

DUPLICATE ALSO

871



Forecasting Research

Met O 11 Technical Note No. 7

**An Assessment of the Impact of a Correction to the
Mesoscale Model Turbulence/Vertical Diffusion Scheme
Implemented in March 1988**

by

S.P. Ballard and O.M. Hammon

April 1988

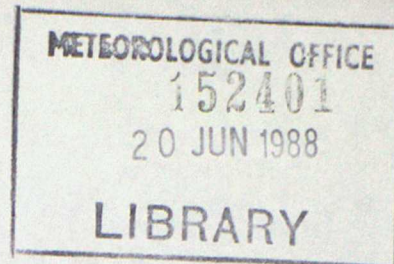
ORGS UKMO M

Met Office (Met O 11)
London Road, National Meteorological Library
FitzRoy Road, Exeter, Devon. EX1 3PB 12 2SZ, England

FH2A

DUPLICATE ALSO

Met O 11 Technical Note No 7



An Assessment of the Impact of a Correction to the Mesoscale Model
Turbulence/Vertical Diffusion Scheme Implemented in March 1988

S. P. Ballard and O. M. Hammon

April 1988

LONDON, METEOROLOGICAL OFFICE.
Met.O.11 Technical Note (New Series) No.7

An assessment of the impact of a correction to
the mesoscale model turbulence/vertical diffusion
scheme implemented in March 1988.

07550688

FH2A

Meteorological Office (Met O 11)
London Road
Bracknell
Berkshire
United Kingdom

NB This paper has not been published. Permission to quote from it must be obtained from the Assistant Director of the above Meteorological Office Branch.

1. Introduction

On March 9th 1988 an error was corrected in the calculation of the static stability parameter N^2 used in the determination of the vertical diffusion coefficients and turbulent kinetic energy in the mesoscale model turbulent diffusion scheme. The error had been present since the second phase of the operational trials began in 1985 and had the effect that the model diagnosed the forecast atmospheric profiles to be more stable in the presence of cloud than they actually were. Thus vertical mixing was erroneously suppressed.

The main impact of the correction is to raise the predicted cloud bases by about 1 to 2 model levels and to slightly alter the distribution of cloud free areas. This is particularly important when stratocumulus cloud cover is observed associated with a surface anticyclone. Statistics from the operational trial have shown that prior to the March change the model had a tendency to predict cloud bases too frequently at model levels 1 to 3 and not frequently enough at model levels 5 and 6 (see table 1) so that this correction should improve that aspect of the forecasts.

Table 1. Percentages of significant low cloud (3 octas or more) observed and forecast at t+18. v.t. 06z October- December 1987

model level height m		2 110	3 310	4 610	5 1010	6 1510	total
Oct	observed	13	12	12	13	8	58
	mesoscale f/c	31	18	15	5	1	69
Nov	observed	11	15	20	12	11	70
	mesoscale f/c	28	19	15	7	1	71
Dec	observed	13	20	14	13	7	67
	mesoscale f/c	25	26	15	4	2	72

The correction is described in section 2, some case studies in section 3 and a summary of the impact of the change is given in section 4.

2. Description of Turbulence scheme and the correction

The turbulence scheme used in the mesoscale model is described in detail in Documentation Paper No 9 and only a brief outline will be given here.

The basic equations used in the mesoscale model turbulence scheme can be expressed as

$$D\theta_L/Dt = -\partial(\overline{w'\theta_L'})/\partial z + F_{\theta_L}$$

$$Dq_t/Dt = -\partial(\overline{w'q_t'})/\partial z + F_{q_t}$$

$$Dv_H/Dt = -\partial(\overline{w'v_H'})/\partial z + F_{v_H}$$

where $\theta_L = \theta - Lm/(c_p\pi)$ = liquid water potential temperature

$q_t = q + m$ = total water content

$\pi = (P/1000)^\kappa$ = Exner function

$\kappa = R/c_p$

v_H = horizontal wind components

and F_{θ_L} , F_{q_t} and F_{v_H} contain the remaining terms in the equations

The turbulence scheme 1 1/2 order closure assumptions give

$$\overline{w'\theta_L'} = -K_r \partial\theta_L/\partial z$$

$$\overline{w'q_t'} = -K_r \partial q_t/\partial z$$

$$\overline{w'v_H'} = -K_m \partial v_H/\partial z$$

where $K_r = c_o^{-1/3} L_r E^{1/2}$

$K_m = c_o^{-1/3} L_m E^{1/2}$

with the stability dependent mixing length $L_r = \text{fn}(E, N^2, S^2, L^2)$

and $L_m = L_r \text{fn}(E, L^2, N^2)$.

The length scale L is determined by $1/L = 1/kz + 1/\lambda$ where $k=0.4$ is Von Karman's constant, $\lambda=h(z)/3$ and $h(z)$ is the depth of the local turbulent layer dependent on the predicted turbulent kinetic energy E .

S^2 is the shear stability parameter $= (\partial u/\partial z)^2 + (\partial v/\partial z)^2$

N^2 is the static stability parameter given by

$$N^2 = \bar{\beta}_T \partial\theta_L/\partial z + \bar{\beta}_w \partial q_t/\partial z$$

where $\bar{\beta}_T = \beta_T - \bar{a}_L \bar{b}_L c_r \beta_L$

and $\bar{\beta}_w = \beta_w + \bar{a}_L c_r \beta_L$

with $\beta_T = g/\theta$, $\beta_w = 0.608g/(1+0.608q-m)$

and $\beta_L = L\beta_T/(c_p\pi) - \beta_w/\eta$

c_r is the cloud fraction.

$\eta = 0.378$

$\bar{a}_L = 1.0/(1.0 + L\alpha_L/c_p)$

$\bar{b}_L = \alpha_L \pi$

$\alpha_L = (0.622Lq_m(T_L)P)/(RT_L^2(P-0.378e_m(T_L)))$

The error that needed correcting was in the calculation of $\tilde{\beta}_w$ where before March 9th 1988

$$\tilde{\beta}_w = \beta_w - \bar{a}_L c_r \beta_L$$

was used in the mesoscale model.

The impact of the error on N^2 , turbulent kinetic energy and the vertical mixing coefficients K_r and K_m for a stratocumulus cloud layer has been examined using a 1 dimensional version of the turbulence scheme. Tables 2 and 3 show the initial values of the variables for the correct and erroneous versions respectively. It can be seen that the correct values of N^2 are more unstable, that larger values of turbulent kinetic energy, K_r and K_m are obtained and that the significant values extend one level higher than in the erroneous version. The equivalent table for a profile with the cloud water removed is shown in table 4 where it can be seen that the increased values of θ_L where the cloud has been removed at levels 4 and 5 and the removal of the β_L terms result in an even shallower boundary layer.

Table 2. Initial values of static stability parameter N^2 , turbulent kinetic energy and vertical mixing coefficients for the correct version

Boundary layer depth from θ_L profile = 1048m

Boundary layer depth from initialised turbulent kinetic energy = 1010m

level	height m	θ_L deg C	q_t g/kg	c_r octa	N^2 s^{-2}	E $m^2 s^{-2}$	K_r $m^2 s^{-1}$	K_m $m^2 s^{-1}$
					1.8×10^{-4}			
7	2010	19.23	1.87	0	3.0×10^{-4}	0.0001	<1	<1
6	1510	13.76	2.59	0	1.6×10^{-4}	0.0001	<1	<1
5	1010	10.73	5.24	8.0	-5.8×10^{-5}	34	2370	1350
4	610	10.62	5.93	3.5	-2.6×10^{-5}	0.8	284	158
3	310	10.55	5.94	0	-1.0×10^{-5}	1	185	102
2	110	10.55	5.94	0	-4.3×10^{-5}	0.4	42	23
1	10	10.64	5.96	0	-4.0×10^{-3}	0.3	0.3	0.3

Table 3. Initial values of static stability parameter N^2 , turbulent kinetic energy and vertical mixing coefficients for the wrong version

Boundary layer depth from θ_L profile = 1048m

Boundary layer depth from initialised turbulent kinetic energy = 610m

level	height m	θ_L deg C	q_t g/kg	c_r octa	N^2 s^{-2}	E $m^2 s^{-2}$	K_r $m^2 s^{-1}$	K_m $m^2 s^{-1}$
7	2010	19.23	1.87	0	1.8×10^{-4}			
6	1510	13.76	2.59	0	3.0×10^{-4}	0.0001	<1	<1
5	1010	10.73	5.24	8.0	2.3×10^{-4}	0.0001	<1	<1
4	610	10.62	5.93	3.5	3.7×10^{-5}	0.0001	<1	<1
3	310	10.55	5.94	0	-2.1×10^{-6}	0.6	120	77
2	110	10.55	5.94	0	-1.0×10^{-5}	1	109	67
1	10	10.64	5.96	0	-4.3×10^{-5}	0.4	34	19
					-4.0×10^{-3}	0.3	0.3	0.3

Table 4. Initial values of static stability parameter N^2 , turbulent kinetic energy and vertical mixing coefficients for profile with cloud water removed

Boundary layer depth from θ_L profile = 716m

Boundary layer depth from initialised turbulent kinetic energy = 310m

level	height m	θ_L deg C	q_t g/kg	c_r octa	N^2 s^{-2}	E $m^2 s^{-2}$	K_r $m^2 s^{-1}$	K_m $m^2 s^{-1}$
7	2010	19.23	1.87	0	1.8×10^{-4}			
6	1510	13.76	2.59	0	3.0×10^{-4}	0.0001	<1	<1
5	1010	11.37	4.99	0	1.5×10^{-4}	0.0001	<1	<1
4	610	10.67	5.91	0	5.0×10^{-5}	0.0001	<1	<1
3	310	10.55	5.94	0	3.5×10^{-6}	0.02	0.01	0.01
2	110	10.55	5.94	0	-1.0×10^{-5}	0.6	60	39
1	10	10.64	5.96	0	-4.3×10^{-5}	0.4	24	15
					-4.0×10^{-3}	0.3	0.3	0.3

3. Case Studies

Comparison forecasts have been run on 7 cases

00Z	21/02/88	- anticyclonic stratocumulus
12Z	27/09/87	- anticyclonic stratocumulus
12Z	4/11/87	- anticyclonic stratocumulus
12Z	15/10/87	- October storm, frontal precipitation, strong winds
12Z	29/02/88	- convection in cold northerly airstream
00Z	06/07/87	- summer convection
18Z	21/06/86	- thundery trough

Since the description of the stratocumulus cases concentrates on charts of low cloud cover bases and amounts the 'N.H' code used in those charts is explained here.

N = total cover of cloud below 6500 ft / 2000m in octas
H = subset of WMO code for cloud base

The assigned H code is determined from the lowest model level with greater than or equal to 3 octas of cloud cover. The H codes and their WMO meaning are given in Table 5. Also given are the model level, its height in feet and associated model layer thickness which are used to forecast a given H code.

Table 5. Low cloud base H code

H code H	Meaning cloud base ft	Derivation in the Mesoscale model	
		cloud at model level(ht ft)	cloud in model layer range in ft
1	< 300	1 (33)	0 - 197
3	< 1000	2 (361)	197 - 689
4	< 2000	3 (1017)	689 - 1509
5	< 3000	4 (2001)	1509 - 2657
6	< 5000	5 (3314)	2657 - 4134
7	> 5000	6 (4954)	4134 - 5938
blank	< 3/8 of low cloud		

In the descriptions of the case studies various versions of the model are compared and are referred to as the November 1987, February 1988 and March 1988 versions. The November 1987 version was the operational trial version after the changes described in Hammon (1987) were implemented in the model. The February 1988 version was the operational trial version after the changes to the convection scheme described in Hammon (1988) were implemented in the model. The March 1988 version is the current operational trial version implemented on March 9th 1988 including the correction to the turbulence scheme described in section 2.

a) Stratocumulus case 00z 21/2/88

On this occasion an anticyclone was centred over England. The forecast from the operational trial was criticised for too many breaks in the low cloud cover in south and central England and not enough clearance in north east England and east Scotland by late afternoon behind a weak cold front, see the operational trial forecast (February 1988 version) for 18z in figure 1(a) compared with the observations in figure 2. There was also concern about the amount of predicted low cloud reaching the ground as fog (code 81 in the 'N.H' chart). This last criticism has been a noticeable feature of most mesoscale forecasts of stratocumulus, the bases are generally too low and reach the ground over too wide an area. As can be seen from figure 1(b) the corrected version of the model (March 1988 version) produces a better forecast of the broken cloud cover in north east England and Scotland. There are also improvements to the distribution of cloud cover in England and Wales but neither forecast has the clearance in south east and north west England. In general the cloud bases are one to two model levels higher but in the areas of northern England and Scotland that previously had fog the base has lifted by up to 3 levels. The change in predicted cloud bases is summarised in table 6

Table 6. Observed and Predicted cloud bases for 18Z(T+18) 21/2/88

Area	Observed 100s ft	February 1988 version 100s ft	March 1988 version 100s ft
Ireland	35 - 44	7 - 26	26 - 41
E. England	28 - 56	15 - 41 mainly 15 - 26	41 - 59
S.W. England	15 - 45	0 - 7	15 - 41
Scotland	20 - 40	0 - 15	15 - 41

The change in forecast cloud base and the improved verification is illustrated in table 7 where the forecast has been interpolated to observing stations with cloud base recorders.

