METEOROLOGICAL OFFICE

Forecasting Research

Met O 11 Technical Note No 5

Trial of proposed changes to the Mesoscale Model for November 1987

by

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December 1987

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DUPLICATE ALSO

MET O 11 TECHNICAL NOTE NO 5

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TRIAL OF PROPOSED CHANGES TO THE MESOSCALE MODEL FOR NOVEMBER 1987

1. INTRODUCTION.

Several changes to the mesoscale model suite have been proposed for implementation at the end of November 1987. The purpose of this note is to describe the proposed changes and the tests carried out in order to assess their impact on the model. The changes are described in detail in section 2. The changes total 15 in number, but some of them can be described as necessary 'stepping stones' towards the future 29-level version of the model, rather than important changes to the present version. The impact of these particular changes on the present version is expected to be negligible. In order to simplify consideration of the model changes, we have divided them into three sub-sections in Section 2. The changes most likely to affect the current version are described in sub-section 2A; those expected to have only a minor effect are described in sub-section 2B and those not expected to have any effect on the current version are in sub-section 2C. Some changes are also to be made to the ancillary programs associated with the new forecast controllee and these are described in sub-section 2D.

In order to assess the new package, eleven forecasts were rerun using a trial version of the model containing all 15 changes. The last changes to the model were made during April 1987. Cases prior to this were also reun using the current operational version. The cases chosen represented a wide range of synoptic situations. They are listed below;

DT 06 GMT 7/01/86	*DT 18 GMT 12/01/87*	*DT 12 GMT 3/03/87*
DT 00 GMT 28/03/87	*DT 00 GMT 12/06/87*	*DT 00 GMT 13/06/87*
DT 00 GMT 6/07/87	*DT 12 GMT 28/09/87*	*DT 12 GMT 9/10/87*
DT 12 GMT 15/10/87	*DT 12 GMT 24/10/87*	

The trial forecasts were compared with the control forecasts run using the current version of the model. The results from this comparison are described in section 3. Finally the main conclusions are listed in section 4

2. DETAILS OF PROPOSED CHANGES TO THE MESOSCALE MODEL FOR NOVEMBER 1987

SUB-SECTION 2A (changes most likely to have an impact on current version)

a. Snow Ablation.

Reason: As snow ages, it is blown off trees, bushes etc., and becomes dirty and icy. All of these processes reduce the albedo which may be interpreted as reducing the effective snow depth since the model albedo depends on snow depth. The formula used is a function of roughness length to allow for clearance from trees etc. before grass, and wind speed to allow for drifting.

Code change: In Sflux the lying water has rain/snow added and evaporation removed. At present 1% of water is lost per minute to allow for percolation but snow is not affected. In the new version, code is added to apply the formula.

$$S = S\left(1 - 0.0002\frac{\Delta t}{60}(1 + 4\sqrt{z_o}) - 0.00005\frac{\Delta t}{60}(0.1 = 4\sqrt{z_o})|V_{10}|\right)$$

if snow is present.

Effects: For Δt = 60 and no other effects, the fraction of snow left after a day is as follows:

z_o m \ V m/s	1	10	20
.01	.66	.62	.52
.1	.62	.42	.25
1	.52	.27	.12

b. Revise area of convective cloud.

Reason: Local convective rates are currently too large and convective cloud cover too small. When the convection parametrization was written the cloud area was specified so as to approximate to an aspect ratio of unity. On closer inspection of the code the aspect ratio turns out to be about 1.3 for large clouds, ie they are taller than their diameter. Recent numerical results suggest that the diameter should be more than the height. Here we use D = 1.275H. In addition, a more rigorous relationship with shear will be introduced assuming an ascent rate of $5.875ms^{-1}$. Also the current definition is based on the mass flux, not the height, which means that the time scaling affects the area giving a constant rain rate. In the new form the area is constant so the local rain rate grows and decays through the life of the cloud. In order to avoid excessive downdraught mass fluxes, these are now scaled with rainfall rate as well as area and cloud base height.

Code: The code for calculating area is replaced by

$A = 1.277(\Delta z / 1000)^2 (1 + 0.0425\,\Delta u)$ where $\Delta u = |\underline{u}\ top - \underline{u}\ base|$.

Expected Impact: This change is expected to increase the convective cloud cover substantially. Rainfall is expected to be lighter , with a bigger proportion evaporating. The decreased downdraught mass flux will result in weaker forcing of new convection.

c. Initialise T* according to surface water phase.

Reason: With an analysis of lying water / snow in the system it is appropriate to adjust the temperatures at the ground (not observed) to agree with the surface water rather than vice versa as is done at present.

Code: In WPXQ the check for sign of temperature and consequent resetting of the lying water is replaced by a check for the sign of lying water and resetting surface temperature to +/- 0.1 if not consistent. In addition, the soil temperature is not allowed to become negative.

d. Modify roughness length for temperature and humidity.

Reason: Observational studies suggest that over homogenous terrain, the roughness length for temperature and humidity z_T should be about 1/5 that for momentum. In addition the increase in momentum roughness due to pressure forces in mountainous areas should not affect z_T. The current formulation could explain a number of model faults including excessive cloud in neutral conditions especially over mountains, and an under-prediction of the temperature difference between 0 and 10m.

Code: The conversion of z_o to $Ln(CFL/z_o)$ is moved from WPXQ to the start of Sflux (and is removed from the recalculation at the end of Sflux). In ZCDCH, CD is first calculated using $Ln(CFL/z_o)$, then $z_T = z_o/5$ with an upper limit of 0.1 and C_H is calculated from

$$C_H(Ri, z_T) = \frac{0.16}{\left(Ln\,\frac{CFL}{z_\phi}\right)\left(Ln\,\frac{CFL}{z_T}\right)} \left[\frac{C_H\ (Ri, z_\phi)}{C_H\ (0, z_\phi\ )}\right]$$

where the function in brackets is interpolated from the lookup table as before.

Expected Impact: Slightly lower night temperatures and less fog in clear conditions. A greater difference between the temperatures at the surface and 10m. during the daytime. A revised screen temperature derivation is being implemented for unstable conditions to take account of this.

e. The melting and freezing of water on the surface corrected.

Reason: At present when mixed phase precipitation reaches the ground it is classified as snow (usually) and it must then all be melted on the surface. There are also some inconsistencies in the treatment of water that is melted or frozen on the surface. The new scheme melts all snow prior to the temperature calculation, including just the frozen part of new precipitation. It then calculates how much (or all if appropriate) to freeze in order to raise the temperature to 0 degrees Celsius.

Code: In KPTER the latent heat of lying and fallen snow is stored in DT0. In TSURF this is first converted to a change in T0 and the lying water is made positive. The change to T0 is subtracted after calculating the other changes to T0. If the result is below freezing, water is frozen until zero is reached or all the water is frozen. Any excess water runs away.

SUB-SECTION 2B (impact slight or negligible on current version)

f. Increase in asymptotic mixing length.

Reason: Evidence from Met.O.14 that an asymptote of 1/6 the boundary height is insufficent to remove instability in convective situations. This accords with model results showing an unstable lapse rate well above the surface.

Code: In the calculation of ELM, the mixing length, the depth of the turbulent layer is divided by three instead of six.

g. Use total convective cloud cover in radiation calculations.

Reason: Where many clouds are in one grid square, only the last is used at present. In the new version all will contribute with a limit of full cover. In practice the current scheme rarely gives more than half cover and with the squared dependence of effective cloud cover , this will effect the short wave radiation little. It could, however, be important for the long wave calculation.

Code: Code for unpacking the convective cloud properly has been added to the front of TSURF.

h. Reintroduce vertical advection of TKE.

Reason: Advection of TKE is in general a desirable though small contribution to the TKE budget. It was removed because the centred scheme produced numerical errors which were not being removed, because there is no horizontal diffusion of TKE. However there is vertical diffusion of TKE and so vertical advection can be reinstated safely.

Code: In TE instead of skipping all of the advection code, only the horizontal advection is skipped.

i. Revised formula for evaporation of grid-scale rain.

Reason: The formula is based on that used in the Met O 15 model and is derived from the best observational studies to date. It is already used in the convection parametrization. Much of the precipitation formulation is based on that used in Met O 15 and there are advantages in being as close as possible. This formula allows for enhanced evaporation in high temperatures over the usual formula which depends only on relative humidity. It also evaporates very light rain more rapidly, by taking account of its slow fall speed.

Code: The present evaporation code in KPTER is replaced by the following formula:

$$E = ((q_s - q)\ 1.5 \times 10^{-6}\ \Delta z(40.09\ PR^{0.4} + 443.4\ PR^{0.6}))/$$

$$(5.5q_s + 0.044/\rho)$$

where PR is the rain rate in $kgm^{-2}\ s^{-1}$, q is HMR, q_s is saturated HMR, Δz is the layer thickness and ρ is density.

Expected impact: Given the same starting conditions, rain should be evaporated slightly more quickly at low temperatures and much more quickly at high temperatures. However, the differences are expected to be very small for humidities above 90%.

j. Mean pressure check at 5 KM instead surface.

Reason:

The mean p* in the mesoscale model is currently tied to the mean fine-mesh p* over the same area, interpolated to the mesoscale orography. By shifting to 5 KM, the uncertainties of the interpolation are reduced and the mesoscale model is given more freedom to deepen lows for instance.

Code change: In MESBDY, TSURF and DBINIT, a different model level is used. Also, a different constant is subtracted before averageing to minimise round-off error.

k. Variable Coriolis Parameter.

Reason: When the domain is expanded next year,the variation will be substantial and could not be ignored. Making the change now reduces the complications of next year's changes.

Code change: At present, variables containing sin θ and cosθ where θ is the latitude, are calculated in ZCONDS for use in the short wave radiation in TSURF and surface evaporation in SFLUX.

In the new version, just $\sin\theta$ and $\cos\theta$ are stored in ZCONDS. In SFLUX an addition to the code has been made to add the multiplying constants there. In KX and KY the $\sin\theta$ field is used in the calculation of fv, fu in place of the fixed value of f used at present.

SUB-SECTION 2C (impact nil on current version)

l. Initialisation of land type.

Reason: In experiments it is inconvenient to create a land type dataset.

Code: If Namelist input LTYPE = 0, land points (orography > 0) are initialised with type 3 (grassland) and sea points with type zero; if LTYPE = 1 (default), the land type dataset is read from UNIT73 as before.

Effect: None.

m. Add "condensation nucleus (CCN) concentration" variable.

Reason: The CCN concentration determines the size of cloud droplets given a cloud water density, and hence affects the radiative and precipitation properties of the cloud. It is also related to the turbidity of the atmosphere in dry conditions and to the formation of haze in humid conditions. At this stage the object is to predict a plausible variation of a vertical mean value for the boundary layer with the object of testing its usefulness in the processes listed above. No sources or sinks are to be included but fixed boundary values will ensure that continental air has high values and maritime air has low values.

Code: The CCN concentration is stored after the cloud fraction levels in the input and output datasets. If not present, a flag is set in the Namelist input and it will be initialised to high values over land and low values over sea. Internally, it is stored as a two time - level variable indexed by KCN, and changes over a double timestep are stored in array DCN and added on in KEXP. The advection and horizontal diffusion increments are calculated in routine KCN, called after KR. There is no effect on other model variables. In the Hybrid and Merge programs, code is added to copy the previous mesoscale forecast. If Namelist input LCN = 1, then the input field is read from the initialisation dataset; if LCN = 0, the field is initialised to 50 over the sea, 200 over land and 500 over urban points.

Effects: None on other model variables. After initialisation the sharp changes at land / sea boundaries produce overshoots in the CCN field.

n. Implement extended definition of cloud fraction.

Reason: The diagnosis of cloud fraction offers, in principle, a knowledge of the probability distribution of cloud water. Two variables are needed to define it. At present these are stored for partial cover (cloud cover and mean cloud water mixing ratio) but only one is stored for full cover. However, for shallow cloud layers, the difference between uniform and non-uniform full cover may be significant in the short wave radiation calculation. It is possible to define an extended cloud cover variable which takes values greater than 1 for full cover, with large values corresponding to more uniform cover.

Code: Mean cloud water mixing ratio is calculated as before:

$$m = \begin{cases} 0 & Q_1 < -\sqrt{3} \\ \frac{\sqrt{3}\sigma_s}{12}(\sqrt{3} + Q_1)^2 & -\sqrt{3} < Q_1 < \sqrt{3} \\ \sigma_s Q_1 & Q_1 > \sqrt{3} \end{cases}$$

then cloud fraction is defined as

$$CF = \sqrt{m / (3\sigma_s)}$$

which is the same as before for partial cover.
All places where cloud fraction is used in other routines are changed to limit it to 1.0 for the present.

Effect: None. a further change will be needed to use the additional information in the radiation code.

o. Generalise levels in radiation code.

Reason: Specific levels are currently coded for;
(i) the levels over which the cloud top radiation budget may be calculated;
(ii) the levels used in the effective temperature for downward longwave radiation.
these need to be changed whenever vertical resolution is changed. To avoid this, the 10 levels for (i) are replaced by all levels below 5000m and the three levels for (ii) by an arithmetic mean of all levels below 500m.

Code: At the start of TSURF the relevant numbers of levels are computed and stored in variables which are used to control the do loops for these calculations.

Effect: None.

SUB-SECTION 2D.

Changes to Ancillary Programs Associated with New Forecast Controllee for November 1987.

i) HYBRID program.

This has been recoded to process the input datasets record by record, thus simplifying the interactive dialogue and making it more flexible. Variables are recognized by index values in the dataset headers, and warnings given when trying to combine differing variables or when the end of one dataset is reached.

In particular this allows the new variable, condensation nuclei concentration, (CCN), to be carried forward from one forecast to the next, and surface type and roughness length to be copied to the hybrid and INIT datasets. Alternatively, if the previous short forecast has failed, the fine-mesh data are copied to the output dataset and the CCN field is initialised, using model orography, as 50 over the sea and 200 over land.

Also, for the first guess, precipitation rates will be limited (to 8mm^{hr}) and smoothed, and relative humidity constrained to lie between 5 and 100%.

ii) MERGE program.

This now allows one or more of the merge options to be omitted, when using this program in non-default mode. Also non-default parameters can be entered for one subroutine, while keeping default values for the others. The version of the precipitation scheme used in the cloud initialisation procedure has been made the same as in the new forecast model. The iterative calculation of cloud water/ice mixing ratio is suppressed (and only first guess values written to the INIT) when cloud cover at all levels is partial, since the model re-initialises it internally. Thus, as is already the case, the INIT will not be identical with the initial cloud fields used in the model and a zero timestep write-up from the forecast should be made if these data are required. The cloud cover analysis value above which cover is assumed to be full has been reduced to 7.0 octas from 7.5, since the smoothing effect of the analysis is known to produce too little full cover cloud.

Condensation nucleus concentration values , and also surface type and roughness length, will be copied if present in the first guess dataset, and lying water/snow depths will be taken from the analysis dataset.

An error in the diagnosis and use of screen temperature has been found which accounts for the negative bias noticed in T+0 verification statistics at 12GMT - this is now corrected.

A major new addition is code to solve a Poisson equation using an ADI method. This is used to make the small re-adjustments to the horizontal wind components at each level that are required to restore continuity equation balance after the vertical velocity profiles have been modified to set them to zero at the top model level.

INTERPOLATION program.

This controllee has been altered to use the same Poisson solver and associated code as the merge program, so that continuity equation balance is preserved for the wind field.

An extra level has been added at the top (at 13610) in the interpolation stages only. This reduces roughnesses in the fields at the top output level which occur currently owing to extrapolation over high orography.

