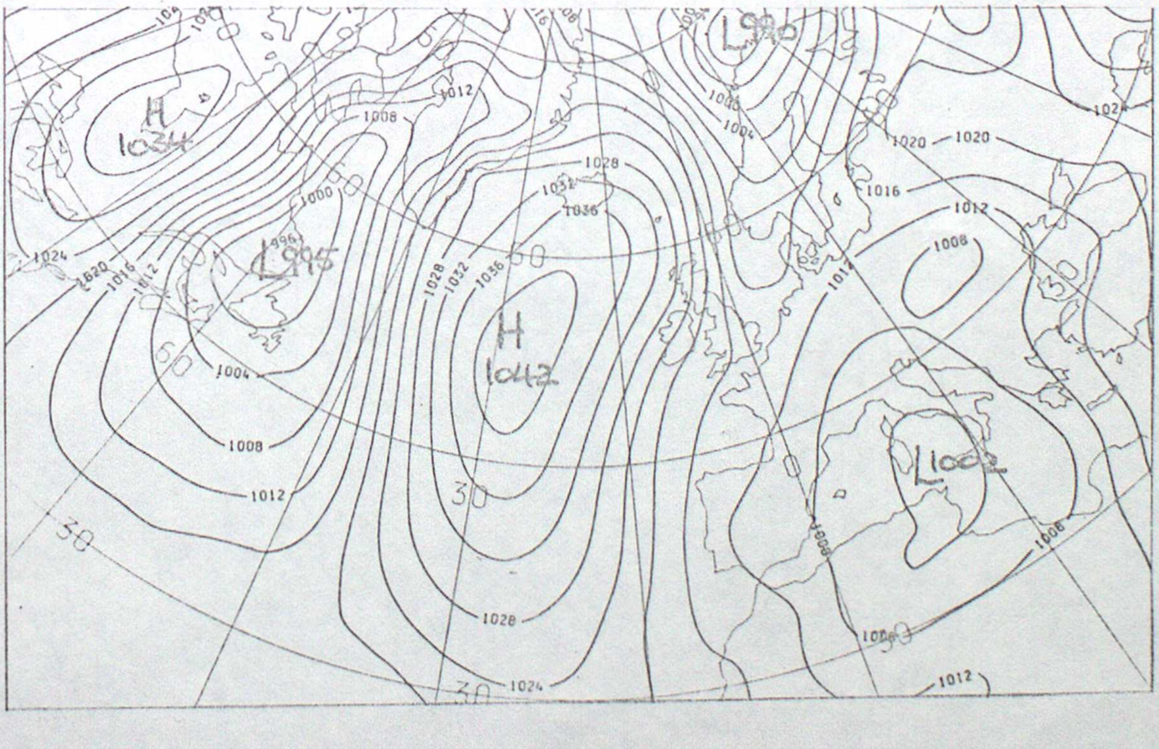
FIG 3(b). 250mb Winds, Heights and Isotachs for D1, 3JAN83 12z.

FIG 4(a). PMSL (mb) , Initial Fields, 10 FEB 83, 12z.

