Forecasting Research

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An assessment of a trial to test small changes to the convection scheme in the Mesoscale Model

by

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January 1987

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RESULTS FROM A TRIAL TO TEST SMALL CHANGES TO THE CONVECTION SCHEME IN THE MESOSCALE MODEL.

1. INTRODUCTION.

A few minor changes to the mesoscale model suite have been proposed for implementation during February 1988. 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 deep convection scheme used in the mesoscale model has been described by Barnes and Golding (1).

In order to assess the new package, ten forecasts were rerun using a trial version of the model containing the changes. Cases prior to November 25th 1987 , (when the last model changes were implemented), were also rerun using the current operational version. The cases chosen are listed below;

DT 18 GMT 12/01/87	*DT 00 GMT 28/03/87*	*DT 00 GMT 12/06/87*
DT 00 GMT 13/06/87	*DT 00 GMT 06/07/87*	*DT 12 GMT 15/10/87*
DT 00 GMT 11/11/87	*DT 00 GMT 09/02/88*	*DT 00 GMT 13/01/88*

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

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

A) CHANGES TO THE CONVECTION SCHEME.

i. Increase maximum number of convective clouds.

The maximum number of convective clouds the model is allowed to have has been increased from one-third to one-half of the number of model grid points, i.e. from 1659 to 2488.

The change is made to try and reduce the number of occasions when the maximum number of convective clouds is reached, as this limit has a distorting effect on the distribution of convection in the model.

Another problem currently is that by testing for convection in 3 successive loops over every 3rd row always starting with row 3, when the maximum number of convective clouds is reached, the distribution can become noticeably striped. To avoid this, as well as testing in 2 loops over every other row (since up to NXY/2 clouds are allowed), the first row tested now swaps between rows 3 & 4 for each successive call of subroutine CONTEST. Thus:-

```
M1 = MOD(NTS/NCTEST,2)
DO  220  M = M1,M1+1
DO  220  J = 3+M,NY2,2
```

ii. Change to anvil cloud.

The amount of water extracted from the total available for precipitation to form an anvil cloud is now dependent on the environment temperature at cloud top.

If T(KT) ≥ -12°C, ANVIL = q_s + 0.5 g kg^{-1}, whereas
if T(KT) < -12°C, ANVIL = q_s + 0.05 g kg^{-1}.

This change is designed to reduce the precipitation rate for shallow convective clouds which do not reach the glaciation level.

iii).Correction of minor error in evaporation of convective precipitation.

When the potential evaporation is greater than the available precipitating water at a level, the evaporation is now reduced to the water value, rather than increasing the water to the evaporation value! However, changes to the temperature and water increments will be very small.

iv).Set small amounts of cloud water to zero.

After time-smoothing in subroutine KEXP, the 'A'-field values of cloud water/ice mixing ratio are checked and absolute values less than 0.5×10^{-6} kg kg^{-1} are set to zero. This is in addition to existing checks in subroutine KPR, which set similarly small 'B'-field cloud water/ice values to zero and insignificant cloud fraction values (less than 0.05, i.e. 0.4 oktas) to the effectively zero value of 10^{10}.

B. CALCULATION OF EXNER PRESSURE DEVIATION.

The method of calculating the exner pressure deviation from the input fields has been changed to a method that has more precision. Previously the exner pressure was calculated from the input pressure fields and then the basic state exner pressure $p\phi(z)$ was subtracted. This suffered from loss of accuracy due to the limited precision of the IBM and Cyber. Now the exner pressure deviation is calculated directly from the potential temperature profile by a vertical integration using the hydrostatic relationship. The input value of pressure is still used at level 1 to calculate the exner pressure deviation at that level.

If exner pressure deviation is PX1 and

$$PX1(1) = (P(1) / 1000)^{R/C_p} + \frac{Eg}{C_p \theta_o} - P\phi(1)$$

it can be shown that

$$PX1(N) = PX1(N-1) + \frac{g(\theta - \theta_o)\Delta z}{C_p \theta_o \theta}$$

where E is orographic height, θ_o is basic state potential temperature and θ is the layer averaged potential temperature.

This provides a more accurate hydrostatic balance initially but the impact on the forecast is expected to be very small.

C. CORRECTION OF ERROR IN LANDTYPE SPECIFICATION INDICATOR.

After the November change, it was found that the input variable LTYPE was overwritten in the forecast so that it was always set to 1. This meant landtypes had to be read in from a landtype dataset. This has been corrected so that landtypes can now be specified in the forecast when LTYPE is set to zero in the input namelist. This is a programming change only which will have no impact on the forecast.

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

In this section, a note will be written on each case run, 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 18 GMT 12/01/87. Forecast Period 18 GMT 12/01/87 - 06 GMT 13/01/87.

This was an extremely cold period over the British Isles with temperatures remaining well below zero throughout and with strong easterly winds blowing from Siberia. The airmass was very unstable and vigorous convection set off by the relatively warm North Sea and Channel produced heavy snowfall over the sea and windward coasts. The control forecast gave a very good forecast of the extent and distribution of the snow showers, so this case was chosen to ensure that the proposed changes did not degrade a good forecast. This case was rerun using both the trial and control versions. Both versions reached the maximum number of convective clouds allowed at each three-hourly write-up. However, in the trial version, the forecast distribution of showers was more even, especially in the south, due to the larger number of convective clouds allowed.

The maximum difference occurred at 03 GMT (T+9 hours forecast). In Figure 1 (a and b), we can compare the convective rates from the control and trial versions verifying at 03 GMT. The control forecast (Figure 1a), similar to the original, produced a 'striped' distribution of showers, especially in the south and west where every third row appears to have been missed. The trial forecast (Figure 1b) shows a more even shower distribution. The individual convective rates are similar. The forecast three-hourly accumulations for the period 00-03 GMT 13/01/87 for the control and trial versions are shown in Figure 2(a and b). Spot values of the three-hourly convective accumulations are similar in both versions but the overall total in the trial version is increased due to the greater number of showers.

b)DT 00 GMT 28/03/87. Forecast Period 00 GMT - 18 GMT 28/03/87.

During this period, a deep depression remained slow-moving over the North Sea with a strong northerly airsteam over the British Isles. During the morning, a band of rain moved southwards over Eastern Britain but during the afternoon the cold unstable northerly airstream spread to all parts, bringing a mixture of rain, sleet, hail and snow showers with isolated thunderstorms. Due to the strong winds, showers were short-lived and accumulations from the showers were small. (Trace - 4mm in 12 hours). This case was chosen as another example in which the control version reached the maximum number of convective clouds allowed throughout the forecast.

In Figure 3 (a and b), we can compare the forecast shower distribution from both versions at 15 GMT . In the trial version, the number of convective clouds forecast varied between 1600 and 2488, so the maximum number was reached only occasionally. In this case, there is actually little difference between the trial and control versions except that the trial version is less banded in the south.

c)DT 00 GMT 12/06/87. Forecast Period 00 GMT - 18 GMT 12/06/87.

With an upper trough over the British Isles, the airmass was cool and very 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 as an example of a summer shower case.

Neither version predicted the maximum possible number of convective clouds. The peak convective rates were slightly lower in the trial version, resulting in slightly less heavy showers being predicted but this did not degrade the forecast. In Figure 4 (a and b), we compare the six-hourly accumulations for the period 12-18 GMT from the control and trial versions. The largest convective accumulations (Humber and South Yorkshire) are locally slightly smaller in the trial version but the overall guidance is very similar. Figure 4c shows the actual accumulations reported for the same period.

d)DT 00 GMT 13/06/87. Forecast Period 00 GMT - 18 GMT 13/06/87.

After a dry start, showers developed inland during the afternoon, becoming heavy and prolonged at times in the east with local thunderstorms. In the west the showers were more isolated. This case was chosen as a second example of a summer shower case.

Figure 5c shows the actual accumulations reported for the period 12-18GMT. In Figure 5(a and b), we can compare the six-hourly accumulations for the period 12-18 GMT from the control and trial versions. The largest convective accumulations (Eastern Scotland andSuffolk/Essex) are locally slightly smaller in the trial version but as in the previous case (12/06/87) the overall guidance is unchanged.

e)DT 00 GMT 06/07/87. Forecast Period 00 GMT - 18 GMT 06/07/87.

This was a hot and humid day with maximum temperatures reaching 28 degrees Celsius. Most places remained dry and sunny but in the Southeast there was an increase of upper cloud with patches of unstable medium cloud producing very isolated showers. Judging from the Crawley midday ascent, temperatures of 28 might have produced isolated CB but none in fact were observed.

Both the trial and control forecasts erred in forecasting shower activity to be too widespread in a band from the Humber to Dorset. The band of showers coincided with the highest forecast temperatures in the model, 28 to 32 degrees Celsius. These forecast temperatures were too high (observed temperatures were 25-28 degrees Celsius)and this probably accounts for the incorrect forecast of showers. The main difference between the trial and control versions was in the timing of the showers. the trial version had most showers at 15 GMT, becoming isolated by 18 GMT. The control forecast forecast more showers at 18 GMT. There was little difference between forecast temperatures.

In Figure 6(a and b), we have compared the forecast accumulations for the period 12-18 GMT. In the trial version, accumulations are locally slightly smaller and less widespread than in the control version, but both forecasts are incorrect.

f)DT 12 GMT 15/10/87. Forecast Period 12 GMT 15/10/87/- 06 GMT 16/10/87.

This forecast covers the period of the great October storm during which a depression moved northeastwards from Biscay and deepened rapidly as it crossed Southern England , bringing heavy rain and storm force winds to the southeast. The case was chosen because it illustrates a fault in the convective routine. In a warm, moist airmass with limited instability, the model can predict very large (unrealistically!) convective rates, from small fractions of convective cloud.

In Figure 7 (a and b), we have compared the forecast convective rates over South-east England at 21 GMT. The control version has forecast local convective rates of 20/21 mm/hour in showers. To forecasters using this output, rates this large would imply the prescence of deep convection and possible thunderstorms. In the model, however, these rates are from less than one octa of convective cloud of depth only 3000m. Typically in this situation, the model is saturated throughout this depth. Figure 8 shows a cross-section across Southern England in the area with rates reaching 20 mm/hour as indicated in figure 7a. The cross section shows the limited depth of instability (indicated by the small circles) and the large amounts of cloud water. In the trial version, these large rates have been reduced to 17/18 mm/hour, which is a small improvement but not a cure. There was a small decrease in the convective accumulations but a corresponding small increase in dynamic accumulations. However, as shown in Figure 9, there was little difference in the total six-hour forecast accumulations during the period 18-24 GMT.

g)DT 00 GMT 11/11/87. Forecast Period 00 GMT - 18 GMT 11/11/87.

This case was chosen as an example of an active frontal system with embedded instability. At 12GMT, the radar (see figure 10), showed the largest rain rates (4mm/hr)to be in the frontal zone in a line approximately from Scillies over West Wales to North-west England. In figure 11, we can compare the forecast convective rates at 12 GMT from the control and trial versions. In both versions of the model forecast, the convective instability was much too widespread. In the control version, the model often reached the maximum possible number of convective clouds and this is indicated by the banded shower distribution in the south.(Figure 11a). The trial version (Figure 11b) reached the maximum number less frequently and the forecast distribution is smoother except in the extreme south. In the trial version, forecast peak rates (>10mm/hr) are generally 2-4 mm/hour lighter. Overall total accumulations for the period 06-12 GMT were very similar for both versions.

h)DT 12 GMT 13/01/88. Forecast Period 12 GMT 13/01/88 - 06 GMT 14/01/88.

An area of rain in the southeast was associated with a wave on a cold front. In the south-westerly airstream in the west, there were scattered light or moderate showers. This case was chosen to assess the forecast of convective rain by the model in a southwesterly airstream with limited depth of instability. Figure 12(a and b) compares the forecast convective rates at 15 GMT, whilst the verifying radar chart is shown in Figure 13. The model seems to have overdone the instability in the rain area in the southeast. Rates as shown by the radar picture (Figure 13) are less than 4 mm/hour. The trial rates are slightly lower locally. Figure 14 is a cross-section over South-east England on the line shown in Figure 13, showing the forecast convective depth, cloud water, relative humidity and potential temperature. The heavy showers (local rates of 10-14mm/hour) predicted by the model in both versions in the southeast are from less than 1 octa of convective cloud depth 3000m. Figure 15 shows an ascent from a point along the line of the cross-section showing that the model is saturated throughout this depth. In the west, both versions, especially the trial version, have overestimated the depth of instability, forecasting heavy showers from 6000m depth of instability.

i)DT 00 GMT 09/02/88. Forecast Period 00 GMT 09/02/88 - 12 GMT 09/02/88.

At 12 GMT, a deep depression was centred close to Western Scotland with a very strong unstable westerly airflow across the area.This case was chosen because the distribution of showers in the control version was noticeably banded in the south. This version forecast the maximum possible number of convective clouds all the way through the forecast. The forecast convective rates at T+12, verifying time 12 GMT, are compared in Figure 16. The trial version also reached the maximum number at times but mainly hovered just below. Consequently the trial forecast gave a better distribution of showers. The radar picture verifying at 12 GMT 09/02/88 is shown in Figure 17. In Figure 18, we compare the six-hourly convective accumulations for the period 06-12 GMT. The trial version has given a better distribution of showers and accumulations have increased due to the greater number of showers forecast.

4. CONCLUSION

Nine cases have been rerun using both a control (current operational) and a trial version of the mesoscale model in order to test small changes to the current model. The main differences noticed between the trial and control versions are described below.

1. In very unstable airmasses, the current version reaches the maximum possible number (1659) of convective clouds frequently. In some cases, this leads to the forecast distribution of showers becoming noticeably striped or banded. In these cases, the trial version improves the forecast distribution of showers substantially by;
a) allowing a greater number of convective clouds (2488);
b) varying the order of calling the rows in the convective test.

2. In the very unstable cases described in para. 1 above, the total convective accumulation is increased in the trial version due to the greater number of showers. Convective rates are mainly unchanged.

3. In warm, moist airmasses, the current version occasionally predicts very high convective rates from a shallow depth of instability. (eg., convective rate 12-20 mm/hour from 1 octa or less of convective cloud of depth 3000m.) In the trial version, the amount of water retained in the cloud (for anvil formation) has been made dependent upon the temperature of the cloud top. This change is partially successful, in that it reduces slightly the erroneously high convective rates in warm airmasses by about 3mm/hour.

