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MESOSCALE MODEL TRIAL OF A REVISED CONVECTION SCHEME AND CLOUD MODIFICATIONS.

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Mesoscale Trial of a revised convection scheme and cloud modifications

1. Introduction.

During the mesoscale model trial during last summer and autumn, two persistent problems were noticed in the objective verification. These problems have been described by Hammon[4] but brief details are given below;

a) There was a rapid increase of cloud during the first few model timesteps;

b) The model over-predicted amounts of convective rain substantially;

c) There were several model failures in hot, thundery conditions.

The way in which cloud is analysed has been described in detail by Barnes[3]. The problems of the increase of cloud in the first few timesteps is also mentioned by Golding[1]. The deep convection scheme is described by Barnes and Golding[2].

The new package was introduced to improve the features described above. The scheme was designed to have a smoother response to convection, giving more but less vigorous convection and to impose conservation of water in the model atmosphere. The changes are described in detail in Section 2.

Before the changes could be introduced operationally, it was necessary to test them thoroughly. The results from the trial forecasts are described in Section 3. Finally, the main conclusions are listed in Section 4. On the basis of this trial, the new version became operational in April 1987.

2. Details of changes

a) revised convection scheme

The diagnosis of convective clouds, and the convection scheme have been considerably revised. The more important changes are:

(i) diagnosis of convective instability is altered from the use of saturation equivalent potential temperature to comparing liquid water potential temperatures of parcel and environment, but with entrainment unaltered. There is only sufficient workspace in the model to carry a number of convective clouds equal to $^1/_3$ of the number of gridpoints. In active situations, with a larger number of less vigorous clouds in the new version, this limit is reached more often and for longer periods. To ensure an even distribution of clouds over the model area, the loop over rows has been altered to :-

```
      DO  220  M = 0,2
      DO  220  J = 3+M,NY2,3
```

to make three successive cycles testing every third row. This change will only affect extreme cases where close to the maximim number of convective clouds is being diagnosed.

(ii) all clouds now have updraught mass flux dependent only on cloud depth (it used to depend also on the maximum departure of the 'parcel ascent' from the 'environment profile'). This is scaled by the same. 'ramp function' as was previously used only to scale the convective mass increments. Thus the mass flux increases linearly during the first quarter of the cloud's lifetime, is constant for the middle half, and decreases to zero during the last quarter. The major part of the convection scheme (subroutine CONUPD) is worked in terms of the scaled updraught mass flux in units of kg/double timestep. The unscaled standard mass flux value is 10^{11}x cloud depth/8000m kg/lifetime, as in the old scheme.

(iii) reconstruction of updraught profiles and calculation of increments are in terms of liquid water potential temperature θ_L and total water q_T, as well as u,v wind components and up/downdraught mass sources/sinks. Updraught mass flux is now kept constant with height, there being an equal detrainment of updraught air to balance the entrainment of environment air.

(iv) from the precipitable water condensed at cloud top, 0.05 g/kg is extracted to contribute to the formation of an anvil cloud. The rest falls as rain with level-by-level evaporation (the old scheme had an average evaporation calculation and an *ad hoc* redistribution within the cloud levels of this moisture) using a formula for evaporation of rain supplied by Met.O.15.

Viz.:-

$$\text{Evap} = \frac{(q_s-\chi)\ 1.5\times10^{-6}\Delta z\ (40.09\ P^{0.4}+443.4\ P^{0.6})}{(5.5\ q_s + 0.044/\rho)}$$

where $\chi = q_T.s + q_s(1-s)$ is an effective humidity (limited to be $\leq q_s$), with $s = 0.2 + 100(\mathbf{v}_T-\mathbf{v}_B)/(z_T-z_B)$ a function of cloud base-top shear, P is precipitation rate in $kgm^{-2}s^{-1}$, q_s is saturated h.m.r., ρ is air density and Δz is level thickness, all for model level k.

(v) the θ_L, q_T, u and v increments are shared bilinearly among the 4 nearest grid-points in the same way as the mass increments.

(vi) also associated with convection in the model but simply affecting output, not the behaviour of the convection scheme itself, are some changes at write-up . Code has been added to check for duplicates in the scattering of convective clouds to their nearest grid-point for outputting, and add or average the values for all clouds in a grid-square. In the old version the output values of convective variables belonged to the most recently diagnosed cloud in a grid-square, and took no account of the fact that there may be several convective clouds within one grid-square and the most recent may not be the most significant. This deficiency would matter more in the new scheme since the size of each cloud evolves during its lifetime.

Since the updraught mass flux depends only on cloud depth, the convective intensity variable (CI,0) would be redundant, so it is now being used to indicate the number **n** of convective clouds located within the 15 km^2 grid-square centred on the grid-point to which the convective variables are scattered. The convective cloud cover (N,1) is now the sum of the rainfall areas of these clouds, and the local convective rain rate (PR,1) is the area weighted mean of the local rate for each cloud, i.e. $\Sigma p_i a_i / \Sigma a_i$, where p_i is the local rate and a_i the rainfall area for each of the n clouds in the 15 km^2 grid-square.

The convective cloud cover is output in units of oktas and is limited to 8, but this will hardly ever need to be applied, since the rain area for a cloud at its mature stage is approx. $5(1+s)dh^{km}$ km^2, where dh^{km} is cloud depth in km and $s = 100(\mathbf{v}_T - \mathbf{v}_B)/(z_T - z_B)$ is the cloud base-top shear, and it should be highly unlikely that more than 4 or 5 clouds occur within a grid-square. To suit operational display requirements, if the cover is < 0.2 oktas, then the local rate is set to a small value of 0.01 $mmhr^{-1}$, so that the symbols will not appear on charts for these small clouds. (see case study DT 06GMT 06/4/86).

The treatment of convective cloud top & base (HT,1 & H,1) is unaltered with the values being those belonging to the most recently diagnosed cloud in the grid-square, thus indicating the current depth of convective instability.

(vii) A problem with the unpacking of dynamic and convective accumulated precipitation has been noticed. When the dynamic accumulation is > 12mm and convective accumulation is small, then the unpacked convective value, though still small, is not accurate and may well even be negative. Therefore a check to reset any negative convective accumulations to zero has been added.

N.B. this problem is only likely to arise in practice in case studies with long intervals between write-ups, and not in the mesoscale suite main runs which use hourly write-ups.

b) partial cloud initialisation

Verification of mesoscale model forecasts has shown that cloud cover often increases markedly (by 1 or 2 oktas) at the start of the forecast run. Indeed the cloud cover values in a 1 timestep forecast have often been significantly larger than those in the corresponding initialisation dataset. A formula has been derived to diagnose the cloud water value which, assuming turbulence effects are small, will give the analysed cloud cover value. Thus for partial cloud cover (cloud cover less than 98%) the cloud water mixing ratio is set to

$$CW(k) = \frac{10^{-4} \Delta z(k)\, CF(k)^2\, q_s(k)}{1 + (L_H/c_p)(\epsilon L_H/R)\, q_s(k) p(k) / (T^2(k)(p(k) - (1-\epsilon)e_s))}$$

where for model level k, Δz is level thickness, q_s is saturated h.m.r. over water or ice, p is pressure, T is temperature and ϵ=0.622. Where T<-15°C or cloud is seeded from above by snow, cloud water is initialized as ice.

c) smoothed cloud cover in the radiation scheme

To simulate the fact that cloud over the full hemispheric view of an observer at a grid-point affects the amount of radiation incident - not just the cloud in the column vertically above - the grid-point cloud cover values are smoothed before use.

The formula used is

$$CF'(i,j) = (1-2h)CF(i,j) + h(CF(i-1,j)+CF(i+1,j))$$

applied in the W-E direction followed by

$$CF^{smoothed}(i,j) = (1-2h)CF'(i,j) + h(CF'(i,j-1)+CF'(i,j+1))$$

applied in the N-S direction, where $h = \arctan(2z/a)/\pi$, z being height of model level k and **a** being model grid-length. Possible influence of cloud from more than one grid-length distant is ignored.

d) precipitation code used from start of forecast

With the better initialization of cloud water it has been found unnecessary to suppress the full precipitation code for the first couple of timesteps.

e) removal of advection of turbulent kinetic energy

The occurrence of hot-spots in isolated cases can be traced to numerical problems arising from there being advection of turbulent kinetic energy (T.K.E) but no horizontal diffusion of it. Strong gradients of T.K.E. can be enhanced and maintained spuriously, giving rise to a stationary minimum of T.K.E. at the hot-spot grid-point. As an interim measure to avoid this problem, advection of T.K.E. has been removed, by by-passing most of the code of subroutine TE. A more satisfactory solution, such as reintroducing advection of T.K.E. with a corresponding diffusion routine, will be sought.

3. Impact of proposed changes on the mesoscale model forecast

In order to assess the impact of the above changes, seven cases were rerun to twelve hours, using:

i) a trial version, including the above changes

ii) a control version, i.e. the current operational version.

These seven cases were selected from those saved on the mesoscale archives during the last twelve months as being either good (or problem) forecasts of important synoptic features.

The important synoptic features of each of these cases and the main differences between the trial and control forecasts are described below.

The seven cases chosen were;
DT 06z 6/4/86 DT 06z 24/4/86 DT 06z 20/5/86 DT 06z 29/5/86
DT 18z 21/6/86 DT 06z 16/7/86 DT 12z 27/3/87
One extra case (D.T.06GMT 27/1/87) was chosen especially to test the new initialisation of partial cloudiness.

a) D.T 06GMT 6th APRIL 1986. FORECAST PERIOD 06-18

With an anticyclone just to the north of Scotland, a cold unstable northerly airstream covered the U.K.. An upper trough was centred over England and Wales. Eastern areas had frequent showers of rain, hail or snow, which were heavy at times in the south. The area of showers moved inland during the afternoon and most places in England and Wales had at least one shower. Western Scotland remained dry.

The chief difference is the increase in the number of light or moderate showers predicted by the trial version throughout the period. In figure 1, we compare the forecast of showers for 12GMT by the control and trial versions. At 12GMT, showers were widespread over Wales, Northern England, the East Midlands and South-east England, whilst Devon, Central Southern England and the West Midlands were mainly dry. Figure 2 shows the observed weather for 12GMT for comparison. Unfortunately, no radar picture is available for this time to verify the distribution of showers. The trial version (see figure 1b) was better in predicting showers over Wales and Northern England, but forecast showers incorrectly over South-west England. The control version (see figure 1a) was correct in the east but had insufficient showers over Wales and Northern England. Note that both versions forecast an area of rain incorrectly over Central Southern England.

The trial version was a better forecast overall, although too many showers were predicted. Whilst it was true that most places had a shower during the afternoon, they did not all occur at the same time, as the trial version suggested. Many of the showers were very light and covered only a small fraction of the grid square, so we considered the possibility of changing the output to omit the smallest showers (i.e. those from newly formed cumulus clouds). We decided to cut out all showers from clouds occupying less than 0.2 oktas (area less than 5.6km^2). In figure 3, we show the effects of this change on the output. Figure 3a shows the convective cloud cover in oktas for each grid-point in the trial forecast for 12GMT and figure 3b shows the reduced cover left after the smallest clouds have been removed. This case resulted in the change described in detail in para.2a(iv) above being added to the trial package.

The impact of the trial version on cloud amounts was small. There was some increase in upper cloud in the trial version which verified quite well with an area of high cloud on infra-red satellite pictures.

b) D.T 06GMT 24th APRIL 1986. FORECAST PERIOD 06-18.

A slack low pressure area covered the U.K. and a small low centre moved northeastwards from Southwest Wales at 06z to Southwest Scotland by 18z. Northern and Eastern England had continuous rain during the morning and Eastern Scotland and Northeastern Scotland remained dull and misty all day. Over Wales and the rest of England showers developed, some becoming heavy with hail and thunder. In the southeast however, showers were mainly light and isolated.