UK Model

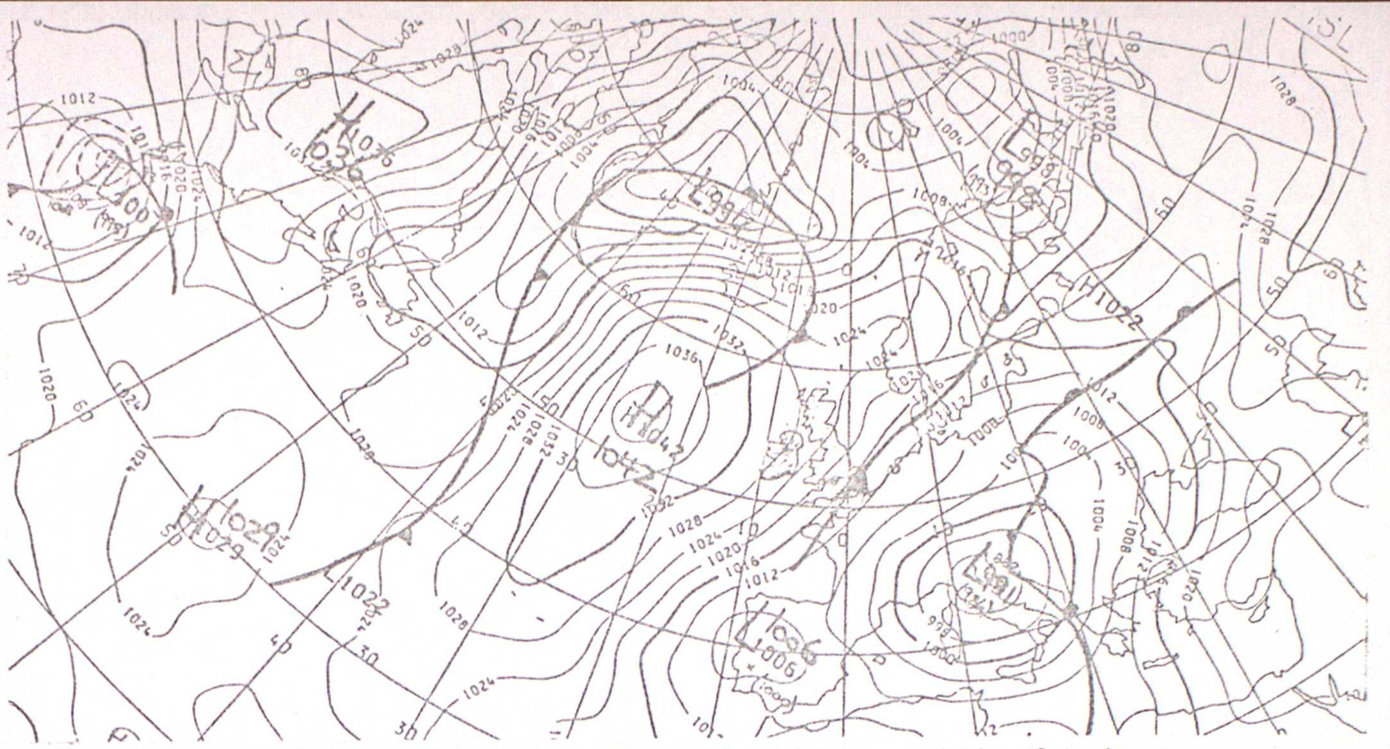


ECMWF Model

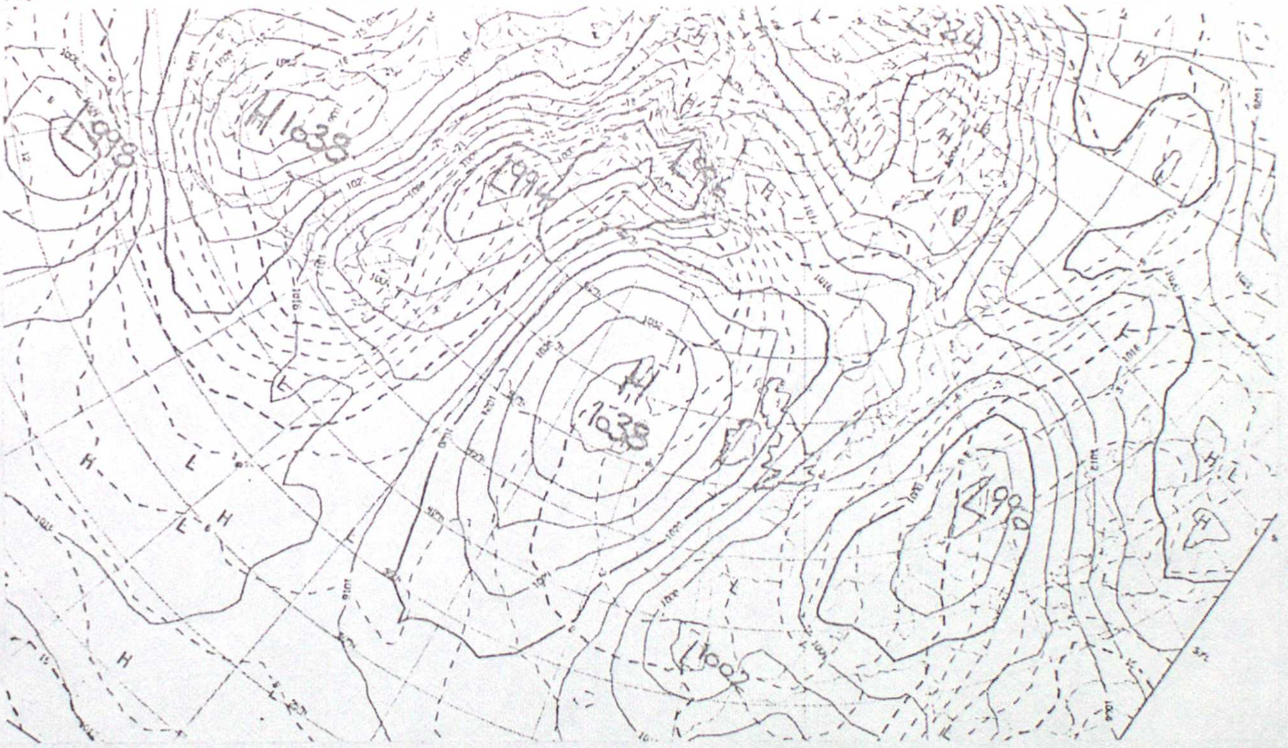


4(b)
PMSL(mb)
D1
11 FEB 83
12z.

