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Forecasting Research

Met O 11 Technical Note No 2

**A case study showing the impact of analysis
differences on medium range forecasts**

by

R.A. Downton and R.S. Bell

January 1988

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1. Introduction

The sensitivity of medium range forecasts to initial conditions is well known (eg Hollingsworth et al 1985). The forecasters in the Central Forecast Office at Bracknell have access to the products of several NWP centres, in addition to the Meteorological Office model (including ECMWF, NMC, DWD) and are often faced with differing evolutions. Clearly the differences can result either from differing initial conditions or the different model formulations. We have examined in some detail six cases during the autumn/winter of 1985/86 where the Meteorological Office operational forecasts significantly disagreed with that from ECMWF. An example of one of these cases is presented in this paper.

The basic technique for comparing operational forecasts from the two centres involves running the ECMWF model from an interpolated Met Office analysis and running the Met Office model from an interpolated ECMWF analysis. This enables us to ascertain the relative importance of the different initial conditions or model formulations for a particular case. We have found that in most instances a strong signal is obtained with both models producing similar results from the same analyses. No consistent difference between the analyses has been found but the technique has enabled us to identify cases which are sensitive to initial conditions and has proved useful in developing new analysis algorithms. A transplant technique has been used to isolate a particular geographical area where one analysis might be deficient. This involves the replacement of a portion of one analysis by the analysis from the other centre.

The case discussed in this paper is from data time 12 GMT on 8th January 1986 and has been used as an example at the 1987 Met Office Summer School on the Interpretation of Numerical Forecast Products. It illustrates very well how subtle analysis differences can grow in the forecast, interact with each other and progress around much of the hemisphere to yield substantial differences in the medium range forecast. In section two, we discuss the evolution of the two operational forecasts and the two additional forecasts where each

centre's model was run from the other centre's interpolated analysis. Difference charts are used to highlight the growth and progression of the differences and these will be discussed in section three, where we will also consider the importance of the main analysis differences and try and identify by means of transplant experiments whether the observed differences have a significant bearing on the subsequent evolution. Further experiments involving the new Met Office analysis scheme are considered in section four. Section five discusses the observational data available in the crucial areas and how it was assimilated.

2. The forecast model runs

a) General Development.

We will first describe the general synoptic development during the period 8-13th January 1986 . At 12 GMT on the 8th, upper vortices were centred over Arctic Canada and just South of Greenland with a strong mid-latitude upper westerly flow extending from the Pacific across the United States to the Eastern Atlantic. This was poised to break down a temporary block that had developed over Scandinavia during the previous two days. By midday on the 9th an upper ridge was crossing the UK ahead of the deepening vortex, still to the south of Greenland. 24 hours later this vortex had moved east, just to the south of Iceland, with a strong southwesterly flow over the UK. At the surface, an anticyclone situated over Scandinavia on the 8th, slipped south into central Europe as a secondary low, moving northeast around a large complex low pressure area extending from Greenland to Iceland, deepened rapidly from 978mb at 12 GMT on the 9th to 934mb by 12 GMT on the 10th, to be centered just to the northwest of Scotland in association with the upper low.

The sequence was almost repeated during the next 72 hrs. Charts of the surface and 500 mb patterns for this period (11-13th) are given in Figure 1 . The deep upper and surface lows to the North of Scotland on the 11th , filled and moved east into the Baltic, whilst another intense development took place as an upper trough, which had been moving east

across the United States moved into the Atlantic on the 12th around another upper low which had drifted southeast from Arctic Canada to Northern Labrador. We see a 500mb vortex to the South of Iceland by 12 GMT on the 13th developed from the trough just East of Newfoundland 24 hours earlier. At the surface a low developed on a waving cold front and deepened from 990mb at 12 GMT on the 12th to 939mb by 12 GMT on the 13th and moved northeast with its centre just south of Iceland.

b) Comparison of Operational runs.

A careful comparison of the 500mb height fields, 250mb winds and surface pressure fields was made for forecast periods at 24 hour intervals up to T+120, from the two operational forecasts made at the Met Office and ECMWF. Throughout the text we shall identify forecasts by analysis and model, thus UK/UK implies a Met Office analysis followed by a Met Office forecast. EC/EC implies the operational ECMWF run, with EC/UK and UK/EC representing the cross comparisons.

Figs 2a & 2b show the T+72 500mb operational forecasts made at the Met Office and ECMWF respectively. Considerable differences can be seen between the two forecasts. The low to the northeast of Iceland has a large closed circulation on EC/EC, whilst this feature has been filled too quickly by UK/UK. Over the Atlantic we see the flow is much better represented in the EC/EC run with, the ridge at 30° W, the low near Northern Labrador and the broad U-shaped trough extending south over New England, all verifying very well with the analysis (at Fig 1a) . The trough at 105° W is also evident on the forecast. In the UK/UK run, the flow is backed too far over the western Atlantic due to the upper vortex near Labrador, being displaced too far to the southeast. A ridge is indicated at 105° W with the trough being further west.

By T+120, (Fig 3b) EC/EC had moved the vortex and the associated trough east to be just southwest of Iceland, with another vortex drifting southeast from the Arctic to Northern Labrador. This development was a little slow when compared with the verification for the 13th shown in Fig 1e. In fact, this was not quite the correct evolution as a detailed study of the actual events showed that a vortex remained almost

stationary near northern Labrador, with cyclogenesis taking place to the south of Iceland, in association with the eastward moving upper trough. The ridge over Western Europe and the trough extending southwards over the Great Lakes are well forecast. The UK/UK run at T+120 (Fig 3a), portrays a somewhat different evolution. The low over the Davis Strait became detached from its trough to the south with its centre forecast to be to the east of Iceland by 12 GMT on the 13th. The trough moved eastwards at a slower rate with its forecast position to be near 60°W on the 12th and 40°W by the 13th. The ridge over Western Europe had been moved too far eastwards and the trough at 80°W is also shown to be too broad and not sharp enough.

Mean sea level pressure forecasts at T+72, Figs 4a & 4b show that both UK/UK and EC/EC had the low between Iceland and Scotland, too far north and not deep enough, with the low in the Davis Strait being too deep. In comparison with the analysis (Fig 1b), we see much larger errors from the UK/UK, particularly in the flow from Hudson Bay across the North Atlantic to Norway, where the westerly flow is too strong and the northerly flow across Iceland is not reproduced. Another feature which is too intense from the UK/UK is the low at 35°N 70°W.

By T+120 (Fig 5a), we see the UK/UK has deep depressions to the east of Iceland, over the mid-Atlantic and just south of Hudson Bay, with a minor ridge extending north to Iceland and a much more pronounced ridge over Newfoundland. The EC/EC (Fig 5b) is much closer to the analysis; a deep low pressure system is forecast just southwest of Iceland with a ridge over the West Atlantic and a shallow low over Northeast Canada. The deep surface low forecast in mid-Atlantic at T+120 by the UK/UK is an interesting feature, as this is the same low that was positioned at 35°N 70°W at T+72 both on the analysis and UK/UK at that time.

It appears that the eastward movement of the trough from the Pacific was very critical, in that the slower movement from the UK/UK run allowed the low and the associated warm air to move far enough north to become engaged by it, with rapid development taking place over the western Atlantic during days 3 and 4 resulting in the deep trough over the mid Atlantic by day 5. Verification (Figs 1d & 1f), on the 12th and 13th show that this particular low drifted east to the mid-Atlantic as a

shallow feature and did not become engaged with the strong baroclinic zone further to the north. EC/EC handled this quite well by having a small low positioned at 35°N 65°W on the 13th, 15° further west than on the verification. This is due to the quicker movement of the upper trough which meant that the central American low had not moved far enough north to become engaged by it, hence with little development taking place and leaving it as a shallow slow moving, filling feature.

c. The cross comparison runs.

The two additional forecasts UK/EC (UK analysis / EC forecast), run at ECMWF using an interpolated UK analysis and the EC/UK (EC analysis / UK forecast), run at Bracknell using the interpolated EC analysis were then compared with the UK/UK and EC/EC. T+72 and T+120 charts for 500mb heights and surface pressure from these cross runs are shown in Figures 2c,d 3c,d 4c,d and 5c,d next to the equivalent operational runs already discussed.

Comparison of all four runs indicate a great similarity in each pair of forecasts from the same analysis. The 500mb low east of Iceland at T+72 is a well developed feature in both forecasts using the EC analysis (Figs 2b & 2d), whilst it becomes a very small feature to the North of Iceland on the forecasts from the UK analysis (Figs 2a & 2c). The corresponding MSLP charts (Figs 4a & 4c) also show the much better positioning of the Icelantic low and a deeper low at 105° W. By T+120 both 500mb forecasts (Fig 3a & 3c), using the UK analysis have the ridge too far east into Europe and an incorrect trough at 40°W, although the UK/EC did produce a slightly better forecast than the UK/UK. Further west the ridge over Newfoundland is incorrect and the trough over the Great Lakes is not sharp enough. Corresponding MSLP charts (Figs 5a & 5c), also show a significantly improved UK forecast using the EC analysis and a much deteriorated EC forecast using the UK analysis.

Clearly not all the difference between the two operational forecasts can be explained by the analysis differences but the analysis differences seem to be giving a dominant signal. To avoid confusing any model differences with the analysis signal, we shall examine the

difference in evolution of the UK/UK and EC/UK runs rather than the two operational runs in order to understand the reasons for the failure of the operational UK/UK run. This procedure may result in a loss of detail from the ECMWF analysis due to interpolation, but the similarity in the forecasts in this and other cases indicate that this is not of great importance.

3. Discussion of the analysis differences

a. The evolution of differences

Fig 6(a-f) shows a sequence of 500mb difference charts between the two UK forecasts using the UK and EC analyses at 24 hour intervals (UK/UK- EC/UK). The sequence of 500mb forecast charts for UK/UK and EC/UK are given in Fig 7 for reference. Comparison of the initial analysis Fig 6a (UK analysis-EC analysis), shows significant differences over the Pacific and Alaska. There is an excess negative (shaded) area in this chart due to the UK model having a cold bias of about 1 dm relative to the EC model. Taking this into account, we might perhaps consider that the small positive anomaly over Alaska is significant. We see in Figure 6 how the relatively small analysis differences can be seen to grow, move with the flow and develop forward. The growth in these differences is initially quite slow, but becomes much more rapid after day 3 as the systems progress.

Figs 7a & 7b show the analysed 500mb flow over the Pacific and western United States. The broad trough at 150°- 180° W analysed as a U shaped feature with a smooth flow around an upper low over southern Alaska by ECMWF, appears V shaped on the UK analysis, with a distorted flow around the low. There is also a more pronounced ridge extending into Eastern Alaska on the UK analysis. The smoother flow around the trough and the flatter ridge, plus the slightly stronger southerly component to the jet on the forward side of the trough from the EC analysis, allowed troughs to progress quicker across the USA than from the UK analysis.

One such trough can be identified extending south from the tip of

the Hudson Bay at 12 GMT on the 10th. This trough is further forward on the EC/UK than the UK/UK as shown by the positive area followed by a negative area on the difference chart Fig 6c. Following the sequence of the 24 hourly forecasts (Fig 7), we see this trough is positioned 60° W at T+96 from the UK/UK (Fig 7i) and 10° further forward on the EC/UK (Fig 7j). By T+120 the both forecasts have advanced this trough a further 20° with the UK/UK run still slow.

A second 500mb trough positioned over the eastern Pacific can also be identified to be further forward on the EC/UK. This trough can be seen to be much further forward at T+72 and T+96 in the EC/UK run, moving from 105° W to 80° W (Figs 7h & 7j), whilst the UK/UK has it 20° further west at T+96 (Fig 7i). From T+96 to T+120, UK/UK moved this trough quicker than the EC/UK so that by T+120 the position of the trough is similar in both forecasts. The EC/UK has it as a much sharper feature which verifies much better with the analysis (Fig 1e).

The differing positions of these troughs can easily be followed on the sequence of difference charts Figs 6(c-f). These show how the differing forecast positions of the trough over the Great Lakes at T+96 become much less by T+120 with a smaller central value of the positive area over the Eastern States. Over the UK and Western Europe there was a significant difference in the T+120 forecast position of a 500mb ridge. The forecasts from the EC analysis produced a well developed though transient ridge over the North Sea, whilst the forecasts from the UK analysis had this ridge 15° further to the east.

A study of the 250mb wind analysis over the Pacific Figs 8a & 8b showed that the UK had analysed the major jet further forward than the EC. The EC had a stronger southerly component to the jet at 120° W with the westerly jet near the Hudson Bay being slightly further to the North, this may well have been a crucial factor in producing a greater acceleration of the troughs as they moved over the Rockies into the central United States. At T+72 (Figs 8c & 8d), the forecast central speeds of the jets over Florida and just south of Newfoundland were 20-30 knots stronger than those produced by the EC/UK, with a much tighter gradient at 45° W. During days 4 and 5 the UK/UK, forecast a major jet to move east across the Atlantic with maximum speeds close to 200kts.

Using the EC analysis the T+120 forecast (Fig 8f) shows a fairly uniform westerly flow across the Atlantic with maximum speeds 110-120kts. Fig 9(a-c) shows the actual evolution of the 250mb winds over the Atlantic from T+72 to T+120. At T+120 Fig 9c we can see the fairly uniform flow across the Atlantic, the main forecast error from the EC/UK appears to be between 10-15° E where the strong northerly flow is not forecast.

b). Transplant experiments.

Several forecasts were rerun with a portion of the EC analysis inserted into the UK analysis. Both mass and wind field variables at all levels were transplanted and a smooth transition between the inner transplant area and the remainder of the field was achieved by merging the analyses over a 3 gridlength boundary zone. The aim of this transplant exercise is to see if any particular area in the UK analysis was responsible for the poor forecasts. Areas where transplants were attempted include the Hudson Bay and Northern Canada, various regions of the Pacific, Alaska, Central America, the Polar region North of 60° and the Eastern Atlantic from N. Africa to Iceland including the UK. All of these regions had initial differences (UK-EC) greater than 4dm in the 500mb fields. Combinations of these transplanted areas were also tried. Transplants over the Hudson bay and Polar regions had little impact on improving the forecast; however the Pacific areas proved much more successful, and three of the T+120 transplant forecasts with the corresponding difference charts UK/UK - UK/Transplant at 500mb are shown in Fig 10.

(i) Transplant A.

The area transplanted extended from 10-65° N and 120-150° W. The resulting T+120 forecast (Fig 10a) shows an improvement in the Ridge over the North Sea but had little impact further west. This is easily seen by comparing with the 500mb height verification (Fig 1e) and the T+120 UK/UK (Fig 3c). and the UK/UK - EC/UK difference map (Fig 6f).

(ii) Transplant B

By extending the above transplanted area to 200° W there is a significant effect on the T+120 forecast (Fig 10c). The North Sea ridge becomes sharper, the low to the northeast of Iceland is filled, with a centre now appearing to the southwest of Iceland. The flow over the mid and west Atlantic becomes flatter with less pronounced troughs and ridges. By comparing the differences charts (Figs 6f, 10b & 10d), we see that by extending the transplanted area further west over the Pacific, the forecast over the Atlantic is significantly improved relative to transplant A.

(iii) Transplant C

The area $2-20^{\circ}$ N $70-100^{\circ}$ W, where the surface low that moved northeast to be engaged by the mid-latitude trough in westerly flow on the UK/UK, and was analysed 4mb deeper by the UK, was transplanted with the Pacific area (transplant b). The T+120 forecast and difference from UK/UK, charts are shown in Figs 10(e&f). Compared with the Pacific transplant alone (Fig 10d) we see a very slight relaxation in the mid Atlantic trough but the effect is very small and we may conclude that the any analysis differences at low latitudes were insignificant in affecting the forecasts.