ANALYSIS program.

Quality control of snow depth observations (against screen temperature) has been added, and tolerances implemented for the snow depth analysis, to avoid spurious results which could arise from corrupt SYNOP reports. To sharpen the edges of the snow depth analysis it will be made in a transformed (logarithmic) co-ordinate.

An END= phrase has been added to the READ in subroutine ENDBLK, to avoid the obs. retrieval/analysis program failing completely when trying to retrieve corrupt or incomplete FRONTIERS radar images.

PROCESSING program.

The diagnosis of screen temperature from surface and model level 1 values has been altered to use the same formula as all other parts of the suite, i.e.

$T_{screen} = \alpha\ T_{surf} + (1-\alpha)\ T_{lev.1}$

where $\alpha = (\ln(h_1) - \ln(1.25))/(\ln(h_1) - \ln(0.02/(T_{surf} - T_{lev.1} + 1)))$

for unstable cases,

or $\alpha = 1 - 1.25/h_1$,

for stable cases, h_1 being the geight of model level 1.

3. IMPACT OF PROPOSED CHANGES ON THE MESOSCALE MODEL FORECAST.

In this section, a note will be written on each case study, giving a brief description of the main synoptic features, the reason for choosing the particular case and the differences noted between the trial and control forecasts.

a) DT 06 GMT 7/01/86. (Forecast period 06-18 GMT 7/01/86. Forecast rerun using both the trial and control versions.)

During this period, a warm front moved slowly northeastwards over England and Wales, with precipitation ahead of the front turning to moderate snow. This was an old snow case kept because the original mesoscale forecast was good. It was chosen to test the impact of the proposed changes on the rain/snow boundary and amount of precipitation.

There were only minor differences between the trial and control forecasts of rain and snow in this case. Those spotted were;

i) The front edge of the dynamic precipitation band was slightly further east in the control version (by 1-2 gridlengths). This was probably due to increased evaporation of very light gridscale precipitation in the trial version (reference Sub-section 2B(i).)

ii) The trial version had slightly more instability, represented by heavy showers, in the South-west Approaches associated with an area of low pressure. This increased convection is due to the revised area of convective cloud (reference sub-section 2A(b).)

iii) Although there were grid-point differences in the three-hourly accumulations, the overall guidance from both versions was similar. In figure 1, we compare the forecast precipitation area verifying at 18GMT.

None of the above differences adversely affected the trial forecast and the position of the rain/snow boundary was unchanged.

b)DT 12 GMT 3/03/87. (Forecast period 12 GMT 3/03/87 - 00 GMT 4/03/87. Forecast rerun using both the trial and control versions.

During this period, most of Britain had a cold and dry day, with temperatures above zero only for a few hours. Eastern areas remained clear, but cloud thickened in the west later, with rain (turning to snow inland) spreading to many western areas by midnight. The mesoscale model forecast was about 3-4 hours too fast with the spread of precipitation into western England. Although there was a significant timing error, this case was chosen to check the impact of the changes on the forecast precipitation area, type and amount.

Differences between the trial and control forecasts were more noticeable in this case. The main differences were;

i) The trial version forecast a larger area of precipitation. This was mainly due to an increase in the number of showers forecast at the back edge of the frontal zone.

ii) The trial version forecast larger accumulations generally. In the west this increase can be attributed to increased instability in the trial version, but over the mainland there was a small increase in dynamic precipitation.

iii) Forecast dynamic rates looked very similar in both forecasts, which makes it difficult to explain the increased accumulations. Convective rates were slightly heavier in the trial version.

Verification of the precipitation was worse for the trial version due to the timing error. Allowing for this, then the accumulations predicted by the trial version in the frontal zone were not excessive. However, the increased instability in the west was overdone.

c) DT 00 GMT 28/03/87.(Forecast period 00 - 18 GMT 28/03/87. Forecast rerun using both the trial and control versions.

With a deep depression slow-moving in the North Sea, a cold unstable northerly airstream covered the U.K. During the morning a band of rain moved southwards over Eastern Britain. During the afternoon, the cold unstable northerly airstream spread to all parts, bringing a mixture of of rain, sleet, snow and hail showers with isolated thunderstorms. Due to the strong winds, the showers were short-lived, so accumulations were small (tr-4mm in 12-hours). This case was chosen to test the impact of the proposed changes on the wintry showers and on the strength of the strong to gale force northerly winds.

This case shows the impact from the revised area of convective cloud (reference Sub-section 2A(b)). In figure 2 (a,b), we compare the two forecasts at 15 GMT, showing the forecast shower distribution and intensity. The trial version has forecast a greater number of showers over the sea but probably slightly less over land. The rates are similar but the trial forecast has more very light showers (0.1-3mmhr^{-1}). Accumulations overland, tend to be lighter in the trial version.

A very small impact on wind speed was noticed, with the trial locally 5KT stronger over the North Sea.

d) DT 00 GMT 12/06/87. (Forecast period 00 - 18 GMT 12/06/87. Forecast rerun using trial version.)

With an upper trough over the U.K, the airmass was cool, moist and unstable, with widespread showers developing during the day. The south-east remained dry during the morning but had the heaviest showers during the afternoon. This case was chosen in order to test the impact of the changes on the forecast distribution and intensity of summer showers.

At 09 GMT, both versions predicted showers in the south-east near the east coast incorrectly, partly due to the backing of the model winds near the eastern boundary and partly to the model being too warm. The trial version forecast a larger number of showers, so verified worse against radar at this stage. However, the trial version was slightly better during the period 12-18.

In figure 3, we compare the shower forecast distribution and intensity and convective cloud cover at 12 GMT. Again, the impact of the change to the convective cloud area (Sub-section 2A (b)) can be seen. The following differences were noted;

i) The trial version has a wider distribution of showers, especially over Northern England and verifies better against radar in the east.

ii) the trial version has a greater number of very light showers (rate 0.1-3mmhr^{-1}) but also more heavy showers (rate > 10mmhr^{-1}).

iii) The trial forecast showed an increase in convective cloud cover in the trial forecast especially over Northern England . In figure 4, we compare the 6-hourly accumulations for the period 06-12 GMT.

e) DT 00 GMT 13/06/87. (Forecast period 00 - 15 GMT 13/06/87. Forecast rerun using trial version.)

This was a second example of a summer shower case, but showers were generally less frequent than during the 12th. However, heavy showers and local thunderstorms still developed in the east from Yorkshire southwards. This case was chosen in order to test the impact of the changes on the distribution and intensity of summer showers.

Results from this case were similar to those of 12/6/87.

f) DT 00 GMT 6/07/87. (Forecast period 00 - 18 GMT 6/07/87. Forecast rerun using the trial version.)

The day was hot and humid, with maximum temperatures reaching 28 to 29 degrees Celsius. The majority of places remained dry and sunny, but in Southeast England, there was an increase of high cloud with occasional patches of unstable medium cloud later producing very isolated showers. The original mesoscale model forecast was too hot (maximum temperatures 30 to 32 degrees Celsius in places) and developed too many showers. This case was chosen in order to test the impact of the changes on;

i) The number of showers predicted.
ii) High summer temperatures

The trial version far predicted fewer showers so was more accurate. At 12 GMT, the temperature forecast by the trial version was about 1-3 degrees lower than the control version and at this stage it was closer to the observations. The 12 GMT temperature forecasts are compared in figure 5. However, the trial version developed a larger area of convective cloud in the predicted shower area and later temperatures were less accurate. The results from this comparison also showed the impact from the change to the area of convective cloud.

g) DT 12 GMT 28/09/87. (Forecast period 12 GMT 28/09/87 - 00 GMT 29/09/87. Forecast rerun using the trial version.)

With an anticyclone centred over England and Wales, the correct forecasting of the extent and distribution of stratocumulus was very important for temperatures. The two forecasts are similar in the area of low cloud forecast but the trial version has slightly less low cloud over Kent, parts of Northern England and Ireland. In these areas, the trial temperatures are 1-3 degrees Celsius lower. No firm conclusions could be made from this case, since the trial forecast was better in some areas, but worse in others.

h) DT 12 GMT 9/10/87. (Forecast period 12 GMT 9/10/87 - 00 GMT 10/09/87. Forecast rerun using the trial version.)

During this period, a cold front moved slowly eastwards across Wales and Southern England, producing a period of very heavy rainfall and thunderstorms. This case was chosen in order to compare the forecast accumulations of dynamic and convective rain.

During the period 15-21 GMT, the forecast rain areas and accumulations were similar. The largest accumulations were forecast in the frontal zone, with local 3-hour forecast accumulations 15-30mm. The trial values were slightly lower. The rates of dynamic rain in the frontal zone were similar. In the trial version, convective rates were less in the unstable southerly airstream ahead of the front (rates 5-10 $mmhr^{-1}$ compared to 10-12$mmhr^{-1}$) with correspondingly less heavy showers, but locally higher in the frontal zone. Convective accumulations were similar in the south in the trial version (inspite of lower rates) due to the increased area of convective cloud. The main differences were noticed during the period 21-24 GMT. In the trial forecast, the front weakened in the south with a corresponding reduction in rainfall accumulations. In figures 6 and 7, we compare the forecast rain areas and 3-hour accumulations verifying at 00GMT 10/10/87. At this time, moderate rain was observed in the frontal zone so the weakening was incorrect. The control forecast was more accurate in the frontal zone, but incorrect in still forecasting heavy showers at 00GMT. These died out after 21 GMT.

i) DT 12 GMT 15/10/87. (Forecast period 12 GMT 15/10/87 - 00 GMT 16/10/87. Forecast rerun using the trial version.)

A depression moved northeastwards from Biscay across Southern England during this period, with heavy rain and severe gales affecting Southern England. This case was chosen in order to test the impact of the changes on;

i) Gale force southerly winds;

ii) Dynamic and convective rainfall accumulations.

There was a small impact from the proposed changes on the strength of the southerly winds over South-east England . Figure 8 compares the forecast wind speeds for 00GMT 16/10/87. In the trial version, there was a small reduction of 1-5 KT in the North Sea, but a similar increase in wind speeds over Southern England. These changes were due to a small difference in the forecast position of the centre of the depression.

The forecast rainfall areas were very similar apart from a small reduction of light rain in the extreme south-east at 00 GMT in the trial forecast. The dynamic rates were similar up to 21 GMT but weakened slightly in the trial version at 00GMT. Convective rates were higher in the trial version generally. Figure 9 compares the forecast accumulations for the period 21-00 GMT. The areas are similar but the peak values near the centre of the depression are smaller in the trial version.

i) DT 12 GMT 24/10/87. (Forecast period 12 GMT 24/10/87 - 06 GMT 25/10/87. Forecast rerun using the trial version.)

Over England and Wales, the weather remained dry and clear throughout this period. Temperatures fell sharply during the evening and night and there was a widespread frost inland with minimum temperatures ranging between -1 and -5 degrees Celsius.Fog patches also formed after midnight. This case was chosen in order to test the impact of the changes on;

i) Minimum temperature forecasts;

ii) The formation and distribution of fog.

This case shows the impact of the modified roughness length for temperature and humidity. In the trial version, the roughness length is equal to 1/5 that for momentum, limited to a maximum of 0.1m. This change had a small impact on screen and surface temperatures . with a few points being a degree lower than the corresponding values in the control version. There was less impact on the 10m temperature, so there was a slightly deeper lapse rate. In figure 10, we compare the control and trial T+18 forecasts for T*, verifying at 06 GMT.

In figure 11, we compare the the control and the trial forecasts of fog at 00 GMT . No fog was observed at this time, although patches formed later in the night. The control version forecast too much fog too early. The trial forecasts containing the modifications to the roughness length have forecast less fog at 00 GMT, which is an improvement.

k)DT 18 GMT 12/01/87. (Forecast period 18 GMT 12/01/87 - 06 GMT 13/01/87. Forecast rerun using both the trial and control versions. A second trial forecast was also run using an amended initial field containing analysed snow depth observations.)

This was an extremely cold period over England and Wales with temperatures remaining well below zero, accompanied by strong easterly winds. The atmosphere was very unstable and vigorous convection set off by the relatively warm North Sea and English Channel produced heavy snowfall over the sea and all windward coasts. This case was chosen partly because the original mesoscale model forecast was good and partly to test the impact of the snow analysis scheme.

Figure 12 compares the snow depths in the initial datasets before and after the snow depth analysis. The hybrid and original analysis had too little snow especially near the east coast. Observed snow depths of 12-24cm near the east coast have been fitted well by the new analysis. However, since there were very few observations at 18 GMT of zero snow depth, the analysis has spread the snow cover too far inland.

Both trial forecasts showed a substantial increase of convection compared to the control forecast. Light showers penetrated well inland , as far as the Midlands and Wales. This was unrealistic but the rates were very small (0.05-3mm/hr) so additional accumulations were negligible. Temperatures were more accurately predicted by the trial versions. Forecast temperatures for 06GMT are compared in figure 13. Observed temperatures were in the range -6 to -11 degrees Celsius inland. The control forecast was too cold with temperatures as low as -19 degrees Celsius. The trial forecasts are warmer with temperatures -7 to -14 degrees Celsius. Figure 14 compares the forecast snow depths at the end of the forecast period at 06GMT. Near the east coast, the trial forecast from the amended snow analysis is much better, although the very small traces of snow in the west are incorrect.

4. CONCLUSIONS

a) SNOW ANALYSIS.
A correct snow depth analysis is important for the mesoscale model forecasts, especially of temperature. However, problems may arise due to;
i) lack of observations epecially at night and over high ground in Wales and Scotland. Also, observations of no snow cover would be useful.
ii) the analysis scheme spreading out the few observations too far.
With regular intervention, the above problems are not too serious but problems could arise over the weekend.

b) CHANGES TO THE CONVECTION SCHEME
i) Increased shower activity showed in most trial cases. In general, the verification was worse early in the forecast due to the model tendency too forecast showers too early (i.e 06-09GMT). However, later, the forecast distribution was sometimes better , sometimes worse than the control version.
ii) Many of the extra showers were very light (convective rates< 3mm/hr)

but there were also more heavy showers (convective rates >10mm/hr) i.e range increased from 3-15 mm/hr in the control forecasts to 0.1-20 in the trial forecasts.

iii) Convective accumulations were slightly increased but no very large gridpoint accumulations were seen in the trial cases.

iv) There was an occasional increase in convective cloud amounts especially in the summer and autumn cases to 4-8 octas. The increase was much slighter in the winter cases.

v) With the increase in convection, the trial version reaches the maximum number of convective clouds (1659=1/3 number of grid-points) more often. This can be seen in the unstable airmass cases by a stripiness in the shower distribution.

c) DYNAMIC ACCUMULATION

The dynamic accumulations were similar in most cases. However, in the two October cases, the trial forecast forecast a slight decrease in accumulations during the period T+9-T+12.

d) TEMPERATURE

Under clear skies,there was a local small decrease (1 degree Celsius) in night-time temperatures and a small decrease in daytime temperatures. A larger impact (locally 3-4 degrees Celsius) was caused by the increase in convective cloud.

e) PRESSURE

In most of the cases , the difference in pressure between the trial and control forecasts was small. In the depression associated with the severe gales (15/16 October), the trial depression was just 1mb lower. A larger difference occurred in the cold winter case, (DT18Z 12/01/87), in which there was a mean pressure difference of 2mb at T+12. In this case, the control pressure was better.

f) WIND

Small differences were noticd (+/-5KT) in a few strong wind cases, but these were due to small evolution changes rather than to the changes in the coriolis force.