4. In the cases described in para 3 above, convective accumulations were slightly less in the trial version, but dynamic accumulations were slightly increased. Hence the total accumulations were very similar.

5. In all other cases, (other than those described in paras 1 and 3 above), the changes had little impact. These include cases of ;
a) deep convection with cloud top temperatures less than -12 degrees Celsius.
b) frontal cases with mainly dynamic rain.

6. Little change was noticed in forecast pressure from the change to the method of calculating the Exner pressure deviation.

The above changes were implemented on February 17th, 1988.

REFERENCES.

MET.O.11 MESOSCALE DOCUMENTATION PAPER NO 5.- DEEP CONVECTION VERSION 2 MAY1987. BY R.T.H.BARNES AND B.W.GOLDING

LIST OF FIGURES.

FIGURE 14. D.T 12 GMT 13/01/88 VT 15 GMT 13/01/88
CROSS-SECTION ACROSS SOUTHEAST ENGLAND, SHOWING CONVECTIVE CLOUD DEPTH (C), CLOUD WATER (M), RELATIVE HUMIDITY (RH),AND POTENTIAL TEMPERATURE (PO.T).

FIGURE 15. D.T 12 GMT 13/01/88 VT 15 GMT 13/01/88
TEPHIGRAM FROM A GRID_POINT OVER SOUTH-EAST ENGLANDGIVING A CONVECTIVE RATE OF 10-13 mm/hr.

FIGURE 16. D.T 00 GMT 09/02/88 VT 12 GMT 09/02/88
a) LOCAL CONVECTIVE RATE (mm/hr) - TRIAL VERSION
b) LOCAL CONVECTIVE RATE (mm/hr) - CONTROL VERSION

FIGURE 17. 12 GMT 09/02/88
RADAR PICTURE FOR 12 GMT 09/02/887

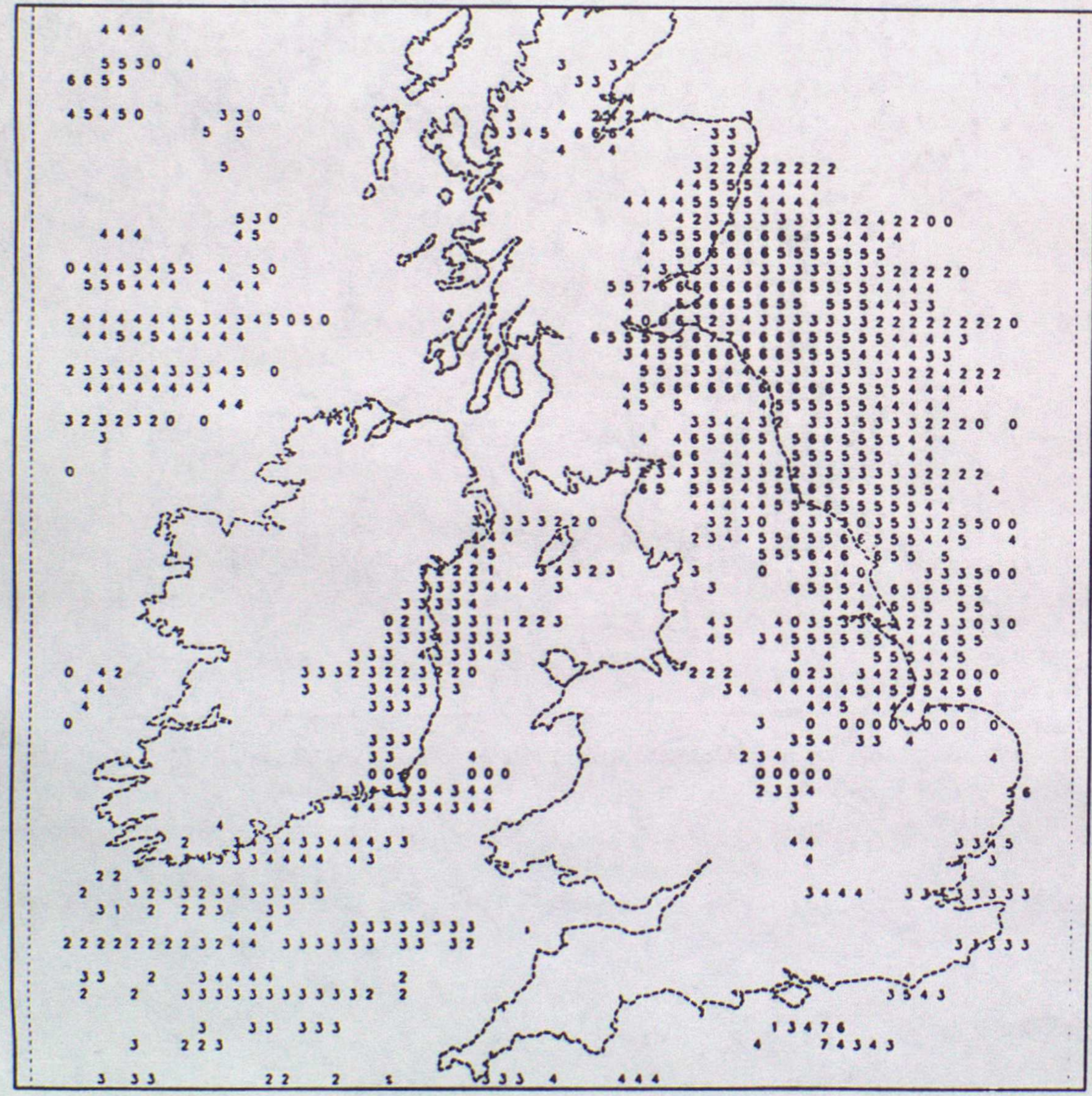
FIGURE 18 D.T 00 GMT 09/02/88 VT 12 GMT 09/02/88
a) CONVECTIVE ACCUMULATION (06GMT-12GMT) - TRIAL
b) CONVECTIVE ACCUMULATION (06GMT-12GMT) - CONTROL

FIGURE 1. D.T 18 GMT 12/01/87 VT 03 GMT 13/01/87

a) LOCAL CONVECTIVE RATE (mm/hr) - CONTROL VERSION

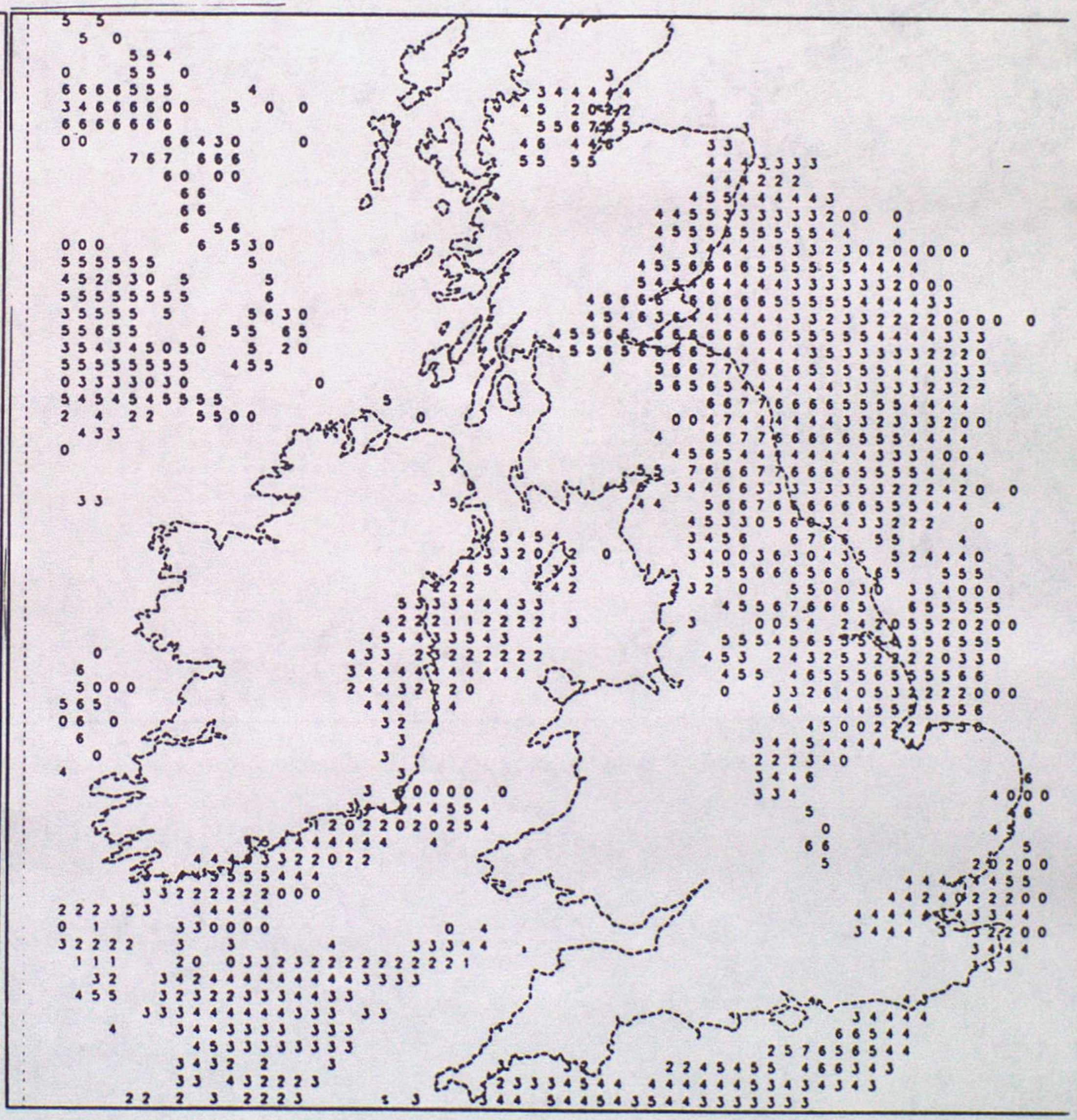
b) LOCAL CONVECTIVE RATE (mm/hr) - TRIAL VERSION

VT 0300Z 13/01/1987 MSFC.OP PR CONVECTIVE



1a

VT 0300Z 13/01/1987 TRIAL PR CONVECTIV



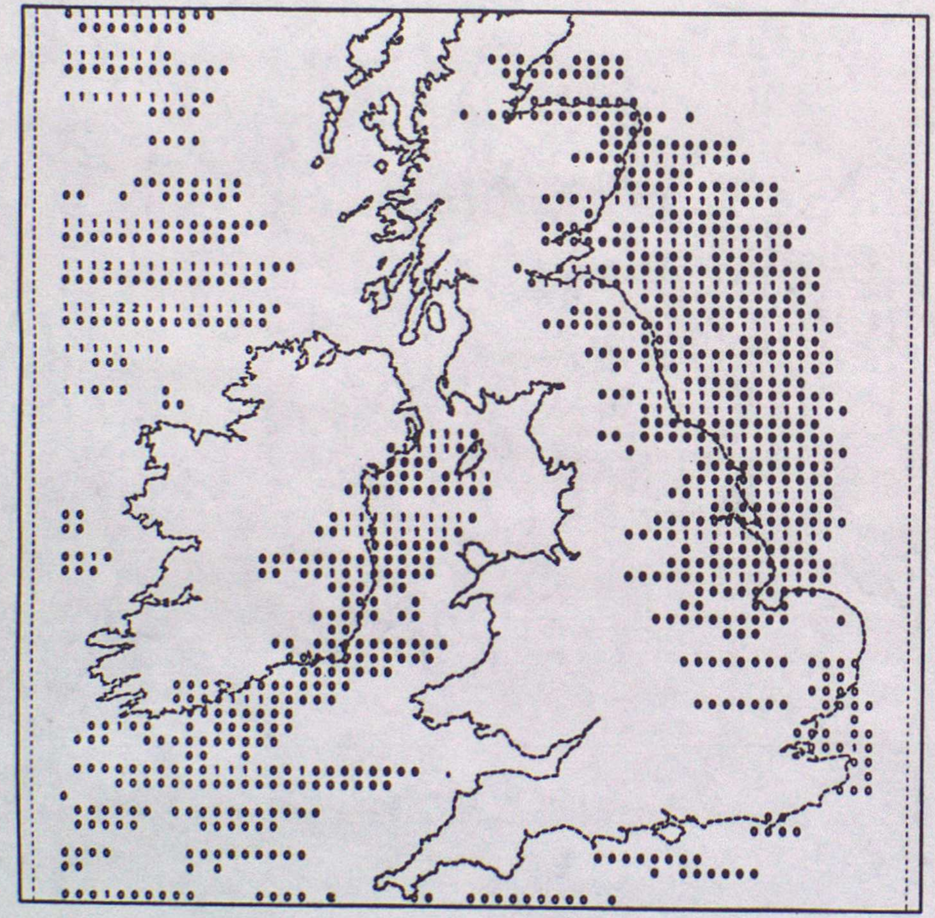
1b

FIGURE 2. D.T 18 GMT 12/01/87 VT 03 GMT 13/01/87

a) CONVECTIVE ACCUMULATION (00GMT-03GMT) - CONTROL

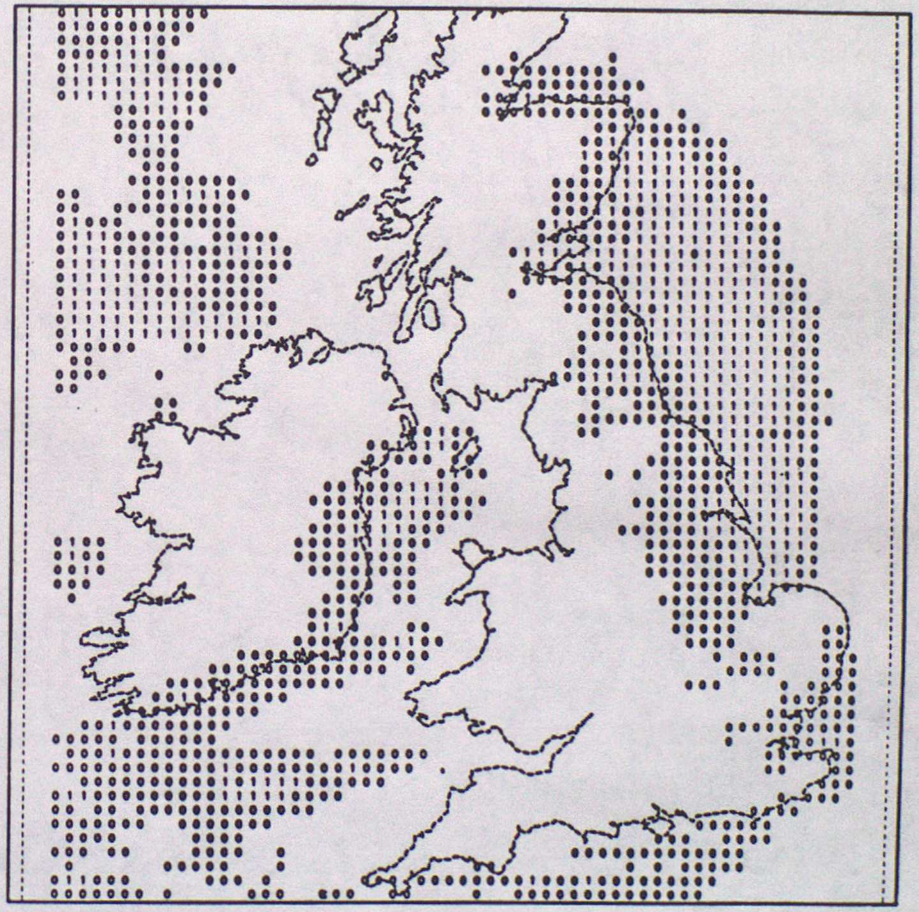
b) CONVECTIVE ACCUMULATION (00GMT-03GMT) - TRIAL