(iii) Transplant D

There was a significant analysis difference just west of Portugal where the UK had a higher 500mb height field. This difference was seen to increase and moved North, so that by T+96 (Fig 6e), the maximum is centred near the Norwegian coast before being displaced eastwards into the Soviet Union (Fig 6f), by the advancing westerly flow from the Atlantic. This indicated the EC/UK relative to the UK/UK was forecasting the flow to be more blocked over Europe and Scandinavia. By transplanting the area $0-25^{\circ}$ W $35-65^{\circ}$ N the northward moving positive area UK/UK-EC/UK was reproduced in the forecasts. This was then combined with the Pacific transplant including the Central American area, in the hope

the resulting forecast would show a greater relaxation of the Mid-Atlantic trough. The resulting forecast showed no improvement over the single large area Pacific transplant, and none of the selective transplants attempted, were able to produce such a good forecast as the global transplant as can be seen by comparing the amplitude in the difference pattern (Fig 6f) with Figs 10(b,d & f).

4. Tests with a revised Met Office Analysis Scheme.

The forecast was also rerun using an analysis produced from the Analysis Correction Scheme (Lorenc and Dumelow 1985). This revision to the repeated insertion analysis scheme used at the Met Office is designed to combat some of the deficiencies in the operational scheme. It allows observations to influence the model over a much larger area and no selection is performed so that all observations with a significant weight within the sphere of influence of a model gridpoint are used. This approach provides a somewhat smoother increment field. The observations are also used in a more timely manner by inserting them into the model during a period around their validity time, which is particularly important for aircraft reports. Comparison of the initial analysis fields between the operational analysis and the analysis correction scheme (AC) at 500mb (Fig 11a & 11b) shows the largest differences over the Pacific and Alaska. Other differences were also produced over Central America and just west of Portugal. The analysis from the AC was very similar to the EC analysis. Comparing Fig 7a with Fig 11a and we see the smoother flow around the Pacific trough with the lower heights over Alaska using the AC scheme.

The 500mb forecast charts are shown for T+72 Fig 11c and T+120 Fig 11e together with the UK/UK-AC/UK differences. A direct comparison with the charts for the same validity times in Figs 1,6 & 8 show the dramatic improvement in the forecast using this scheme. However as with the transplants the trough in Mid Atlantic was about 5° further west than from the EC/UK at T+120.

The 250mb winds for T+0, T+72 and T+120 from the AC/UK run are shown in Fig 12(a-c). The revised analysis Fig 12a is very similar to the EC

analysis Fig 8b, particularly near 120° W, and with the forward edge of the Pacific jet tending to curve slightly northwards. The T+72 and T+120 forecasts Figs 12b & 12c verify much closer to the EC/UK than the UK/UK.

5. Use made of Observations

The Met Office update analysis was used in this study as the early operational data cut-off time used operationally might result in a substantial difference in data availability between the two centres. The differences appear to be due to the UK analysis being unable to fit some of the observations. It is also likely that the background field was in error as forecasts produced during the previous 48 hours were not particularly accurate. As the upper flow was broadly zonal from the Pacific to the Atlantic, these analysis errors grew and propagated quickly eastwards, to affect the western Atlantic by day 3 and the UK by day 5.

Figs 13a & 13b show the actual observations minus the analysis fields at 500mb for the UK and EC analysis. The negative values over Alaska shown on Fig 13a confirm that the ridge on the UK analysis is too prominent, while the zero's on Fig 13b indicate that the observations are fitted better by the EC analysis, although there are only a small number of observations in this area.

Over the Pacific, aircraft reports and satellite observations are the main source of data. By studying the 250mb wind data that was available, the observations minus the UK analysis (Fig 13c), and observations minus EC analysis (Fig 13d), we can see that the southerly flow over the western coast of the United States is too weak, as indicated by the observed minus model wind vector showing a 20-30kt southerly component on the UK analysis, whilst the jet to the southwest of the Hudson Bay is positioned a little too far south. Note the observation differences show a westerly component to the north and the easterly to the south of this jet, (Fig 13c), whilst Fig 13d the EC analysis, shows much smaller observed wind differences over this area. The Pacific jet at 40°N 140°W appears to have been analysed too strong

by the UK as indicated by the 25kt easterly differences (Fig 13c), compared with a only a 15kt easterly difference on the EC analysis (Fig 13d). In having the jet too strong, the area of lighter winds in the area 130 - 135°W has been displaced too far east on the UK analysis, as shown by the observed wind differences of 30 and 35 kt in this area. Barwell and Lorenc (1985) have discussed the importance of aircraft observations and the problems of assimilating such data using an earlier version of the Met Office repeated insertion scheme

Figs 14a & 14b show both centres 500mb analysis and 1000-500 thickness, along with the thickness differences, satellite observations minus analysis. On the UK analysis (Fig 14a), we see the majority of these differences are positive indicating the cold bias, whilst many of the values on the EC analysis (Fig 14b) are negative, indicating a warmer bias relative to the observations. There appears to be little evidence from these charts that the EC analysis was fitted any better than the UK analysis to the satellite observations.

For this particular case it would appear that the ECMWF analysis scheme has made more effective use of the sparse volumes of data in the Pacific, particularly the single level wind data. The improved analysis may be due to the larger sphere of influence given to the observations by the EC scheme, as this is a feature which is incorporated in the AC scheme which also provided a better result.

6. Summary

We have demonstrated that a poor UK analysis was responsible for the poor forecast from T+72. AN ECMWF forecast run from this poor UK analysis gave a similar evolution to the operational Met Office run. By using initial conditions derived from the Met Office analysis for both UK and ECMWF forecast models a similar forecast is produced.

Difference charts were quite successful in tracing back the large T+120 difference in the east Atlantic to differences in the analyses in mid-Pacific. We have also shown, by means of a transplant technique, that an analysis error in a relatively small section of the Pacific at upper levels contributed to most of the subsequent forecast error. In

this instance it seems that the UK analysis scheme had difficulty accepting single level wind aircraft wind data.

The new analysis correction scheme which is currently nearing operational implementation provided a much better analysis on this occasion and the forecast from that analysis evolved correctly in most respects to give excellent guidance at T+120 apart from a small timing error.

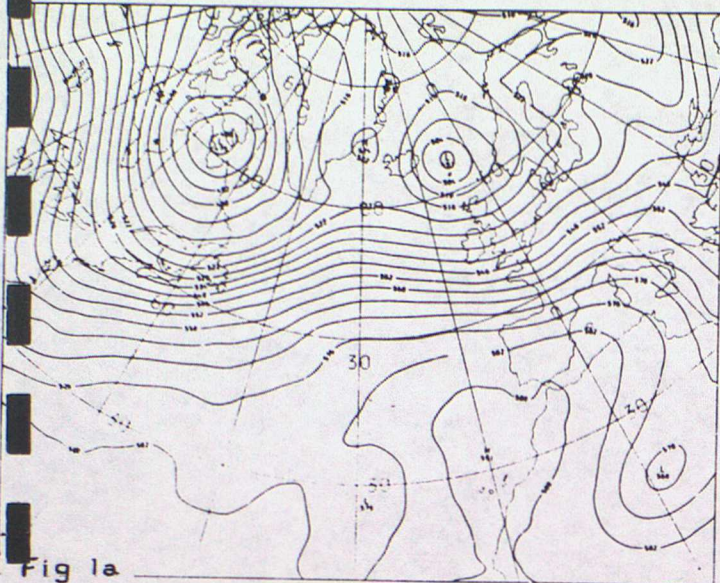
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<i>Quart J R Met Soc</i> 111,103-129 |
| Hollingsworth, Lorenc, Tracton, Arpe, Cats, Uppala, Kallberg. | 1985 | The response of NWP systems to FGGE IIb data
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<i>Quart J R Met Soc</i> 111,1-67 |
| Lorenc AC, Dumelow RK | 1985 | Four dimensional analysis by repeated insertion of observations in the Meteorological Office NWP model
<i>Met O 11 TN</i> 224 |

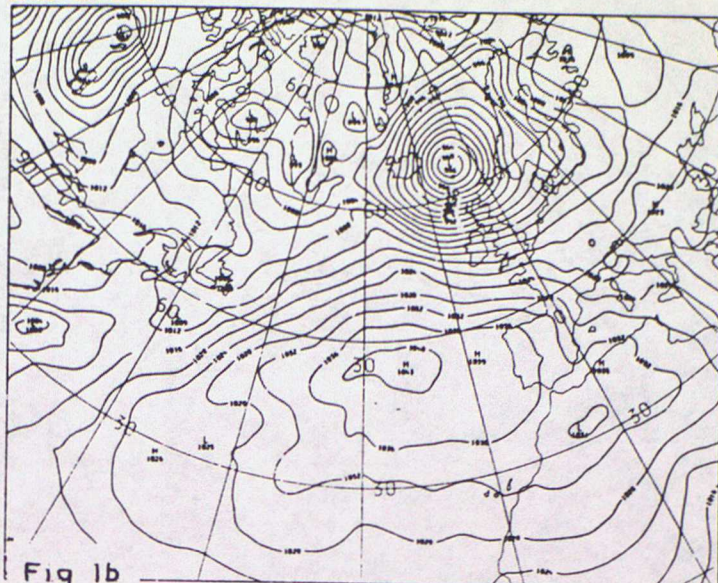
Captions for Figures

- Fig 1(a&b) Verification charts at T+72. 500mb hts, MSLP
- (c&d) Verification at T+96. 500mb hts, MSLP
- (e&f) Verification at T+120. 500mb hts, MSLP
- Fig 2(a-d) UK/UK. EC/EC. UK/EC. EC/UK. T+72 500mb hts.
- Fig 3(a-d) UK/UK. EC/EC. UK/EC. EC/UK. T+120 500mb hts.
- Fig 4(a-d) UK/UK. EC/EC. UK/EC. EC/UK. T+72 MSLP
- Fig 5(a-d) UK/UK. EC/EC. UK/EC. EC/UK. T+120 MSPL
- Fig 6(a-f) Differences UK/UK - EC/UK T+00, 24, 48, 72, 96, 120 500mb hts
- Fig 7(a-l) UK/UK. EC/UK. Forecast evolution (500mb hts).
- Fig 8(a-f) UK/UK. EC/UK 250mb winds T+00, T+72, T+120.
- Fig 9(a-c) Verification 250mb winds at T+72, T+96, T+120.
- Fig 10(a-f) UK with selected area EC transplanted analysis.
T+120 forecast & Differences from UK/UK. (500mb hts).
- Fig 11a UK revised analysis from Analysis Correction Scheme.
- Fig 11b Difference UK/UK - UK revised analysis (500mb hts).
- Fig 11(c-f) UK Analysis correction Scheme T+72, T+120 forecasts &
Differences from UK/UK. (500mb hts).
- Fig 12(a-c) UK Analysis correction 250mb winds T+00, T+72, T+120.
- Fig 13(a&b) Observations minus initial analysis 500mb hts (UK, EC)
- Fig 13(c&d) Observations minus initial analysis 250mb winds (UK, EC)
- Fig 14(a&b) Satellite Observations minus 1000-500mb thickness
analysis (UK, EC)

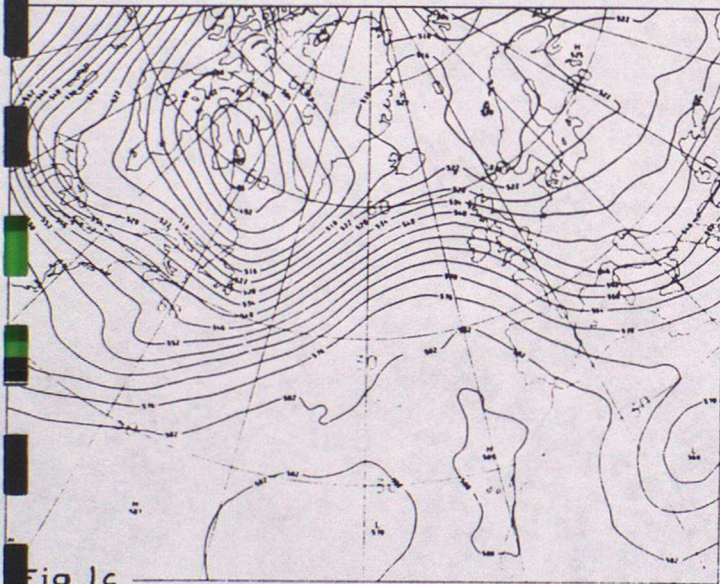
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GEOPOTENTIAL HEIGHT
VALID AT 12Z ON 11/1/1986
LEVEL: 500 MB



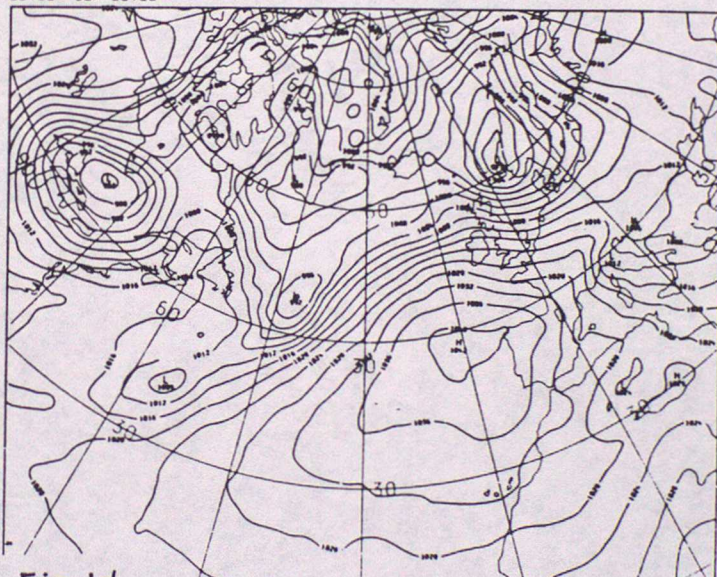
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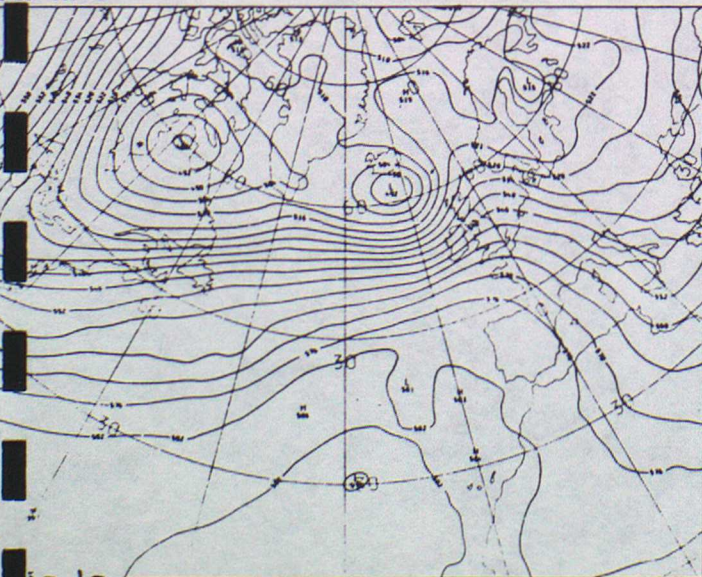
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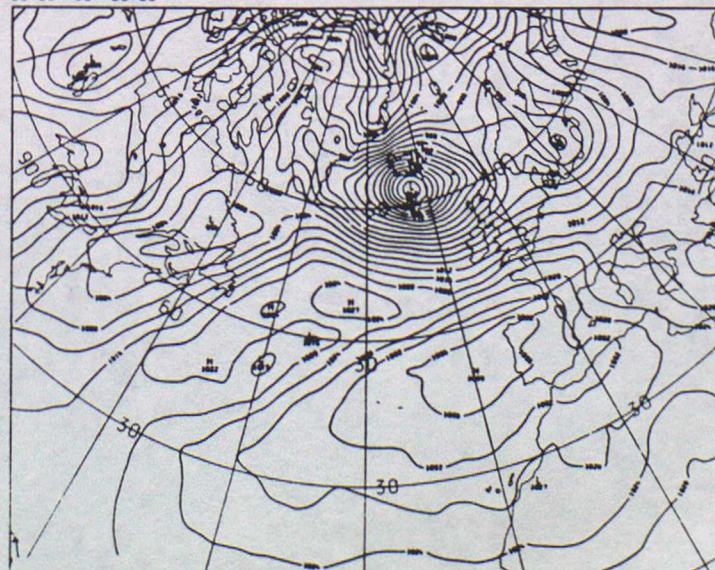
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UK ANALYSIS
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VALID AT 12Z ON 13/1/1986
LEVEL: 500 MB