Actual



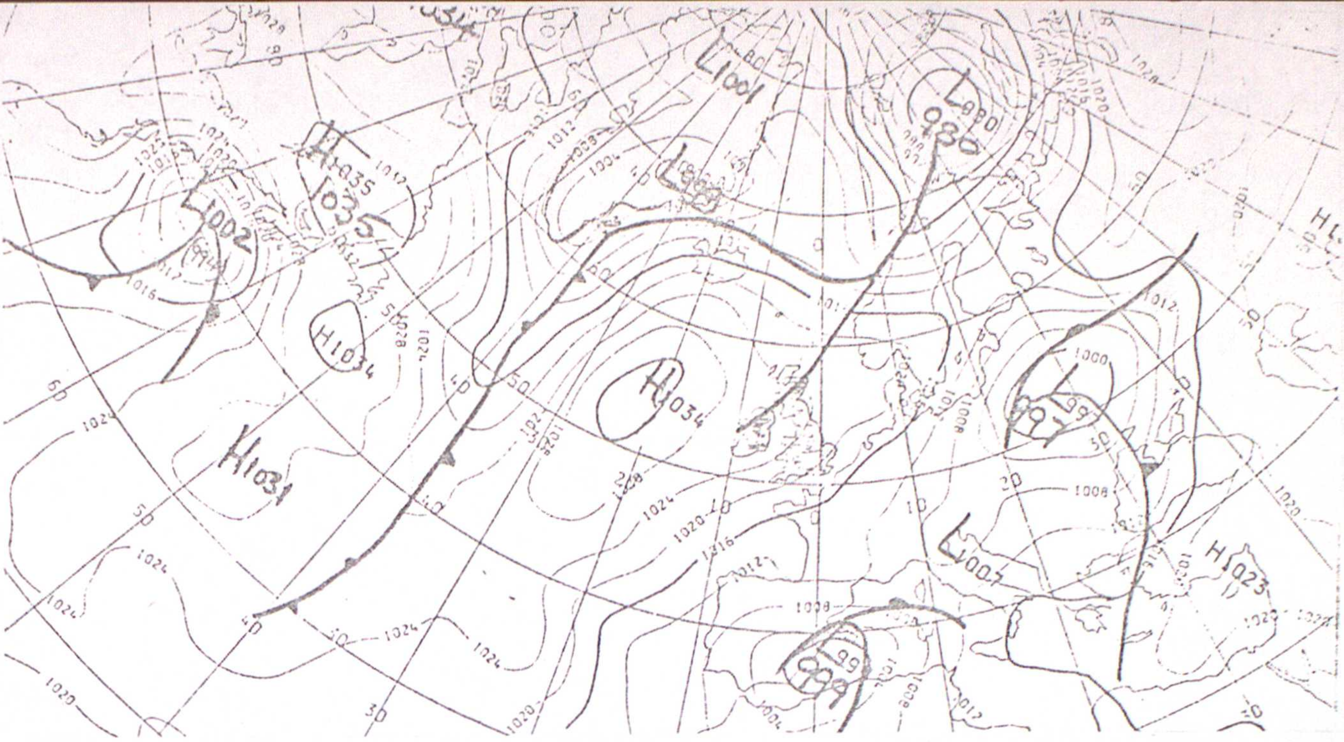
UK Model



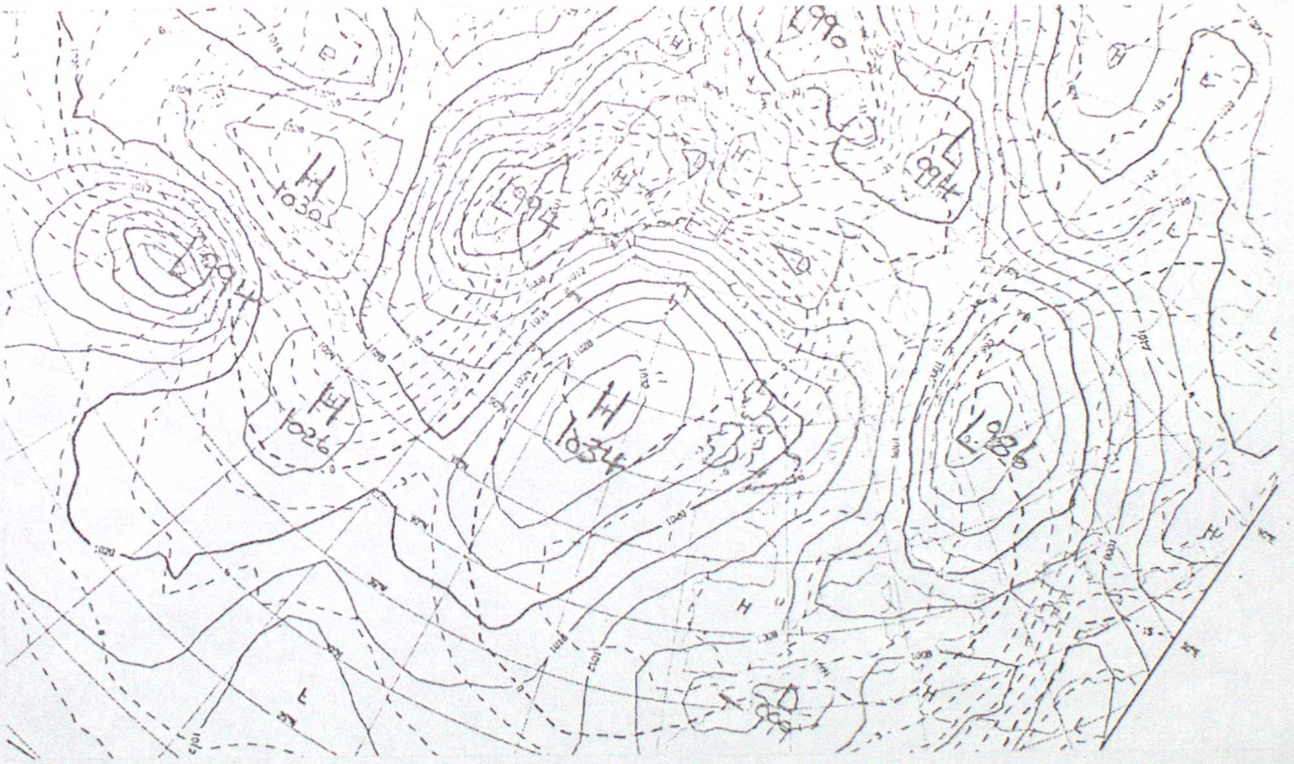
ECMWF Model

4(c)
PMSL(mb)
D2
12 FEB 83
12z.

Actual



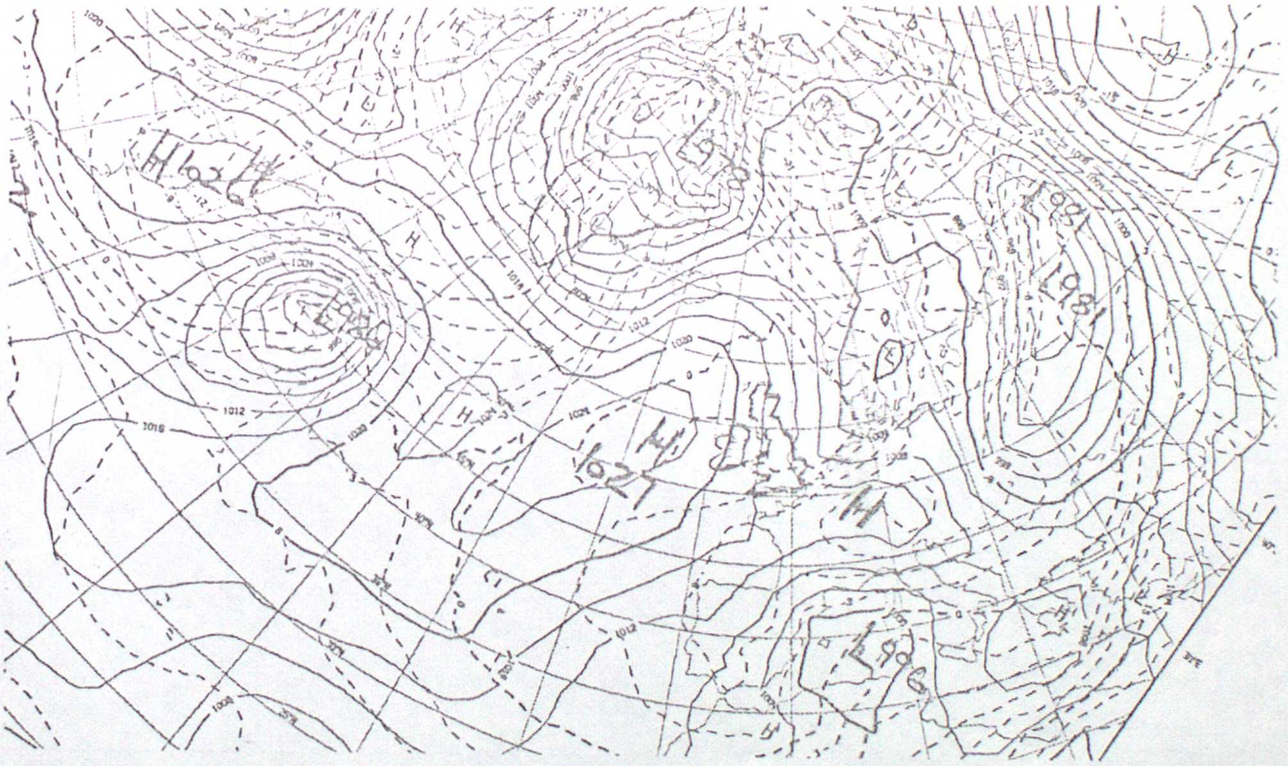
UK Model



ECMWF Model

FIG 4(d)
PMSL(mb)
D3
13 FEB 83
12z.

