# Forecasting Research

Met O 11 Technical Note No. 20

## Improvements to low cloud forecasts from the mesoscale and fine-mesh models

by

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## IMPROVEMENTS TO LOW CLOUD FORECASTS FROM THE MESOSCALE AND FINE-MESH MODELS.

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## IMPROVEMENTS TO LOW CLOUD FORECASTS IN THE MESOSCALE AND FINE-MESH MODELS.

### 1. INTRODUCTION.

This note describes attempts to improve two poor model forecasts of the amounts of low cloud in anticyclonic conditions. The persistence or dispersal of a layer of stratocumulus overnight is often critical for the possibility of frost. The current version of the fine-mesh model is poor at forecasting low cloud unless it is associated with an active frontal system. In particular, it is poor at predicting the persistence of a layer of stratocumulus beneath a sharp inversion associated with an anticyclone, partly due to dryness and partly due to insufficient vertical resolution in the model boundary layer. In these circumstances, the mesoscale model is expected to produce a more accurate forecast of low cloud. However, the current version of the mesoscale model operates over a small area not much bigger than the British Isles. Hence when advection is important, the model's prediction of low cloud may be affected adversely by the advection of dry air across the boundaries from the fine-mesh model forecast.

Two cases of persistent stratocumulus are investigated in this note (*DT12GMT 4/11/87 and DT12GMT 5/4/88*). The synoptic situation was similar in both cases with an anticyclone centred over Northern England and the North Sea and a fresh easterly airsteam over Southern England. In both cases a layer of stratocumulus persisted over Southern England overnight but was poorly predicted by both models. This note is concerned with describing possible modifications to both models to improve the accuracy of these low cloud forecasts.

A third case (DT12GMT 11/02/87), in which the prediction of low cloud was important, was included as an extra check on proposed fine-mesh model cloud changes.

### 2. MODIFICATIONS TO THE MESOSCALE AND FINE-MESH MODELS.

The following modifications to the fine-mesh and mesoscale model suites were used.

#### 2.1) The fine-mesh model.

The cloud fraction used in the fine-mesh radiation scheme depends upon the relative humidity according to the algorithm;

$$Q = ( U - U_{CRIT} )^2 / ( 1 - U_{CRIT} )^2$$

where $Q$ = cloud fraction,
$U$ = model relative humidity,
$U_{CRIT}$ = 0.85

The total amount of low cloud is the maximum found in levels 2,3 or 4.

Two schemes were proposed to improve fine-mesh low cloud forecasts. These are described below.

a) To improve the humidity in the boundary layer by amending the initial moisture fields in the fine-mesh model.

This was done by increasing the relative humidity to 95-100% at the relevant low cloud levels in the analysis. The technique of increasing the initial relative humidity by 'painting over' the original values has been described fully in another paper by Bell and Hammon[1].

b) To relocate the clouds to occupy model levels rather than between levels as in the current version.

The current operational scheme is unsatisfactory since the cloud is assumed to straddle two model layers and so the radiation changes affect two model levels. At the bottom level there is a net warming below the cloud base which tends to decrease relative humidity and therefore cloud amounts. At the upper level, which is usually above the model inversion, there is a net cooling which may tend to weaken the inversion.

In the modified scheme, the cloud is assumed to occupy one level only. The combined radiation effect should be a net cooling below the inversion which should lead to increased relative humidity and cloud. This modification was first tried operationally for a brief period during February and March 1987. However, it produced large areas of spurious rainfall with unsatisfactory results. This was due to cloud at level 2 causing excessive cooling to produce a saturated layer and hence precipitation. The realistic cooling was not compensated by convection or boundary level fluxes since, operationally, convection between levels 1 and 2 is not allowed and boundary layer mixing of heat and moisture is excluded under unstable conditions. The modification was removed whilst the problem was investigated. The following changes have now been made to the coding (Wilson and Slingo, 1988 [2]);

i) corrections made to the interactive radiation scheme;

ii) diffusion of temperature occurs at the cloud top with a coefficient proportional to cloud amount;

iii) the boundary layer scheme operates in unstable conditions as well as stable;

iv) convection starts from level 1;

v) option to use the lapse rate formulation to check for low cloud.

In this formulation low cloud amount depends upon the strength of the inversion ($\Delta\theta / \Delta p$) and the relative humidity at the base of the inversion ($U_{base}$).

$Q' = -16.67\ \Delta\theta / \Delta p - 1.167$ for $\Delta\theta / \Delta p < 0.07$

$Q = Q'$ if $U_{base} > 0.8$

$Q = Q'\ (0.8 - U_{base}) / 0.2$ for $0.6 < U_{base} < 0.8$

$Q = 0.0$ otherwise.

The modifications described above were tried on three cases and the results are described in section 3.

2.2) The mesoscale model.

The mesoscale model differs from the fine-mesh model in that cloud water / ice is retained in the model as an additional variable at all model levels. The total water (i.e. vapour plus cloud water / ice) is predicted at each model time-step. Grid scale cloud and precipitation is descibed in Met.O.11 Documentation Paper No.12.[3] The division between water vapour and cloud water / ice allows for partial cloudiness over a grid box, as representated by a cloud fraction variable. The diagnosis of cloud water / ice from the total water depends on the relative humidity and the turbulence scheme of the model, as described in Met.O.11 Documentation Paper No.9.[4]. A correction to the turbulence and vertical diffusion schemes, implemented in March 1988 made a marked improvement to the accuracy of the model's cloud base predictions. The assessment of the impact of this correction on the model has been described by Ballard and Hammon[5]. Because of the importance of this change, the operational mesocale model forecast for the case (*DT12GMT 04/11/87*) was rerun using an updated version containing the correction.

In the two stratocumulus cases assessed, the accuracy of the mesoscale model's low cloud forecasts was affected by dry air being advected through the eastern boundary from the fine-mesh. We therefore decided to move the model area further east to test the impact of an increased number of observations and also the use of satellite data.

The ideal solution for the two stratocumulus cases would have been to move the eastern boundary to 10 degrees east to allow for a 20KT low level easterly advection across Southern England. However, with the limitations of the current version of the model, it was not possible to have a sufficiently large area to cover both the U.K and the continent to 10 degrees east. Also, even when the ETA[10] becomes operational, the enlarged mesoscale model area will still only extend to 5 degrees east. Because of these reasons, the eastern boundary was set at 5 degrees east for the test forecasts. Both cases were rerun over the new area and the results are described in section 3.

For the mesoscale model, the forecast of the low cloud base is as important as the cloud amount. Therefore the description of the mesoscale model forecasts and analyses concentrates on charts giving both the low cloud base and also the amount in octas. The 'N.H' code used in the charts is explained here.

N = total cover of cloud in octas below 6500 feet / 2000 metres
H = WMO code for cloud base

The mesoscale model 'H' code is obtained from the lowest model level with 3 or more octas of low cloud cover. The 'H' code is explained in Table 1 below . Also given are the model levels and height and the associated model layer thickness which are used to forecast a given 'H' code.

TABLE 1. LOW CLOUD BASE 'H' CODE

| H code | Meaning | Derivation in the Mesoscale Model | | |
|---|---|---|---|---|
| H | Cloud Base in feet | Cloud at model level | ( ht ft) | Cloud in model layer range in feet |
| 1 | < 300 | 1 | ( 33 ) | 0 - 197 |
| 3 | < 1000 | 2 | ( 361 ) | 197 - 689 |
| 4 | < 2000 | 3 | ( 1017 ) | 689 - 1509 |
| 5 | < 3000 | 4 | ( 2001 ) | 1509 - 2657 |
| 6 | < 5000 | 5 | ( 3314 ) | 2657 - 4134 |
| 7 | > 5000 | 6 | ( 4954 ) | 4134 - 5938 |
| blank | < 3 octas of low cloud | | | |

e.g. A code figure of 83 means 8 octas of low cloud, base below 1000 feet.

## 3. CASE STUDIES.

### 3.1 DT12 GMT 11/02/87

This case is an example chosen from the brief, ill-fated operational period in February and March 1987 during which the fine-mesh model clouds were located at model levels rather than between. It illustrates well the problems of the excessive cooling in cloud because of inaccuracies in the radiation scheme at that time. It was therefore important to rerun this case as a check on the current improved version of this change.

At 12 GMT 11/02/87, a slack low pressure area covered the British Isles giving overcast weather with rain and low cloud. These conditions gradually moved away eastwards with pressure building in the west. By T+36 , 00 GMT 13/02/87, a ridge of high pressure had become established giving dry conditions in most places although a few spots of rain still lingered over East Anglia. Figure 1 shows the observed cloud amounts at 00GMT 13/02/87. with the shaded area indicating a low cloud cover of 4 octas or more. A good deal of cloud still persisted near the east coast and over high ground in Wales and North-west England but elsewhere the cloud was dispersing.

The original operational fine-mesh model forecast run from DT12GMT 11/02/87 predicted the rain and low cloud correctly in the early part of the forecast period. However, the forecast retained the low cloud throughout the period and for T+36, verification time 00 GMT 13/02/87, the model predicted overcast conditions with widespread light snow over the British Isles. The cloud and precipitation forecast is shown in Figure 2. The poor forecast was caused by excessive cooling in the cloud in the lowest layers of the model.

A rerun using the current operational version ( post May 1987) of the fine-mesh model forecast the dry weather in the ridge at T+36 correctly but was too dry in the boundary layer and hence cleared the cloud completely. The low cloud and precipitation forecast for T+36 from this rerun is shown in Figure 3.

A third forecast, this time using the modifications described in 2.1b was tried. The resulting low cloud and precipitation forecast for T+36 is shown in Figure 4. This forecast maintained much of the low cloud but predicted the dry weather correctly. Although this was the best forecast of the three fine-mesh versions, the predicted low cloud was slightly too widespread especially over Central England. The boundary layer differences between the versions are illustrated in Figure 5, which compares the T+36 model profiles for Aughton with the radio-sonde ascent for 00GMT 13/02/87. The Aughton radio-sonde ascent (Figure 5d) had a moist layer at the inversion at 840mb which agrees with the observed cloud base of 4500 feet at Manchester. The best representation of this layer is given by the test forecast (Figure 5c) using the new cloud modifications. The original operational version, Figure 5a, was too cold and moist at 960mb showing that the forecast light snow was falling from a very shallow but saturated layer. The forecast ascent from the current operational version (Figure 5b) was better but slightly too dry at 850mb.

3.2 DT12 GMT 05/04/88 .

This case was chosen for study after C.F.O criticized the mesoscale model overnight low cloud forecast for Southeast England.

During this period an anticyclone remained slow-moving over Northern England and the North Sea, keeping an easterly airstream over Southern England. The analysis for 12GMT 05/04/88 is shown in Figure 6. A correct forecast of the cloud cover overland during the night was important because of the risk of frost if the cloud dispersed. Both the mesoscale and fine-mesh models predicted mainly clear skies for Southern England overnight with temperatures falling to around zero degrees Celsius. In reality, the stratocumulus cloud cover persisted over the Midlands, Southern and Central England and temperatures remained at about plus 4 degrees Celsius.

Around the initial time 12 GMT 05/04/88, satellite imagery showed an extensive layer of stratocumulus extending from South-eastern England into the North Sea with more broken cloud over the continent. The extent of the low cloud at 1526GMT is shown by the visual satellite image in Figure 7. From observations and ascents at 12GMT the base of the cloud was generally between 1500 and 2000 feet with the tops 3000 feet.

i) Fine-mesh forecasts DT 12 GMT 05/04/88.

In the operational fine-mesh cloud analysis for 12GMT, shown in Figure 8b, the extensive stratocumulus layer observed over Eastern England and the North Sea is missing. The analysed chart in Figure 8a shows that the model's relative humidity at 950mb (approximately the base of the low cloud) was too low to support cloud. Following from this poor cloud analysis, the fine-mesh predicted only small amounts of low cloud for the U.K overnight. In the T+18 forecast, (see Figure 8c) the fine-mesh model has predicted a little low cloud but not nearly as much as indicated by the verification chart Figure 9c. This chart, based on visual satellite imagery at 06GMT shows that most of England and Wales were covered by low cloud. Two attempts to improve the prediction of low cloud associated with the anticyclone were made.

a) Modification of the Analysis.

In the first attempt, we modified the model's 950mb analysis by increasing the relative humidity to 100% over Eastern England and the North Sea. The modified analysis is shown in Figure 8d. The forecast rerun from this modified analysis predicted more low cloud generally over the U.K and the North Sea. The T+18 forecast, (see Figure 8e) compares more favourably with the verification chart in Figure 9c.

b) Relocation of the clouds to occupy model levels rather than between levels as in the current operational version.

For the second rerun, we incorporated all the cloud modifications described in Para.2.1b into the forecast, but we did not redo the 4-cycle assimilation. Starting from the dry operational analysis meant that the cloud modifications took 6-12 hours to show any impact, so that the cloud forecast showed a similar cloud deficit to the operational forecast up to T+12. However, at T+18. the modified version predicted significantly more low cloud. The low cloud forecasts for T+18 from the operational and modified versions are compared in Figures 9a and 9b respectively. Although the cloud forecast from the modified version was an improvement, an undesirable side effect was the increase in the very small amounts of rain forecast around the anticyclone (see Figures 10 a-d). This is caused by the tendency of the fine-mesh to produce rain from a single saturated level.

ii) Mesoscale model forecasts DT 12 GMT 05/04/88.

The mesoscale model performs its own analysis of base and amount using all available observations. At 12GMT 05/04/88, satellite data was not yet being used in the interactive analysis. The operational mesoscale model cloud analysis is shown in Figure 11a. The analysis is good over land but there is a deficit of cloud over the North Sea. The mesoscale model is dependent upon the fine-mesh model for boundary updates. On this occasion, this had most importance over Southern and Central areas of the U.K, where there was a 20KT easterly advection of low cloud. Consequently the mesoscale model forecast soon lost all cloud over these areas due mainly to dry advection from the boundaries from the fine-mesh. The T+12 and T+18 forecasts, verifying at 00GMT and 06GMT 06/04/88 are shown in Figures 12a and 13a respectively. Although the model has predicted some cloud in the south, it has no cloud at all over East Anglia, Lincolnshire and the Midlands. An attempt to improve the cloud forecast was made by running the model over the eastern area described in Para 2.2.

One disadvantage of using a more eastern area was that no hybrid analysis was available so the analysis had to be done using the fine-mesh plus observations. However, this was countered by the advantage of using extra observations and satellite data over the North Sea, Holland, Belgium and North France in the analysis of cloud for 12 GMT. Satellite data supplies cloud cover and cloud top temperatures. In the analysis, the meteosat I.R. digital data, combined with model temperature profiles and surface temperatures, gives the total cloud cover and cloud top analysis. The base is obtained from observations or from the background in the absence of observations. The new analysis over the eastern area is shown in Figure 11b. In Figure 12, we can compare the T+12 forecast from this new analysis (12b) with the operational forecast.(12a) The new forecast has greatly improved the low cloud forecast south of the Humber although the cloud base is too low near the east coast. in particular, the area of predicted low stratus and fog (indicated by the N.H. code Figure 81) approaching the Thames estuary is incorrect. This may be due to problems with determining the initial cloud top from the I.R. temperatures. Nevertheless, extending the mesoscale model forecast area further east has made an improvement to the T+12 cloud forecast over Southern England. In Figures 13 a and b, we compare the two versions at T+18 with the observed cloud shown in Figure 14. The forecast from the eastern analysis (Figure 13b) has predicted more cloud, especially over Lincolnshire, East Anglia and the Midlands, but the area of fog and low stratus predicted over South-east England is incorrect. The improvement in the forecast due to the extra observations in the analysis ,gained by extending the eastern boundary to 5 degrees east, was confined to the first 12 hours. Thereafter, the forecast accuracy diminished because of the fine-mesh influence.

3.3 DT12 GMT 04/11/87 .

The synoptic situation at 12GMT 04/11/87 is shown in Figure 15. A ridge of high pressure extended across Northern England eastwards into Germany. The shaded area indicates a low cloud cover of 4 octas or more. The shading over the North Sea has been drawn with the aid of visual satellite imagery. The area of interest again was Southern England. Over Scotland and Northern England, the winds were very light but across Southern England there was an easterly advection of approximately 20 KT from the continent. Figure 15 shows a narrow band of cloud extending upwind of Southern England across Holland and Germany. The problem was whether the low cloud cover would persist or break overnight. The cloud sheet over Southern England at 12GMT 04/11/87 was at least 1000 feet thick, with a base of 2000 feet and tops 3000 feet, but over the continent the cloud layer was thin and located beneath a sharp inversion at 1500-2000 feet. Across Southern England the cloud sheet persisted through most of the night, although a clearance spread into Kent and Sussex late in the night. Figures 16a and 16b show the observed cloud cover at 00GMT and 06GMt respectively.

The initial cloud analysis for the Mesoscale model is shown in Figure 17a. The model multilevel cloud analysis assisted by intervention over the North Sea achieved a fairly accurate cloud picture for 12GMT, although rather too much cloud has been added to the Northern North Sea. The fine-mesh model initial cloud analsis (shown in Figure 17b) in contrast is very deficient in low cloud, with little or no low cloud over the U.K., the North Sea or the continent. This is not surprising since the low cloud was thin and tucked beneath a sharp inversion which the fine-mesh model is not capable of resolving. In Figure 18, we compare the radio-sonde ascent for 12GMT at Hemsby with the Fine-mesh model T+0 ascent for 12GMT at the nearest grid-point to Hemsby. In the model ascent, the inversion is spread over a depth of 150mb from 960mb to 810mb and the model boundary layer is too dry to support cloud.

In Figure 19, we can compare the low cloud forecasts at T+12, verifying time 00GMT and T+24, verifying time 12GMT 05/11/87 from three fine-mesh model forecasts. Figure 19a shows the operational forecast with little or no low cloud in the relevant areas. Figure 19b shows the low cloud forecast from a modified analysis with extra moisture added at level 2 to represent the observed low cloud area at 12GMT. The relative humidity was added to level 2 (approx. 700 feet) rather than level 3 (approx. 1500-2000 feet) which would have been closer to observed cloud bases, in order to fit in with the model inversion. In this case, the increased moisture has made very little improvement to the low cloud forecast over the U.K.. In the forecast shown in Figure 19c, the low cloud has been relocated at model levels. The T+12 forecast still shows a deficit over the U.K but this is probably the result of starting from a cloud deficient analysis. By T+24 however. the forecast low cloud has increased significantly over the North Sea and U.K.. On the whole this is the best forecast, although too much cloud has been forecast over Southern England.