The control version forecast too little rain during this period. Even at T+3, 09GMT, an area of continuous rain over the whole of Northern England was under-predicted by the model. The trial version with an increased coverage of rain/showers in this region gave the better forecast. The main difference between the two versions was the number of showers predicted. The control version was too selective and made errors in the distribution of showers, whilst the trial version forecast the showers to be too widespread. At 18z, thunderstorms were observed over the North Midlands and Northern England, with showers north west of a line from the Wash to Portland. In figure 4, we compare the two model rainfall forecasts at T+12, V.T 18 GMT with the corresponding radar. The radar picture shows the shower distribution clearly but without colour the position of the heaviest showers are not clear. However,the main line of heavy shower activity at this time was roughly from Humberside to Shawbury. The control version forecast the main line of showers to be from Humberside to Bristol which was not correct. The trial version forecast many more showers especially over Wales and North-west England. This was the better forecast on the whole although showers were too widespread. The disappointing feature of the trial forecast was the absence of heavy showers forecast in the observed thunderstorms area at 18 GMT, whilst heavy showers were predicted too far north.

Observed amounts of cloud in the South ranged between 5 and 7 oktas. This partial cloudiness was forecast better by the trial version at 9,12 and 18z.However, at 15z the trial version forecast an area of 8 oktas associated with showers which was incorrect.

c) D.T 06GMT 20th MAY 1986. FORECAST PERIOD 06-18

May 19th was mainly dry and warm with isolated thunderstorms in the southwest. During the night 19/20th May, these storms became more widespread over Southwest England, Central Southern England and the Midlands. During the morning of 20th May, the thunderstorms continued to move northwards into Northern England and Southern Scotland. Widespread showers and thunderstorms occurred over eastern areas but the west became mainly dry.

This case provided a good example of the over-development of convective systems by the mesoscale model in thundery situations. The original forecasts connected with this period, D.T.18GMT 19/5/86 and D.T.06GMT 20/5/86 failed after 269 and 42 time-steps respectively. Modifications were made to the deep convection scheme during December and the rerun of the control version was successful.

Radar pictures for 06 and 14 GMT,20/5/86 are shown in figure 5 (no picture was available for 12 GMT). These pictures show the main area of precipitation over England and Wales but without colour, the heaviest areas do not stand out clearly. At the initial data time 06GMT, (figure 5a), outbreaks of rain with scattered thunderstorms covered most of

England. Figure 6 shows details of cross-sections from the trial forecast on an approximate line from Lyneham to Manston at the initial time 06GMT and after 10 time-steps. Figure 6a(ii) shows that large vertical velocities were present in the initial conditions. The contours of vertical velocity are in intervals of 0.05m/s and the shaded areas indicate descending air. These were passed into the analysis from the previous forecast via the hybrid. Figure 6b shows the situation after 10 timesteps. The cloud water contours in figure 6b(i) are in intervals of 0.1g/kg. In the output, positive values indicate water and negative values are used to indicate ice. The strong gradient in the contours at 3600m marks the position of the freezing level. The large vertical velocities have increased further and have started to lift large quantities of cloud water up to 5-7km, and this is a feature associated with many model failures in thundery conditions. Both versions of the model produced a poor forecast for this period. Even at T+3, there was a marked evolution error with the main rain area being moved too quickly into the North Sea. In reality the rain and thunderstorm area covered most of England and Wales.

One of the two test failures with this case resulted in an extra change connected with the initialisation of cloud water (para.2d above) being added to the package and this may help to improve model forecasts in thundery situations. The trial version again forecast many more showers than the control version and this was a slight improvement. A switch was noted in the large rainfall accumulations in the first three hours from convective in the control run to dynamic in the trial version.

d) D.T 06GMT 29th May 1986. FORECAST PERIOD 06-18

An unstable northerly airstream covered the U.K. with an upper trough in the North sea. Showers became most frequent in eastern areas, whilst South Wales and South-west England remained dry. Cloud increased over Northern Ireland and Western Scotland during the period.

Results from the forecasts for this period were rather mixed. At T+6, the trial version gave the better forecast of the distribution of showers. The control version confined showers to the east, missing the showers which occurred over the Midlands. Both missed the light showers which were observed over Wales and Ireland. At 18GMT, the main band of observed showers was located down the meridian and this was better forecast by the control version. In reality the cloud was quite well broken, but both versions predicted far too much low cloud. At 15GMT, 18GMT the trial version increased cloud amounts over East Anglia to 8 oktas in showers and this was incorrect. Away from showers, the trial cloud forecast was marginally better.

e) D.T 18GMT 21st June 1986. FORECAST PERIOD 18-06.

High pressure was centred to the north of Scotland with low pressure over Biscay. An occlusion over South-west England moved slowly northwards. Thunderstorms and locally heavy rain over Devon and

Cornwall at 18z spread northwards over the rest of Southern England during the evening but died out after midnight. The night was generally cloudy with fog patches and occasional drizzle. Eastern England and Scotland remained dry but with extensive mist and patches of fog. Western Scotland and North-west England were dry with clear periods.

The control version failed after 6 hours and 20 minutes, whereas the trial version ran for the full 12 hours. In figure 7 we compare the control and trial forecasts at T+6, V.T. 00GMT with the radar picture. The radar picture shows the position of the main thundery trough at 00GMT, but the heaviest rain areas do not stand out clearly without colour. The trial version forecast extra showers and verified well when compared with radar. The main frontal trough was forecast in the correct position by both versions. The trial version forecast the development of a second band of showers over South-west England. Although this was not correct,the radar picture shows the existence of an area of rain or showers in the extreme south-west. In the later stages of the forecast, the trial version tended to keep the heavy showers going too long. In particular. the model forecast heavy showers over Wiltshire at 06GMT which was incorrect. Only small amounts of residual rain remained. Again there was a rainfall switch in the trial version, with the largest grid-point accumulations appearing as dynamic rather than convective. Both versions had grid-point storms, with the largest three-hourly accumulation being 90mm.

This case was a success for the trial version, with the control version failing after 6 hours and the original operational fôrecast failing after three hours. The control forecast developed a small thunderstorm high cell in the English Channel (see figure 8c). Figures 8a and 8b are cross-sections through this high cell showing cloud water and vertical velocity respectively. In figure 8a, the contours of cloud water are in intervals of 0.1g/kg and in the output, negative values are used to indicate ice. The strong gradient in the contours at 3600m indicates the freezing layer. In figure 8b, the contours of vertical velocity are in intervals of 0.2m/s and the shaded areas indicate descending air. These cross-sections show the prescence of large values of vertical velocity and cloud water at 9000m. This forecast failed shortly after this time.

f) 16th July 1986. FORECAST PERIOD 06-18.

South-east England had a hot, dry and sunny day in most places, with temperatures reaching a maximum of 30°C but mist and fog patches affected the South coast. It was cloudier and cooler in the west and north with fog patches on coasts and hills. A band of rain associated with a cold front crossed Northern Ireland and Scotland during the period and moved into Wales towards 18GMT.

The trial forecast for this period was not expected to be different to the control version for this case. However some differences were noticed and this case meant that an extra change (para 1e) had to be added to the trial package. Temperature forecasts were generally the same, with a maximum of 31°C being forecast over the Norfolk coast in both versions.

The only noticeable temperature difference occurred at the grid-point for Manchester at 15GMT, where the trial version forecast 29°C compared with 24°C by the control version (the observed temperature was 26°C). This difference appeared to be related to effects over an isolated urban grid-point (which has a high surface resistance to evaporation), rather than to the trial changes. Figure 9a shows the temperature forecast at 15 GMT from the first trial version. This shows the localised 'hot spot' over the Manchester area. This urban spot is over 3 degrees higher than the surrounding grid-points. Figure 10a is a cross-section through the hot spot showing values of turbulent kinetic energy. There is a stationary minimum value over this grid-point. This is thought to be due to using horizontal advection of turbulent energy but no horizontal diffusion of it. As an interim measure, the advection term was removed (para 2e). Figure 9b shows the temperature forecast from the trial version following the removal of the advection of turbulent kinetic energy. The temperature over the Manchester grid-point is now 26°C which compares more closely with the surrounding points. Figure 10b is the cross-section through this grid-point showing values of turbulent kinetic energy. Over the Manchester grid-point, there is now a much higher value compared with the values in figure 10a.

The trial version developed a more active front over the Southwest approaches and Wales, with slightly larger amounts of convective rain. This appeared to be incorrect, although it is difficult to verify.

g) D.T 12GMT 27th March 1987. FORECAST PERIOD 12-24.

A very deep depression, central pressure 956mb, centred over Central Scotland at 12z, moved eastwards during the period into the North Sea. Gale force winds and occasional heavy rain and showers affected the whole of the U.K.. Rain was particularly heavy over Northwest England. Over southern England, most of the showers died out during the evening, with clear periods developing.

Both forecasts were similar in the amounts and areas of precipitation, except that the trial version forecast more showers over Southern England at 15GMT and 18GMT.

This forecast showed the greatest differences between the cloud forecasts of the two versions. During the evening, the showers died out over Southeast England and clear periods developed. The control version forecast too much cloud during the evening. Figure 11a and 11b compare the cloud forecasts at 00GMT for the control and trial forecasts. The first figure in each pair of numbers gives the amount of low cloud in oktas. The second figure relates to cloud base and is zero if the cloud amount is less than 5. The non zero numbers relate to a cloud base code which is given below:

0 = Amount of low cloud less than 5 oktas,
3 = 5 oktas or more with base < 1000FT
4 = 5 oktas or more, base 1000 - 2000 FT
5 = 5 oktas or more, base 2000 - 3000 FT
6 = 5 oktas or more, base 3000 - 4500 FT
7 = 5 oktas or more, base 4500 - 6000 FT

The clear periods are much better forecast by the trial version.

h) D.T.06GMT 27th January 1987. FORECAST PERIOD 06-18.

This case was rerun in order to test the new partial cloud initialisation scheme in the trial version. In the old scheme there was a rapid increase of cloud in the first few timesteps, which meant that the model started too cloudy and tended to remain so throughout the forecast. We hoped to show that the cloud in the new scheme would remain much closer to the cloud analysis in the first few timesteps. It was not possible to use the old archived cases to test the new scheme because they were rerun from initial data which was a T+1 timestep forecast (i.e the initial data was already contaminated with too much cloud).

In figure 12, we compare the control and trial forecasts of low cloud cover after one timestep. In the control forecast (figure 12a). there is already an increased area of cloud greater than 7.5 octas in comparison with the trial forecast, which was more correct. In figure 13, we compare low cloud forecasts after five timesteps. The low cloud cover in the control version has increased dramatically to cover most of the model area with > 7.5 oktas.. In contrast, the trial version has remained much closer to its analysis and compares much better with observations.

3. Conclusion

A set of seven archived and recent cases were rerun using the old (control) and new (trial) versions of the mesoscale model to compare the performance in a variety of situations. The main conclusions are listed below.

a) The trial version forecast a significantly greater number of showers than the control version for six out of the seven cases rerun. The control version was too selective and made errors in the forecast distribution of showers. The trial version gave an improved forecast but tended to forecast a wider distribution than observed.

b) The trial version forecast more but lighter showers. Typically, the new version forecasts a small cluster of showers compared to one heavier shower in the control forecast. There seem to be less heavy showers (rate greater than 10mm/hr). The extra showers contribute 0.1 to 2mm to the 3-hourly rainfall accumulation. For cases with only light or moderate showers the overall convective accumulation is slightly greater due to the greater number of showers. However, for the thundery cases, the overall convective accumulation is less than in the control version, because most of the large grid-point values are output as dynamic rain. The overall dynamic accumulation is slightly increased.

c) The trial forecast should have a greater chance of running successfully on hot thundery days. However, these cases will remain borderline. The presence of grid-point storms in the 21st June case suggest that the problem is not solved completely and further failures may occur.

d) The trial version had a small but significant impact on the forecasting of convective cloud amounts. The trial version forecasts the maximum allowed number of convective clouds more often than the control version. In general, the trial version forecast a better distribution of convective cloud.

e) For dry periods, the trial forecasts showed a small increase in partial cloudiness at the expense of a full cover, i.e. when compared with the control forecast,.there were less gridpoints with 8 octas and more with 6 or 7 octas. The impact was greatest in the March case in which the breaking of the cloud over Southern England during the evening was significantly better.

f) In areas where the trial version increased the number of showers significantly, cloud amounts were increased occasionally to 8 octas. This increase did not compare well with observed cloud amounts.

g) The new cloud initialisation scheme shows a significant improvement on the old scheme. There was a rapid increase of cloud in the first few timesteps in the old version, whereas the new version remained much closer to the original cloud analysis and was therefore much better.