DT 1800Z 12/01/1987 VT 0300Z 13/01/1987 CONTROL PRAC CONVECTIVE



a

DT 1800Z 12/01/1987 VT 0300Z 13/01/1987 TRIAL PRAC CONVECTIVE



b

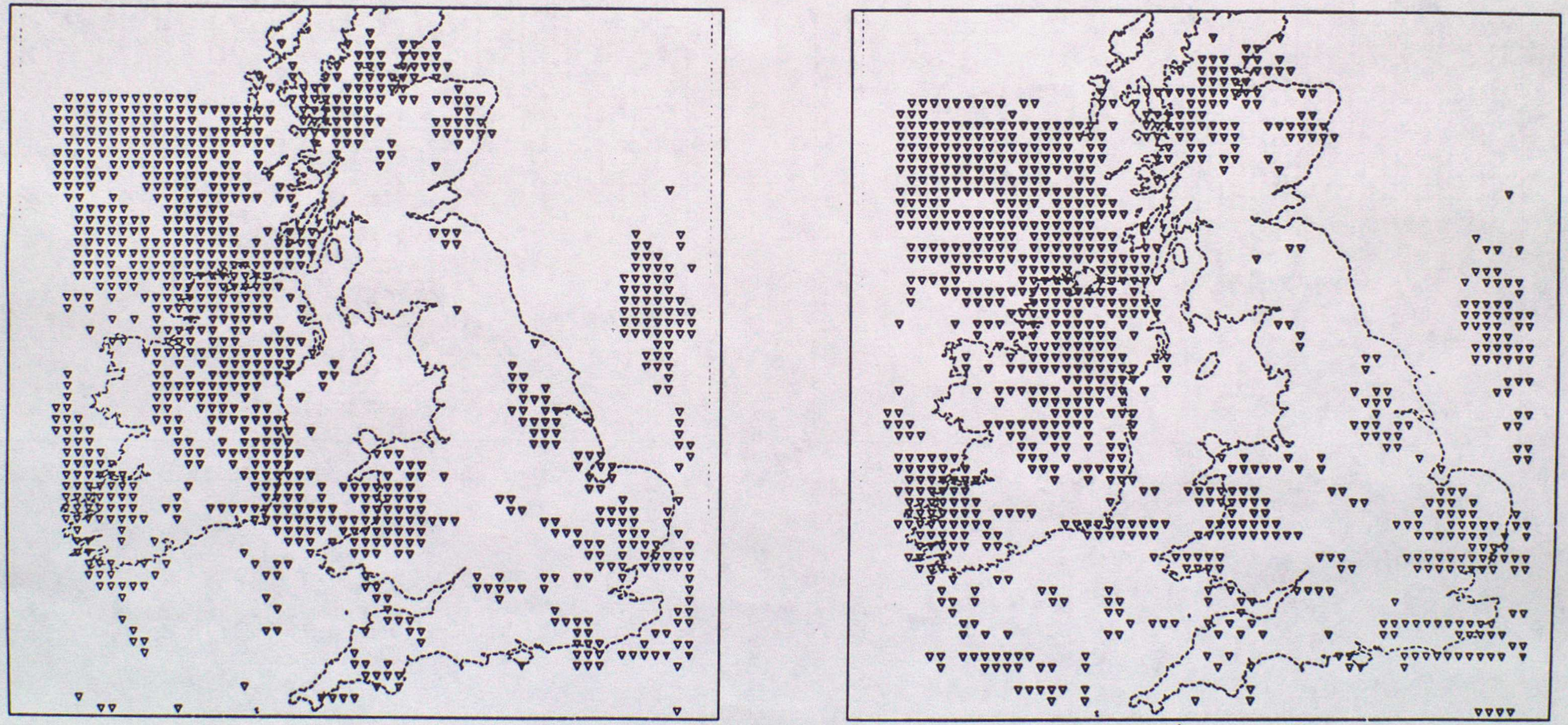
FIGURE 3. D.T 00 GMT 28/03/87 VT 15 GMT 28/03/87

a) DISTRIBUTION OF SHOWERS - TRIAL VERSION

b) DISTRIBUTION OF SHOWERS - CONTROL VERSION

DT 0000Z 28/03/1987 VT 1500Z 28/03/1987 TRCON PR CONVECTIVE

DT 0000Z 28/03/1987 VT 1500Z 28/03/1987 CONTROL PR CONVECTIV



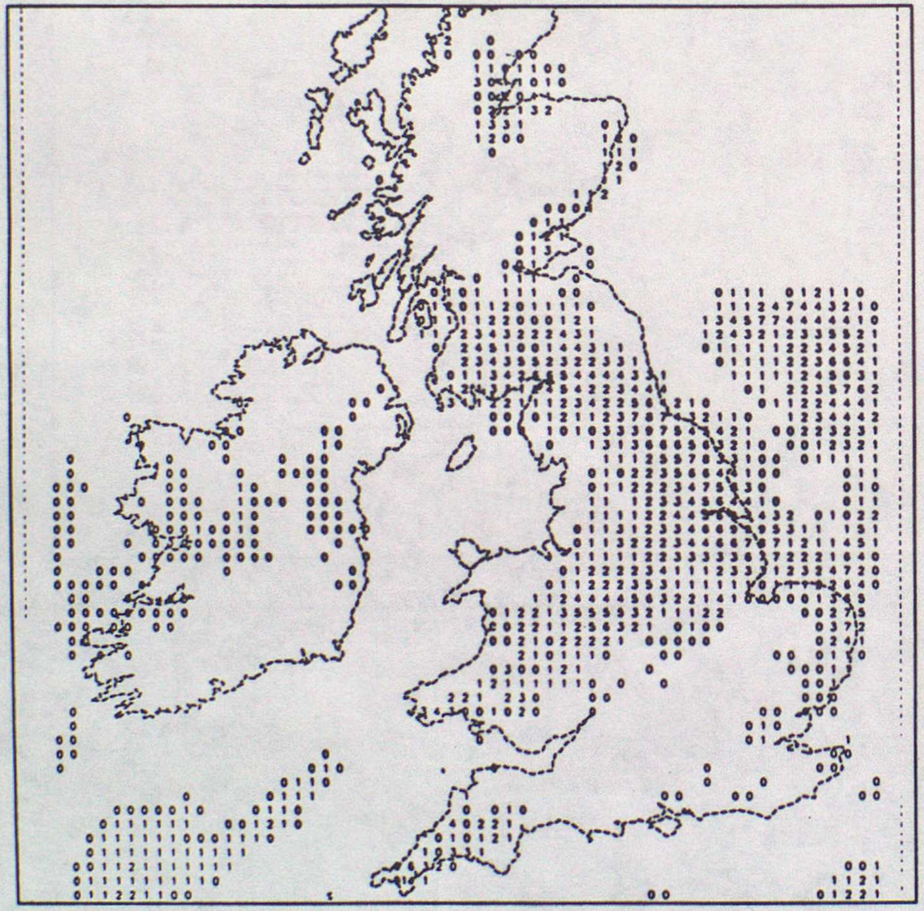
a b

FIGURE 4. D.T 00 GMT 12/06/87 VT 18 GMT 12/06/87

a) 6-HOUR ACCUMULATION (12GMT-18GMT) - CONTROL

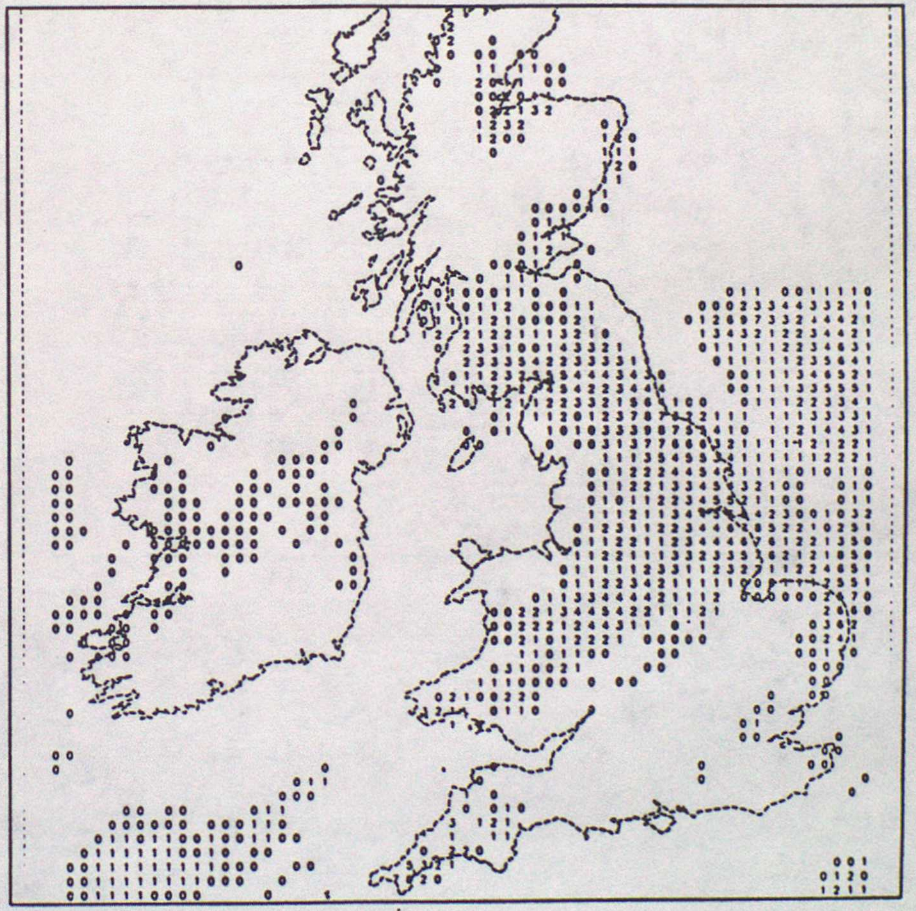
b) 6-HOUR ACCUMULATION (12GMT-18GMT) - TRIAL

DT 0000Z 12/06/1987 VT 1800Z 12/06/1987 CONTROL PRAC



a

DT 0000Z 12/06/1987 VT 1800Z 12/06/1987 TRIAL PRAC



b

[redacted] 6 HOURS [redacted] OBSERVED [redacted] ACCUMULATED [redacted] PRECIPITATION [redacted] (MM). [redacted]