For the mesoscale model, the operational forecast was first rerun over the standard area using the latest version of the model (post March 1988). This was done to take advantage of the improvement to the model's prediction of low cloud following the correction to the turbulence / diffusion scheme. The forecast was also rerun over the eastern area as before. The initial cloud analysis was carried out with observations analysed on to a fine-mesh background field since no hybrid analysis was available for the eastern area. No satellite data was used in the analysis on this occasion because of difficulties in calibrating it accurately but several observations were available for the North Sea. The resulting analysis is shown in Figure 20. The weather and low cloud forecast for T+12, verifying at 00GMT 05/11/87, from the standard mesoscale model run is shown in Figure 21a. If this is compared with the observations for 00GMT (see Figure 16a), then we can see that the model forecast has predicted clear skies incorrectly over South-east and Central England. This is due to dry air being advected over the eastern boundary from the fine-mesh. In the clear areas model temperatures have fallen too low to 4-6 degrees Celsius and fog has been predicted wrongly. Figure 21b shows the weather and low cloud forecast from the model rerun starting from the eastern area analysis. This is a more accurate forecast with more low cloud predicted over East Anglia and the Midlands, although the cloud clearance has reached the extreme southeast too early. The forecast temperatures are more accurate and less erroneous fog has been predicted.

## 4. CONCLUSIONS.

### 1. FINE-MESH MODEL

a) The relocation of model cloud at sigma levels rather than in between resulted in a significant increase of low cloud predicted by the model. Figure 22 shows the percentages of low cloud forecast by the operational and modified fine-mesh versions. The modified version shows a 10-15 percentage increase of low cloud. In the three cases rerun, the modified version produced the better low cloud forecast. However, an undesirable increase in the amount of spurious light rain predicted in anticyclones needs to be removed before a full trial can be considered. This spurious rain is produced only from a single saturated layer, but accumulations can total 1mm in six hours. An increased diffusion at cloud top would alleviate this problem.

b) Improving the analysis by increasing the relative humidity at the sigma level closest to observed cloud bases and then rerunning the forecast produced less predictable results. One of the cases tried (DT12GMT 05/04/88) produced better results whist the other (DT12GMT 04/11/87) did not.

The results from the fine-mesh forecasts are summarised briefly in Table 2 below.

TABLE 2

| | DT12Z 11/02/87 | DT12Z 05/04/88 | DT12Z 04/11/87 |
|---|---|---|---|
| OPERATIONAL F.M ( FEB 87) | Spurious snow f/c T+36 in ridge | not applicable | not applicable |
| OPERATIONAL F.M ( CURRENT) | Correct dry f/c Too little cloud | Cloud deficit in anticyclone | Cloud deficit in anticyclone |
| TEST F.M (CLOUD AT σ LEVELS) | Correct dry f/c Increased cloud | Increased cloud f/c in anticyclone | Increased cloud f/c in anticyclone |
| F.M WITH RH BOGUSSING | Not tried | Increased cloud f/c up to T+36 | Little improvement |

## 2. MESOSCALE MODEL

In the two cases rerun advection of low cloud across Southern England was important. Relocating the eastern boundary at 5 degrees east resulted in improved low cloud forecasts up to T+12. Beyond this time, however, advection of dry air across the boundary from the fine-mesh still affected adversely the forecast of low cloud across Southern England. When the mesoscale model is run over the proposed larger area when the ETA[10] becomes available, improvements in the fine-mesh boundary layer will still be necessary. The results from the mesoscale model forecasts are summarised briefly in Table 3 below

TABLE 3

| | DT 12Z 05/04/88 | DT12Z 04/11/87 |
|---|---|---|
| CURRENT OPERATIONAL AREA | Too little low cloud f/c overnight for S.E. England | Too little low cloud f/c overnight for S.E. England |
| NEW EASTERN AREA | Improved low cloud f/c for S.E. England up to T+12 | Improved low cloud f/c for S.E. England up to T+12 |

*Acknowledgements*

I am grateful for help received from S.P. Ballard, W. Taylor and Dr. C.A. Wilson in the rerunning of the cases described in this note.

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4. B.W. Golding — Met.O.11 Mesoscale Model Documentation Paper No 9 November 1986. 'Turbulent Diffusion'

5. S.P. Ballard and O.M. Hammon — Met.O.11 Technical Note No.7. April 1988 'An Assessment of the Impact of a Correction to the Mesoscale Model Turbulence/Vertical Diffusion Scheme Implemented in March 1988'