REFERENCES

1. B.W.GOLDING: The Meteorological Office Mesoscale Model: An Overview (Version 4 Feb.1987).
2. R.T.H.BARNES,B.W.GOLDING: Mesoscale Model Documentation Paper No 5: Deep Convection. (Version 2 May 1987).
3. R.T.H.BARNES: Mesoscale Model Documentation Paper No 16: Combining Fine-mesh and Mesoscale Forecast Fields and then Incorporating Analysis Data (Version 1 Sept.1986).
4. O.M.HAMMON: Verification of Mesoscale Model Forecasts During The Period August - September 1986

D.T.06 GMT 6/4/86. CONTROL FORECAST. (OLD VERSION) FOR T+6, V.T.12 GMT. SHOWING RAINFALL, WIND AND SCREEN TEMPERATURE FORECASTS.

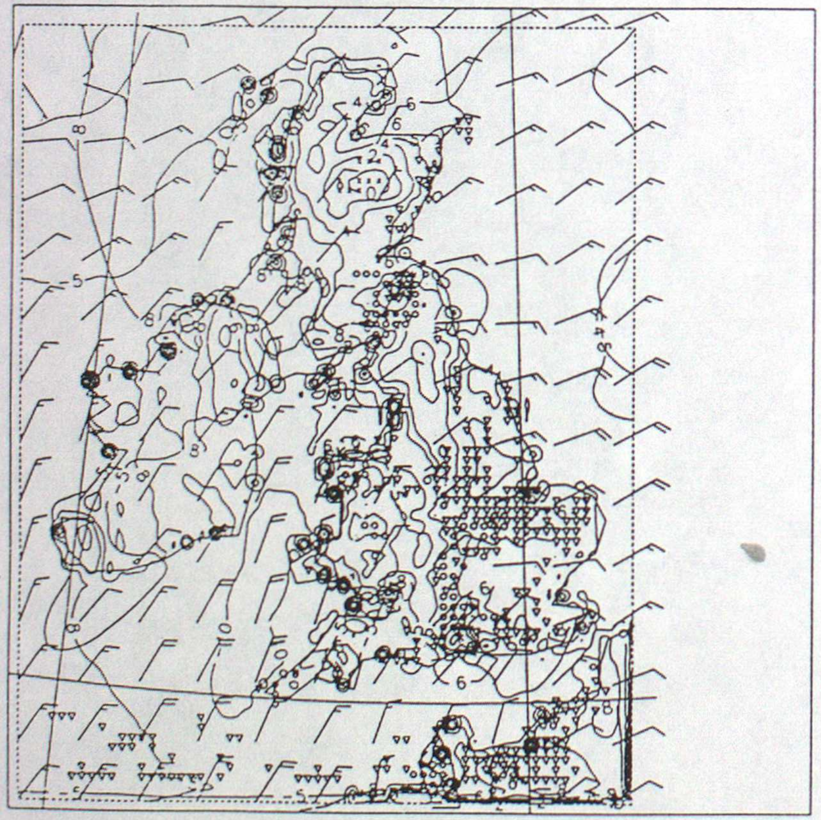


FIGURE 1a

KEY

DYNAMIC RAIN
· 0·01
o 0·1
● 0·5
mm/hr
CONVECTIVE RAIN
0·4
▽
10·0
▼
mm/hr (LOCAL)
SNOW
0·01
× 0·5
* mm/hr

D.T.06 GMT 6/4/86. TRIAL FORECAST. (NEW VERSION) FOR T+6, V.T.12 GMT. SHOWING RAINFALL, WIND AND SCREEN TEMPERATURE FORECASTS.

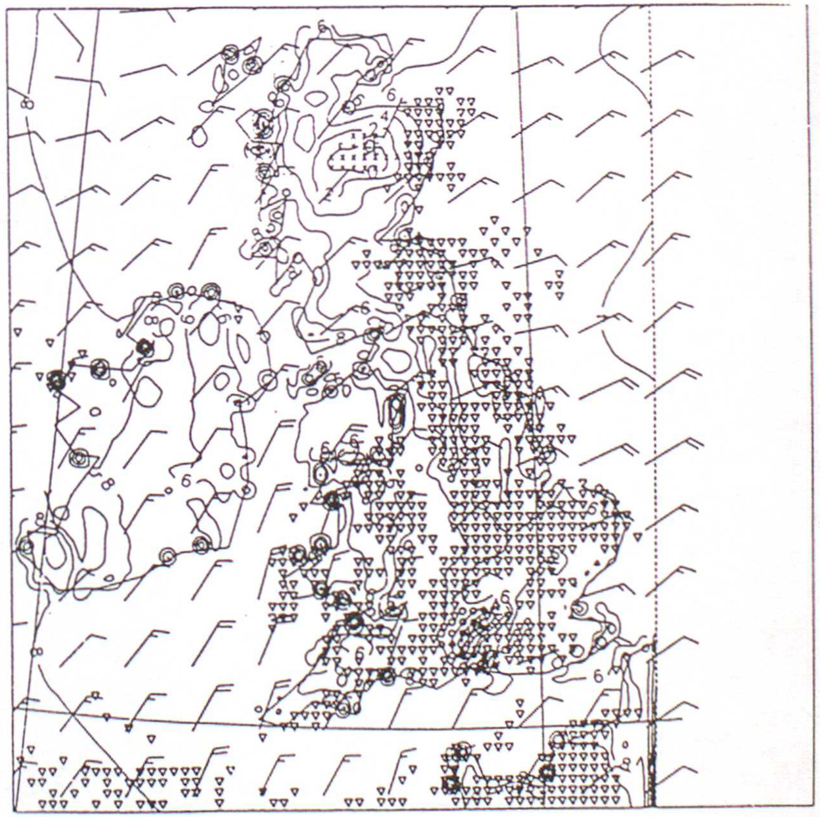


FIGURE 1b

CONTOUR INTERVALS

— 2 DEG C

12 GMT OBSERVATIONS ON 6/4/86 SHOWING DISTRIBUTION OF SHOWERS

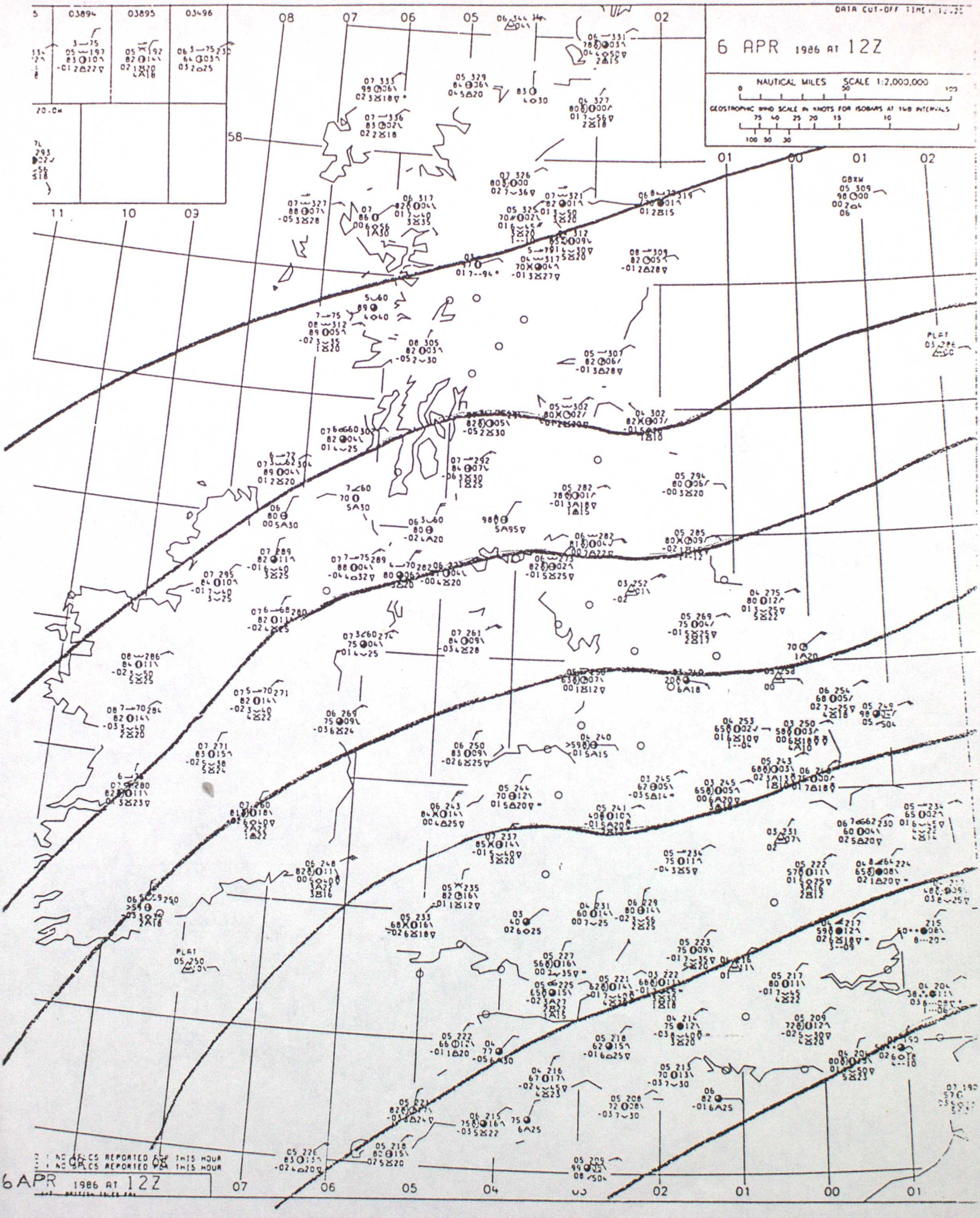


FIGURE 2

D.T.06 GMT 6/4/86, VERIFICATION TIME 12 GMT
6/4/86, TRIAL FORECAST SHOWING THE CONVECTIVE CLOUD
COVER IN OKTAS FOR EACH GRID-POINT.

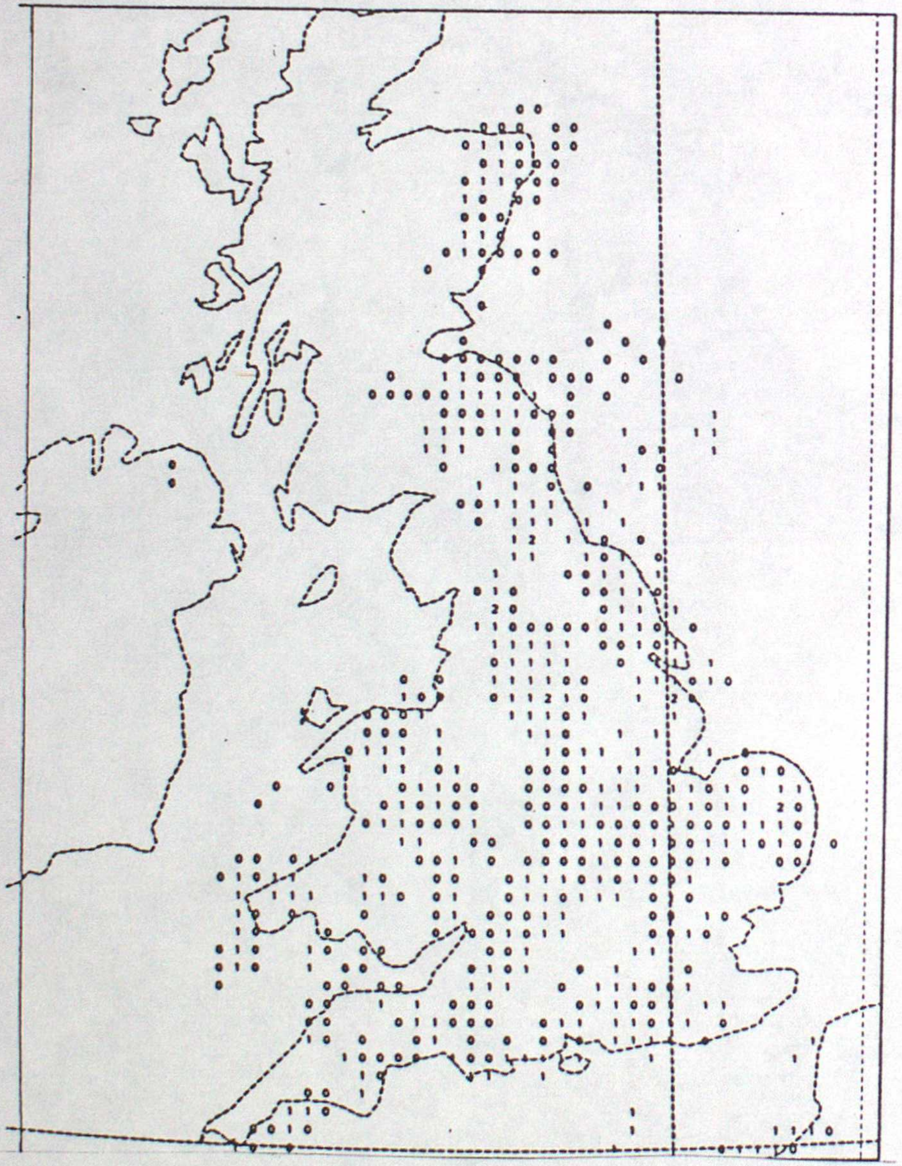


FIGURE 3a. TRIAL VERSION (ORIGINAL OUTPUT)