Actual

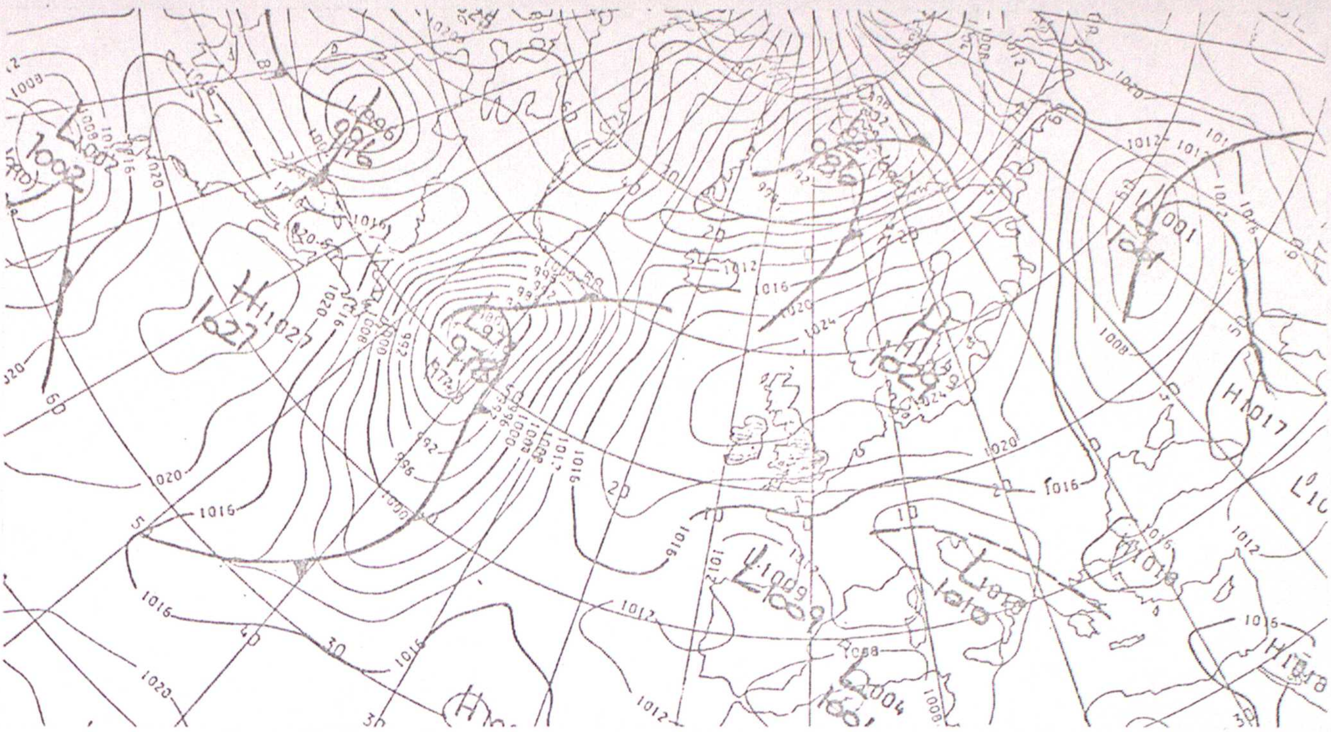


UK Model

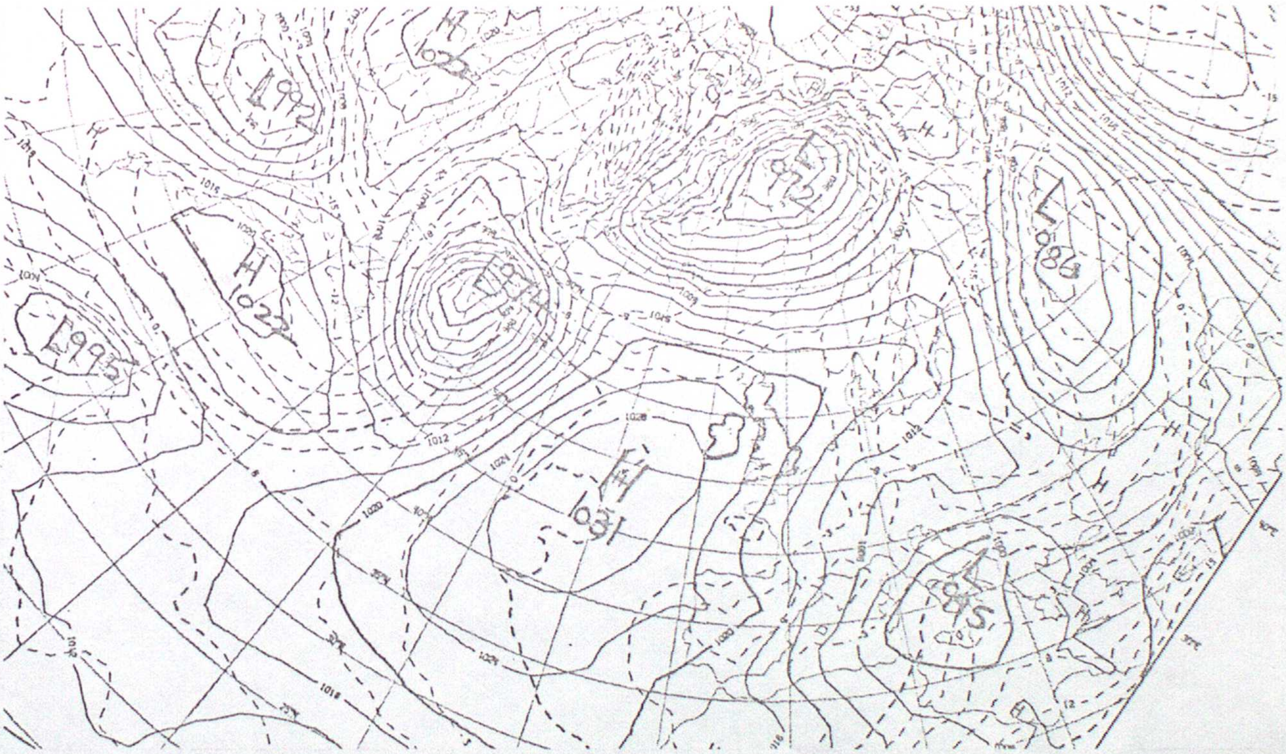
ECMWF Model

4(e)
PMSL(mb)
D4
14 FEB 83
12z.

Actual



UK Model



ECMWF Model.

4(f)
PMSL(mb)
D5
15 FEB 83
12z.

FIG 5.