UK ANALYSIS
MEAN SEA LEVEL PRESSURE
VALID AT 12Z ON 13/1/1986
LEVEL: SEA LEVEL



UK ANALYSIS / UK FORECAST
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 11/1/1986 DAY 11 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB

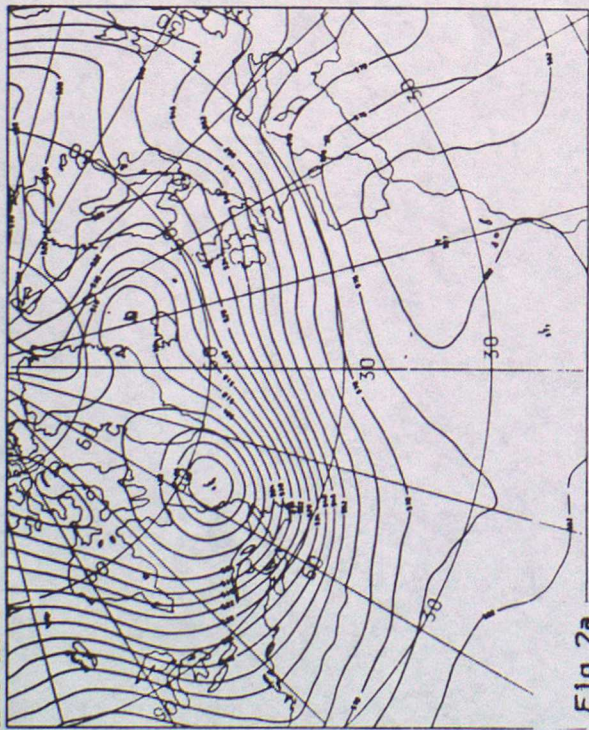


Fig 2a

EC ANALYSIS / EC FORECAST
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 11/1/86
 LEVEL: 500 MB

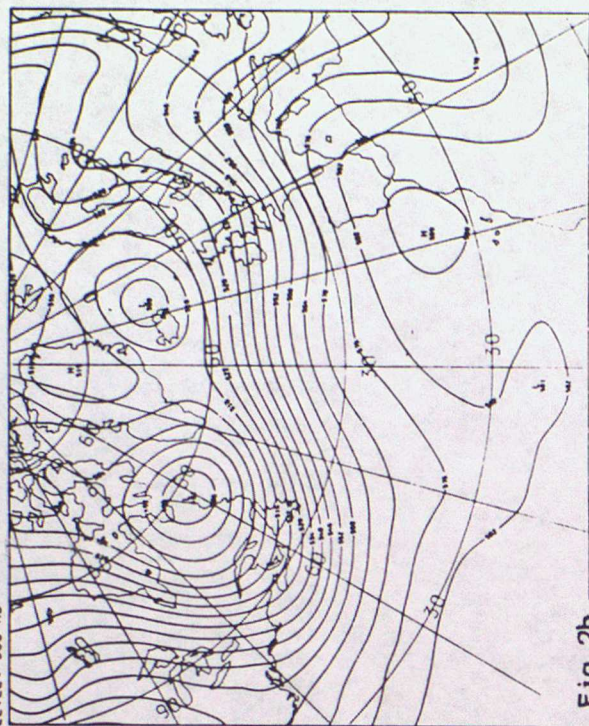


Fig 2b

UK ANALYSIS / EC FORECAST
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 11/1/86
 LEVEL: 500 MB

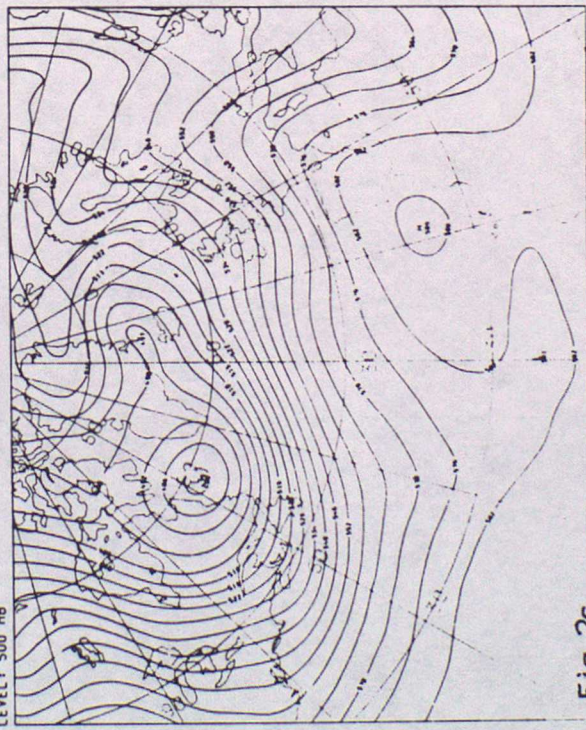


Fig 2c

EC ANALYSIS / UK FORECAST
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 11/1/1986 DAY 11 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB

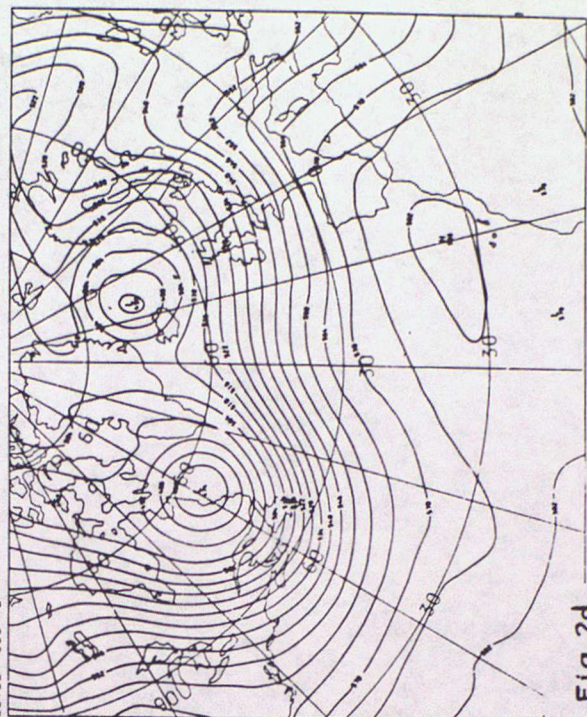


Fig 2d

UK ANALYSIS / UK FORECAST

GEOPOTENTIAL HEIGHT

VALID AT 12Z ON 13/1/1986 DAY 13 DATA TIME 12Z ON 8/1/1986 DAY 8

LEVEL: 500 MB

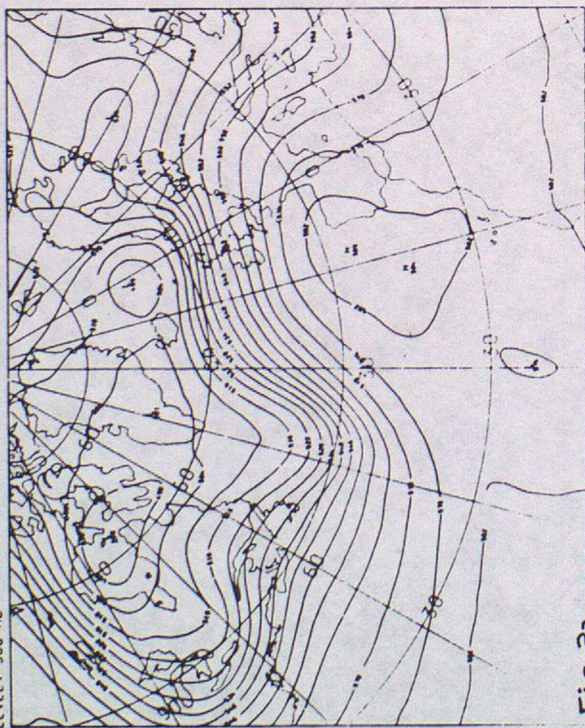


Fig 3a

EC ANALYSIS / EC FORECAST

GEOPOTENTIAL HEIGHT

VALID AT 12Z ON 13/1/86

LEVEL: 500 MB

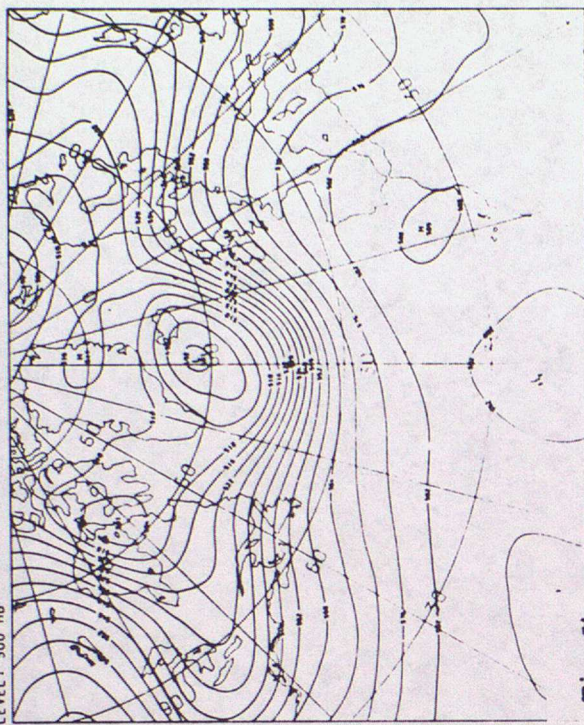


Fig 3b

UK ANALYSIS / EC FORECAST

GEOPOTENTIAL HEIGHT

VALID AT 12Z ON 13/1/86

LEVEL: 500 MB

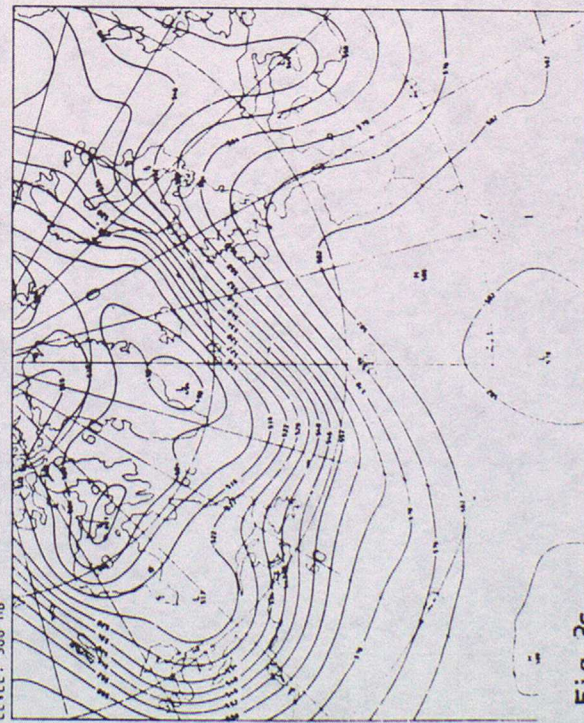


Fig 3c

EC ANALYSIS / UK FORECAST

GEOPOTENTIAL HEIGHT

VALID AT 12Z ON 13/1/1986 DAY 13 DATA TIME 12Z ON 8/1/1986 DAY 8

LEVEL: 500 MB

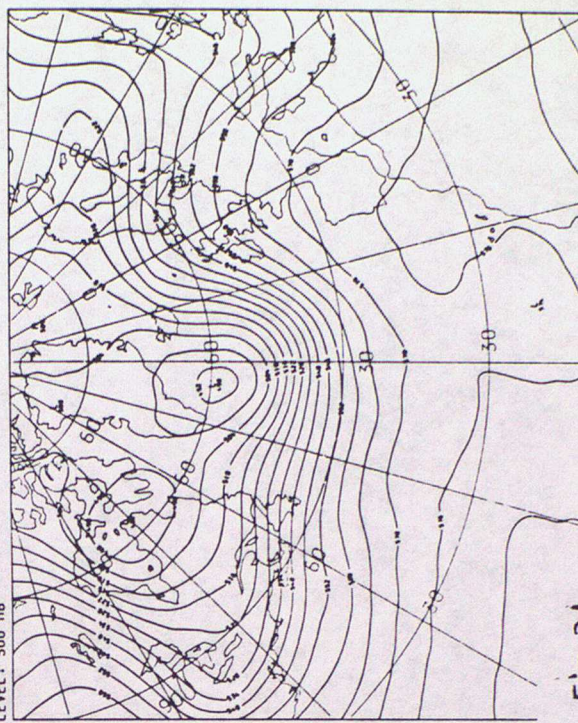


Fig 3d

UK ANALYSIS / UK FORECAST
 MEAN SEA LEVEL PRESSURE
 VALID AT 12Z ON 11/1/1986 DAY 8
 LEVEL: SEA LEVEL

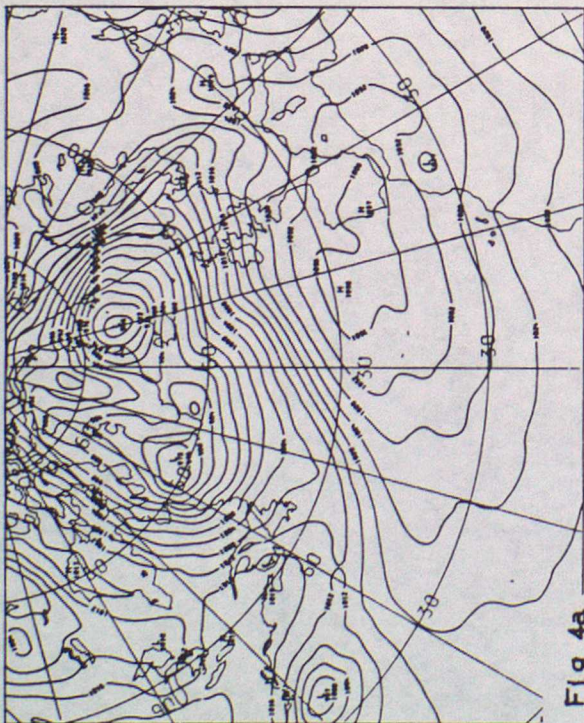


Fig 4a

EC ANALYSIS / EC FORECAST
 MEAN SEA LEVEL PRESSURE
 VALID AT 12Z ON 11/1/1986
 LEVEL: SEA LEVEL

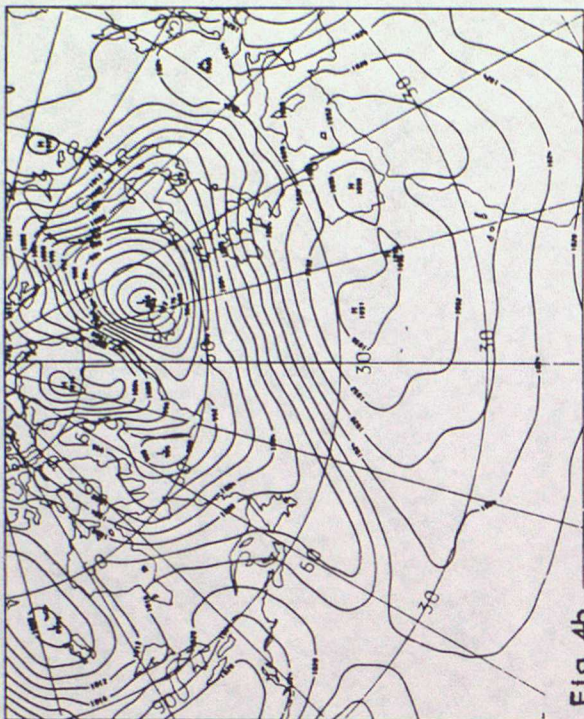


Fig 4b

UK ANALYSIS / EC FORECAST
 MEAN SEA LEVEL PRESSURE
 VALID AT 12Z ON 11/1/1986
 LEVEL: SEA LEVEL

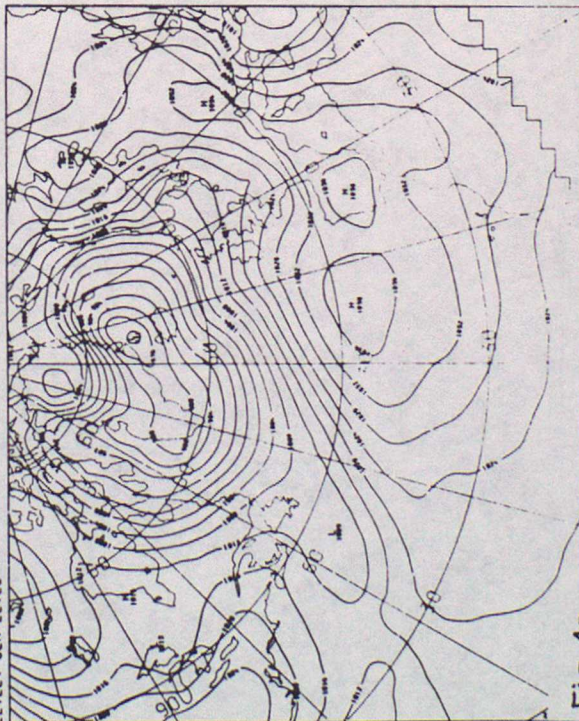


Fig 4c

EC ANALYSIS / UK FORECAST
 MEAN SEA LEVEL PRESSURE
 VALID AT 12Z ON 11/1/1986 DAY 11
 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: SEA LEVEL

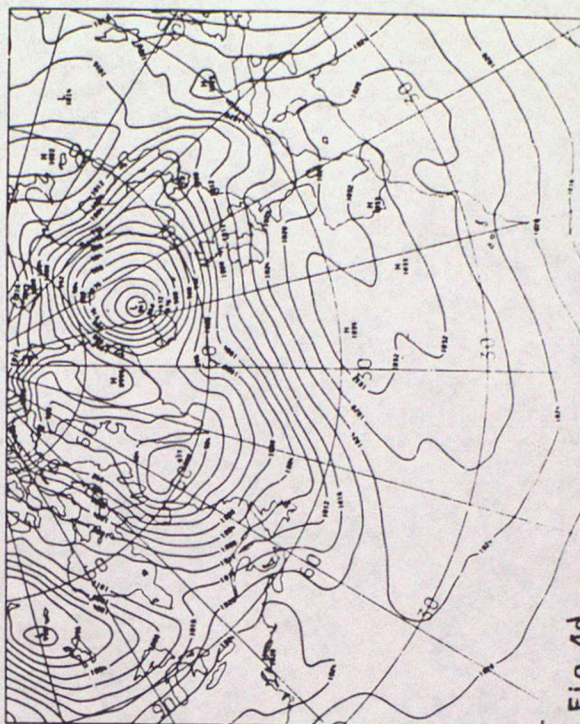


Fig 4d

EC ANALYSIS / EC FORECAST
MEAN SEA LEVEL PRESSURE
VALID AT 12Z ON 13/1/86
LEVEL: SEA LEVEL

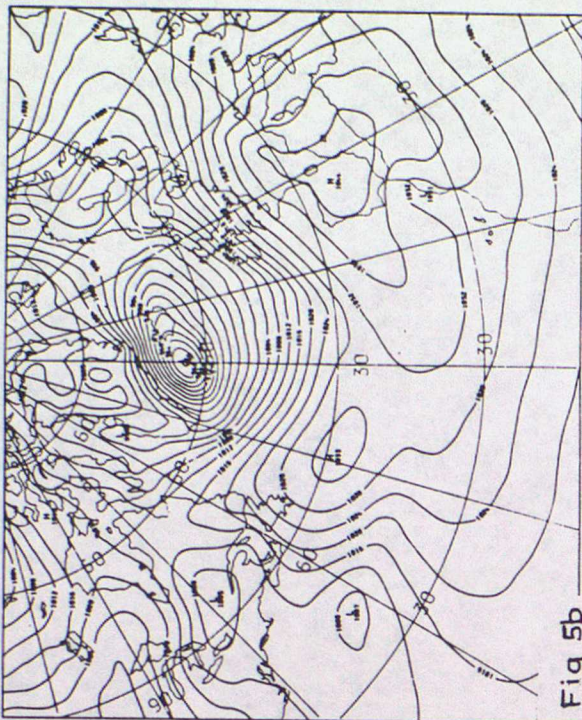


Fig 5b

UK ANALYSIS / UK FORECAST
MEAN SEA LEVEL PRESSURE
VALID AT 12Z ON 13/1/1986 DAY 13
LEVEL: SEA LEVEL

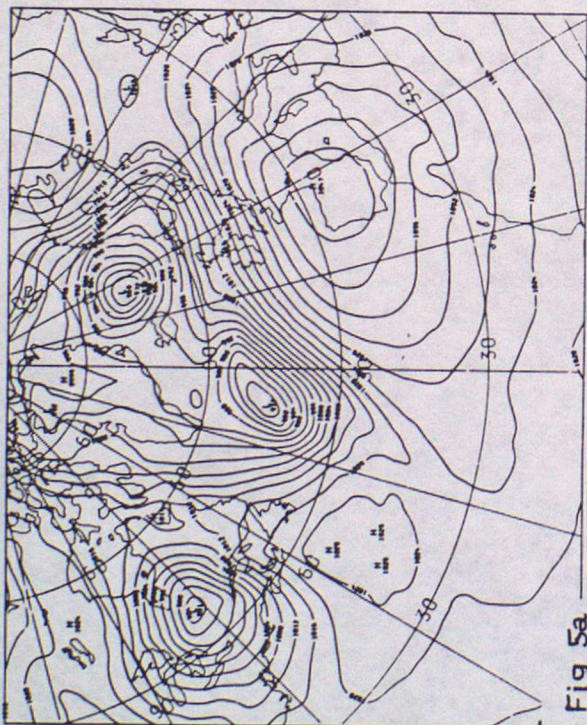


Fig 5a

UK ANALYSIS / EC FORECAST
MEAN SEA LEVEL PRESSURE
VALID AT 12Z ON 13/1/86
LEVEL: SEA LEVEL

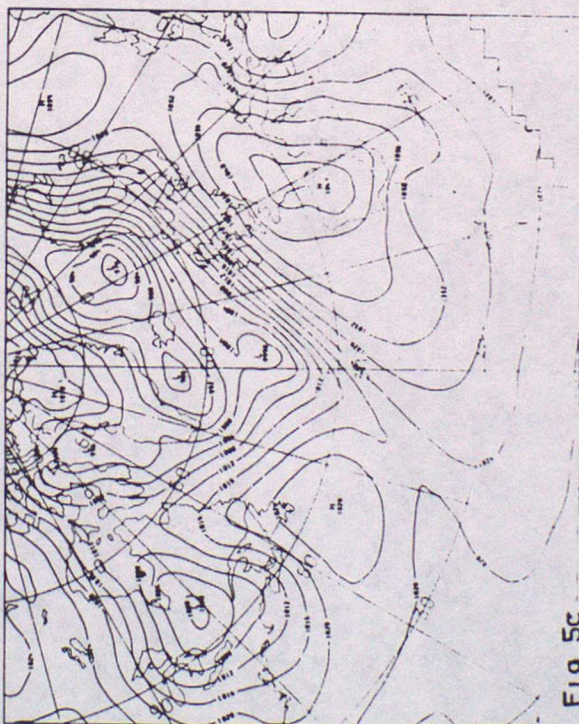


Fig 5c

EC ANALYSIS / UK FORECAST
MEAN SEA LEVEL PRESSURE
VALID AT 12Z ON 13/1/1986 DAY 13
LEVEL: SEA LEVEL

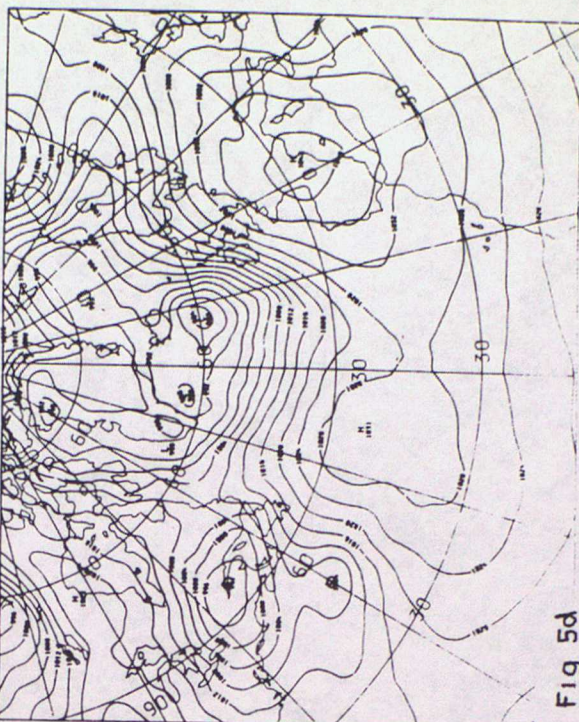


Fig 5d

DIFFERENCE UK/UK - EC/UK
GEOPOTENTIAL HEIGHT
VALID AT 12Z ON 8/1/1986 DAY 8 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 500 MB



Fig 6a

DIFFERENCE UK/UK - EC/UK
GEOPOTENTIAL HEIGHT
VALID AT 12Z ON 9/1/1986 DAY 9 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 500 MB



Fig 6b

DIFFERENCE UK/UK - EC/UK
GEOPOTENTIAL HEIGHT
VALID AT 12Z ON 10/1/1986 DAY 10 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 500 MB

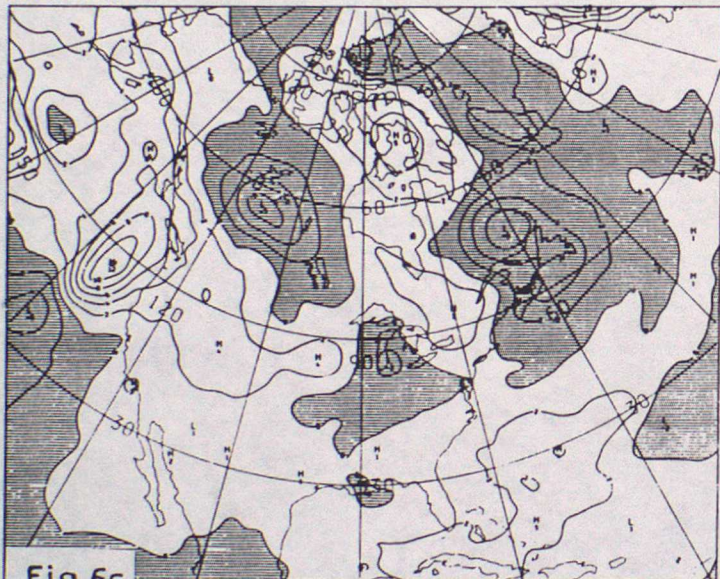


Fig 6c

DIFFERENCE UK/UK - EC/UK
GEOPOTENTIAL HEIGHT
VALID AT 12Z ON 11/1/1986 DAY 11 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 500 MB

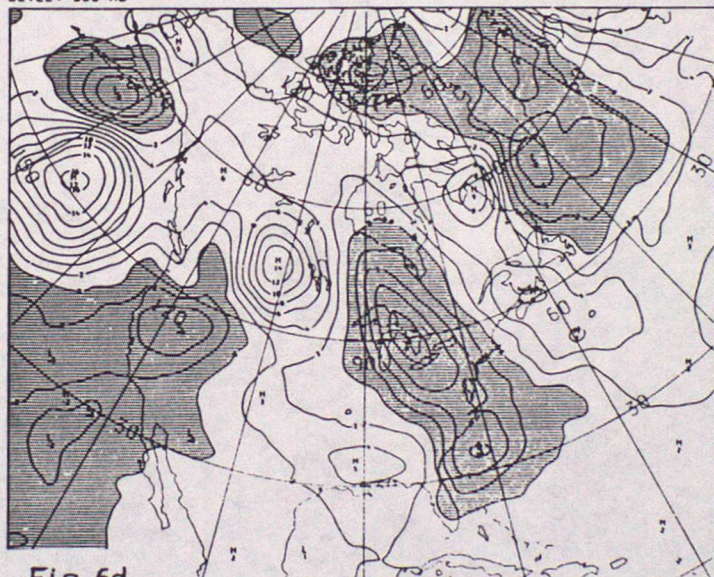


Fig 6d

DIFFERENCE UK/UK - EC/UK
GEOPOTENTIAL HEIGHT
VALID AT 12Z ON 12/1/1986 DAY 12 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 500 MB

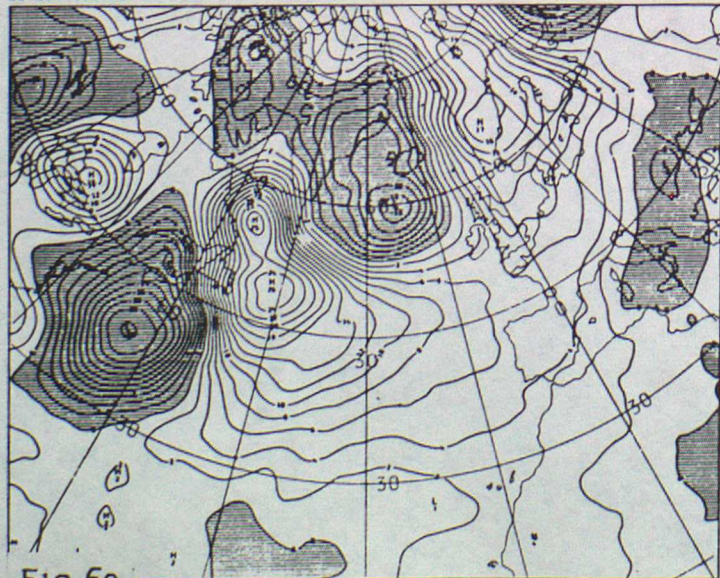


Fig 6e

DIFFERENCE UK/UK - EC/UK
GEOPOTENTIAL HEIGHT
VALID AT 12Z ON 13/1/1986 DAY 13 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 500 MB