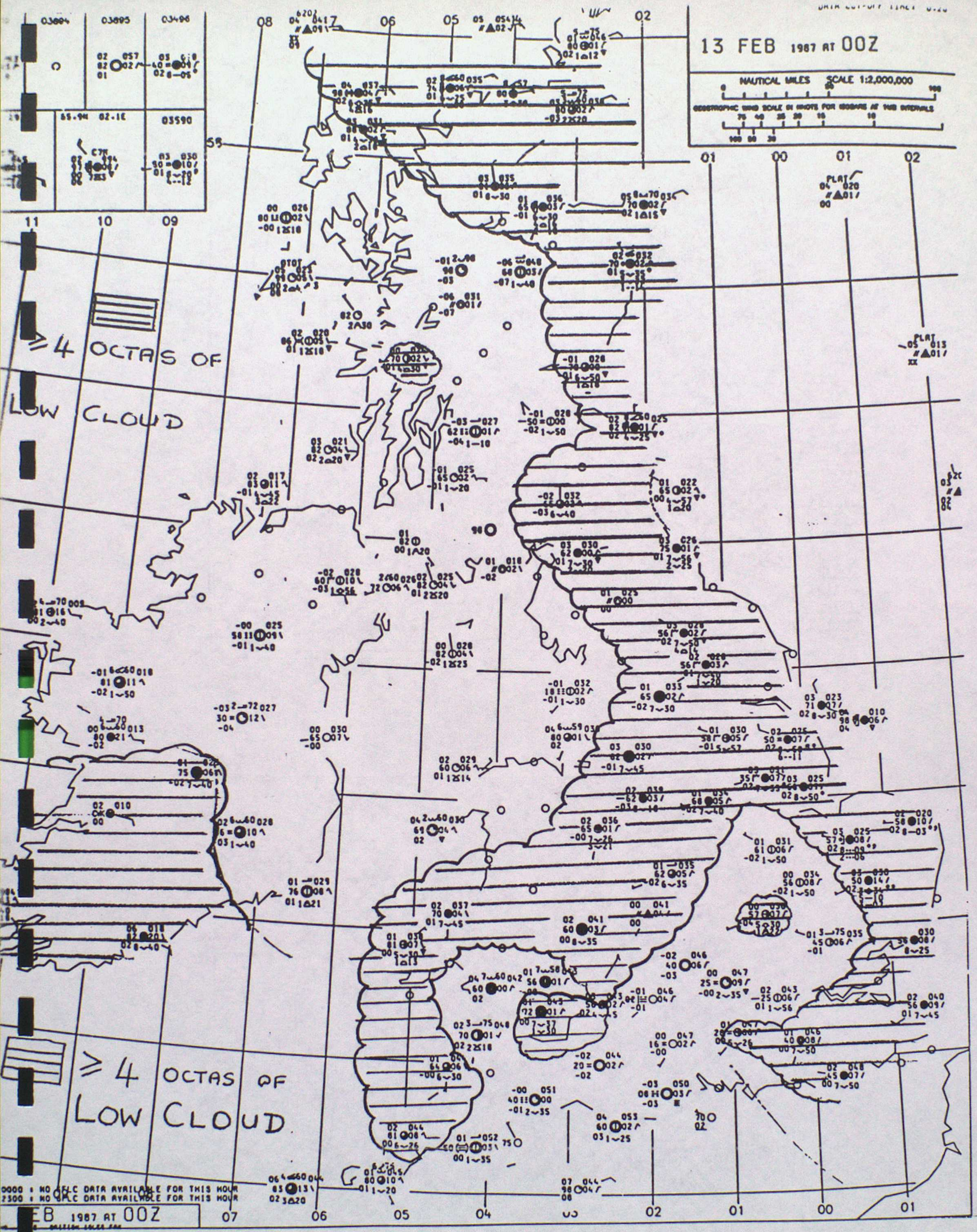



FIGURE 1. OBSERVATIONS FOR THE U.K AND EIRE

AT 00 GMT 13/02/87

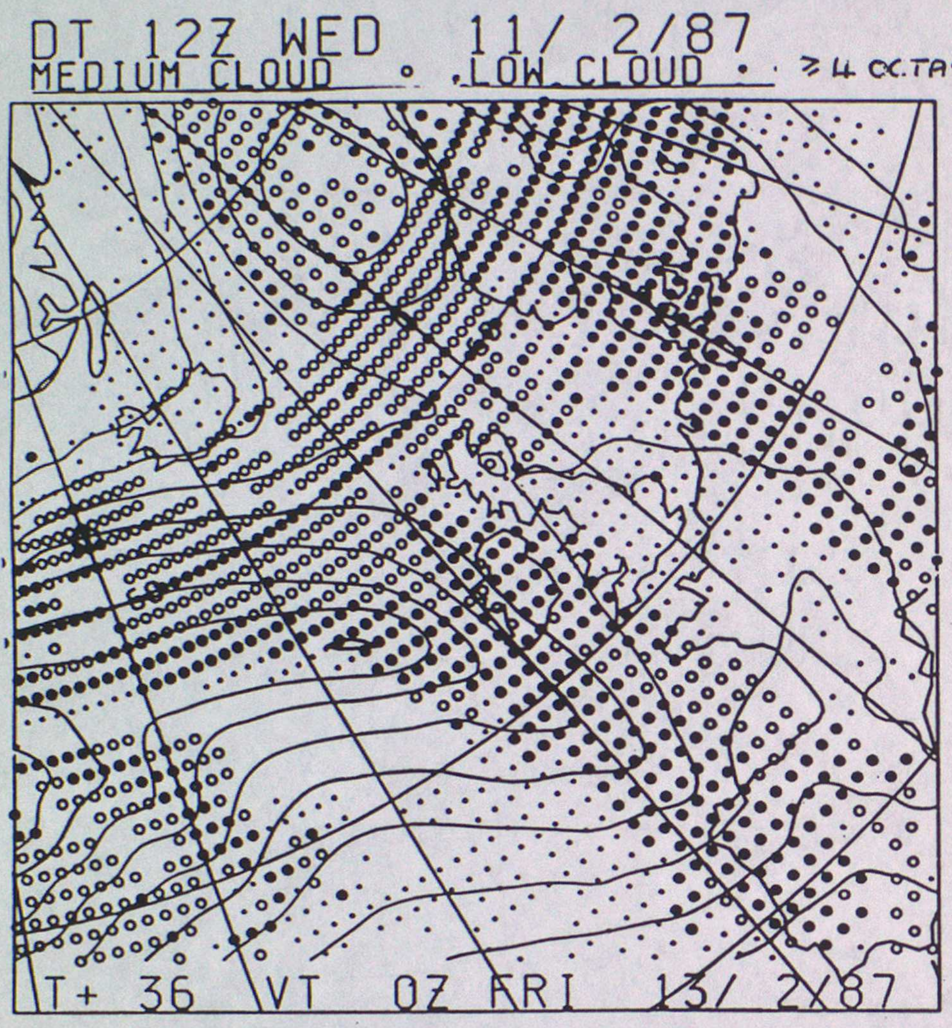



FIGURE 2a. THE ORIGINAL OPERATIONAL FINE-MESH CLOUD FORECAST FOR T+36, VERIFYING AT 00GMT, 13/02/87

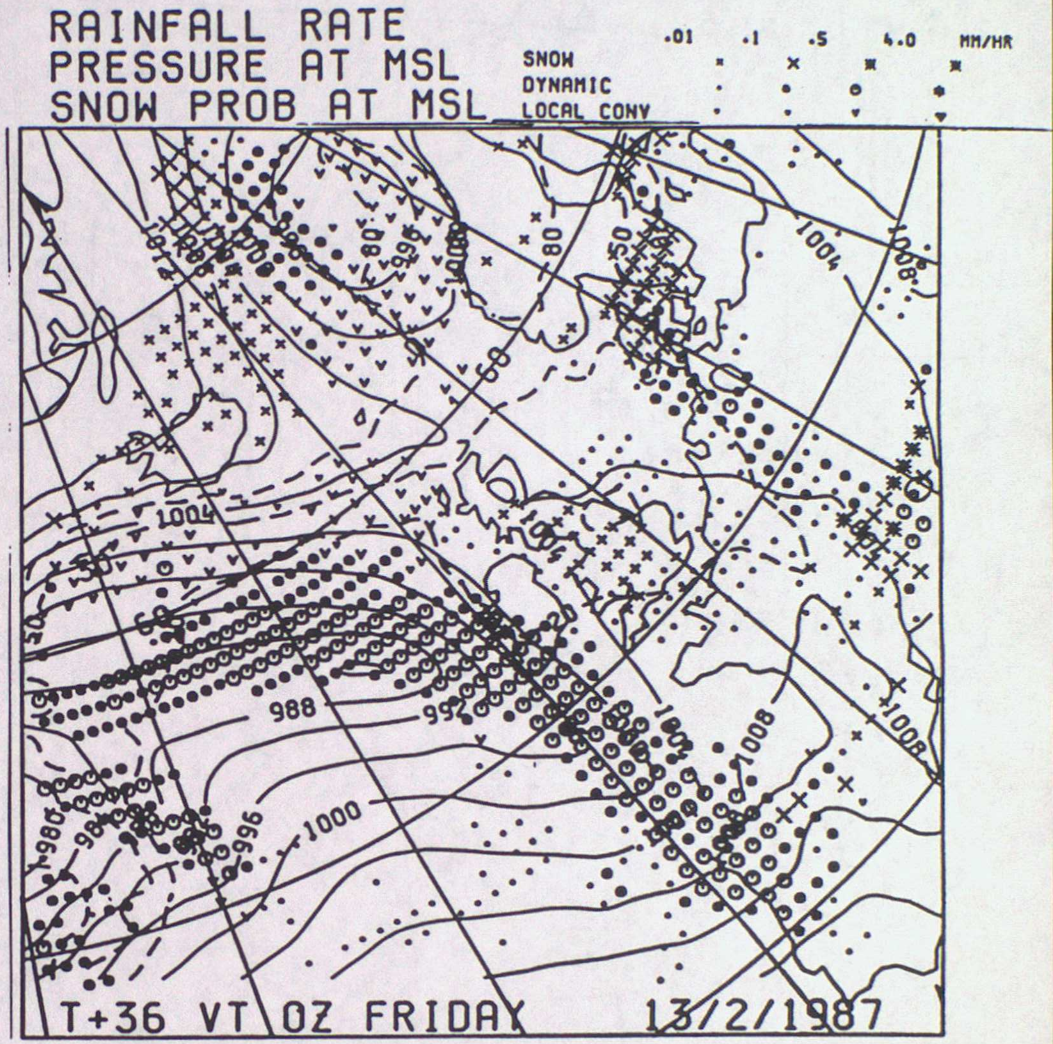



FIGURE 2b. THE ORIGINAL OPERATIONAL FINE-MESH T+36 PRECIPITATION FORECAST VERIFYING AT 00GMT 13/02/87

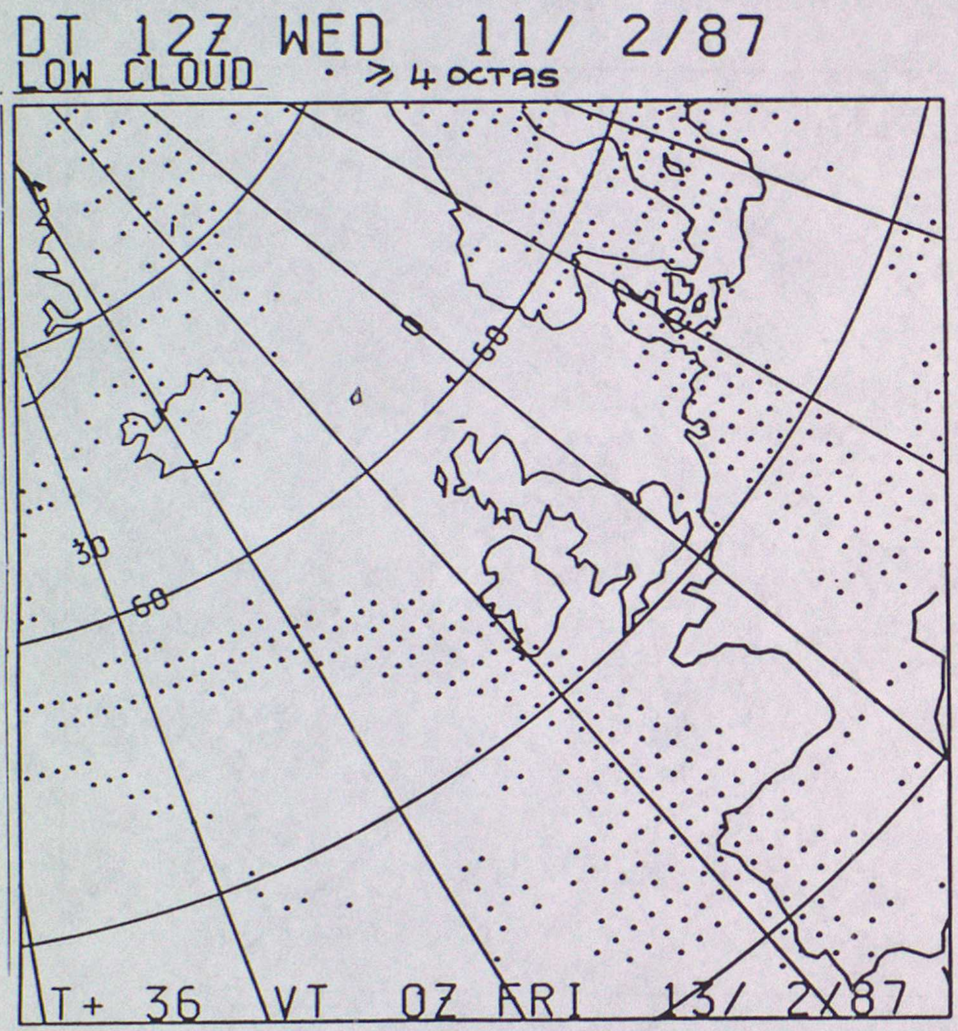



FIGURE 3a. THE CURRENT OPERATIONAL FINE-MESH CLOUD FORECAST FOR T+36, VERIFYING AT 00GMT, 13/02/87

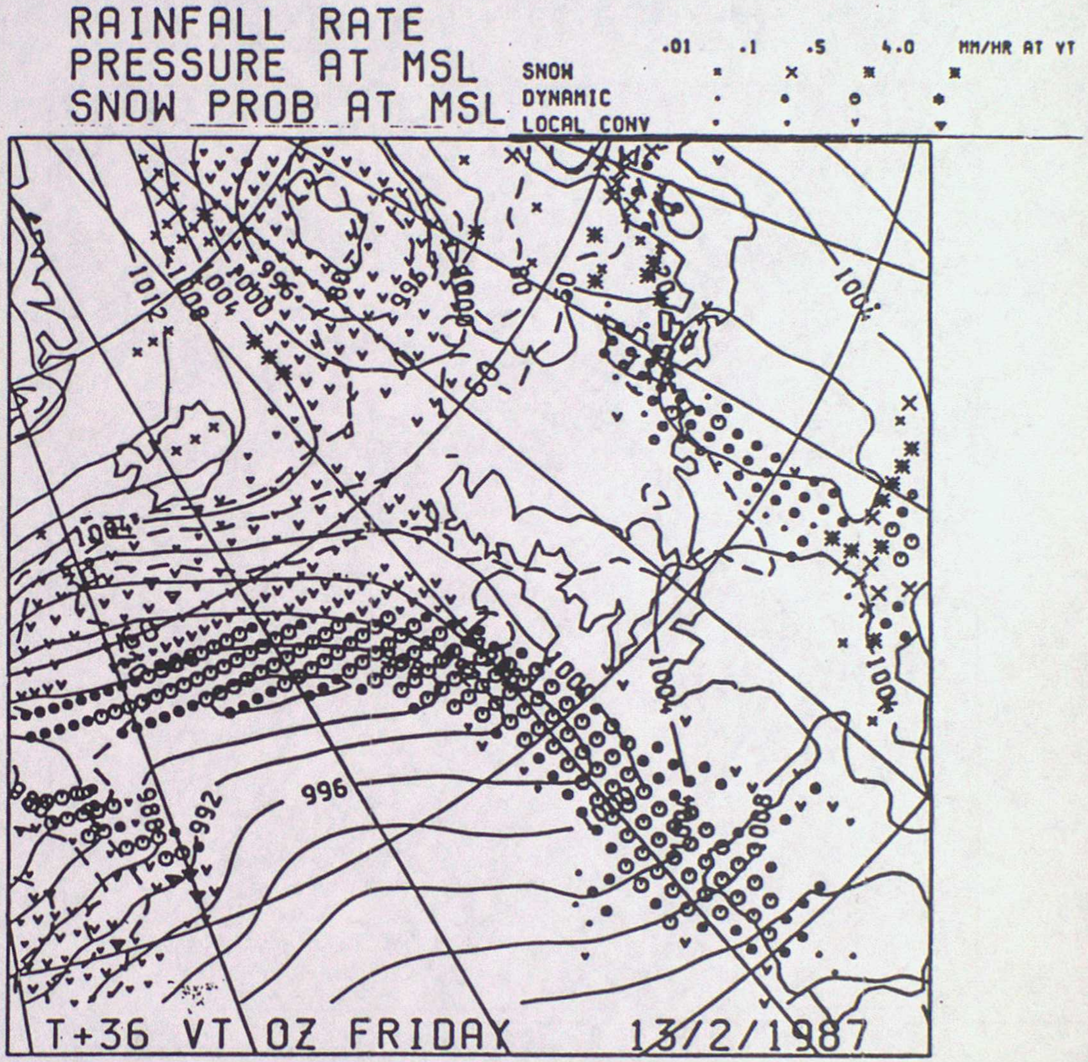



FIGURE 3b. THE CURRENT OPERATIONAL FINE-MESH T+36 PRECIPITATION FORECAST VERIFYING AT 00GMT 13/02/87

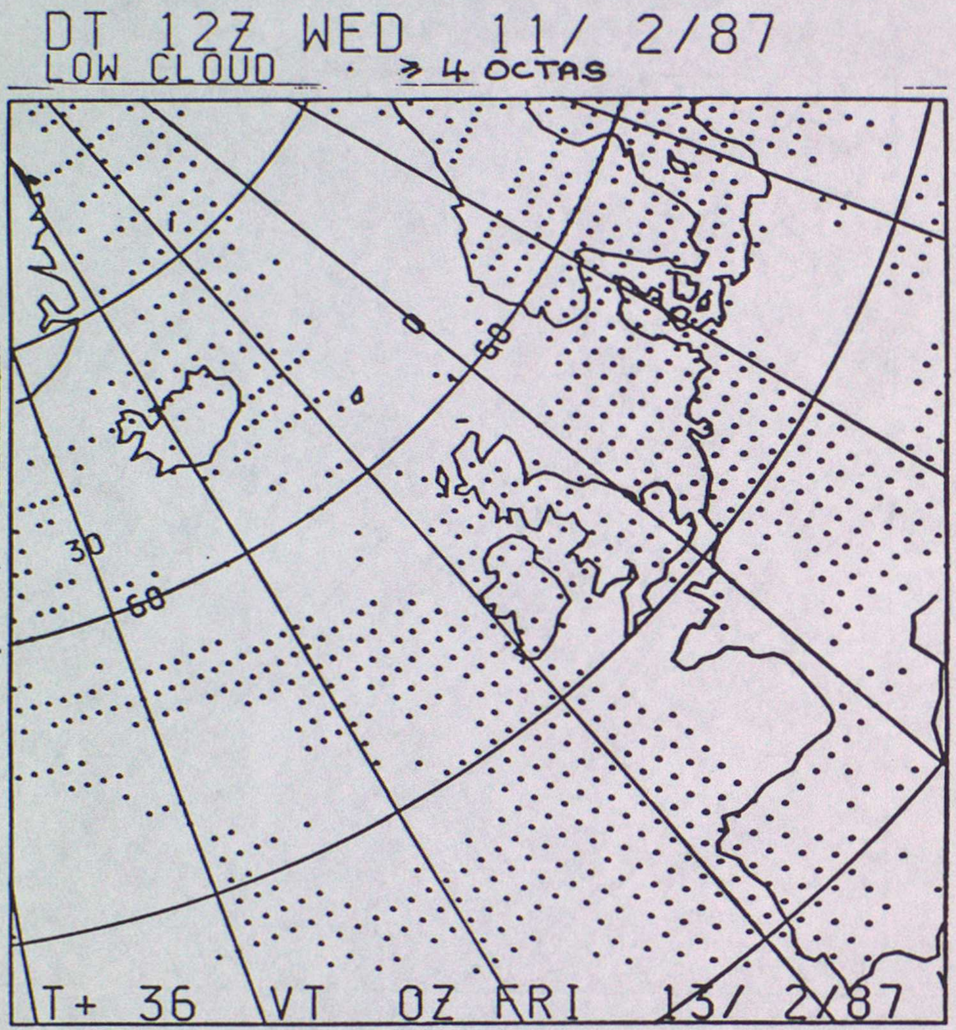



FIGURE 4a. THE MODIFIED FINE-MESH CLOUD FORECAST FOR T+36, VERIFYING AT 00GMT, 13/02/87

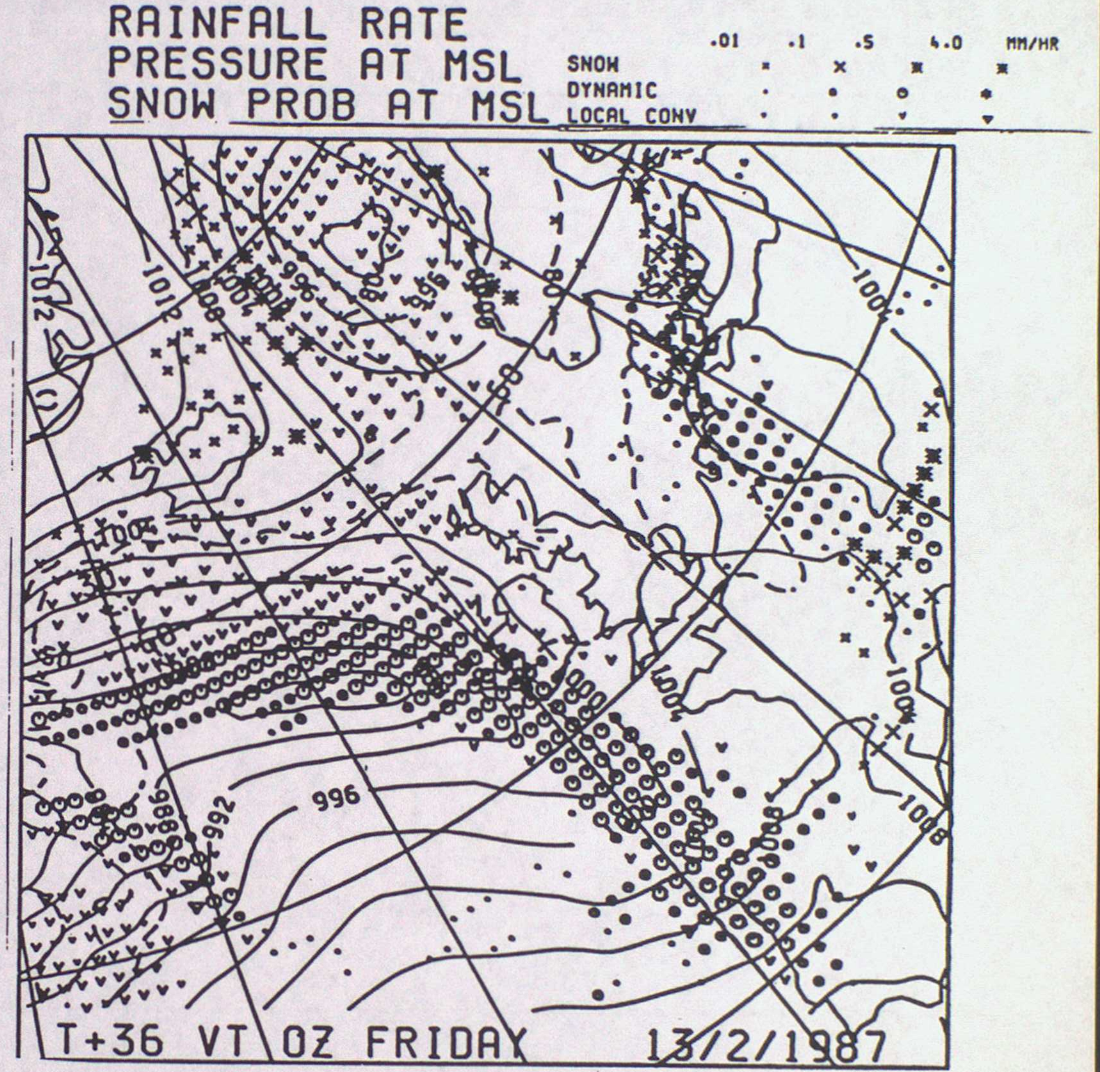
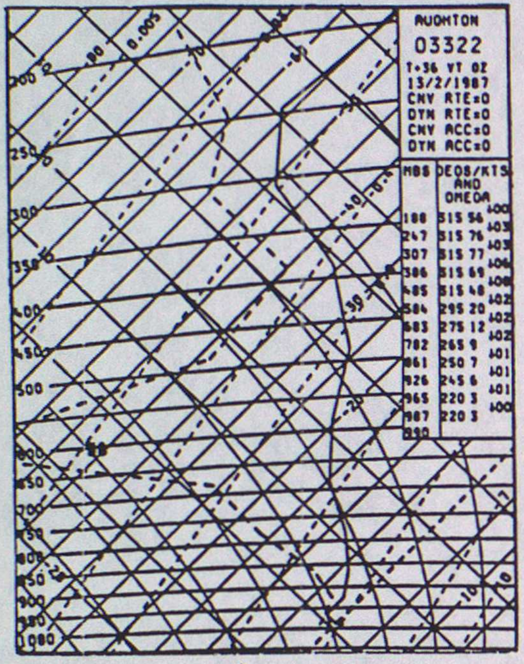
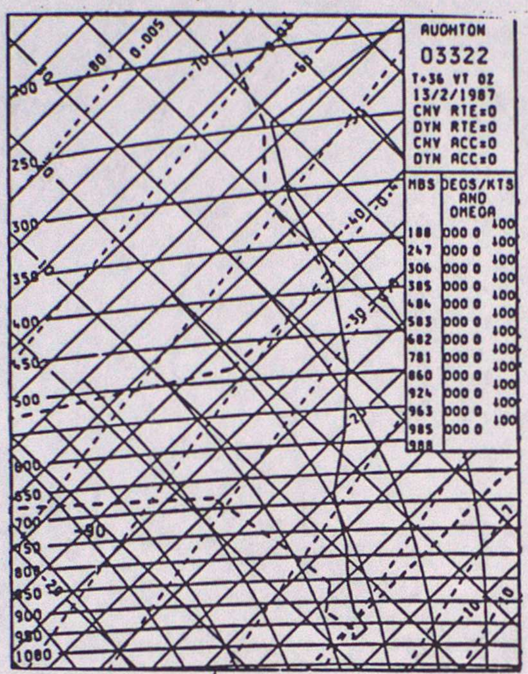



FIGURE 4b. THE MODIFIED FINE-MESH T+36 PRECIPITATION FORECAST VERIFYING AT 00GMT 13/02/87

FINE MESH TEPHIGRAMS  T+36 VT OZ 13/2/1987




a

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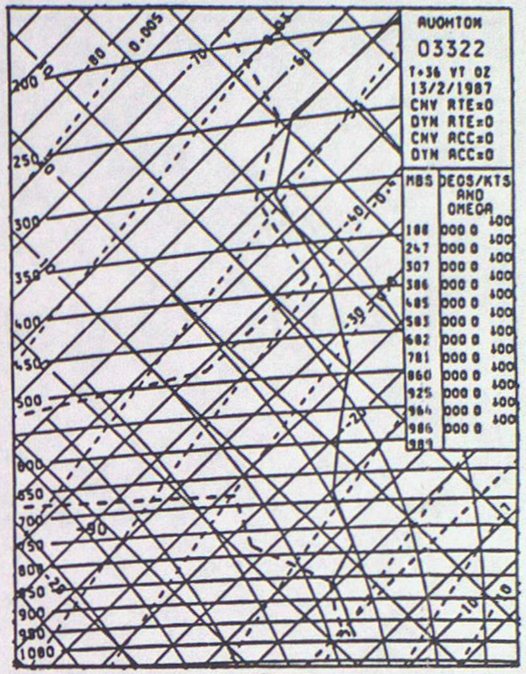
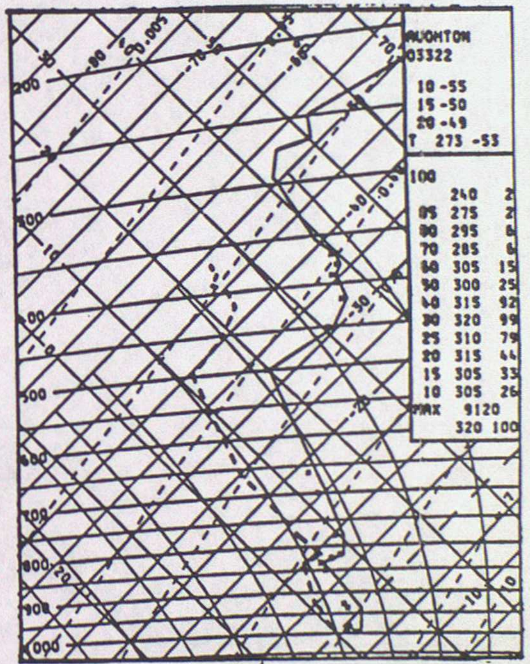