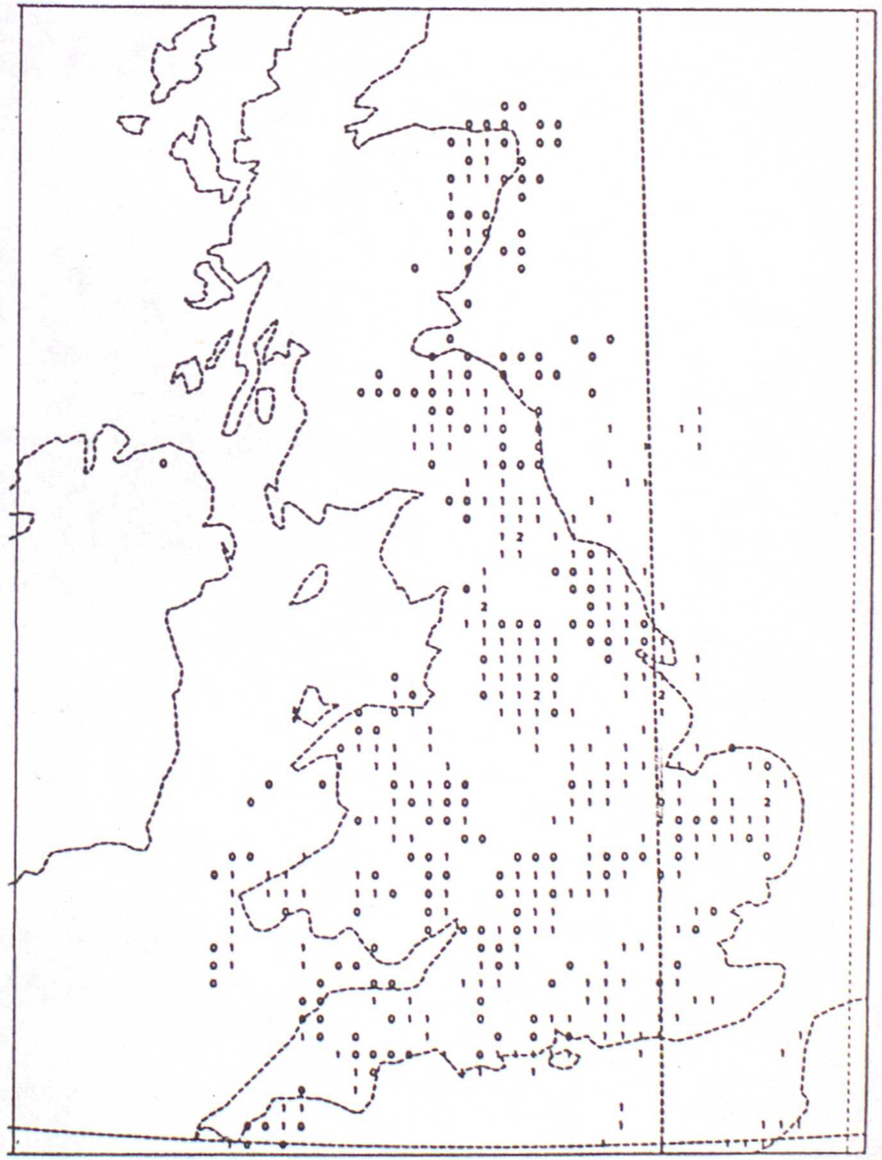
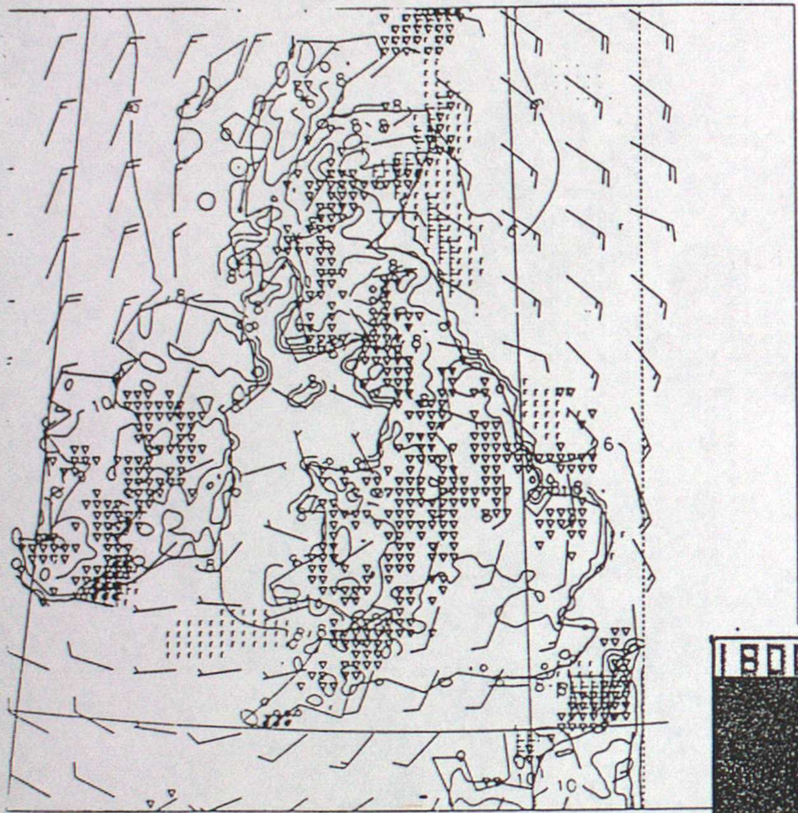


FIGURE 3a TRIAL VERSION WITH THE SMALLEST CLOUDS area < 6 KM) REMOVED

FIGURE 4a TRIAL FORECAST
(NEW VERSION)



KEY

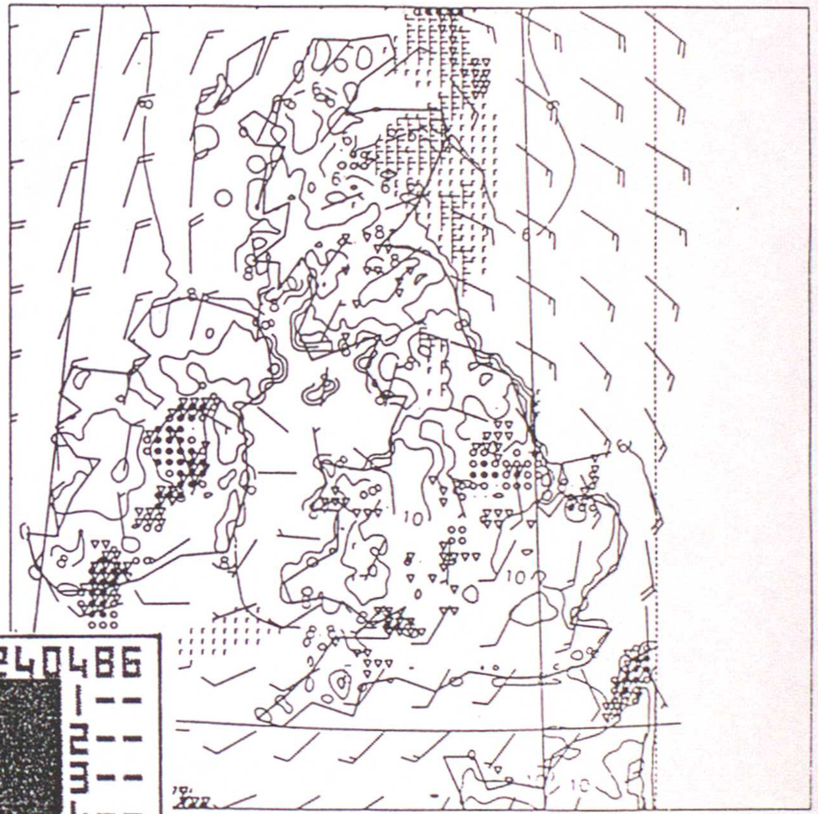
DYNAMIC
. 0·01
o 0·1
● 0·5 mm/hr

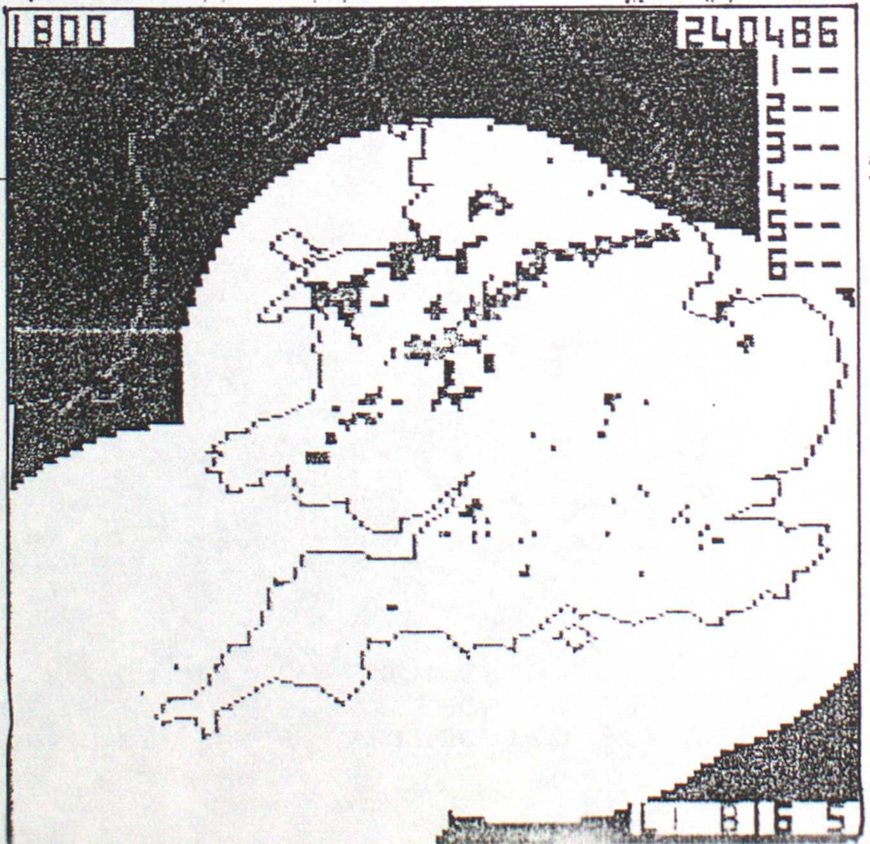
CONVECTIVE
0·4
▽ 10·0
▼ mm/hr (local)

VISIBILITY
1000
F 200
F metres.