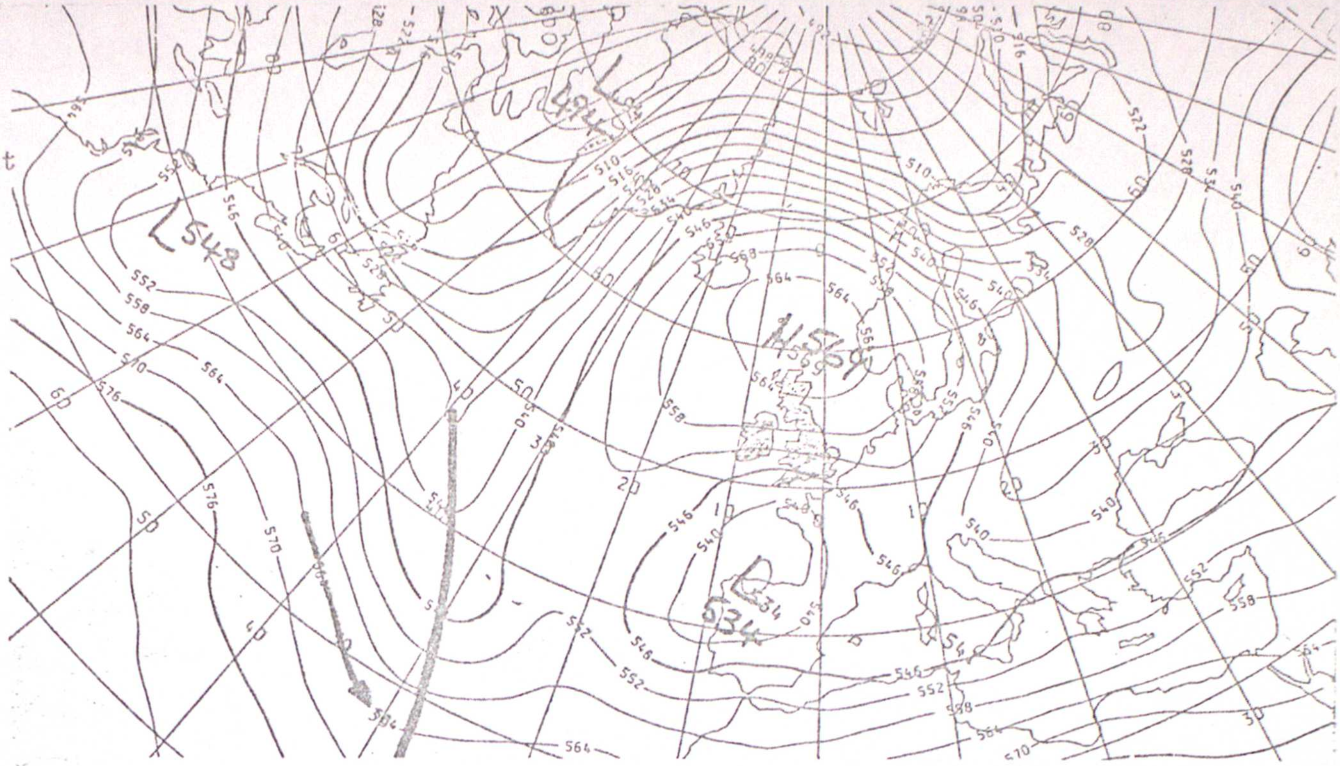
500mb Height

D5

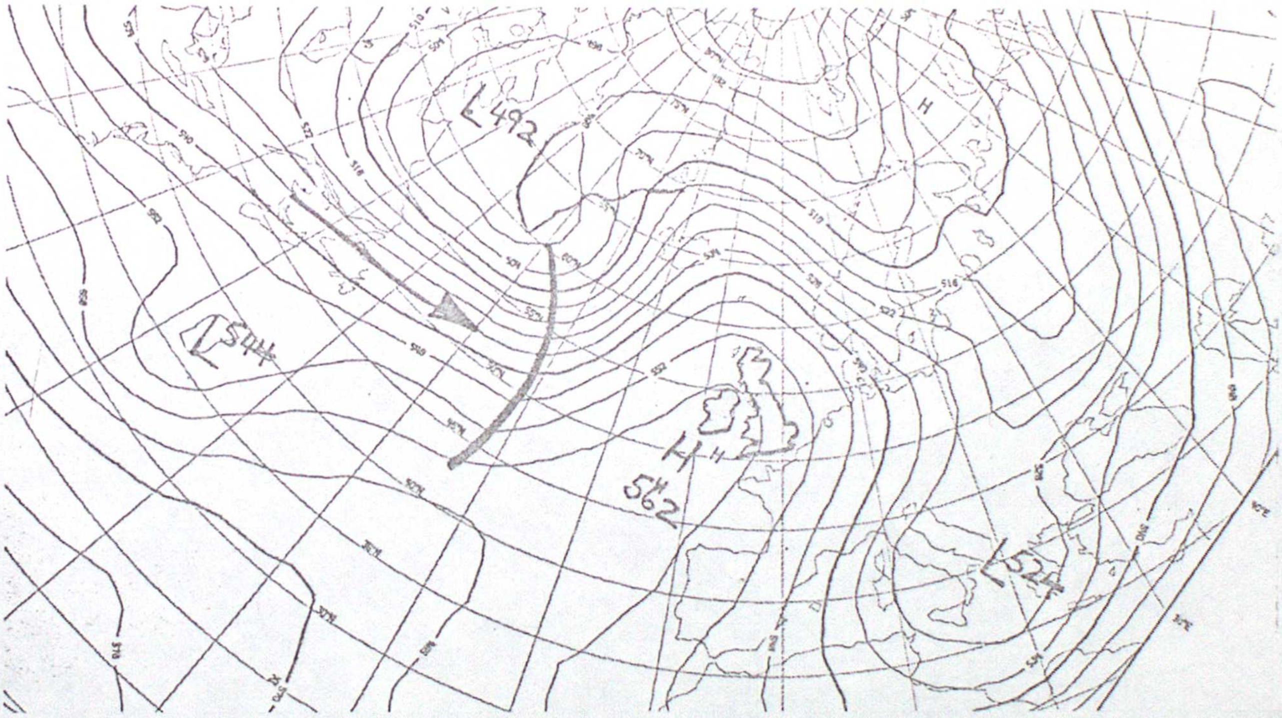
15 FEB 83

12z.