FROM 12Z 12/6/87 TO 18Z 12/6/87

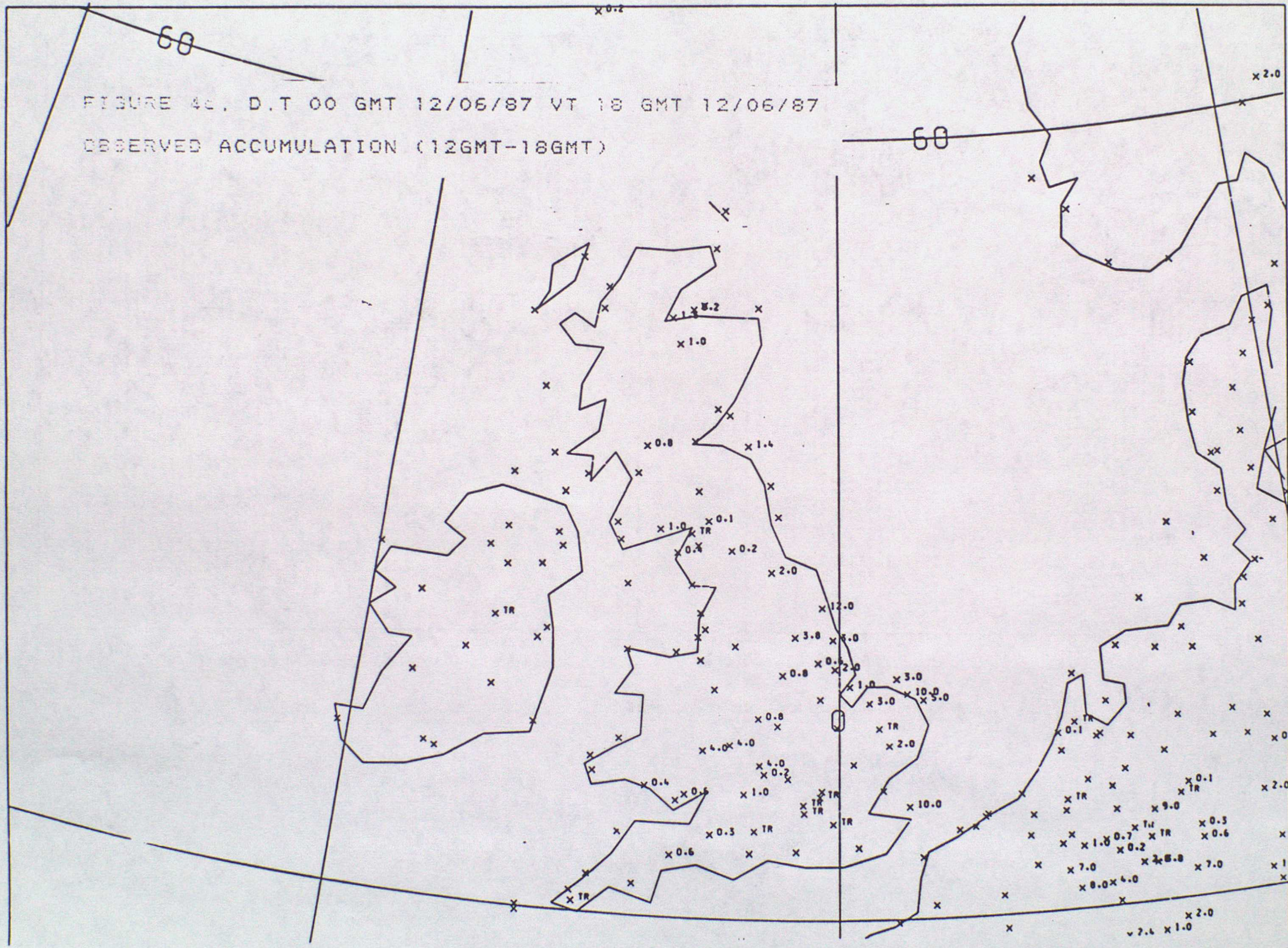


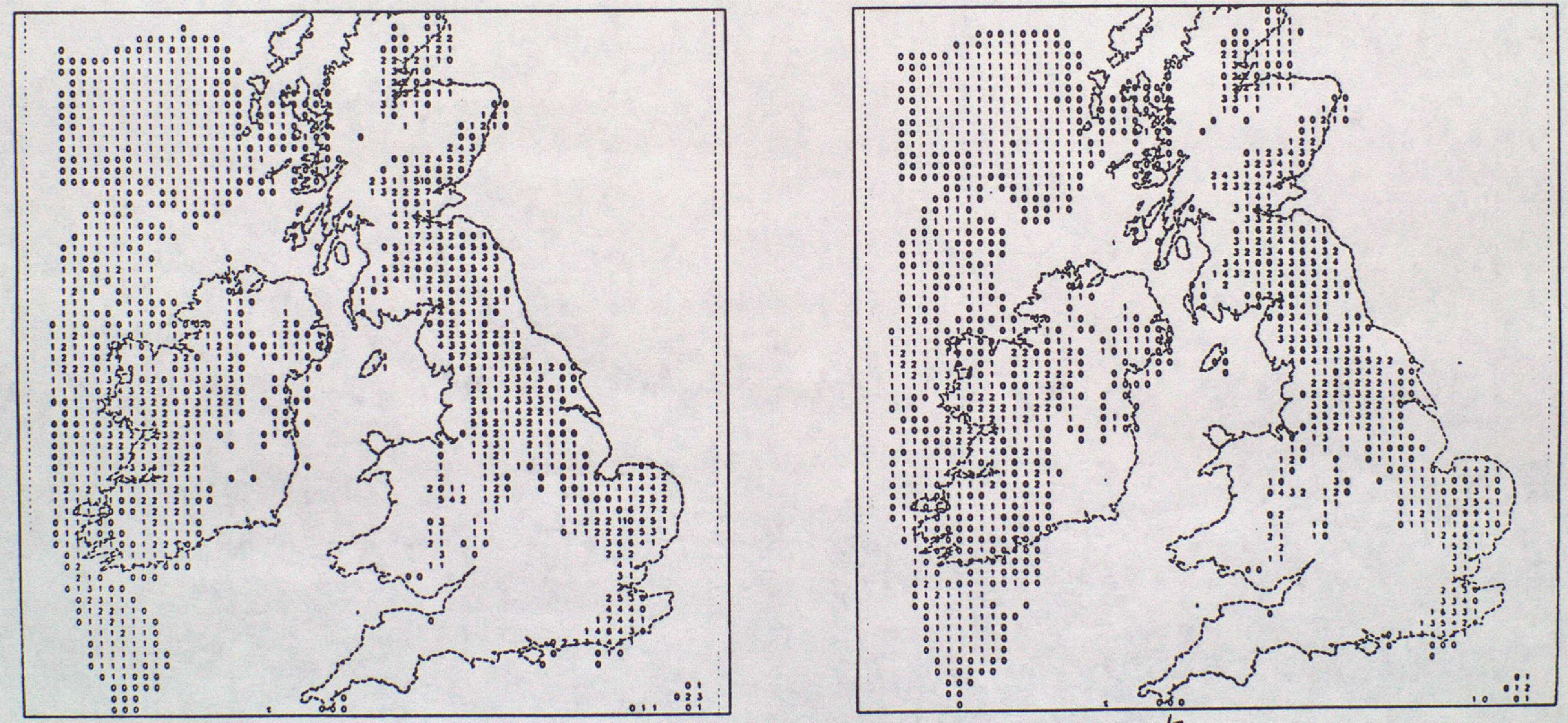
FIGURE 5. D.T 00 GMT 13/06/87 VT 18 GMT 13/06/87

a) 6-HOUR ACCUMULATION (12GMT-18GMT) - CONTROL

b) 6-HOUR ACCUMULATION (12GMT-18GMT) - TRIAL

DT 0000Z 13/06/1987 VT 1800Z 13/06/1987 CONTROL PRAC

DT 0000Z 13/06/1987 VT 1800Z 13/06/1987 TRIAL PRAC



a

b

6 HOURS OBSERVED ACCUMULATED PRECIPITATION (MM).
FROM 12Z 13/6/87 TO 18Z 13/6/87

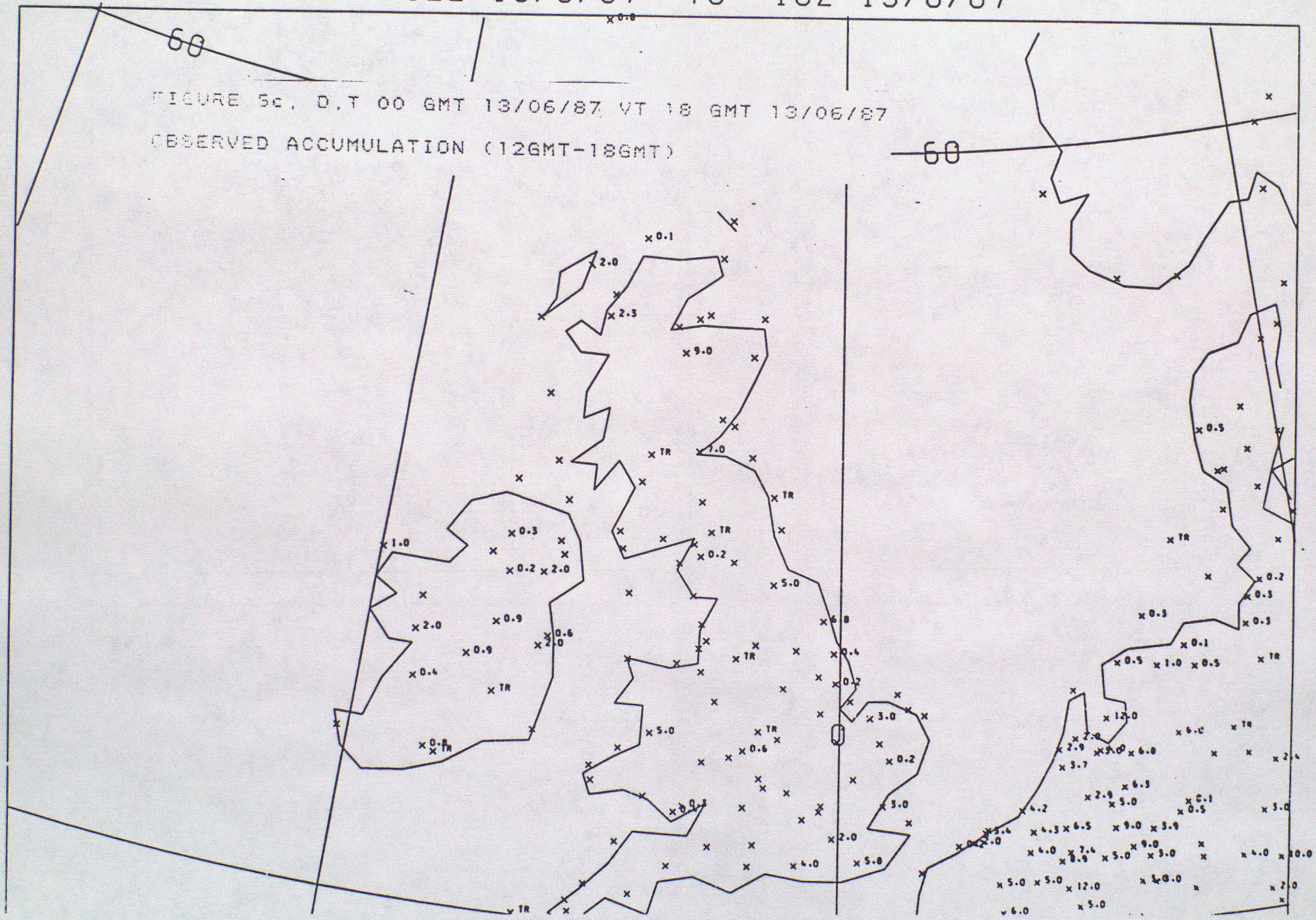
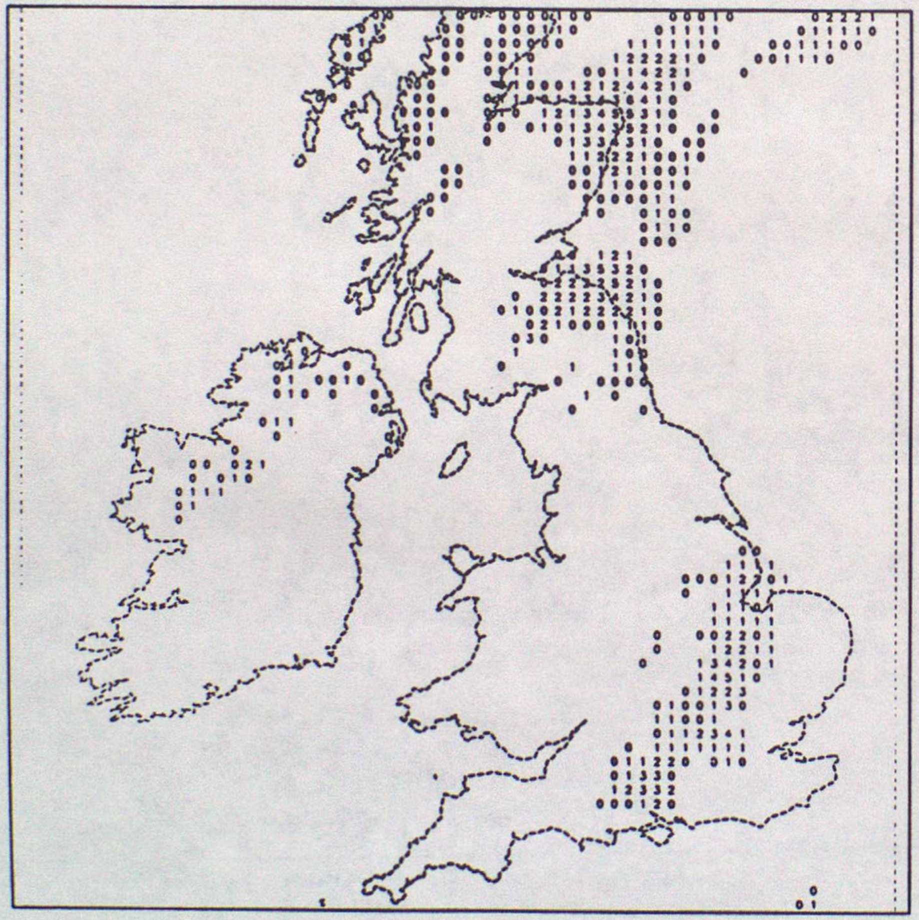


FIGURE 6. D.T 00 GMT 06/07/87 VT 18 GMT 06/07/87

a) 6-HOUR ACCUMULATION (12GMT-18GMT) - CONTROL

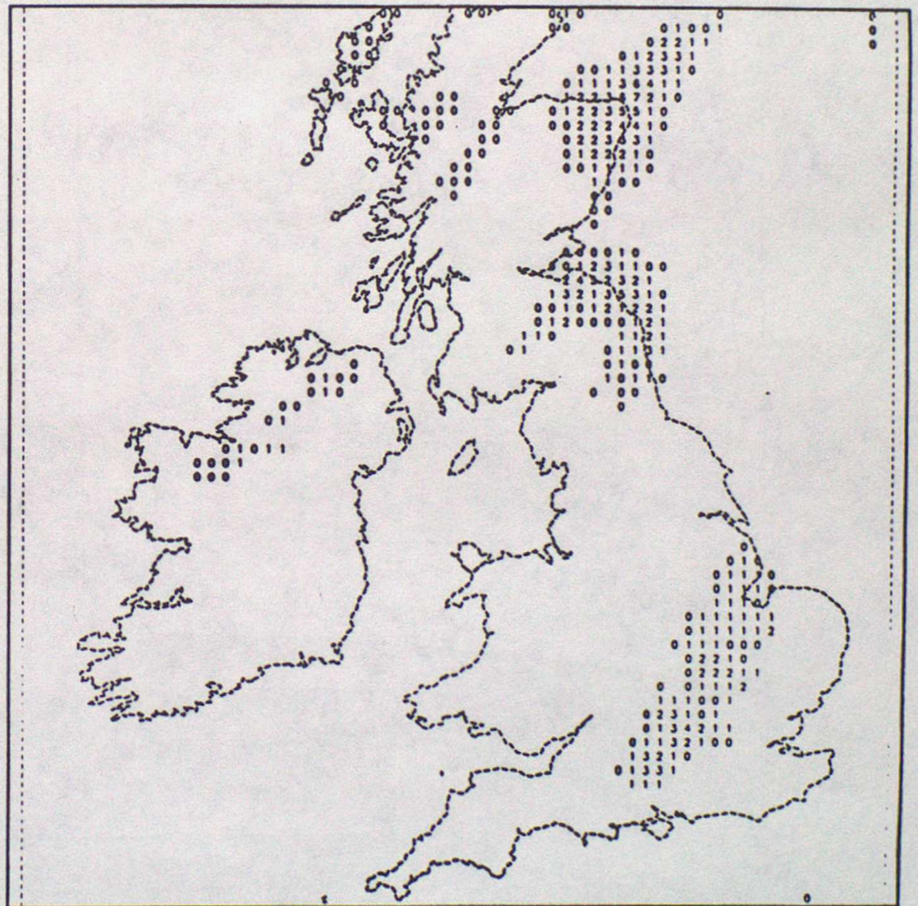
b) 6-HOUR ACCUMULATION (12GMT-18GMT) - TRIAL