CONTOUR INTERVALS

FIGURE 4b CONTROL FORECAST
(OLD VERSION)





D. T. 06 GMT
24/4/86. VERIFICATION TIME
18 GMT 24/4/86. MESOSCALE
MODEL FORECAST OF
RAINFALL, TEMPERATURE AND
WIND.

FIGURE 5a RADAR PICTURE FOR 06 GMT 20/5/86

FIGURE 5b RADAR PICTURE FOR 14 GMT 20/5/86

FIGURE 6a. CROSS SECTIONS ACROSS AN APPROXIMATE LINE FROM LYNEHAM TO MANSTON AT THE INITIAL DATA TIME 06 GMT

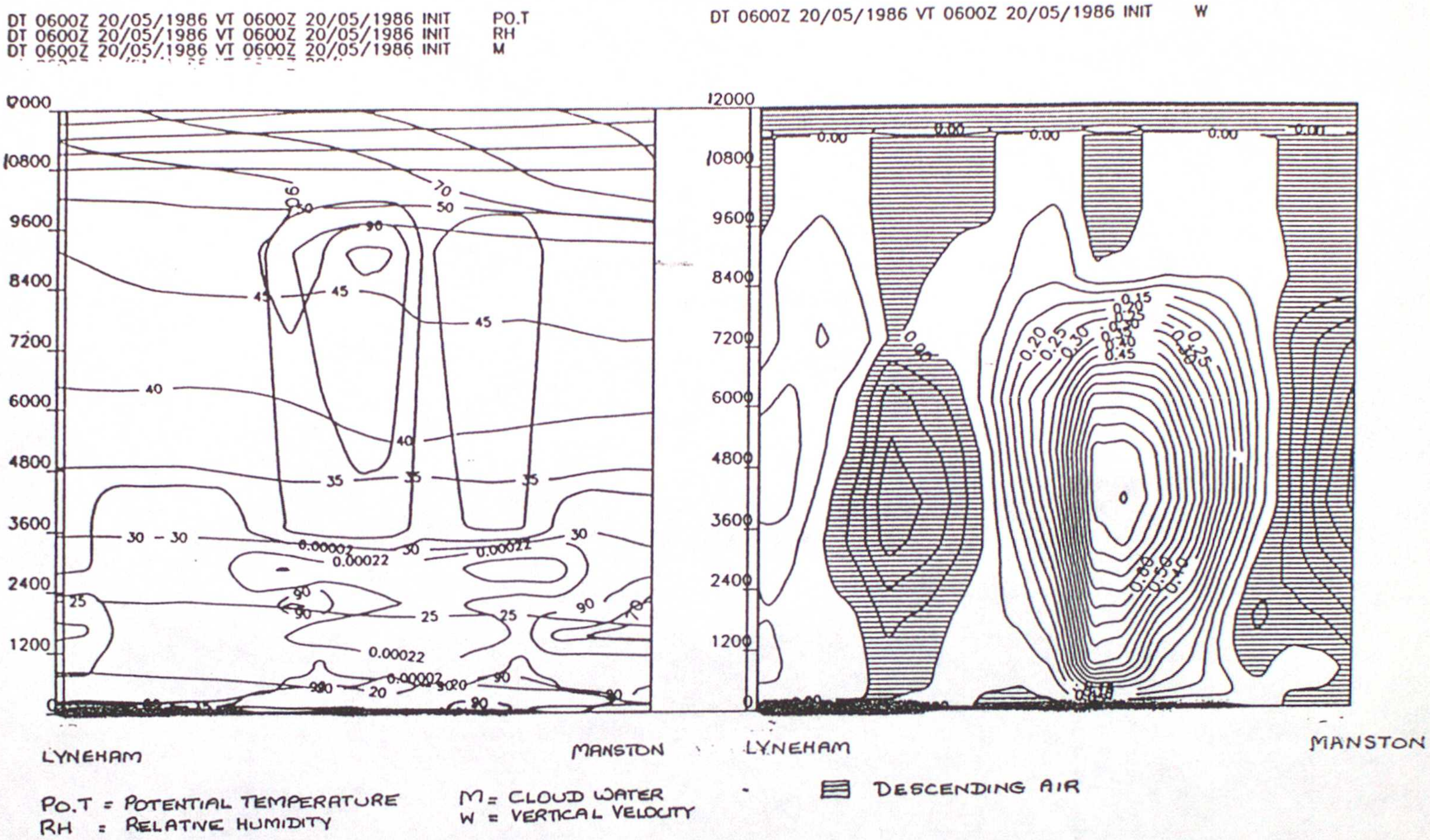


FIGURE 6b. CROSS SECTIONS ACROSS AN APPROXIMATE LINE FROM LYNEHAM TO MANSTON AT 0610 GMT

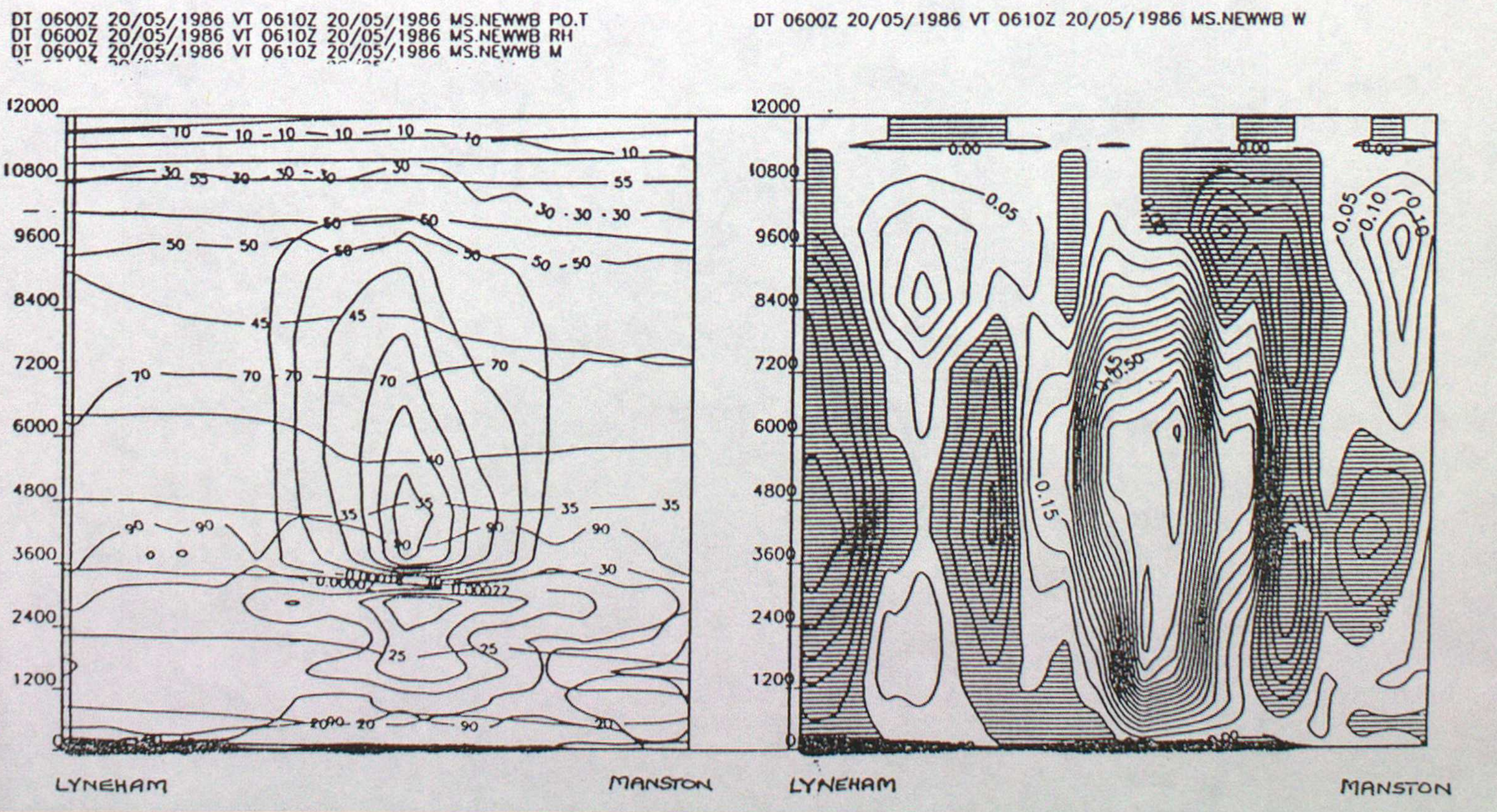
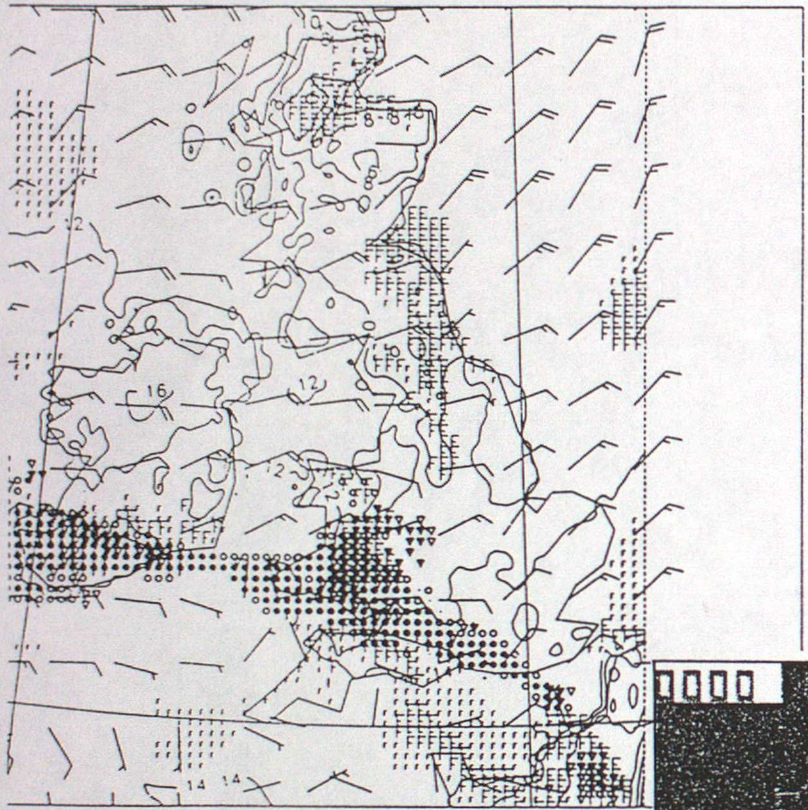


FIGURE 7a CONTROL FORECAST OF RAINFALL, TEMPERATURE AND WIND FOR T+6, V.T 00GMT, 22/6/86



KEY

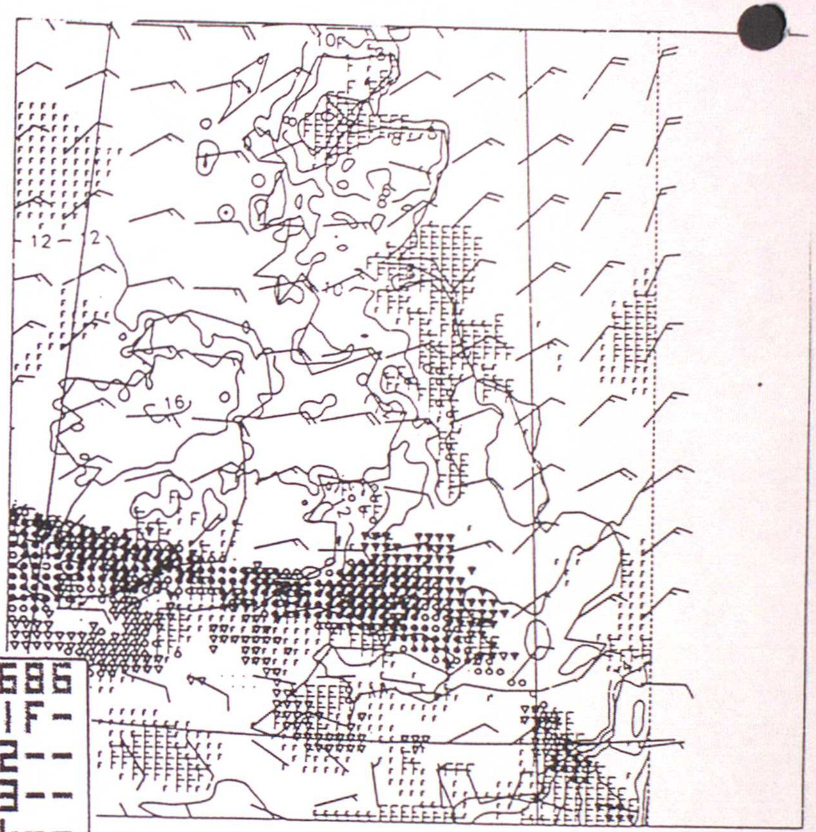
. 0·01
o 0·1
• 0·5 mm/hr DYNAMIC RAIN

▽ 0·4
▼ 10·0 mm/hr CONVECTIVE RAIN (LOCAL)

