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RESULTS FROM THE FINE-MESH TRIAL OF A MODIFIED PHYSICS PACKAGE

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1. INTRODUCTION

A new physics package was introduced into the fine-mesh model w.e.f 12GMT 11th February 1987. The current operational scheme is described in Met 02b Documentation Paper No.4 (Dickinson[1]). The changes involved are described briefly below. A more detailed justification of the changes will be found in another note (Wilson [2]).

a) Resistance to surface evaporation will be maintained at 60s/m throughout the year over land, instead of during the summer only. This change is intended to reduce the moist bias in the bottom levels of the model, thereby reducing the amount of spurious low cloud forecast by the model between late September and early May and improving surface temperature verification.

b) The explicit calculation of vertical diffusion has been replaced by an implicit calculation in the boundary layer routines. The overall impact of the new implicit boundary layer scheme is expected to be small but it enables the existing correction to the explicit scheme to be removed. The change should remove the surface temperature oscillation produced occasionally by the old operational boundary layer scheme.

c) The interactive radiation scheme has been modified to include the effects of ozone.

d) The assumed boundaries of cloud relative to model levels have been changed.

e) A split final detrainment scheme has been introduced into the convection scheme. This scheme is intended to improve the moisture distribution in the boundary layer by reducing the moist bias near the surface and increasing moisture just above inversions. A convective adjustment is made between levels 1 and 2. In unstable conditions, mixing in the rest of the boundary layer is left to the deep convection scheme rather than to the boundary layer scheme.

f) The roughness length is allowed to vary over the sea according to the Charnock formula. This change is intended to reduce excessively strong low-level winds over the sea in the vicinity of deep depressions and allow the depressions to fill more rapidly.

g) The marine stratocumulus parametrisation has been removed. In its place, shallow cumulus is included in the output of low cloud amounts. No change has been made to the cloud algorithm, which uses a critical threshold of 85% relative humidity.

h) The initial stratospheric humidities were reset to more realistic values. This is intended to remove systematic errors in the radiative cooling rates at upper levels.

i) Negative humidities were reset to zero in a more conservative way, eliminating a spurious source of moisture and improving the relative humidity distribution.

This package is the result of cumulative changes made to the version of the fine-mesh model used for comparison in the mesoscale model trials and run off 06GMT and 18GMT data. The main impact of these changes is to improve surface temperature forecasts and to reduce the moist bias just above the surface. In particular, the new package removes a recurring problem with cold spots developing in the model forecast. (see case (i)).

As a result of this trial, it was decided to introduce the changes operationally on February 11th . After making these changes, it was found that the continued poor humidity structure in the boundary layer together with the changes to the radiation scheme (change (d)) resulted in occasional generation of spurious small amounts of rain from a shallow layer of cloud, often at level 2. The changes to the radiation scheme were therefore withdrawn on March 11th.

The new versions were tested by comparison with the operational scheme in eleven cases. The cases included five cases chosen from the 1986 summer and five cases chosen from the winters of 1985/6 and 1986/7. The remaining case was selected from the autumn anticyclonic spell in September 1986. The cases assessed are listed below;

DT 00GMT 10/6/86	DT 12GMT 16/6/86	DT 12GMT 20/6/86
DT 00GMT 27/6/86	DT 00GMT 15/7/86	DT 00GMT 29/9/86
DT 00GMT 14/12/86	DT 12GMT 11/1/87	DT 00GMT 16/12/86
DT 12GMT 30/1/86	DT 12GMT 11/2/87	

In the next section, we will describe the main differences noticed between the old and new versions of the fine-mesh model in the eleven case studies. Finally, in section 3 a brief summary of the results is given.

2. CASE STUDIES.

This section describes the impact of the model changes on the eleven cases listed in the introduction. Eleven case studies cannot be described fully in one technical note due to space, so we will select the important forecasting features from each case and describe the differences noted between the different versions of the fine-mesh model forecasts. Three versions will be included in the comparisons. These are;

(i) The control version - operational fine-mesh model prior to 11/2/87;
(ii) The interim version - operational fine-mesh model 11/2/87 - 11/3/87;
(iii) The final version - operational fine-mesh model w.e.f. 11/3/87.

.The problems connected with the interim version will discussed more fully in another Technical Note (Wilson[2]). However, the differences between the interim and final versions will be described. The maximum differences between the versions will be shown in the figures following the case studies.

a) MODEL D.T 00 GMT 10/6/86. FORECAST PERIOD 00GMT 10/6/86-12GMT 11/6/86

This case was chosen as an example of a cool, wet, cyclonic summer period. The important features to assess were the pressure pattern (i.e. the forecast position and depth of the two depressions which influenced the weather over the U.K. during this period) and the associated areas of rainfall.

During the 10th, a depression moved north-eastwards from Southern Ireland to North-east Scotland. An associated area of rain also moved north-east over the U.K during the morning, although south-east England escaped with a short spell of light rain. During the afternoon, thundery showers developed over Wales and northern England, whilst Scotland experienced heavy rain with snow over the Cairngorms. This type of weather continued over Scotland during the 11th..There was no difference between the three model versions in the forecast central position of the depression during the 36 hours of the forecast period. However, after T+24hr.,the final and interim versions began to fill the depression a little more quickly than the control version. All the versions predicted a similar area and intensity of rain over Scotland and all failed to predict the heavy showers in the north-west. Overall, slightly less rainfall was predicted by the final and interim versions, but the difference was not significant. Whereas the control version forecast a small amount of rain associated with the cold front as it crossed south-east England, both the final and interim versions gave a dry forecast. This difference was not crucial,since observed accumulations in the south-east were mostly less than 1mm. In figure 1 we compare the T+30hr. forecasts (verification time 06GMT 11/6/86) of pressure and rainfall from the control and final versions of the fine-mesh model with the chart analysed by the forecasters. The forecast position of the centre of the depression over Scotland is identical in all three versions, but the central pressure is slightly higher (approximately 2mb) in the final version. This slight filling of the depression was correct.

During the 11th, a small wave depression developed in the South-west Approaches and a further area of rain spread eastwards over southern England. There was a small difference in the treatment of this depression by the three versions. The control forecast over-deepened the low by at least 6mb. and was slightly fast with the spread of rain across Southern England. The final version forecast the central pressure 2-3mb higher, which was more correct and was slightly slower with the timing of the rain. This difference in the timing was due to slightly weaker thermal advection fields. The forecast rainfall areas over Southern England at T+30 are compared in figure 1.The observed area of rainfall over Southern England lies between the two forecast areas.

The interim version gave a similar rainfall forecast to the control version over the U.K. but,in addition, forecast areas of spurious very light rain and low cloud over the sea. This light rain was forecast to fall from a thin layer of cloud at level 2. If we look at two model grid-points at 52.5N 11.3W and 53.3N 11.3W, then the interim version was predicting 8 octas of low cloud at level 2. At levels 3 and 4,the forecast relative humidity was less than 85%, hence no cloud was predicted.At the corresponding grid-points in the final version, only a trace of cloud was predicted from relative humidities 84-88% at level 2. The model profiles are compared in Table 1 below.

52.5N 11.3W	INTERIM		52.5N 11.3W	FINAL	
MODEL LEVEL	TEMP	RH	MODEL LEVEL	TEMP	RH
1	10C	91%	1	12C	80%
2	8C	100%	2	10C	88%
3	7C	71%	3	7C	76%
4	3C	61%	4	5C	63%

b) MODEL D.T 12 GMT 16/6/86.FORECAST PERIOD 12GMT 16/6/86-00GMT 18/6/86

This case was chosen as an example of a hot,humid,period with the risk of thunderstorms developing. The important forecasting features to assess were the location of thunderstorms and the high temperatures over the U.K. and continent.

Throughout the period,the weather remained very warm and thundery over the continent, with maximum daytime temperatures around 24-28 degrees C.During the 16th,over the U.K.,patchy fog and low cloud affected eastern coastal areas, but inland,it was hot,humid and mainly sunny. During the evening, isolated thunderstorms developed over the hottest areas (maximum temperature 29C) over south-east England, with more widespread thundery activity over west Wales and north-west England ahead of a cold front. On the 17th, the cold front weakened as it moved eastwards across England. so the east had another dry,hot day.Elsewhere over the U.K. it was cooler and cloudier and further thundery showers developed over North-west England and Southern Scotland.

The high daytime temperatures were slightly better forecast by the final and interim versions. Overall, daytime temperatures were 1-2 degrees C higher in these two versions. Pressure also was slightly higher (2-4mb) in the final and interim versions. In figure 2 we compare the forecast rainfall and pressure pattern at T+36hr.,verification time 00GMT 18/6/86, from the three versions with the forecasters analysed chart.The rise of pressure in the interim and final versions was not correct. None of the versions predicted the showers which developed over the U.K. during the evening of the 16th. During the 17th, all versions predicted a slow-moving trough in the south-east associated with the cold front and so forecast too much precipitation for this area. The final version, with less rain, gave a slightly better forecast. However,the main difference between the versions occurred at T+36, verification time 00GMT, 18/6/86 in the Denmark area.(see figure 2).The control and interim versions forecast showers associated with a low pressure area over Denmark and this forecast verifies well when compared with the analysed chart. The final version gave a dry forecast for Denmark, with less convective cloud generally and the pressure was 2-4mb higher. Two gridpoints in this region showed a predicted convective depth of 8km but forecast no rain. The small increase in pressure means that the final version extended the ridge over the U.K slightly further north and filled the low over the continent. This was incorrect, as the operational forecast pressure was already too high.

In Tables 1 and 2,we compare the forecast convective cloud amounts and depth from the control and final versions in the Denmark area.

(A)	8.4E	9.4E	10.3E	(B)	8.4E	9.4E	10.3E
56.3N	0	9	9	56.3N	0	11	13
55.5N	10	0	13	55.3N	10	14	23
54.8N	0	0	0	54.8N	11	9	9

TABLE 2.Forecast convective cloud amounts at T+36,V.T 00GMT 18/6/86 from the Final (A) and Control (B) versions of the fine-mesh model.

(A)	8.4E	9.4E	10.3E	(B)	8.4E	9.4E	10.3E
56.3N	0	8	8	56.3N	0	10	10
55.5N	2	0	8	55.3N	2	10	9
54.8N	0	0	0	54.8N	10	10	8

TABLE 3. Forecast convective cloud depths at T+36, V.T 00GMT 18/6/86 from the Final (A) and Control (B) versions of the fine-mesh model.

The impact of the model changes was slightly detrimental in the forecasting of pressure and showers but an improvement in the forecasting of temperatures.

c) MODEL D.T 12 GMT 20/6/86, FORECAST PERIOD 12GMT 20/6/86-00GMT 22/6/86.

This case was chosen in order to assess the impact of model changes on the forecasting of two important features; North Sea stratus / stratocumulus and the location of thunderstorms.

During this period, an anticyclone was centred to the north of Scotland and a north-easterly flow covered the British Isles, later veering easterly. During most of the period, eastern coastal regions remained cool and cloudy as low cloud was advected in from the North Sea. Well inland, during daytime, the cloud sheet became more broken and western and south-coastal regions were sunny and warm. During the evening of the 20th, the cloud sheet started to spread well inland and by midnight, clear intervals were confined to western areas. In figure 3, we have compared the forecasting of low cloud by the three versions at T+12. verification time 00GMT 21/6/86, and in figure 4 the low level profiles from model tephigrams at the nearest gridpoints representing Hemsby and Shanwell. The best forecast of low cloud was from the control version (see figure 3) which correctly predicted the spread of low cloud inland. The interim and final versions predicted only small amounts of cloud. Model profiles at grid-point 54.0N 3.8E are compared in Table 4 below.

54.0N 3.8E	CONTROL	54.0N 3.8E		FINAL
MODEL LEVEL	RH	MODEL LEVEL	TEMP	RH
1	88%	1	12C	100%
2	78%	2	10C	72%
3	1%	3	16C	5%
4	13%	4	14C	11%
% LOW CLOUD	100%	% LOW CLOUD		0%

TABLE 4. MODEL LOW LEVEL PROFILES OF TEMPERATURE AND HUMIDITY AND LOW CLOUD FOR T+12, V.T 00GMT 21/6/86

There is not much difference between the humidity profiles of the control and final versions. Humidities are less than 85% at levels 2,3 and 4 and both have the extreme dryness at level 3. However, whereas the control version has 100% of low cloud at this gridpoint, the final version has none. The difference is the marine stratocumulus parametrisation in the control version.

In figure 4, we compare model tephigrams from the three versions at the nearest grid-points to Hemsby and Crawley for T+12, V.T 00GMT 21/6/86..The strong inversion of about 9 degrees C at 950mb shown by the Hemsby ascent is better represented in the final and interim versions although the humidity is slightly too low. At Crawley the three versions are similar, all failing to predict the strong inversion of almost 10C.

A thundery trough threatened Southern England throughout the period. During the 20th, heavy showers and thunderstorms were confined to Cornwall, but during the evening of the 21st, the thundery activity became more widespread over the rest of Southern England. We have compared the forecasting of these thundery outbreaks by the three model versions at T+36, verification time 00GMT 22/6/86. Figure 5 shows the forecast rainfall and pressure pattern of the interim, final and control versions at T+36 and the corresponding radar chart. In addition to the thunderstorms affecting the U.K., further ones developed over the continent, where maximum temperatures reached 24-28 degrees C. The thundery activity over Southern England was perhaps best predicted by the control version which forecast the northwards and eastwards spread of the rain slightly better than the other versions, although even this version failed to predict the exact eastern boundary of the thundery rain. However, the rain band was too wide and rain was still forecast incorrectly over Southwest England. The final version was a little disappointing both at T+30 and T+36 in that less gridpoint showers were forecast. The T+36 forecast failed to forecast the eastwards spread of thundery rain across Southern England.

Over the continent, most thunderstorms occurred just ahead of a cold front (lying at 48N 10-30E at 00GMT, 22/6/86.) The final version forecast less gridpoint showers than the control version, but without radar it is difficult to judge which was the better forecast. The impression gained from chart observatios is that showers may have been too widespread in the control version.

d) MODEL D.T 00 GMT 27/6/86. FORECAST PERIOD 00GMT 27/6/86-12GMT 28/6/86

Since the forecasting of showers in the last case, D.T. 12GMT 20/6/86 seemed slightly worse in the final version, we decided to choose a second example of a hot summer case with the threat of thunderstorms. The important features of this case were the forecasting of high daytime temperatures inland and the occurrence of thunderstorms.

Most of Europe had a hot, dry day on the 27th with maximum temperatures reaching 28-33 degrees C, but scattered thunderstorms developed over Northern France and South-west England. During the 28th, the fine weather continued in most places but it was cloudier in the south-west with residual outbreaks of thundery rain. However, no further storms developed over land before 12GMT, although some were observed in the South-west Approaches.

The high temperatures were slightly better forecast by the interim and final versions but the difference was only +1 to +2 degrees C. At T+18, all versions predicted a similar area of showers over South-west England but amounts were slightly greater in the final and interim versions. However, the greatest difference occurred at T+36, verification time 12GMT 28/6/86 over North-west France. In figure 6, we compare the forecast rainfall and pressure patterns at T+36, V.T 12GMT 28/6/86 from the three versions with the analysed chart for this time. The control version developed an area of showers over North-west France with isolated showers extending northwards into South-west England. The final and interim versions predicted isolated showers only and were more correct. Pressure was forecast to be slightly higher in the trial versions but this time the control version was more correct. In Tables 5a and 5b, we compare the forecast convective cloud amount and depth over Northern France for T+36, V.T 12GMT,28/6/86.