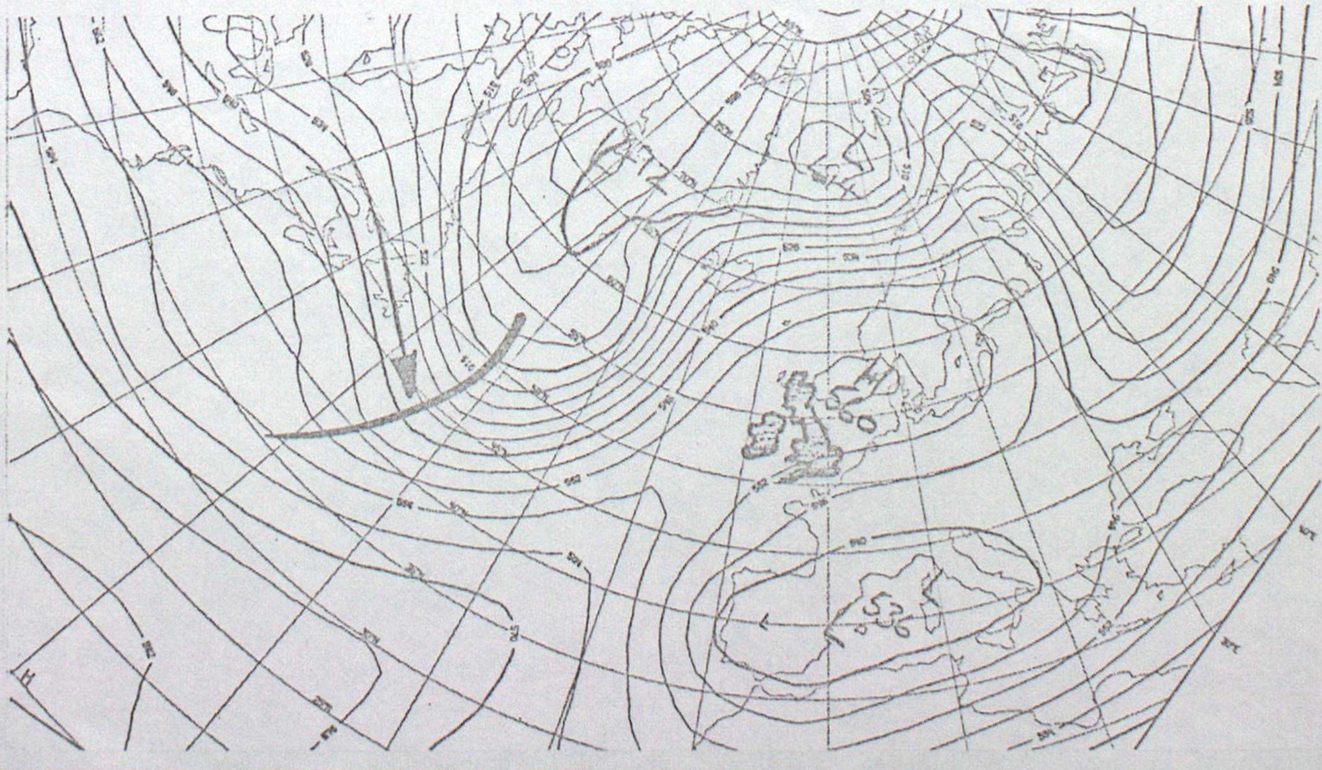
Actual



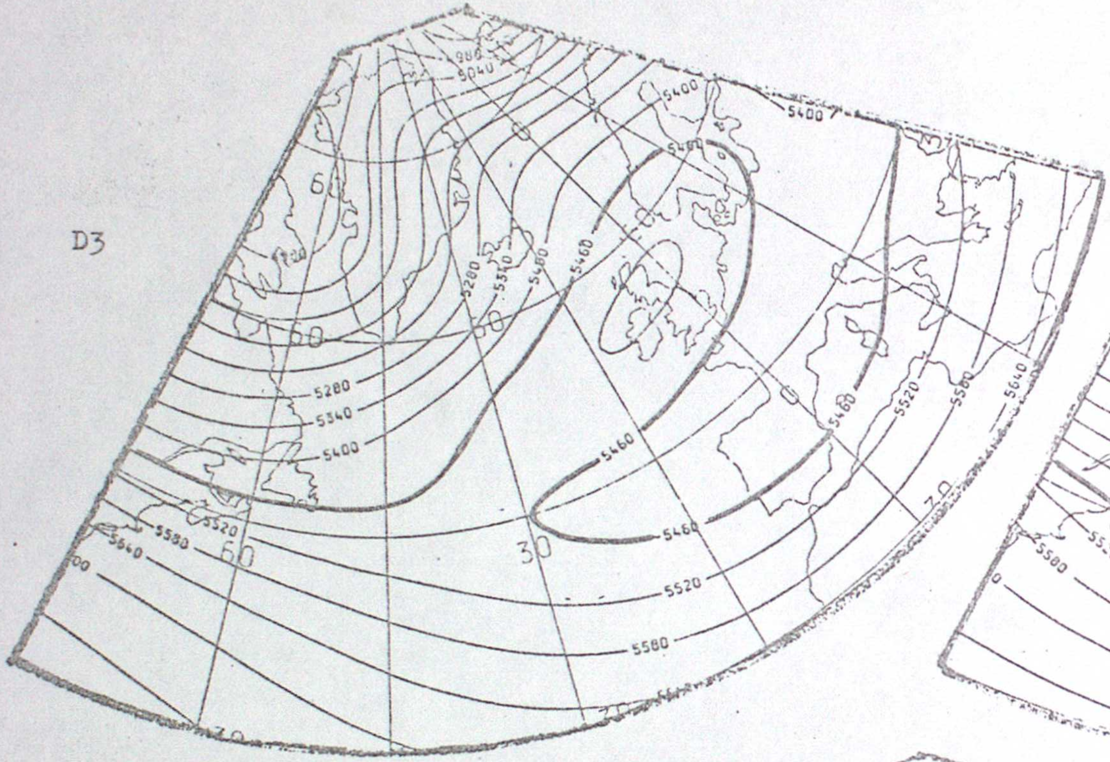
UK Model



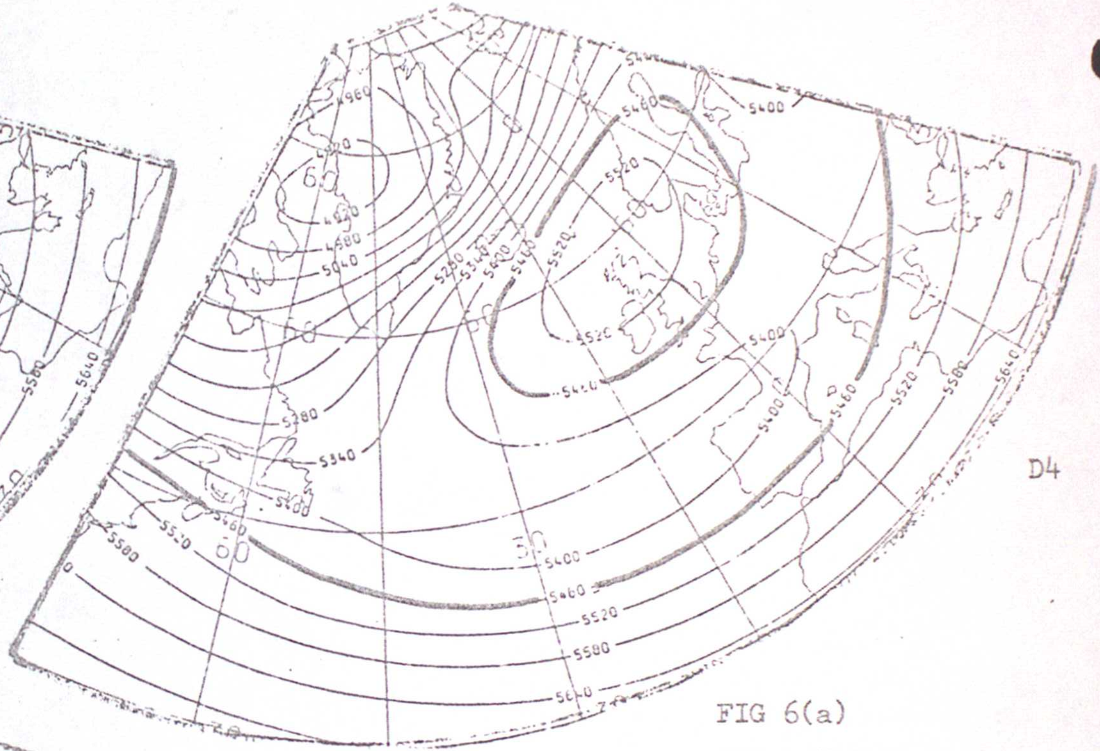