c




d

FIGURE 5. TEPHIGRAMS FOR AUGHTON OOGMT 13/02/87

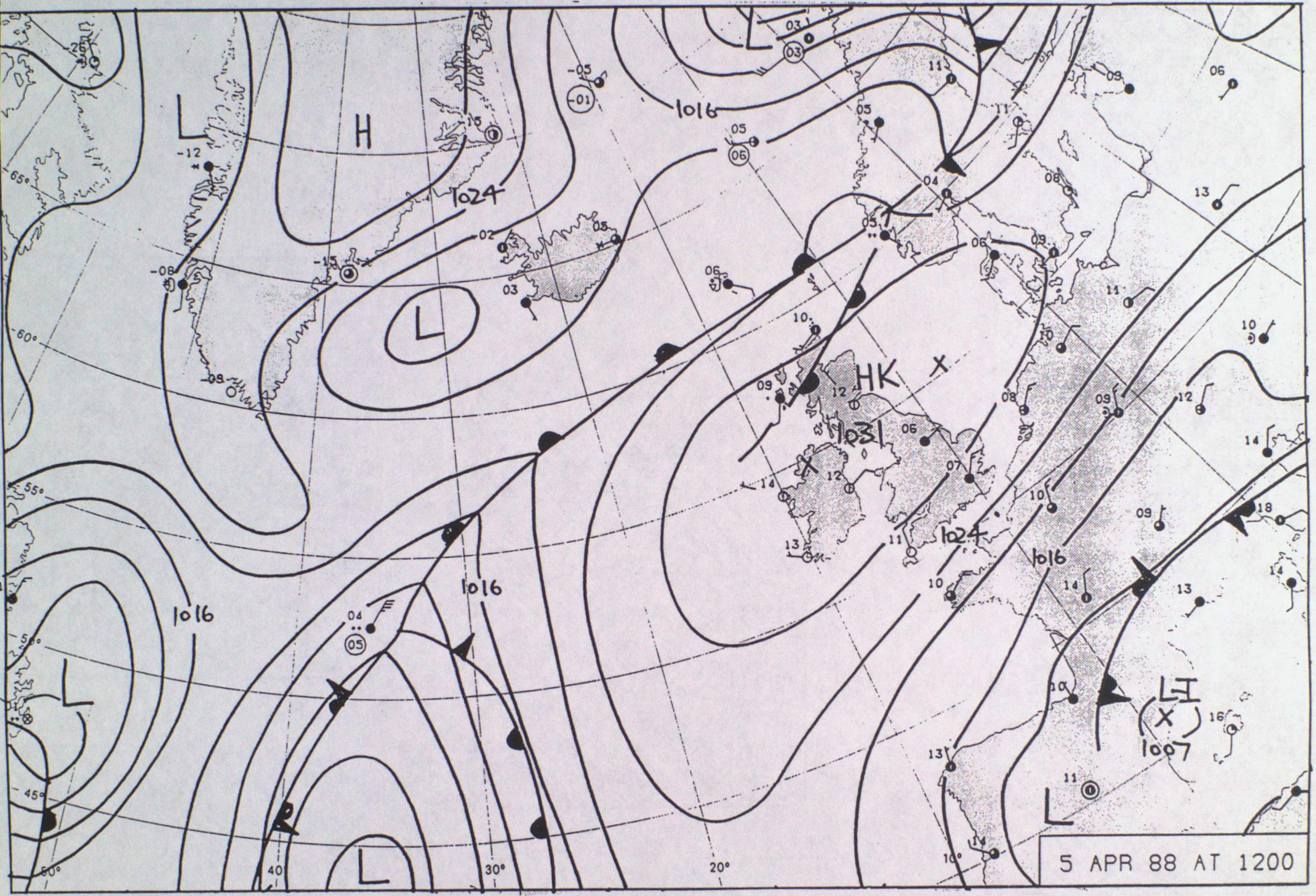
a) ORIGINAL OPERATIONAL FINE-MESH VERSION FOR T+36

b) CURRENT OPERATIONAL FINE-MESH VERSION FOR T+36

c) MODIFIED CLOUD FINE-MESH VERSION FOR T+36

d) AUGHTON RADIO SONDE ASCENT

FIGURE 6. SYNOPTIC SITUATION AT 1200 GMT 05/04/88



SATELLITE PICTURE BY

COURTESY OF DUNDEE UNIVERSITY

FIGURE 7. NOAA9 VISUAL

SATELLITE IMAGE AT 1526

GMT 05/04/88

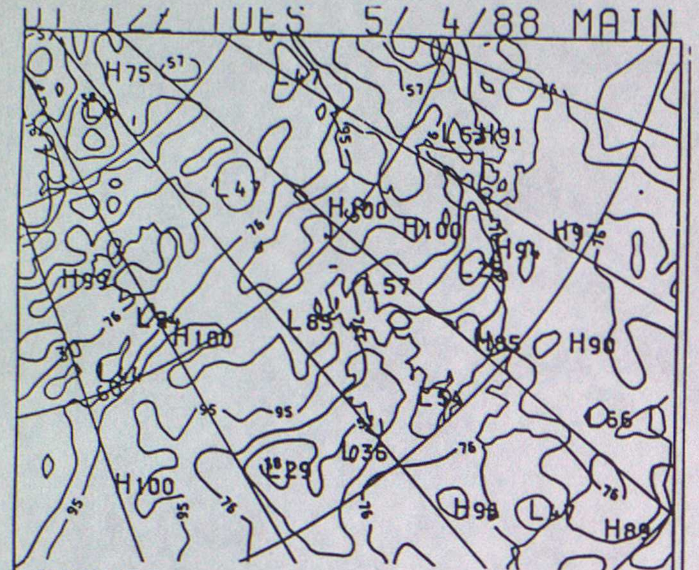



FIGURE 8a. THE OPERATIONAL FINE-MESH RELATIVE HUMIDITY ANALYSIS AT 950MB FOR 12GMT 05/04/88

FIGURE 8b. THE OPERATIONAL FINE-MESH CLOUD ANALYSIS FOR 12 GMT 05/04/88

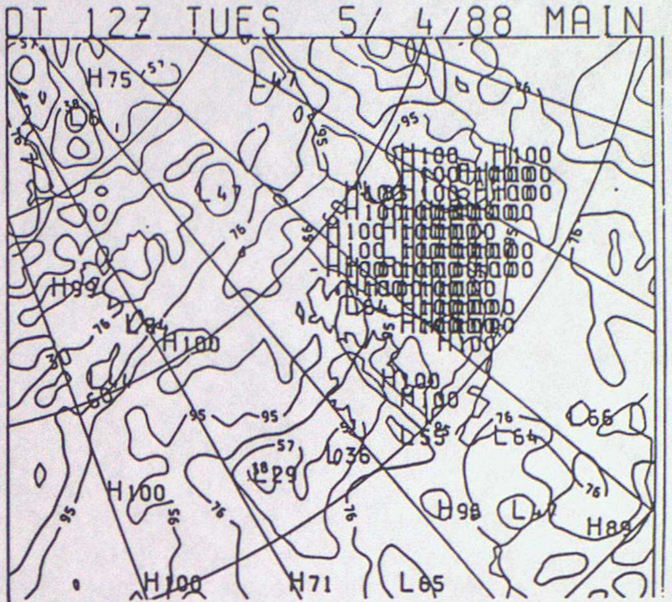



FIGURE 8d. MODIFIED FINE-MESH RELATIVE HUMIDITY ANALYSIS AT 950MB FOR 12GMT 05/04/88

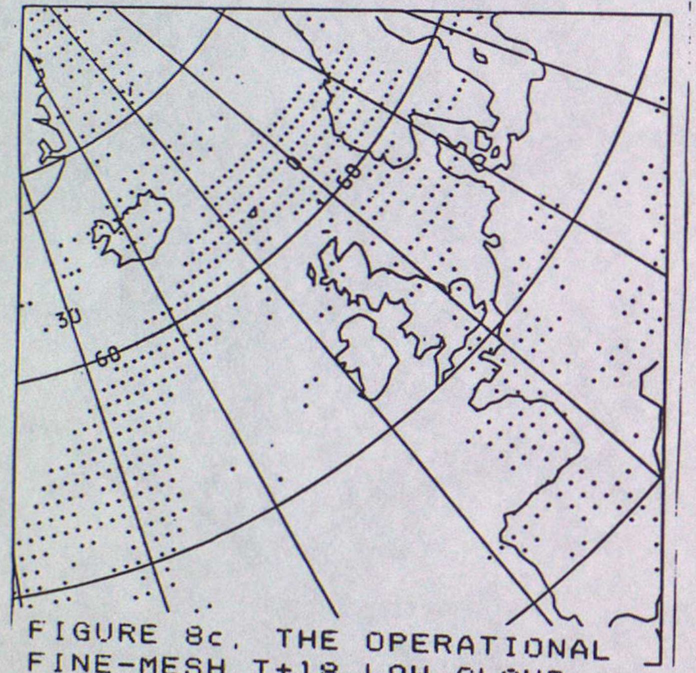


FIGURE 8c. THE OPERATIONAL FINE-MESH T+18 LOW CLOUD FORECAST VERIFYING AT 06GMT 06/04/88

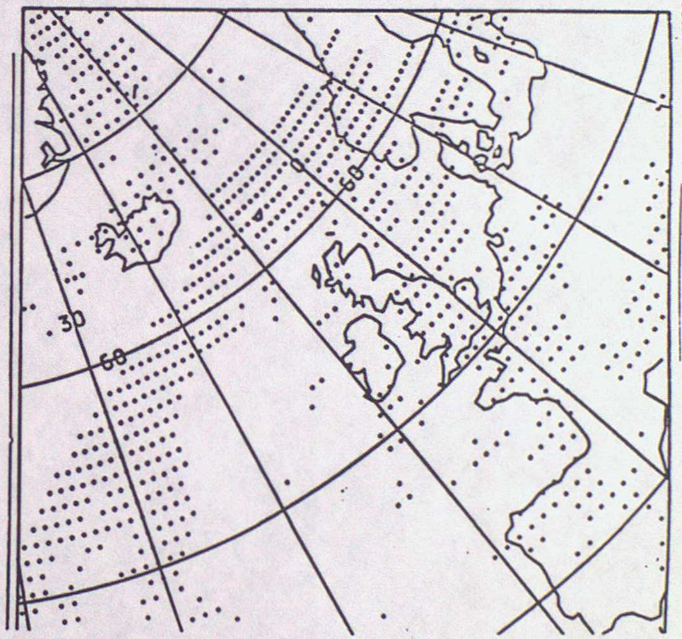


FIGURE 8e. MODIFIED(RH)FINE-MESH LOW CLOUD FORECAST FOR T+36, VERIFYING 06GMT 06/04/88

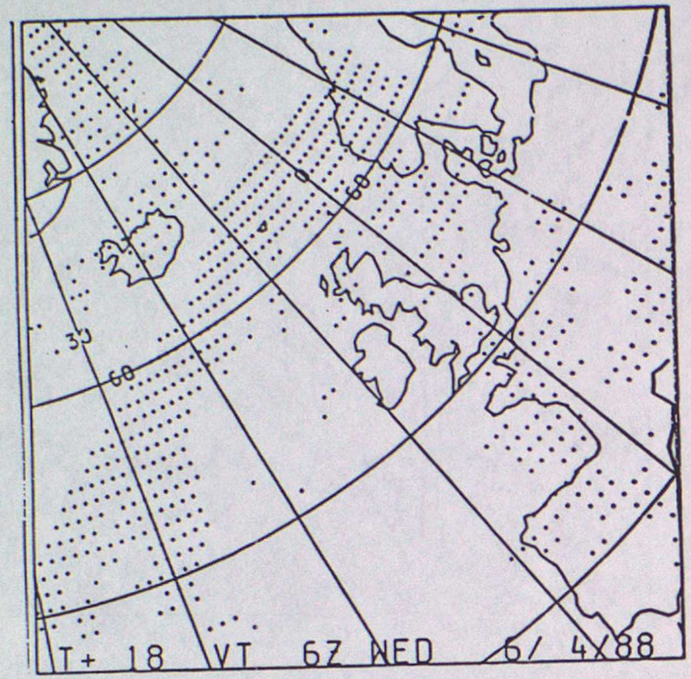



FIGURE 9a. THE OPERATIONAL FINE-MESH T+18 LOW CLOUD FORECAST VERIFYING AT 06GMT 06/04/88

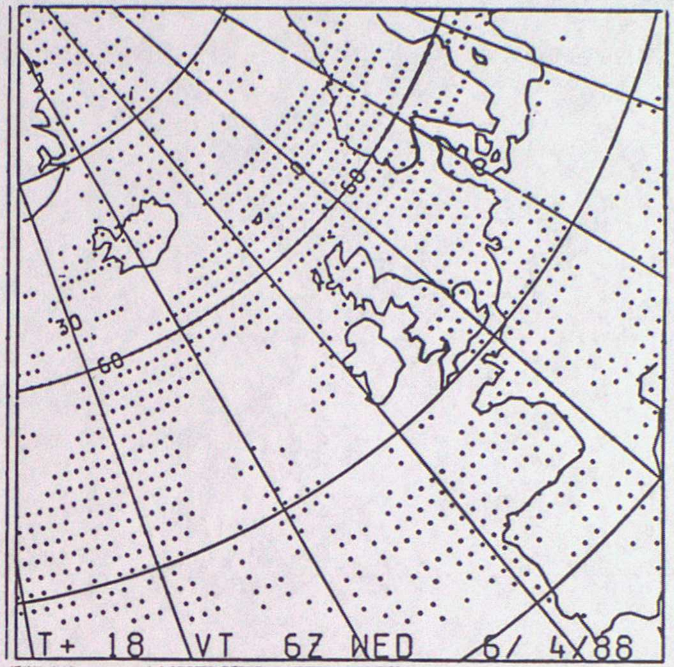



FIGURE 9b. THE MODIFIED FINE-MESH (CLOUD RELOCATED AT SIGMA LEVELS) FINE-MESH LOW CLOUD FORECAST FOR T+36 VERIFYING AT 00GMT 06/04/88