	CONTROL					FINAL			
	2.8W	1.9W	0.9W	0.0E		2.8W	1.9W	0.9W	0.0E
49.5N	24	0	0	0	49.5N	0	0	0	0
48.8N	13	0	16	0	48.8N	0	43	0	0
48.0N	10	18	25	14	48.0N	24	0	0	0

TABLE 5a FORECAST CONVECTIVE CLOUD AMOUNT FOR T+36,V.T 12GMT 28/6/86.

	CONTROL					FINAL			
	2.8W	1.9W	0.9W	0.0E		2.8W	1.9W	0.9W	0.0E
49.5N	10	0	0	0	49.5N	0	0	0	0
48.8N	10	0	11	0	48.8N	0	8	0	0
48.0N	1	11	13	11	48.0N	6	0	0	0

TABLE 5b FORECAST CONVECTIVE CLOUD DEPTHS FOR T+36,V.T 12GMT 28/6/86.

There is more deep convection in the control version but forecast temperatures were the same or slightly lower than in the final version. The final version seemed to be drier. This was a borderline case for showers and thunderstorms and the control version predicted showers too early.

e) MODEL D.T 00 GMT 15/7/86. FORECAST PERIOD 00GMT 15/7/86-12GMT 16/7/86

This case was chosen in order to compare temperature forecasts from the three versions on a hot,dry sunny day.

Southern England and most of the continent enjoyed a hot, dry, mainly sunny day on the 15th, as a large anticyclone drifted slowly eastwards in the Channel. Maximum temperatures reached 30 degrees C over Southern England and locally 32 degrees over the continent. Very isolated showers occurred over Eastern England during the late afternoon and early evening. During the 16th, the anticyclone drifted eastwards into Germany, allowing a depression and cold front to make progress towards Wales and Western Scotland. However, most of England, away from coasts, had a dry, sunny morning. Scotland remained cool and cloudy with occasional rain throughout the period.

Up to T+30hr.,there was little difference between the temperature forecasts from the three versions, although the final and interim forecasts were 1 to 2 degrees higher by day. However,at T+36hr, verification time 12GMT, 16/7/86, there was a marked difference in forecast temperatures over Eastern England. In figure 7, we compare the interim, final and control temperature forecasts at T+36hr with the analysed chart. The control version spread low cloud from the cold front too quickly eastwards and forecast a 12GMT temperature of only 20 degrees C over Eastern England. Observed temperatures were as high as 28 degrees C over East Anglia at this time. The final version, in contrast, with little or no low cloud, forecast a much higher temperature of 26 degrees C. The interim version, with partial cloud cover, forecast a maximum temperature of 22 degrees C. However,this version forecast areas of spurious very light rain and low cloud over the sea and near the centre of the anticyclone.

The approaching depression and cold front were treated similarly by all versions although there was slightly more convective rain in the trial versions.

<u>f) MODEL D.T. 00GMT 29/9/86. FORECAST PERIOD 00GMT 29/9/86 - 12GMT 30/9/86</u>

A large anticyclone controlled the weather over most of Europe during this period. Although most of England and Wales remained dry, the formation and clearance of low cloud and fog did pose a problem for forecasters.. It is unrealistic to expect a good model forecast in this situation, since the model's vertical resolution is too coarse. However, this case was chosen in order to compare model profiles in the boundary layer.

At 00GMT on the 29th, Southern England was already overcast with extensive low cloud and occasional drizzle. The Crawley ascent for this time indicated a saturated layer about 70mb deep from the surface to about 960mb. Further north, over East Anglia and the Midlands there were still some gaps in the cloud sheet at 00GMT, but fog formed in these areas later in the night. The depth of the fog and cloud in this region was much shallower than further south. During the morning of the 30th, this area was the first to clear and further breaks further south also occurred during the afternoon. However an area of cloud persisted all day over Central Southern England.

In figure 8, we compare the forecasts of low cloud amount at T+12, verification time 12GMT, 29/9/86. The charts indicate forecast low cloud of more than 4 octas. All three versions gave a different forecast of low cloud for the period 12-18, on the 29th. The control and interim versions forecast about the right amount of cloud at 12GMT, as figure 8 shows. However the control forecast for 18GMT was much better than the interim forecast, indicating more broken cloud. The interim forecast maintained too much low cloud throughout the afternoon. The final trial version, in contrast, has forecast less than 4 octas of low cloud in most places.. In Table 6, we compare the control and final versions forecast of low cloud amount at T+12, V.T 12GMT, 29/9/86 over a section of southern England.

	CONTROL					FINAL			
	2.8W	1.9W	0.9W	0.0E		2.8W	1.9W	0.9W	0.0E
54.0N	100	100	55	1	54.0N	48	72	6	0
53.3N	46	93	24	22	53.3N	6	35	2	0
52.5N	57	60	82	100	52.5N	10	13	42	41
51.8N	100	100	100	100	51.8N	78	100	79	31
51.0N	100	100	88	82	51.0N	60	44	30	22

TABLE 6. FORECAST PERCENTAGES OF LOW CLOUD FOR T+12, V.T 12GMT 29/9/86

The final version is actually better for predicting the holes in the cloud over East Anglia and the W Midlands but has too little cloud elsewhere. In general, however, the final version was too dry and the control version was better.

In figure 9, we compare model profiles for Crawley at T+12, verification time 12GMT, 29/9/86. The cloud at Crawley must have been very close to breaking at 12GMT and a better impression of the persistent cloudy region is gained from the 12GMT Larkhill ascent, which is also shown in figure 9. The radio sonde ascents show a strong inversion of 7-10 degrees C between 970 and 950mb. The best inversion is forecast by the interim version although it is too low and the model is showing signs of cooling in the cloudy region just beneath the inversion. The final version profile is similar to the control profile but drier. The boundary layer in the trial versions have not improved on the control version in this case.

The central pressure of the anticyclone was forecast to be 4mb higher in the trial versions. The interim version again forecast spurious areas of very light rain and low cloud over the sea and in the centre of the high.

g)MODEL DT00GMT 14/12/86.FORECAST PERIOD 00GMT 14/12/86-12GMT 15/12/86

The main feature of interest in this case is the explosive deepening of a depression in the Atlantic. The case was chosen in order to assess the impact of the Charnock formula on strong low level winds around a very deep depression.

The depression first appeared on the Atlantic charts on 13/12/86. During the 14th, the depression moved north-east towards Iceland deepening rapidly. The control and final versions were compared closely to detect any differences in the handling of the depression. There was no change in evolution and the central positions of the low were identical. However, the central pressure was higher in the final version after T+18 and the low was filled more quickly in the last 6 hours of the forecast period. The forecast and analysed pressures are listed below for 6 hourly intervals.

Verification Time	Analysed Pressure	Final Version	Control Version
T+6 06Z 14/12/86	956mb	964mb	960mb
T+12 12Z 14/12/86	930mb	940mb	940mb
T+18 18Z 14/12/86	920mb	916mb	916mb
T+24 00Z 15/12/86	916mb	912mb	908mb
T+30 06Z 15/12/86	920mb	908mb	904mb
T+36 12Z 15/12/86	930mb	916mb	908mb

TABLE 7.Forecast and analysed central pressures for depression near Iceland at 12GMT 14/12/86

The control was very good up to T+18, then started to over-deepen the depression and was about 20mb too deep at T+36. The final version also over-deepened the depression but by a smaller amount.

In figure 10, we compare the forecast pressure patterns at T+36. The final version has started to fill the depression more quickly than the control version and the difference between them is 8mb. Part of this (1-2mb) is due to a tendency of the final version to forecast a higher pressure anyway but this difference is mainly due to the impact of the Charnock formula..Figure 11 compares the forecast 10m winds from the control and final versions around the depression at T+36, verification time 12GMT 15/12/86. The speeds are 5-15kt lighter in the final version and compare well with reported wind speeds from ships. No difference was noted in the timing of the rain belts reaching the U.K or in intensity.

The impact of the Charnock formula was seen clearly in this case, both in the filling of the depression at the end of the forecast and in the reduced wind speeds.

h)MODEL D.T 12GMT 11/1/87.FORECAST PERIOD 12GMT 11/1/87 - 00GMT 13/1/87

This case was chosen in order to compare forecast minimum temperatures for the coldest night of last winter. During this period, easterly winds brought extremely cold weather from Siberia across the U.K, with temperatures remaining well below zero day and night. In figure 12, we have compared the temperature forecasts for T+18hr, verification time 06GMT 12/1/87, from the three versions with the observed temperatures. Observed temperatures were between -8 and -12 degrees C at this time. The final and interim versions were 1-2 degrees colder than the control version and more accurate.

The final version tended to forecast about 20% more convective cloud than the control version mainly over the sea.

i)MODEL D.T 00GMT 16/12/86.FORECAST PERIOD 00GMT 16/12/86-12GMT 17/12/86

A strong westerly airstream covered the British Isles during the period. This case was brought to our attention by C.F.O who complained about a poor temperature forecast over Southern England at T+12hr. and T+18hr. At one gridpoint (51.8N 0.0E), positioned to the north of London on the meridian, the control version forecast a temperature of only 1 degrees C at 12GMT and 2 degrees C at 18gmt. This point was colder than surrounding grid-points and verified badly with observed temperatures of about 5 degrees C in this area at 12GMT. The control version forecast mainly clear skies between 00GMT and 06GMT and forecast temperatures fell to -2 degrees C at this grid-point by 06GMT. The observed minimum temperature was +1 degrees C. After 06GMT, the model forecast increased cloud cover which prevented temperatures from rising above 2 degrees C at this point during the day.

The final version forecast less cloud and produced a more accurate temperature forecast of 5 degrees C at 12GMT and 18GMT. The interim version gave a similar answer. In Table 8, we compare forecast values of screen temperature and low cloud amount amount from the control and final versions for grid-point 51.8N 0.0E at T+6, T+12 and T+18.

	CONTROL F/C			FINAL F/C		
	T+6	T+12	T+18	T+6	T+12	T+18
screen temperature	-2	1	2	2	5	5
level 1 temperature	-1	1	3	3	5	5
level 2 temperature	2	3	4	2	3	5
low cloud cover	0	51	33	0	0	64

TABLE 8.MODEL OUTPUT OF LOW-LEVEL TEMPERATURES AND LOW CLOUD AMOUNT AT 51.8N 0.0E at 06,12 and 18GMT 16/12/86.

Figure 13 compares the temperature forecasts form the control and final versions at T+12, V.T 12GMT, 16/12/86 with observed temperatures. The final version has removed the cold spot correctly. A second small difference was noted in this case at T+30hr. The control version forecast a slightly deeper low(2-4mb) in the Atlantic and a more extensive area of rain over Scotland.

j)MODEL D.T 12GMT 11/2/87.FORECAST PERIOD 12GMT 11/2/87-00GMT 13/2/87

This was the first forecast produced operationally by the interim version. The forecast was brought to our attention by C.F.O, who complained about an incorrect forecast of light snow over the U.K at T+36 and also about excessive low level cooling indicated by the model ascents. This forecast led to the further changes in March. In figure 14, we compare forecasts of precipitation and mean sea level pressure at T+36, V.T 00GMT 13/2/87 from the interim and final versions with observations. The interim version built the ridge over the U.K and forecast very light precipitation, which was incorrect. An improved dry forecast was produced by the final version .In figure 15, we compare model low level profiles at grid-point 53.2N 2.8W for T+24 and T+36 with the corresponding Aughton radio-sonde ascents. This shows the excess cooling of 2-4 degrees C in the bottom two model levels in the interim version. Again,the final version is more accurate. In Tables 9 (a) and (b), we compare model forecasts of low cloud amount and low-level temperatures at six-hourly intervals at the grid-point 53.2N 2.8W.

INTERIM VERSION	T+6	T+12	T+18	T+24	T+30	T+36
	VT18	VT00	VT06	VT12	VT18	VT00
Low cloud amount	100	98	97	99	98	100
Level 1 temperature	3	2	1	0	1	0
Level 2 temperature	2	0	-1	-2	-1	-2
Level 3 temperature	0	0	0	-1	-2	-2
Level 4 temperature	-4	-4	-5	-4	-4	-4

TABLE 9a.FORECASTS OF LOW CLOUD AND TEMPERATURES AT 6-HOURLY INTERVALS AT GRID-POINT 53.2N 2.8W FROM THE INTERIM VERSION.

FINAL VERSION	T+6	T+12	T+18	T+24	T+30	T+36
	VT18	VT00	VT06	VT12	VT18	VT00
Low cloud amount	43	20	1	4	19	3
Level 1 temperature	4	3	1	3	4	2
Level 2 temperature	2	2	2	1	3	2
Level 3 temperature	0	-1	-1	-1	-1	-1
Level 4 temperature	-4	-5	-4	-5	-5	-4

TABLE 9b.FORECASTS OF LOW CLOUD AND TEMPERATURES AT 6-HOURLY INTERVALS AT GRID-POINT 53.2N 2.8W FROM THE FINAL VERSION.

In the interim version,the model formed cloud at level 2 early in the forecast period, and retained it throughout the period. In the interim version, the cloud was centred around the model level, i.e the base was halfway between level 1 and 2,and the top halfway between level 2 and 3. Cooling was initially at level 2, which cooled by 4 degrees C during the forecast period. In the final version, which had less low cloud throughout, the temperature at level 2 did not change.

j)MODEL D.T 12GMT 30/1/86.FORECAST PERIOD 12GMT 30/1/86-00GMT 01/2/86

A strong cold unstable easterly airstream covered the U.K and most places remained cloudy throughout with occasional light rain, drizzle or sleet. At T+24, V.T 12GMT 31/1/86, infra-red satellite pictures showed a great deal of cloud over the North Sea and the U.K. The radio-sonde ascents for this time from Hemsby, Crawley and Shanwell showed cloud tops generally to be between 4000 and 6000FT. Beneath the inversion, the airmass was unstable to sea temperatures. Over the U.K, there was a full cover of low cloud except over Western Scotland and many places were reporting light rain or drizzle.

The control version produced the best forecast of a complete low cloud cover with light rain for this time. The final version predicted a partial cover of low cloud(which was still good guidance) but no rain was forecast. The instability to sea temperatures was well represented in both versions, but the final version generally had 10-30% more convective cloud.

In figure 16, we compare model profiles at T+24, V.T 12GMT, 31/12/86 with the corresponding radio-sonde ascents for Hemsby and Crawley. Both versions forecast the inversion to be too low. The final version was too dry at the inversion level.

CONCLUSION

In this report of the fine-mesh trial, we have concentrated on verifying surface variables rather than upper air. The following conclusions were reached from the cases tested.

1. TEMPERATURE.

The range of temperature was slightly increased, i.e maximum temperatures were 1-2 degrees higher, whilst minimum temperatures were 0.5-1 degree lower. The increase in maximum temperatures was beneficial provided that the forecast cloud cover was correct. Generally, there was a very slight cold bias in the minimum temperatures. All versions forecast too high a temperature on the extremely cold night 12/1/87 due to the absence of a frozen ground surface in the model.