ECMWF Model



D3



D4



D5

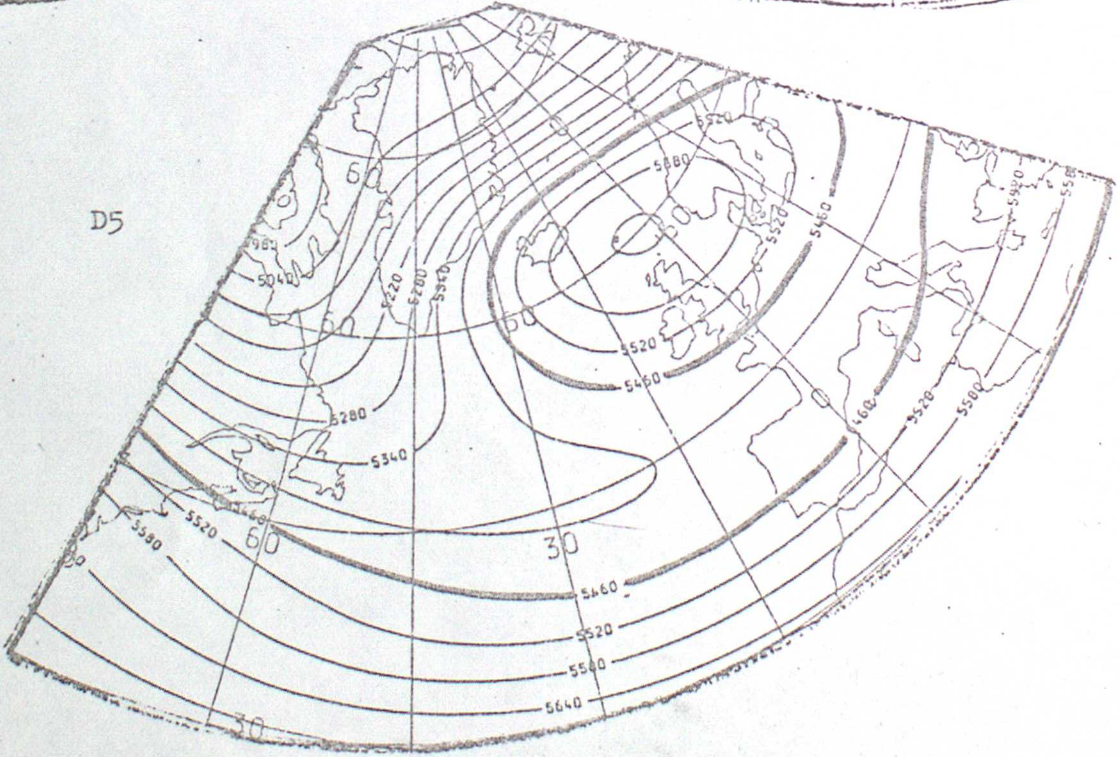


FIG 6(a)
500mb Heights,.
Wave Number 0-3 Only,
ANALYSES D3 - 5,
13-15 FEB 83, 12z.