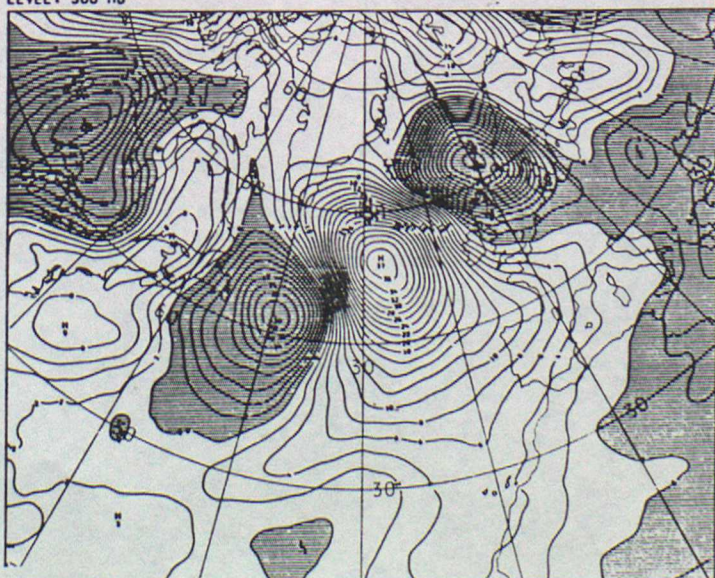


Fig 6f

ANALYSIS / UK FORECAST
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 8/1/1986 DAY 8 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB

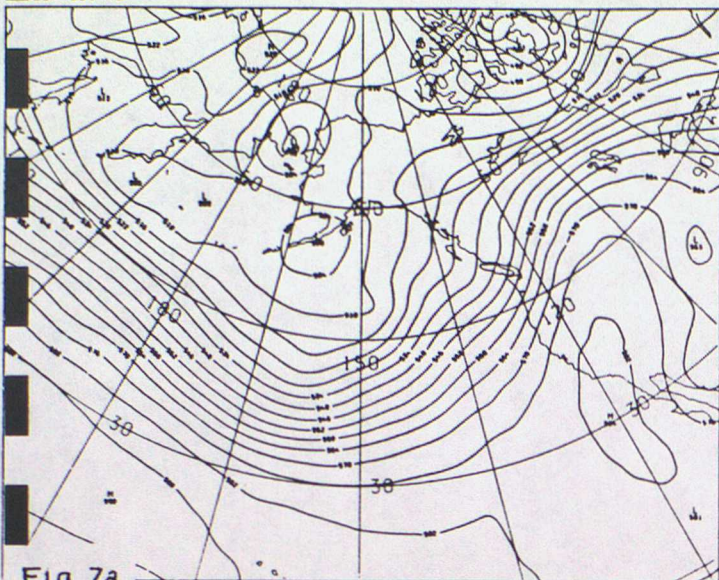


Fig 7a

EC ANALYSIS / UK FORECAST
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 8/1/1986 DAY 8 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB

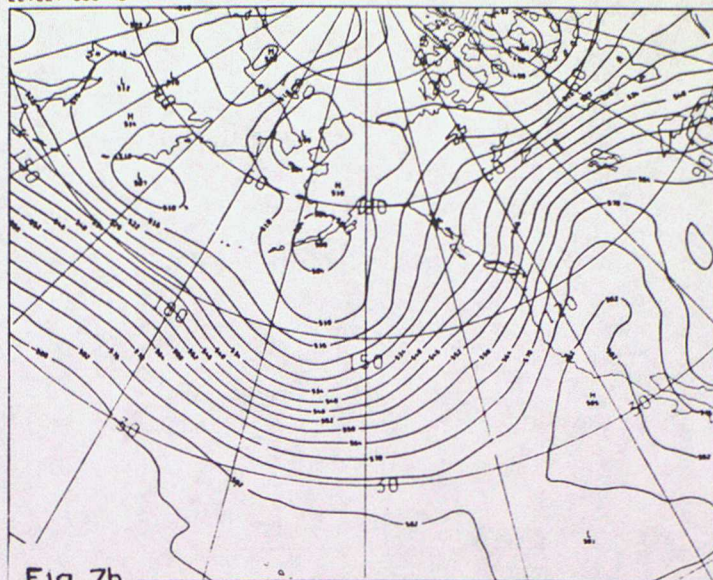


Fig 7b

UK ANALYSIS / UK FORECAST
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 9/1/1986 DAY 9 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB

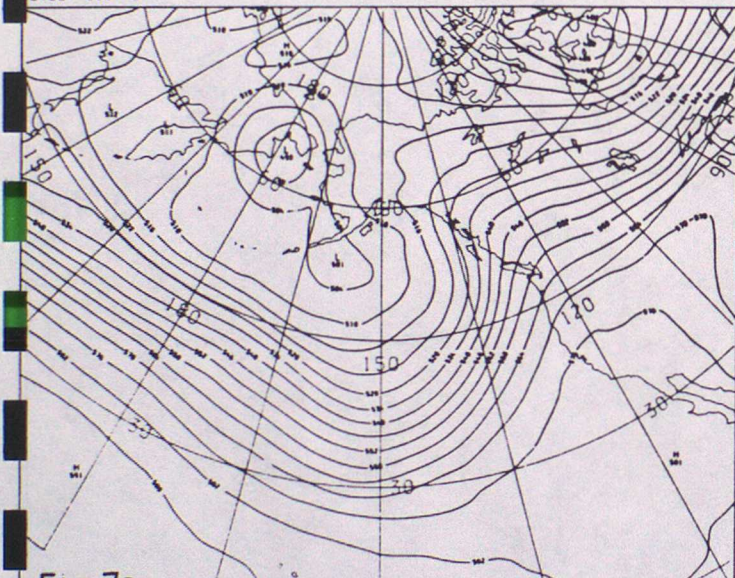


Fig 7c

EC ANALYSIS / UK FORECAST
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 9/1/1986 DAY 9 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB

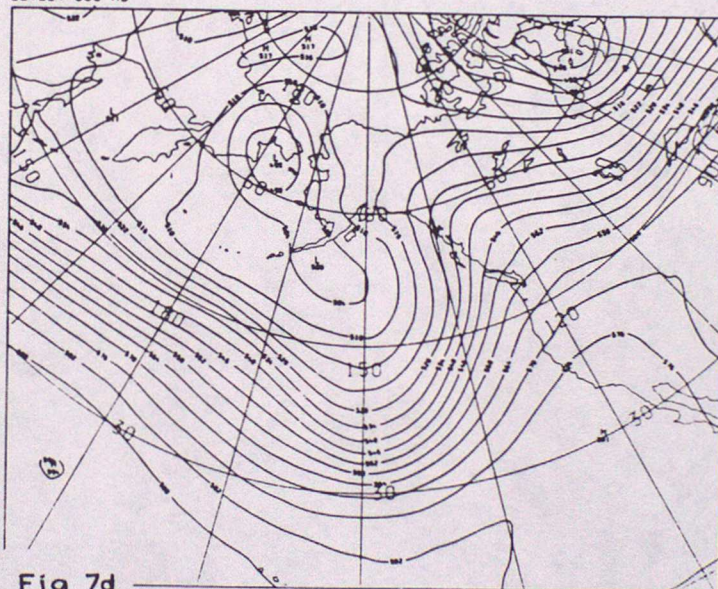


Fig 7d

UK ANALYSIS / UK FORECAST
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 10/1/1986 DAY 10 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB

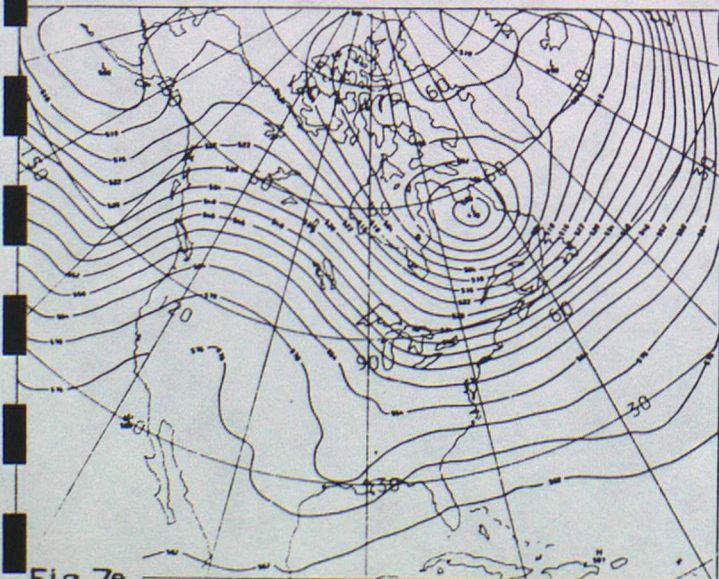


Fig 7e

EC ANALYSIS / UK FORECAST
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 10/1/1986 DAY 10 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB

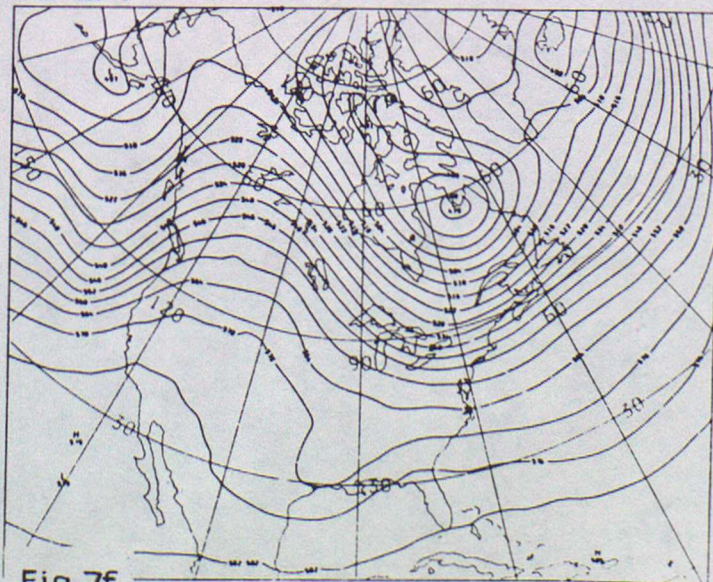
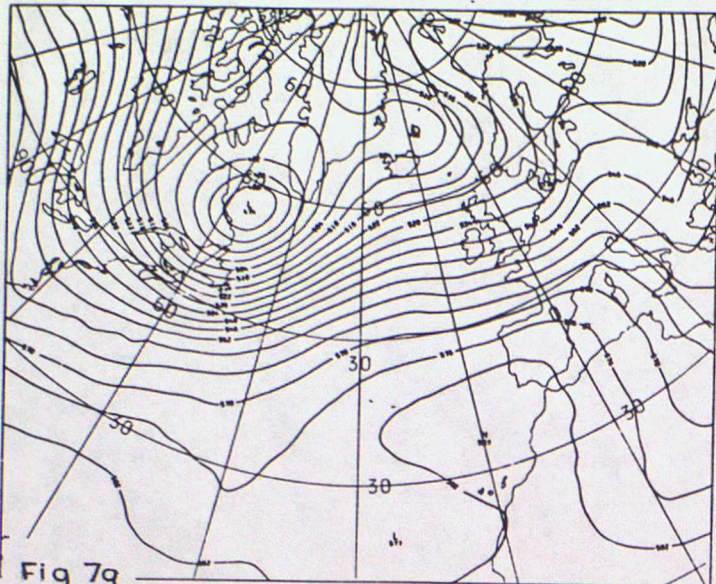
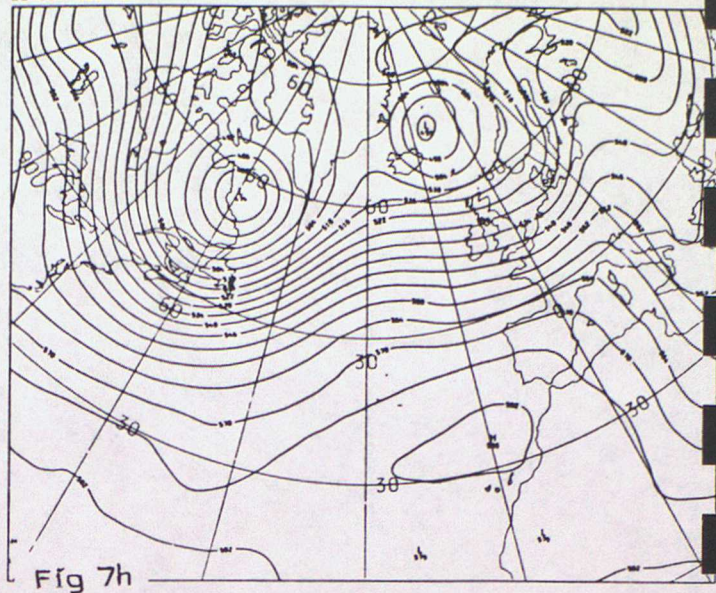


Fig 7f

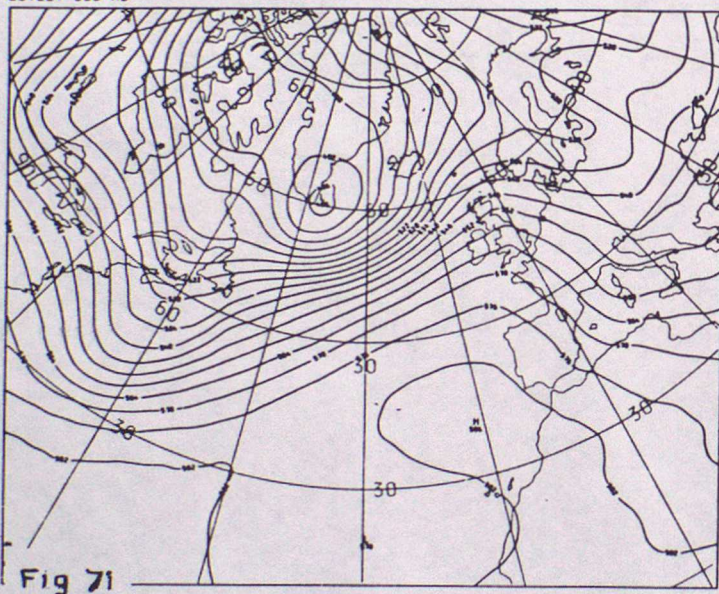
UK ANALYSIS / UK FORECAST
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 11/1/1986 DAY 11 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB



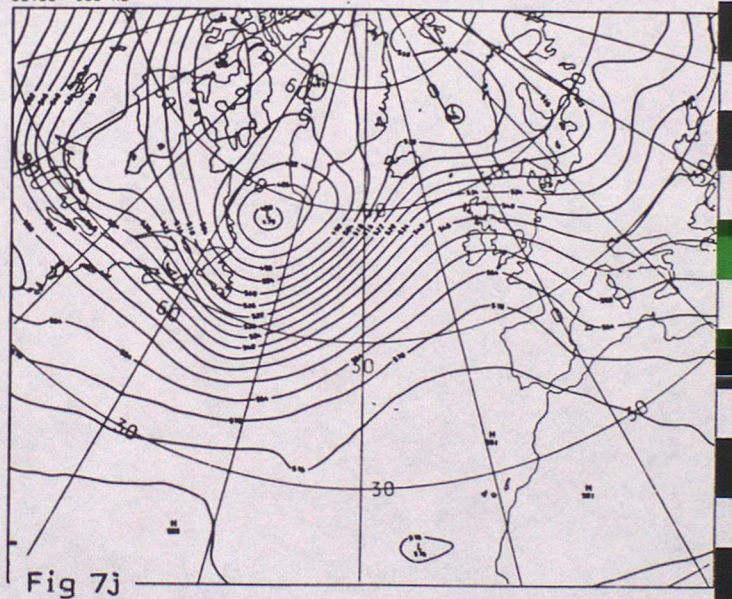
EC ANALYSIS / UK FORECAST
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 11/1/1986 DAY 11 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB