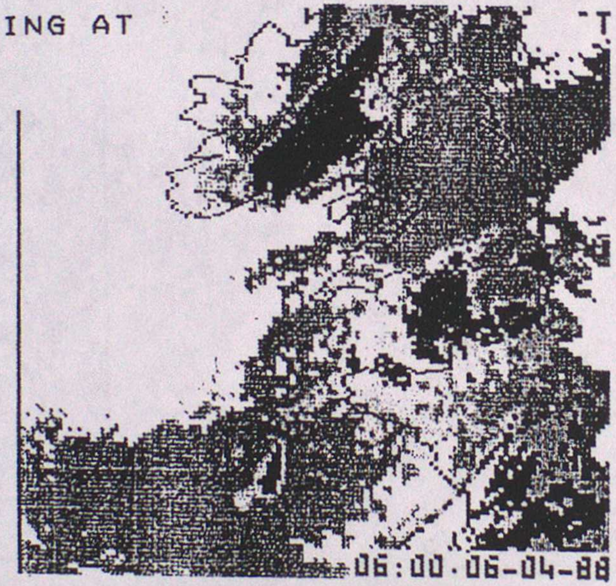



FIGURE 9c. VISUAL SATELLITE IMAGE AT 0600 GMT 06/04/88

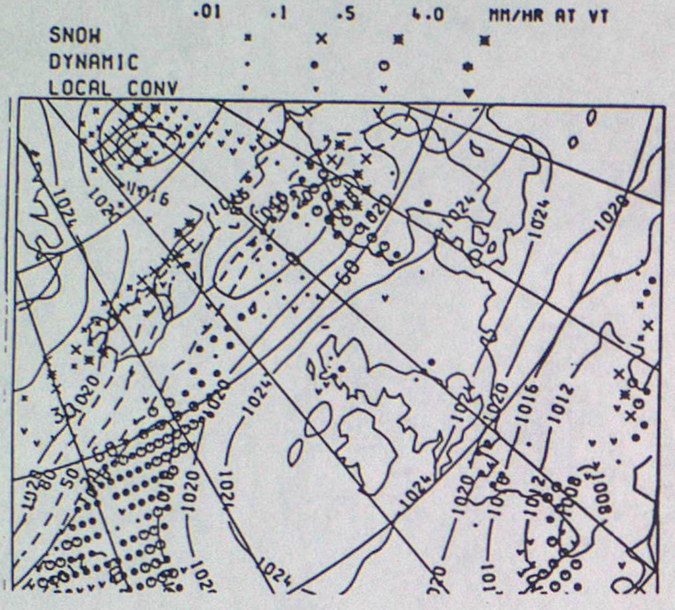


FIGURE 10a. THE OPERATIONAL FINE-MESH T+18 PRECIPITATION FORECAST VERIFYING AT 06GMT 06/04/88

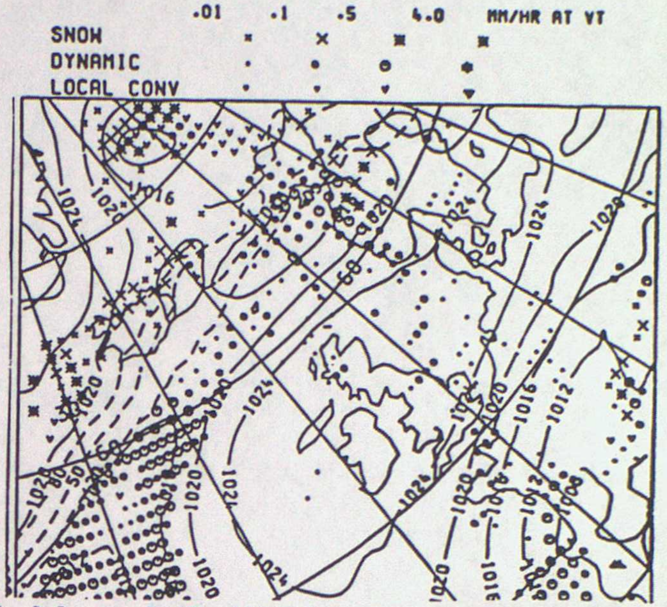


FIGURE 10c. THE MODIFIED FINE-MESH T+18 PRECIPITATION FORECAST VERIFYING AT 06GMT 06/04/88

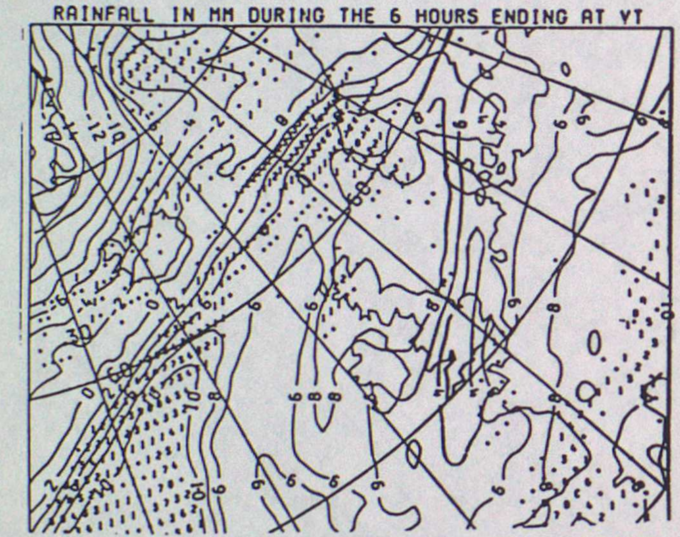


FIGURE 10b. THE OPERATIONAL FINE-MESH RAINFALL ACCUMULATION FORECAST FOR THE PERIOD 00-06 GMT 06/04/88

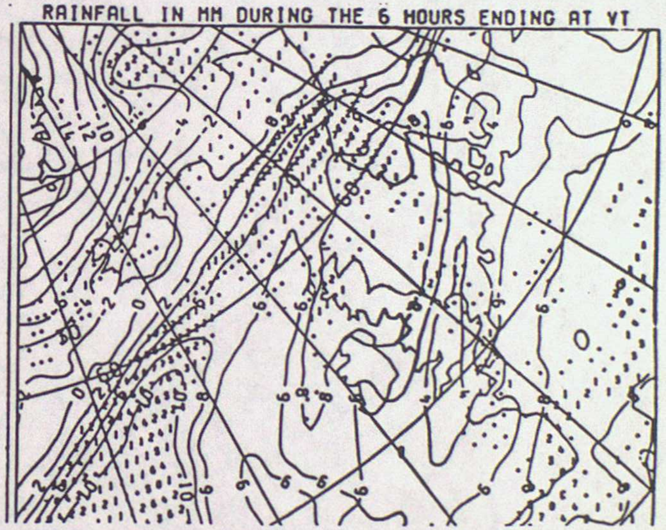


FIGURE 10d. THE MODIFIED FINE-MESH RAINFALL ACCUMULATION FORECAST FOR THE PERIOD 00-06 GMT 06/04/88

DT 1200Z 05/04/1988 VT 1200Z 05/04/1988 INITAMPM N.H LEVEL 2 N.H CODE IS DESCRIBED IN PARA.2.2

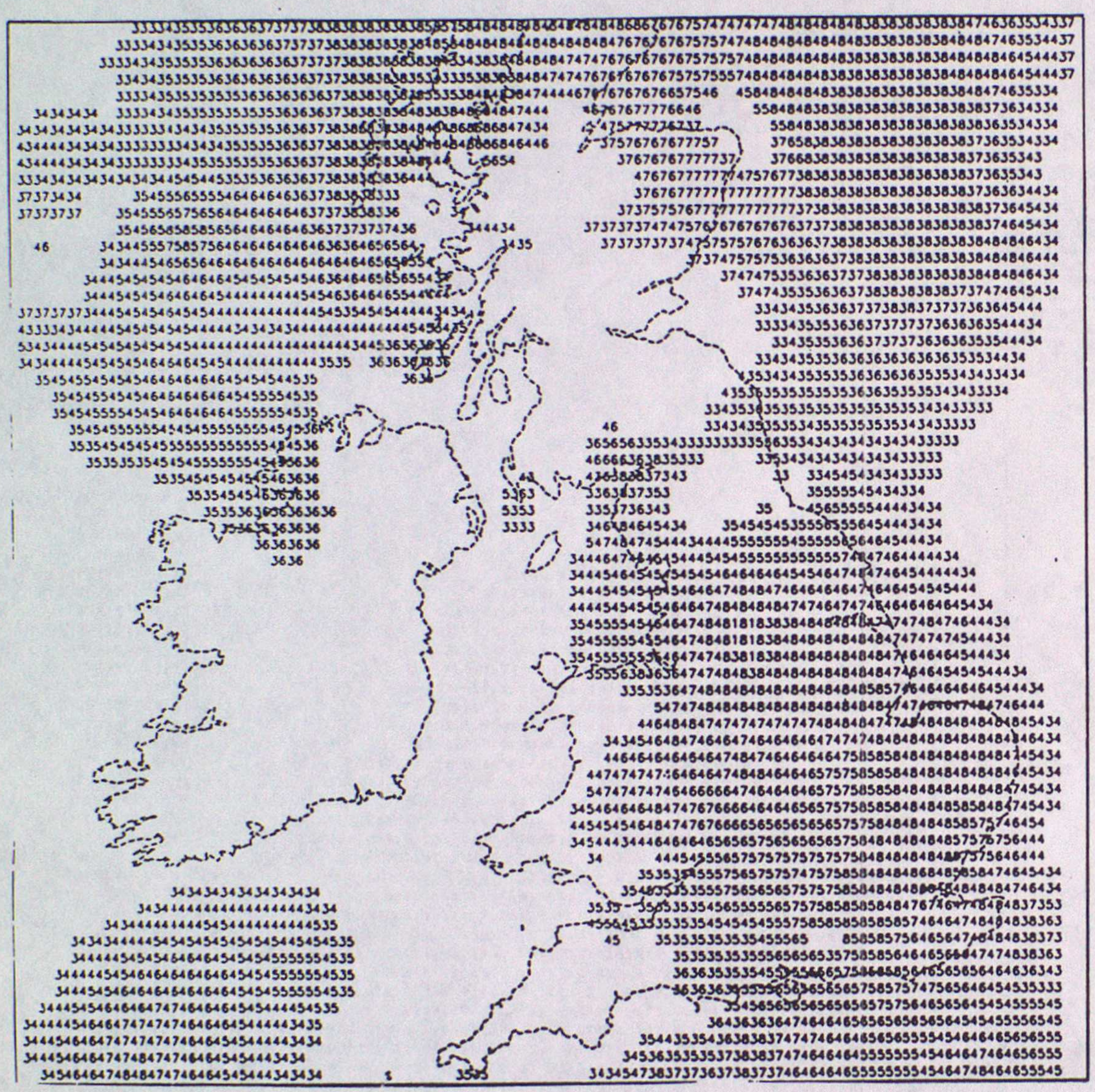


FIGURE 11a. THE OPERATIONAL MESOSCALE MODEL INITIAL CLOUD ANALYSIS FOR 12 GMT 05/04/88

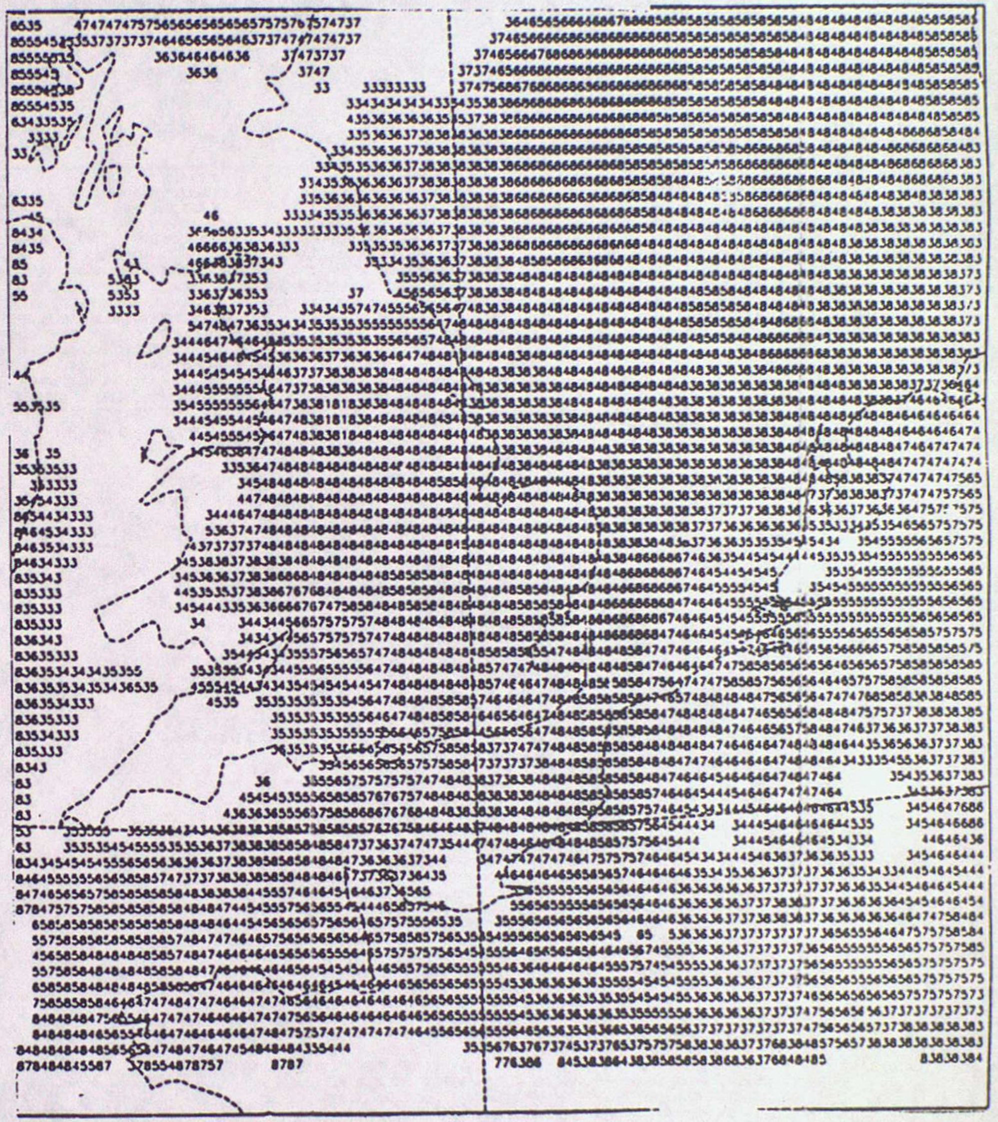


FIGURE 11b. THE MESOSCALE MODEL INITIAL CLOUD ANALYSIS FOR 12 GMT 05/04/88 OVER THE EASTERN AREA

DT 1200Z 05/04/1988 VT 0000Z 06/04/1988 MSFC.PR

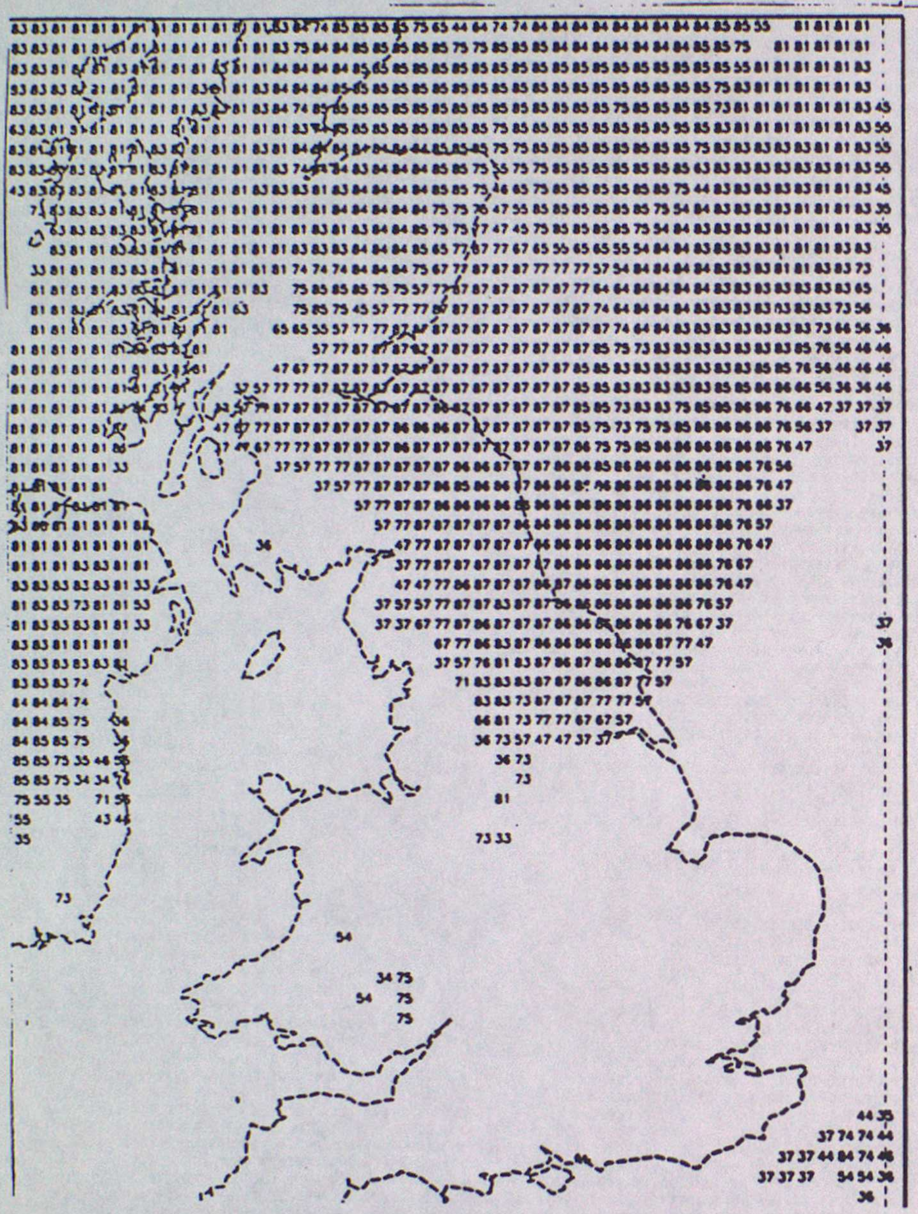


FIGURE 12a. THE OPERATIONAL MESOSCALE MODEL T+12 FORECAST OF LOW CLOUD BASE AND AMOUNT VERIFYING AT 00GMT 06/04/88

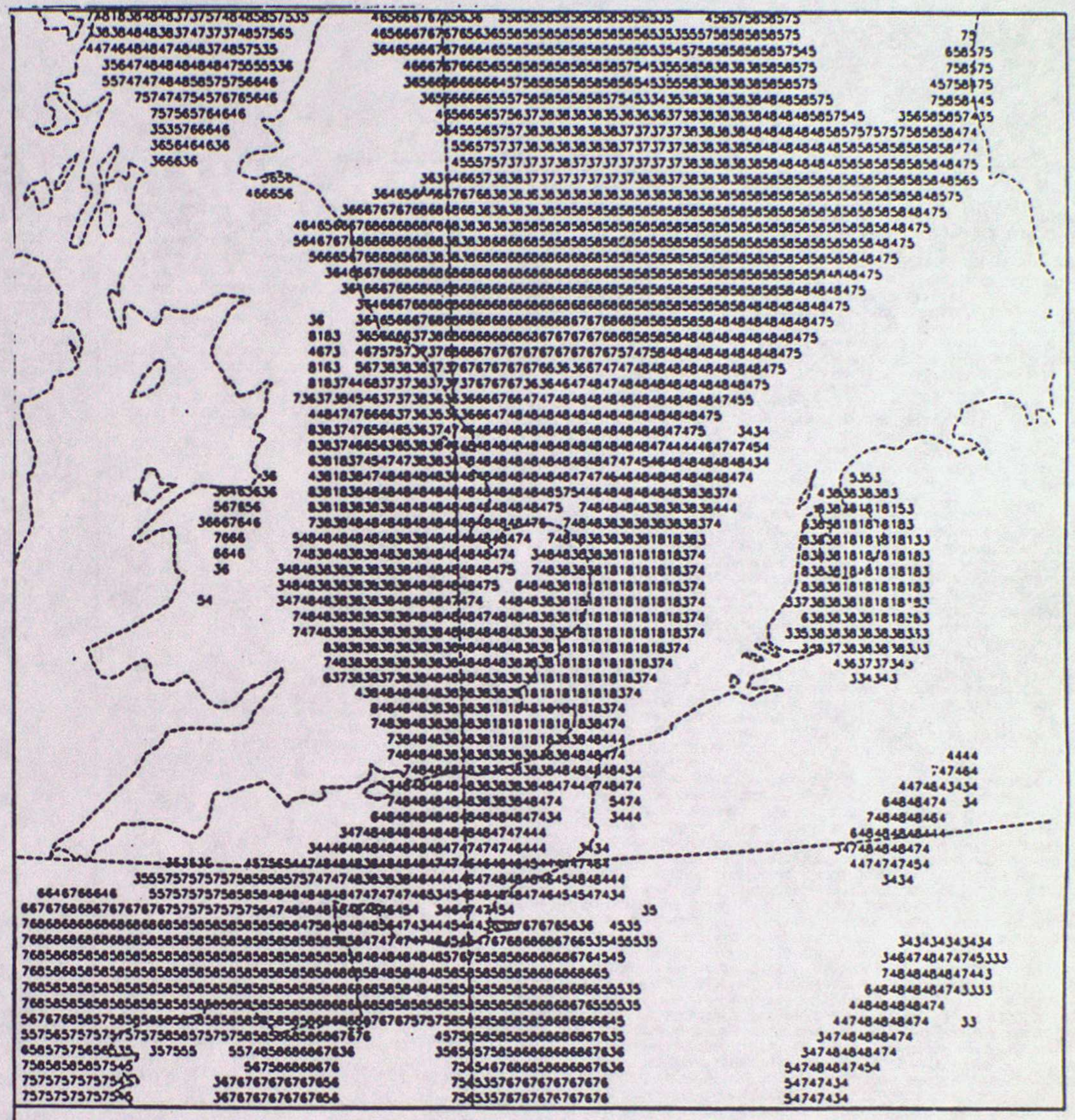


FIGURE 12b. THE REPEAT MESOSCALE MODEL (RUN OVER EASTERN AREA) T+12 FORECAST OF LOW CLOUD BASE AND AMOUNT VERIFYING AT 00GMT 06/04/88