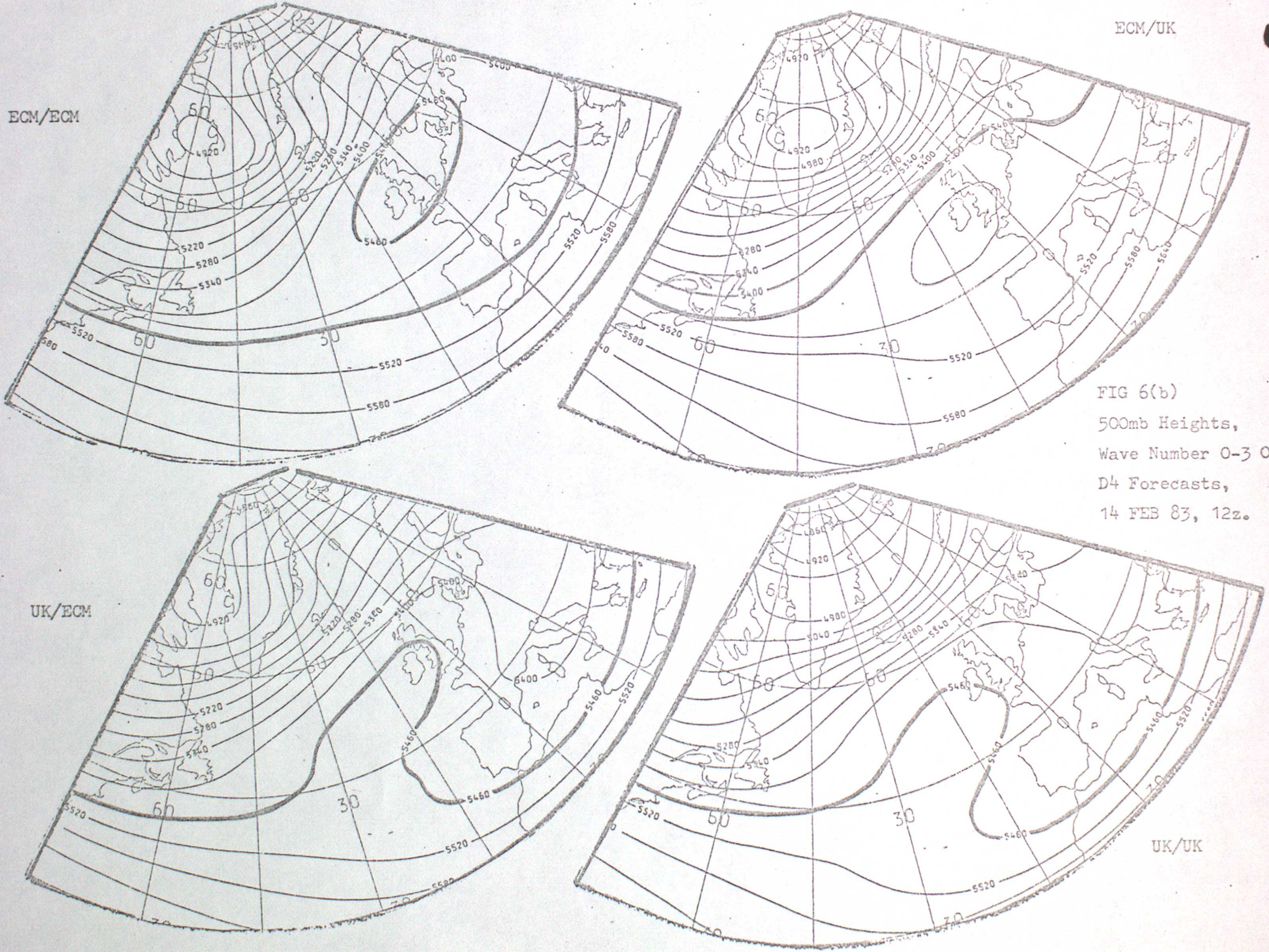


FIG 6(b)
500mb Heights,
Wave Number 0-3 Only,
D4 Forecasts,
14 FEB 83, 12z.

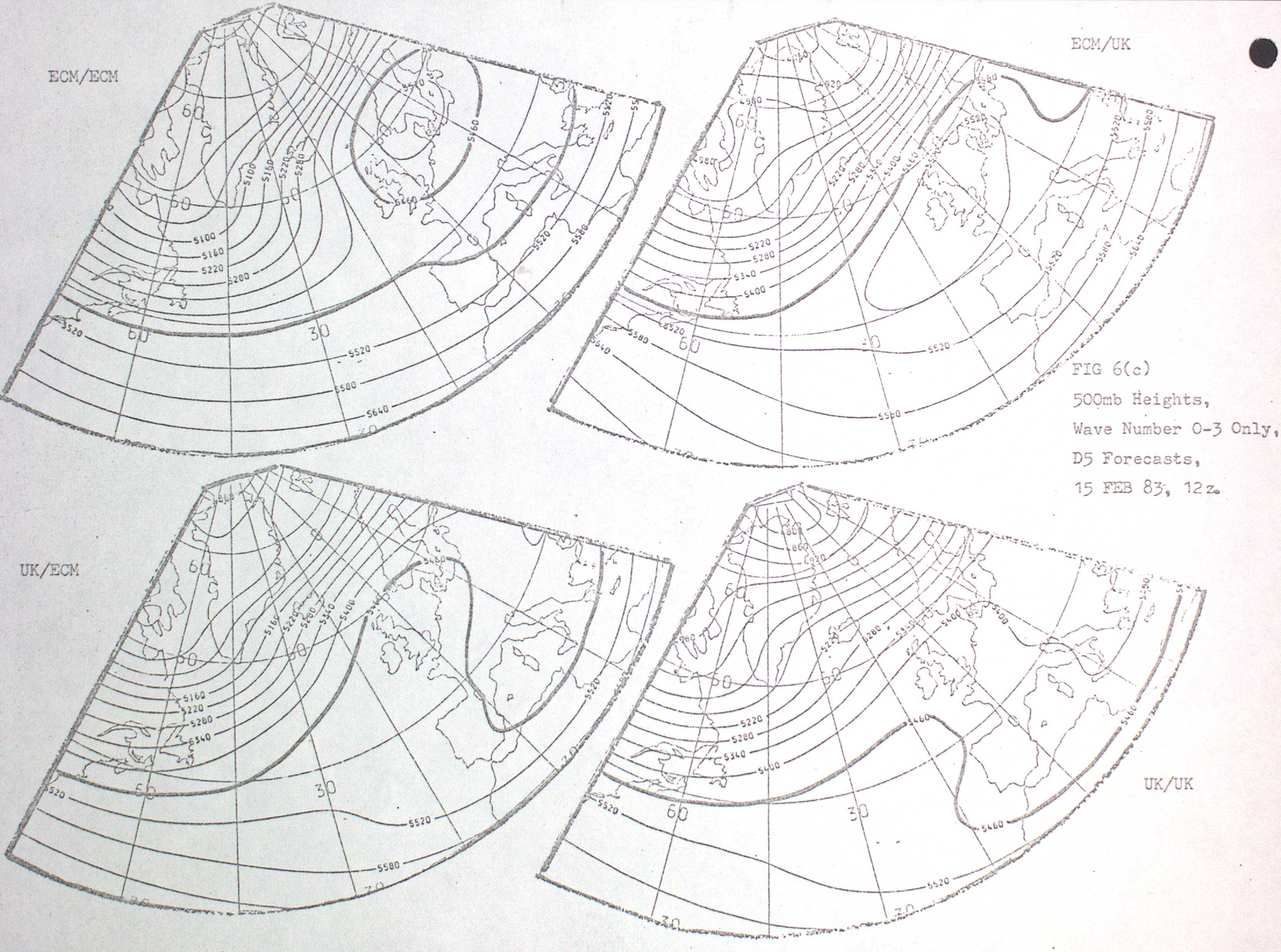


FIG 6(c)
500mb Heights,
Wave Number 0-3 Only,
D5 Forecasts,
15 FEB 83, 12z.