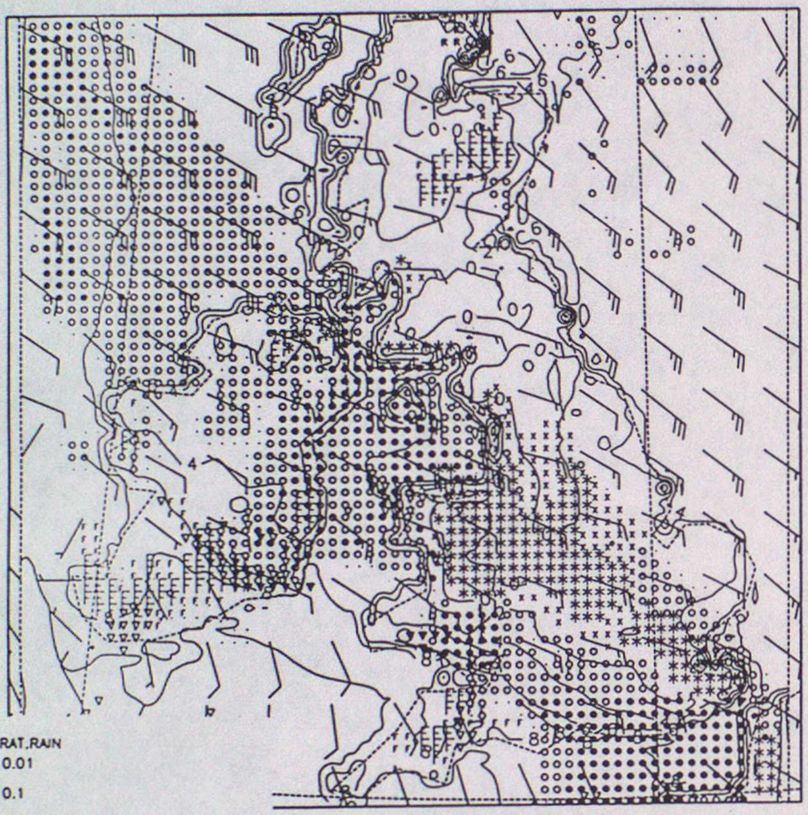
g) VISIBILITY

The control version (24/25 October) forecast the formation of fog by midnight, which was too early. The trial version predicted slightly less fog than the control version, which was an improvement.

The changes described were implemented at the end of November 1987.

CONTROL FORECAST

DT 0600Z 07/01/1986 VT 1800Z 07/01/1986 MSFC VV LEVEL 10
DT 0600Z 07/01/1986 VT 1800Z 07/01/1986 MSFC PR CONVECTIVE
DT 0600Z 07/01/1986 VT 1800Z 07/01/1986 MSFC PR GRID-SCALE
DT 0600Z 07/01/1986 VT 1800Z 07/01/1986 MSFC LEVEL 10
DT 0600Z 07/01/1986 VT 1800Z 07/01/1986 MSFC SCREEN TEMPERATURE



CONTOUR INTERVALS
— 2

STRAT.RAIN
0.01
0.1
° 0.5
• MM/HR

CONV.RAIN
▾ 0.4
10.0
▼ MM/HR(LOCAL)

STRAT.RAIN
0.01
0.1
° 0.5
• MM/HR

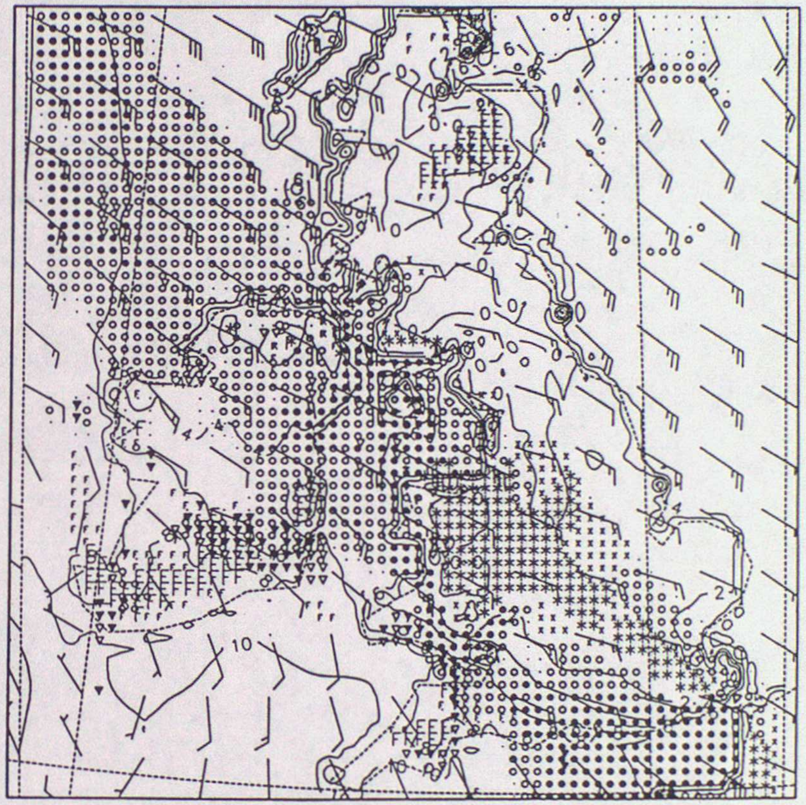
SNOW
x 0.01
0.5
* MM/HR(RAIN)

CONV.RAIN
▾ 0.4
10.0
▼ MM/HR(LOCAL)

VISIBILITY
f 1000
200
F METRES

TRIAL FORECAST

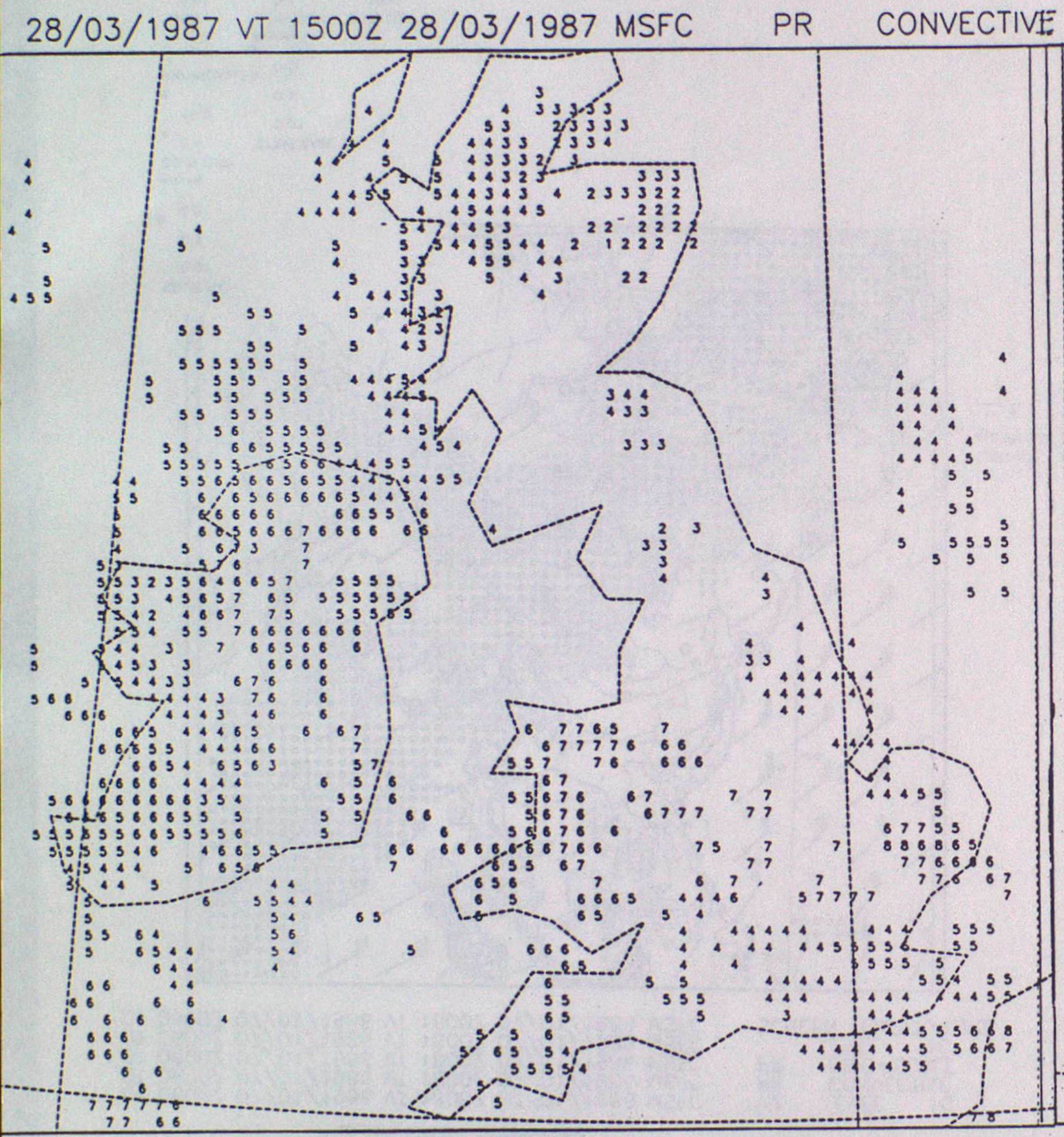
DT 0600Z 07/01/1986 VT 1800Z 07/01/1986 MSTRIAL3 VV LEVEL 10
DT 0600Z 07/01/1986 VT 1800Z 07/01/1986 MSTRIAL3 PR CONVECTIVE
DT 0600Z 07/01/1986 VT 1800Z 07/01/1986 MSTRIAL3 PR GRID-SCALE
DT 0600Z 07/01/1986 VT 1800Z 07/01/1986 MSTRIAL3 LEVEL 10
DT 0600Z 07/01/1986 VT 1800Z 07/01/1986 MSTRIAL3 SCREEN TEMPERATURE



CONTOUR INTERVALS
— 2

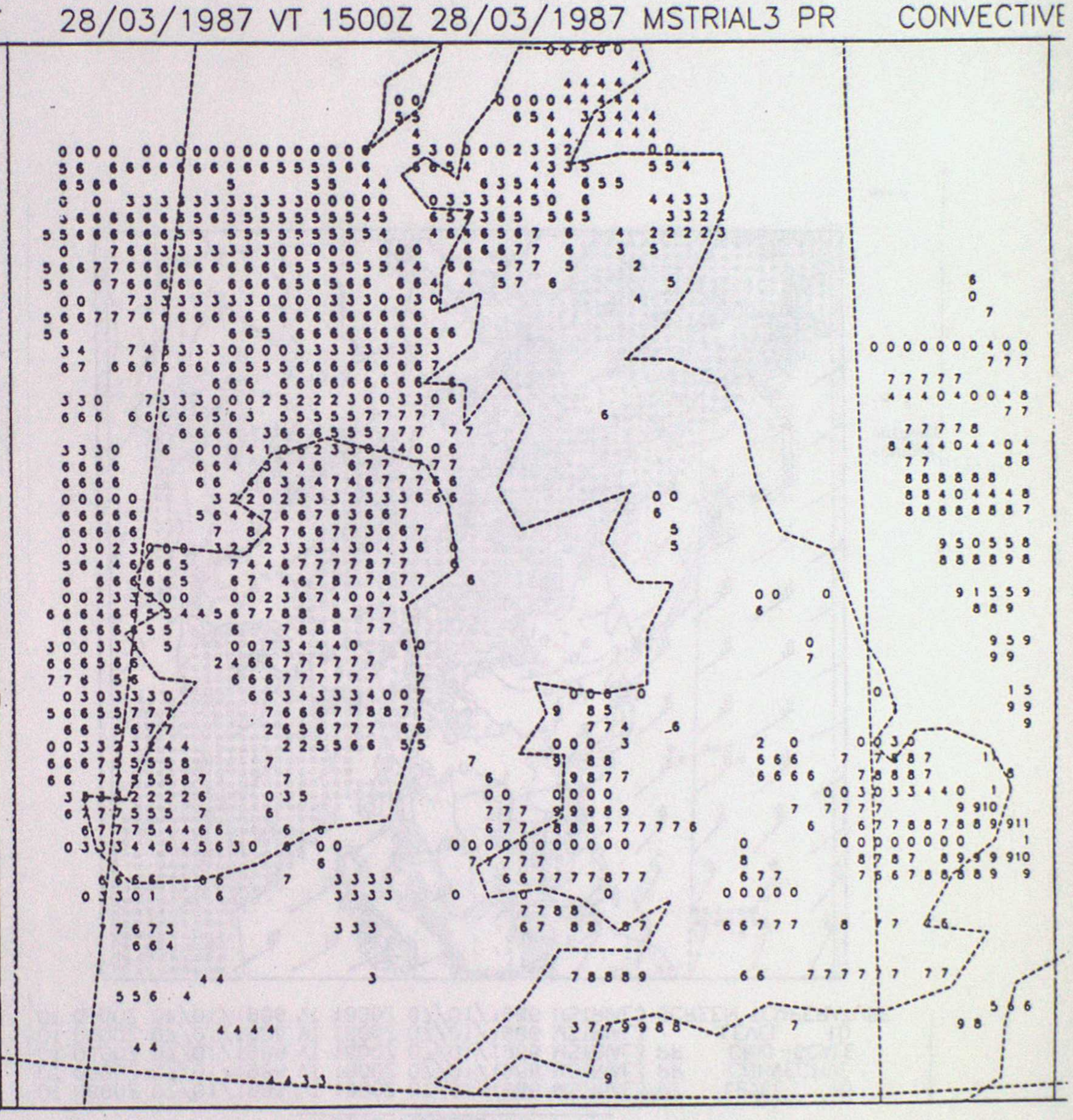
FIGURE 1.