N.H CODE IS DESCRIBED IN PARA. 2.2

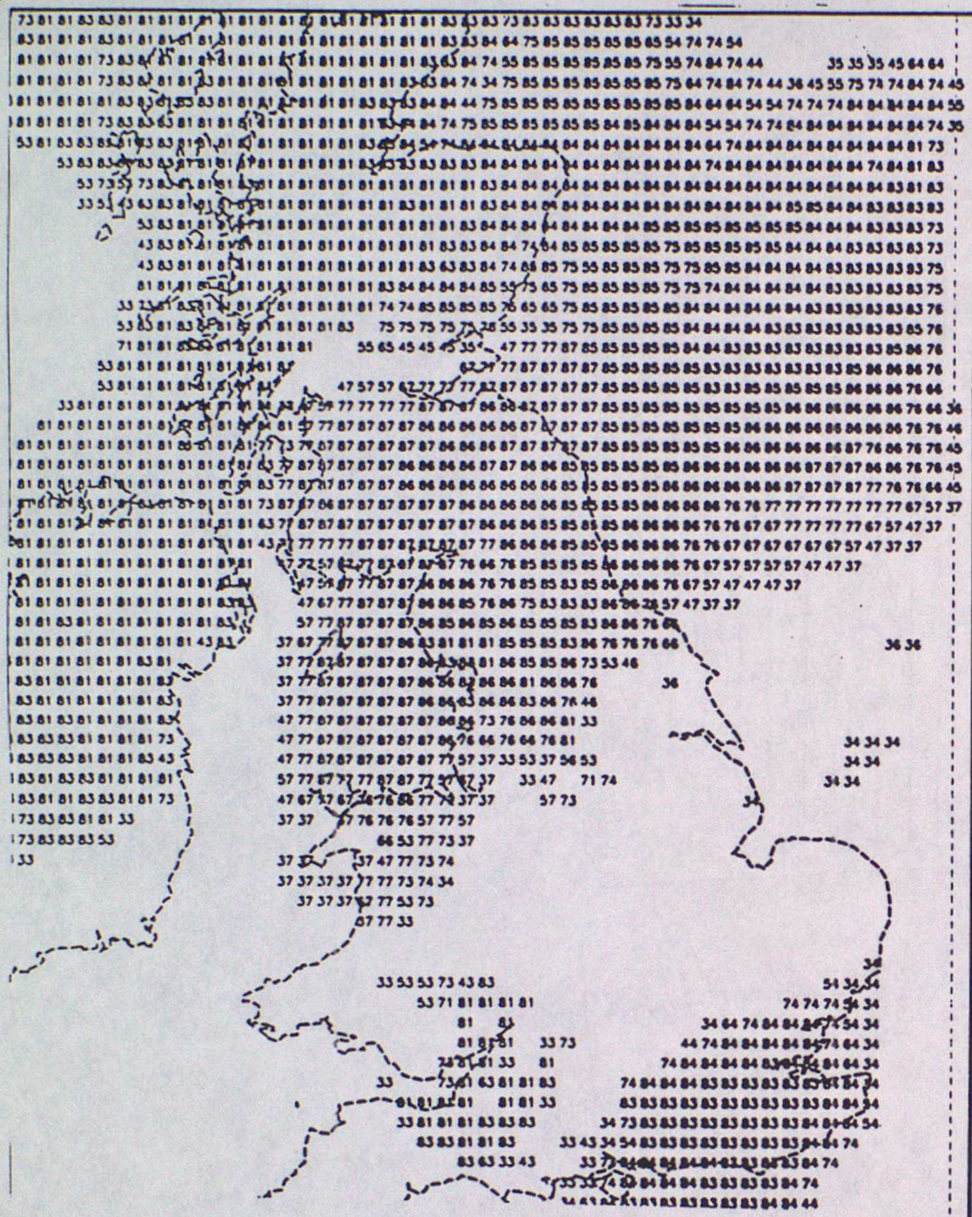


FIGURE 13a. THE OPERATIONAL MESOSCALE MODEL T+12 FORECAST OF LOW CLOUD BASE AND AMOUNT VERIFYING AT 06GMT 06/04/88

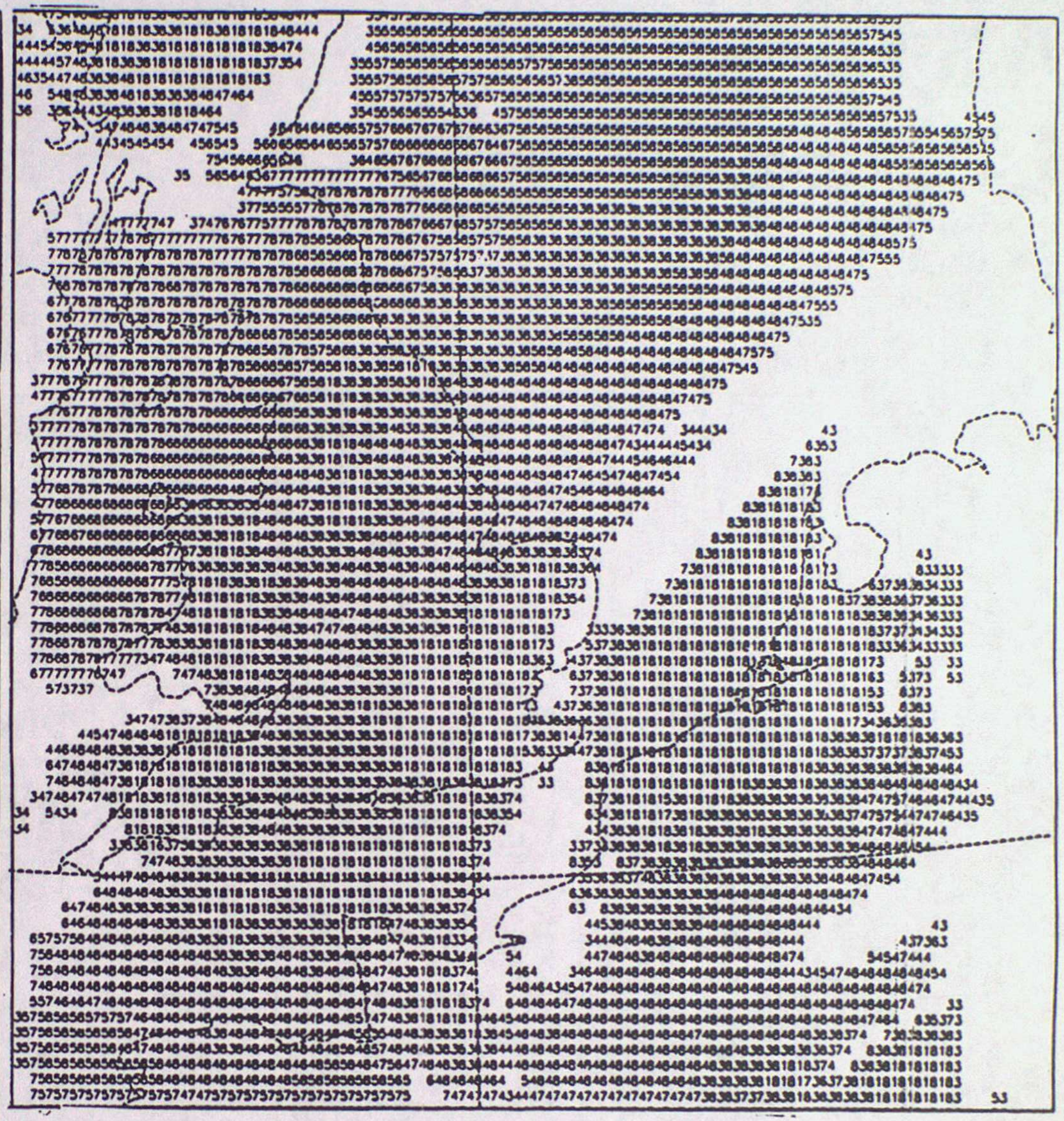


FIGURE 13b. THE REPEAT MESOSCALE MODEL (RUN OVER EASTERN AREA) T+18 FORECAST OF LOW CLOUD BASE AND AMOUNT VERIFYING AT 06GMT 06/04/88

N.H CODE IS DESCRIBED IN PARA. 2.2

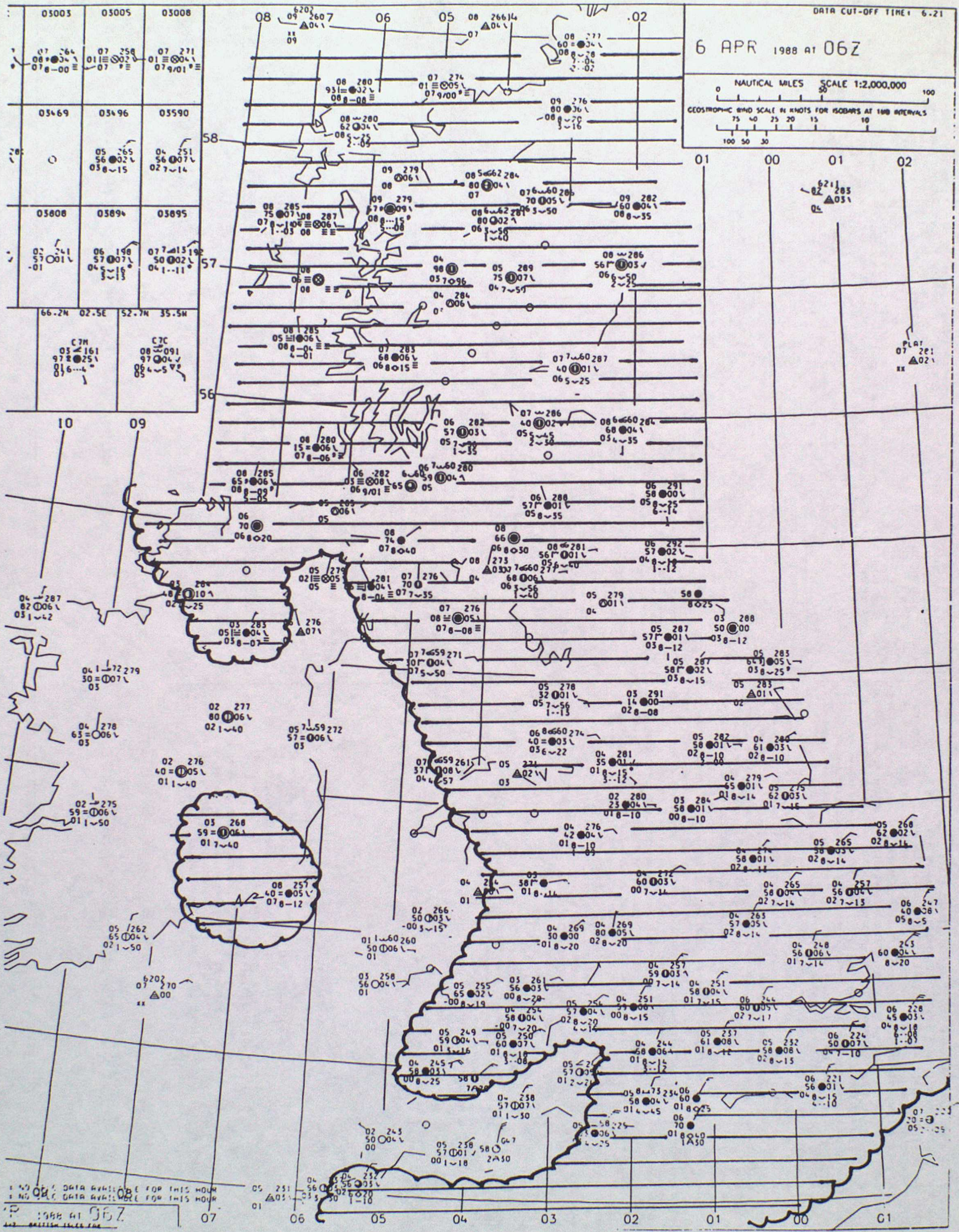



FIGURE 14. OBSERVATIONS FOR THE U.K. AND EIRE FOR

06 GMT 06/04/88

15

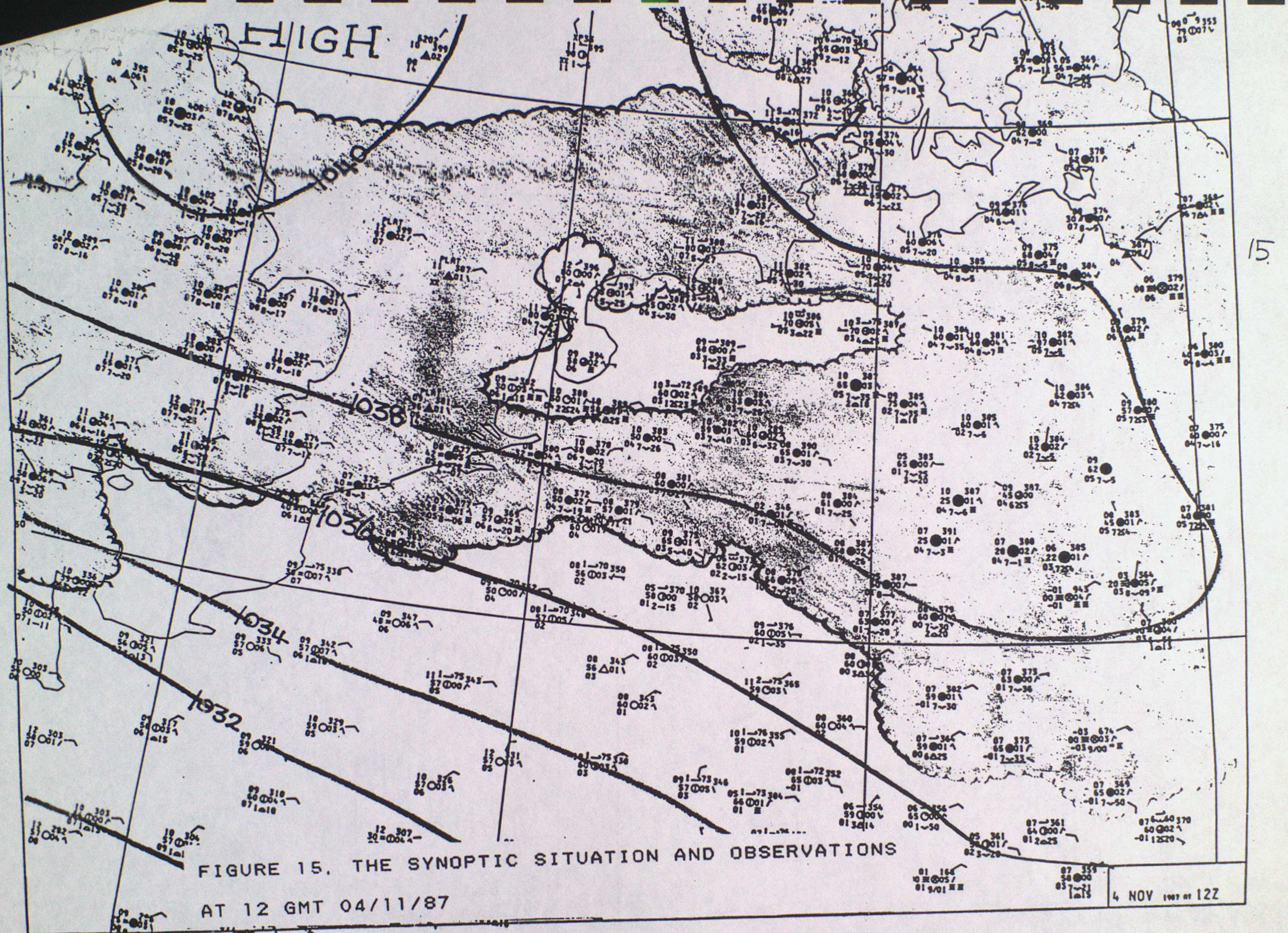
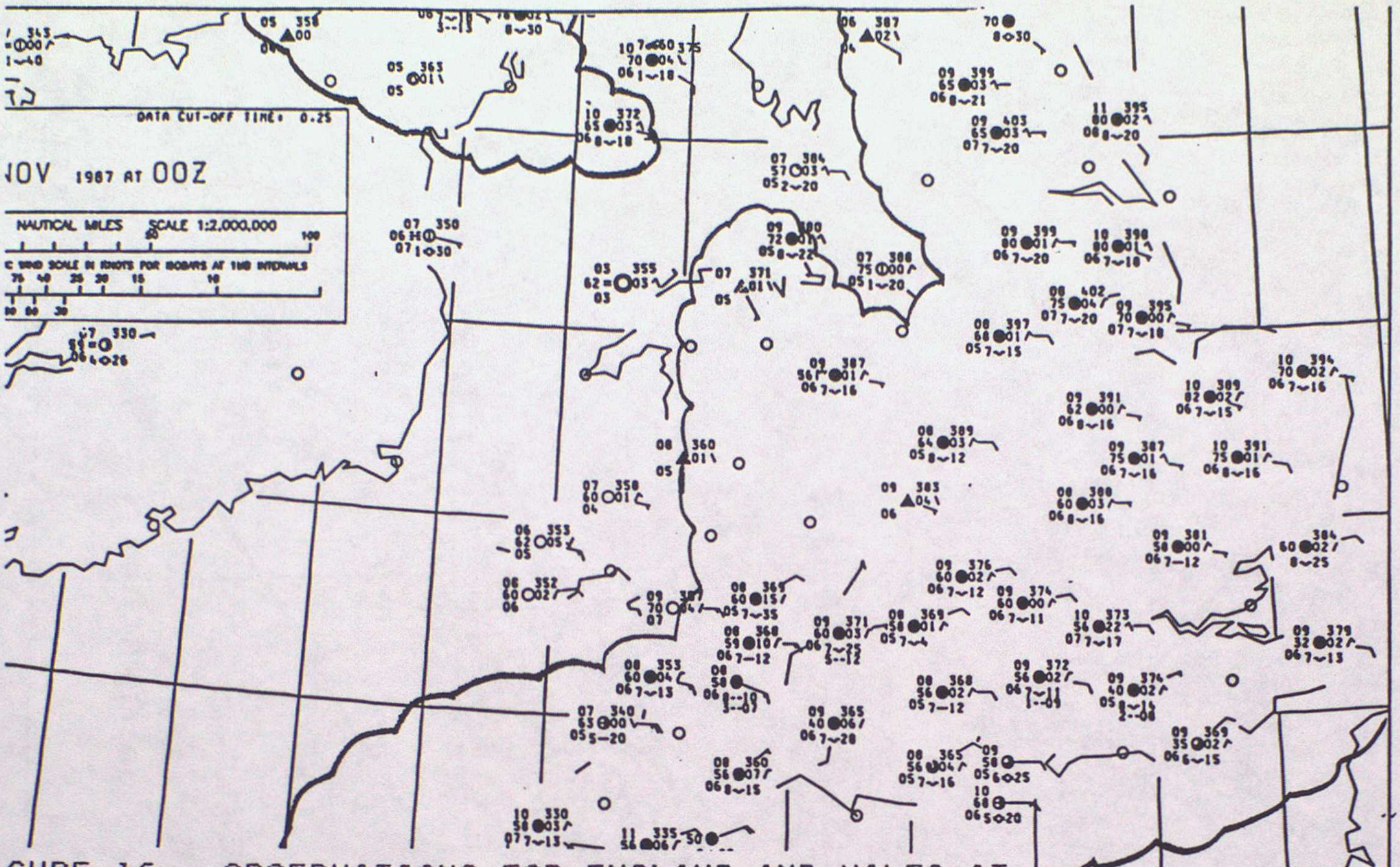