DT 0000Z 06/07/1987 VT 1800Z 06/07/1987 CONTROL PRAC



a

DT 0000Z 06/07/1987 VT 1800Z 06/07/1987 TRIAL PRAC



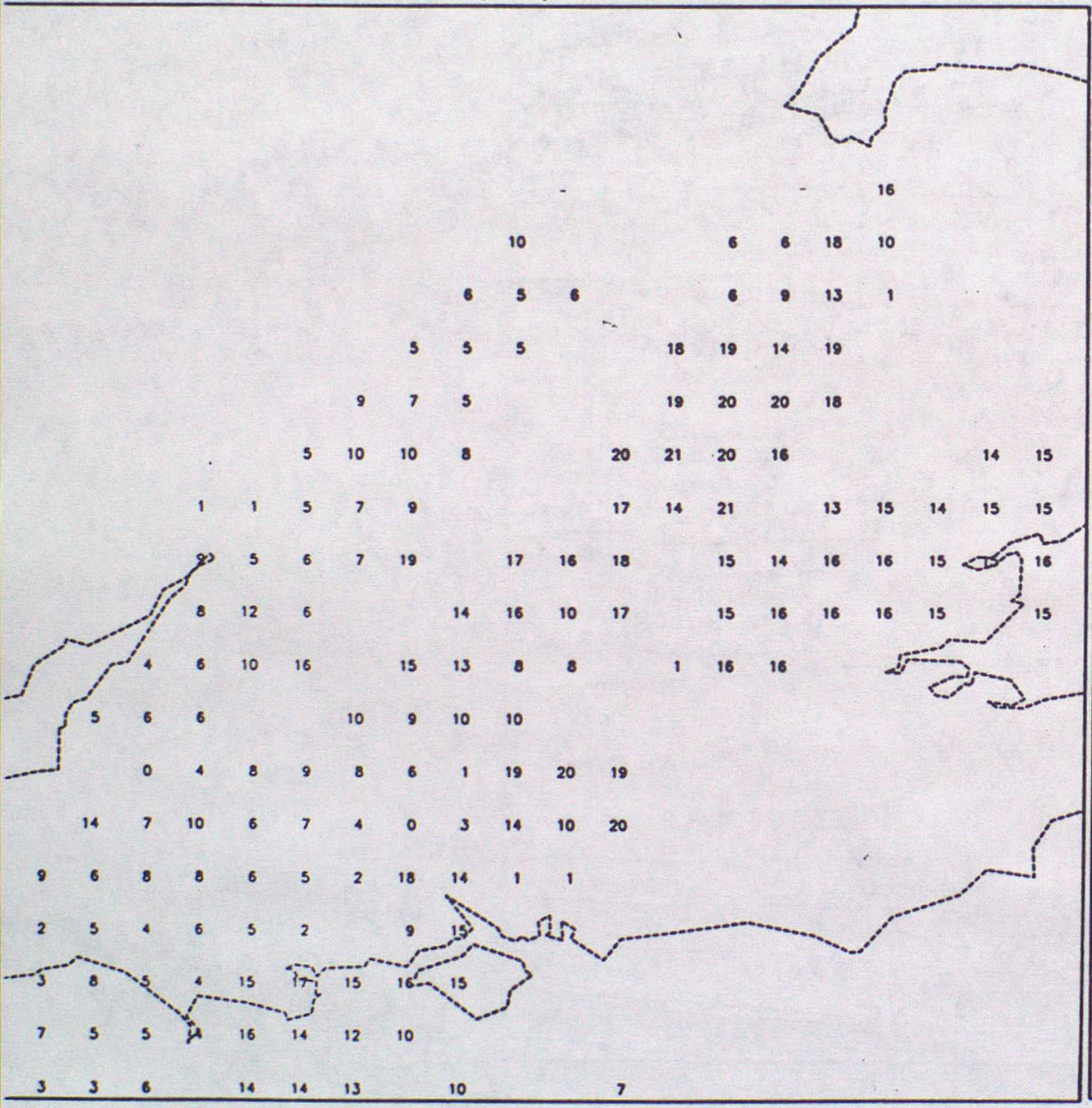
b

[redacted]

a) LOCAL CONVECTIVE RATE (mm/hr) - CONTROL VERSION

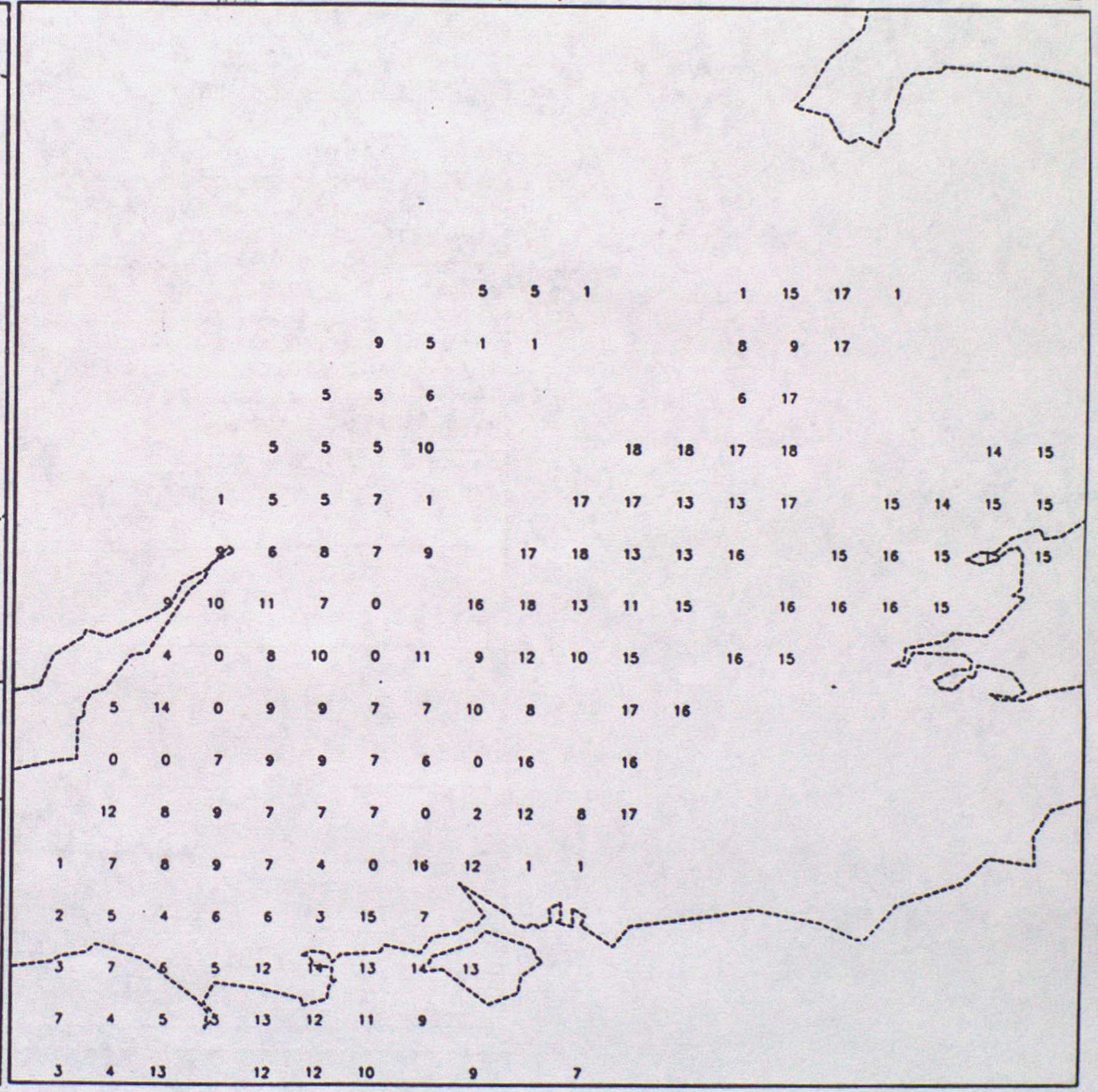
b) LOCAL CONVECTIVE RATE (mm/hr) - TRIAL VERSION

VT 2100Z 15/10/1987 CONTROL PR CONVECTIVE



a

VT 2100Z 15/10/1987 TRIAL PR CONVECTIVE



b

FIGURE 8. D.T 12 GMT 15/10/87 VT 21 GMT 15/10/87

c) CROSS-SECTION ACROSS SOUTHEAST ENGLAND, SHOWING CONVECTIVE CLOUD DEPTH (C), CLOUD WATER (M), RELATIVE HUMIDITY (RH), AND POTENTIAL TEMPERATURE (PO.T).