Control Forecast From D.T 00z 28/03/87



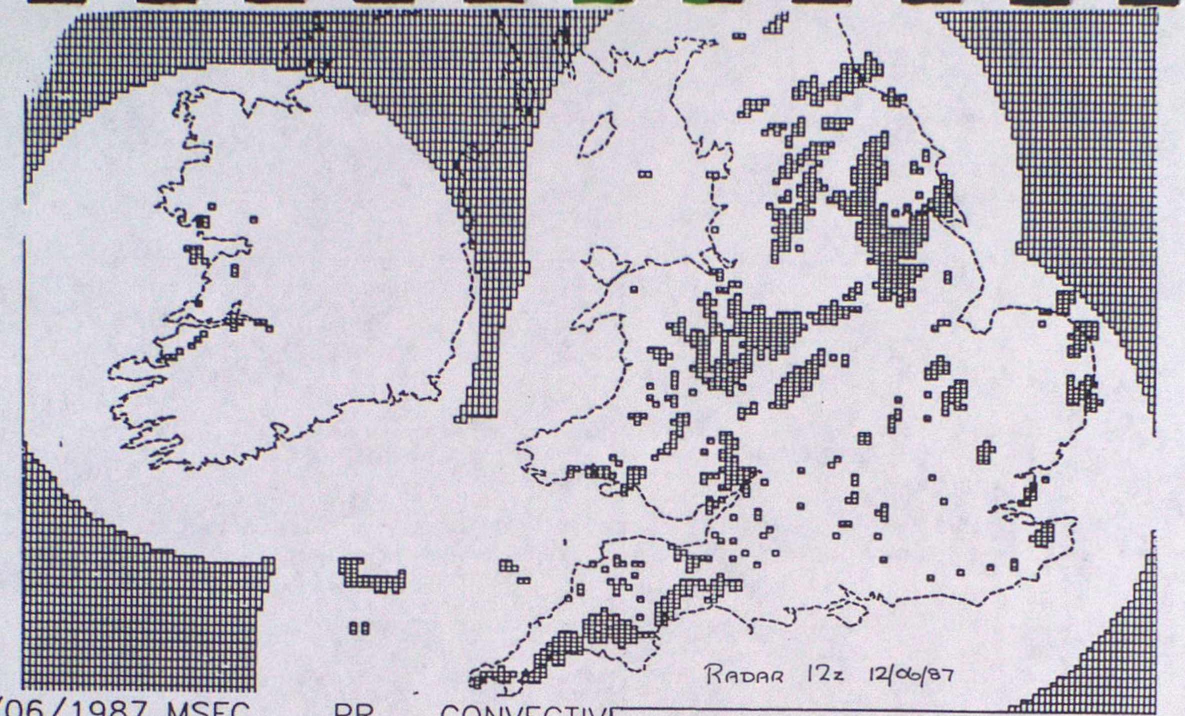
Local Convective Rates

Trial Forecast From DT 00z 28/03/87

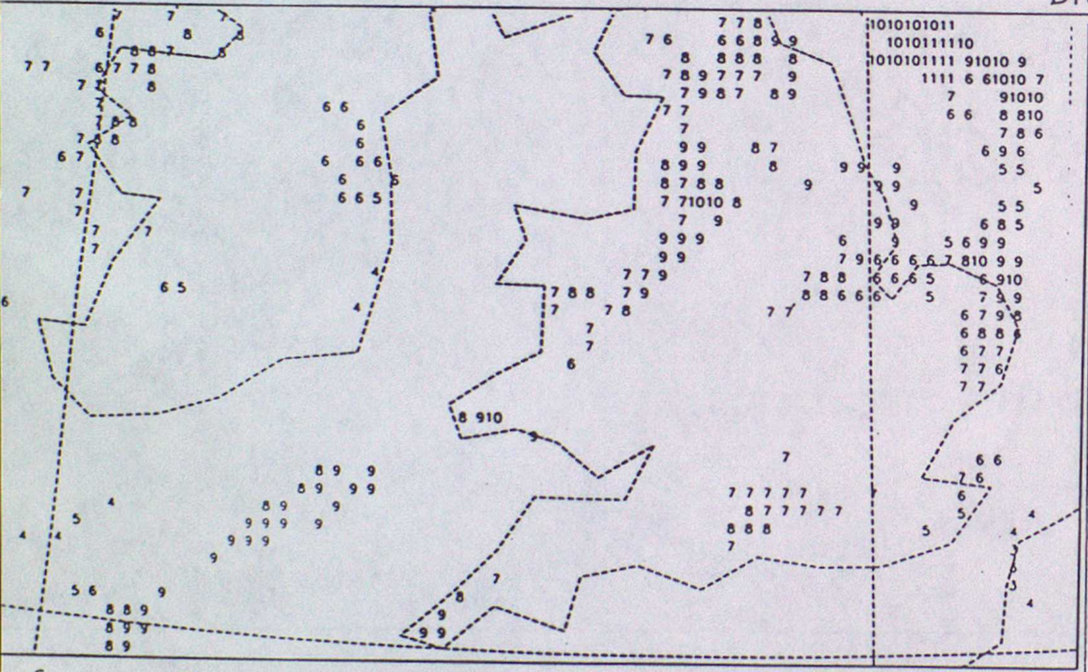


Local Convective Rates

Figure 2.

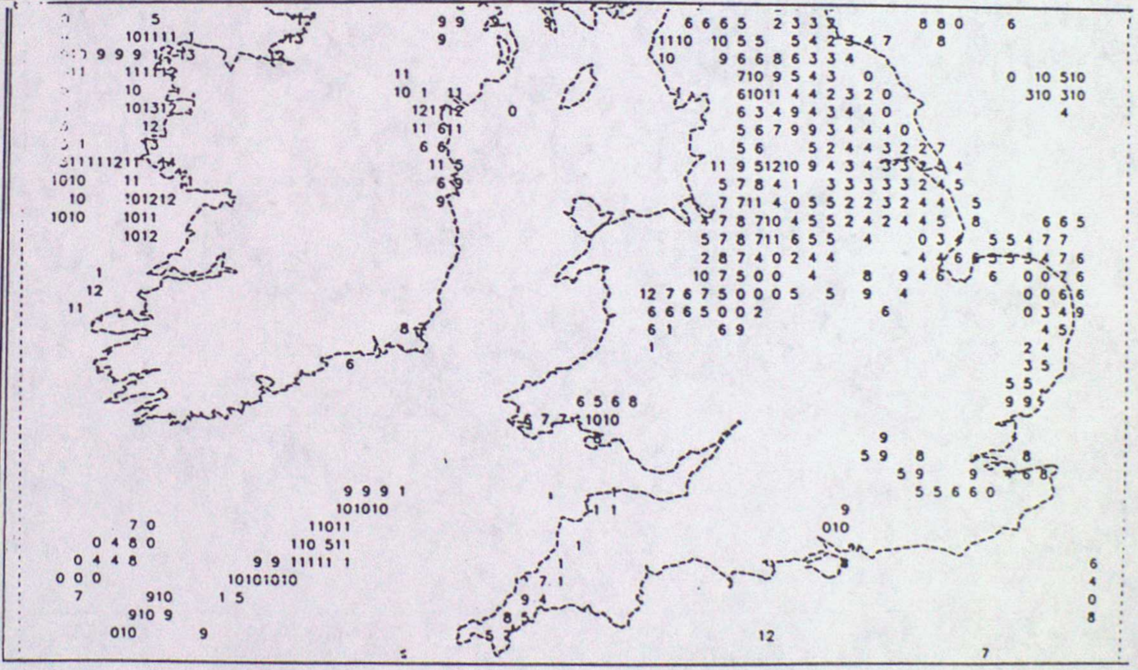


T
Z 12/06/1987 VT 1200Z 12/06/1987 MSFC PR CONVECTIVE



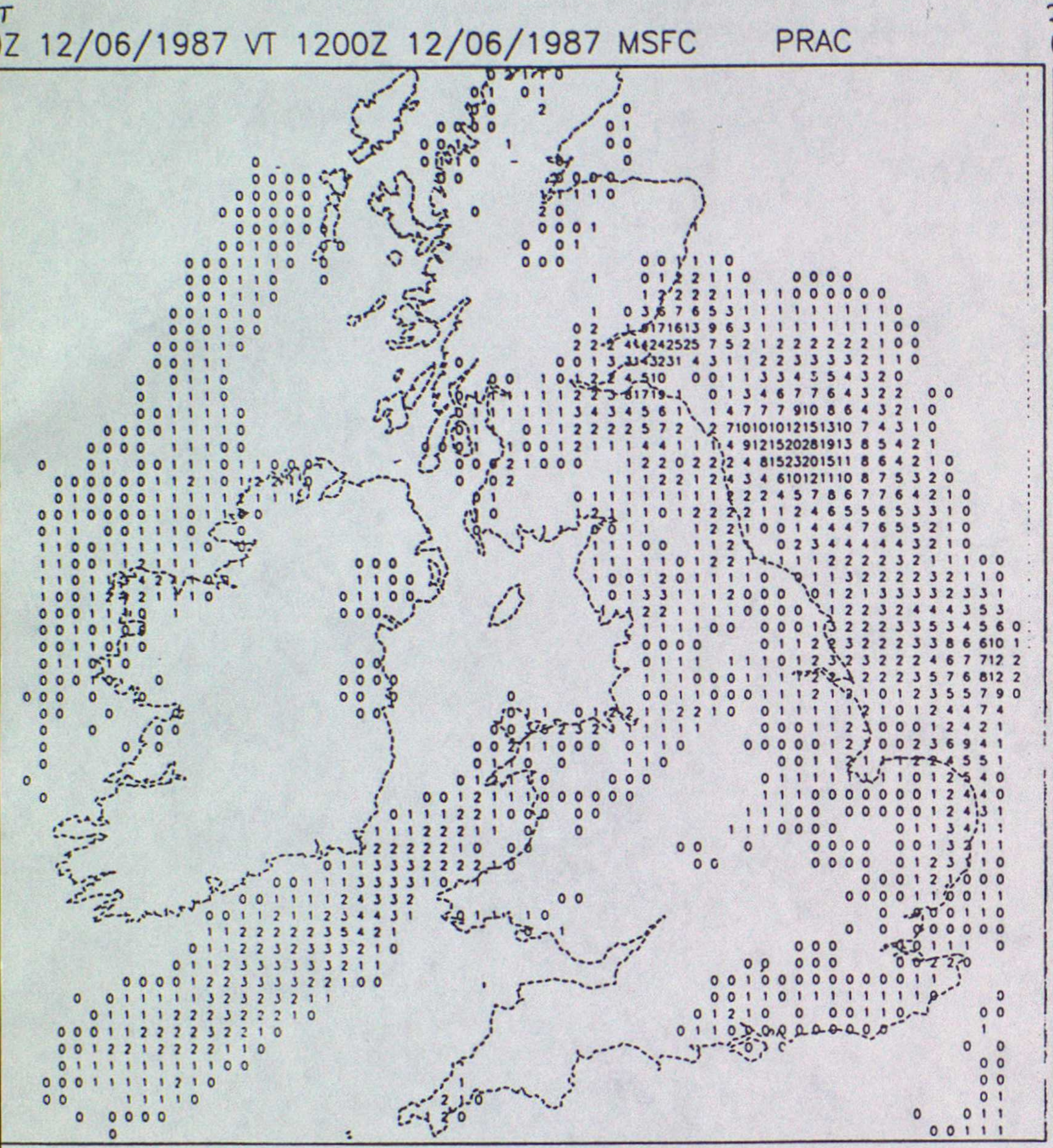
CONVECTIVE RATE DT 00z VT 12z 12/06/87 - CONTROL FORECAST

DT00Z 12/06/1987 VT 1200Z 12/06/1987 MSTRIAL3 PR CONVECTIV

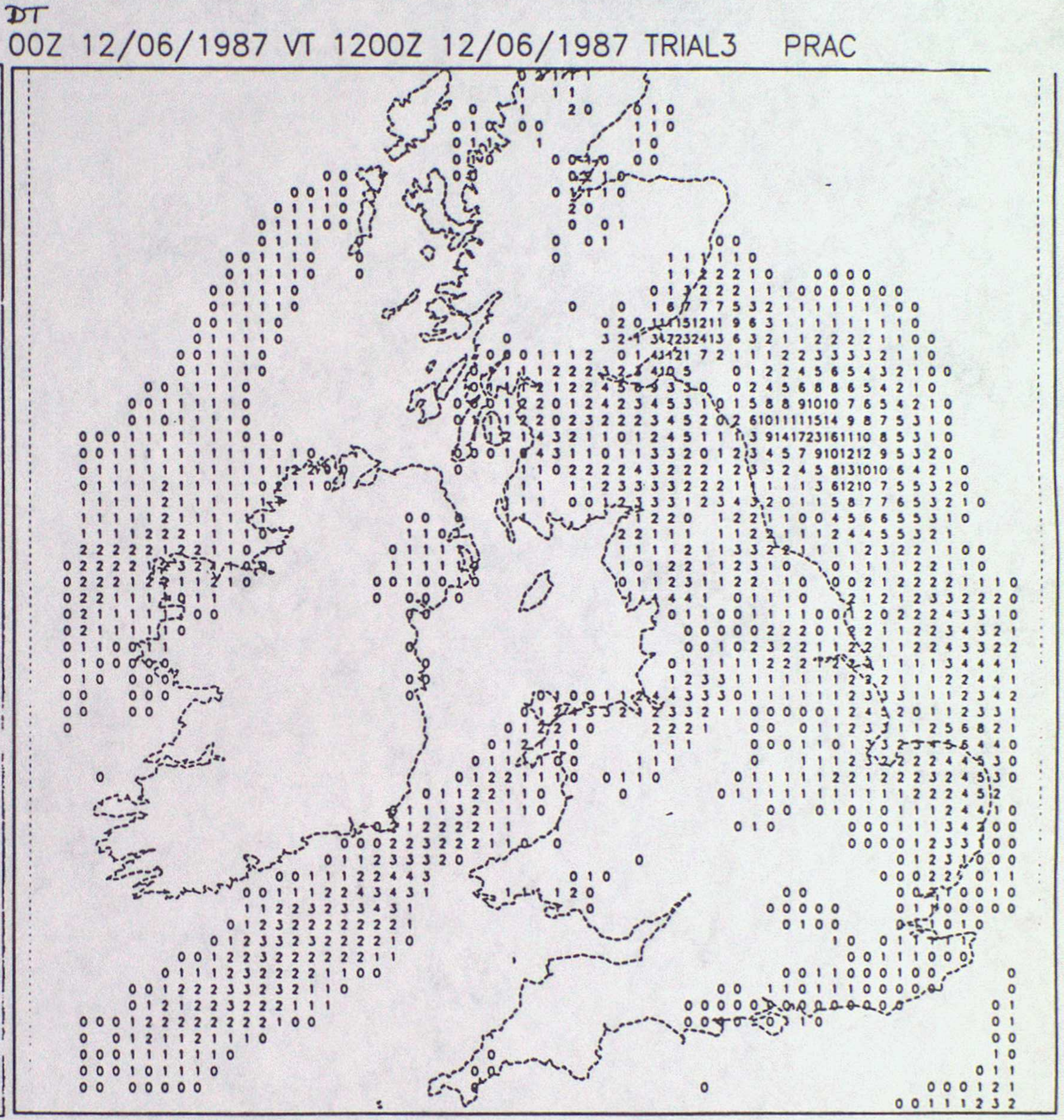


CONVECTIVE RATE DT 00z VT 12z 12/06/87 - TRIAL FORECAST

FIGURE 3



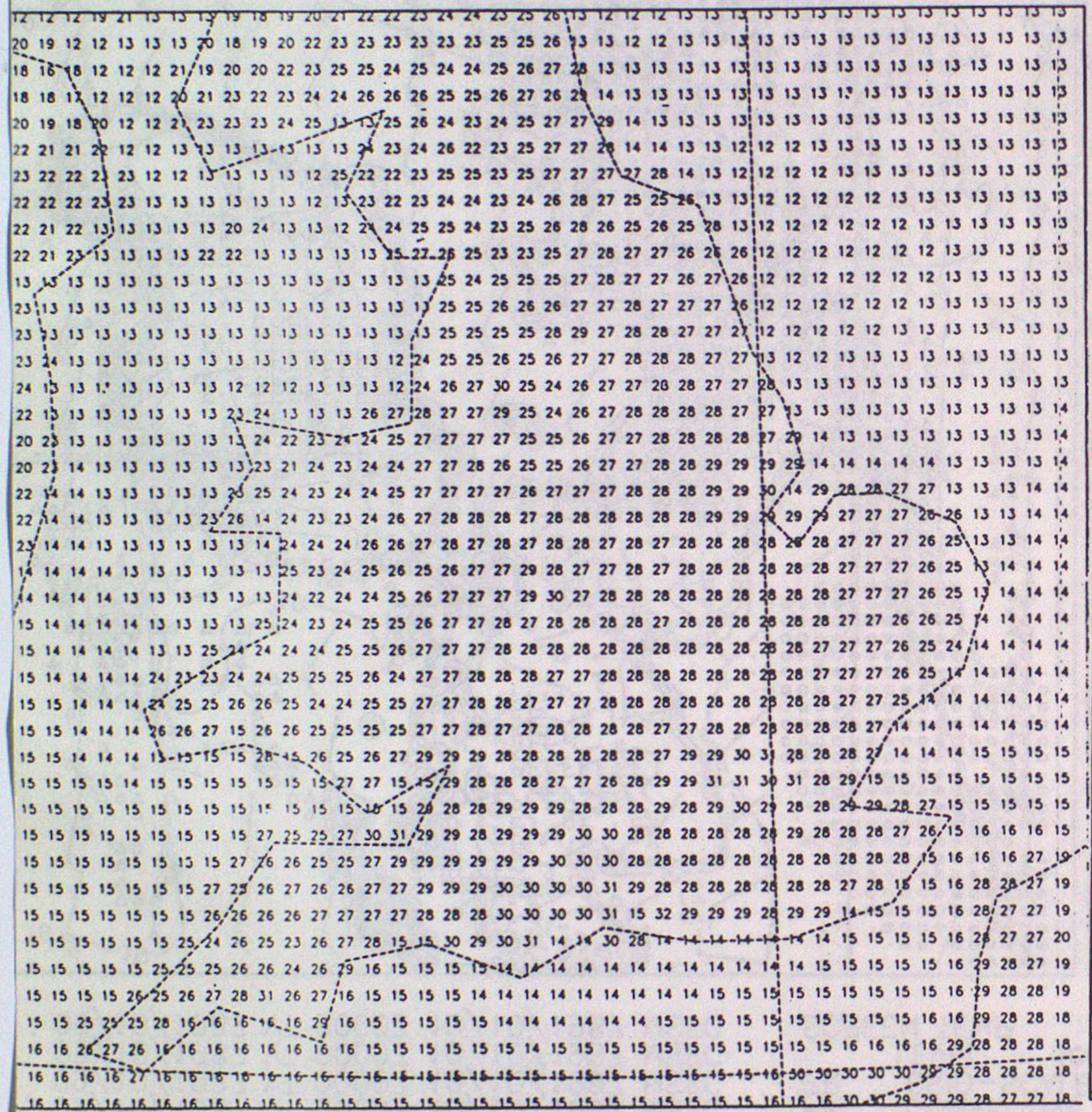
TOTAL ACCUMULATION 06-12 GMT CONTROL FORECAST