Table 7. Percentages of significant cloud (3 octas or more) observed and forecast for stations with cloud base recorders at t+18 v.t. 18z 21/2/88

level	110	310	610	1010	1510	high	none
observed	0.0	2.9	5.9	44.1	14.7	32.4	0.01
Feb. 1988 version	5.9	14.7	47.1	5.9	0.0	11.8	14.7
March 1988 version	0.0	2.9	2.9	35.3	32.4	20.6	5.9

Figure 3 illustrates the effect of the correction on cross-sections and tephigrams in the area of reported stratocumulus in the Southern Uplands behind the cold front at 18z. The line of the cross-section AB is shown in figure 3(c) and the location of the tephigrams is also marked as point C. From figure 3(a) we can see that in the February 1988 version of the model the cloud top was also depressed on the eastward facing, lee side, of the mountain ranges as was the level of maximum cloud water mixing ratio. From

figure 3(d) we see that the cloud base and top and value and level of maximum cloud water mixing ratio is far more uniform in the corrected March 1988 version. The tephigrams are also improved by the correction as can be seen by comparison of figures 3(b) and 3(d).

b) Other Stratocumulus cases

The impact on the other stratocumulus cases was essentially the same as described above. Cloud bases were correctly raised by 1 to 2 levels in many areas, there were slightly changed areas of cloud clearance and a reduction in the size of areas of cloud with bases erroneously down to the surface.

As part of the routine verification of the mesoscale model operational trial nine February 1988 forecasts were rerun using the corrected March 1988 version of the model in order to study the impact of the correction. These forecasts were from a period of settled anticyclonic weather with associated stratocumulus from 12z 17/2/88 to 00z 22/2/88 and of the 9 forecasts rerun, which included the 21/2/88 forecast discussed above, 5 were forecasts starting at 12z and the rest started at 00z. The change in forecast cloud base and the improved verification for 18 hour forecasts is illustrated in tables 8 and 9 where the forecasts have been interpolated to observing stations with cloud base recorders.

Table 8. Percentages of significant cloud (3 octas or more) observed and forecast for stations with cloud base recorders at t+18 v.t. 06z

level	110	310	610	1010	1510	total % low
observed	2	4	19	39	14	79
Feb. 1988 version	38	30	14	9	1	92
March 1988 version	9	23	17	20	8	77

Table 9. Percentages of significant cloud (3 octas or more) observed and forecast for stations with cloud base recorders at t+18 v.t. 18z

level	110	310	610	1010	1510	total % low
observed	1	8	33	37	11	90
Feb. 1988 version	17	28	35	7	1	88
March 1988 version	8	15	27	23	17	90

It can be seen from Tables 8 and 9 that the forecasts of low cloud bases have been greatly improved by the correction but there are still too many occasions with bases below 610m and not enough with bases above 610m. It is possible that some of the remaining error may be the result of differences between the station heights and the model's orography.

The change does not correct gross evolution errors such as those in the 12z 4/11/87 forecast. For this case the forecast was not rerun with the February 1988 version of the model and comparisons are made between the November 1987 and March 1988 versions. Convection was not important on this occasion so the comparison is valid. The advection of boundary conditions from the fine-mesh in easterly/south easterly winds removed the stratocumulus from the south east corner of the mesoscale model area and too

much cloud was forecast in northern England, Wales and southern Scotland in both forecasts as can be seen by comparing figure 4 and figure 5 (a) and (b). However the cloud base has been correctly raised over the Irish Sea and Ireland in the March 1988 version as is also shown by the reduction of fog in the cloud covered area in figures 5(d) compared with figure 5(c).

There is very little impact from the change on forecasts of radiation fog. This is illustrated in figures 5(c) and 5(d) where there is little difference in the area of radiation fog forecast in the erroneous region of clear sky in England.

c) Convection and frontal cases

The change has a slight impact on the distribution of frontal and convective rain. There are slight variations in the amount of convection in given areas and a reduction in the amount of fog associated with areas of precipitation. Again bases of low cloud are raised in general and the distribution is slightly altered. The impact of the change on individual forecasts is described below.

c.1) October Storm 12z 15/10/87

At 12GMT on 15th October 1987 a system of complex lows was situated to the North West of Corunna with very strong pressure gradients on the south-eastern flank and ahead of a trailing cold front. From this system a storm developed and moved north eastwards across England from south of Plymouth to Humberside between 00Z and 06Z on 16/10/87 with very strong winds, gusting to hurricane force, in a belt to the south, east and west of the storm centre.

The mesoscale forecasts described here were run from a test finemesh analysis produced using the trial analysis correction scheme and without a separate mesoscale analysis. This finemesh analysis produced the best finemesh forecast of the storm from the 12z 15/10/87 data time. However the forecast evolution is still not perfect and the position of the low was forecast too far north before 06z 16/10/87. The forecast was run using the February 1988 and March 1988 versions of the mesoscale model. The forecasts were essentially the same as the finemesh forecast in the timing of the passage of the storm centre.

We are just concerned with the impact of the mesoscale model change on the precipitation and low cloud. From figures 6(a), and 6(b) we can see that at T+18 there is less fog over the Highlands and the fog ahead of the front over the North Sea has been removed in the corrected forecast. The distribution of the convection differs between the two forecasts but neither verify well as can be seen by comparison with figure 7(a) where the observed distribution of precipitation has been outlined. In fact the forecast for 03z produces a better verification as can be seen from figure 7(b). From figures 6(c) and 6(d) we can see that the cloud base has been raised by 1 to 2 model levels in most areas. Figures 8(a) and (b) show the 3 hour accumulations between 03z and 06z of convective and dynamic precipitation respectively for the erroneous version of the model and figures 8(c) and 8(d) the same for the corrected version. In general in the corrected forecast the convective accumulations have decreased and the dynamic accumulations have increased in some of the areas of reduced convective accumulations.

c.2) Thundery trough 18z 21/6/86

A thundery trough moved northwards from a line between the south west tip of Ireland and south west England into southern England during the night. There was heavy rain and thunderstorms in the trough in the early night but these died out by the morning. The night turned cloudy over much of England, Wales and Northern Ireland with only the south west clear.

The forecasts from the March 1988 and November 1987 versions ran to completion whereas the forecast from the February 1988 version failed. Thus direct comparisons cannot be made of the effect on the convection. However, as the February 1988 model change was principally to the convection scheme, comparisons with the November 1987 version allows the impact on the low cloud cover over the rest of the British Isles to be studied. From Figures 9 (a) and (b) compared with the observations for 06z 22/6/86 in figure 10 we can see that where stratus is observed the corrected version of the model does still forecast stratus. the base is too low in both forecasts but this is probably a result of poor vertical resolution. The corrected forecast has also correctly lifted the cloud base in the Irish Sea.

c.3) Summer Convection 00z 6/7/87

A weak cold front with no marked precipitation moved southwards from a line through central Scotland and south west Ireland at 00z to between north east England and North Wales by 18z. Scotland and Ireland were cloudy with some bright areas in the east whereas most parts of England and Wales were sunny. Parts of southern England turned more cloudy in the afternoon and evening and there were a few evening showers. It was generally hot and many places were quite humid.

Forecasts from the February 1988 and March 1988 versions both produced more showers than were observed. There were slight differences in the number of showers and timings in the old and new versions but they were produced in the same areas. Both forecasts had an area of convection in a line from Southampton to the Wash between 12z and 18z, present at 12z in the new version but not until later in the old version. They also forecast showers in Northern Ireland in a southwest to north east strip at 12z with most gone by 15z, no showers were reported in the areas at 12z, 15z or 18z. There was a slight difference in the forecast maximum temperatures at 15z, the new version forecast 30 as opposed to 31 in the old version. The maximum observed temperature was 28. The areas of maximum temperature in London and southern England were correct in both forecasts. The major impact of the change on this case was to remove the line of single gridpoints of fog produced around the west coasts of Ireland, Scotland and Wales and the south coast of England in the February 1988 version as can be seen in the comparison of figures 11 (a) and (b) with figure 12. This line of fog was probably erroneous as none of the surface observations reported fog.

c.4) Cold northerly airstream 12z 29/2/88

A cold front lay in a north west to south east orientation through Ireland and during the early hours of the night of 30/2/88 a wave on the front brought an area of rain, sleet and snow southeastwards over south Wales and south west England. Snow fell mainly on the high ground where some places had an inch or more. Elsewhere it was a mostly clear frosty night with wintry showers on north facing coasts and hills.

The mesoscale forecast was run using the February 1988 and March 1988 versions of the model.

In the area of convection over the North sea there were more breaks in the coverage of low cloud in the corrected forecast and the cloud fractions were generally less than in the February 1988 forecast. The cloud bases seem to have more horizontal variability in the corrected run and some are raised and some lowered as can be seen from figure 13. This is difficult to verify as there are no surface observations over the sea. Although the corrected version predicted lower bases (H code 4) of cloud greater than 3 octas than the February 1988 version (H code 5) at 00z and 03z in East Anglia , as can be seen for 03z in figures 13 a) and b), neither version predicted the low bases of between 200 to 300 ft observed during the snow and hail showers around the Wash and in East Anglia , see figure 14. This is still the case even if all cloud with greater than 0.8 octas is included as can be seen from figures 13 c) and d) . This may be due to limitations of the convective parametrization which is dominant in this region. The formulation of the convection scheme in the model which uses a minimum cloud base of model level 4 , only evaporates precipitation below cloud base into model level 1 and does not have a full treatment of mixed phases of water. At 03z the distribution of low cloud along the east coast of England is better in the corrected forecast as can be seen by comparison of figures 13 and 14. Cloud bases were raised by at least one level in the corrected forecast in the area of the cold front as can be seen in figure 13. The cloud bases in the February 1988 version were too low. The low cloud on the eastern edge of the cloud associated with the cold front wave did not spread far enough eastwards in the corrected forecast at 18z, 21z, 03z and 06z and the forecast from the February 1988 version was better at those times. However at 00z the eastward extent of the low cloud in south west England was better in the corrected version, the cloud in the February 1988 version was too far east . From figure 13 we can see that , although the eastward extent of the cloud was slightly better in the February 1988 forecast, the March 1988 version has a better indication of the breaks in the cloud cover. Throughout the period of the forecast the convective and grid scale precipitation over the North Sea and in the cold front was more evenly spread in the corrected forecast as can be seen from the maps of accumulated precipitation in figure 15. The accumulations are also greater on and off the east coast of England and in the cold front in the corrected forecast. This is due to increases in both the grid scale and convective precipitation. These differences have not been verified due to the lack of observations. An important aspect of this forecast was the prediction of the sleet and snow fall in the south west of England. From figures 15 (a) and (b) we can see that the corrected forecast predicts far less precipitation in this region in the 3 hours before midnight. From the areas of observed precipitation in figure 16(a) , extracted from the hourly surface observations, it appears that neither forecast is exactly right. The precipitation has spread too far eastwards before midnight in the February 1988 forecast but not far enough eastwards in the corrected forecast. However in the 3 hours after midnight the distribution of accumulated precipitation in the corrected forecast is slightly better than in the February 1988 forecast as can be seen by comparing figures 15 (c) and (d) with figure 16 (b). Verification over central Wales is not possible due to the lack of observations.

4. Conclusions

The March 1988 correction to the turbulence scheme has improved the forecast of cloud base in all the situations tested. However the change does

not correct gross evolution errors in low cloud cover such as those due to advection of poor finemesh boundary conditions into the mesoscale model area. Remaining errors in predicted cloud bases are likely to be partly due to poor vertical resolution. There is an indication that the edges of low cloud cover may be eroded too much in the corrected version of the model. The change reduces the over prediction of fog associated with low cloud and in one case removed spurious fog forecast around the coastlines. There is very little impact on forecasts of radiation fog.

Preliminary results from the monthly verification of the mesoscale model trial indicate an improvement in the forecasting of minimum temperature since the correction was implemented on March 9th 1988. Previously there was a positive bias in the forecasts due to the overprediction of low cloud cover at night.

There are changes to the distribution of precipitation and the relative proportions of dynamic and convective precipitation. However this study does not cover enough cases to enable conclusions to be made. This should be possible to study in the monthly verification figures.