F 1000m VISIBILITY
F 200m

CONTOUR INTERVALS
— 2

FIGURE 7b TRIAL FORECAST OF RAINFALL, TEMPERATURE AND WIND FOR T+6, V.T 00GMT, 22/6/86



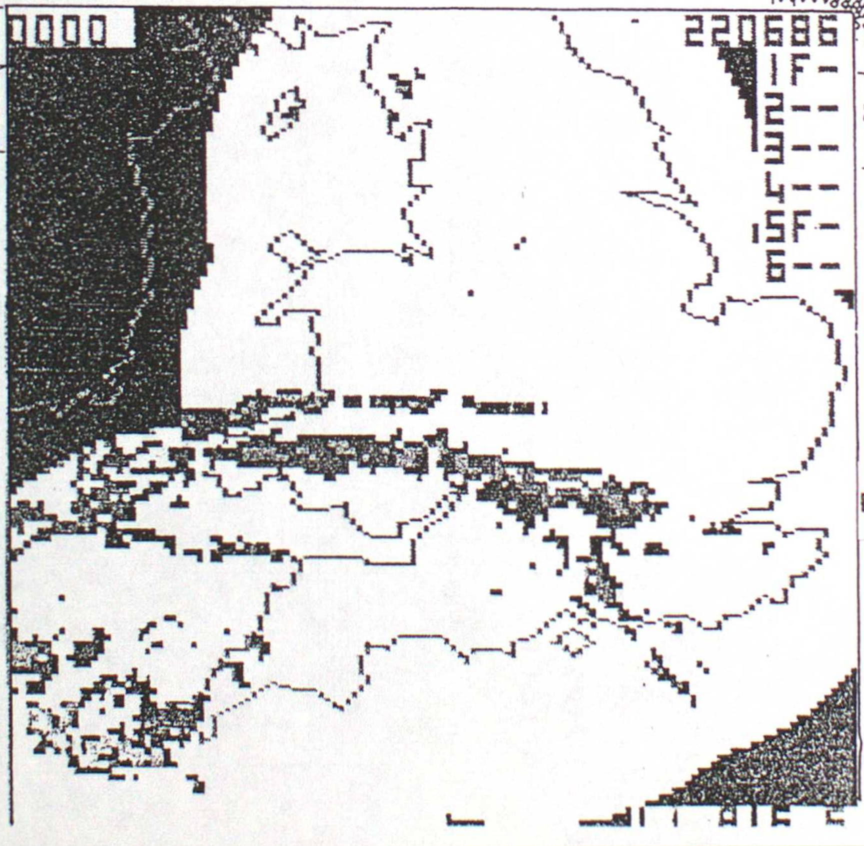
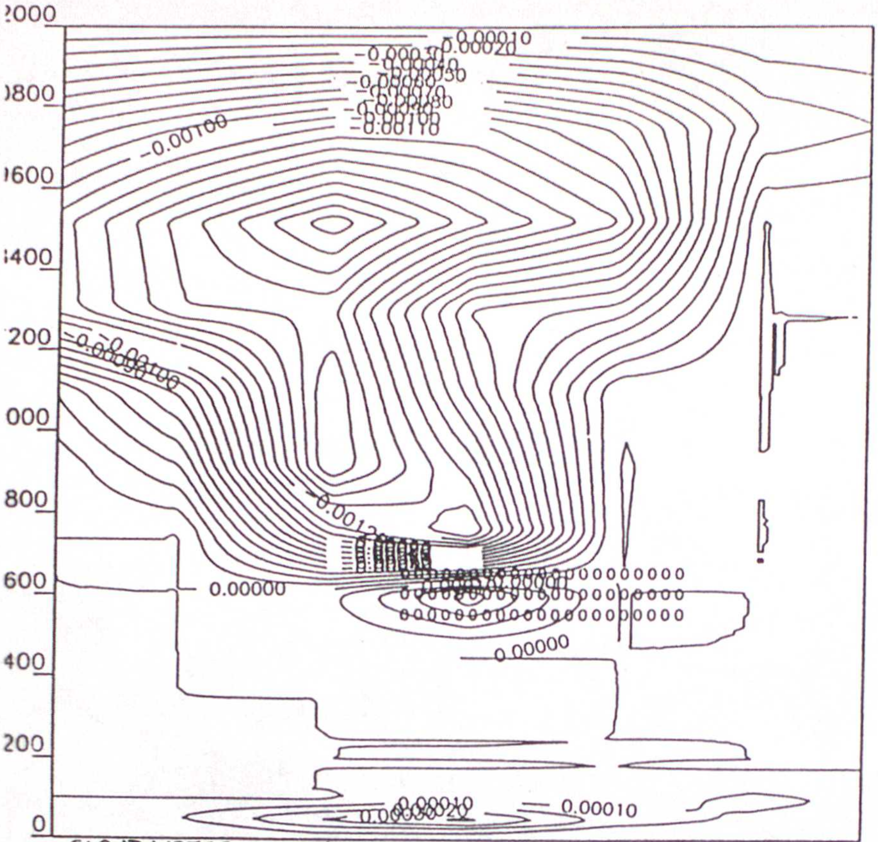


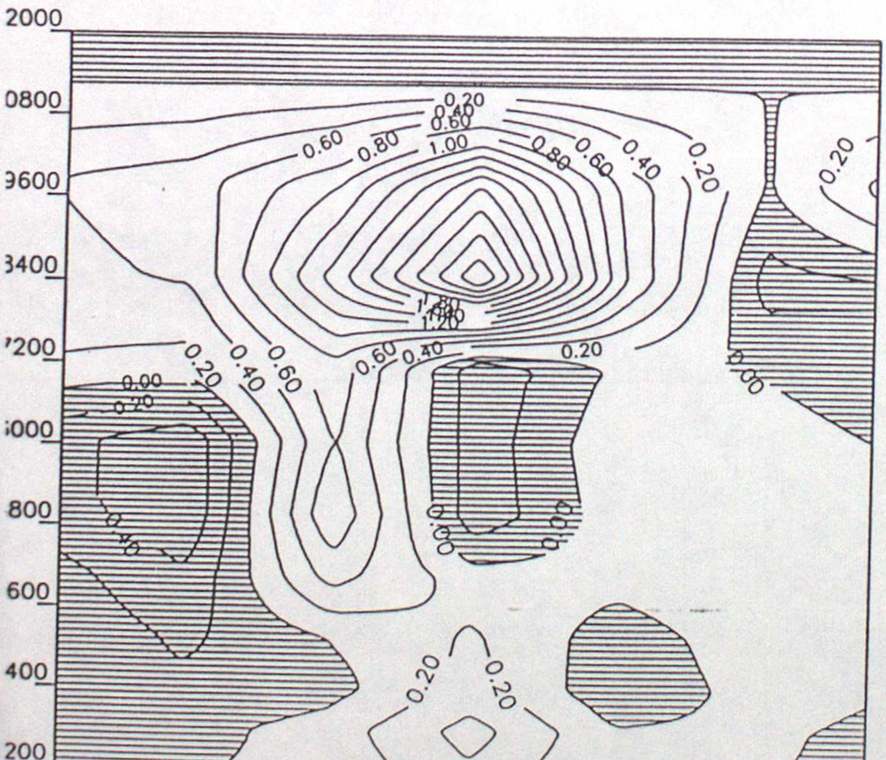
FIGURE 7c RADAR PICTURE FOR 00GMT 22/6/86

FIGURE 8a CROSS-SECTION TAKEN THROUGH THE THUNDERSTORM HIGH IN THECHANNEL, SHOWING CLOUD WATER.



CLOUD WATER IN G/kg

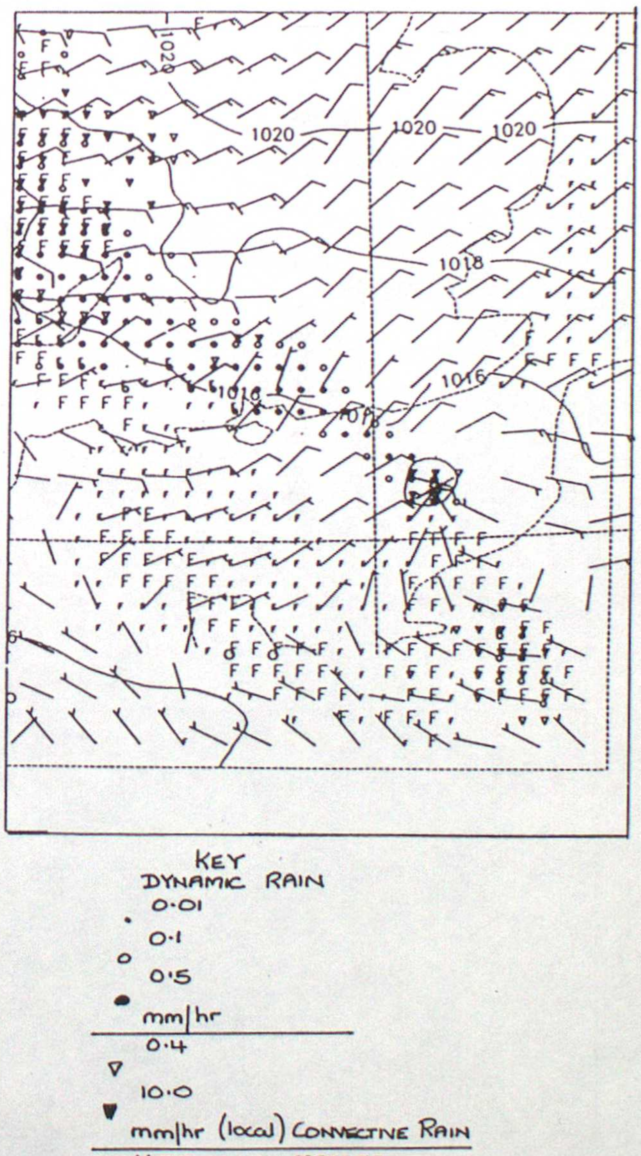
FIGURE 8b CROSS-SECTION TAKEN THROUGHTHE THUNDERSTORM HIGH IN THECHANNEL, SHOWING VERTICAL VELOCITY.



VERTICAL VELOCITY IN M/S.

DESCENDING AIR.

FIGURE 8c MESOSCALE MODEL CONTROLL FORECAST OF RAINFALL AND MEAN SEA LEVEL PRESSURE FOR T+6 VERIFICATION TIME 00 GMT 22/6/86



KEY

DYNAMIC RAIN

0·01

0·1

0·5

mm/hr

0·4

10·0

mm/hr (local) CONVECTIVE RAIN

VISIBILITY IN METRES

1000

200

FIGURE 9a TEMPERATURE FORECAST AT T+9 VERIFICATION TIME 15 GMT 16/7/86 FROM THE TRIAL VERSION, SHOWING THE LOCALISED HOT SPOT OVER MANCHESTER

13.6	13.4	13.5	17.8	18.3	18.8	19.1	20.0	25.0	26.5
13.7	13.5	13.5	19.5	20.0	19.8	20.5	21.1	24.8	25.8
13.9	13.7	13.7	21.5	20.0	19.6	20.8	23.1	25.6	25.1
13.9	13.7	23.0	22.8	21.1	21.3	20.8	22.5	24.5	25.0
14.0	14.1	24.0	24.5	24.5	25.0	21.3	21.8	23.6	25.0
23.0	24.8	25.3	24.8	25.5	(28.8)	21.8	21.5	22.6	24.8
21.3	22.3	24.5	24.3	25.1	24.6	21.8	22.0	22.6	24.3
20.5	20.8	25.0	24.8	25.6	24.1	22.1	21.8	23.0	24.5
19.6	21.3	25.0	24.8	25.1	24.0	23.5	23.5	24.6	25.6
20.0	22.3	24.6	25.1	25.3	24.5	24.0	24.3	25.1	26.1
22.0	23.0	23.8	24.8	24.6	24.1	23.3	24.3	25.8	26.1

TEMPERATURES IN DEGREES CELSIUS.