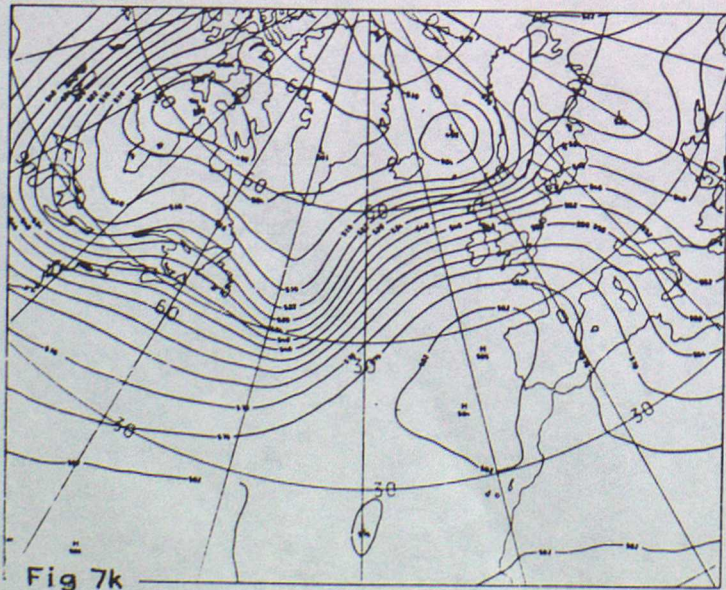
UK ANALYSIS / UK FORECAST
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 12/1/1986 DAY 12 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB



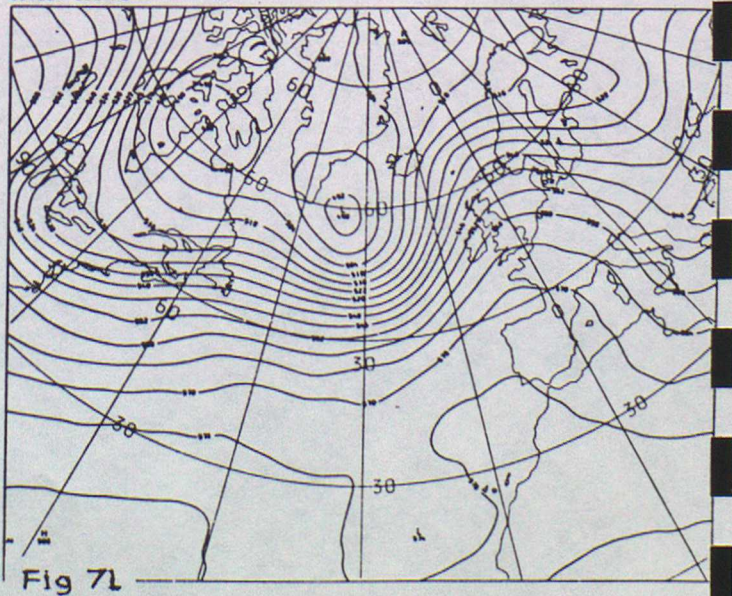
EC ANALYSIS / UK FORECAST
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 12/1/1986 DAY 12 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB



UK ANALYSIS / UK FORECAST
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 13/1/1986 DAY 13 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB



EC ANALYSIS / UK FORECAST
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 13/1/1986 DAY 13 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB



UK ANALYSIS / UK FORECAST
ISOTACHS (KNOTS)
VALID AT 12Z ON 8/1/1986 DAY 8 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 250 MB

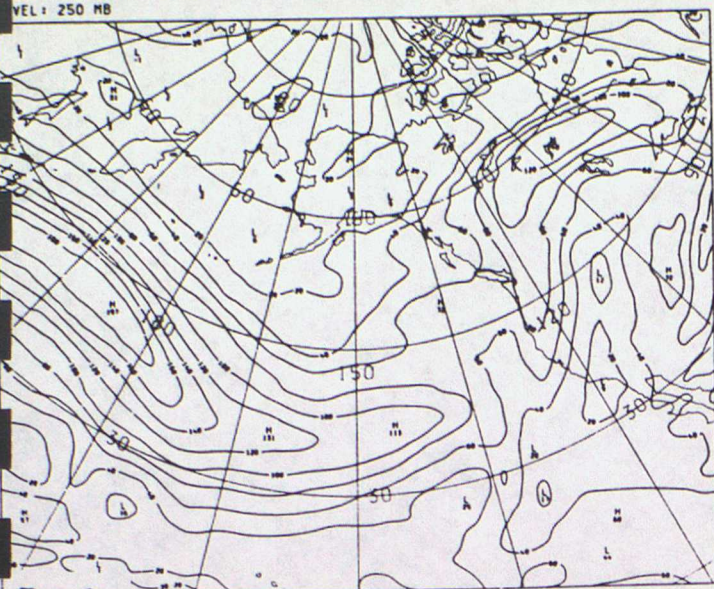


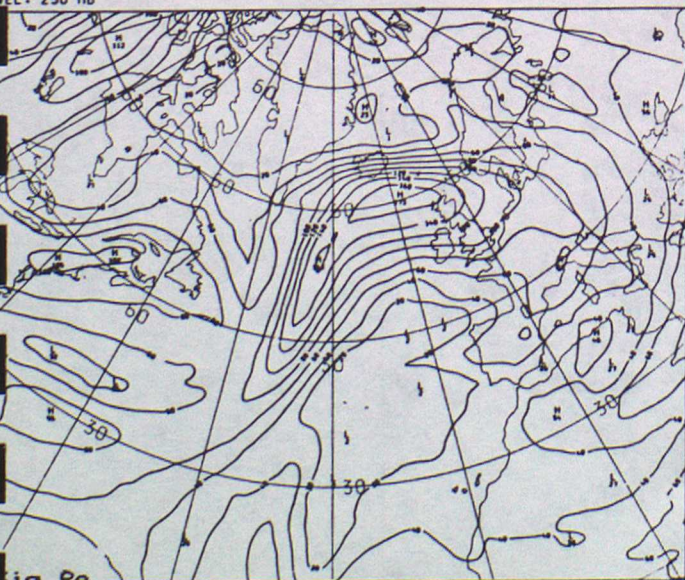
Fig 8a

UK ANALYSIS / UK FORECAST
ISOTACHS (KNOTS)
VALID AT 12Z ON 11/1/1986 DAY 11 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 250 MB



Fig 8c

UK ANALYSIS / UK FORECAST
ISOTACHS (KNOTS)
VALID AT 12Z ON 13/1/1986 DAY 13 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 250 MB



UK ANALYSIS
ISOTACHS (KNOTS)
VALID AT 12Z ON 12/1/1986 DAY 12 DATA TIME 12Z ON 12/1/1986 DAY 12
LEVEL: 250 MB



UK ANALYSIS
ISOTACHS (KNOTS)
VALID AT 12Z ON 13/1/1986 DAY 13 DATA TIME 12Z ON 13/1/1986 DAY 13
LEVEL: 250 MB

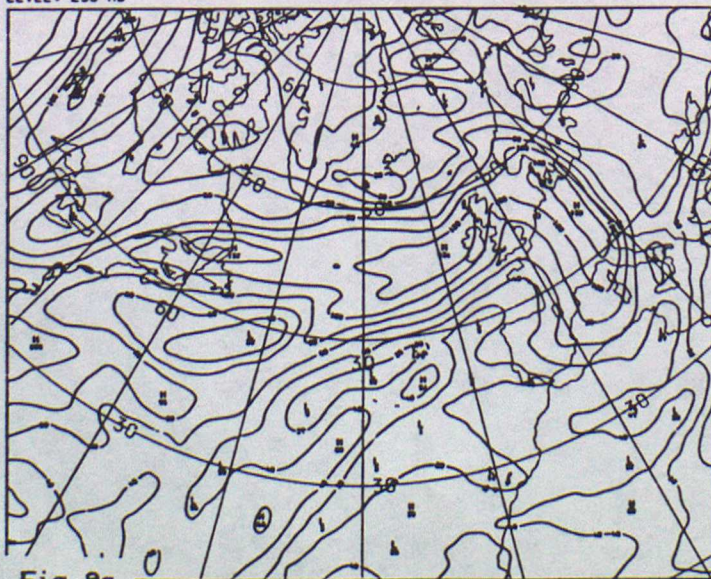


Fig 9c

UK WITH EC TRANSPLANT 10-65N 120-150W
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 13/1/1986 DAY 13 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB

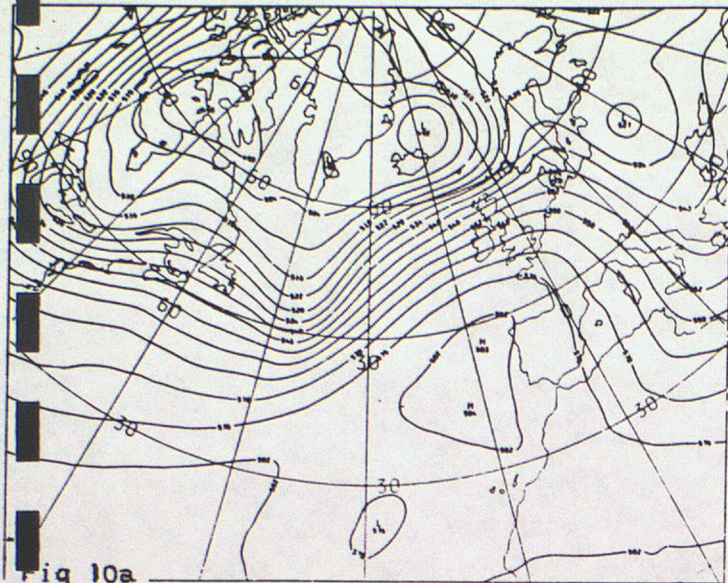


Fig 10a

DIFFERENCE UK/UK - UK WITH EC TRANSPLANT 10-65N 120-150W
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 13/1/1986 DAY 13 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB



Fig 10b

UK WITH EC TRANSPLANT 20-65N 120-200W
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 13/1/1986 DAY 13 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB

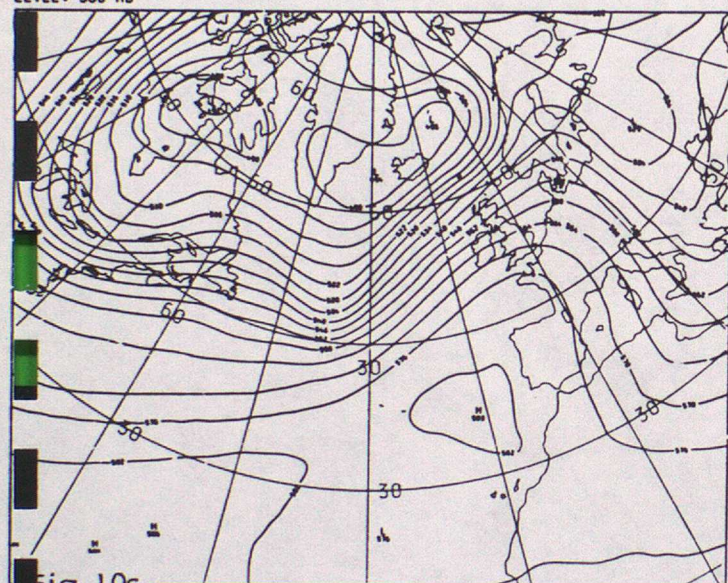


Fig 10c

DIFFERENCE UK/UK - UK WITH EC TRANSPLANT 20-65N 120-200W
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 13/1/1986 DAY 13 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB



Fig 10d

UK WITH EC TRANSPLANTS 20-65N 120-200W 2-20N 70-100W
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 13/1/1986 DAY 13 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB

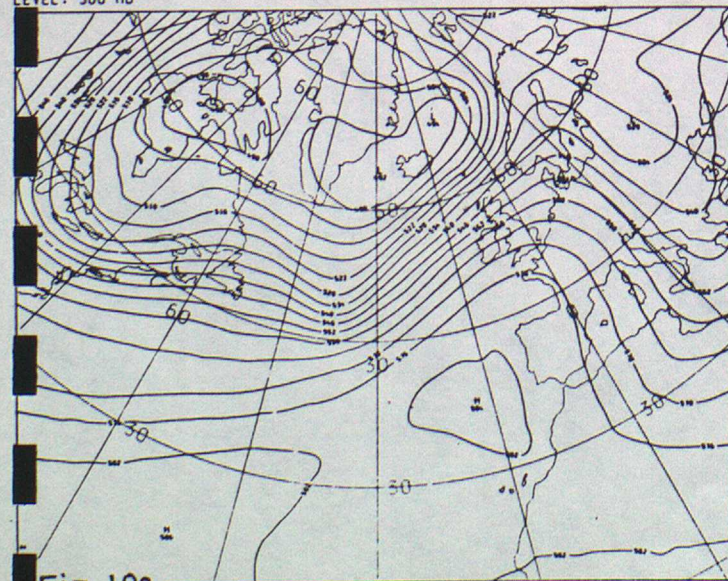


Fig 10e

DIFFERENCE UK/UK-UK/EC TP 20-65N 120-200W 2-20N 70-100W
 GEOPOTENTIAL HEIGHT
 VALID AT 12Z ON 13/1/1986 DAY 13 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB

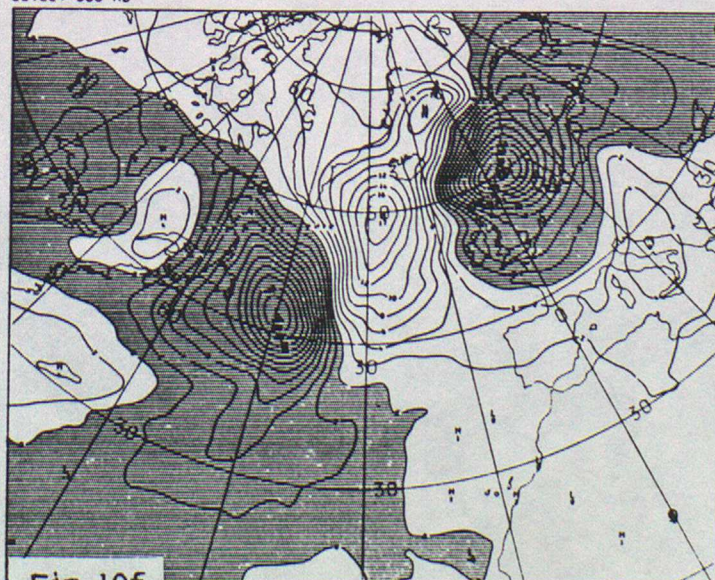


Fig 10f

UK WITH AC SCHEME CYCLE 4
GEOPOTENTIAL HEIGHT
VALID AT 12Z ON 8/1/1986 DAY 8 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 500 MB

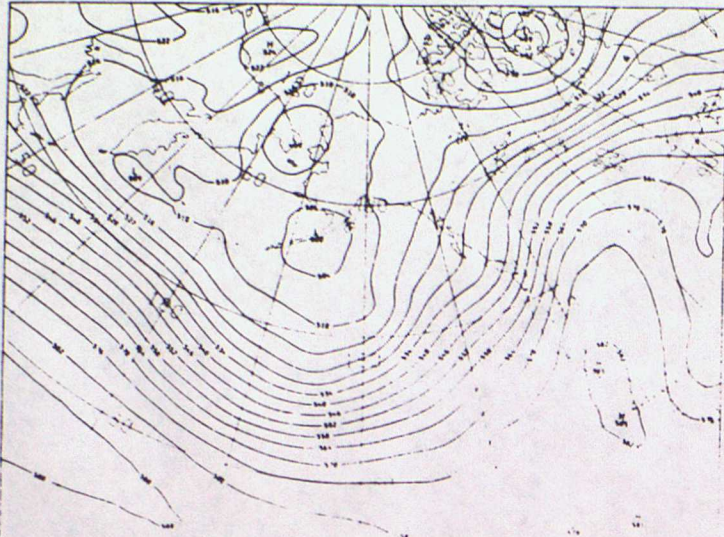


Fig 11a

DIFFERENCE UK/UK - UK/UK AC 4
GEOPOTENTIAL HEIGHT
VALID AT 12Z ON 8/1/1986 DAY 8 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 500 MB