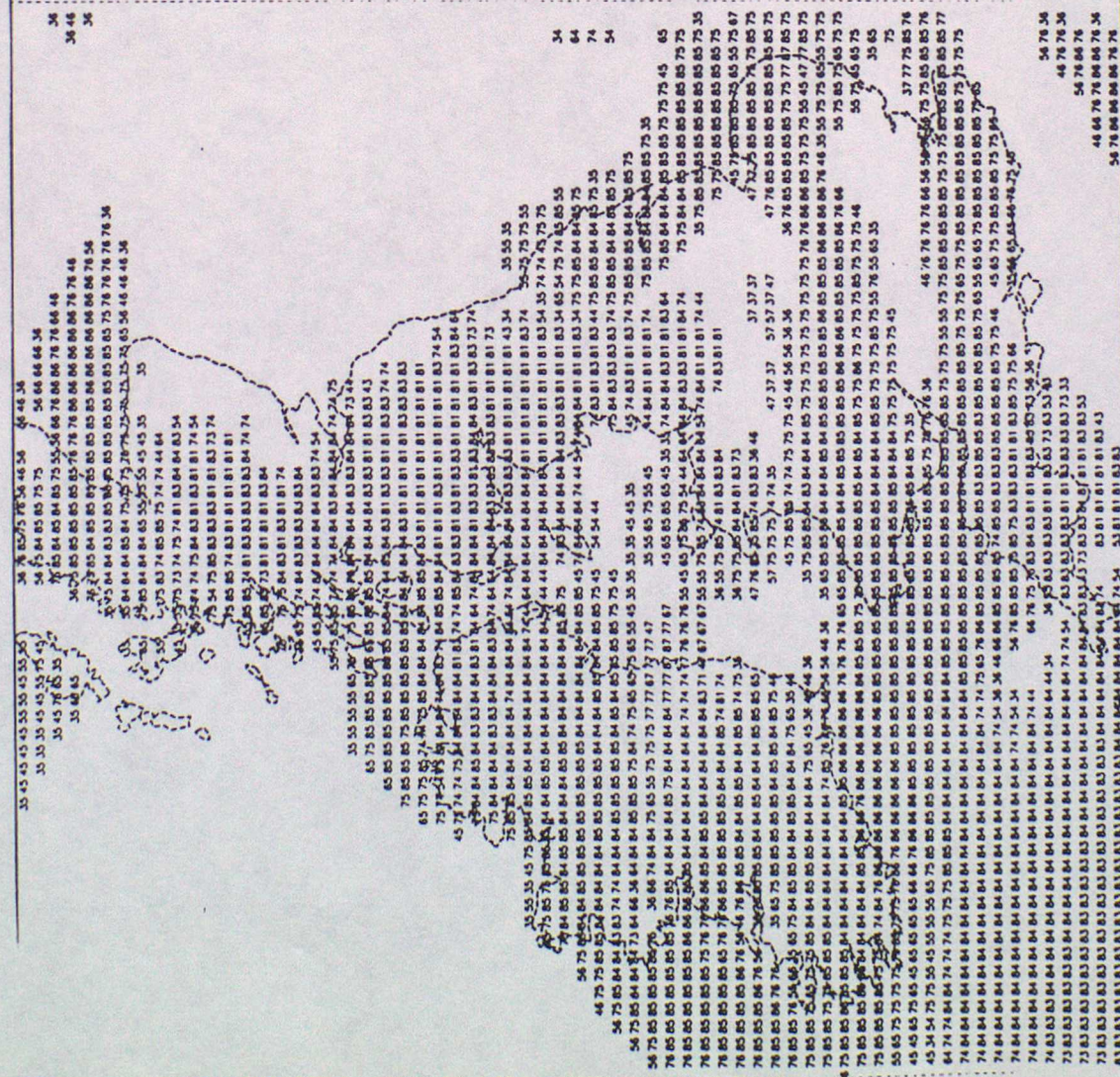
Finally one would expect the correction to improve the boundary layer structure in the mesoscale model. However this has not been investigated here and needs further study.

References

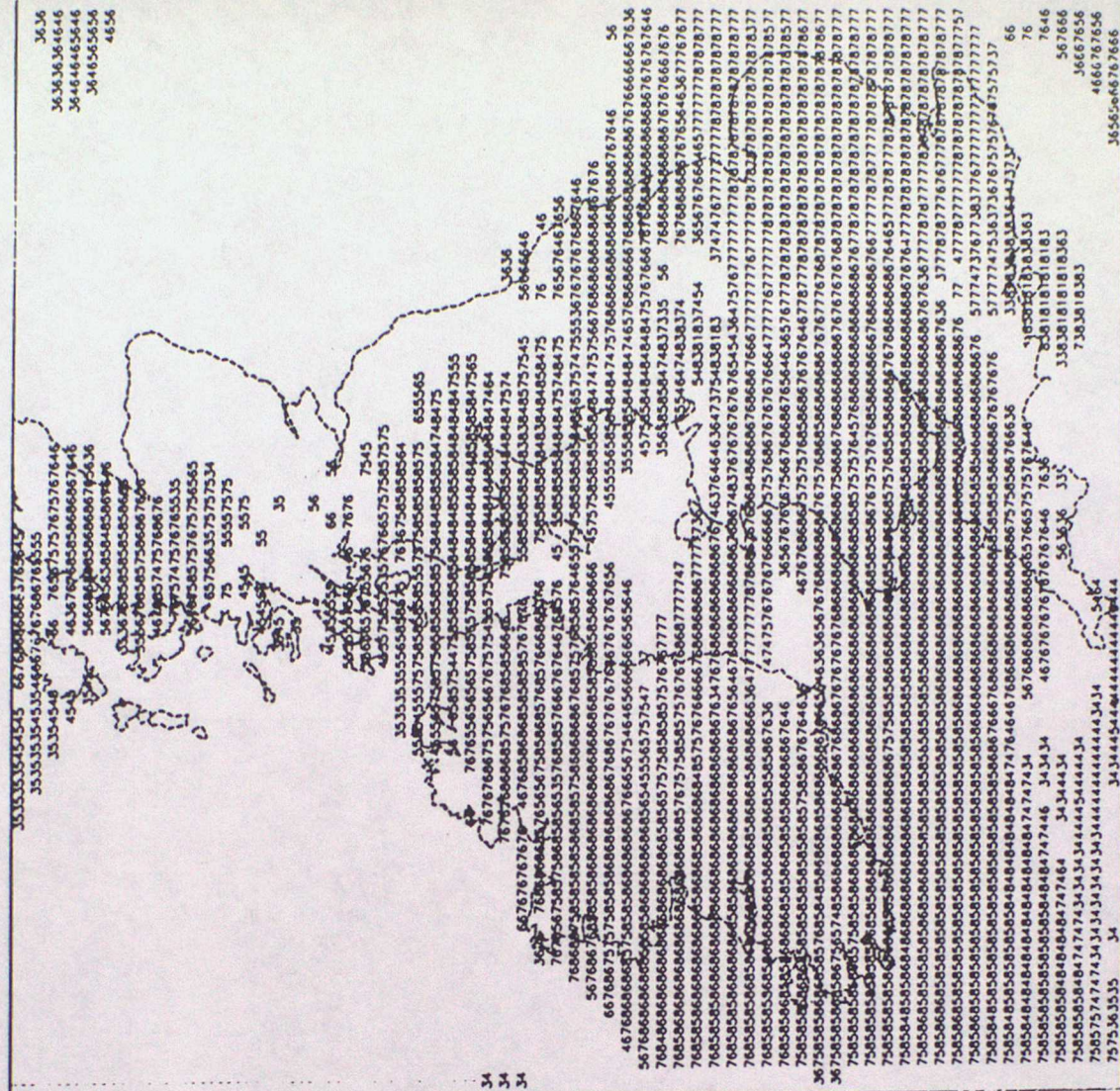
- | | | |
|--------------|------|---|
| Hammon O. M. | 1987 | Trial of proposed changes to the mesoscale model for November 1987. Met O. 11 Technical Note No. 5 |
| Hammon O. M. | 1988 | An assessment of a trial to test small changes to the convection scheme in the mesoscale model Met O. 11 Technical Note No. 4 |

Figure 1. 18 hour forecasts of low cloud cover shown as N.H code verifying

at 18z 21/2/88



(a) February 1988 version



(b) March 1988 version

Figure 2. Surface observations for 18z 21/2/88 with the edge of 4 octas or more low cloud cover marked

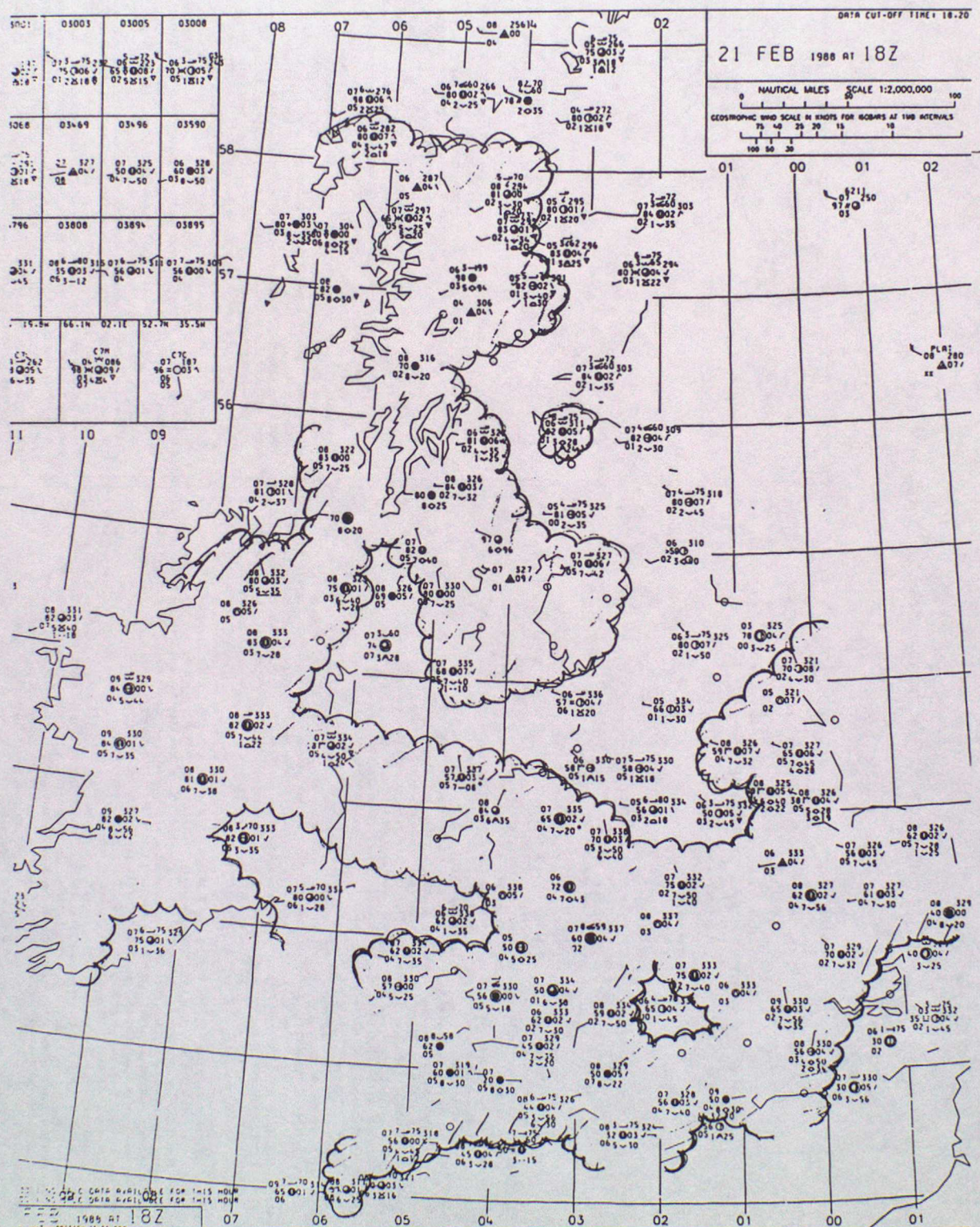
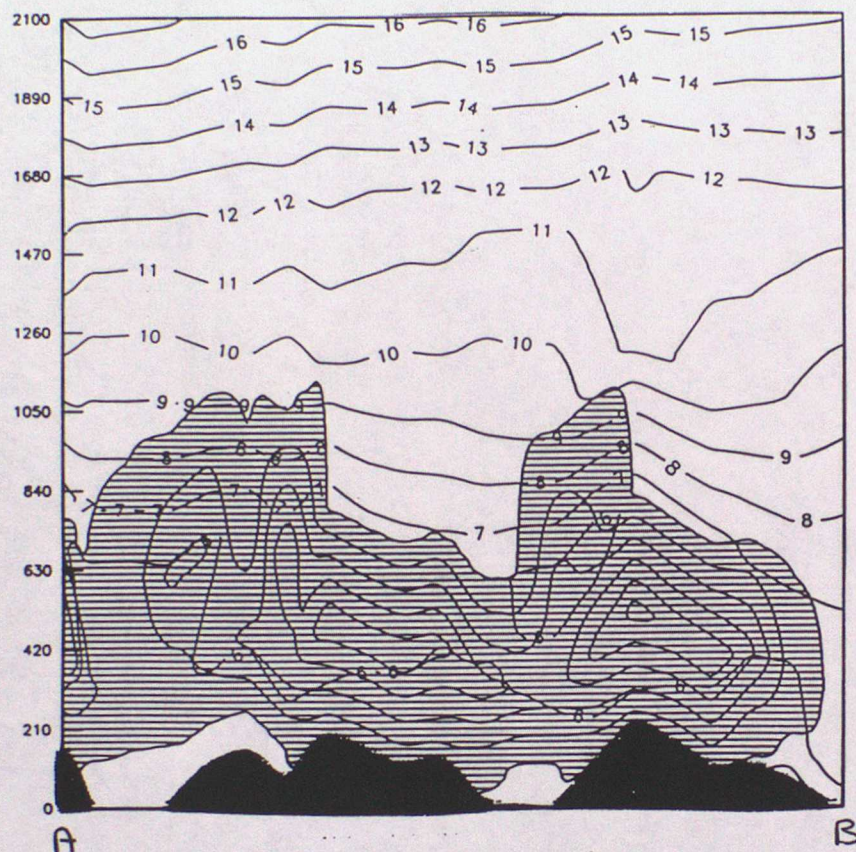
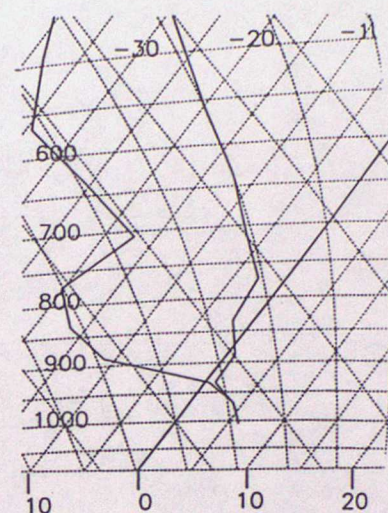