2. PRESSURE.

There were two noticeable effects on mean sea level pressure.

a) In most of the cases assessed, pressure was slightly higher, (2-4mb) after T+24 in the final and interim versions compared with the control version. In particular, pressure in ridges and anticyclones was higher. The reason for this small pressure rise is unknown but it was usually not correct.

b) The small beneficial impact of the Charnock formula could be seen in the speedier filling of depressions and the associated reduction of low level windspeeds around the low.

3. DYNAMIC RAINFALL.

In general, there was little impact on the forecasting of dynamic rain in the cases assessed. There was no major change in evolution and the timing of rain areas across the U.K was unchanged in most cases. In the 10/6/86 case, a slightly slower timing of the rain area in the south-west in the final version appeared to be due to a small reduction in thermal advection. Weak fronts tended to have less rain in the interim and final versions. Elsewhere, the impact was variable, with some grid-points having more rain and some less.

4.CONVECTIVE RAINFALL.

No improvement was observed in the forecasting of showers in unstable westerly, northwesterly or northerly airstreams and, indeed, none was expected. Most cases showed a deficit of showers.
In the humid thundery cases, there was a slight reduction in the number of grid-points forecasting showers, especially at 00GMT in the interim and final versions. This was sometimes better, e.g when the control version forecast too many showers too soon, (D.T 00GMT 27/6/86) and sometimes worse,(D.T.12GMT,20/6/86).

5.LOW CLOUD.

No major improvement was noticed in the forecasting of low cloud. On the positive side, the changes reduced the moist low level bias in the model and reduced the spurious forecasting of low cloud in the Autumn and Winter. However, the change seemed to go too far in other cases and the boundary layer seemed to be too dry at the inversion. In the North Sea stratus case, D.T 12GMT. 20/6/86, the marine stratocumulus parametrisation improved the forecasting of low cloud in the control version.

6.BOUNDARY LAYER.

Using the implicit boundary scheme did not improve the model's boundary layer as much as had been hoped, but it did not make it worse and it meant that the over-deepening correction could be removed. The final version sometimes showed signs of forecasting a better inversion but it was often too low and there was no sign of a well- mixed boundary layer. The moist bias at level 2 was reduced but instead the model became too dry. It was difficult to see any positive benefit from the split final detrainment scheme when looking at the usual charts seen in C.F.O. However, when comparing model ascents, a slight moistening could be seen occasionally above the inversion .

The changes tested above succeeded in the main objectives, i.e temperature forecasts were slightly improved, the temperature oscillation was removed and the moist low level bias was reduced. However, the forecast boundary layer still needs further improvement.

REFERENCES.

A.DICKINSON Met.02b Documentation Paper No.4. Operational Numerical Weather Prediction Model.

C.A.WILSON Met.0.11 Technical Note to be issued

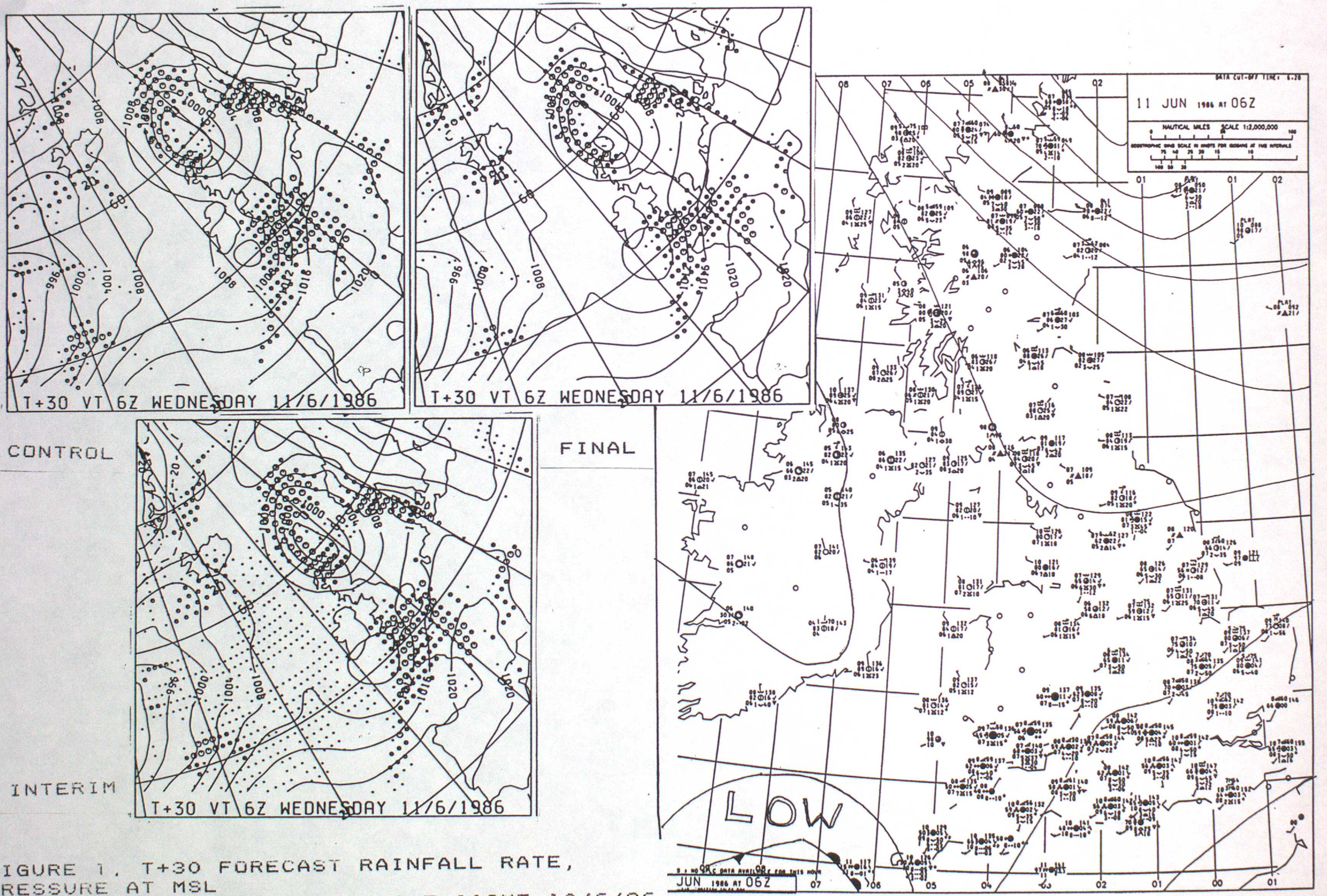
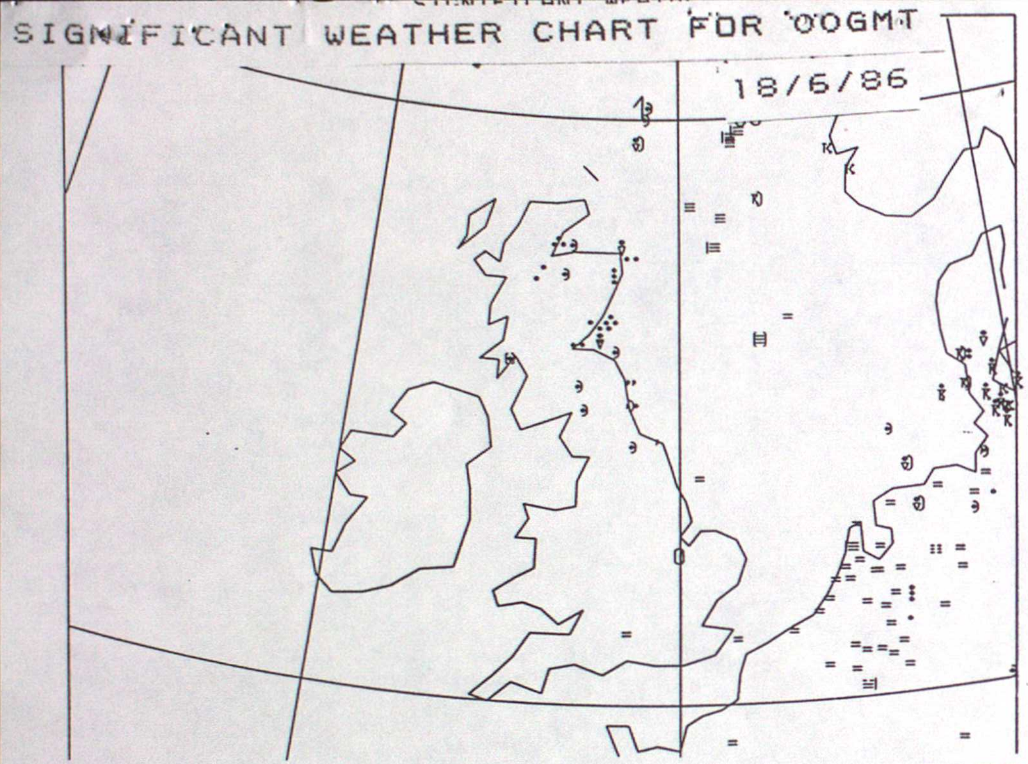


FIGURE 1. T+30 FORECAST RAINFALL RATE, PRESSURE AT MSL
FINE-MESH MODEL D.T 00GMT 10/6/86



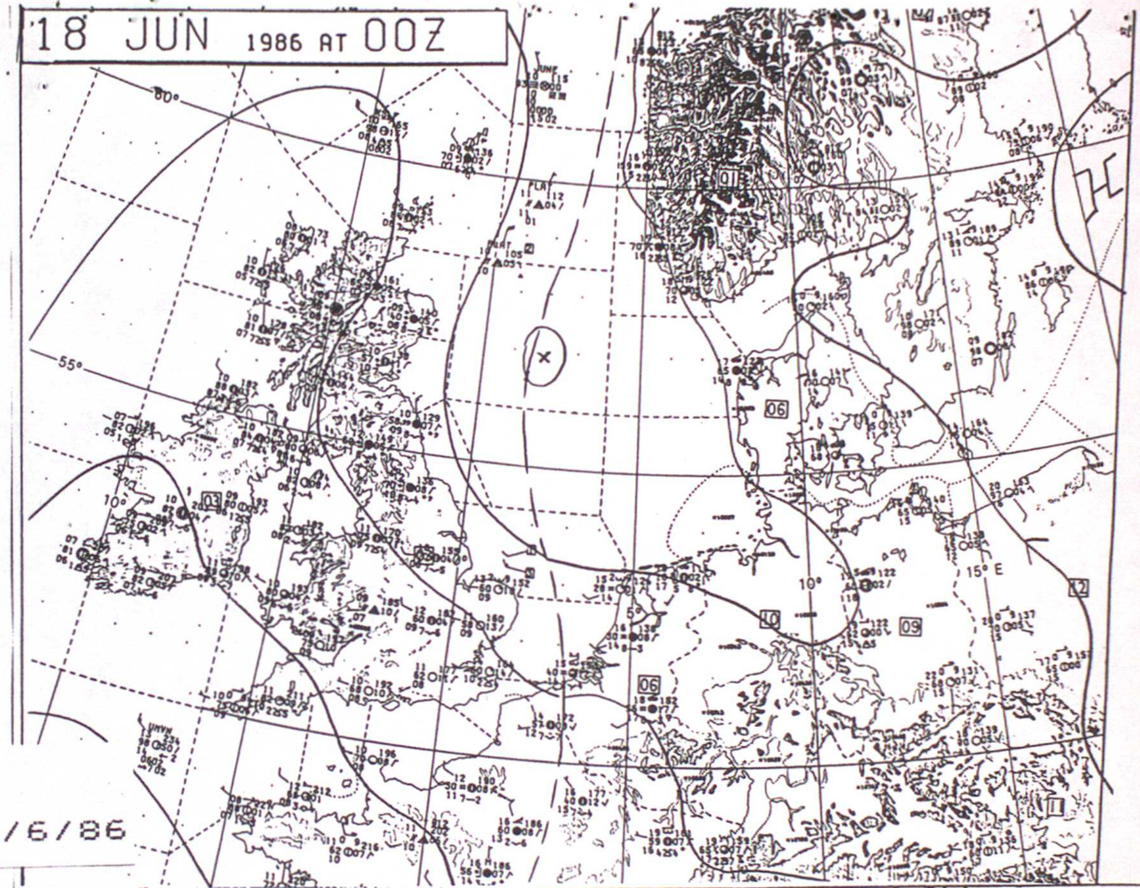
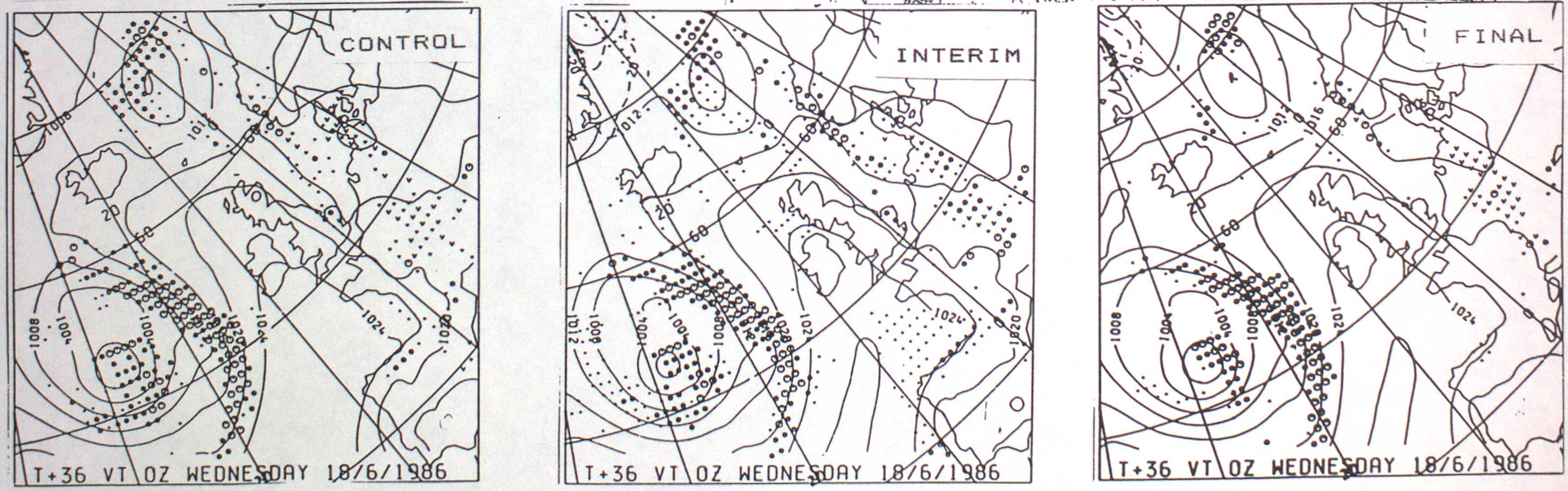