FIGURE 9b TEMPERATURE FORECAST AT T+9 VERIFICATION TIME 15 GMT 16/7/86 FROM THE TRIAL VERSION, FOLOOWING THE REMOVAL OF THE ADVECTION OF TURBULENT KINETIC ENERGY.

13.5	13.6	13.5	13.5	15.7	17.0	18.3	17.3	16.0	17.0	19.3	25.3
13.6	13.6	13.7	13.5	13.5	13.5	17.8	18.3	18.8	19.0	20.1	25.0
13.6	13.6	13.7	13.6	13.5	13.5	19.8	20.0	19.6	20.5	21.3	24.8
13.6	13.7	13.7	13.7	13.6	13.7	21.8	20.3	19.6	21.0	23.5	25.6
13.7	13.7	13.7	13.8	13.7	23.0	23.0	21.3	21.5	21.3	22.6	24.5
13.7	13.8	13.8	14.0	14.1	24.0	24.5	24.5	25.0	22.0	21.8	23.6
13.8	13.9	14.0	23.1	24.8	25.3	24.8	25.1	(25.6)	22.5	21.5	22.8
14.6	16.5	18.3	21.6	22.3	24.5	24.5	25.3	24.3	21.8	22.0	22.8
13.7	·6.0	16.6	20.6	21.0	25.0	24.8	25.6	24.1	22.3	22.0	23.1
15.7	15.2	18.0	19.8	21.3	25.0	24.8	25.3	24.1	23.5	23.5	24.6
16.3	16.1	17.0	20.0	22.3	24.6	25.3	25.5	24.5	24.0	24.5	25.3

FIGURE 10a CROSS SECTION THROUGH THE URBAN GRIDPOINT REPRESENTING MANCHESTER, SHOWING THE STATIONARY MINIMUM OF TURBULENT KINETIC ENERGY AT 15GMT 15/7/87.

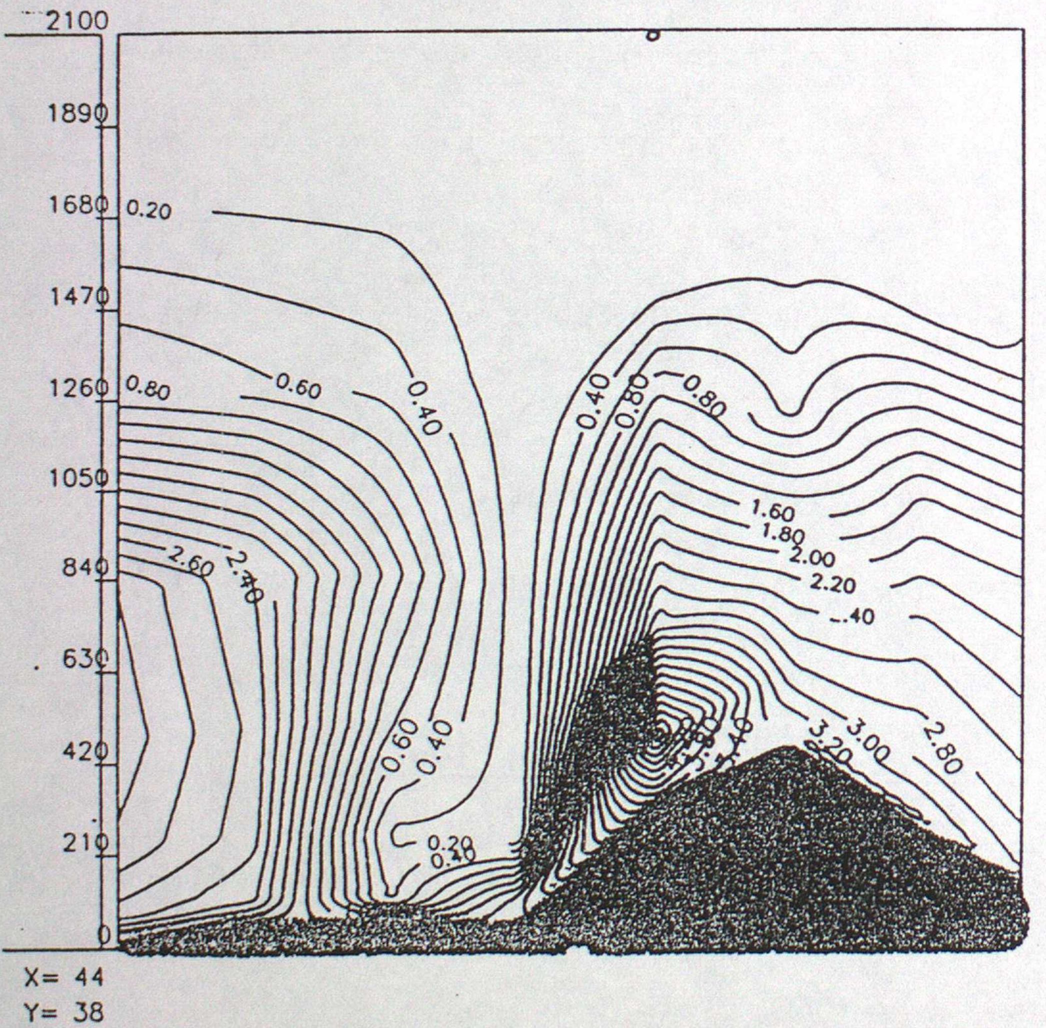


FIGURE 10b CROSS SECTION THROUGH THE URBAN GRIDPOINT REPRESENTING MANCHESTER, SHOWING THE VALUES OF TURBULENT KINETIC ENERGY AT 15 GMT 15/7/87 FOLLOWING THE REMOVAL OF THE ADVECTION TERM.

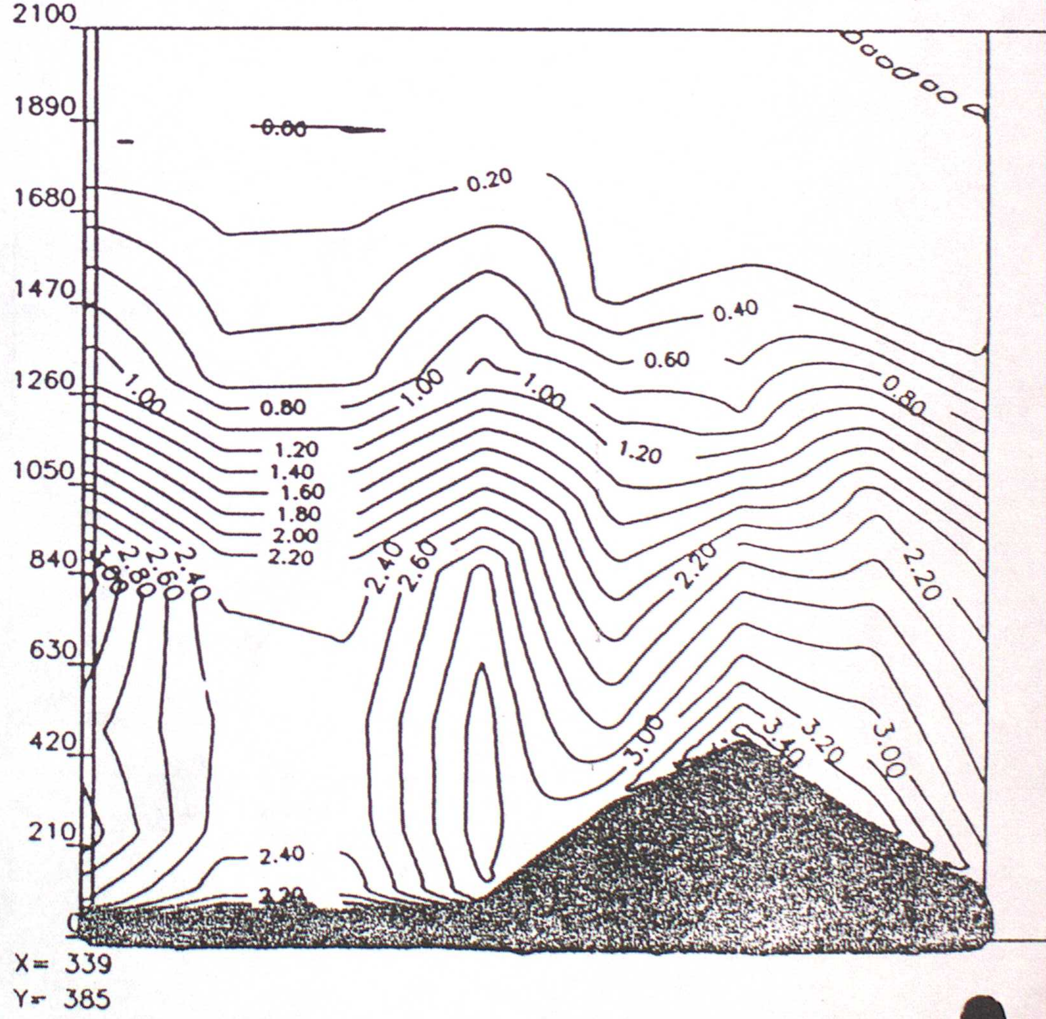


FIGURE 11a. CONTROL FORECAST OF LOW CLOUD COVER FOR T+12, V.T 00GMT 28/3/87.