TOTAL ACCUMULATION 06-12GMT TRIAL FORECAST

FIGURE 4

)Z 06/07/1987 VT 1200Z 06/07/1987 MSFC SCREEN TEMP



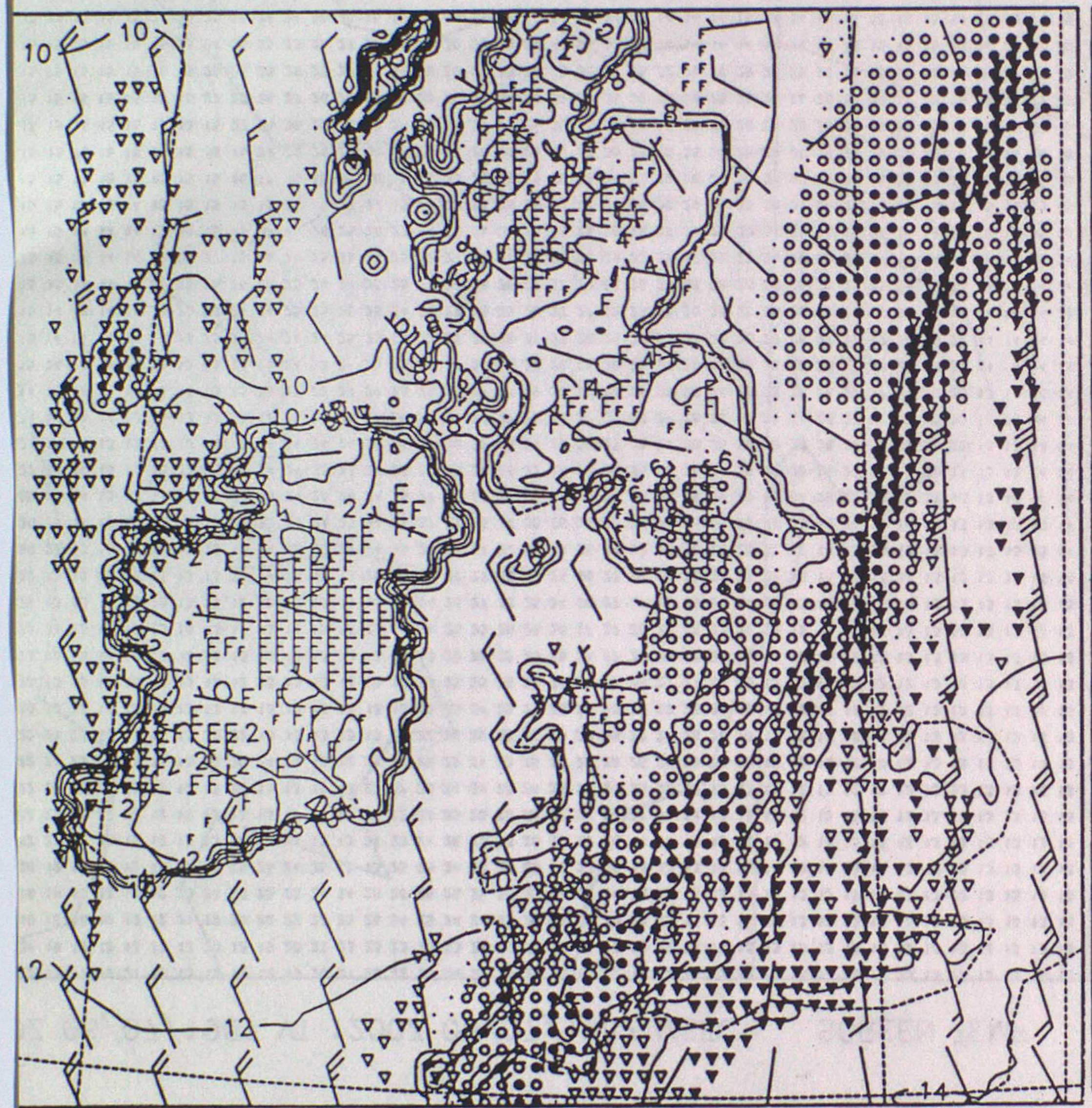
CONTROL

DT
00Z 06/07/1987 VT 1200Z 06/07/1987 MSTRIAL3 SCREEN TEMP

TRIAL

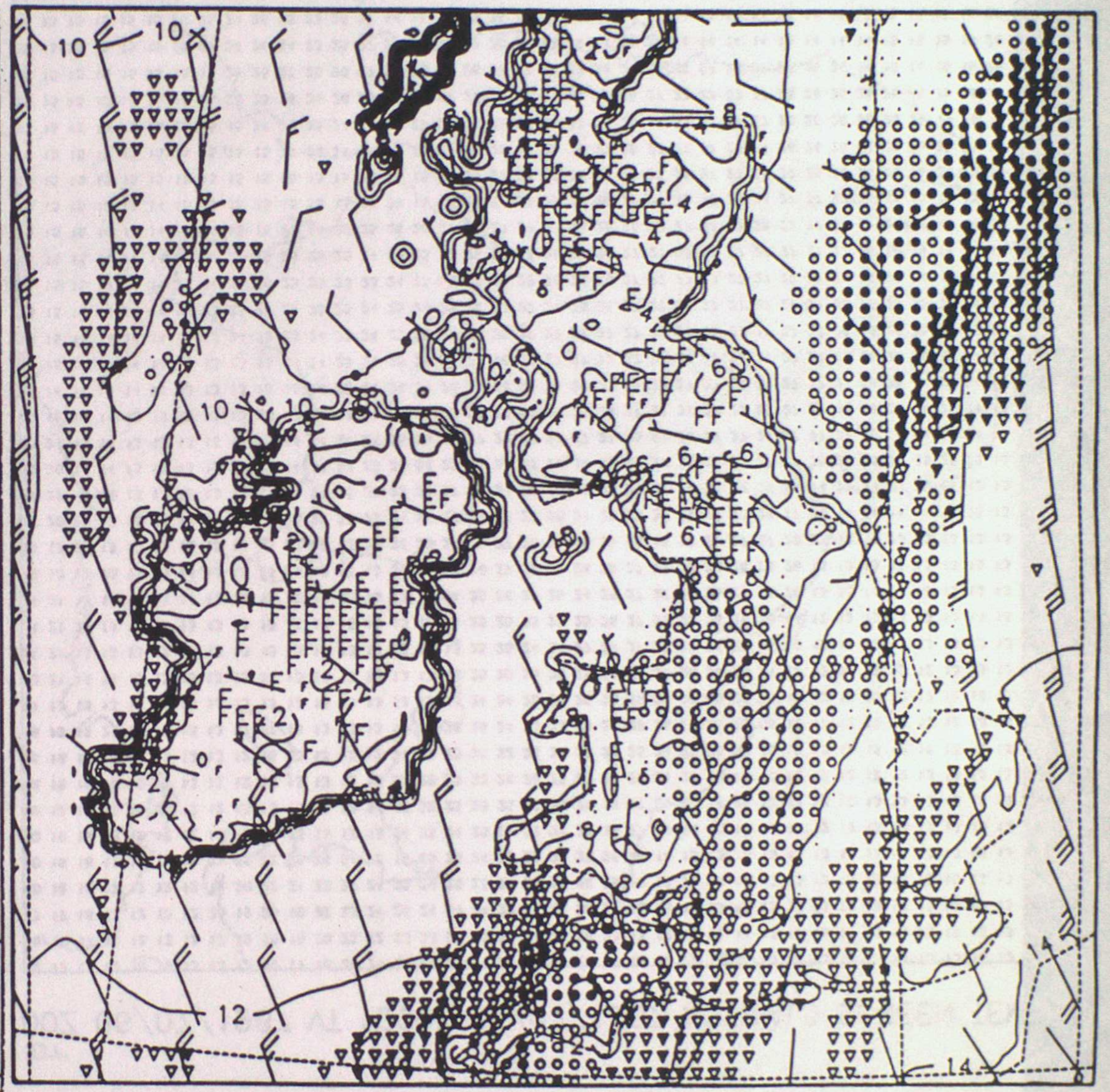
FIGURE 5

09/10/1987 VT 0000Z 10/10/1987 MSFC VV LEVEL 10
09/10/1987 VT 0000Z 10/10/1987 MSFC PR CONVECTIVE
09/10/1987 VT 0000Z 10/10/1987 MSFC PR GRID-SCALE
09/10/1987 VT 0000Z 10/10/1987 MSFC LEVEL 10
09/10/1987 VT 0000Z 10/10/1987 MSFC SCREEN TEMP



CONTROL FORECAST. DT 12GMT VT 00GMT 10/10/87

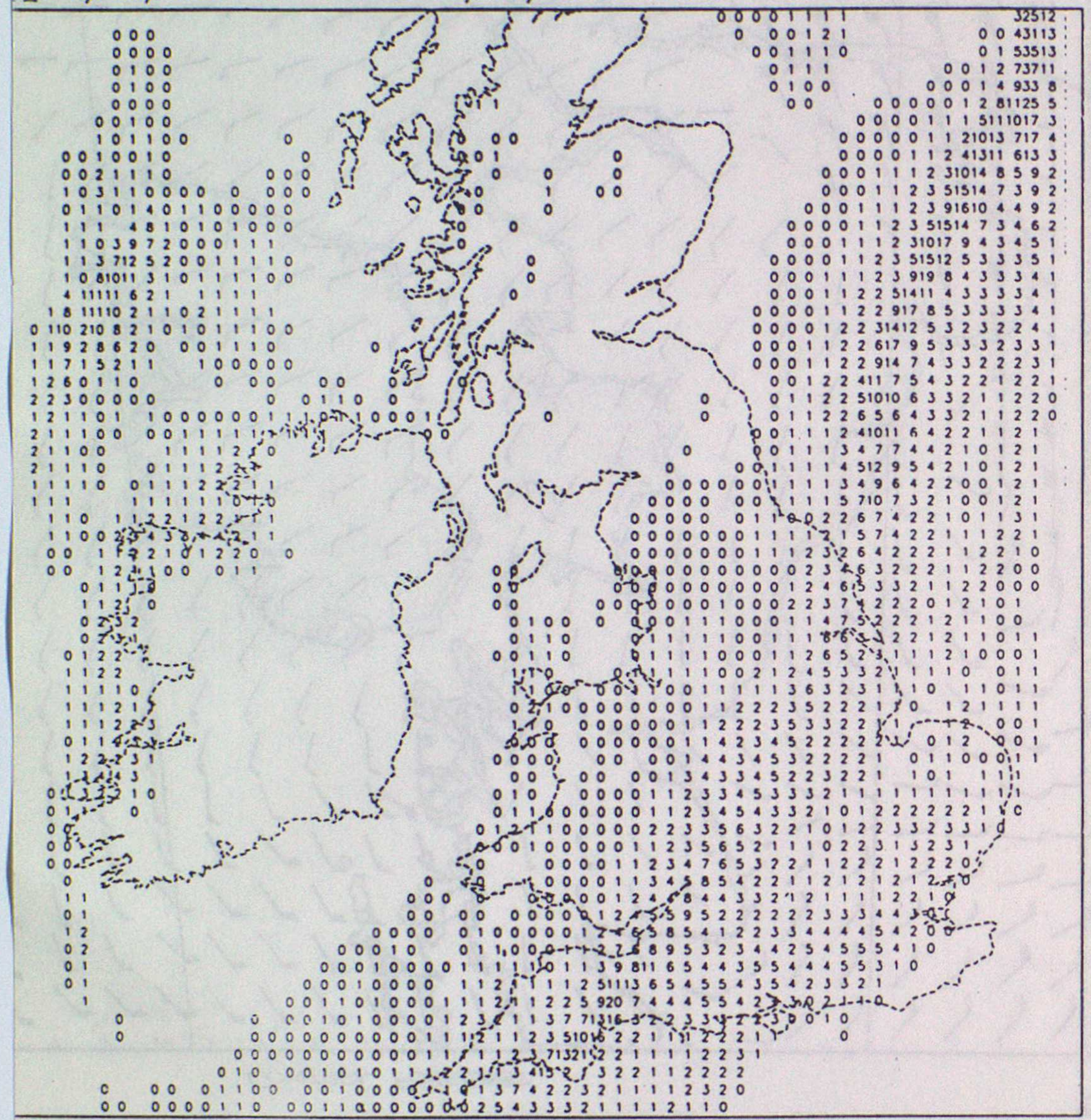
09/10/1987 VT 0000Z 10/10/1987 MSTRIAL3 VV LEVEL 10
09/10/1987 VT 0000Z 10/10/1987 MSTRIAL3 PR CONVECTIVE
09/10/1987 VT 0000Z 10/10/1987 MSTRIAL3 PR GRID-SCALE
09/10/1987 VT 0000Z 10/10/1987 MSTRIAL3 LEVEL 10
09/10/1987 VT 0000Z 10/10/1987 MSTRIAL3 SCREEN TEMP