FIGURE 2. T+36 FORECAST RAINFALL RATE,
PRESSURE AT MSL
FINE-MESH MODEL D.T 12GMT 16/6/86



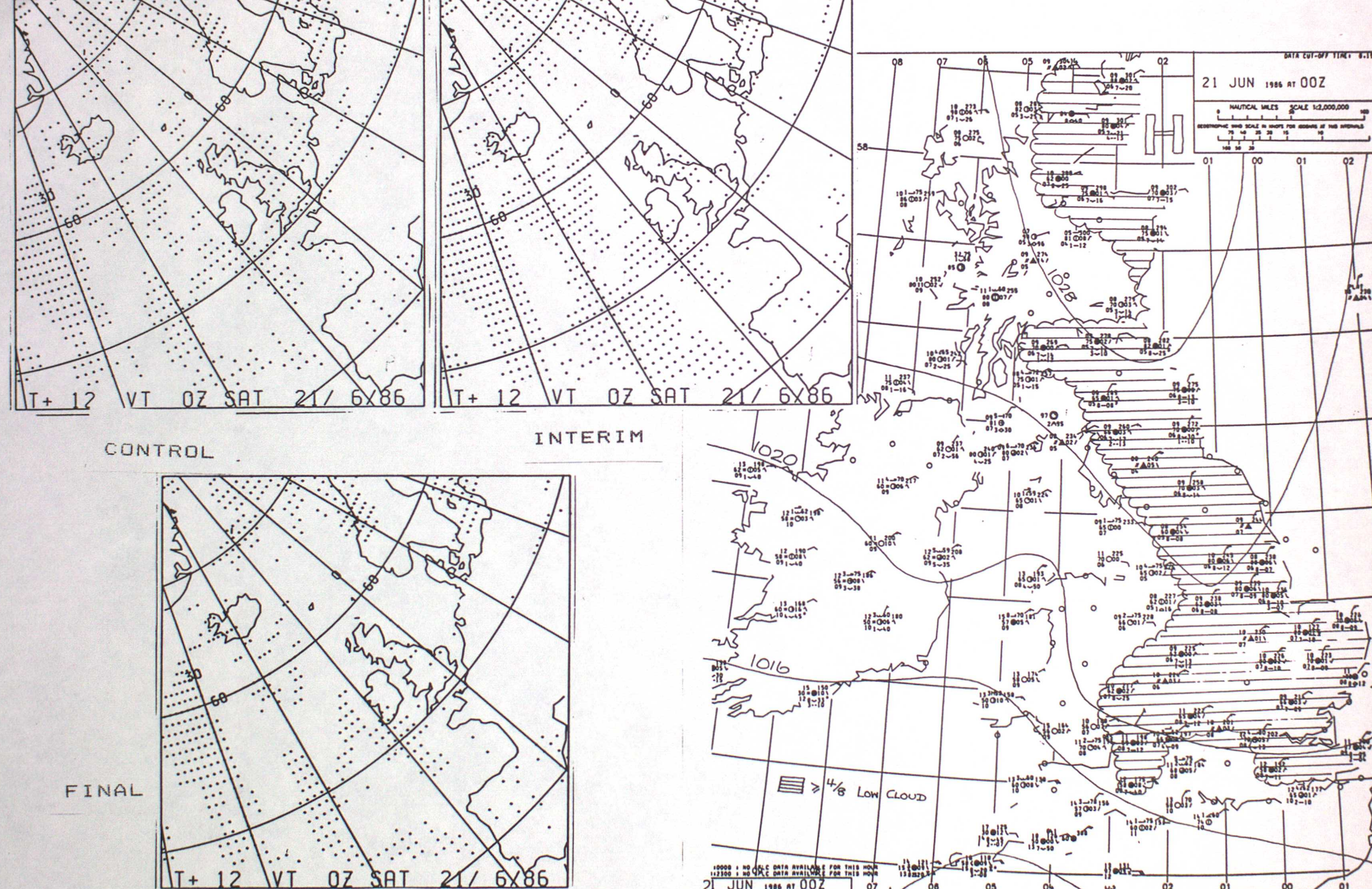


FIGURE 3. T+12 FORECAST OF LOW CLOUD AMOUNT
FINE-MESH MODEL D.T 12GMT 20/6/86

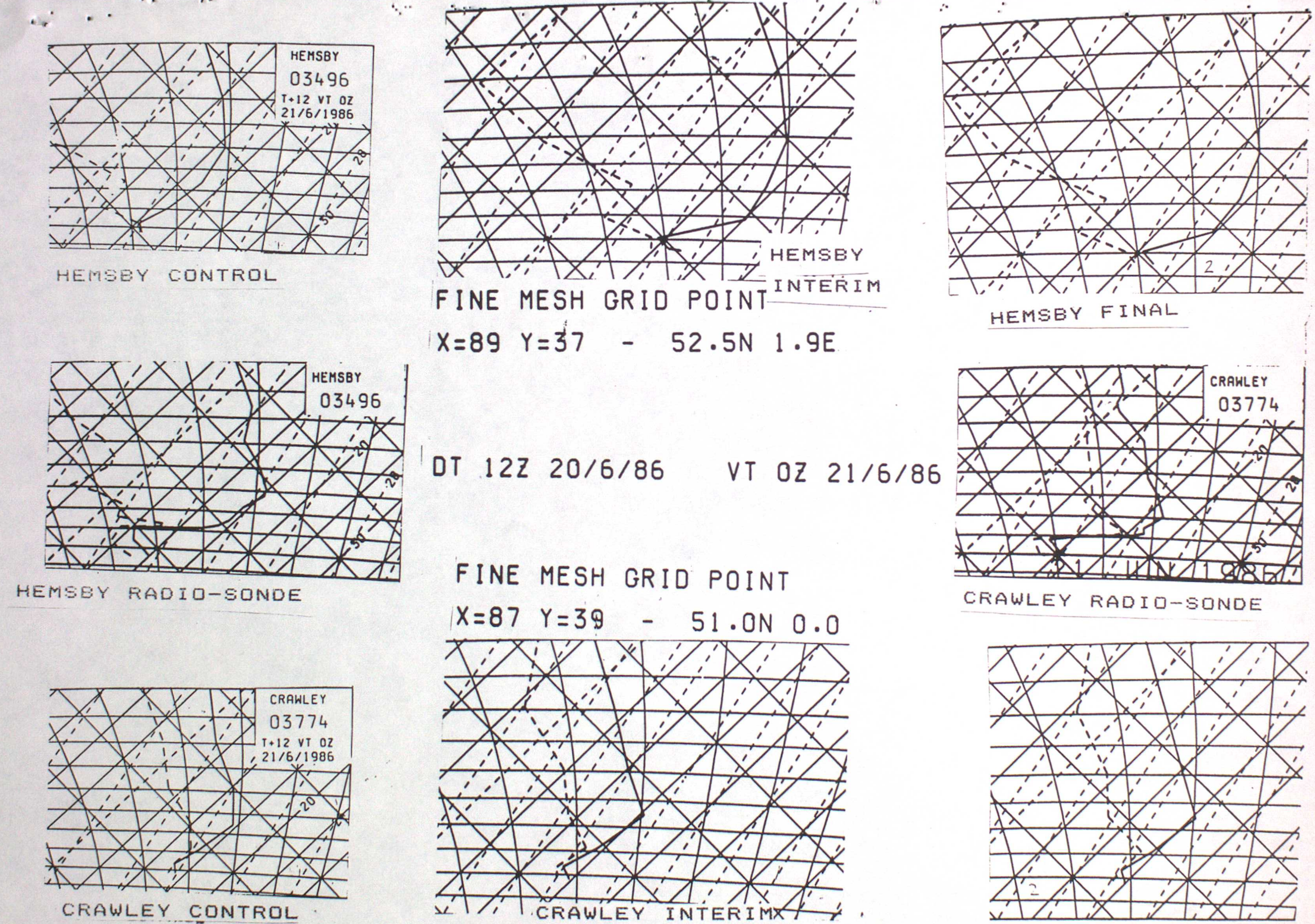
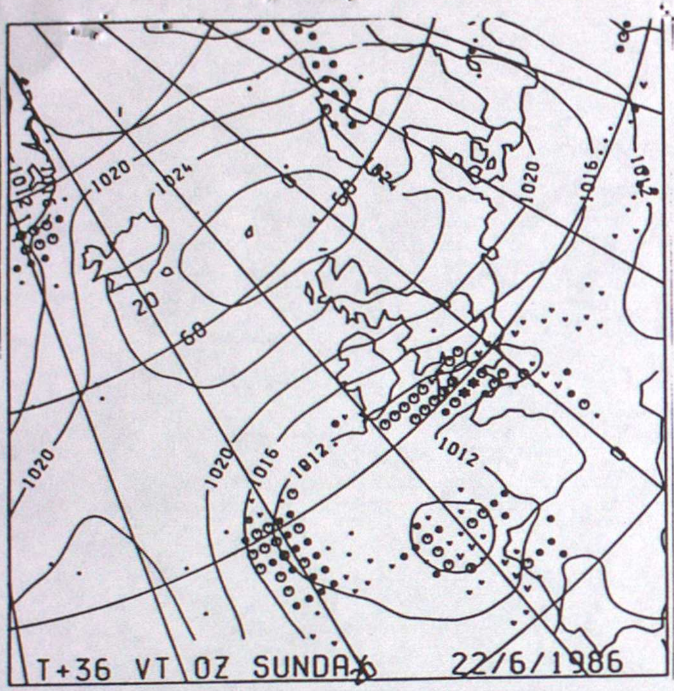


FIGURE 4. T+12 FINE-MESH MODEL TEPHIGRAMS



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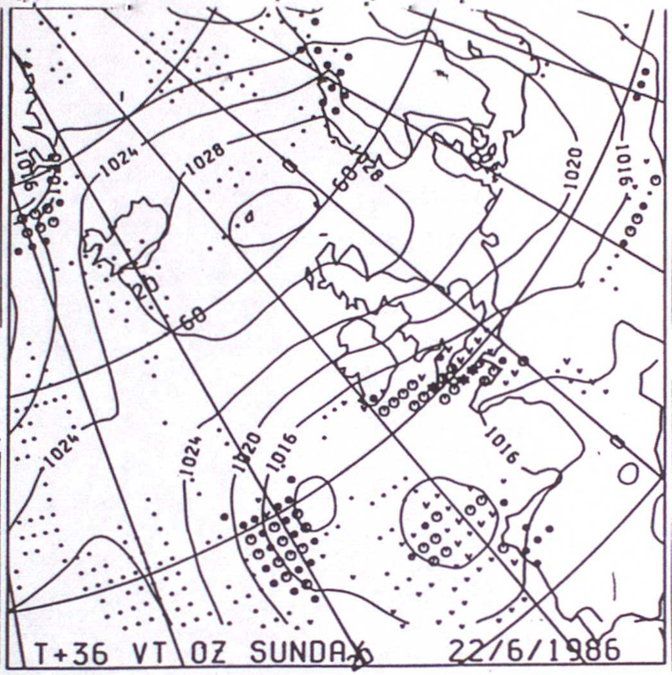
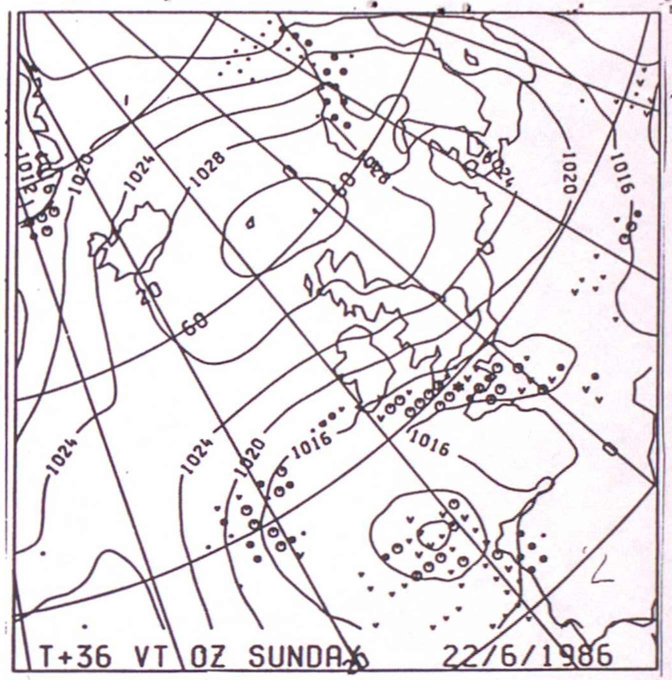
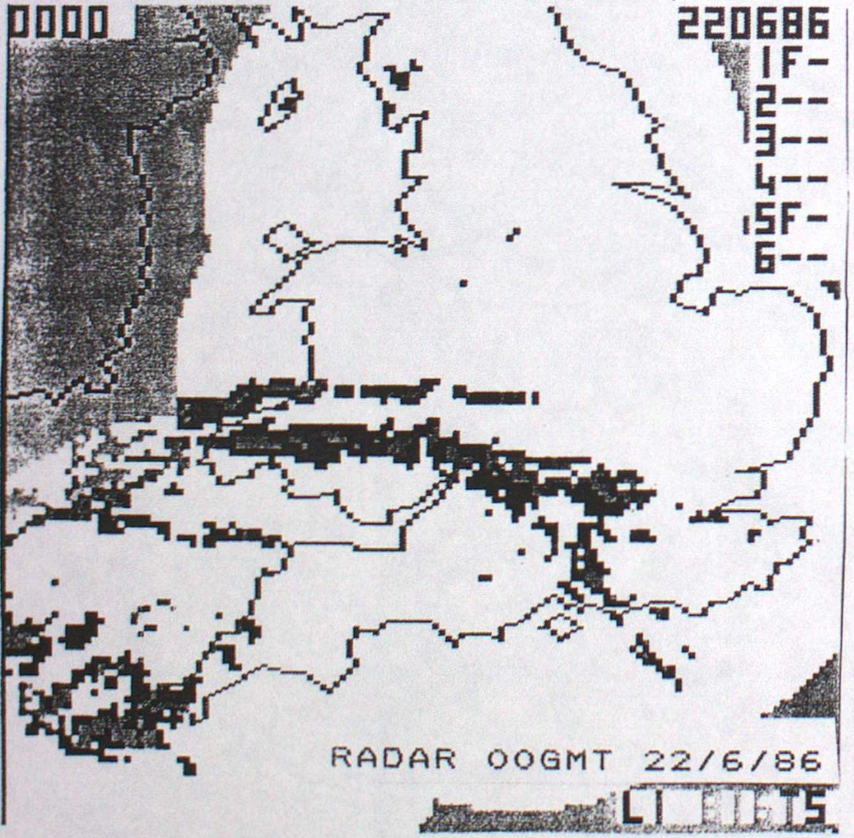