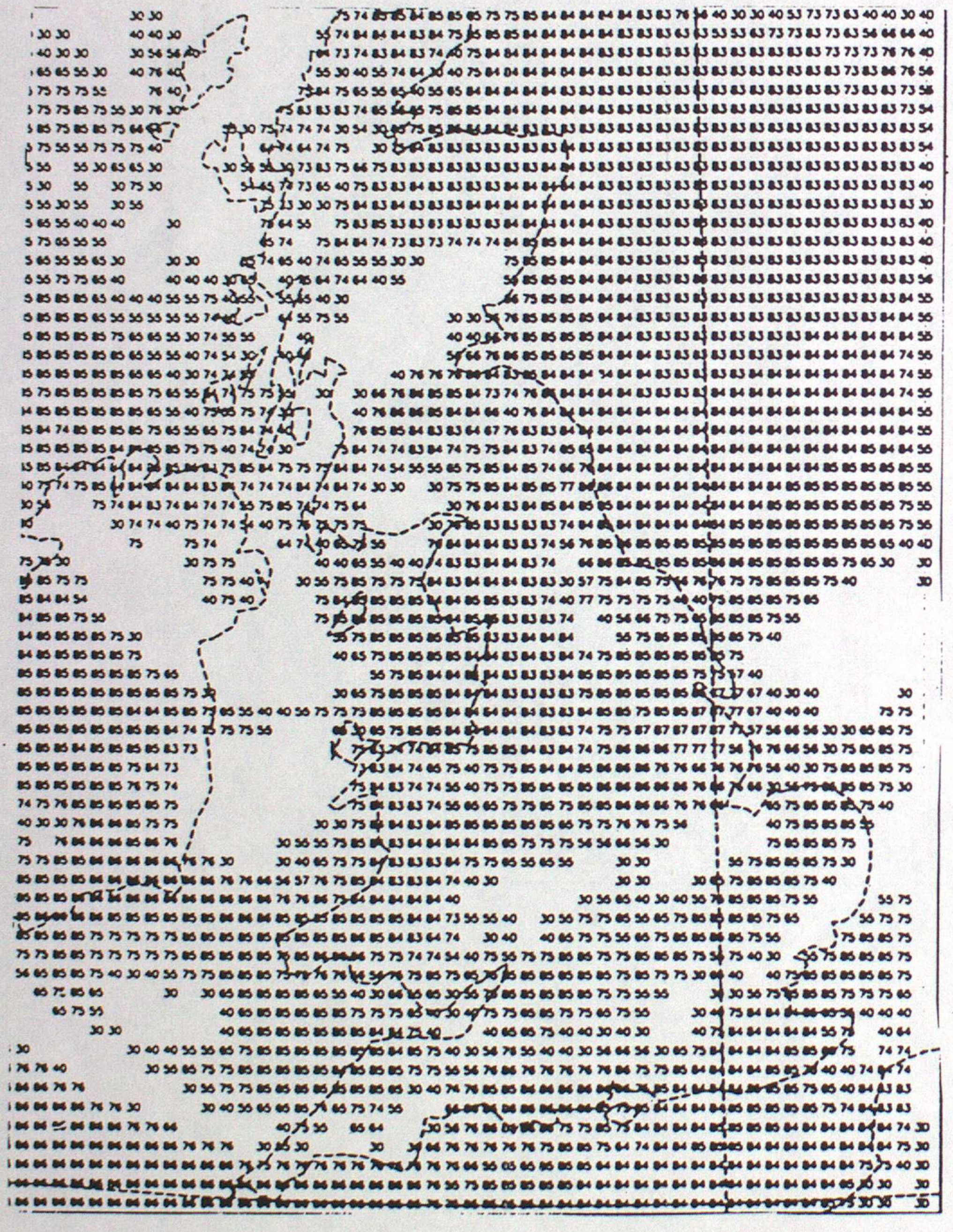


FIGURE 11b TRIAL FORECAST OF LOW CLOUD COVER FOR T+12, V.T 00GMT 28/3/87.

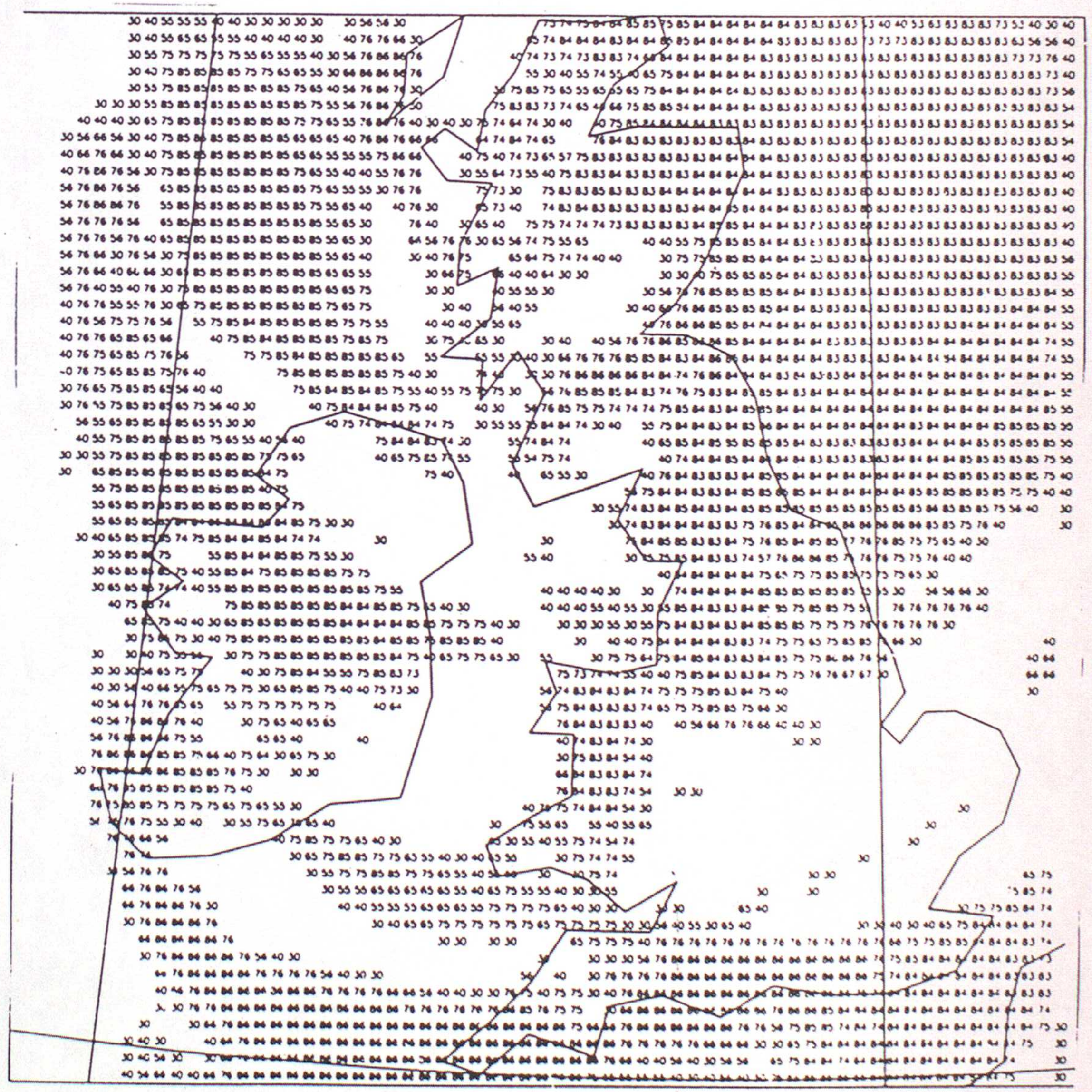


FIGURE 12a , CONTROL FORECAST OF LOW CLOUD COVER AFTER ONE TIMESTEP , V.T. 06GMT 27/1/87

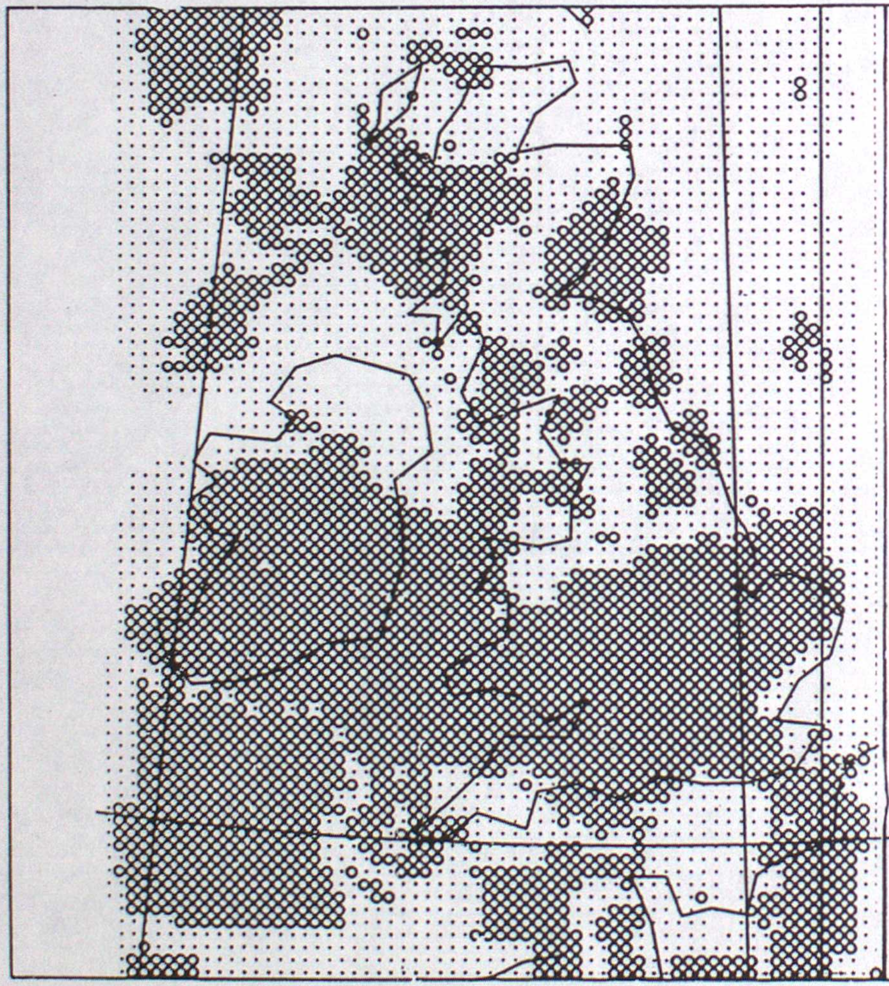
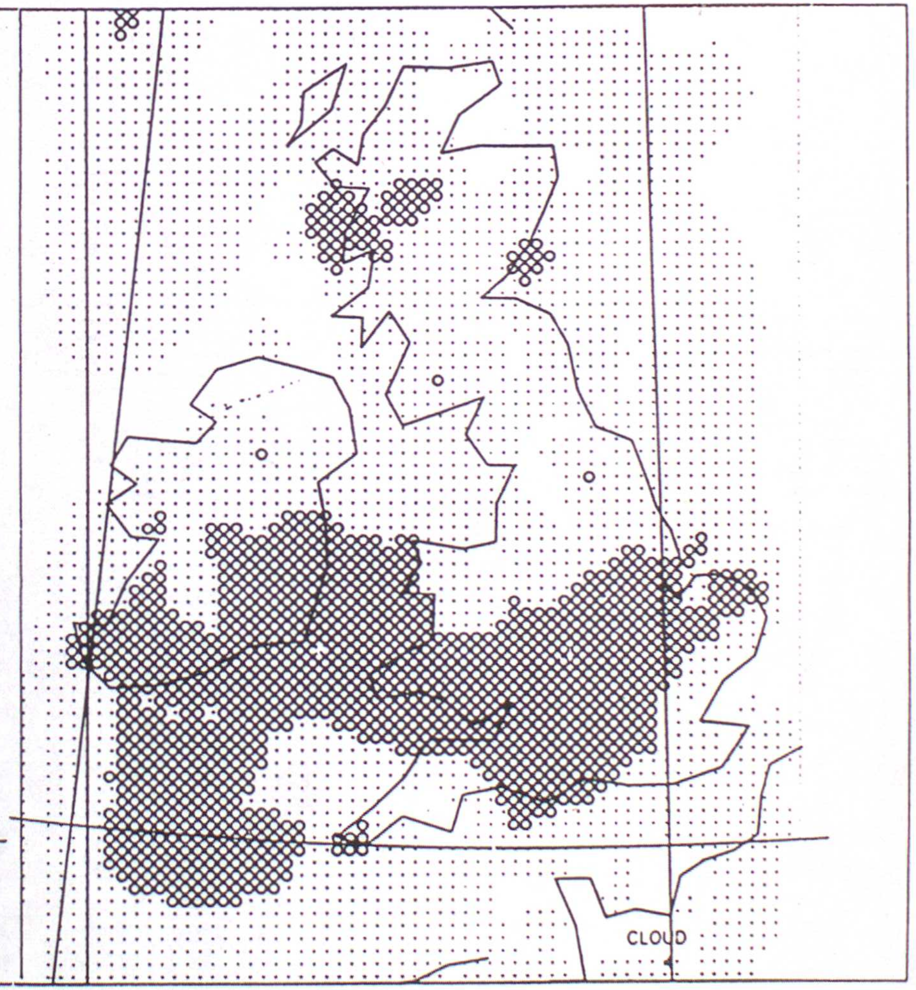


FIGURE 12b TRIAL FORECAST OF LOW CLOUD COVER AFTER ONE TIMESTEP V.T 06GMT 27/1/87.



○ ≥ 7·5 octas low cloud

• 4-7·5 octas low cloud

CLOUD
4
7.5
O
OKTAS

FIGURE 13a CONTROL FORECAST OF LOW CLOUD COVER AFTER FIVE TIMESTEPS .V.T.06GMT 27/1/87

FIGURE 13b TRIAL FORECAST OF LOW CLOUD COVER AFTER FIVE TIMESTEPS V.T 06GMT 27/1/87.