Figure 3. Cross-sections of potential temperature and cloud water mixing ratio and Tephigrams from 18 hour forecasts verifying at 18z 21/2/88

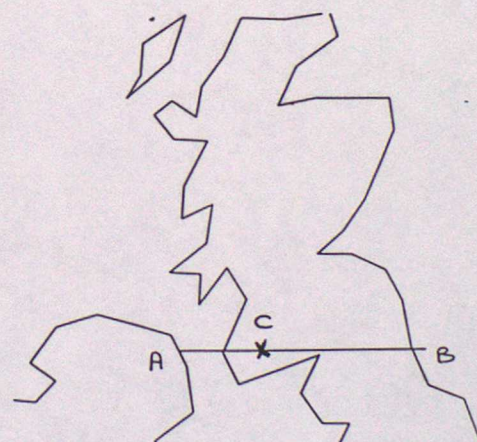
contours of cloud water mixing ratio are at 0.0001 kg/kg intervals and values above 0.00001 kg/kg are shaded



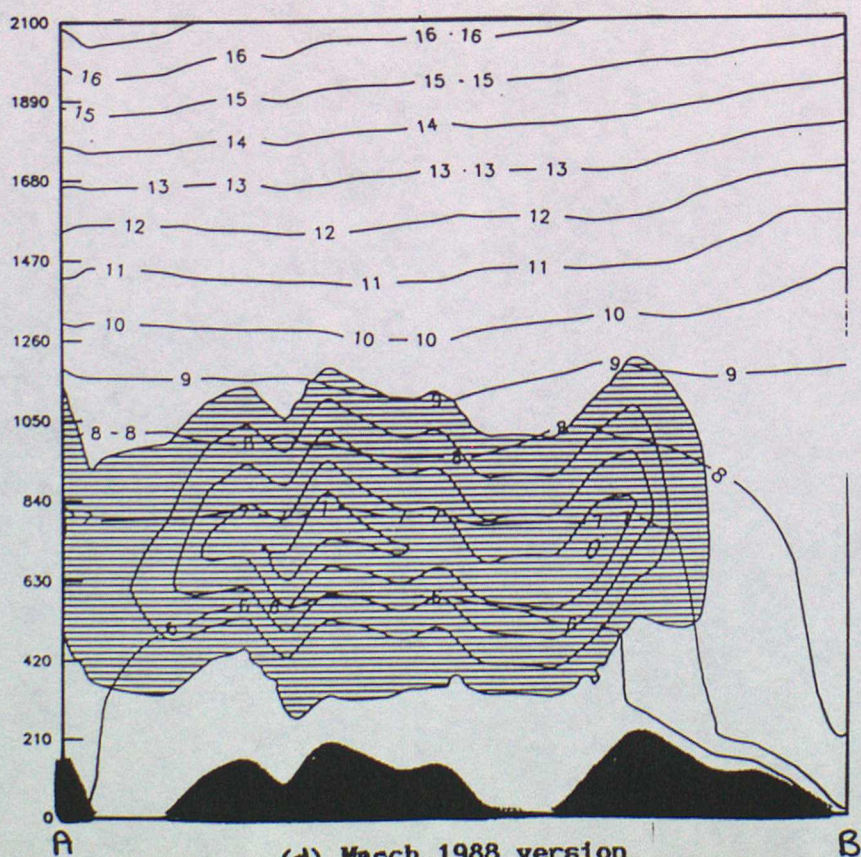
(a) February 1988 version



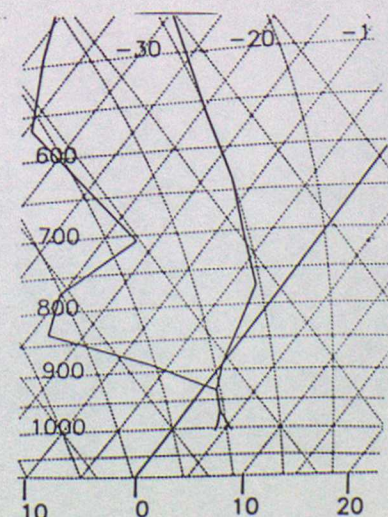
(b) February 1988 version



(c) line of cross-section



(d) March 1988 version



(e) March 1988 version

Figure 4. Surface observations for 06z 5/11/87 with the edge of 6 octas or more low cloud cover marked

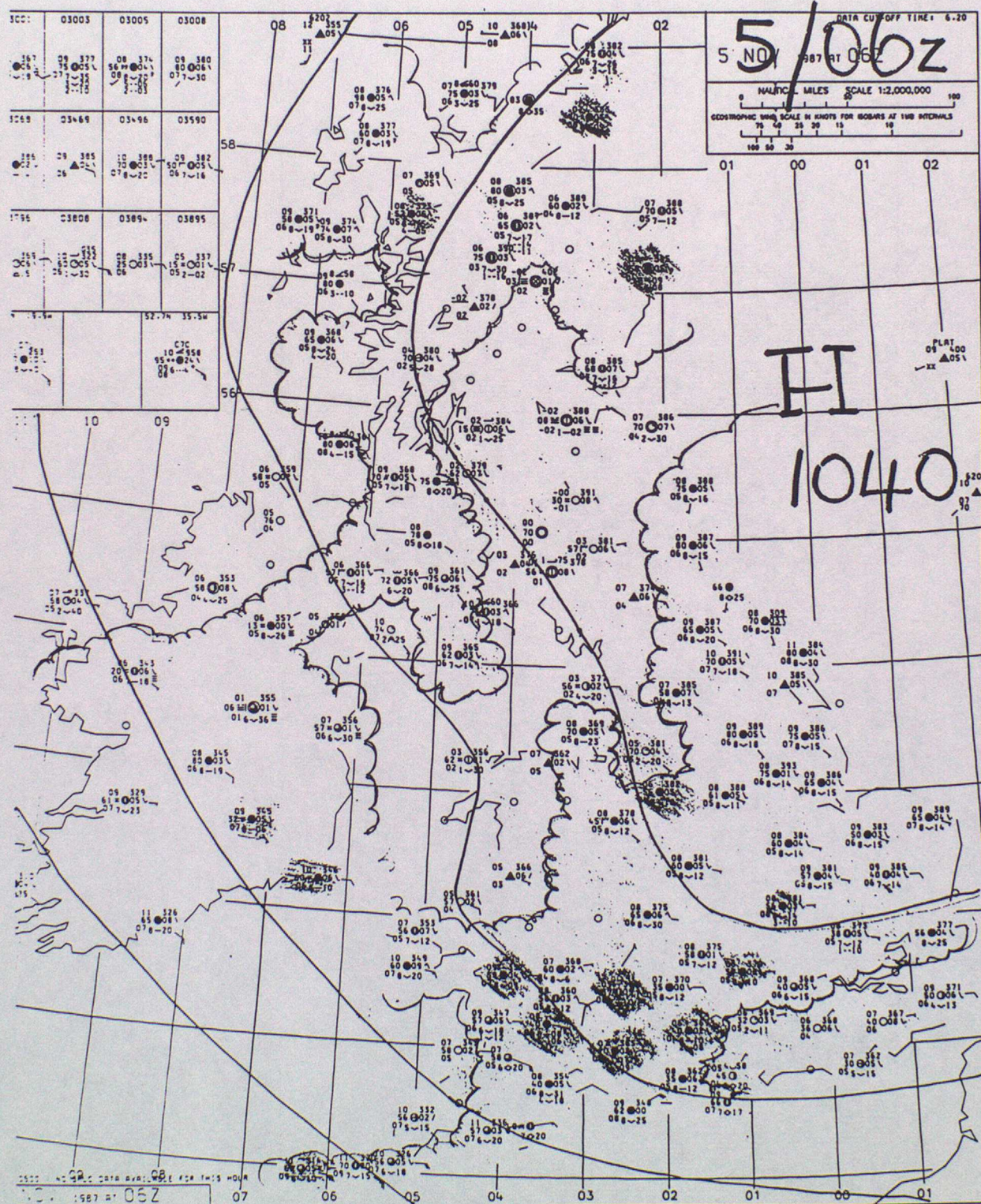
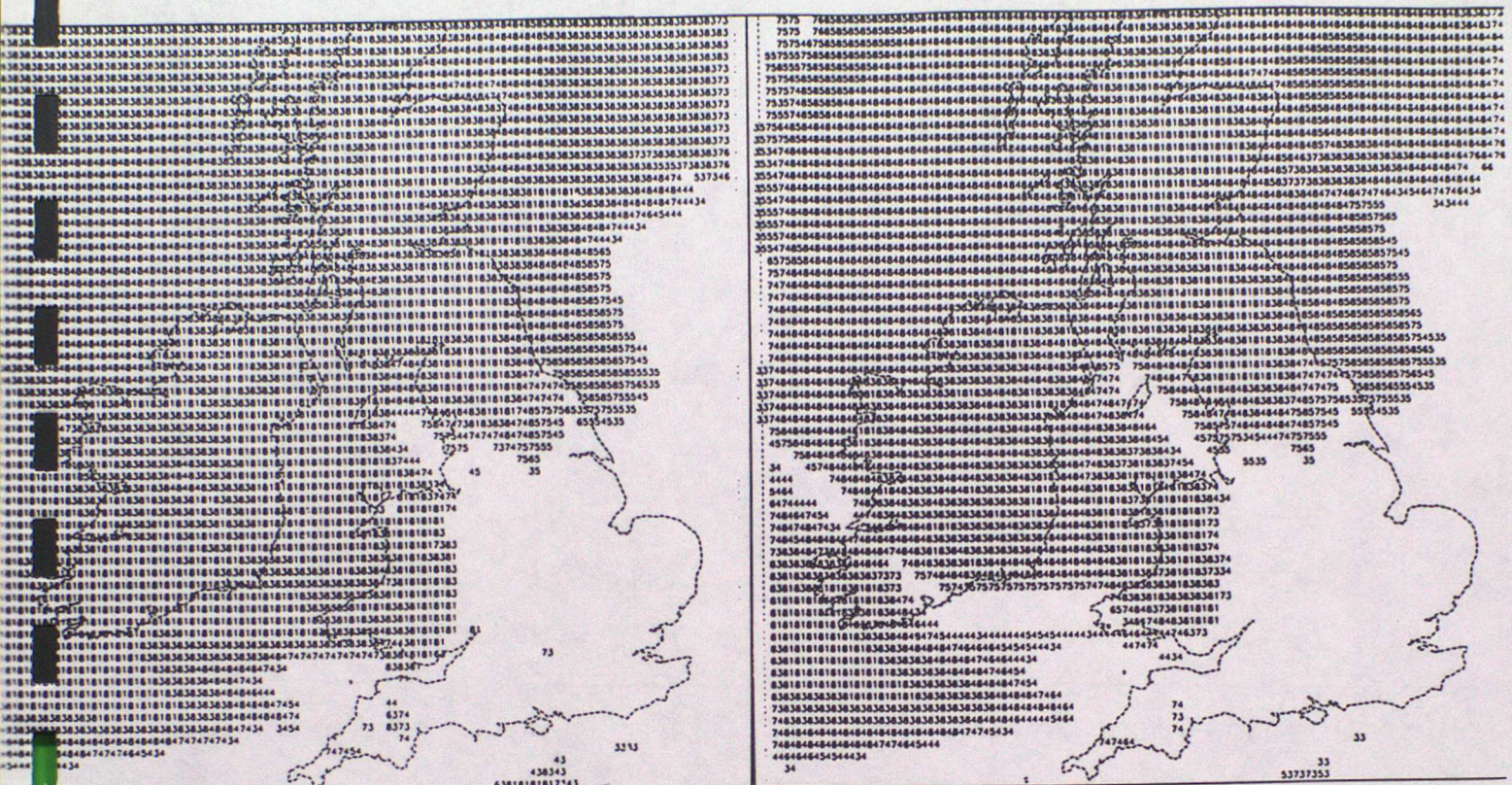