INTERIM



FINAL



RADAR 00GMT 22/6/86

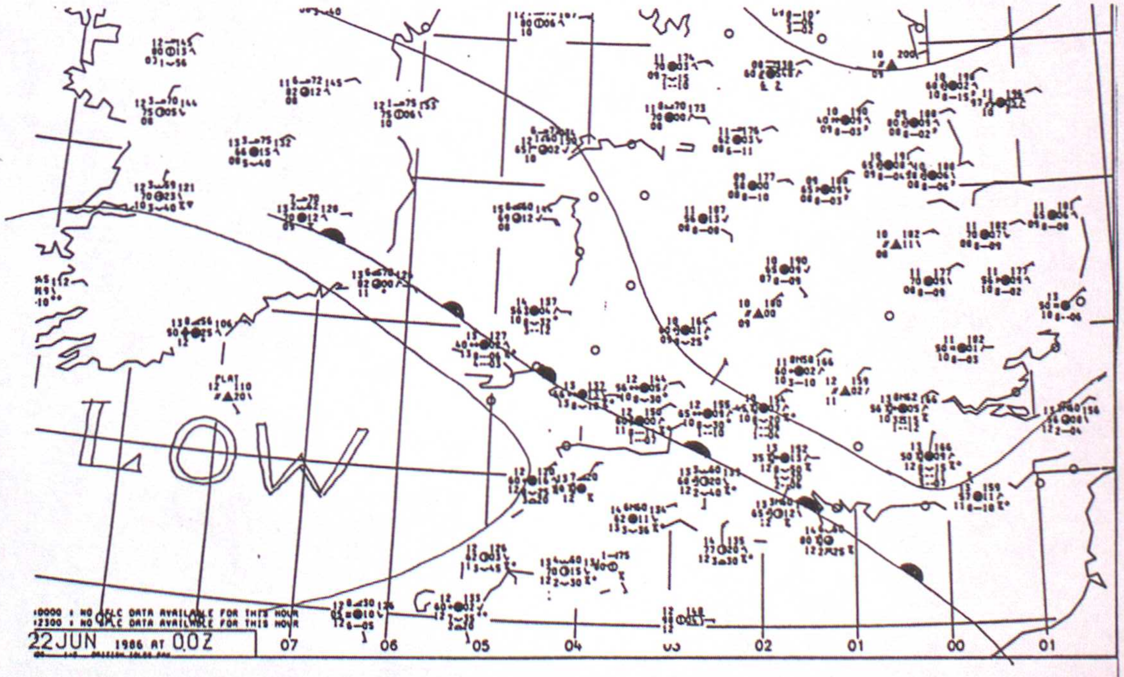


FIGURE 5. T+36 FORECAST RAINFALL RATE, PRESSURE AT MSL FINE-MESH MODEL D.T 12GMT 20/6/86

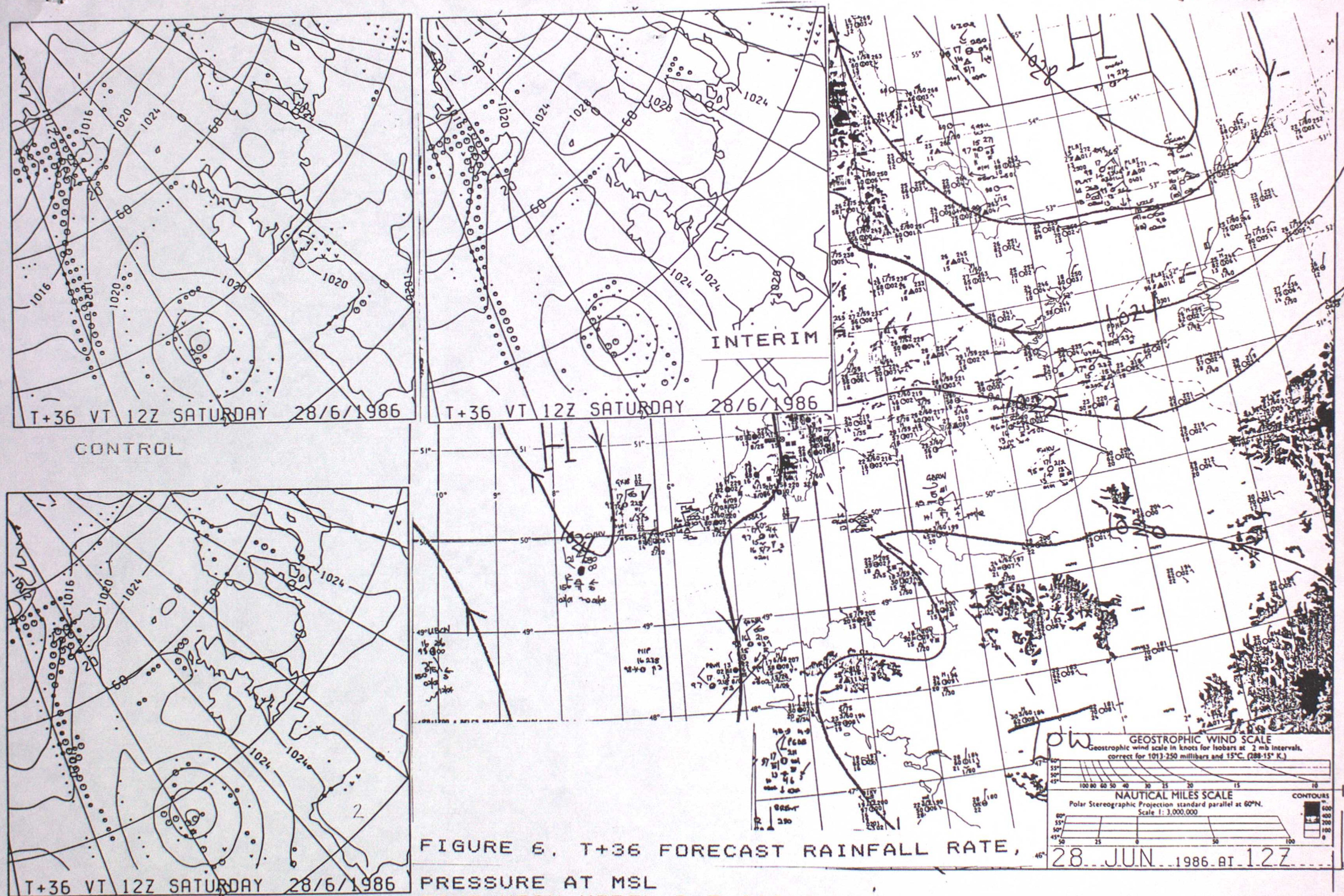


FIGURE 6. T+36 FORECAST RAINFALL RATE,
PRESSURE AT MSL

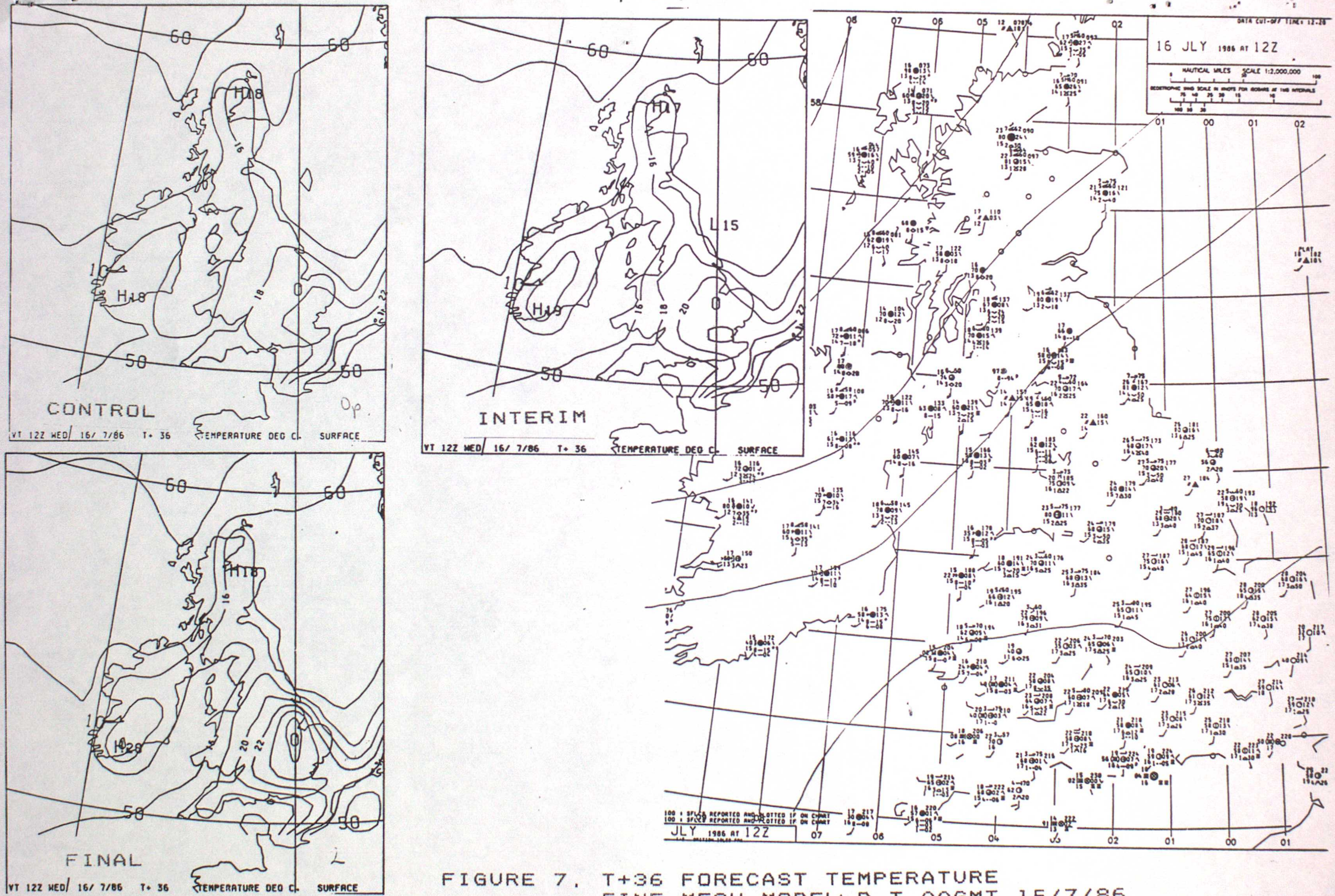
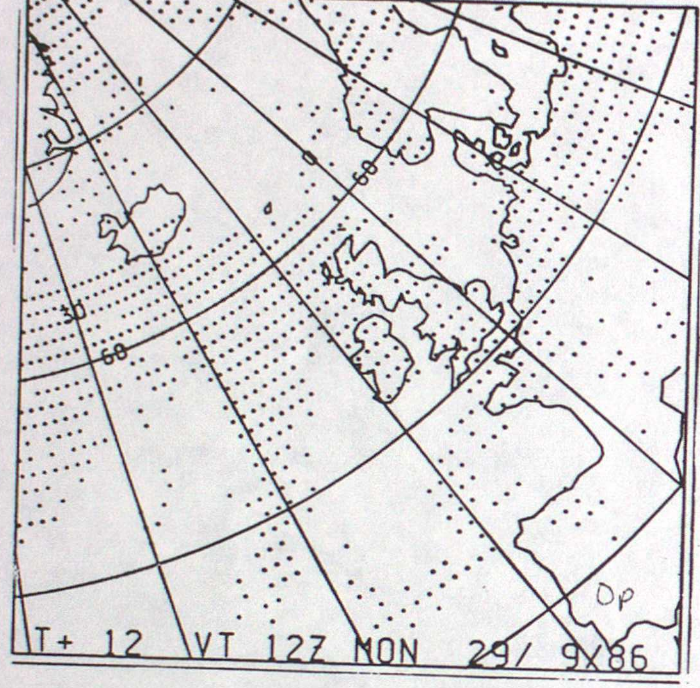
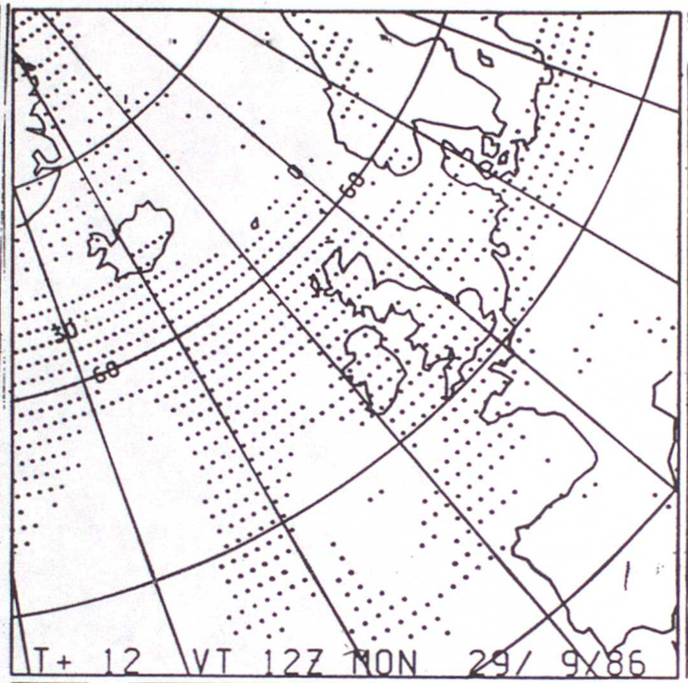