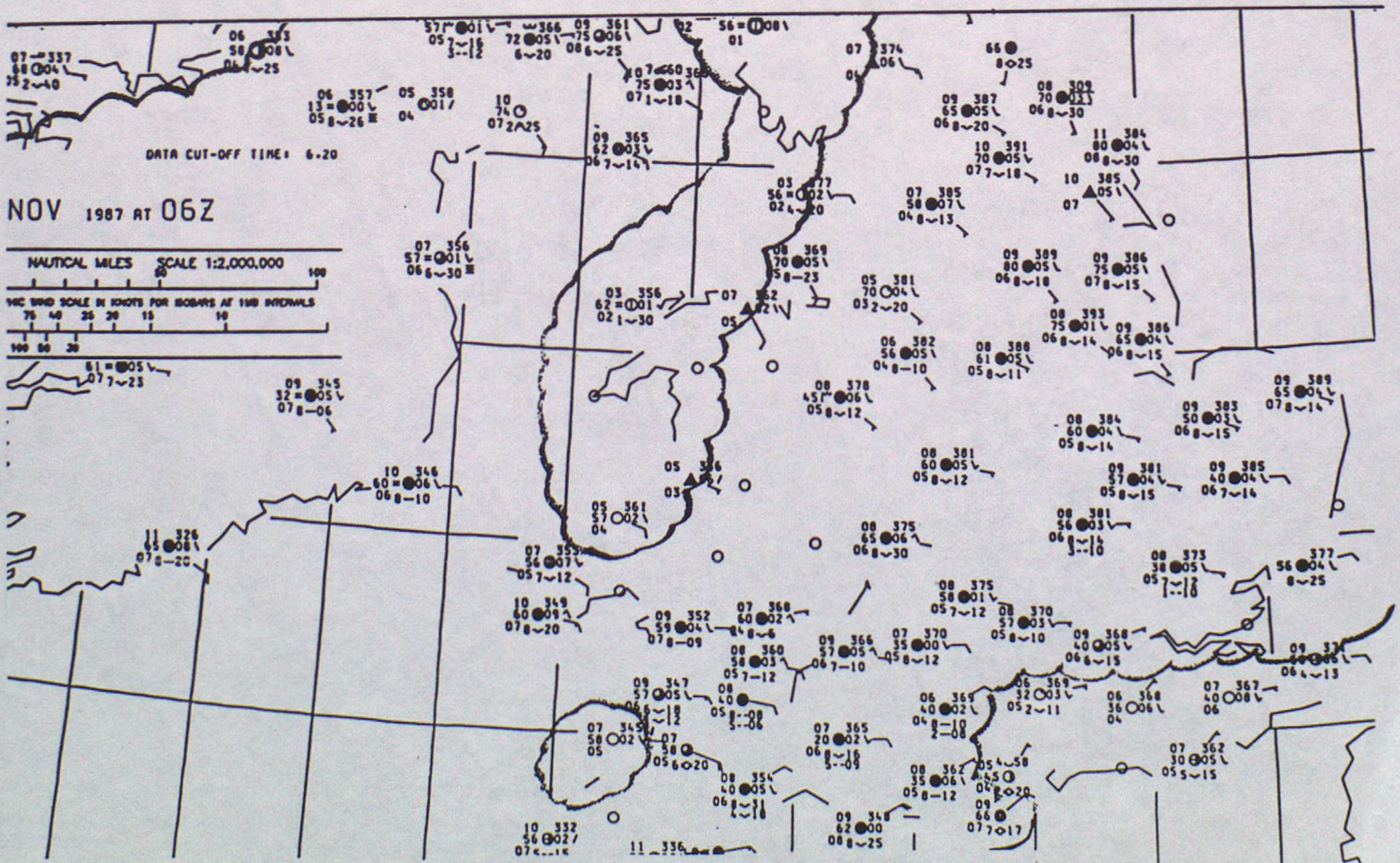

FIGURE 15. THE SYNOPTIC SITUATION AND OBSERVATIONS

AT 12 GMT 04/11/87




GURE 16a. OBSERVATIONS FOR ENGLAND AND WALES AT

GMT 05/11/87




IGURE 16b. OBSERVATIONS FOR ENGLAND AND WALES AT

GMT 05/11/87

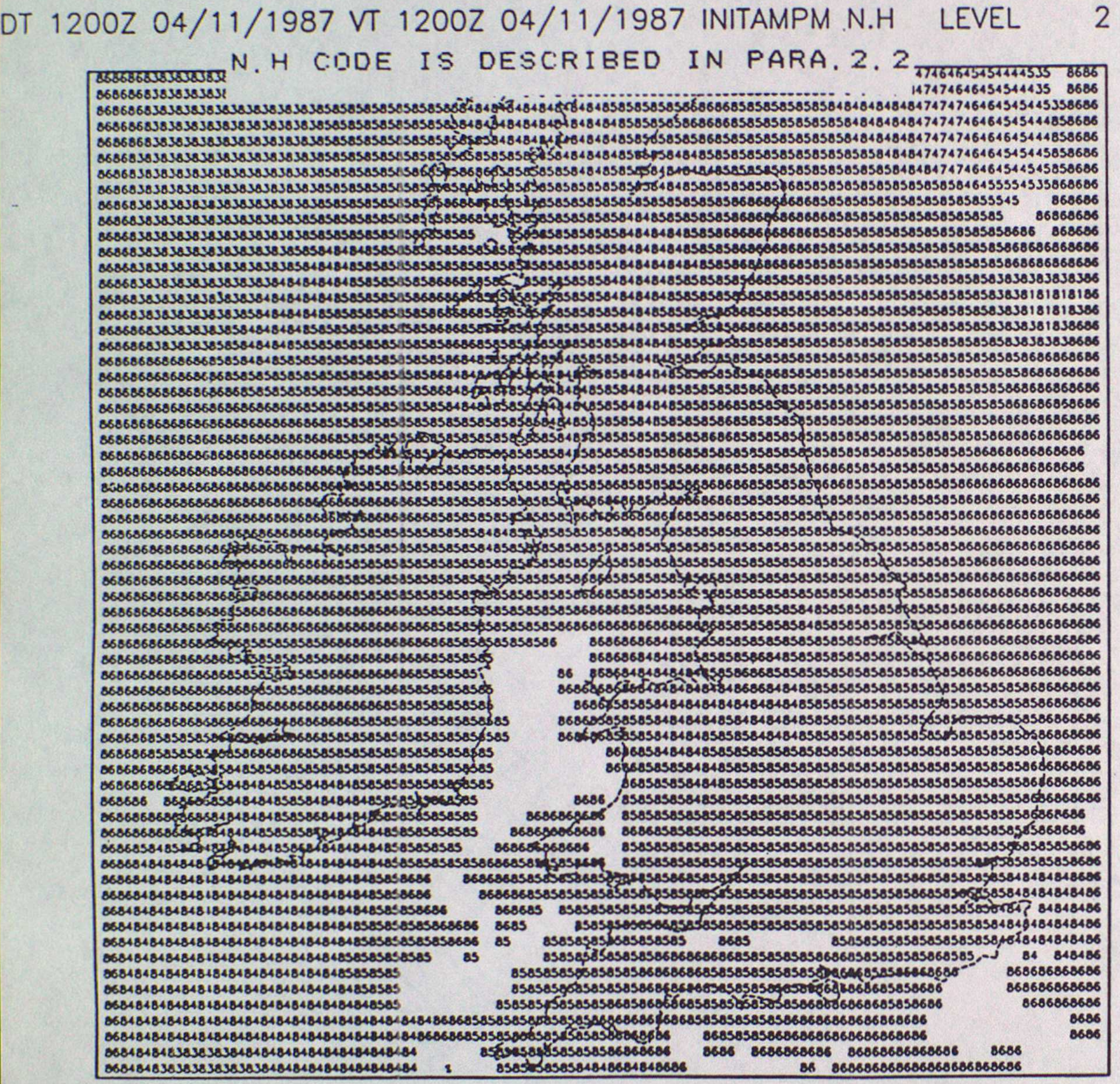



FIGURE 17a. THE OPERATIONAL MESOSCALE MODEL INITIAL CLOUD ANALYSIS FOR 12 GMT 04/11/87

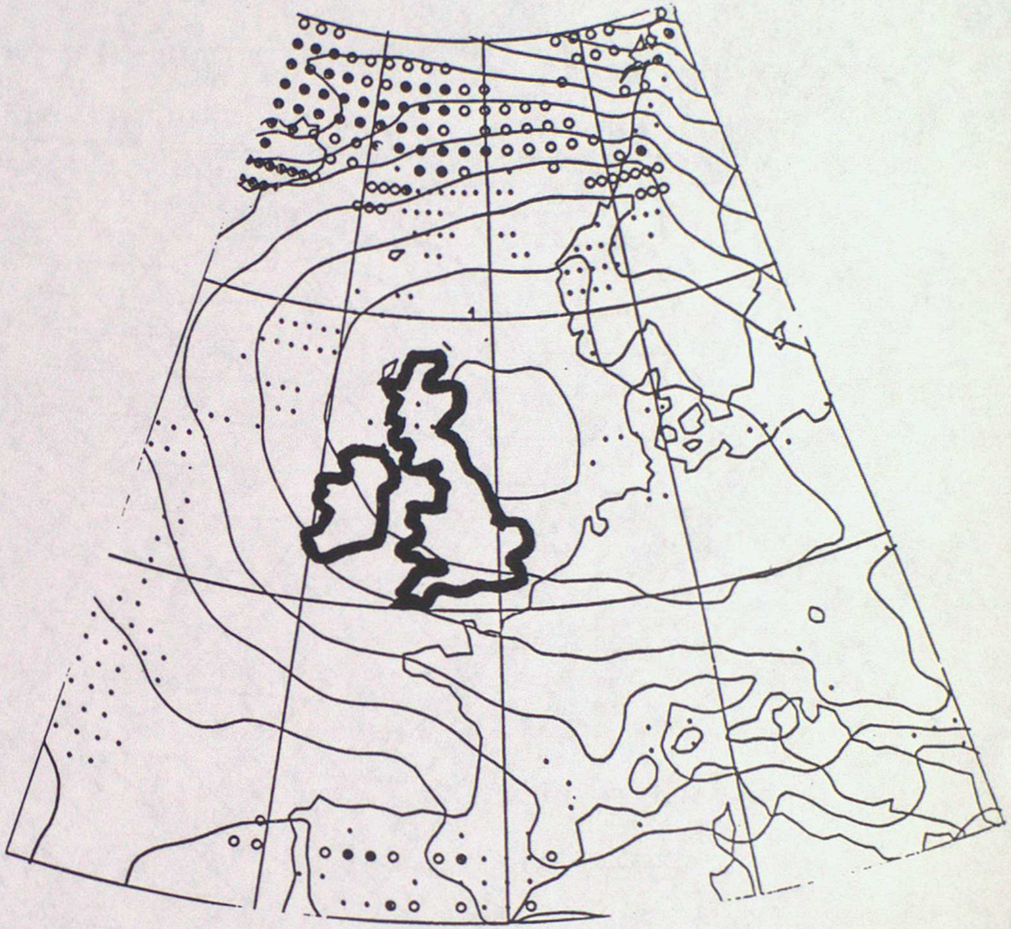


FIGURE 17b. THE OPERATIONAL FINE-MESH CLOUD ANALYSIS FOR 12 GMT 04/11/87

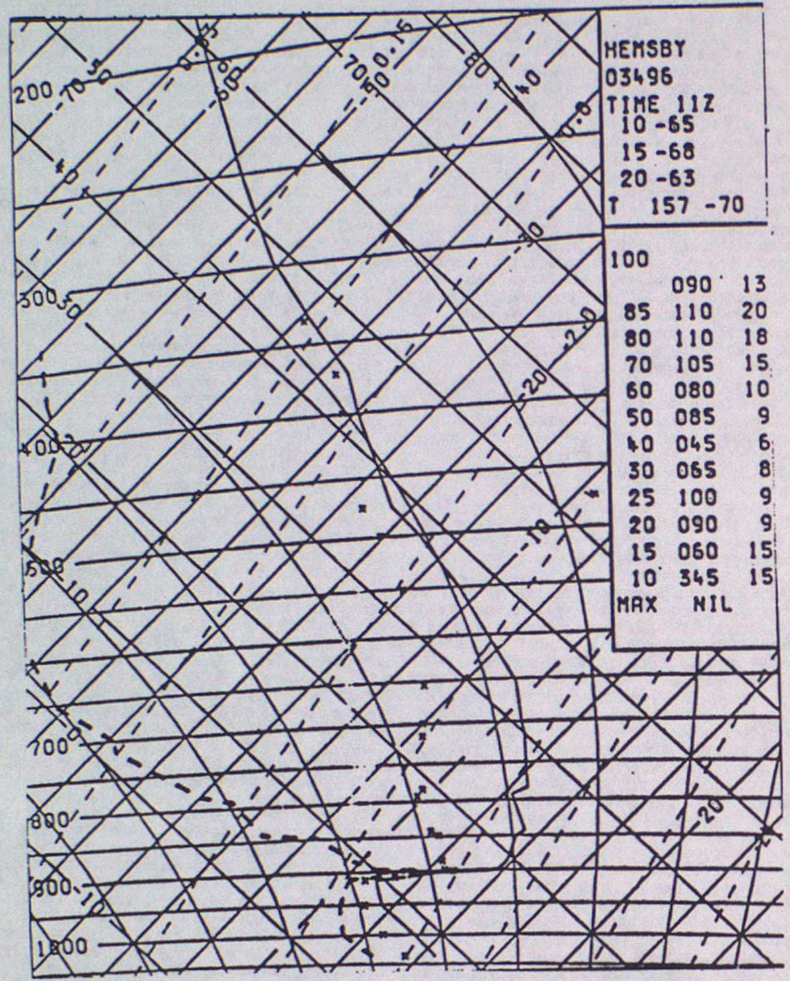



FIGURE 18a. HEMSBY RADIO-SONDE ASCENT AT 12GMT

04/11/87

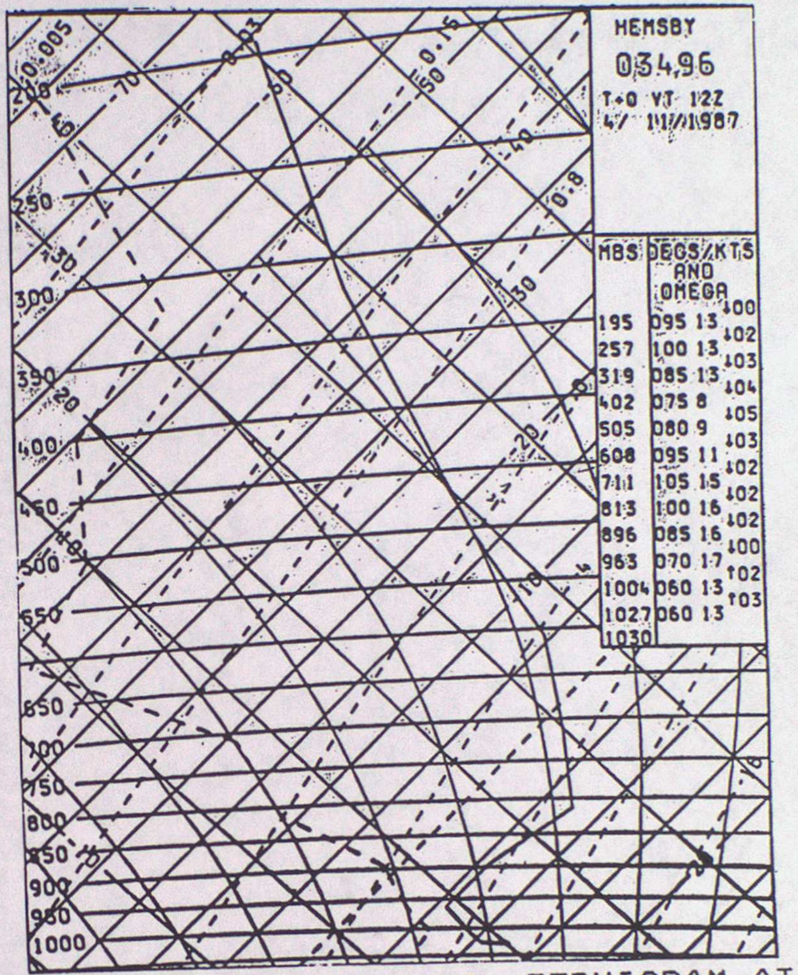



FIGURE 18b. FINE-MESH MODEL TEPHIGRAM AT T+0 FOR THE NEAREST GRID-POINT TO HEMSBY VERIFYING AT 12GMT

04/11/87

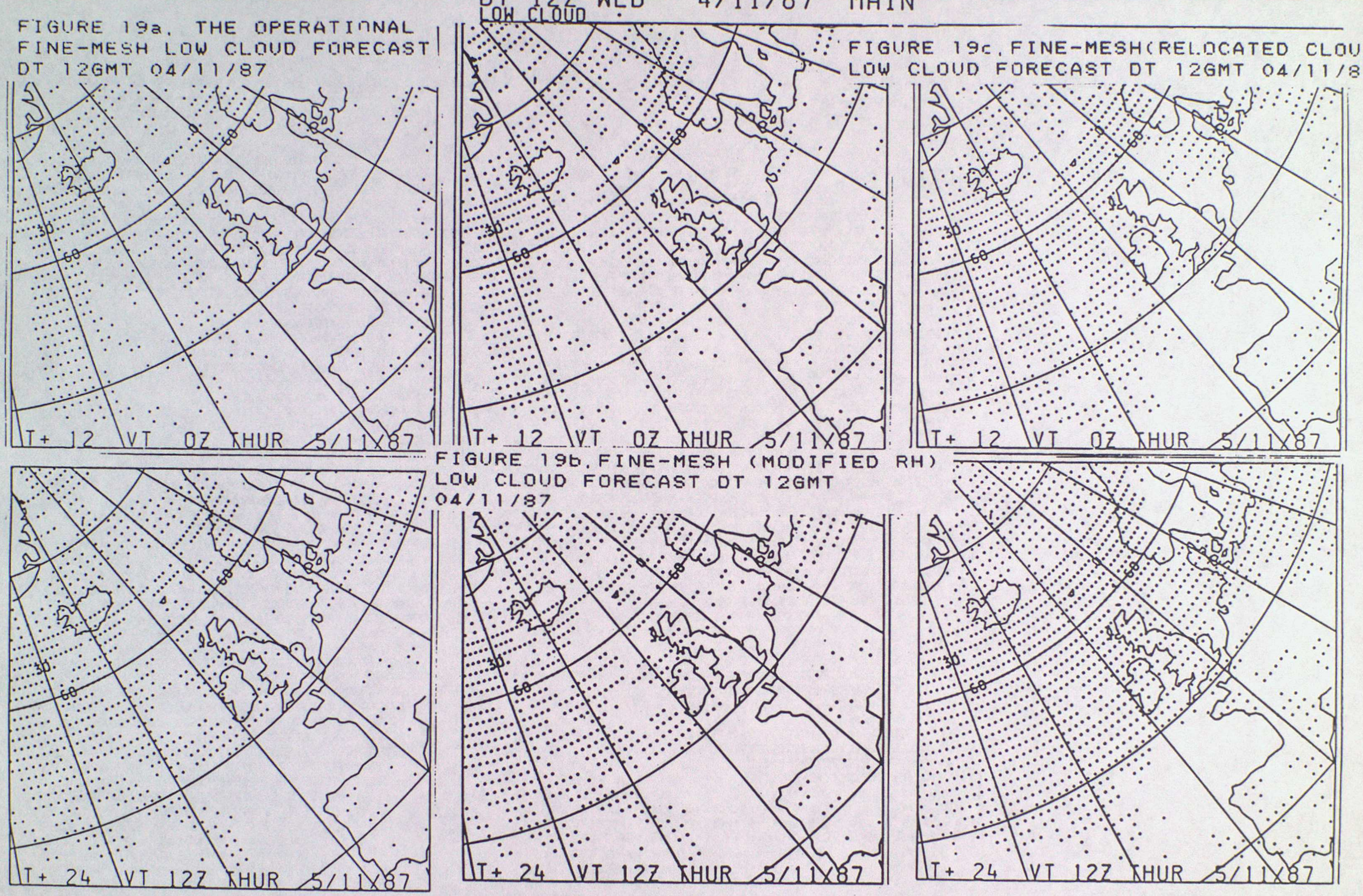



FIGURE 19a. THE OPERATIONAL FINE-MESH LOW CLOUD FORECAST DT 12GMT 04/11/87