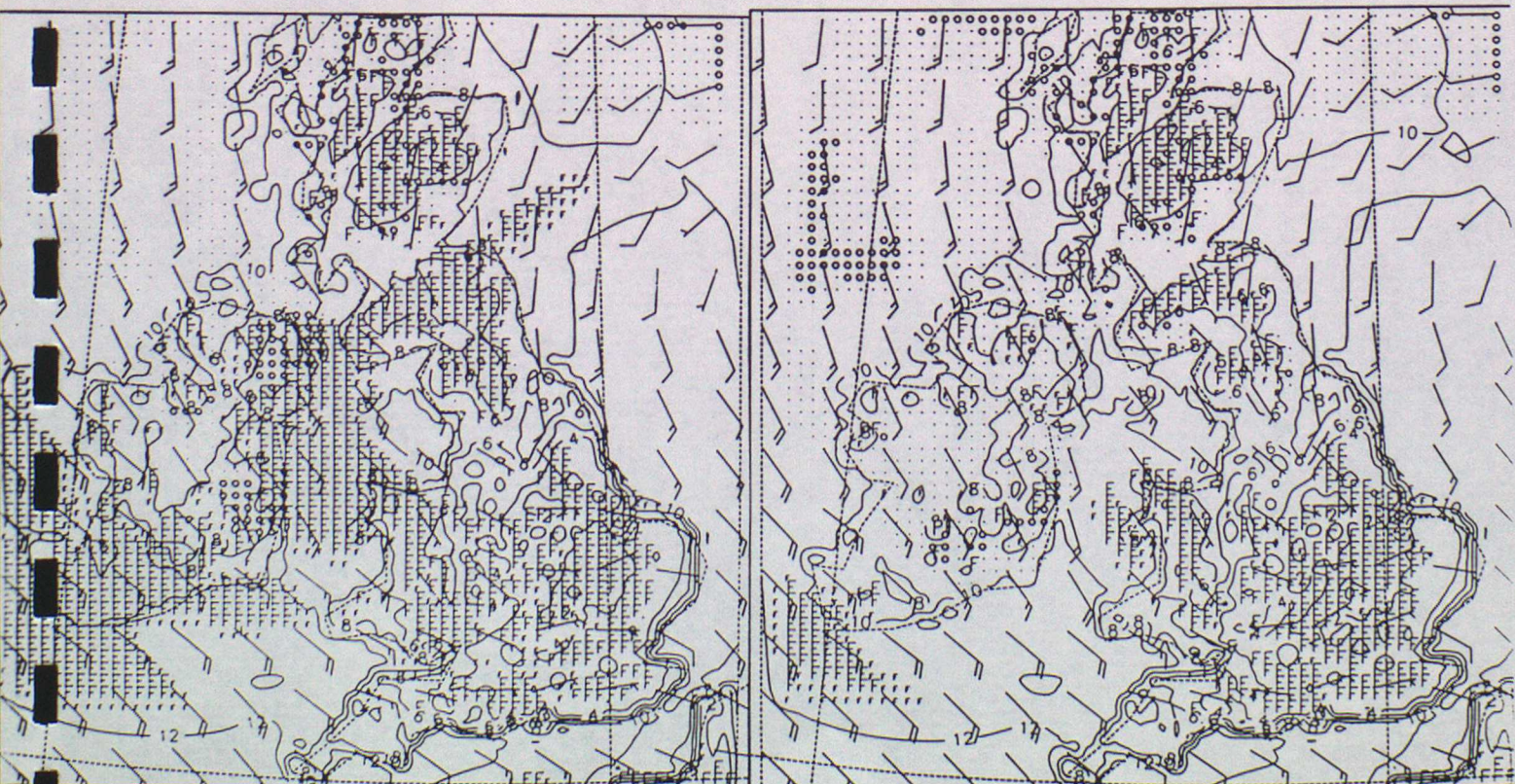
Figure 5. 18 hour forecasts of low cloud cover in N.H code and surface weather verifying at 06z 5/11/87



(a) November 1987 version

(b) March 1988 version

key for surface weather charts is the same as in figure 6
contours of screen temperature at intervals of 2 deg C

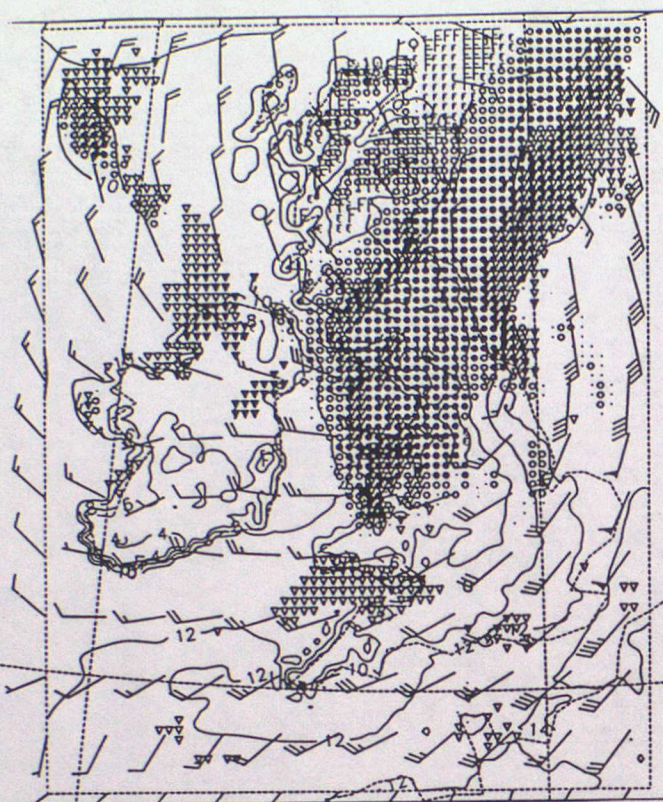


(c) November 1987 version

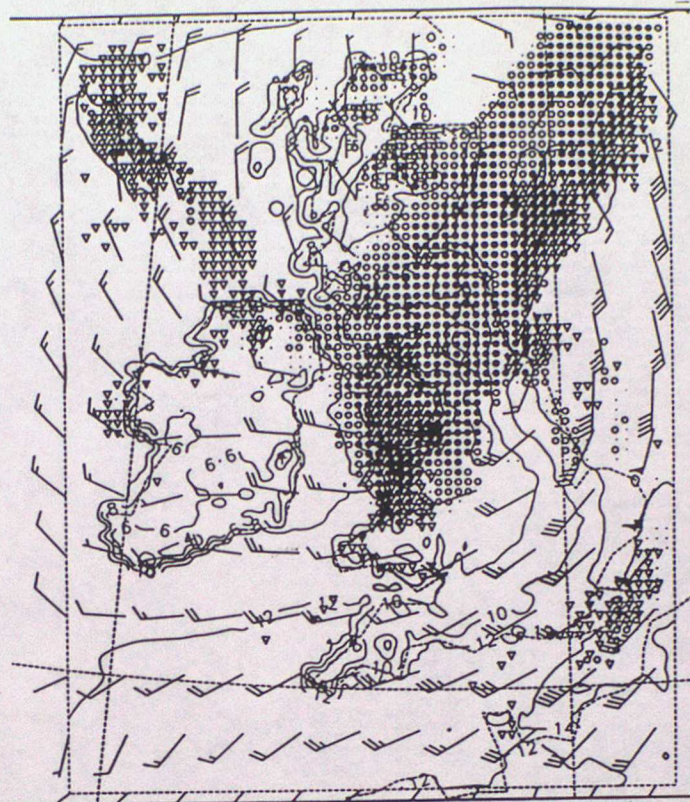
(d) March 1988 version

Figure 6. 18 hour forecasts of surface weather and low cloud cover in N.H

code verifying at 06z 16/10/87



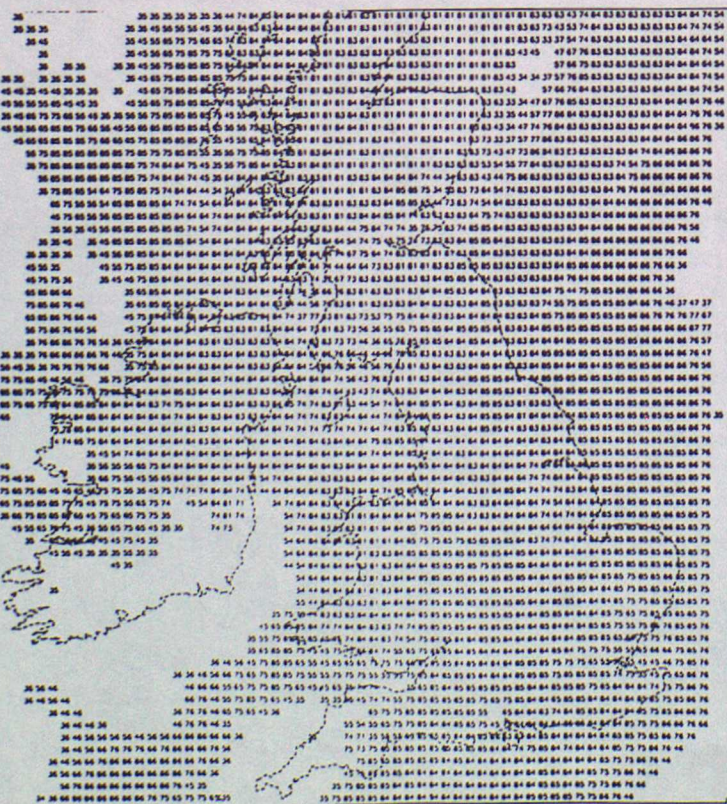
(a) February 1988 version



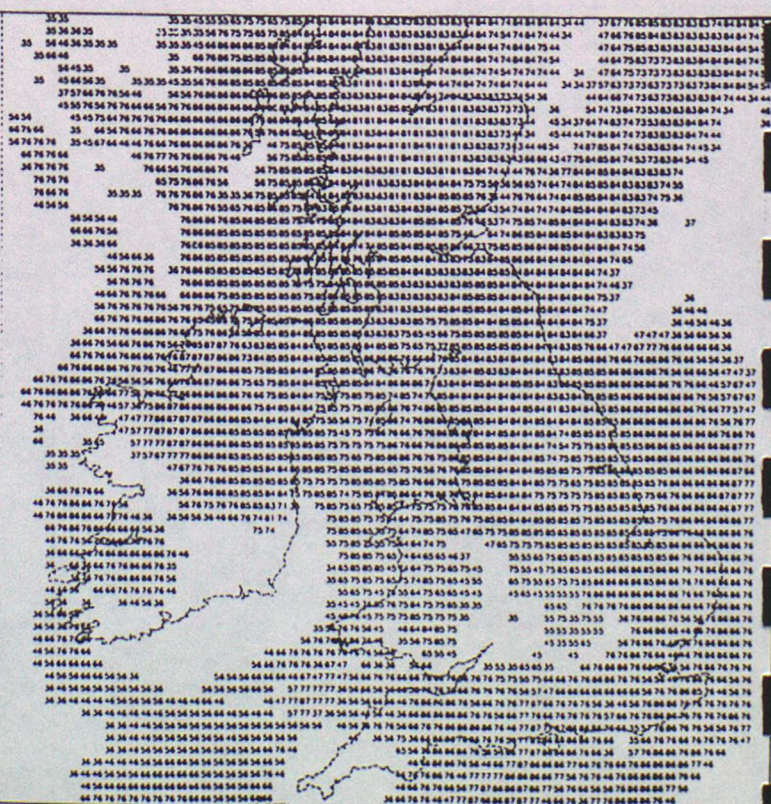
(b) March 1988 version

STRAT. RAIN
0.01
0.1
0.5
MM/HR
CONV. RAIN
0.4
10.0
F
MM/HR (LOCAL) METRES
VISIBILITY
1000
200

contours of screen temperature at intervals of 2 deg C



(c) February 1988 version



(d) March 1988 version

Figure 7(a). Surface observations for 06z 16/10/87 with the area of precipitation marked