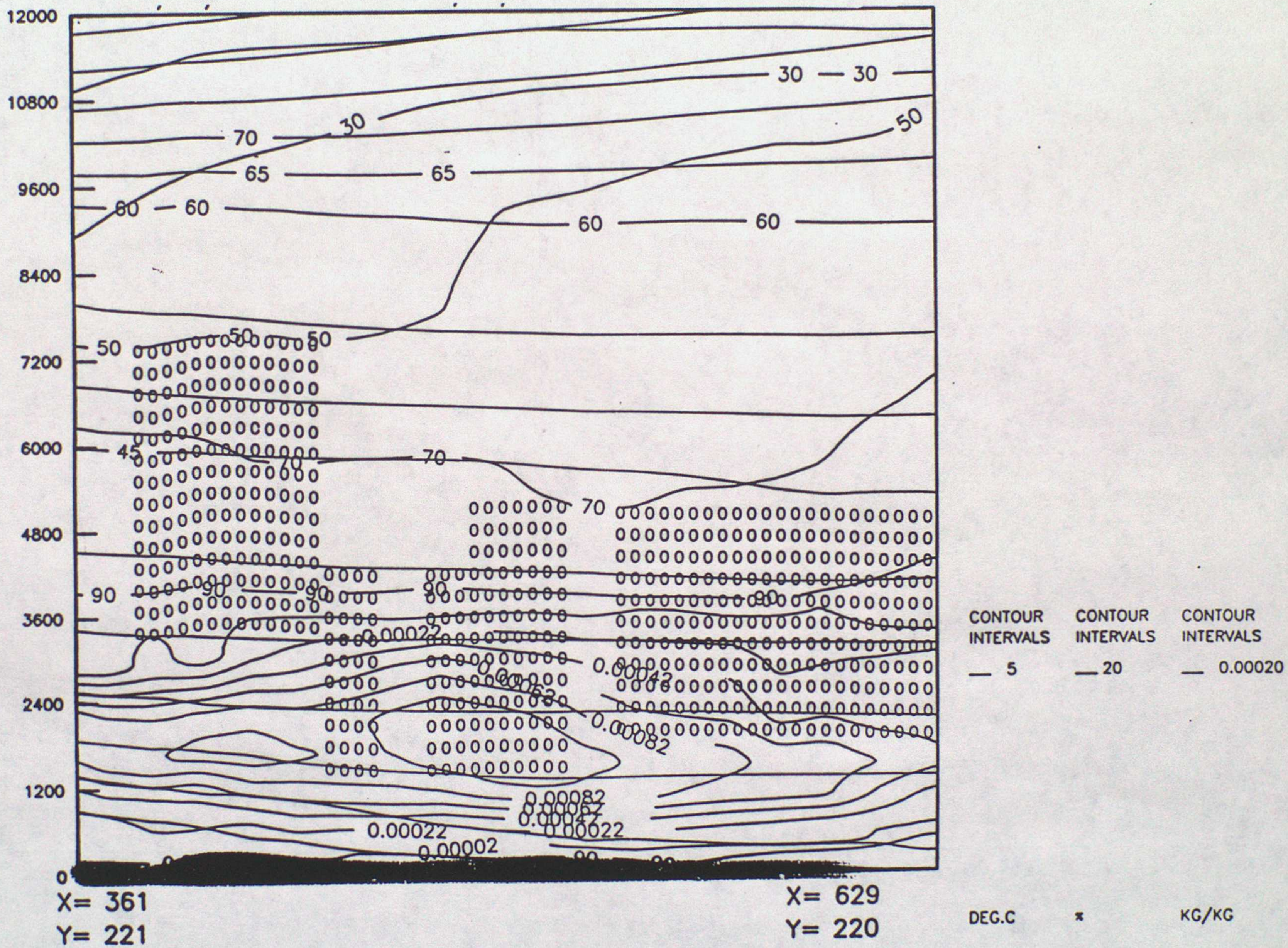


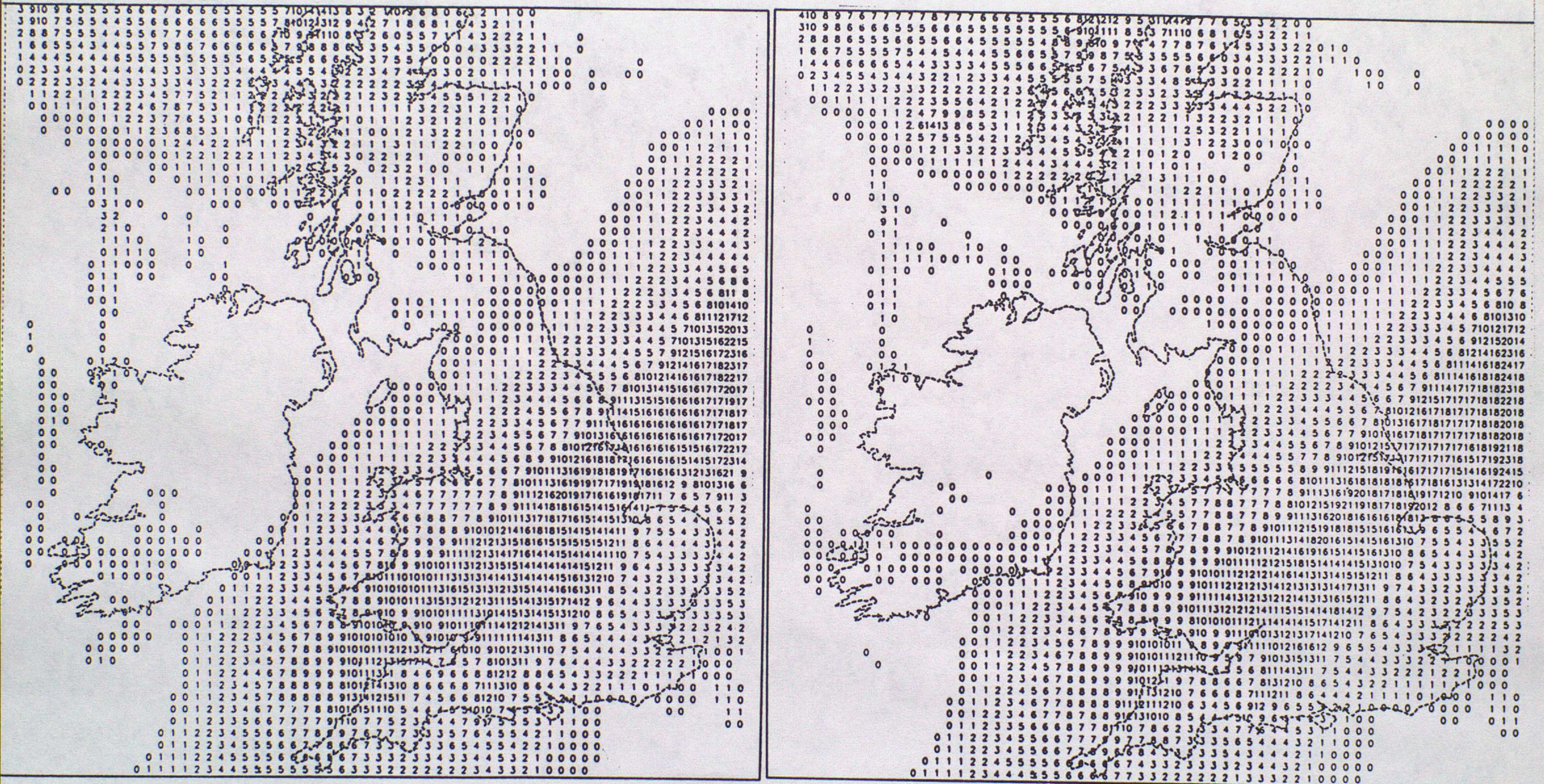
FIGURE 9. D.T 12 GMT 15/10/87 VT 21 GMT 15/10/87

a) 6-HOUR ACCUMULATION (18GMT-24GMT) - CONTROL

b) 6-HOUR ACCUMULATION (18GMT-24GMT) - TRIAL

VT 0000Z 16/10/1987 CONTROL PRAC

VT 0000Z 16/10/1987 TRIAL PRAC



a

b

FIGURE 10. 12 GMT 11/11/87

RADAR PICTURE FOR 12 GMT 11/11/87

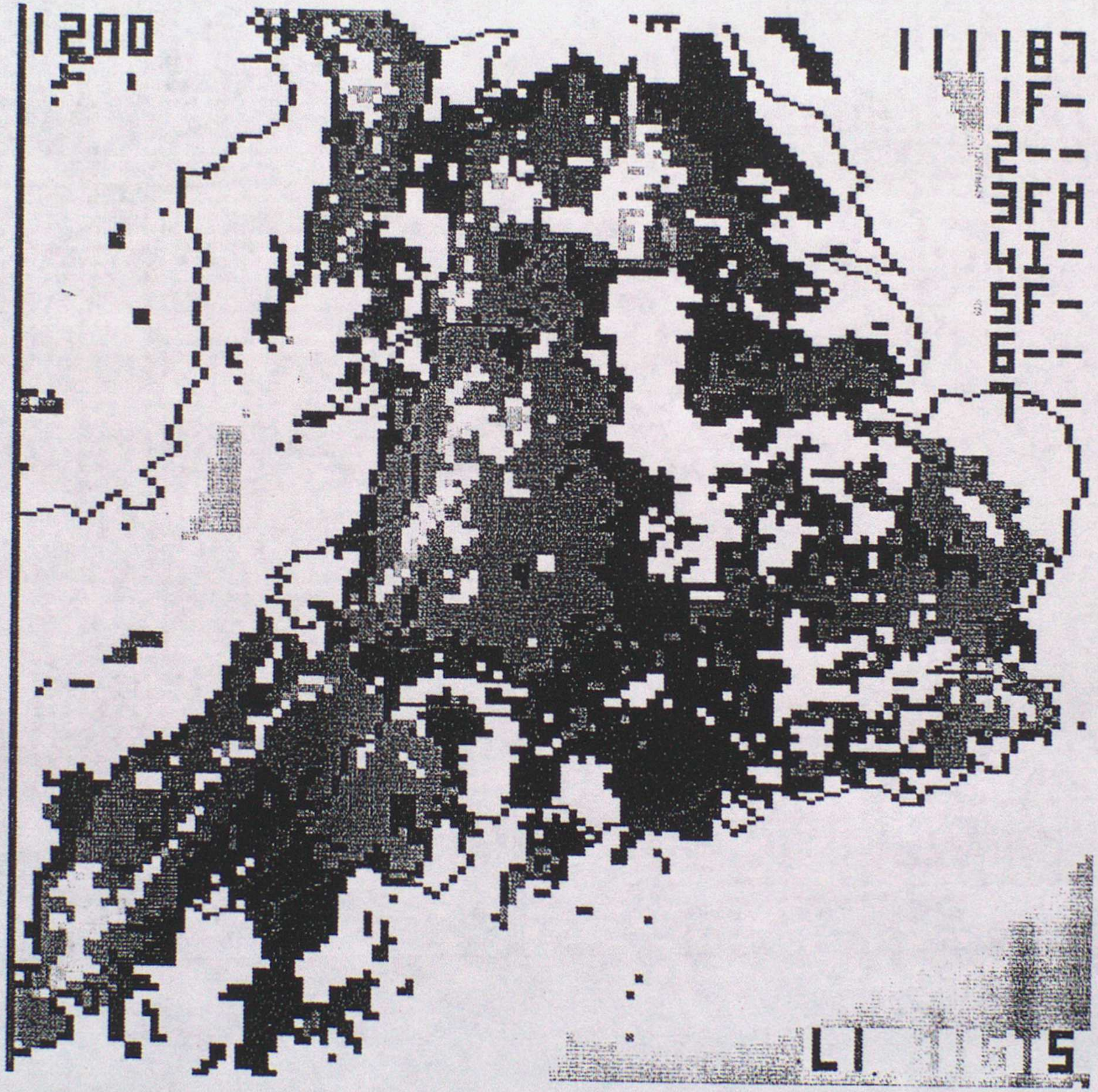


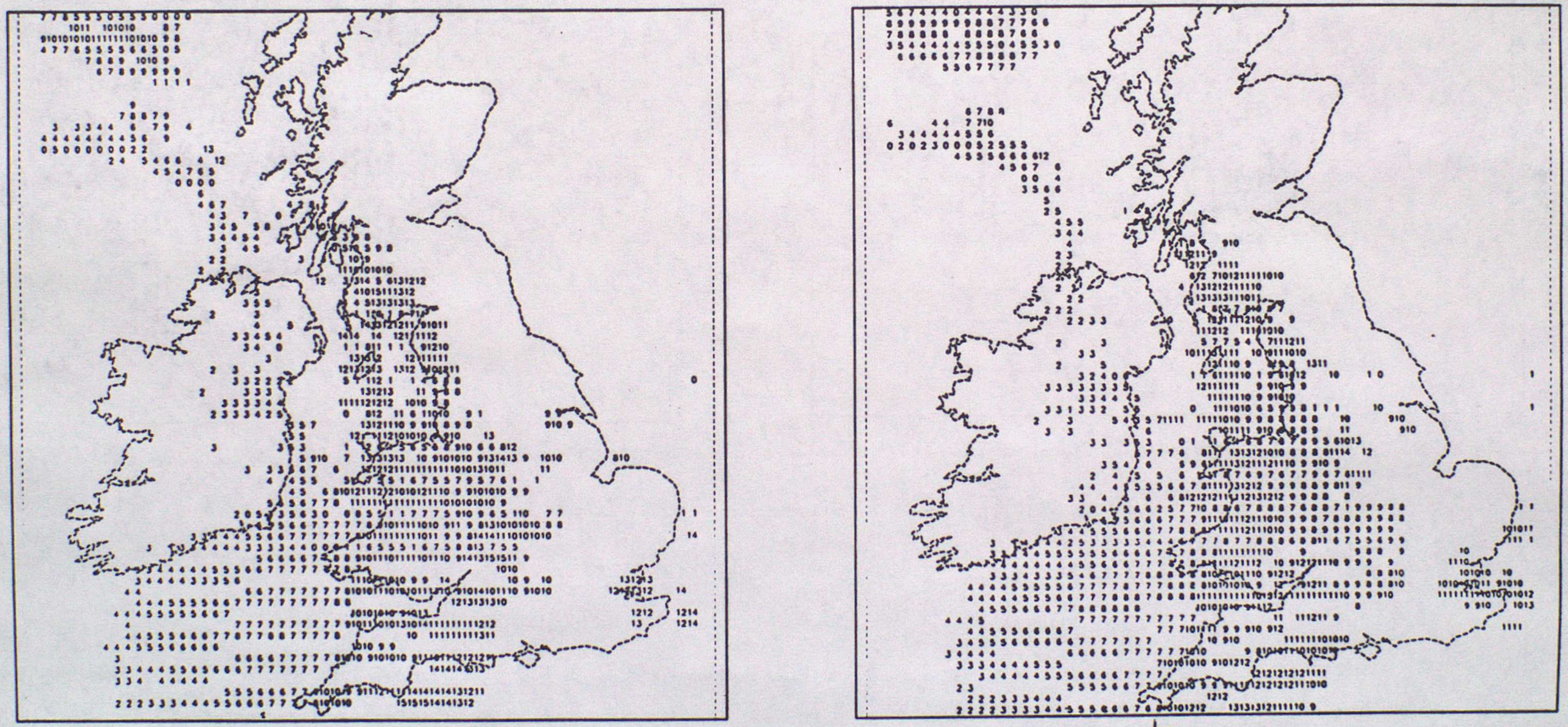
FIGURE 11. D.T 00 GMT 11/11/87 VT 12 GMT 11/11/87

a) LOCAL CONVECTIVE RATE (mm/hr) - CONTROL VERSION

b) LOCAL CONVECTIVE RATE (mm/hr) - TRIAL VERSION

DT 0000Z 11/11/1987 VT 1200Z 11/11/1987 CONTROL PR CONVECTIVE

DT 0000Z 11/11/1987 VT 1200Z 11/11/1987 TRIAL PR CONVECTIVE



a b

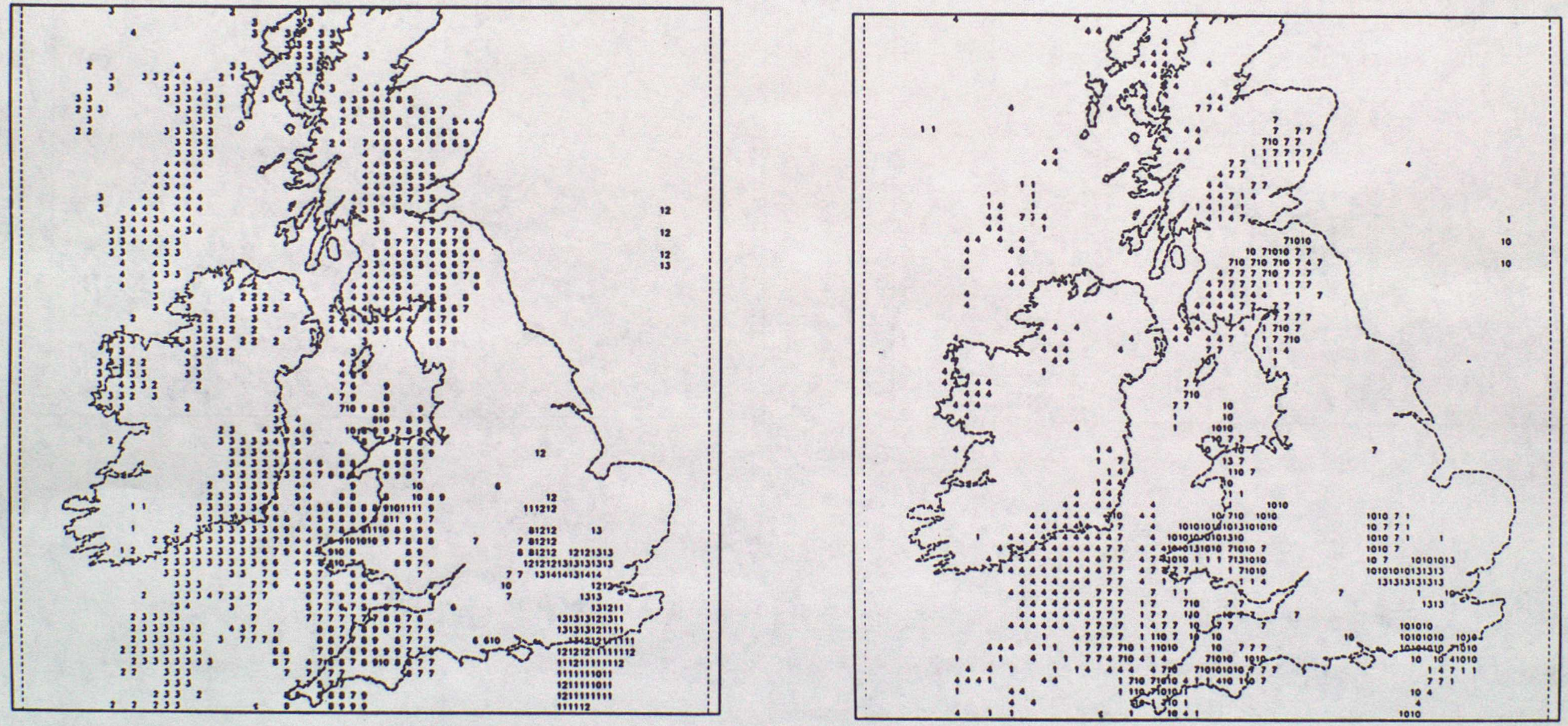
FIGURE 12. D.T 12 GMT 13/01/88 VT 15 GMT 13/01/88