TRIAL FORECAST DT 12GMT VT 00GMT 10/10/87

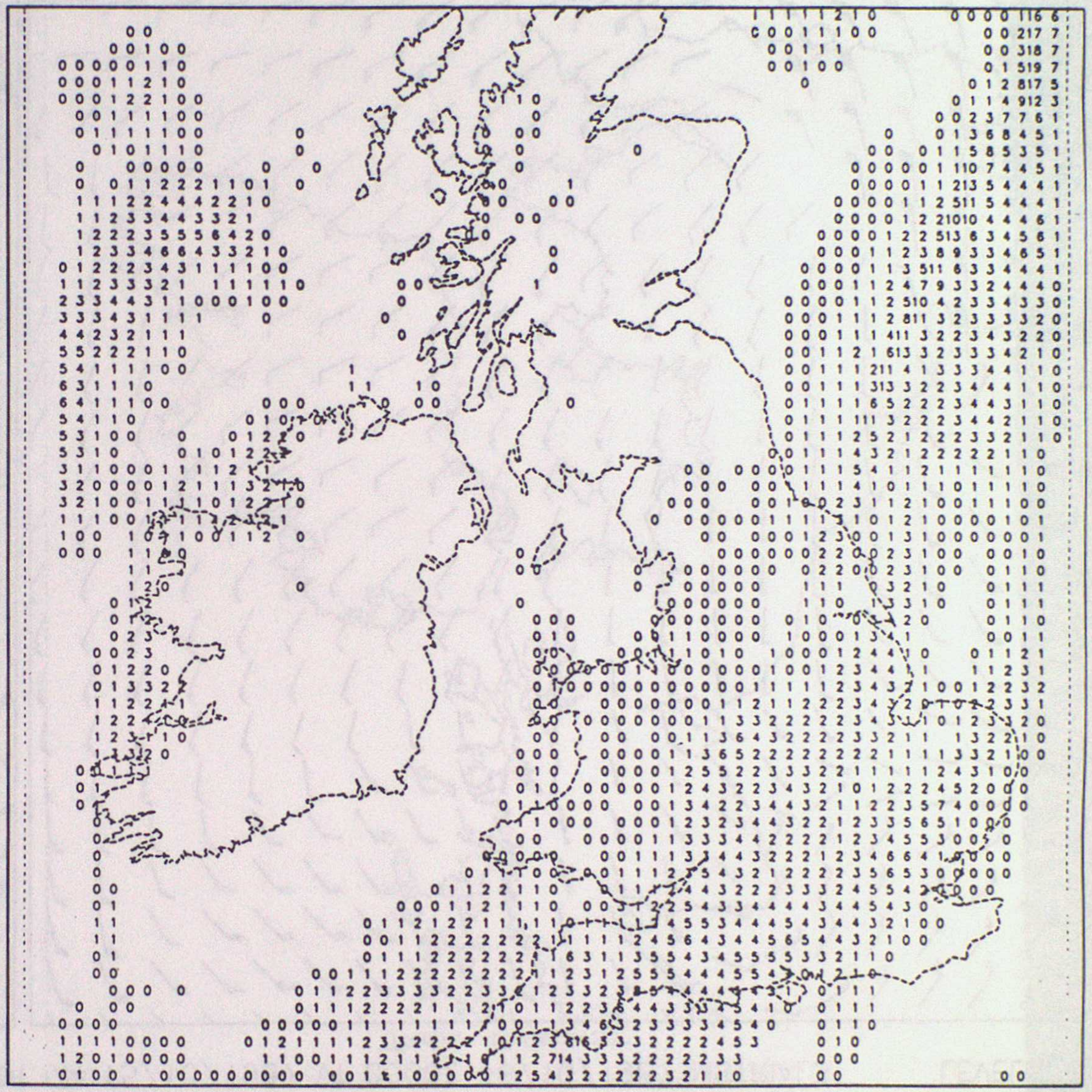
FIGURE 6

12z 09/10/1987 VT 0000Z 10/10/1987 MSFC PRAC



CONTROL FORECAST ACCUMULATIONS – PERIOD 21-00 GMT

DT 12z 09/10/1987 VT 0000Z 10/10/1987 TRIAL3 PRAC



TRIAL FORECAST ACCUMULATIONS – PERIOD 21-00 GMT

FIGURE 7

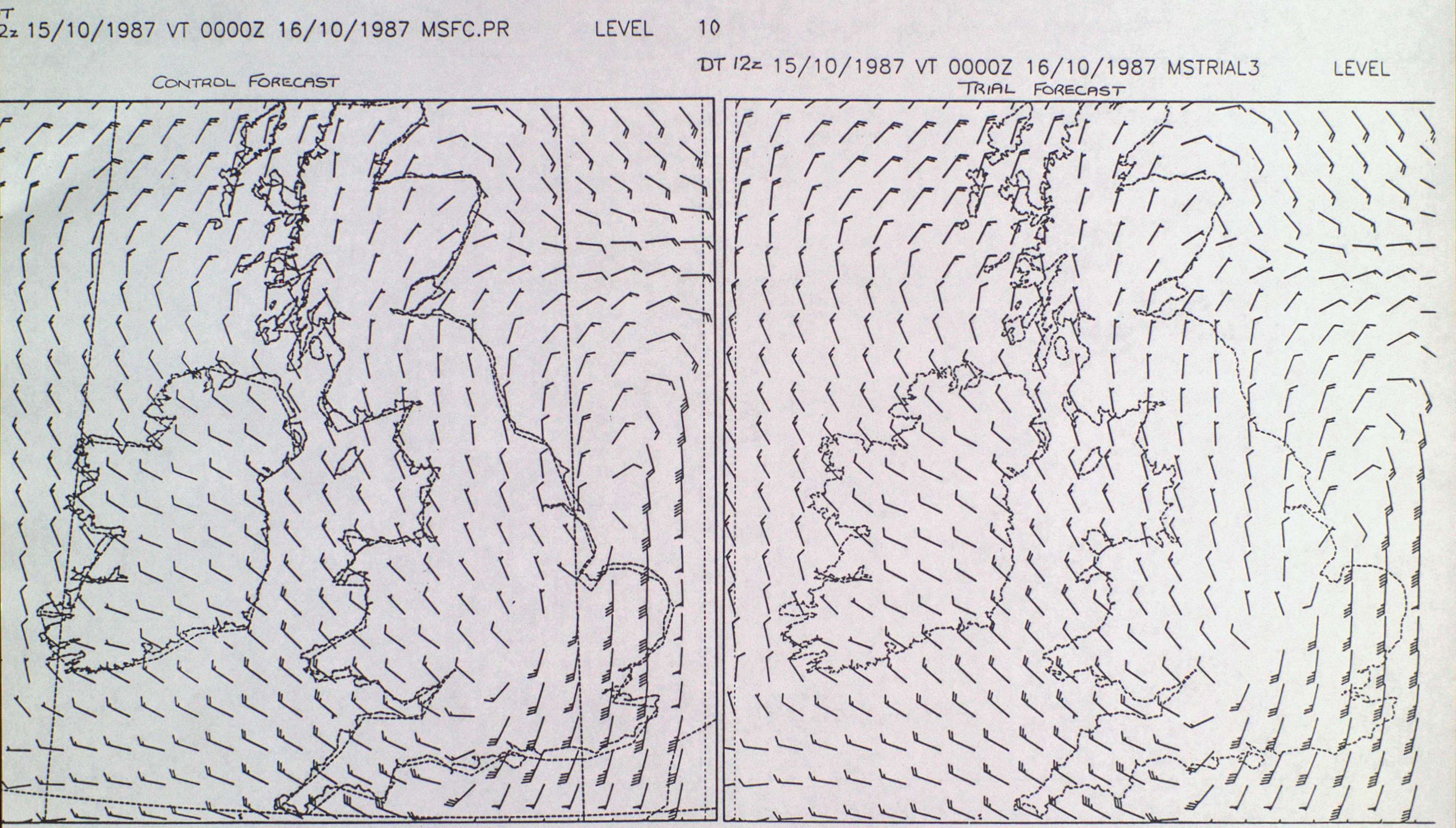
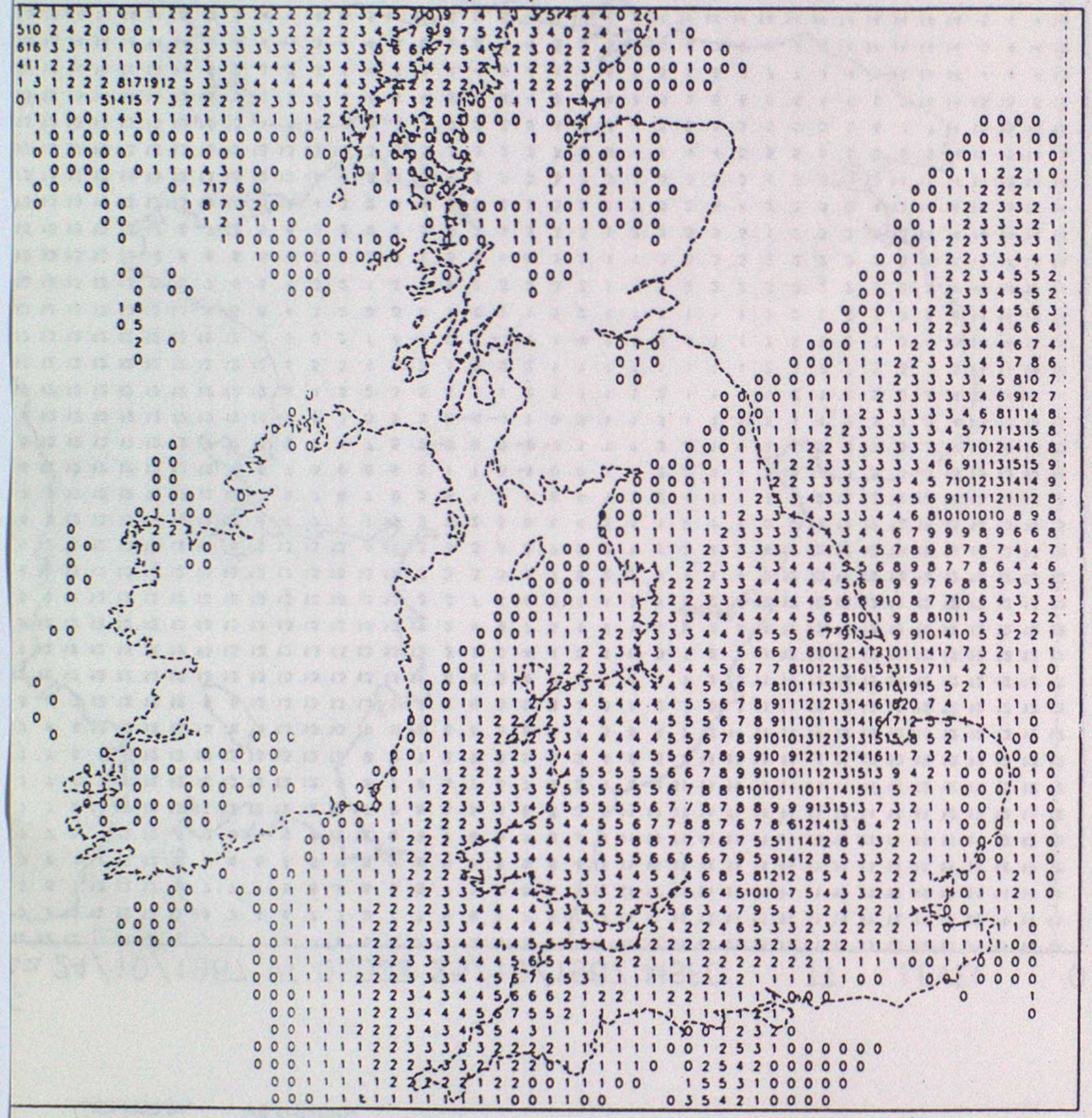

T
2z 15/10/1987 VT 0000Z 16/10/1987 MSFC.PR LEVEL 10
CONTROL FORECAST
DT 12z 15/10/1987 VT 0000Z 16/10/1987 MSTRIAL3 LEVEL
TRIAL FORECAST