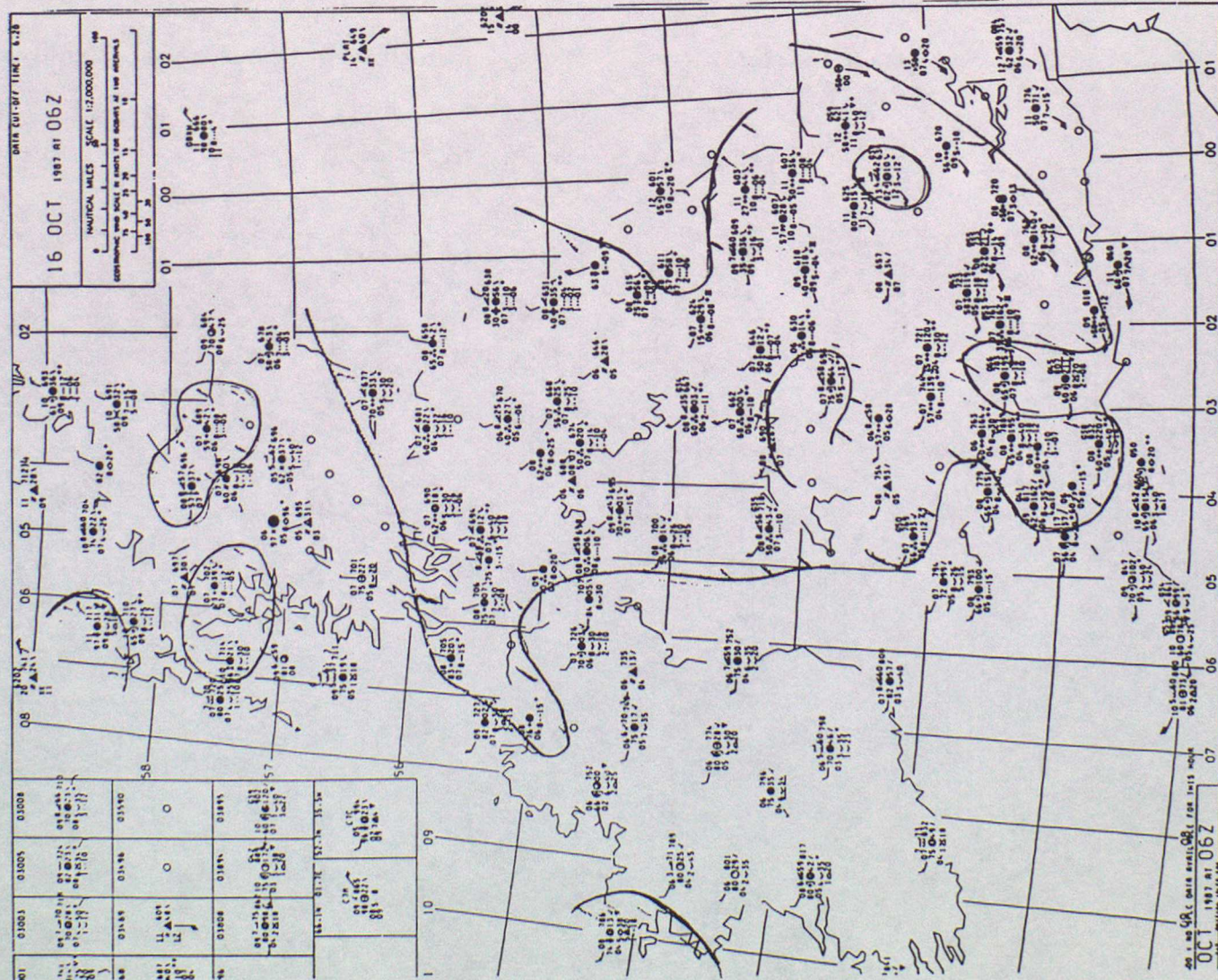


Figure 7(b). 15 hour forecast of surface weather verifying at

03z 16/10/87 from March 1988 version

contours of screen temperature at intervals of 2 deg C

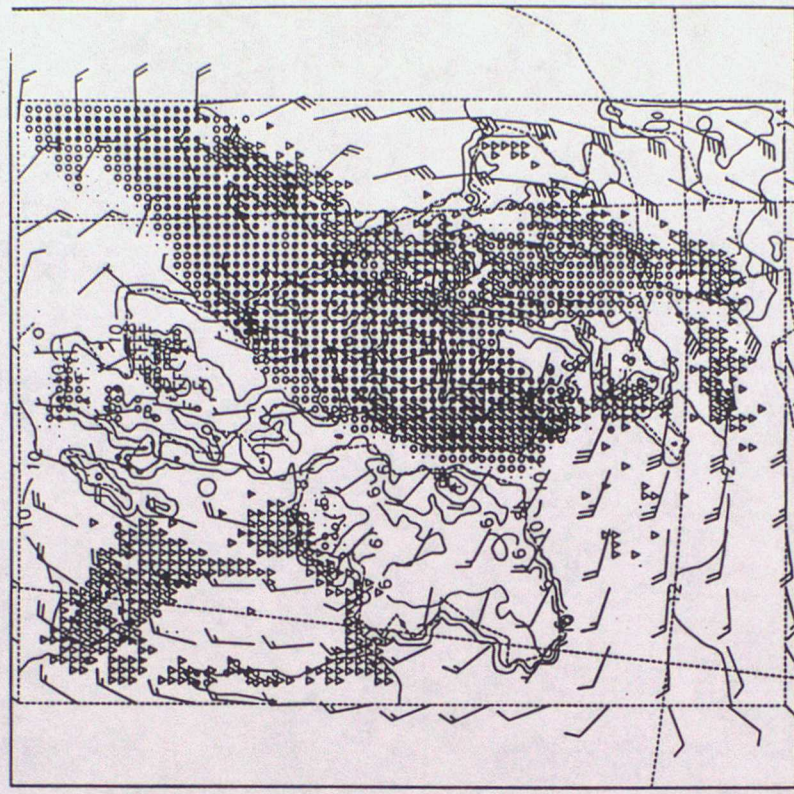
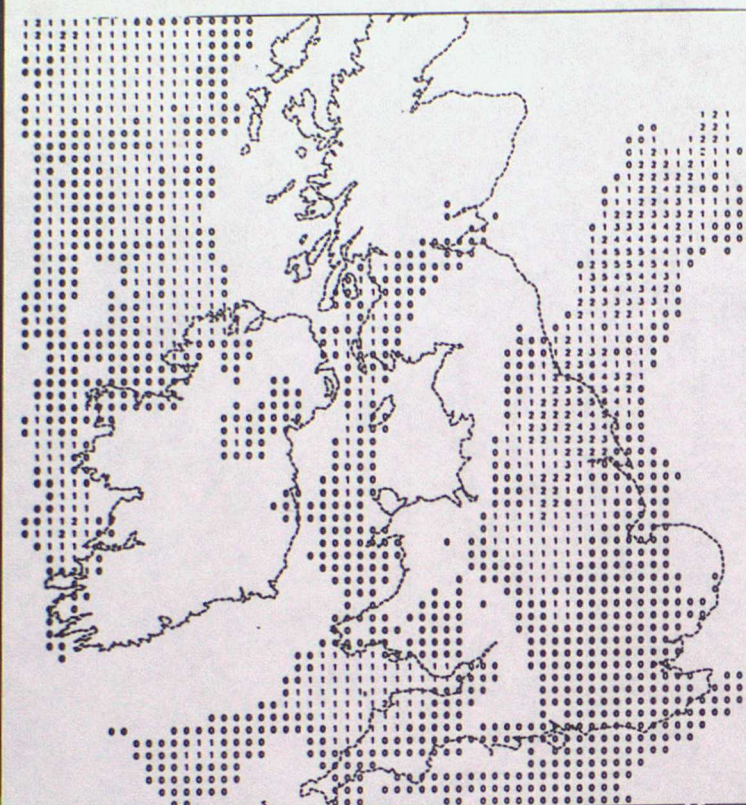
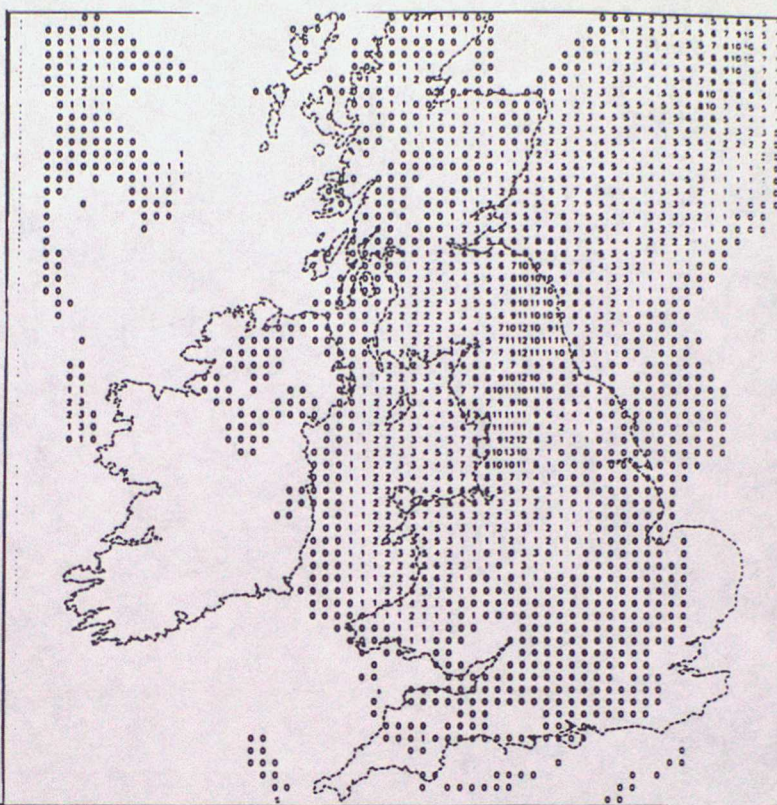


Figure 8. Forecast accumulations of dynamic and convective precipitation between 03z and 06z 16/10/87 from forecasts starting at 12z 15/10/87