FIGURE 19b. FINE-MESH (MODIFIED RH) LOW CLOUD FORECAST DT 12GMT 04/11/87

FIGURE 19c. FINE-MESH(RELOCATED CLOUD) LOW CLOUD FORECAST DT 12GMT 04/11/87

N.M CODE IS DESCRIBED IN PARA. 2.2

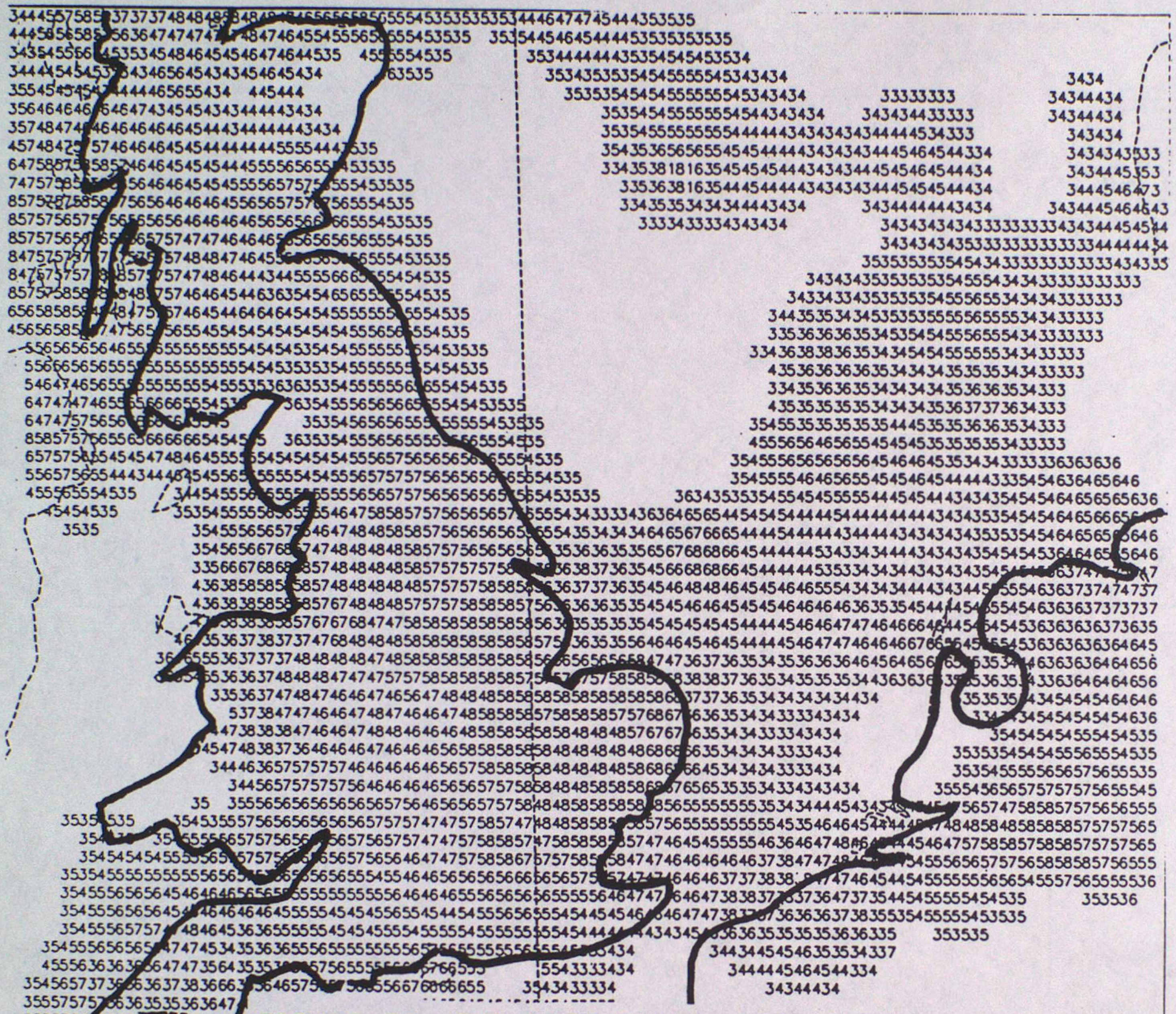
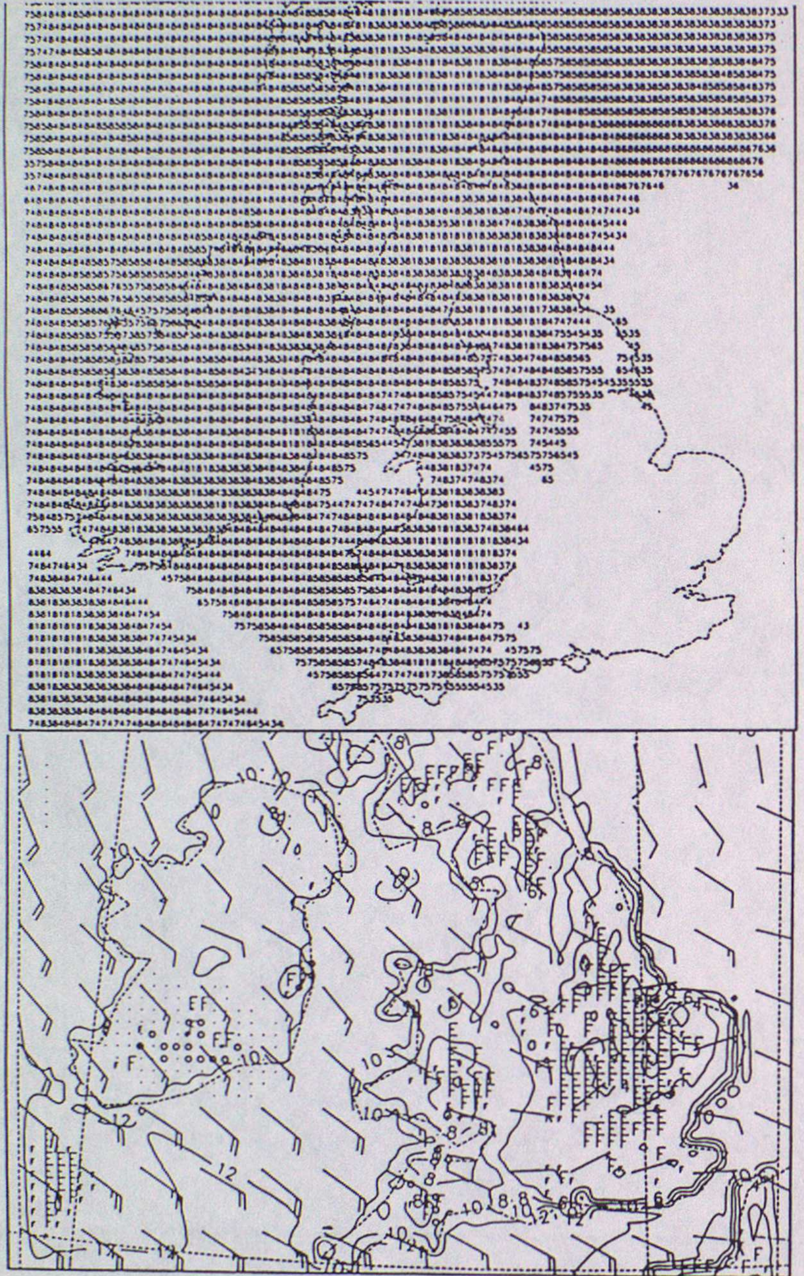


FIGURE 20. THE MESOSCALE MODEL INITIAL CLOUD ANALYSIS FOR 12 GMT 04/11/87 OVER THE EASTERN AREA

FIGURE 21a. THE OPERATIONAL MESOSCALE MODEL T+12

FORECAST OF WEATHER, LOW CLOUD BASE AND AMOUNT

VERIFYING AT 00GMT 05/11/87



N.H CODE IS DESCRIBED IN PARA. 2.2

DT 1200Z 04/11/1987 VT 0000Z 05/11/1987 E1MSFC N.H LEVEL 2

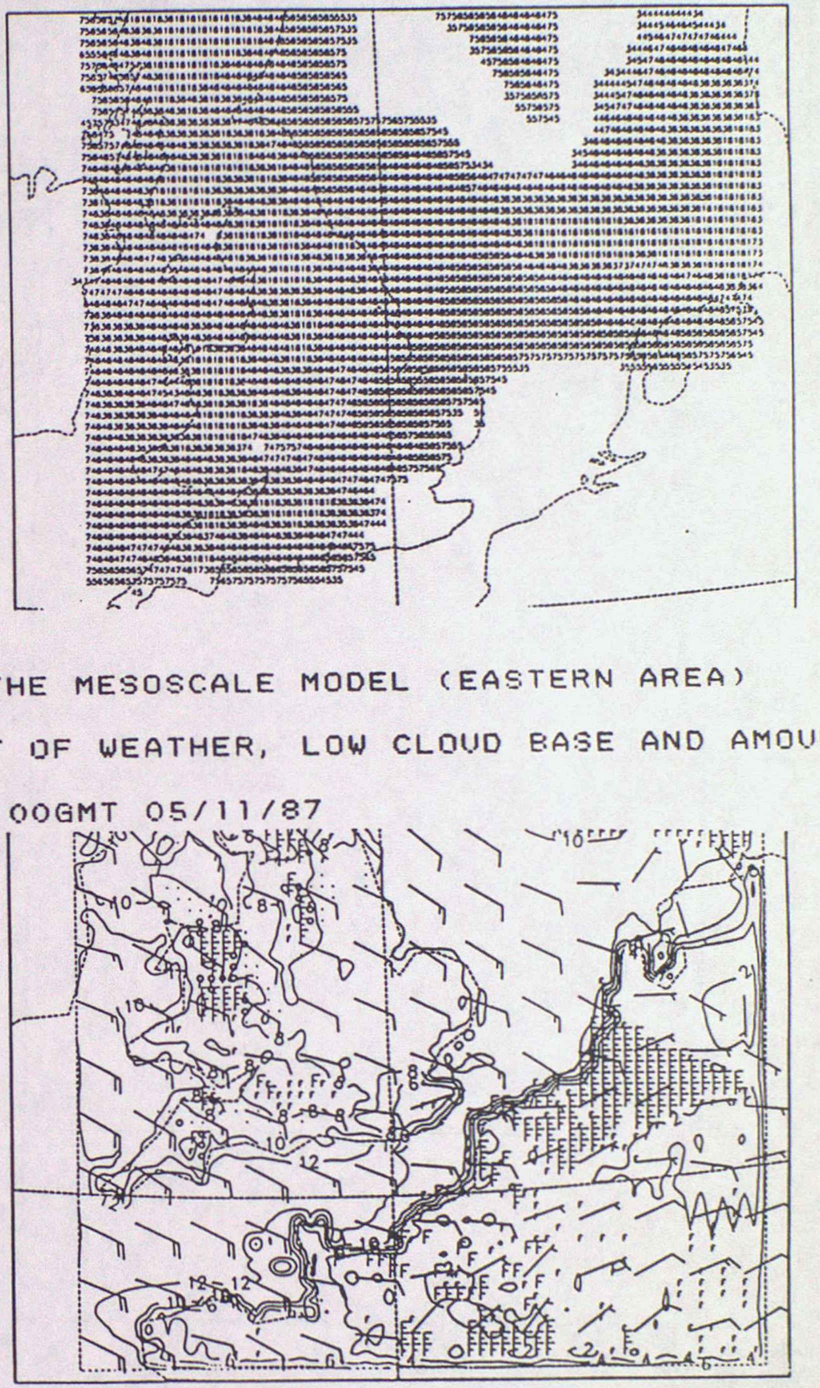


FIGURE 21b. THE MESOSCALE MODEL (EASTERN AREA)

T+12 FORECAST OF WEATHER, LOW CLOUD BASE AND AMOUNT

VERIFYING AT 00GMT 05/11/87

VIS CODE

F <1000M

F <200M.

LOW CLOUD COVER IN THE FINE-MESH AREA

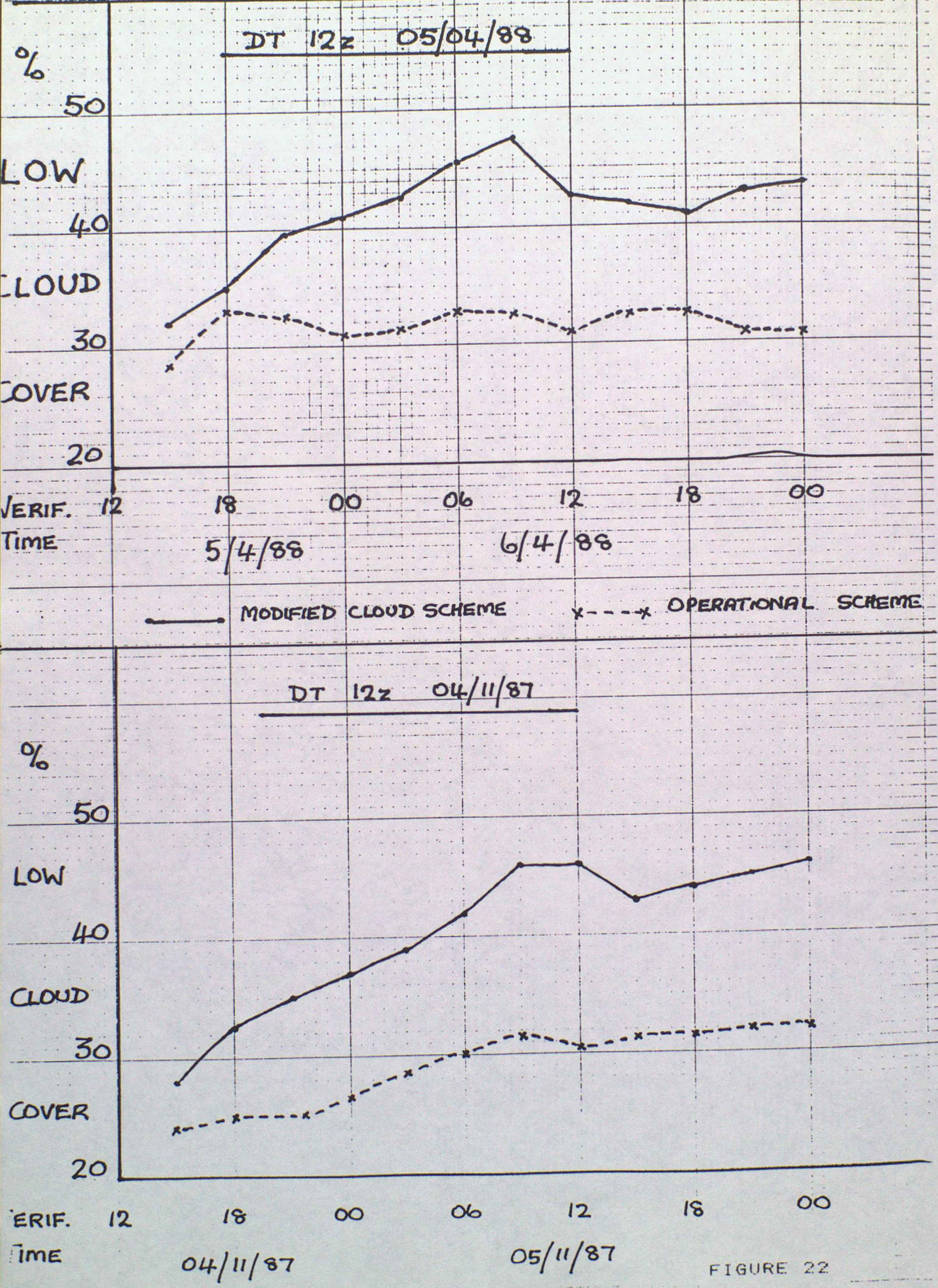



FIGURE 22