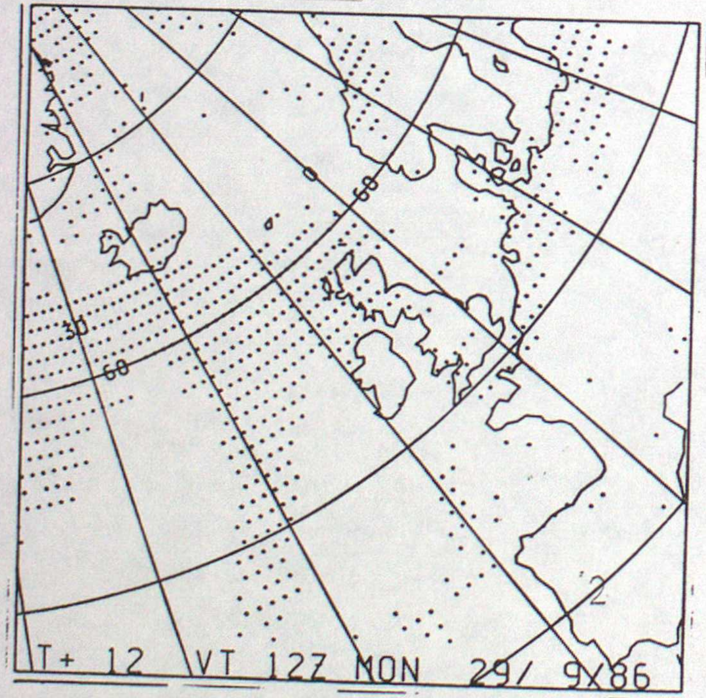
FIGURE 7. T+36 FORECAST TEMPERATURE
FINE-MESH MODEL' D.T OOGMT 15/7/86



CONTROL



INTERIM



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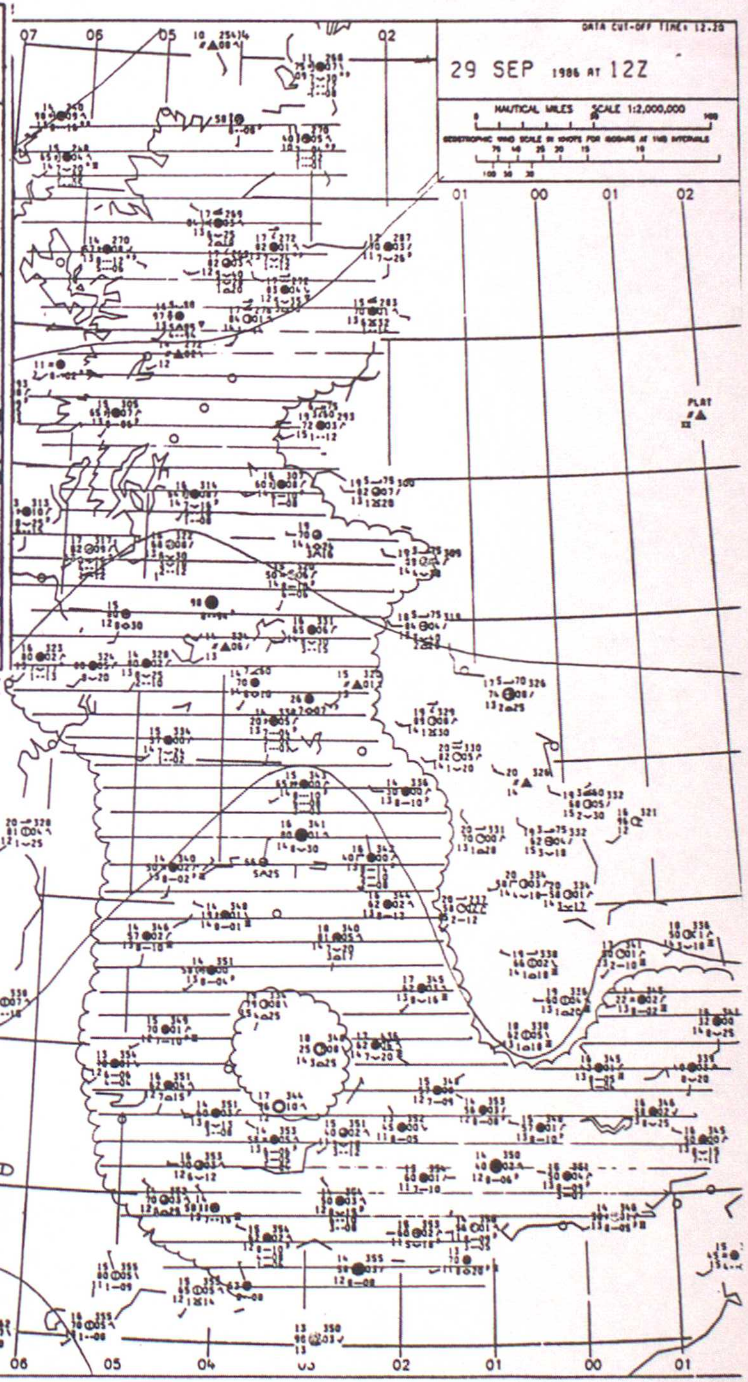
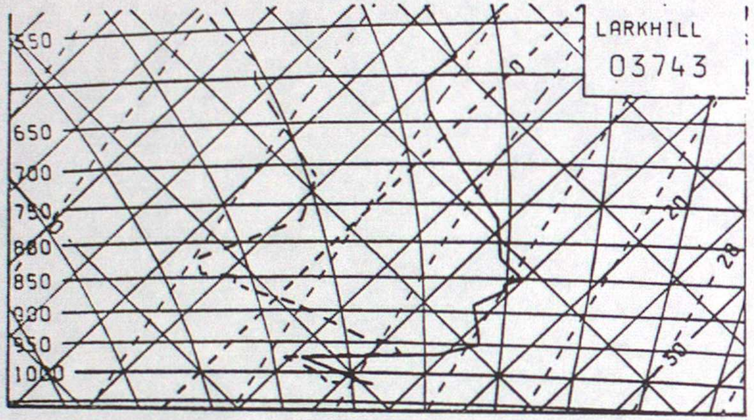
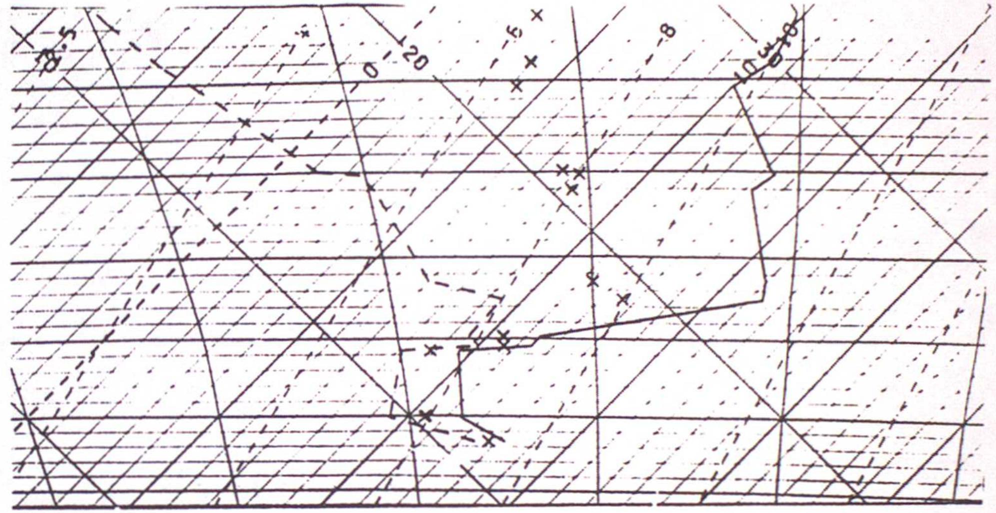



FIGURE 8. T+12 FORECAST OF LOW CLOUD AMOUNT
FINE-MESH MODEL D.T OOGMT 29/9/86

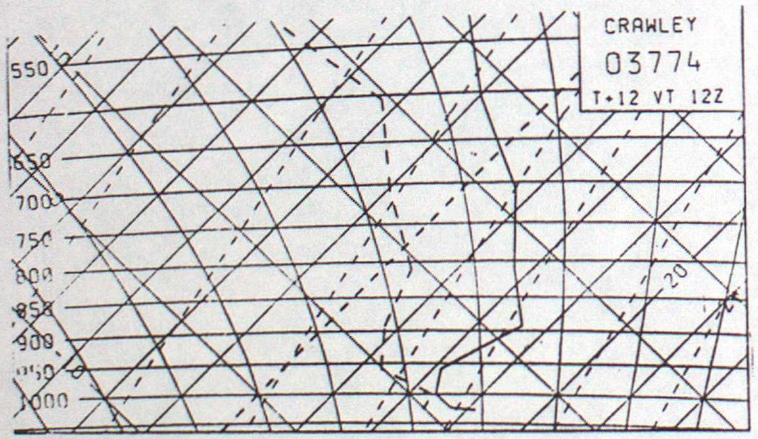
29 SEP 1986 12Z



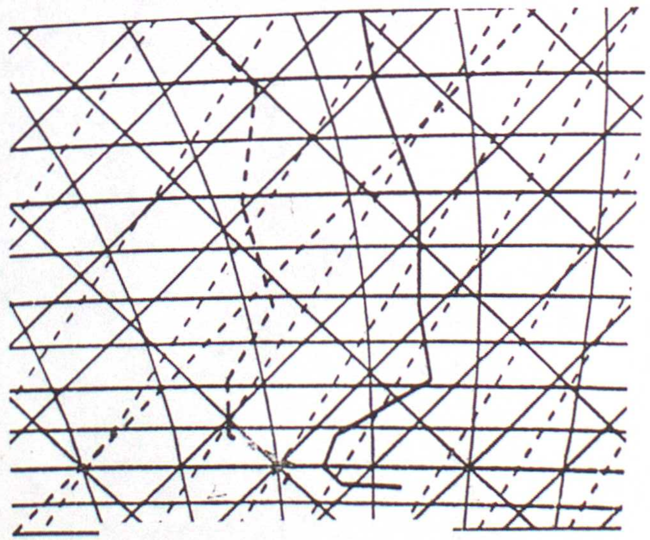
LARKHILL RADIO-SONDE



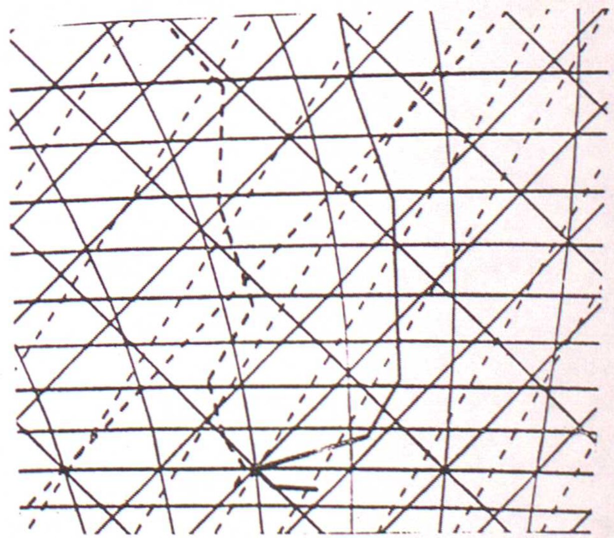
CRAWLEY RADIO-SONDE



CRAWLEY CONTROL

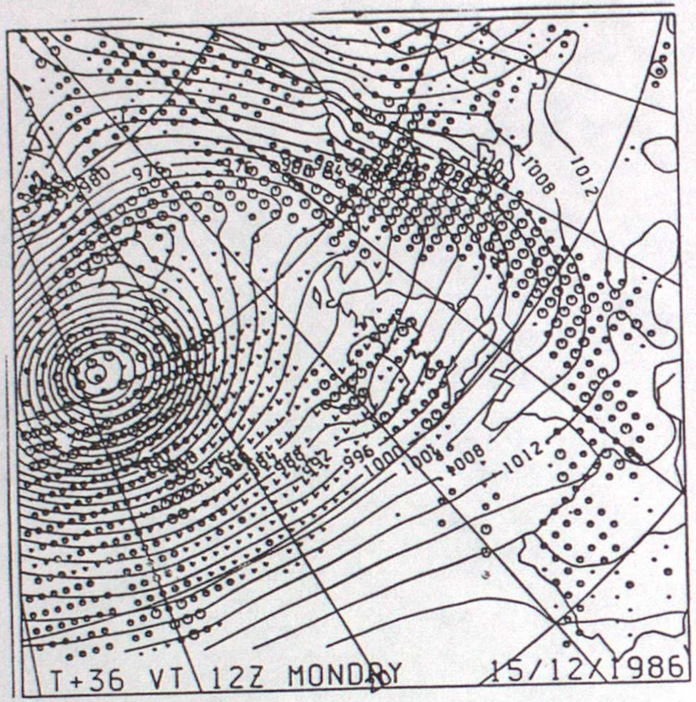


CRAWLEY FINAL



CRAWLEY INTERIM

FIGURE 9. T+12 FINE-MESH MODEL TEPHIGRAMS
FINE-MESH MODEL D.T OOGMT 29/9/86



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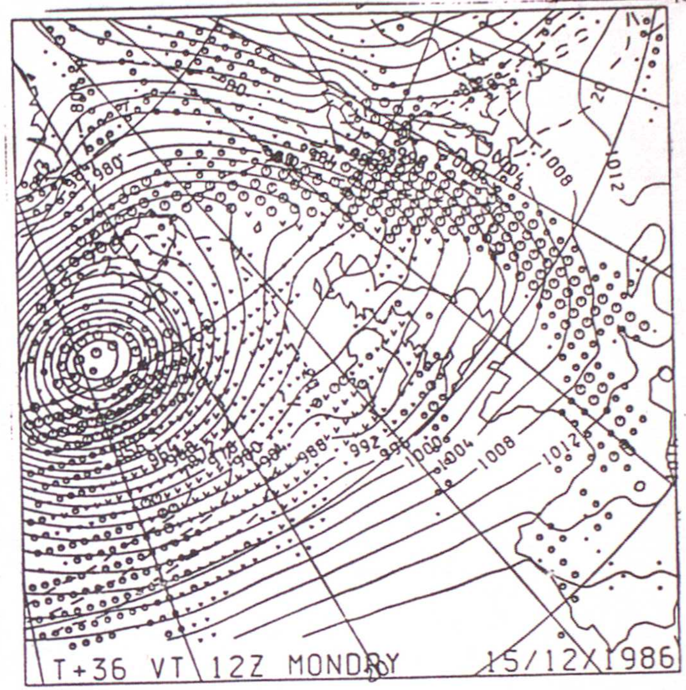

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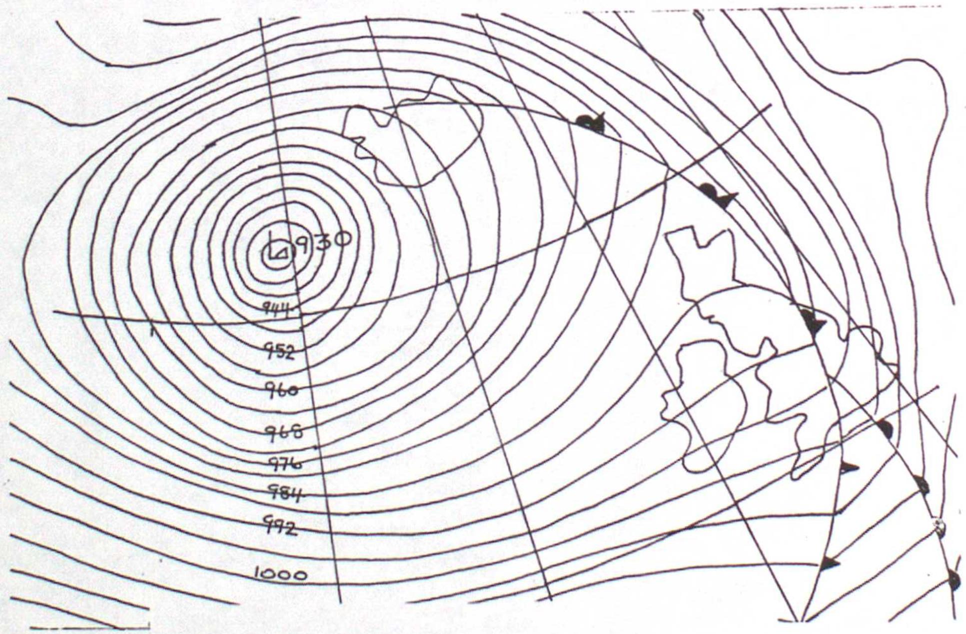
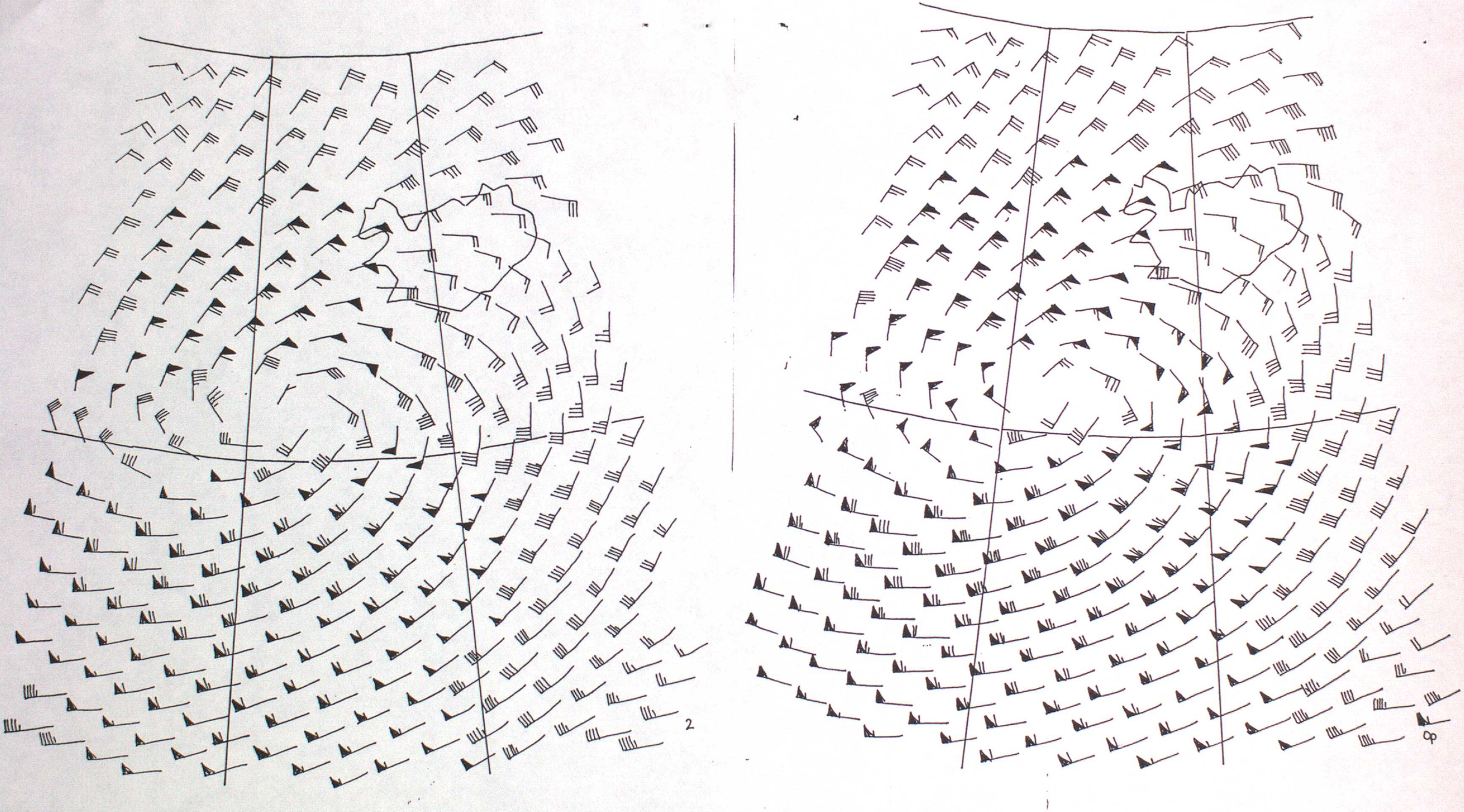