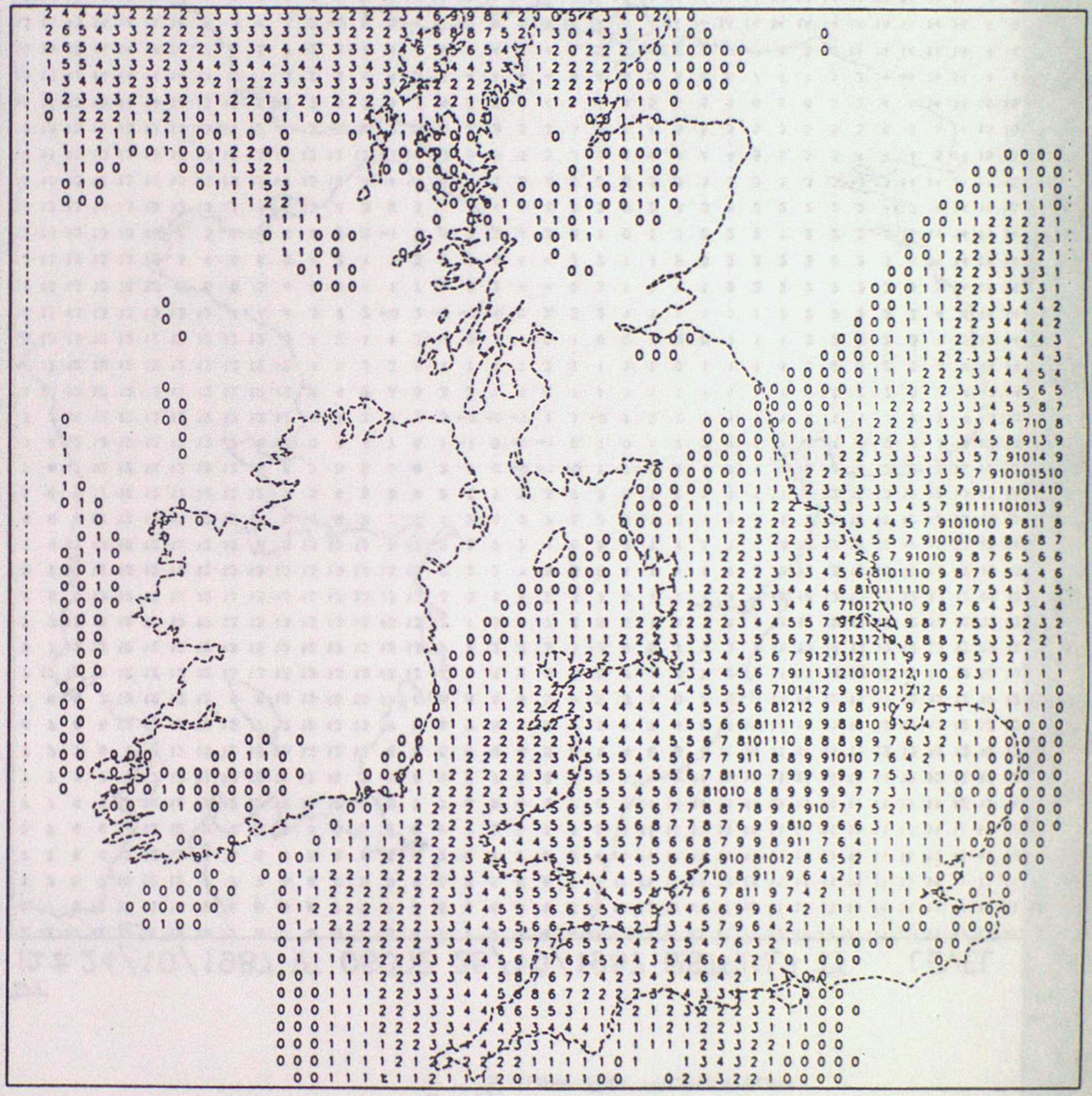
FIGURE 8

15/10/1987 VT 0000Z 16/10/1987 MSFC PRAC



Control Forecast DT 12GMT. 15/10/87
Accumulations Period 21-00 GMT

15/10/1987 VT 0000Z 16/10/1987 TRIAL3 PRAC



Trial Forecast DT 12 GMT 15/10/87
Accumulations Period 21-00 GMT

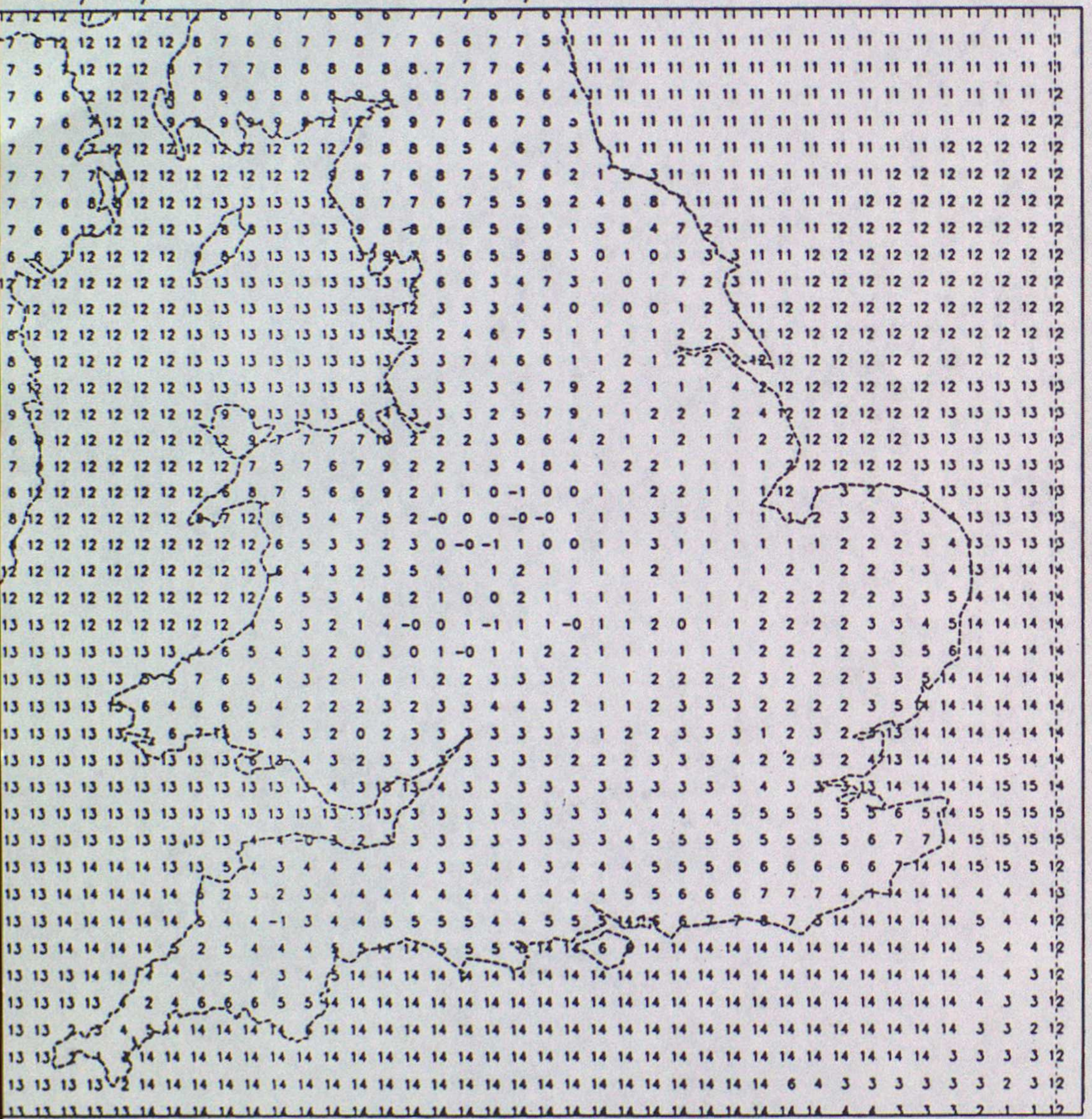
Figure 9

Control Version

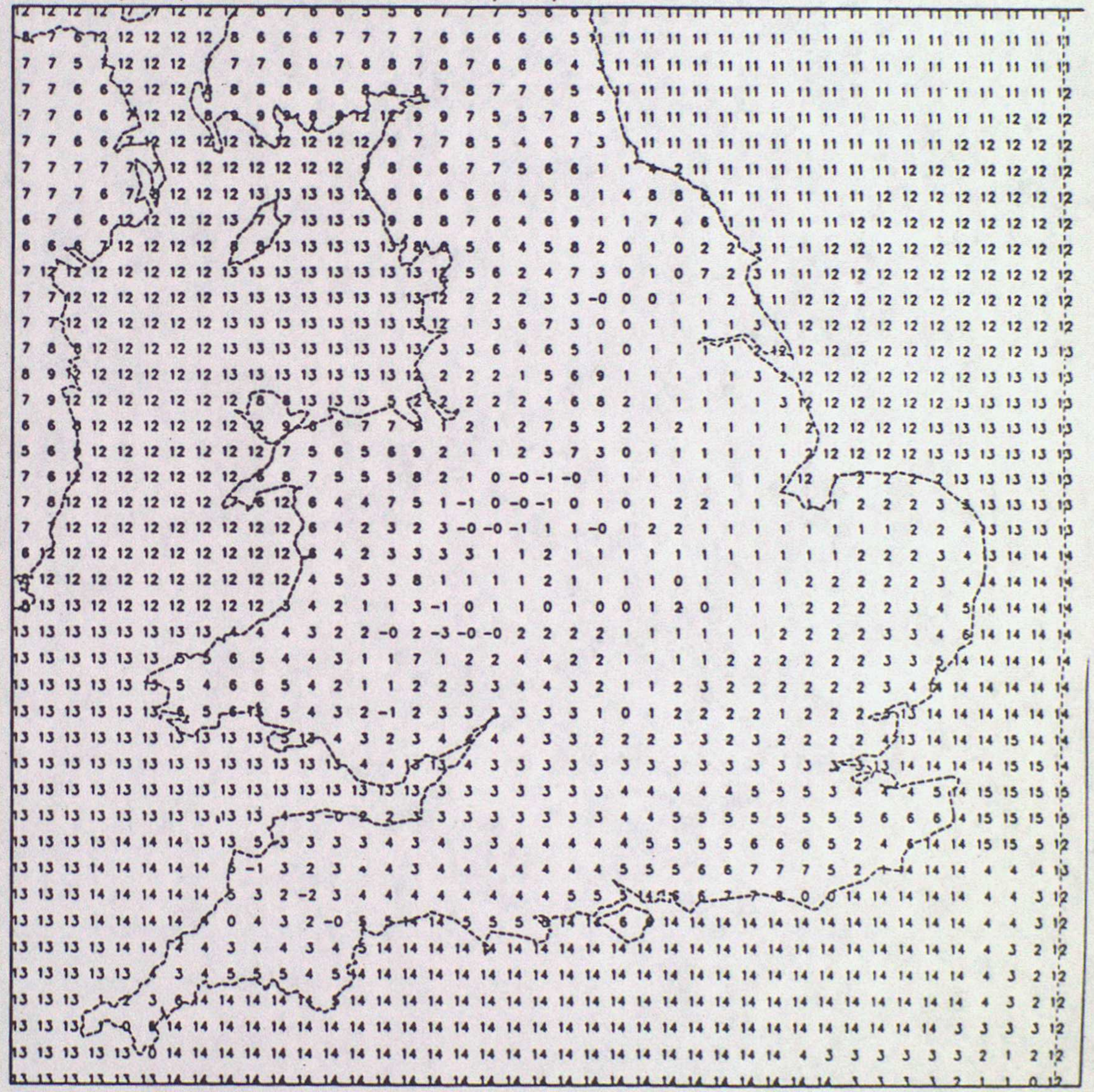
Trial Version [Roughness length for temp, humidity = 1/5 that for momentum]

DT

12Z 24/10/1987 VT 0600Z 25/10/1987 MSFC TT LEVEL 0



12Z 24/10/1987 VT 0600Z 25/10/1987 MSTRIAL4 TT LEVEL 0



DT
12z 24/10/1987 VT 0000Z 25/10/1987 MSFC W LEVEL 10
CONTROL FORECAST

DT
12z 24/10/1987 VT 0000Z 25/10/1987 TRIAL4 W LEVEL 10
TRIAL FORECAST (ROUGHNESS LENGTH FOR TEMP/HUM = 1/5 VALUE FOR MOMENTUM)

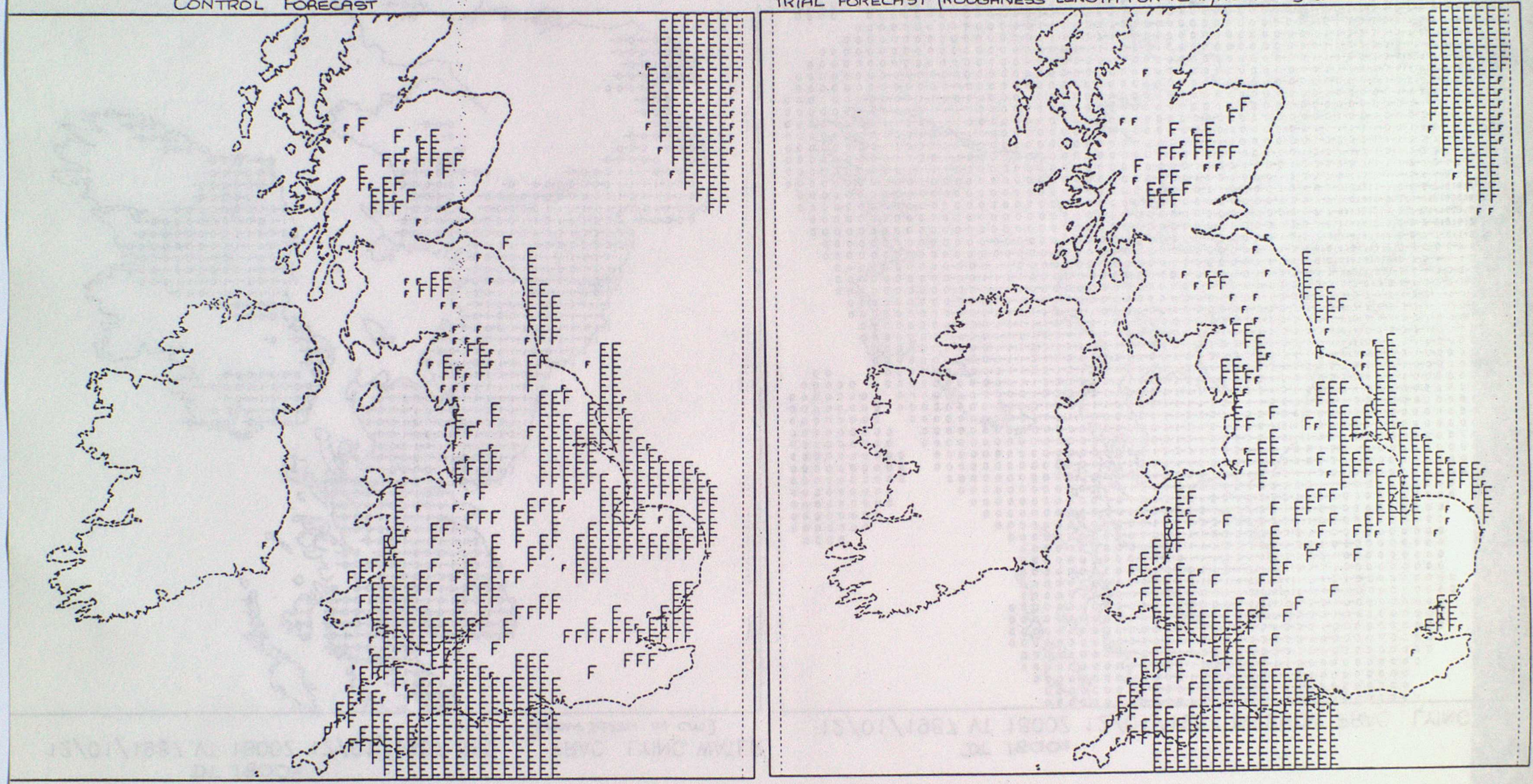
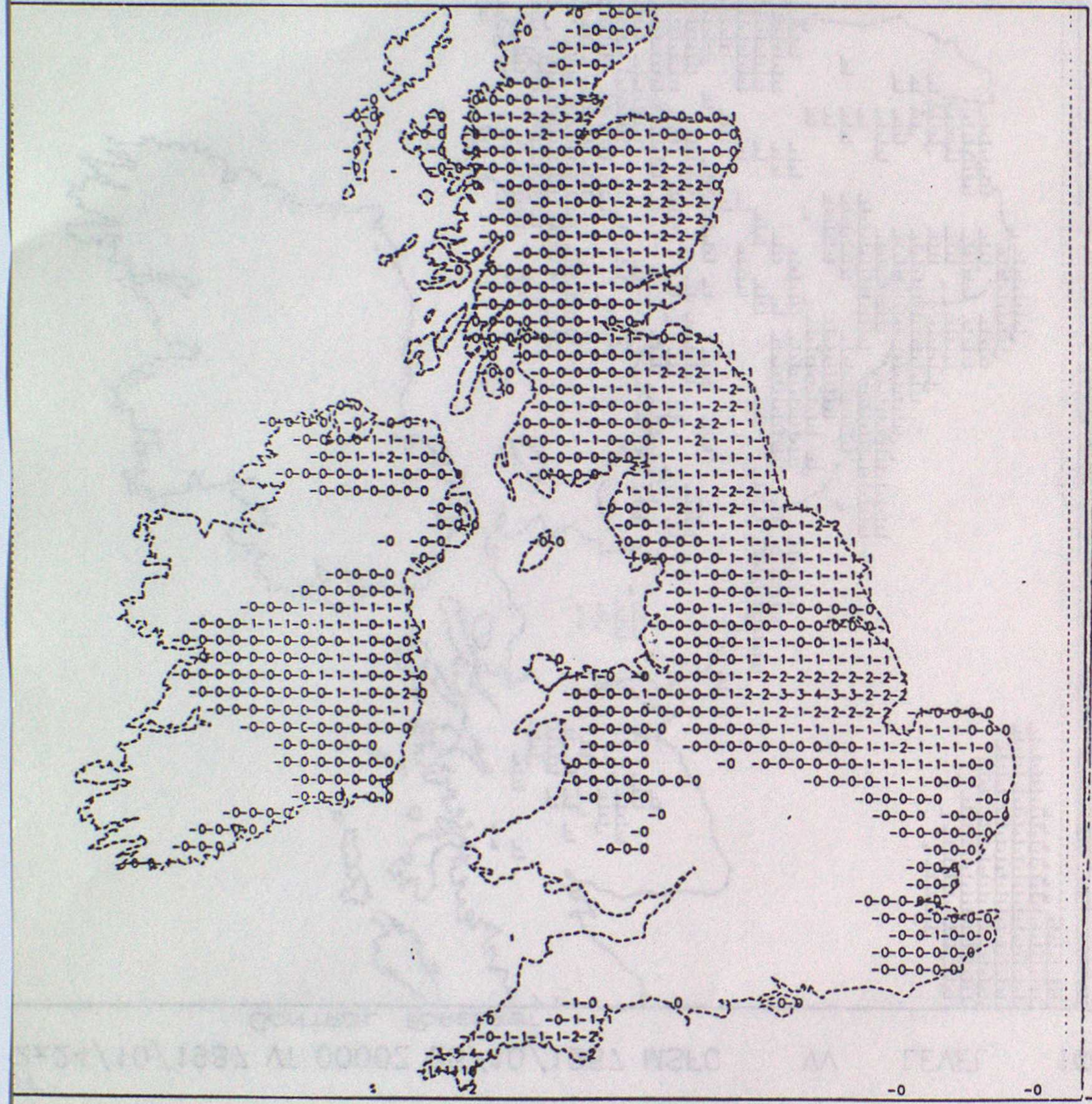