(a) February 1988 version

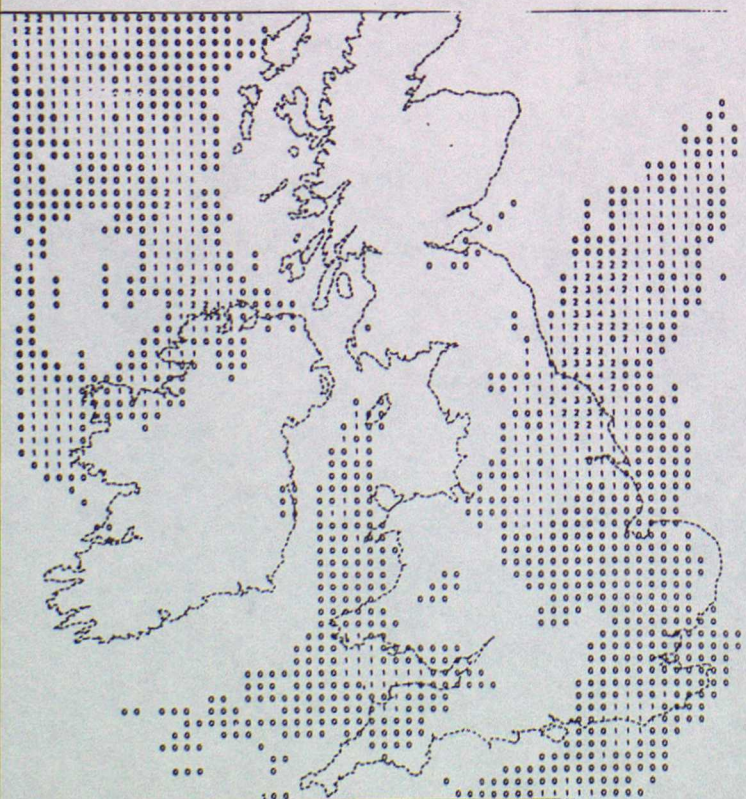
accumulated convective precipitation



(b) February 1988 version

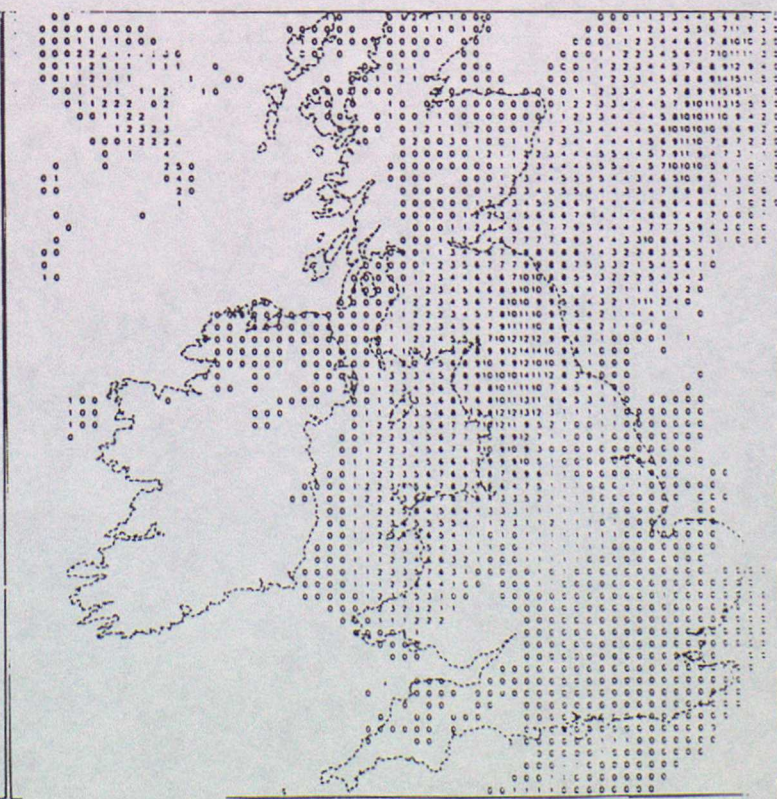
accumulated dynamic precipitation

accumulations are given in mm



(c) March 1988 version

accumulated convective precipitation

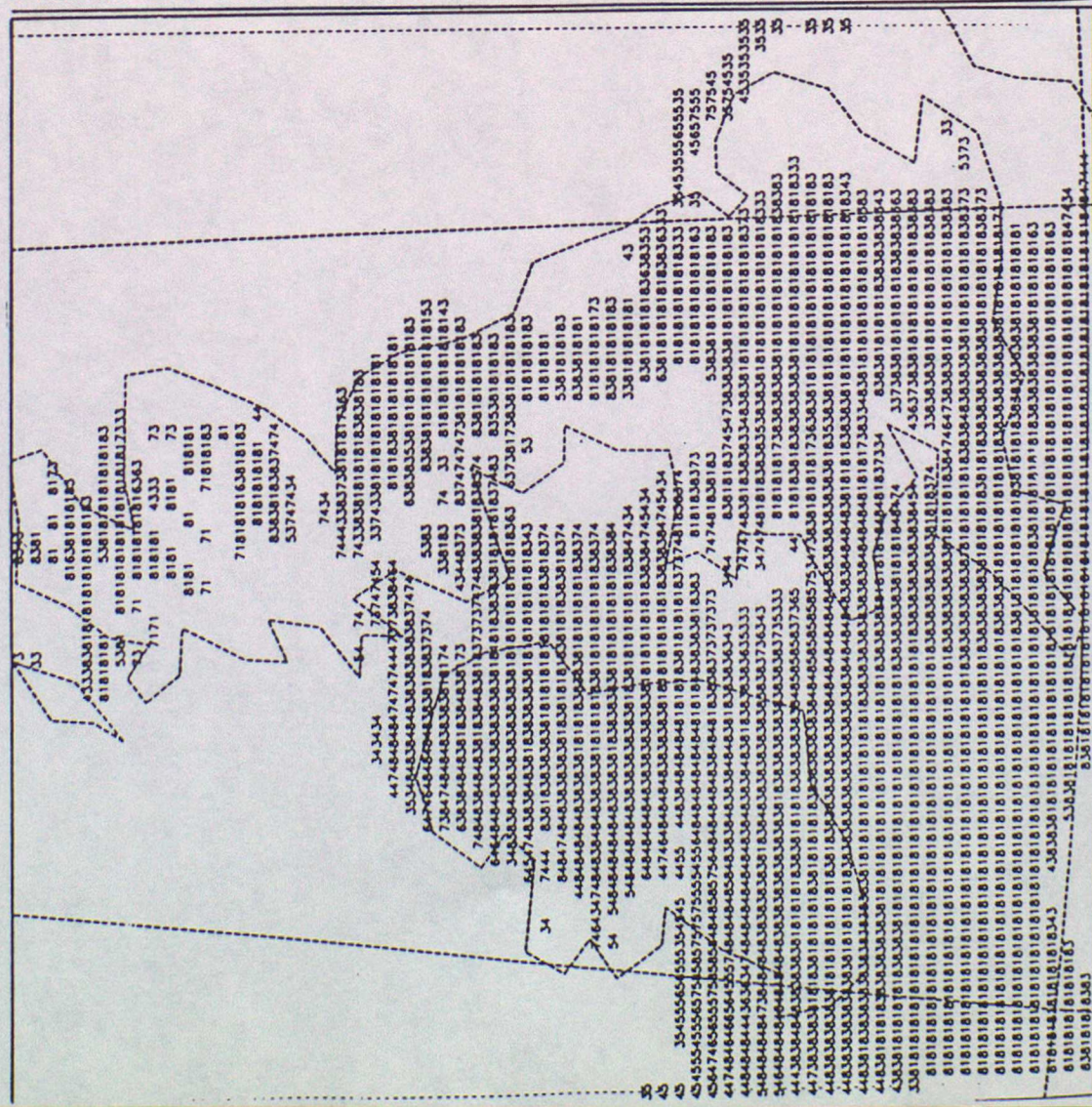


(d) March 1988 version

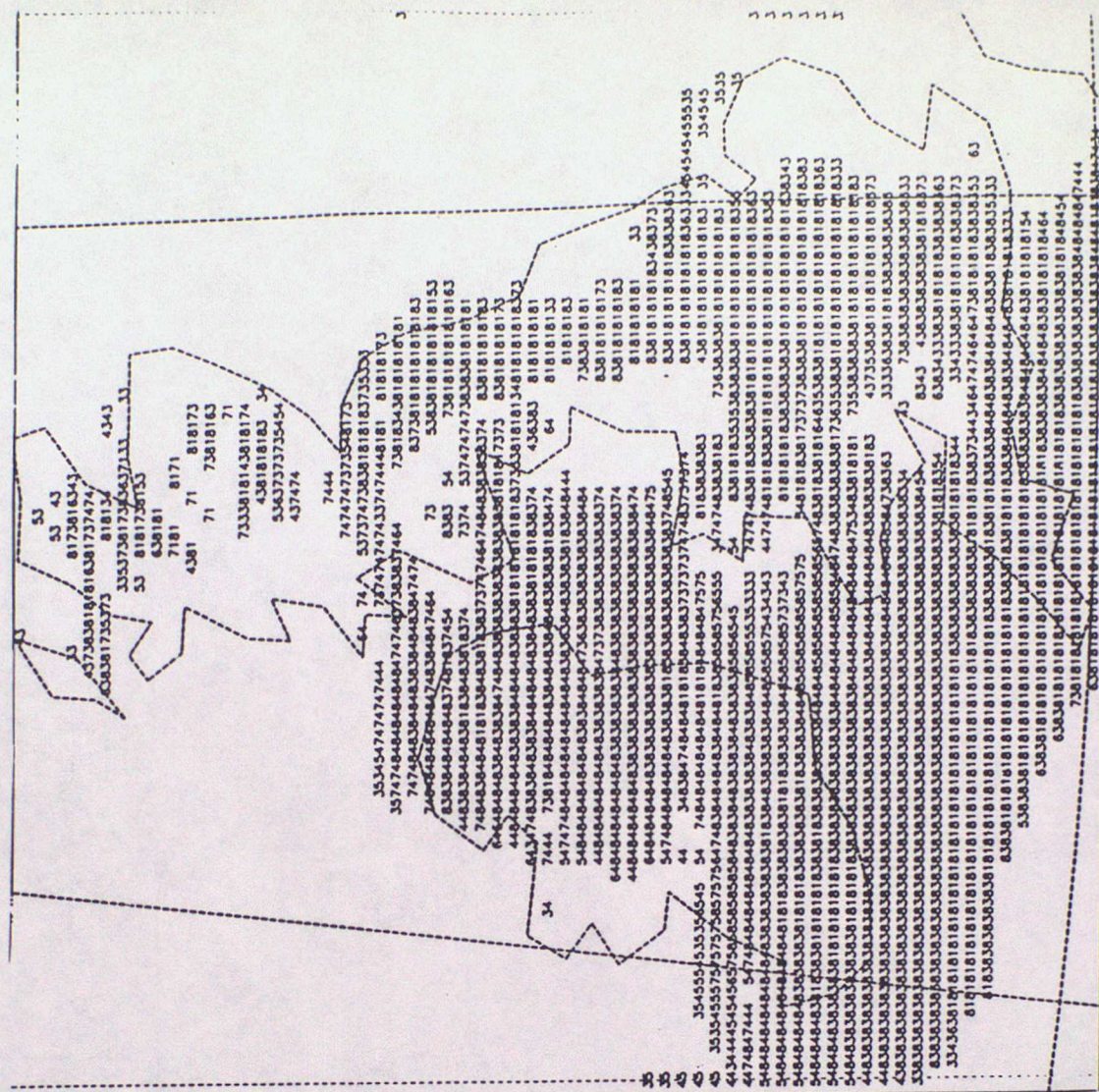
accumulated dynamic precipitation

Figure 9. 12 hour forecasts of low cloud cover shown as N.H code verifying

at 06z 22/6/86



(a) November 1987 version



(b) March 1988 version

DATA CUT-OFF TIME: 6-21

22 JUN 1986 AT 06Z

NAUTICAL MILES SCALE 1:2,000,000

GEOSTROPHIC WIND SCALE BY SHOTS FOR ISOBAHS AT 1MB INTERVALS