ANALYSIS 12GMT 15/12/86

FIGURE 10. T+36 FORECAST RAINFALL RATE, PRESSURE AT MSL
FINE-MESH MODEL D.T OOGMT 14/12/86



FINAL

CONTROL

FIGURE 11. T+36 FORECAST WINDSPEED
FINE-MESH MODEL D.T OOGMT 14/12/86

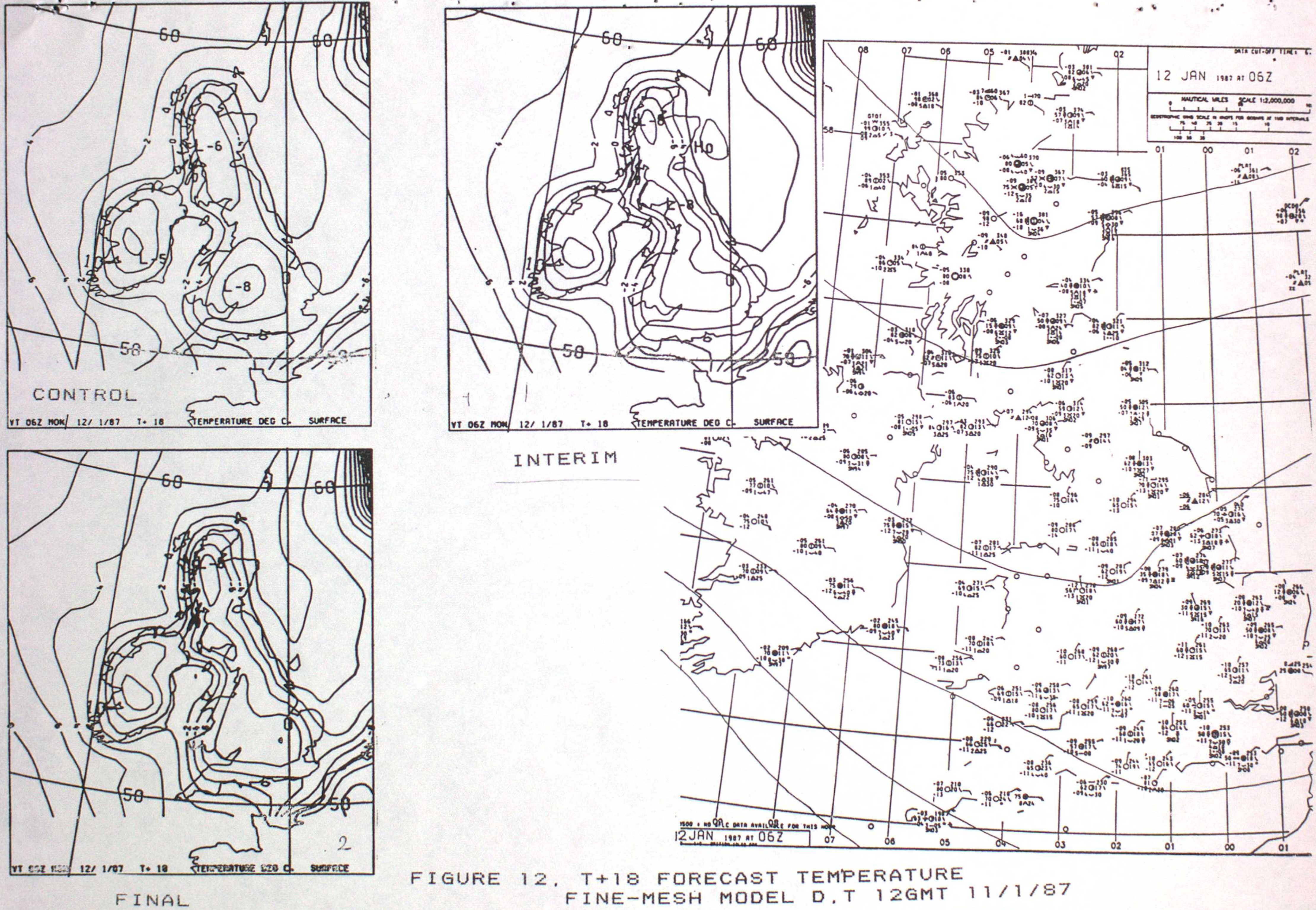
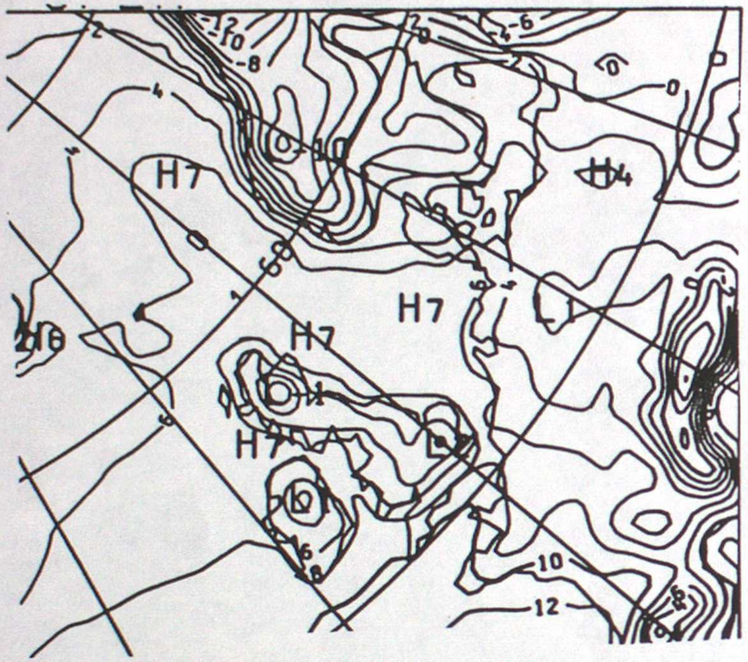


FIGURE 12. T+18 FORECAST TEMPERATURE
FINE-MESH MODEL D.T 12GMT 11/1/87



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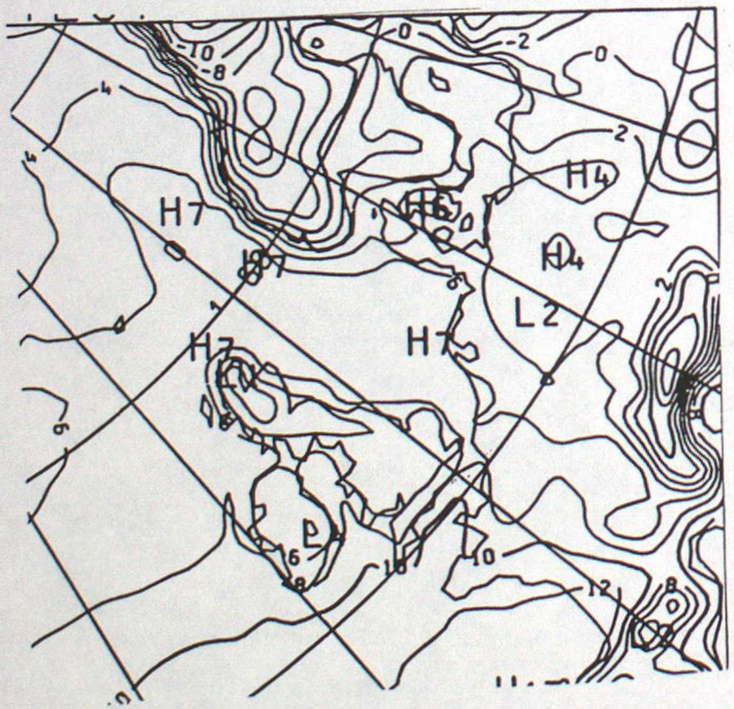


FINAL

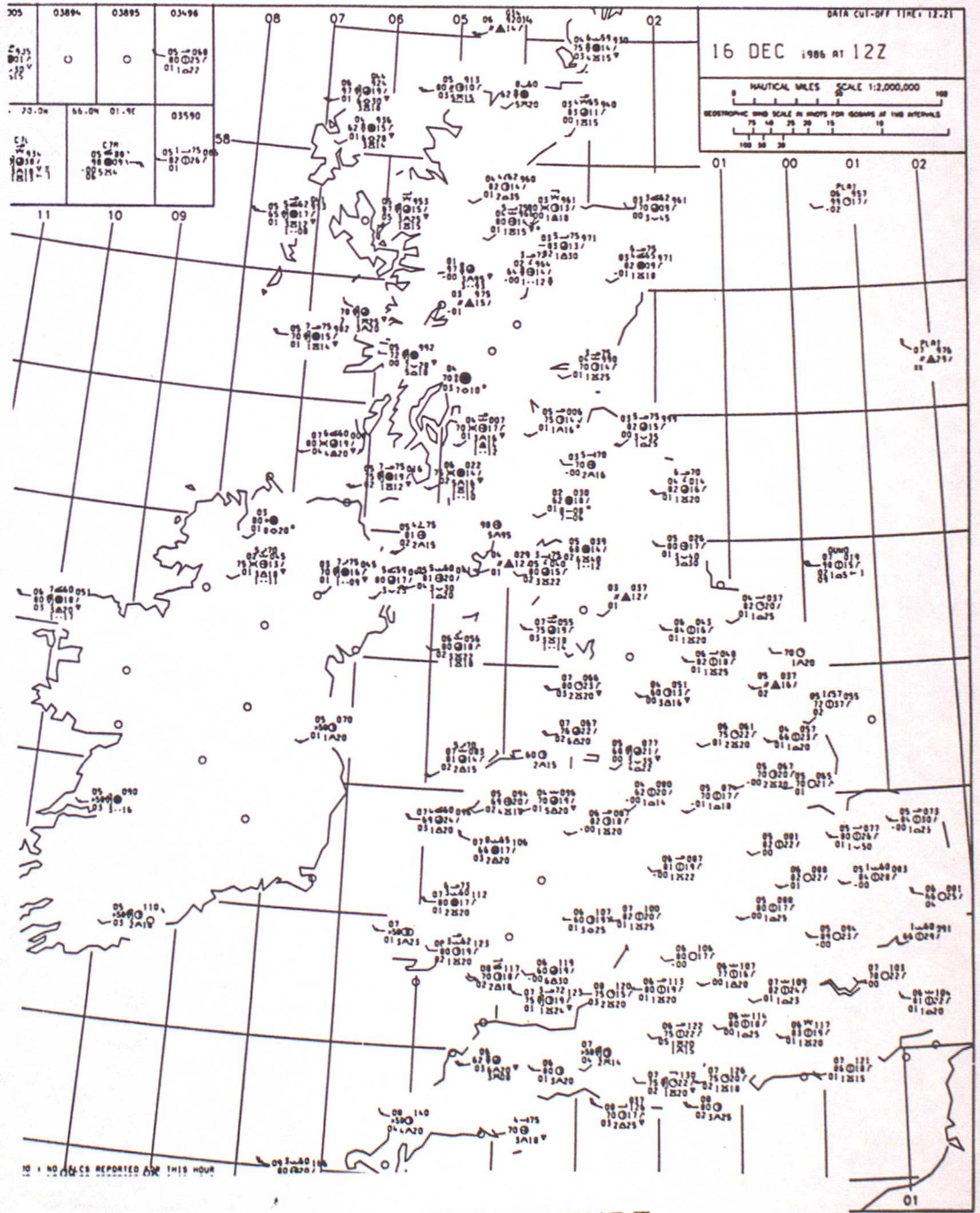
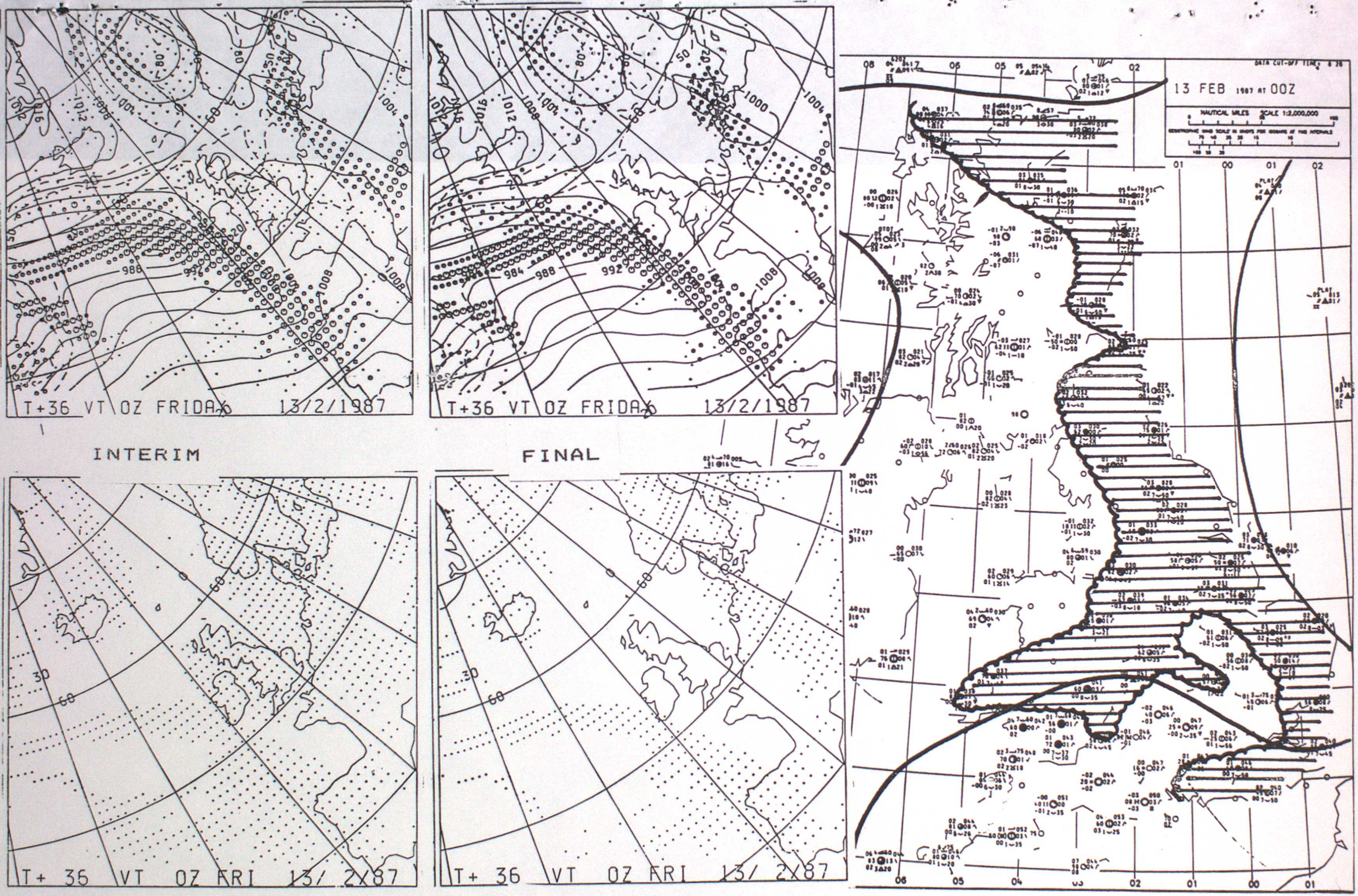