a) LOCAL CONVECTIVE RATE (mm/hr) - CONTROL VERSION

b) LOCAL CONVECTIVE RATE (mm/hr) - TRIAL VERSION

DT 1200Z 13/01/1988 VT 1500Z 13/01/1988 MSFC. PR CONVECTIVE

DT 1200Z 13/01/1988 VT 1500Z 13/01/1988 TRCON PR CONVECTIVE



a

b

FIGURE 13. 15 GMT 13/01/88

RADAR PICTURE FOR 15 GMT 13/01/88

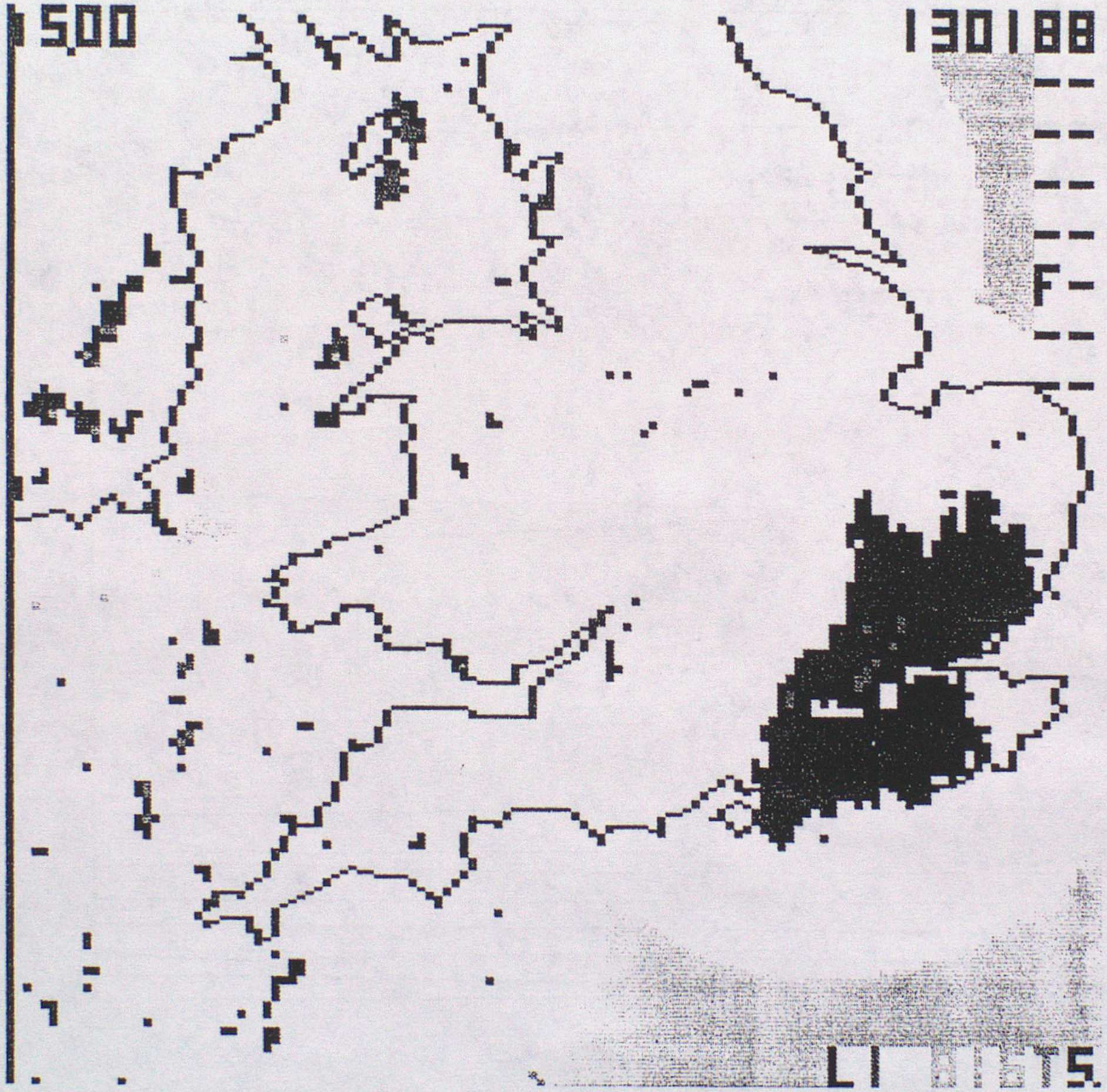


FIGURE 14. D.T 12 GMT 13/01/88 VT 15 GMT 13/01/88

CROSS-SECTION ACROSS SOUTHEAST ENGLAND, SHOWING CONVECTIVE CLOUD DEPTH (C), CLOUD WATER (M), RELATIVE HUMIDITY (RH), AND POTENTIAL TEMPERATURE (PO.T).

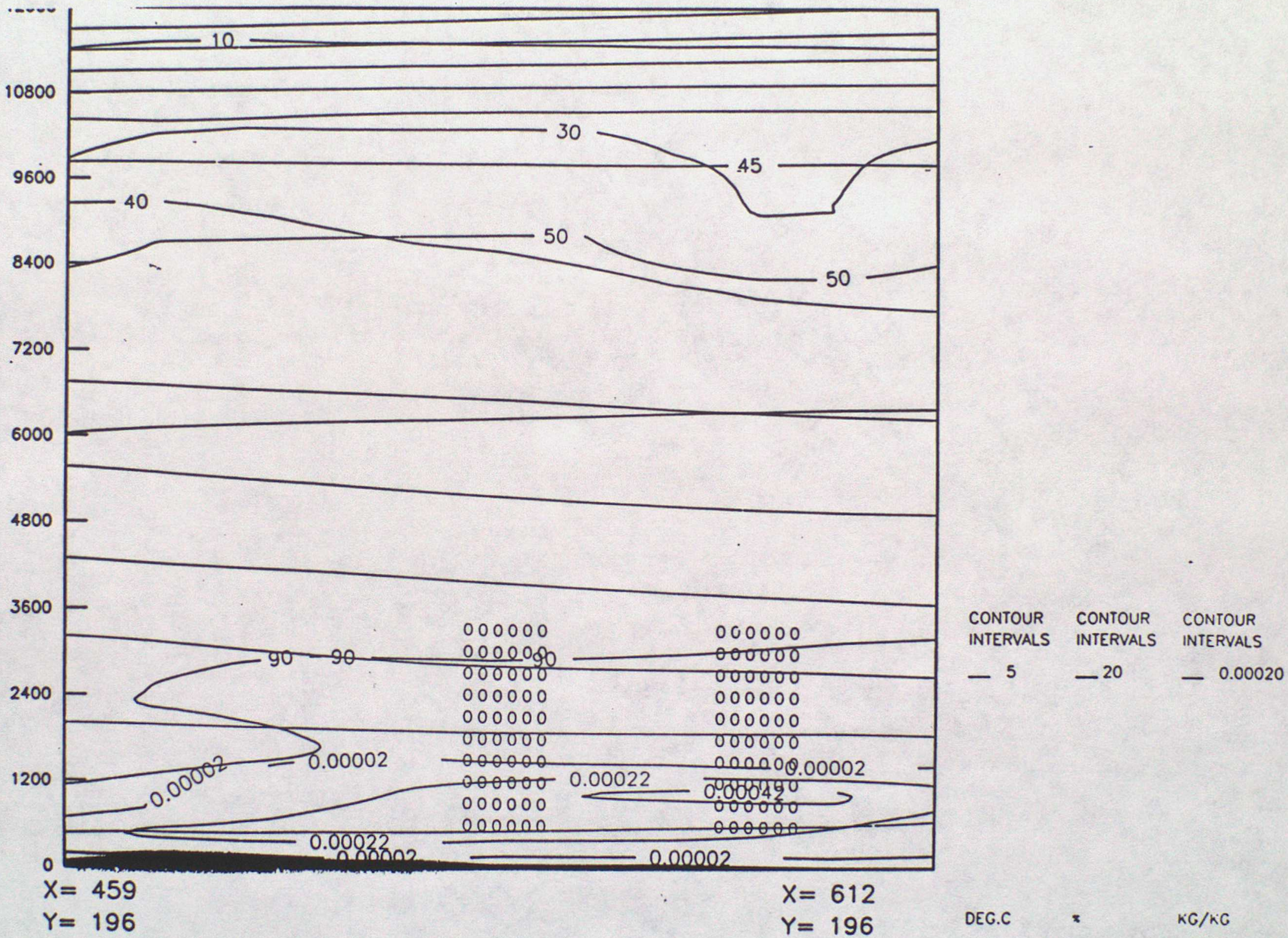


FIGURE 15. D.T 12 GMT 13/01/88 VT 15 GMT 13/01/88

TEPHIGRAM FROM A GRID_POINT OVER SOUTH-EAST ENGLANDGIVING A CONVECTIVE RATE OF 10-13 mm/hr.

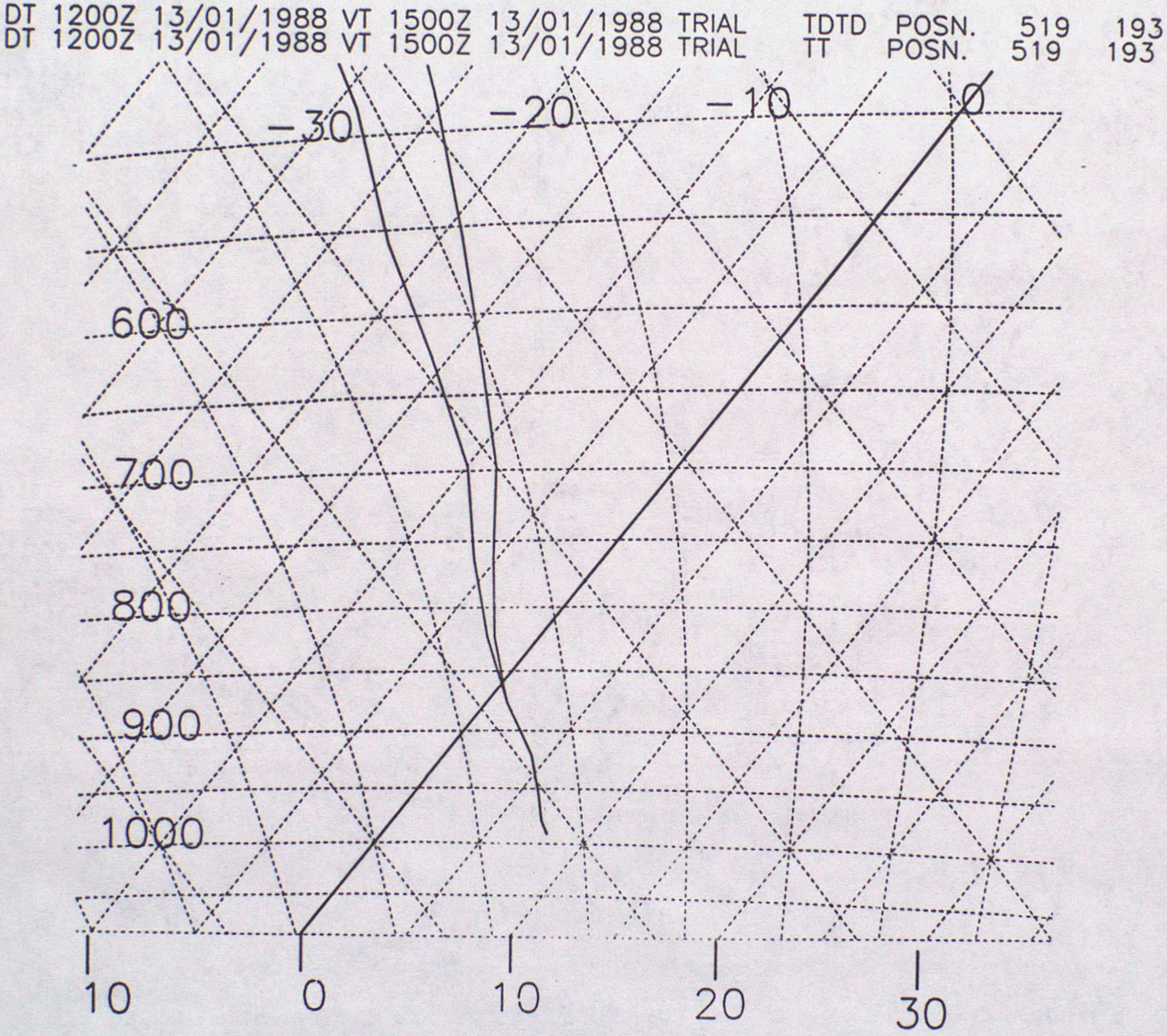
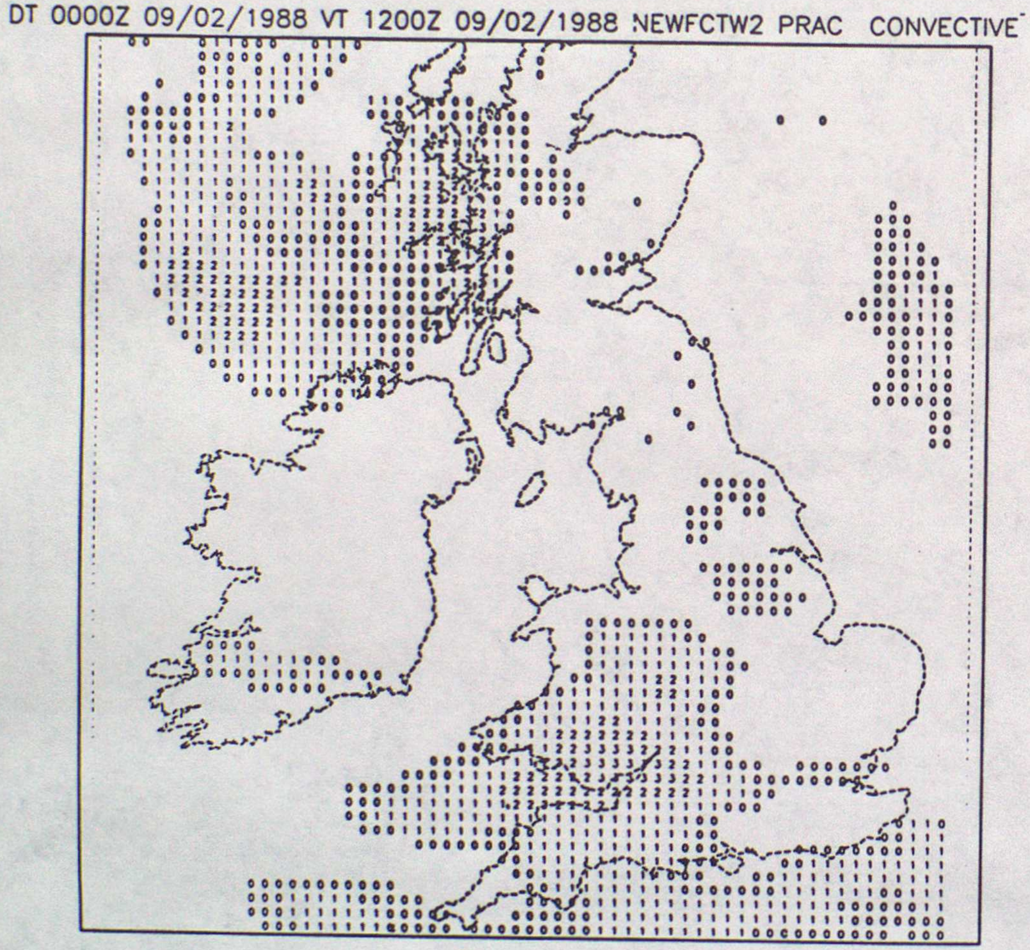