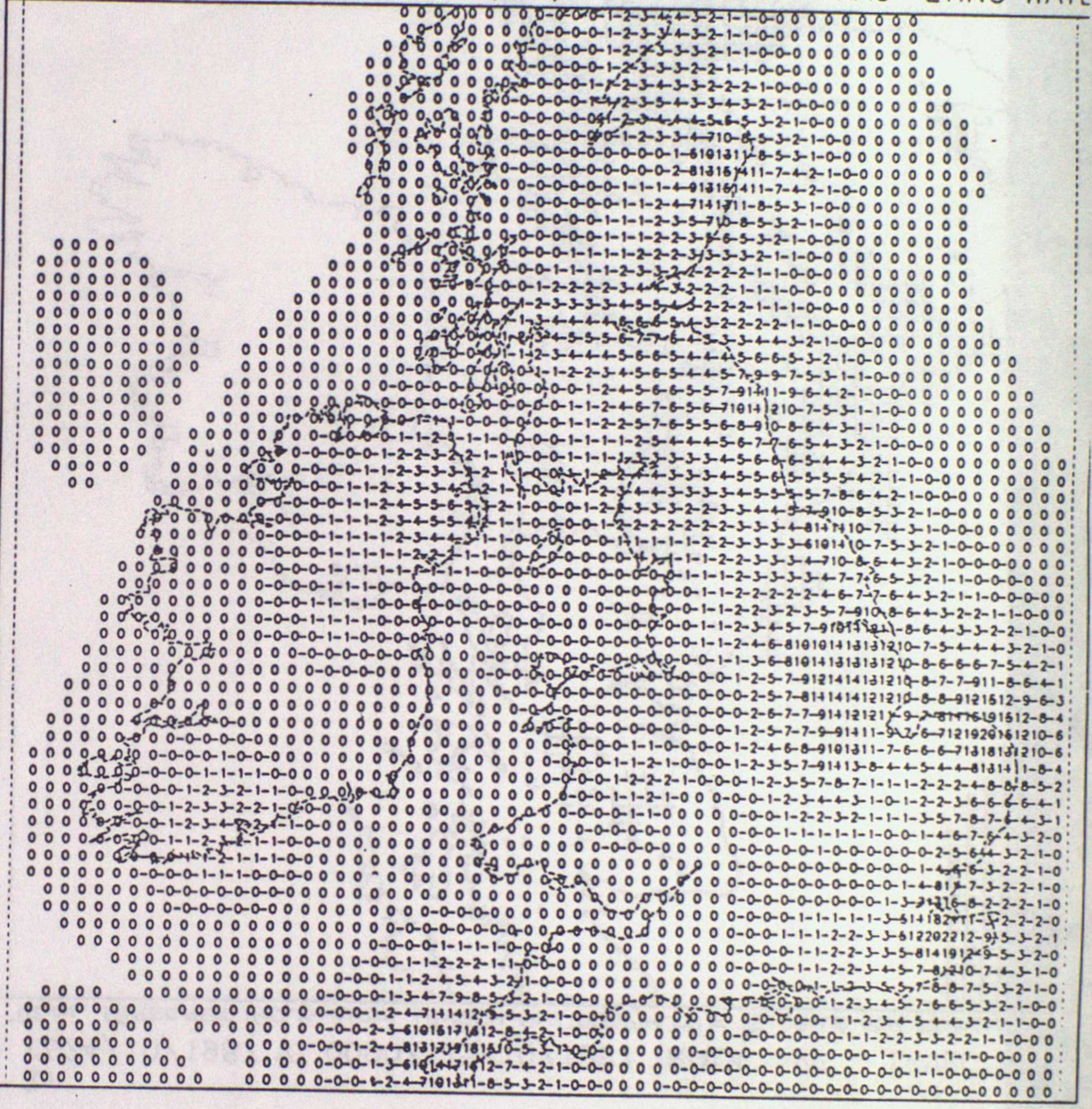
FIGURE 11

DT 1800z
12/01/1987 VT 1800Z 12/01/1987 INIT PRAC LYING WATER
[SNOW DEPTH IN cm]



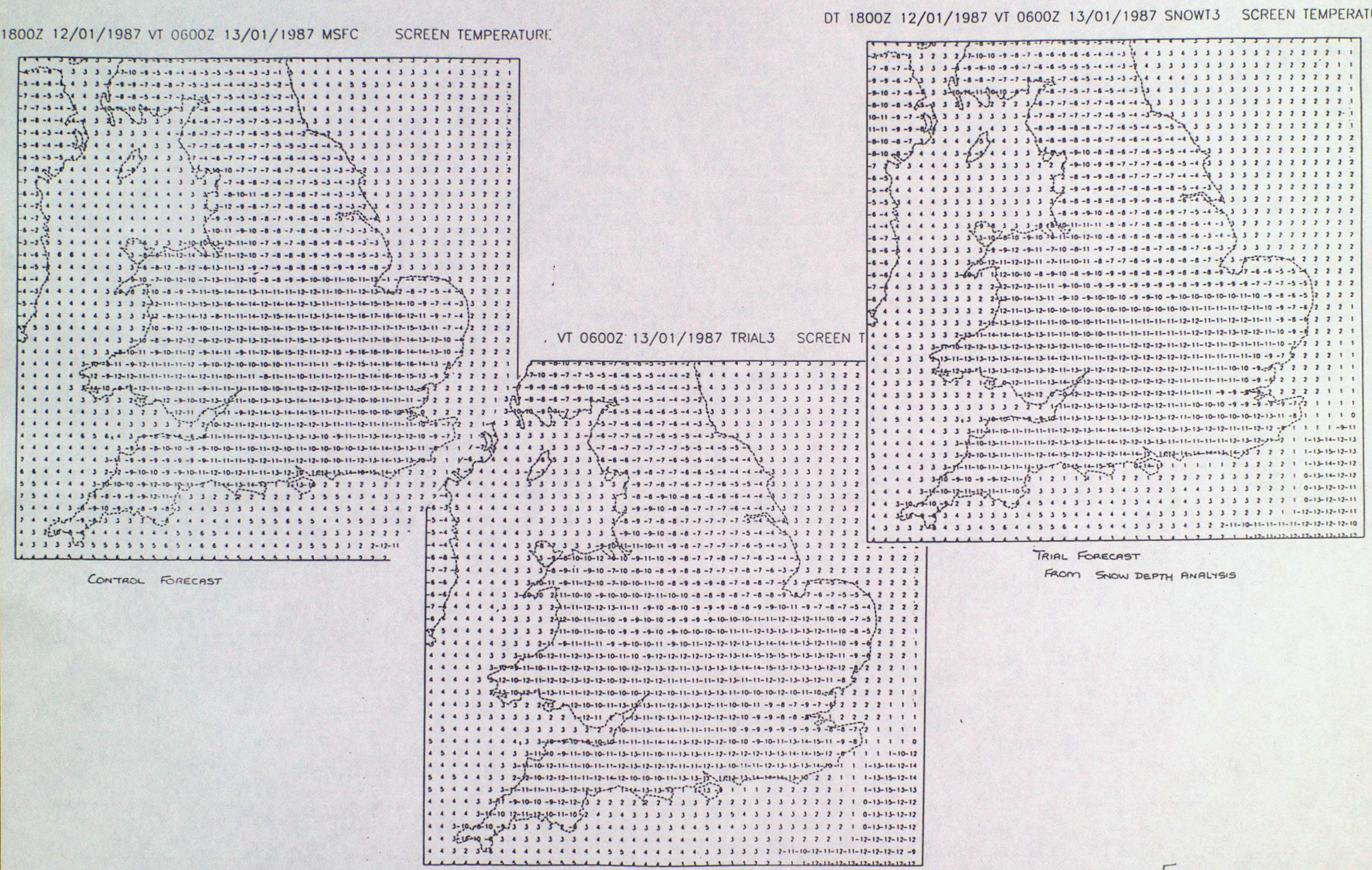
ORIGINAL INITIAL DATASET BEFORE SNOW DEPTH ANALYSIS

DT 1800z
12/01/1987 VT 1800Z 12/01/1987 INI.SNOW PRAC LYING WATE



INITIAL DATASET AFTER SNOW DEPTH ANALYSIS (SNOW DEPTH IN cm)

FIGURE 12



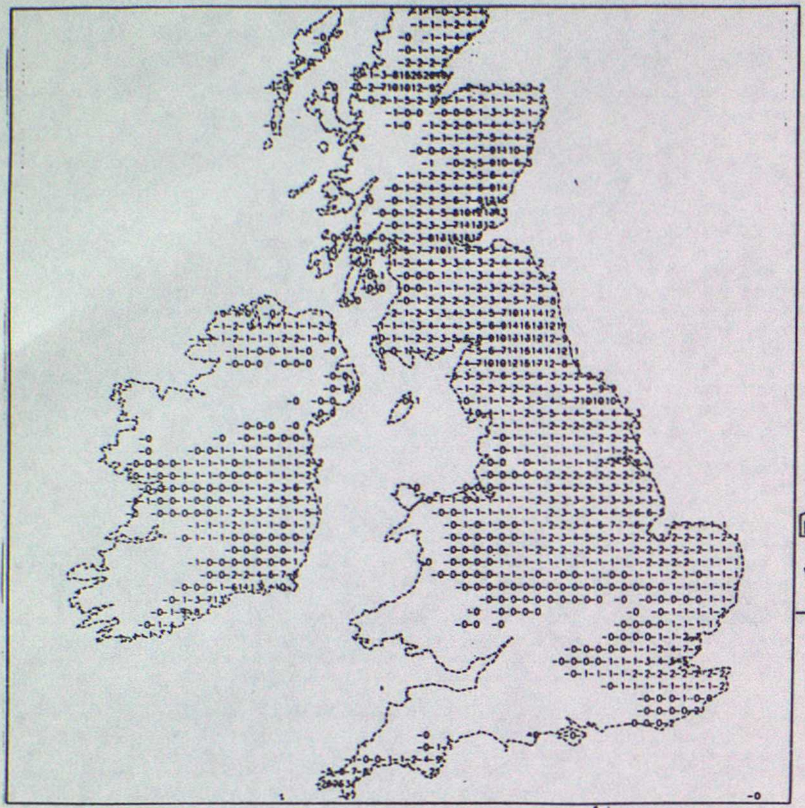
CONTROL FORECAST

TRIAL FORECAST FROM SNOW DEPTH ANALYSIS

TRIAL FORECAST FROM ORIGINAL ANALYSIS

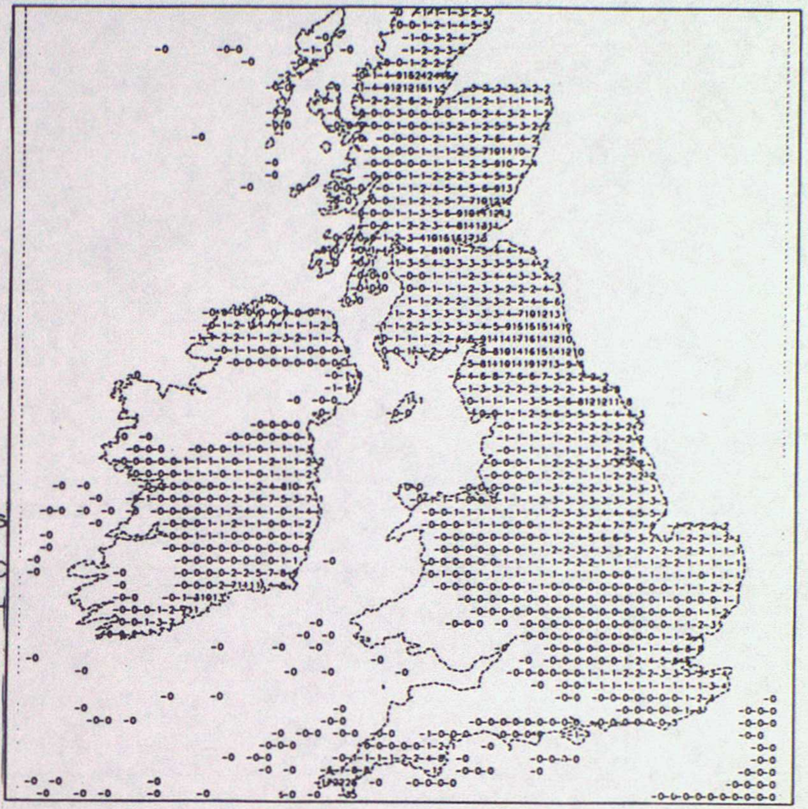
FIGURE 13

DT 1800Z 12/01/1987 VT 0600Z 13/01/1987 MSFC PRAC LYING WATER



CONTROL FORECAST SNOW DEPTH AT T+12

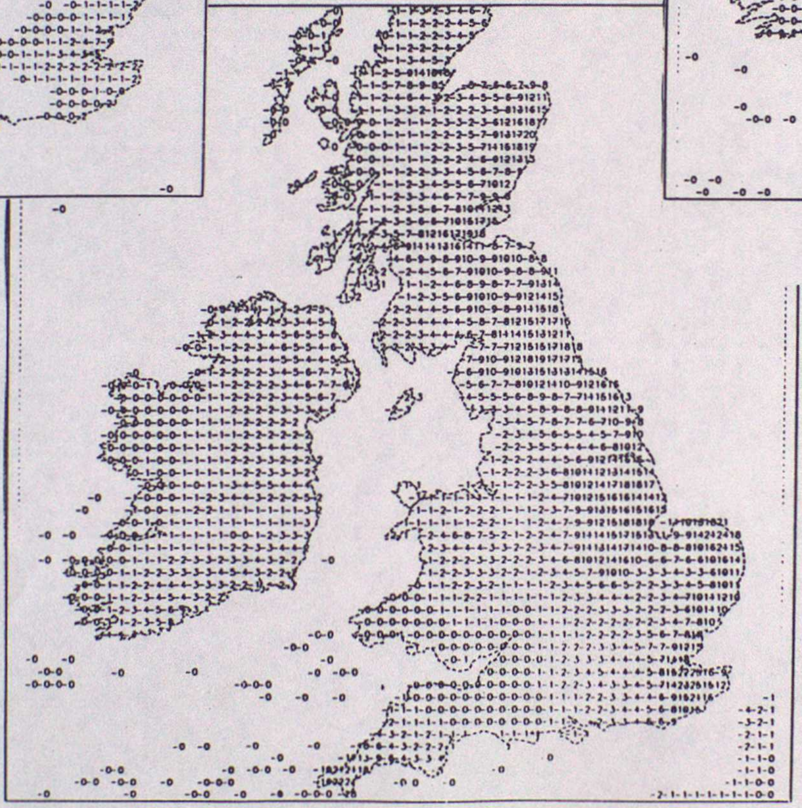
DT 1800Z 12/01/1987 VT 0600Z 13/01/1987 TRIAL3 PRAC LYING WATER



TRIAL FORECAST SNOW DEPTH AT T+12.
[FORECAST RUN FROM ORIGINAL ANALYSIS]

TRIAL FORECAST SNOW DEPTH AT T+12
[FORECAST RUN FROM NEW SNOW DEPTH ANALYSIS]

VT 0600Z 13/01/1987 SNOWTR PRAC



(DEPTHS ≥ 0·01cm PRINTED)

FIGURE 11.