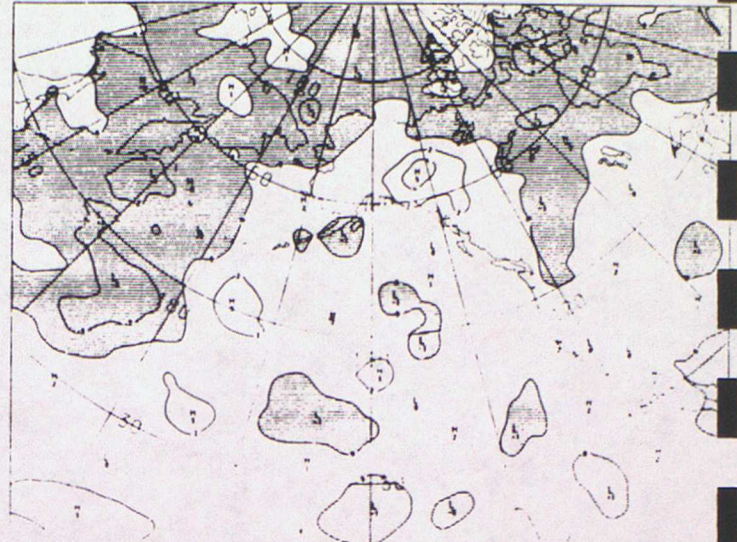


Fig 11b

UK WITH AC SCHEME CYCLE 4
GEOPOTENTIAL HEIGHT
VALID AT 12Z ON 11/1/1986 DAY 11 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 500 MB

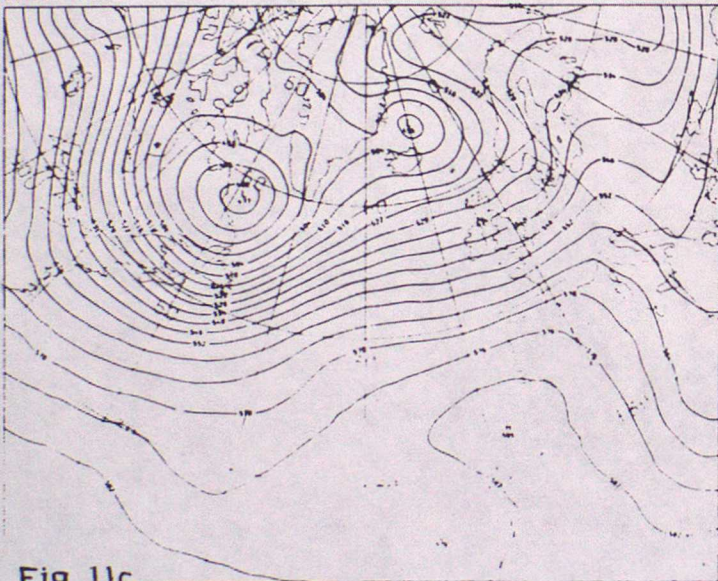


Fig 11c

DIFFERENCE UK/UK - UK/UK AC 4
GEOPOTENTIAL HEIGHT
VALID AT 12Z ON 11/1/1986 DAY 11 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 500 MB

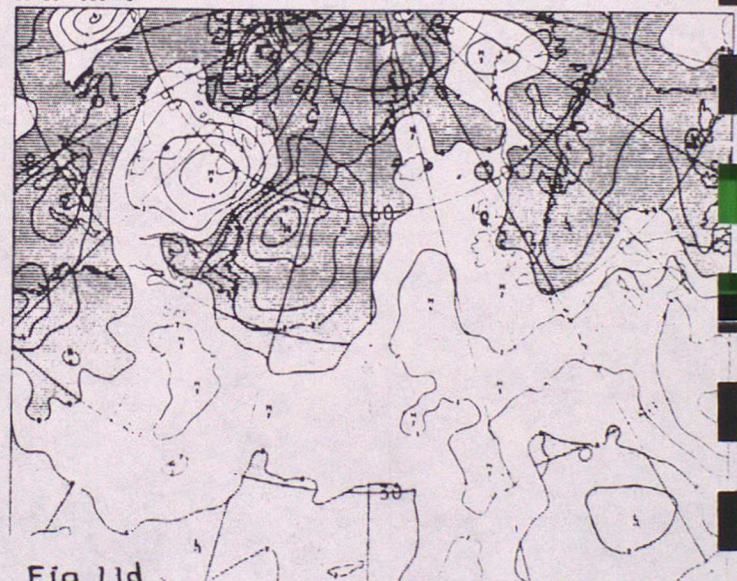


Fig 11d

UK WITH AC SCHEME CYCLE 4
GEOPOTENTIAL HEIGHT
VALID AT 12Z ON 13/1/1986 DAY 13 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 500 MB

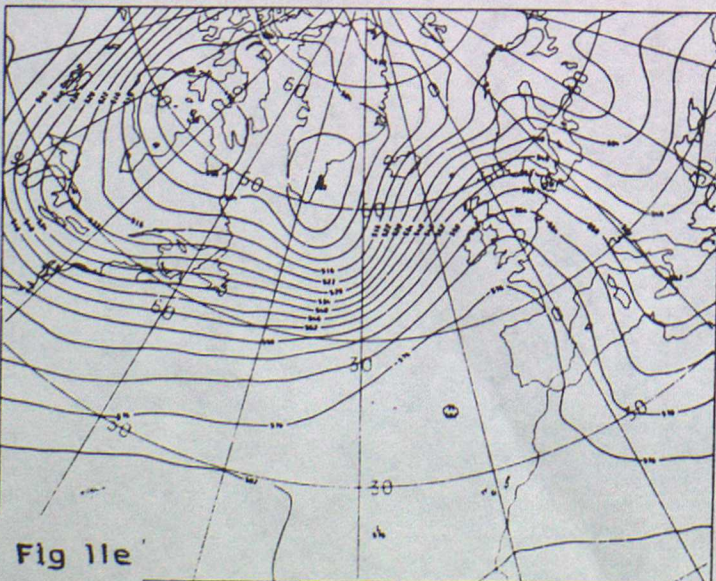


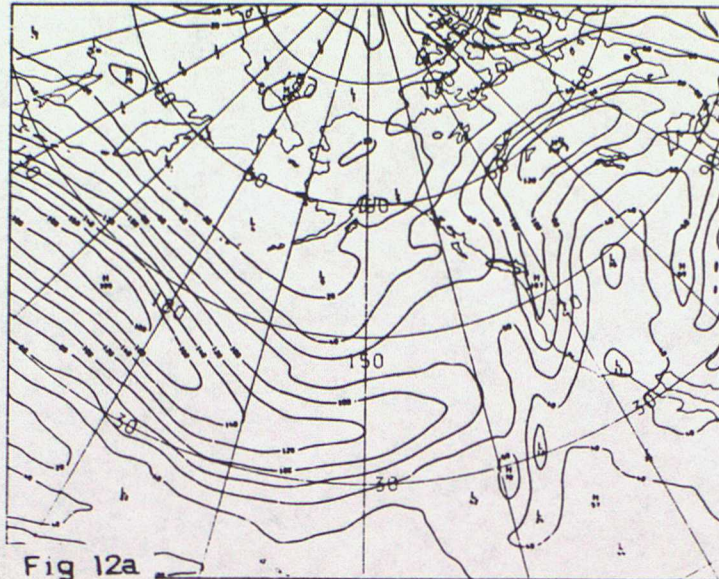
Fig 11e

DIFFERENCE UK/UK - UK/UK AC 4
GEOPOTENTIAL HEIGHT
VALID AT 12Z ON 13/1/1986 DAY 13 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 500 MB

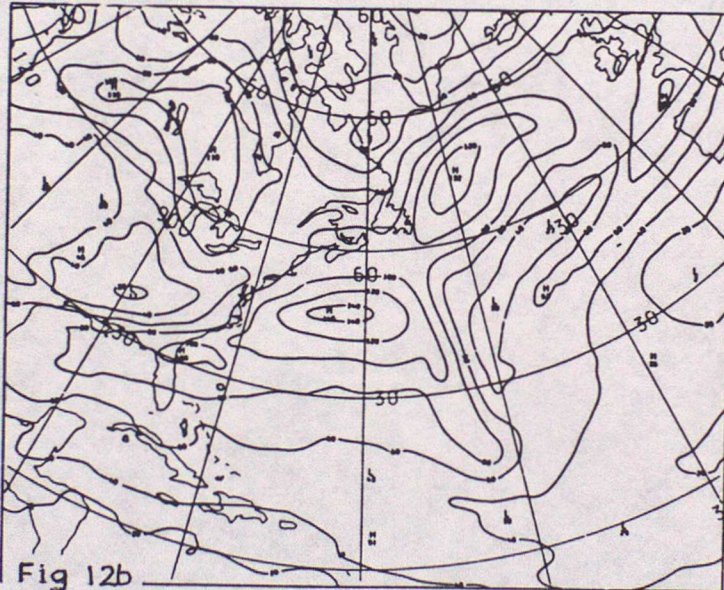


Fig 11f

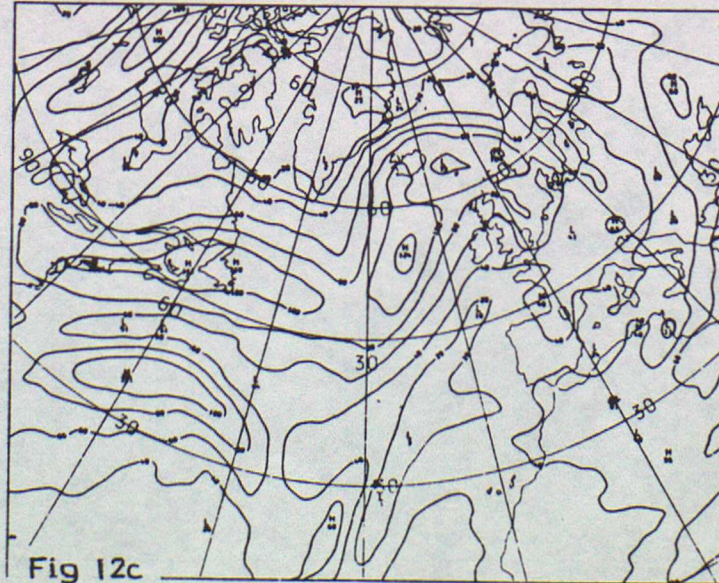
UK ANALYSIS CORRECTION
ISOTACHS (KNOTS)
VALID AT 12Z ON 8/1/1986 DAY 8 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 250 MB



UK ANALYSIS CORRECTION
ISOTACHS (KNOTS)
VALID AT 12Z ON 11/1/1986 DAY 11 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 250 MB

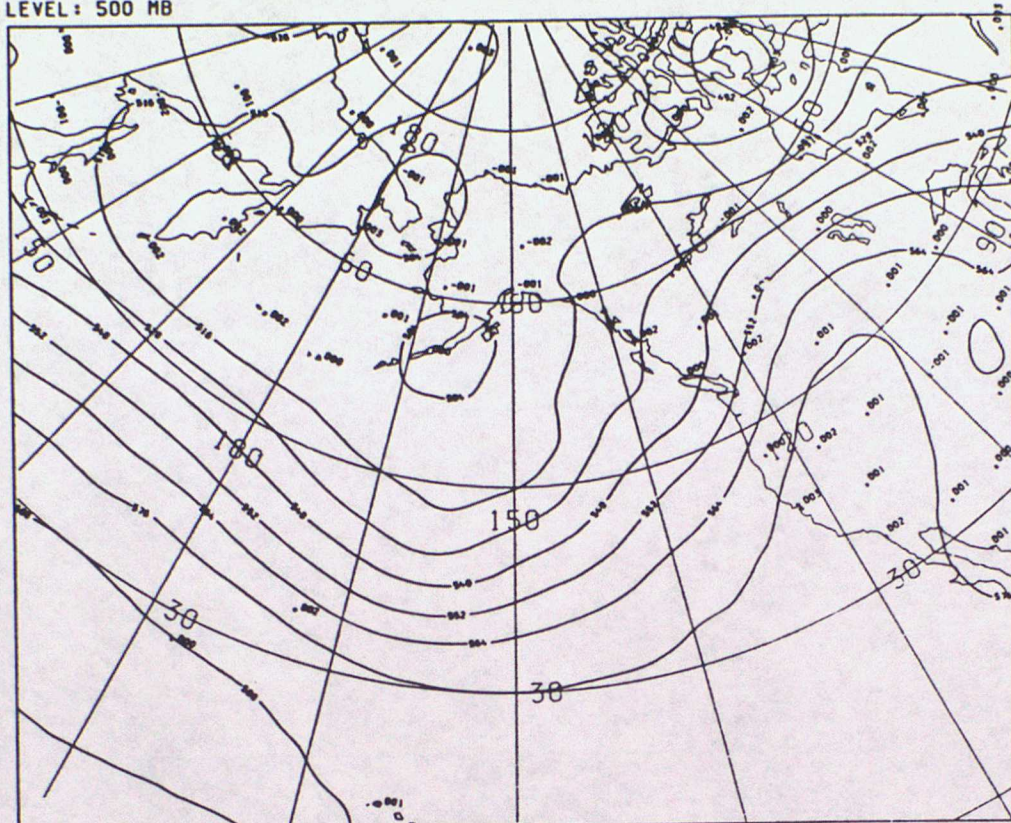


UK ANALYSIS CORRECTION
ISOTACHS (KNOTS)
VALID AT 12Z ON 13/1/1986 DAY 13 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 250 MB



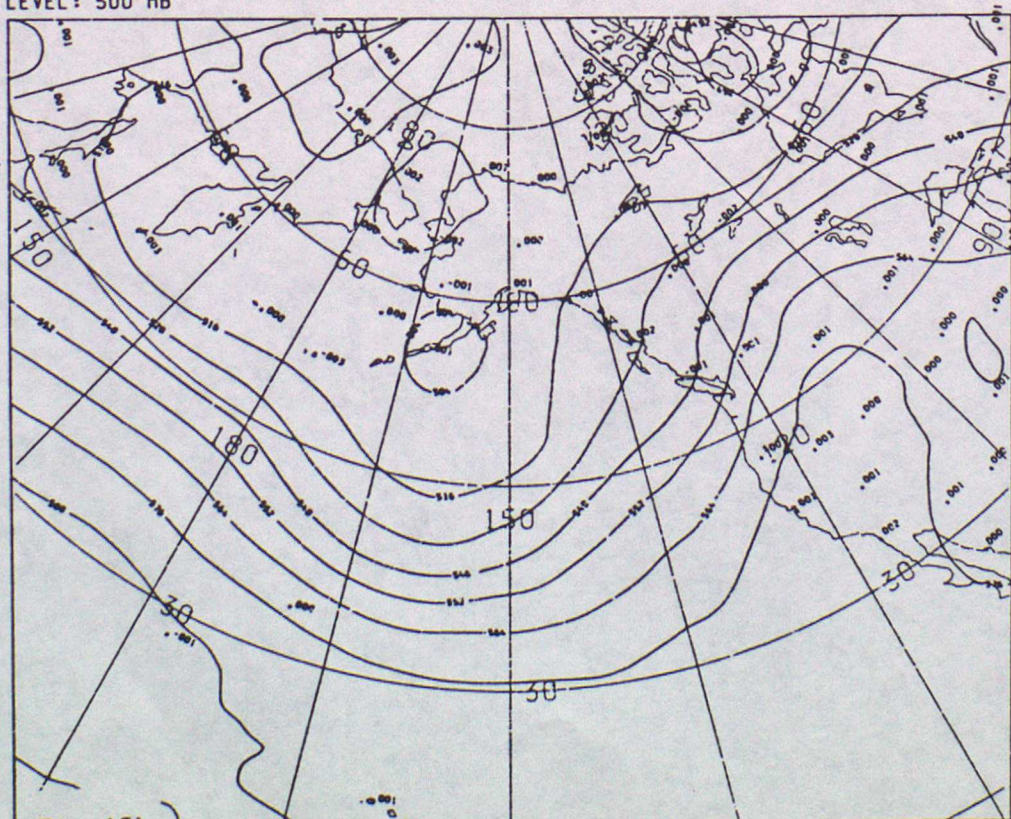
DIFFERENCE (VERIFYING OBSERVATIONS - UK ANALYSIS) 500mb Hts.