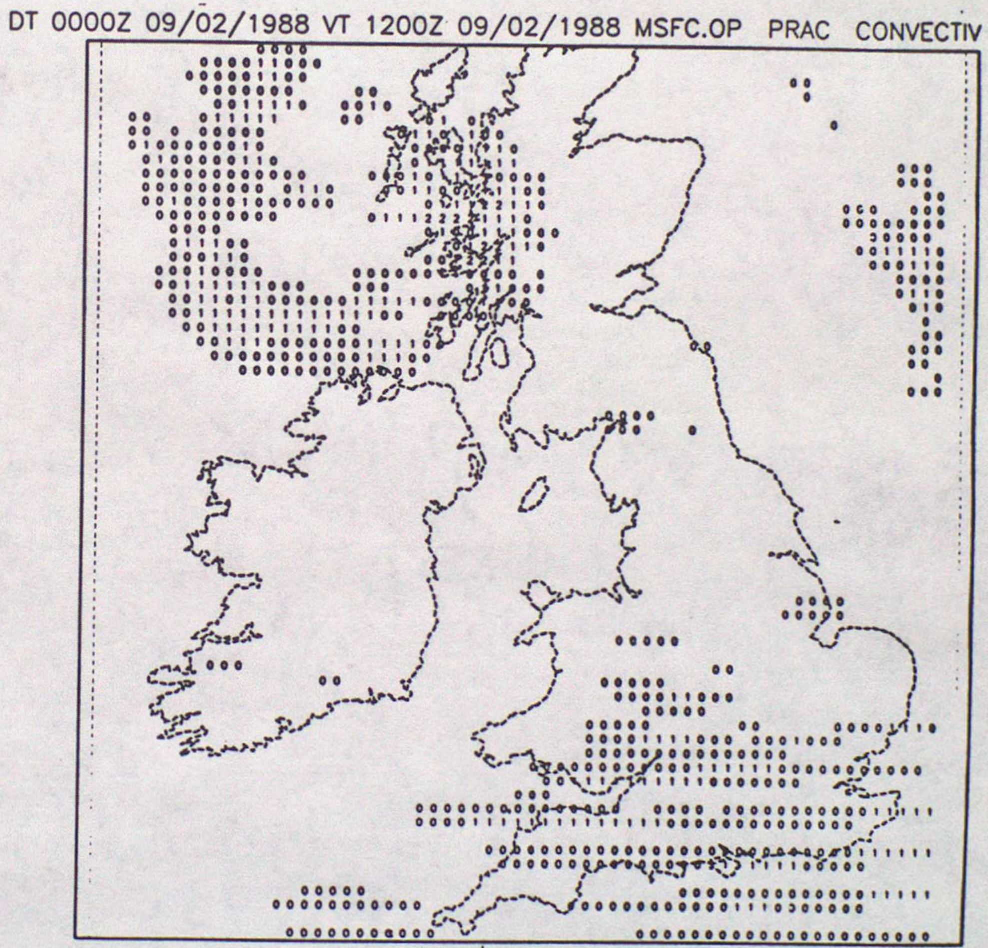
FIGURE 16. D.T 00 GMT 09/02/88 VT 12 GMT 09/02/88

a) LOCAL CONVECTIVE RATE (mm/hr) - TRIAL VERSION

b) LOCAL CONVECTIVE RATE (mm/hr) - CONTROL VERSION



a



b

FIGURE 17. 12 GMT 09/02/88

RADAR PICTURE FOR 12 GMT 09/02/88

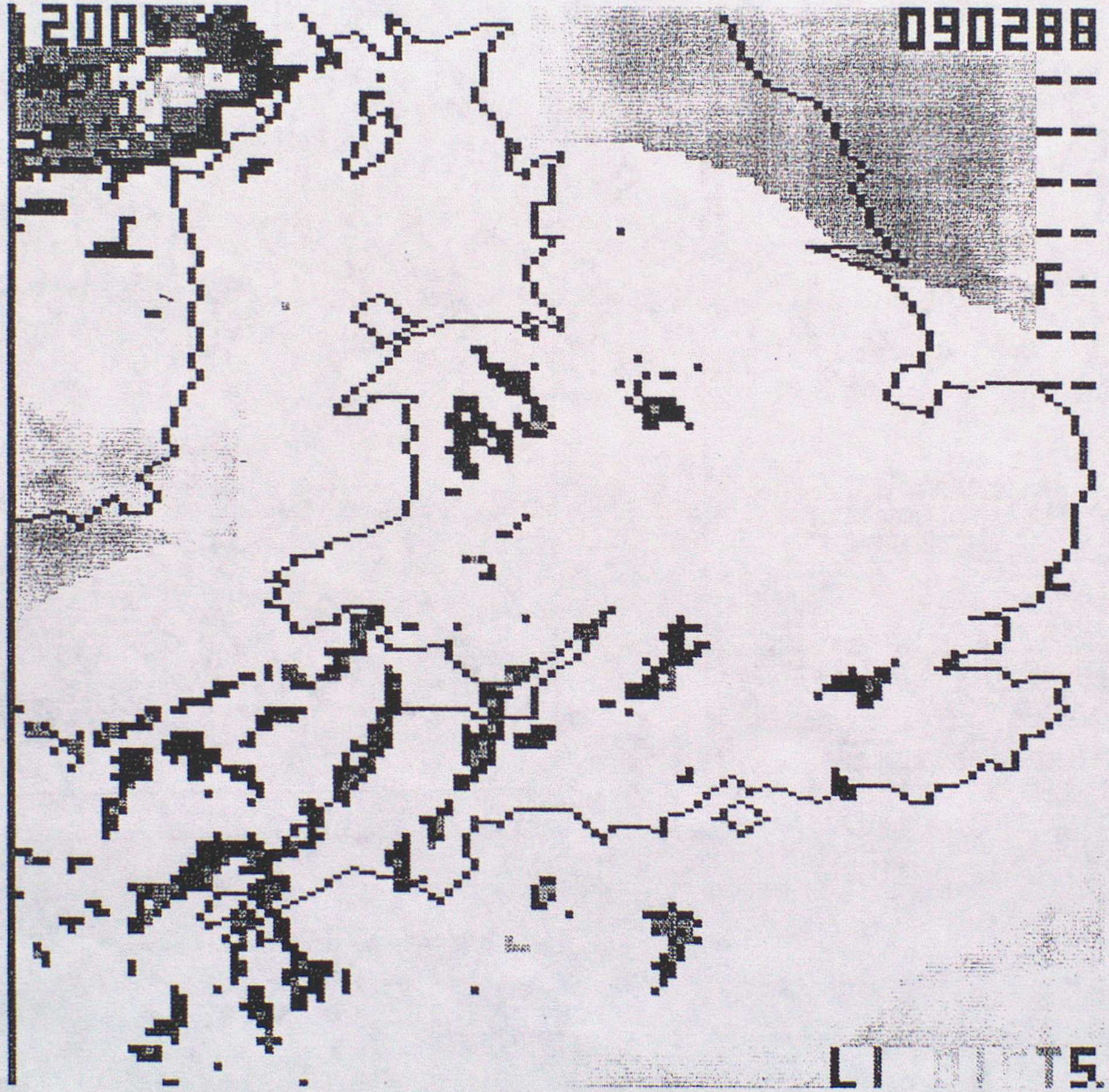
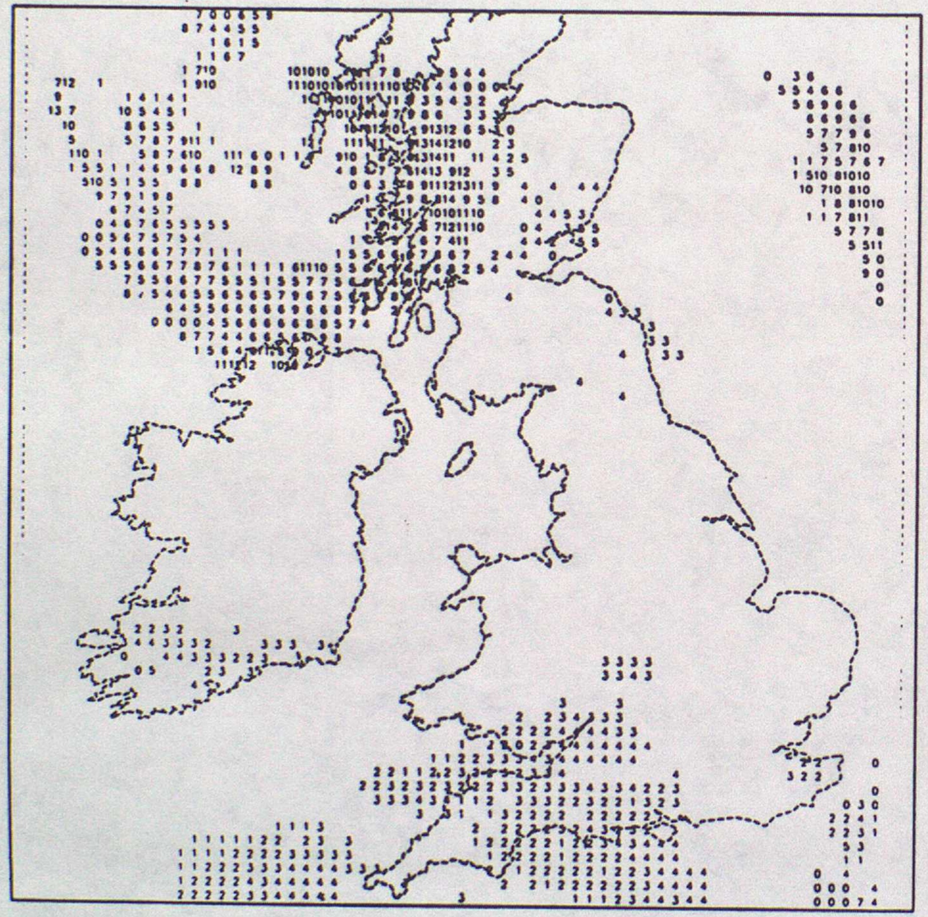


FIGURE 18 D.T 00 GMT 09/02/88 VT 12 GMT 09/02/88

a) LOCAL CONVECTIVE RATE VT 12GMT - TRIAL

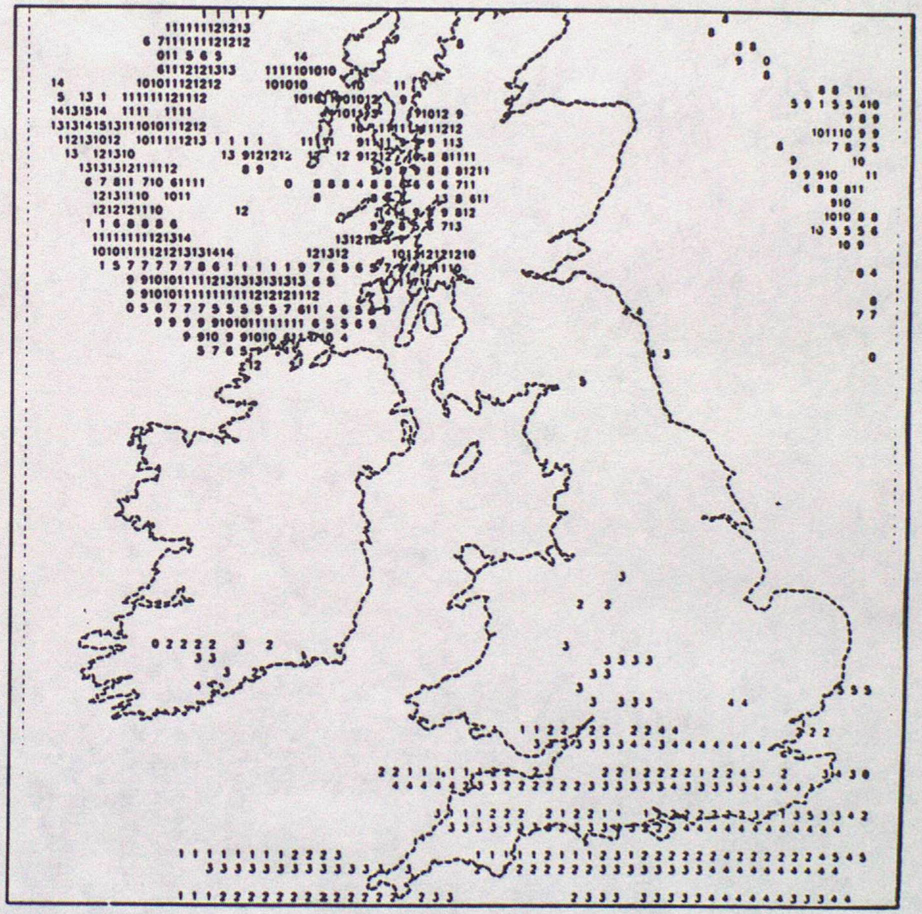
b) LOCAL CONVECTIVE RATE VT 12GMT - CONTROL

DT 0000Z 09/02/1988 VT 1200Z 09/02/1988 NEWFCTW2 PR CONVECTIVE



a

DT 0000Z 09/02/1988 VT 1200Z 09/02/1988 MSFC.OP PR CONVECTIVI



b