FIGURE 13. T+12 FORECAST TEMPERATURE
FINE-MESH MODEL D.T OOGMT 16/12/86



INTERIM

FINAL

FIGURE 14. T+36 FORECAST RAINFALL RATE,
PRESSURE AT MSL, LOW CLOUD AMOUNT
FINE-MESH MODEL D.T 12GMT 11/2/87

FIGURE 15. T+24 FINE-MESH MODEL TEPHIGRAMS
FINE-MESH MODEL D.T 12GMT 11/2/87

DT 12Z 11/2/87 VT 12Z 12/2/87

FINE MESH GRID POINT
X=84 Y=36 - 53.2N 2.8W

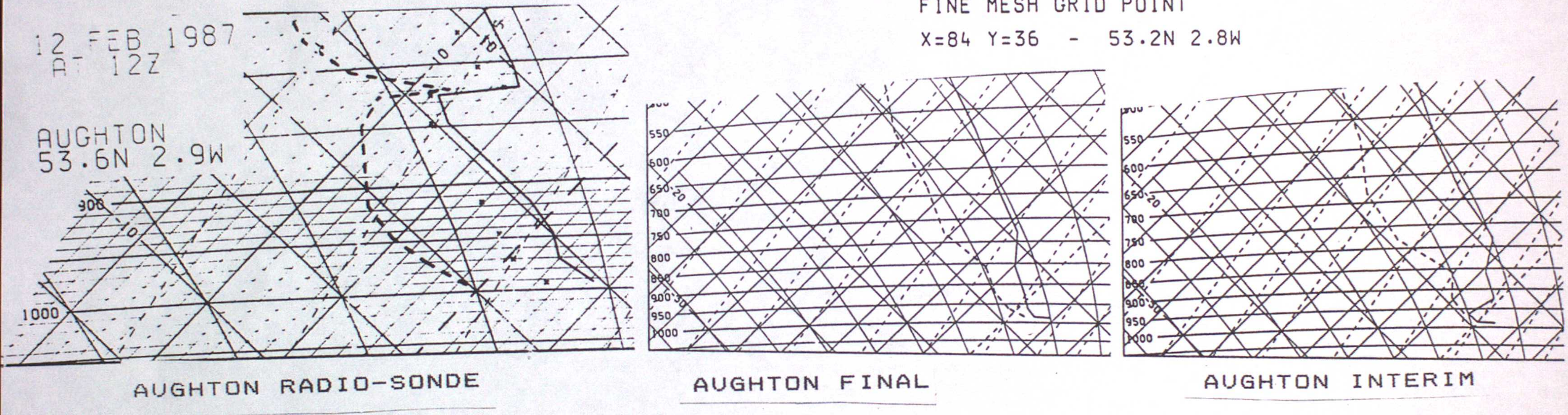
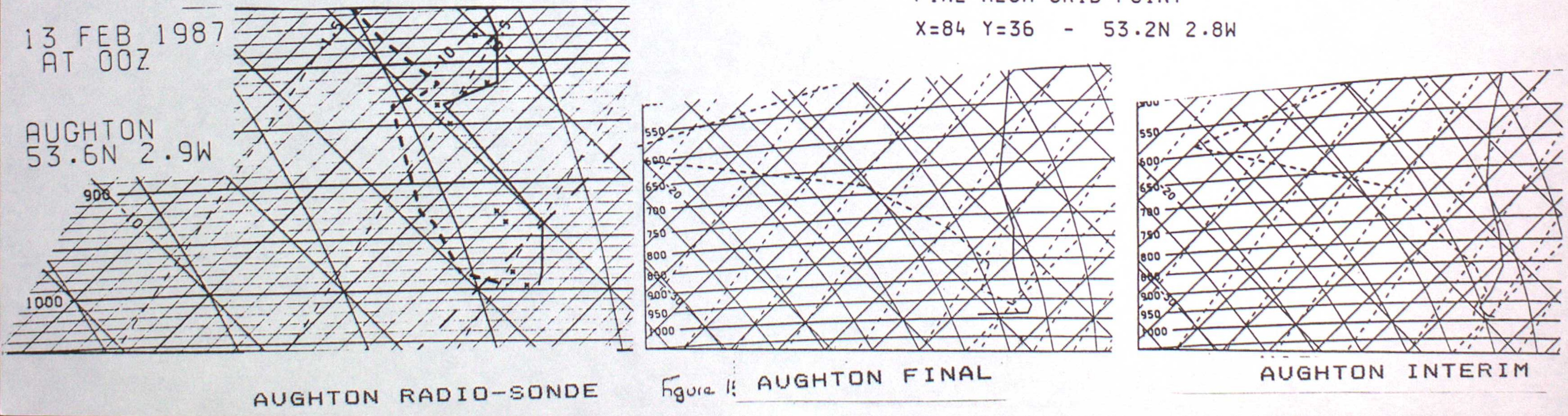
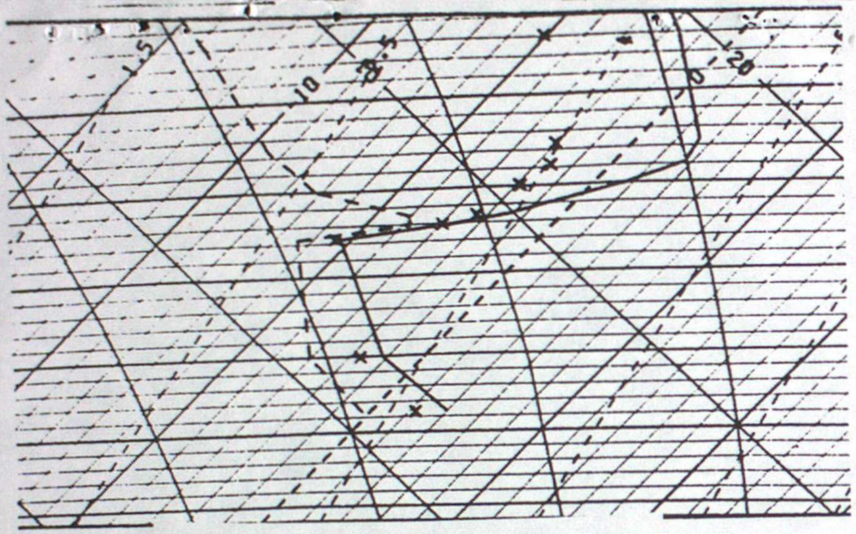


FIGURE 15. T+36 FINE-MESH MODEL TEPHIGRAMS
FINE-MESH MODEL D.T 12GMT 11/2/87

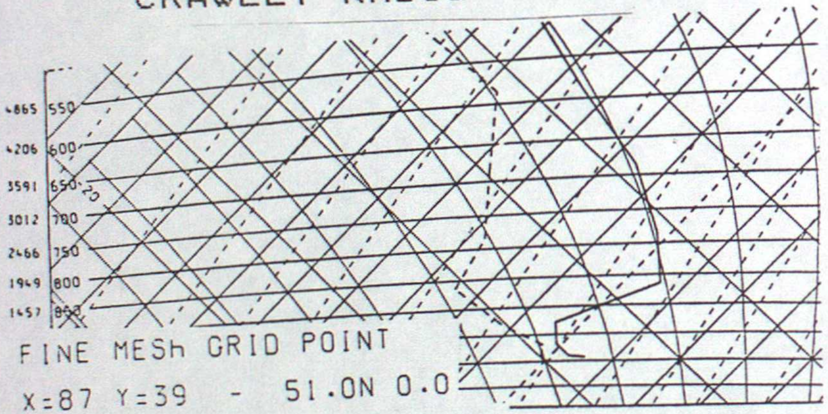
DT 12Z 11/2/87 VT 0Z 13/2/87

FINE MESH GRID POINT
X=84 Y=36 - 53.2N 2.8W





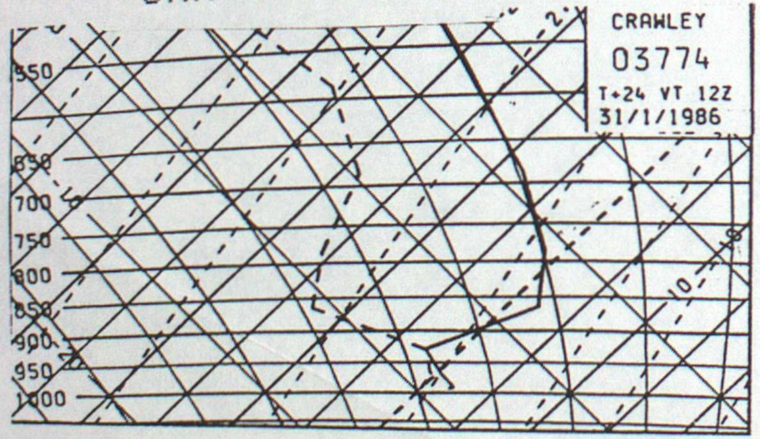
CRAWLEY RADIO-SONDE



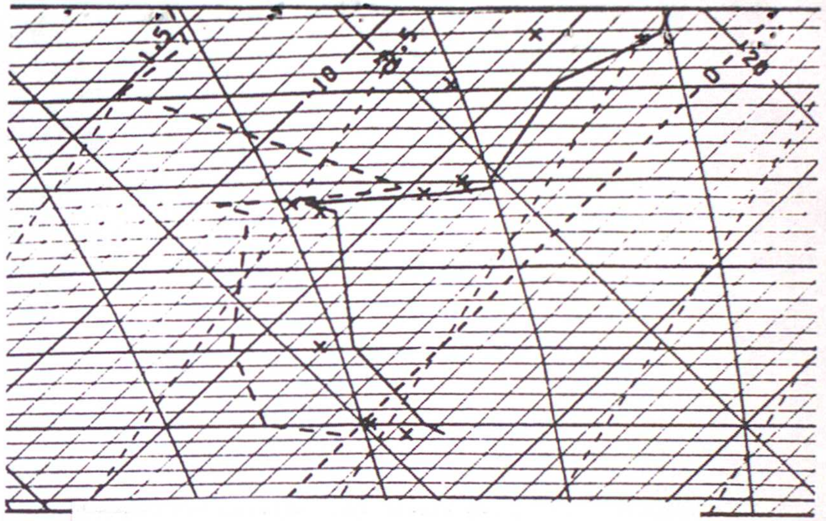
FINE MESh GRID POINT

X=87 Y=39 - 51.0N 0.0

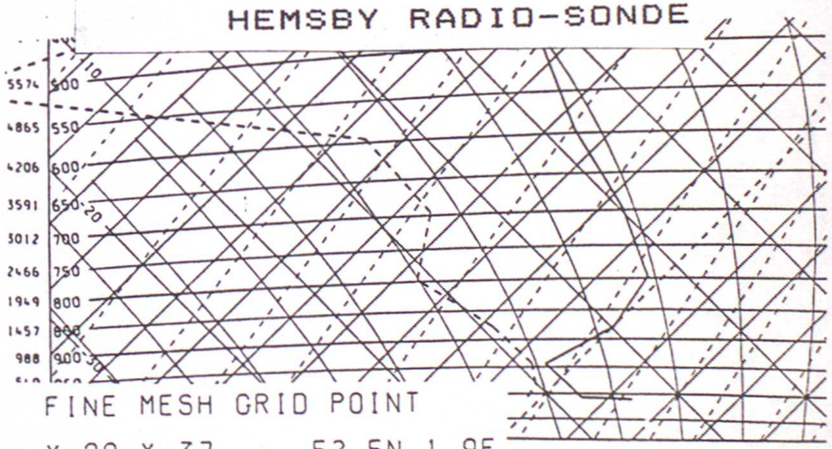
CRAWLEY FINAL



CRAWLEY CONTROL



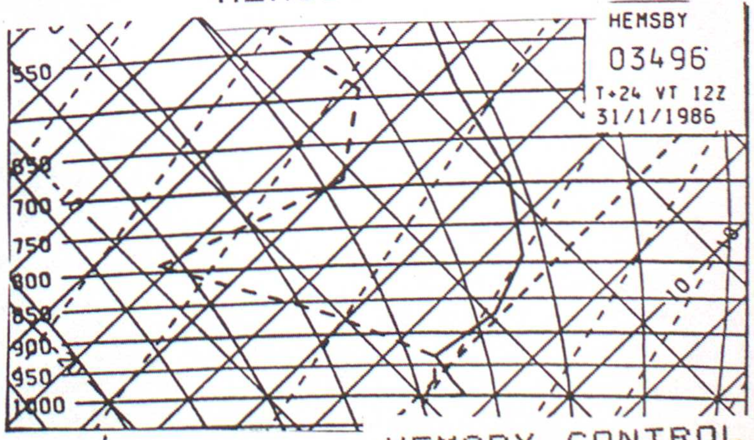
HEMSBY RADIO-SONDE



FINE MESH GRID POINT

X=89 Y=37 - 52.5N 1.9E

HEMSBY FINAL



HEMSBY CONTROL

FIGURE 16. T+24 FINE-MESH MODEL TEPHIGRAMS
FINE-MESH MODEL D.T 12GMT 30/1/86