VALID AT 12Z ON 8/1/1986 DAY 8 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 500 MB



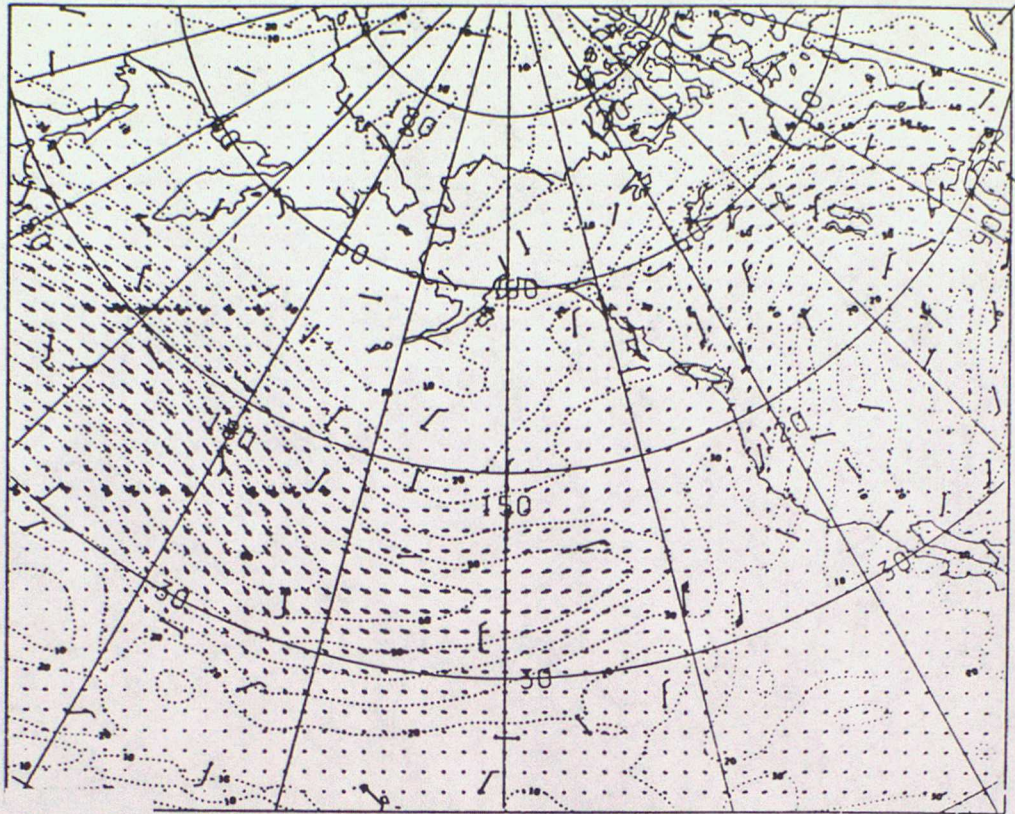
DIFFERENCE (VERIFYING OBSERVATIONS - EC ANALYSIS) 500mb Hts.

VALID AT 12Z ON 8/1/1986 DAY 8 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 500 MB



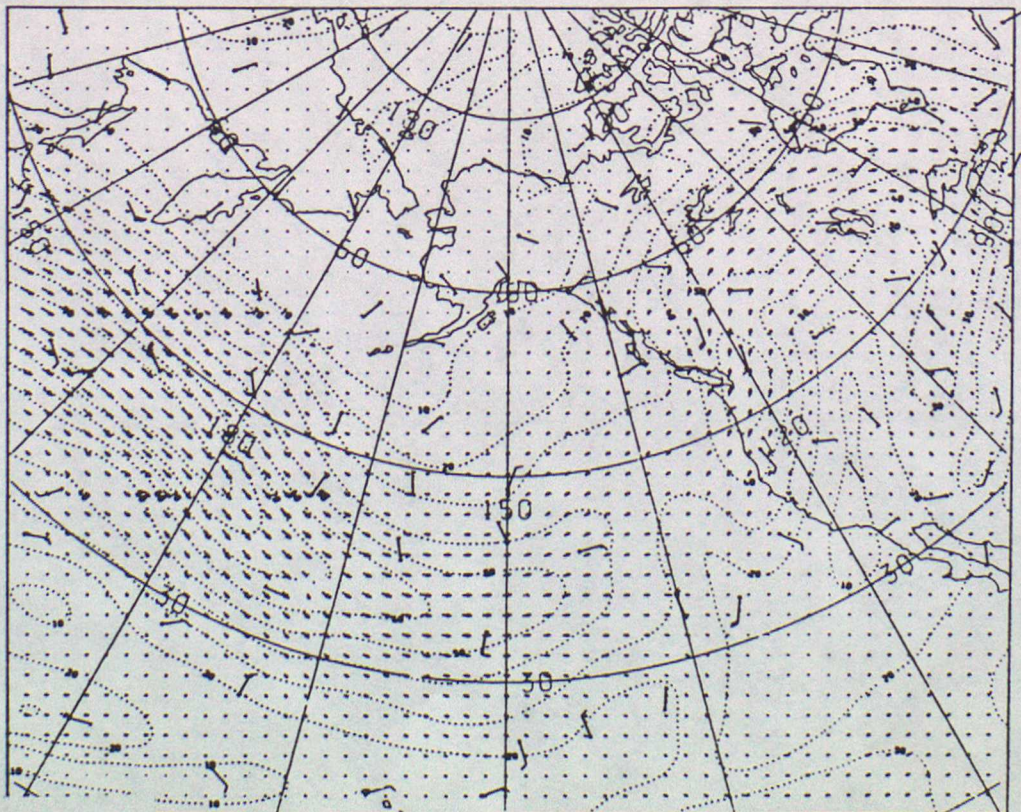
DIFFERENCE (VERIFYING OBSERVATIONS - UK ANALYSIS) 250mb Winds.

VALID AT 12Z ON 8/1/1986 DAY 8 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 250 MB

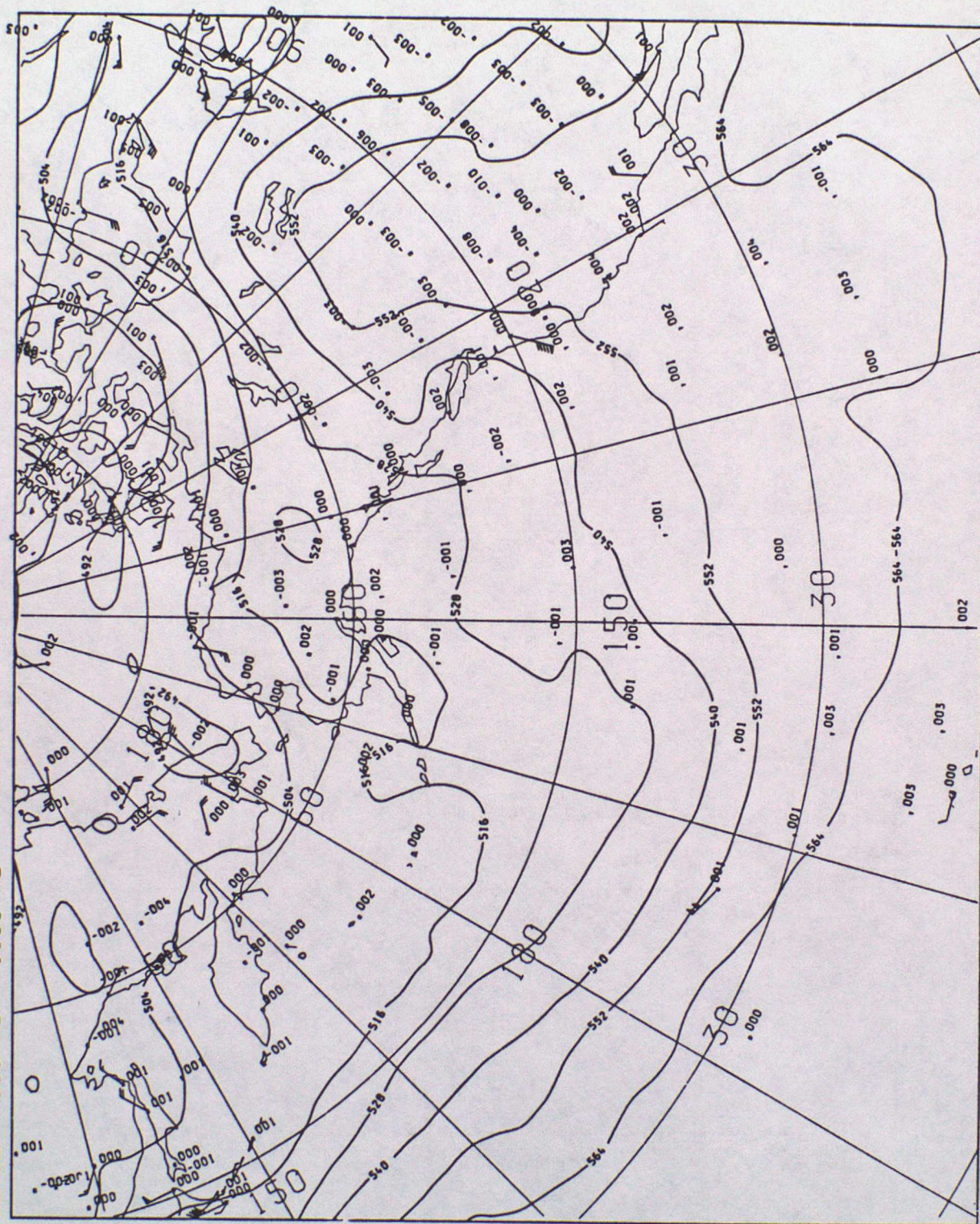


DIFFERENCE (VERIFYING OBSERVATIONS - EC ANALYSIS) 250mb Winds.

VALID AT 12Z ON 8/1/1986 DAY 8 DATA TIME 12Z ON 8/1/1986 DAY 8
LEVEL: 250 MB



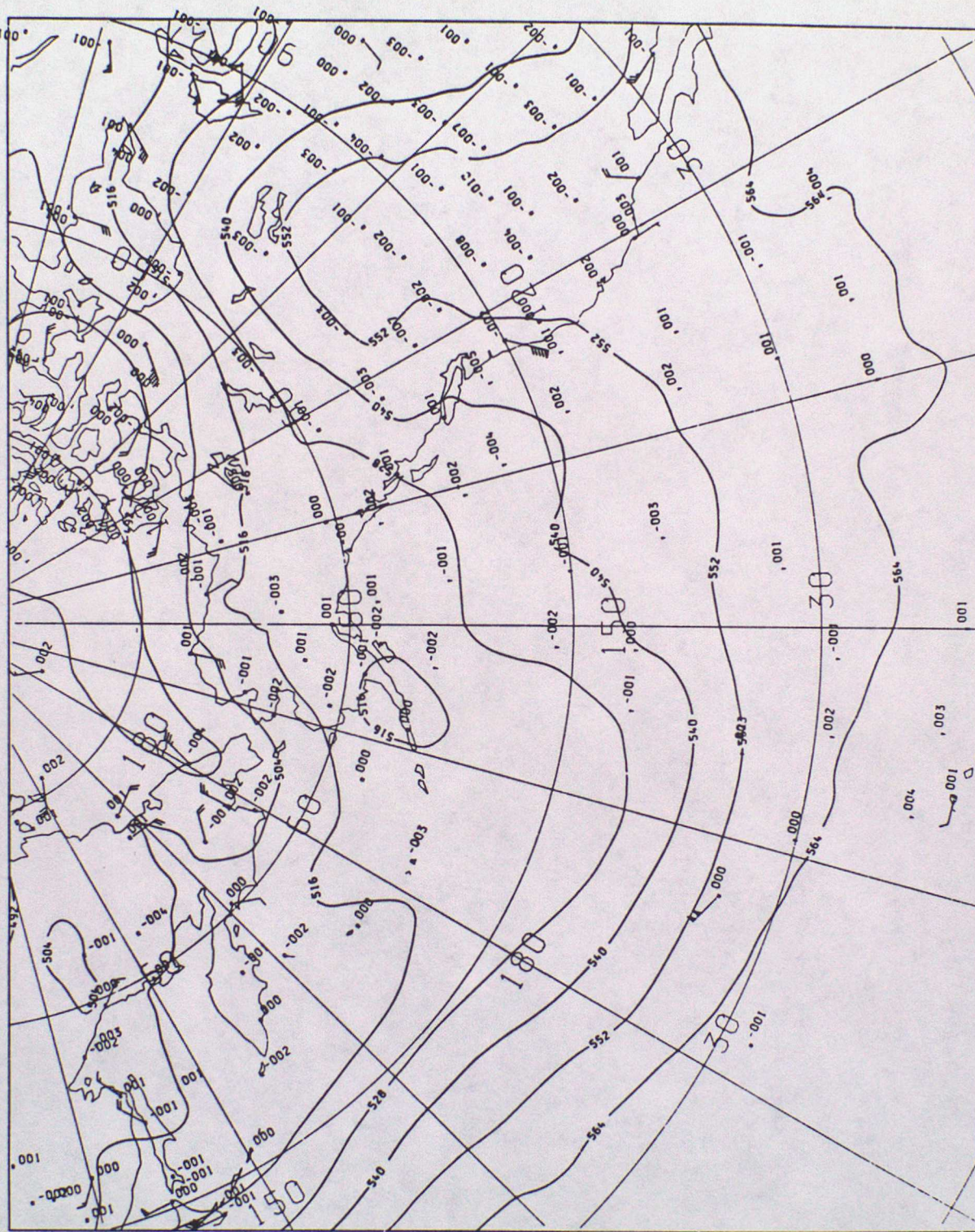
12Z UK ANALYSIS 08/01/86
 THICKNESS(DAM) & OBSERVED - FIELD VALUES
 VALID AT 12Z ON 8/1/1986 DAY 8 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB - 1000 MB



CONTOUR INTERVAL: 120 HRS UNITS 107R TEMP A PLOTTED 20 SHIP A PLOTTED 501 SATHE PLOTTED 1590Z MM: -0.6 RMS: 22.9H.

Fig 14a

12Z EC ANALYSIS 08/01/86
 THICKNESS(DAM) & OBSERVED - FIELD VALUES
 VALID AT 12Z ON 8/1/1986 DAY 8 DATA TIME 12Z ON 8/1/1986 DAY 8
 LEVEL: 500 MB - 1000 MB



CONTOUR INTERVAL: 120 MMS UNITS
 107R TEMP A PLOTTED 2U SHIP A PLOTTED 50T SALEM FLOTTED 1590Z MMS: -6.0 RMS: 22.7M.

Fig14b