NO DATA AVAILABLE FOR THIS HOUR

JUN 1986 AT 06Z

Figure 11. 18 hour forecasts of surface weather verifying at 18z 6/7/87

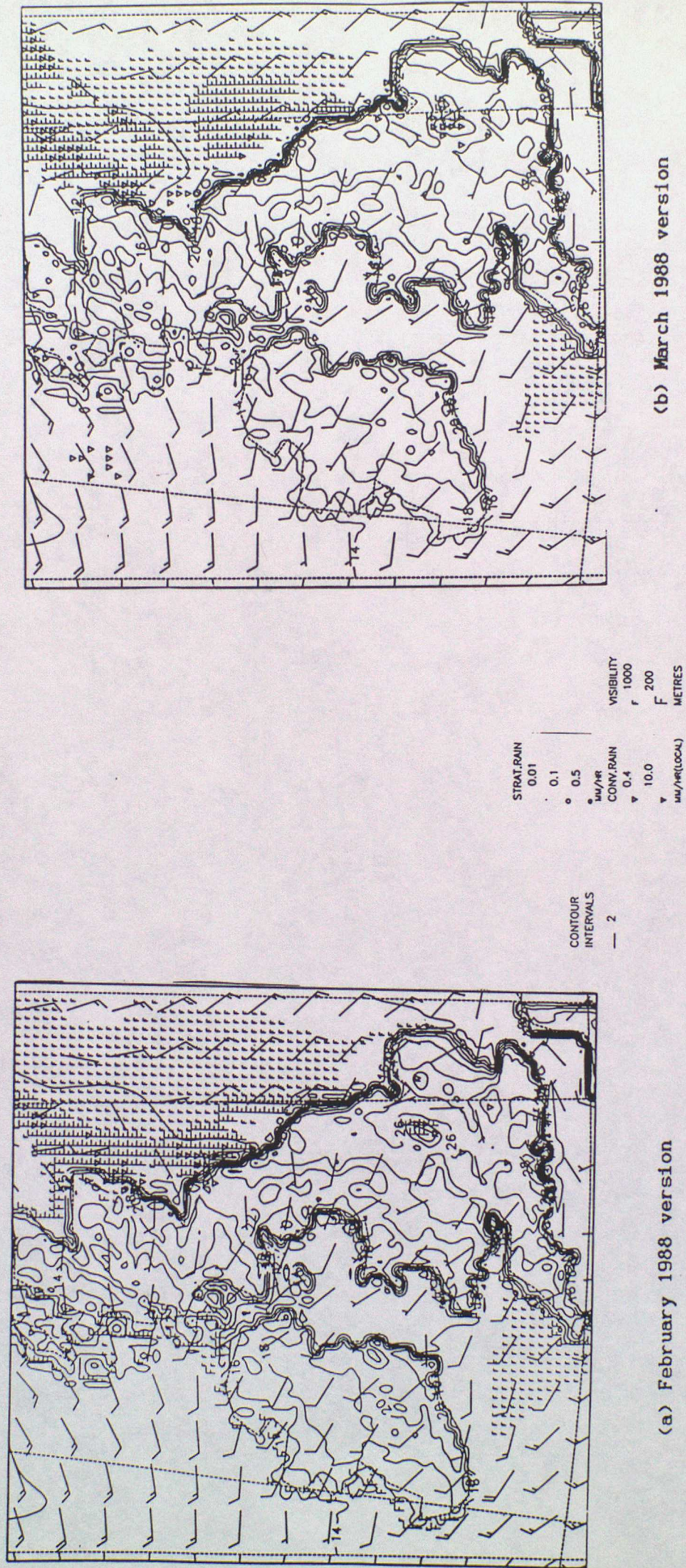


Figure 12. Surface observations for 18z 6/7/87

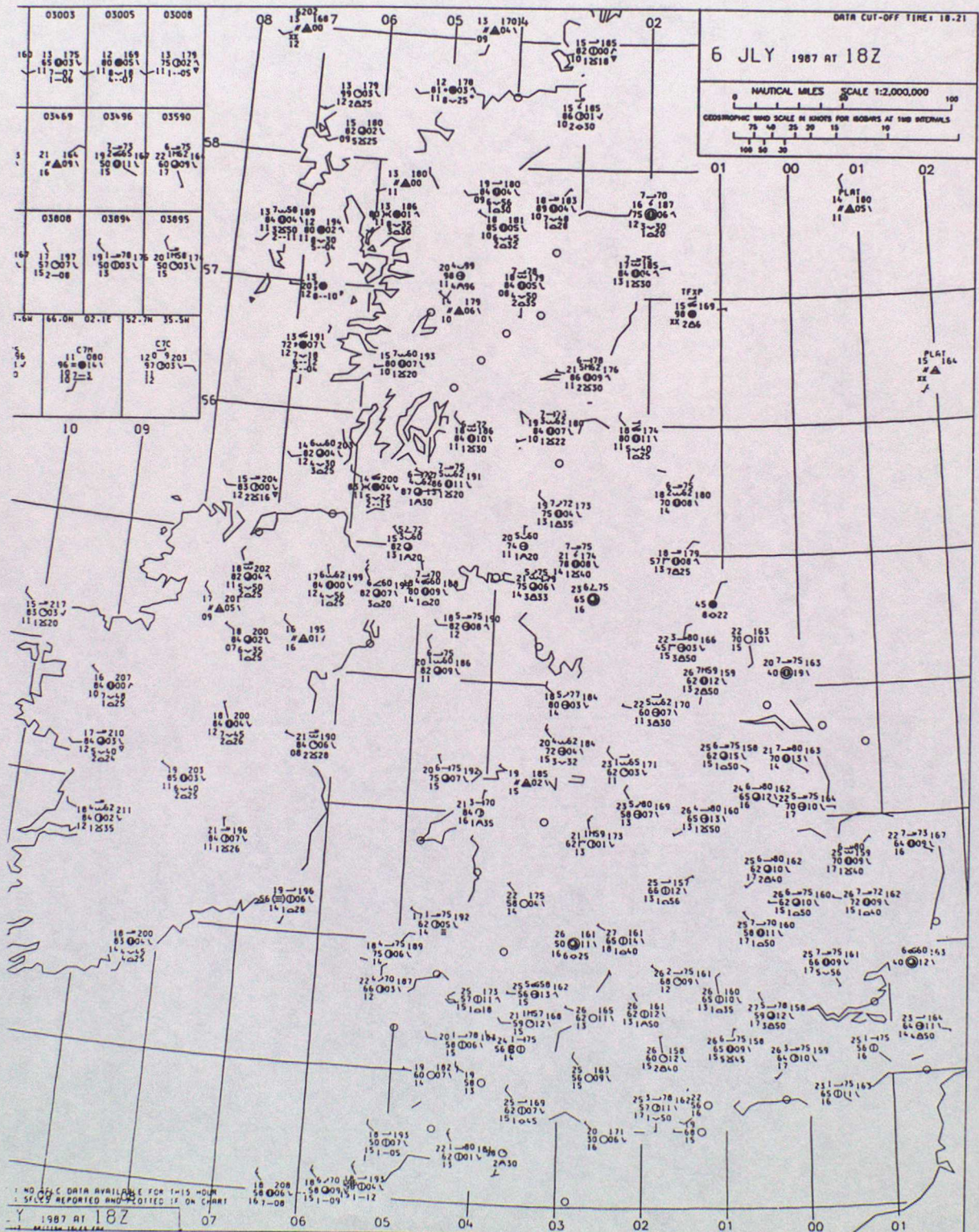
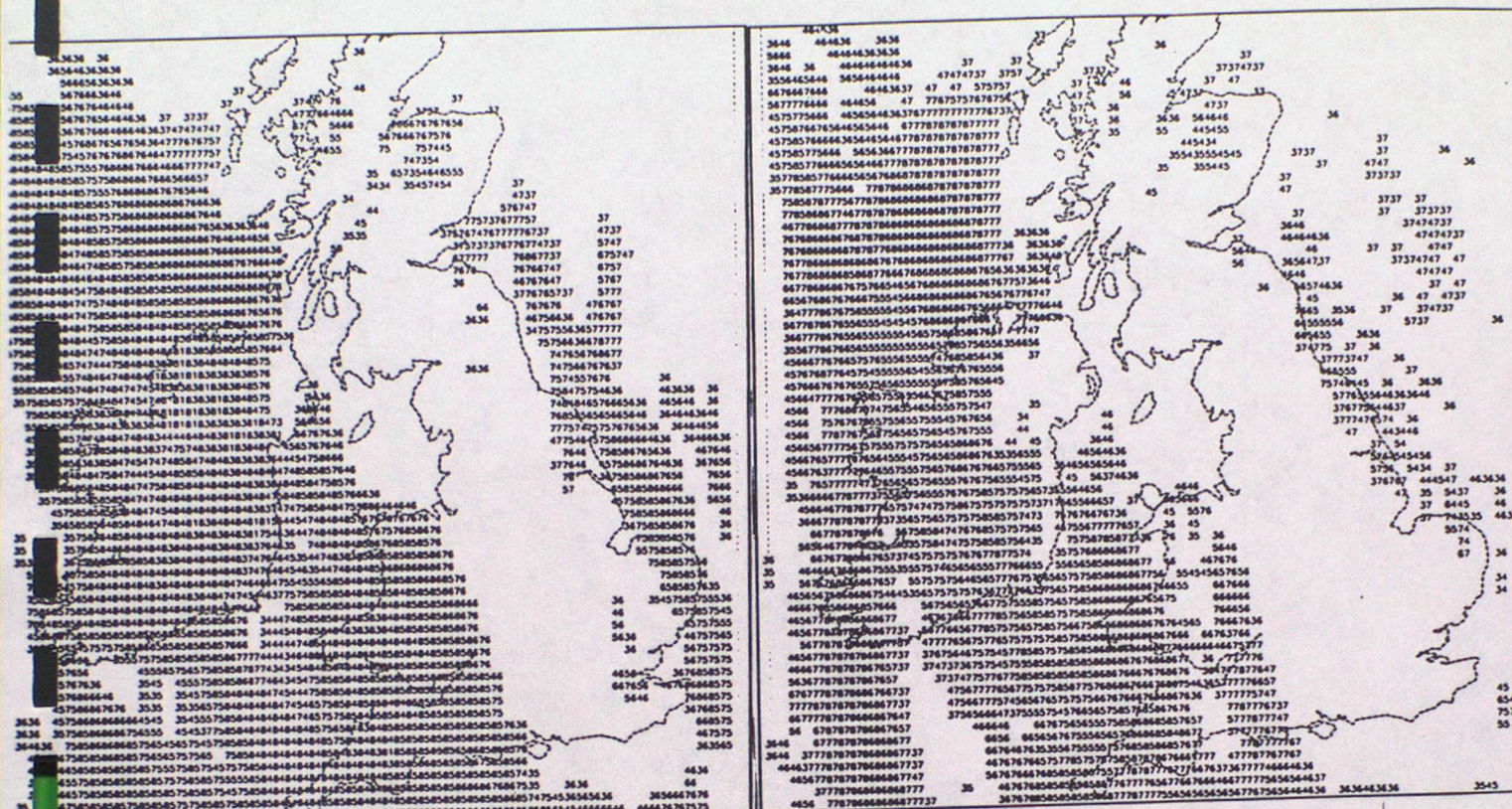


Figure 13. 15 hour forecasts of low cloud cover verifying at 03z 1/3/88

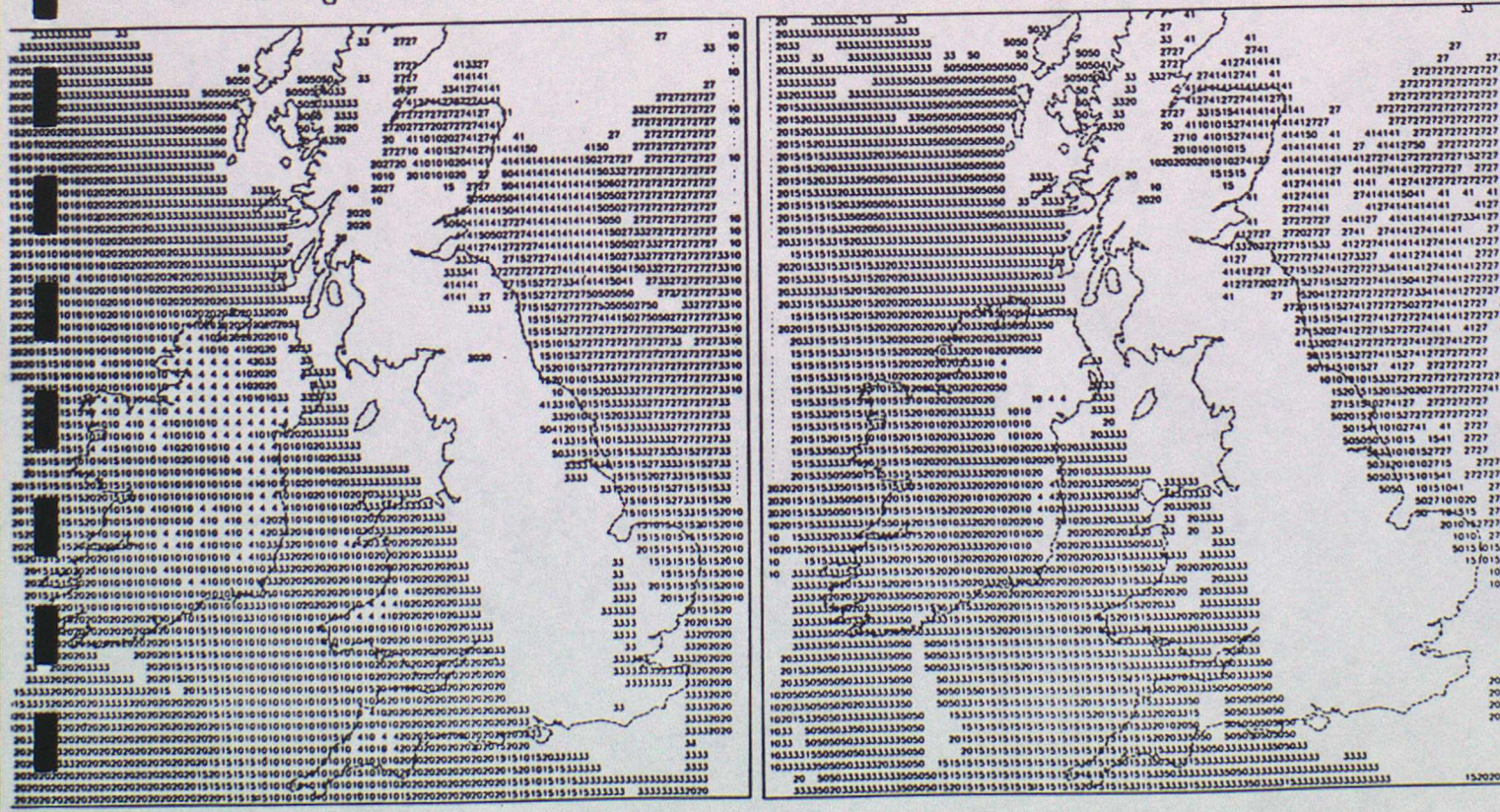
a) and b) N.H code



a) February 1988 version

b) March 1988 version

c) and d) height in 100s of ft of lowest model level with greater than 0.8 octas of cloud



c) February 1988 version

d) March 1988 version

Figure 14. Surface observations for 03z 1/3/88 with the edge of 3 octas or more low cloud cover marked

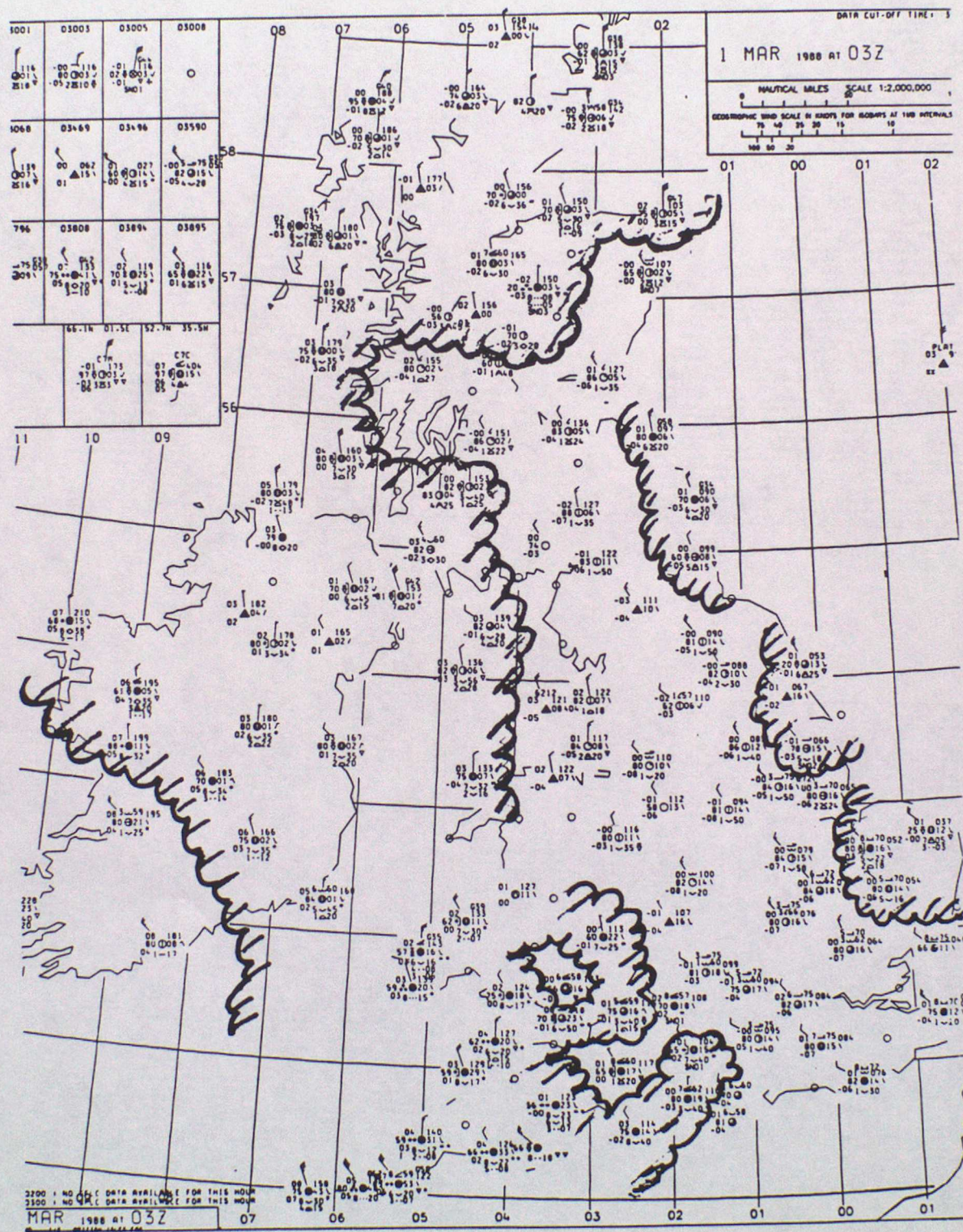
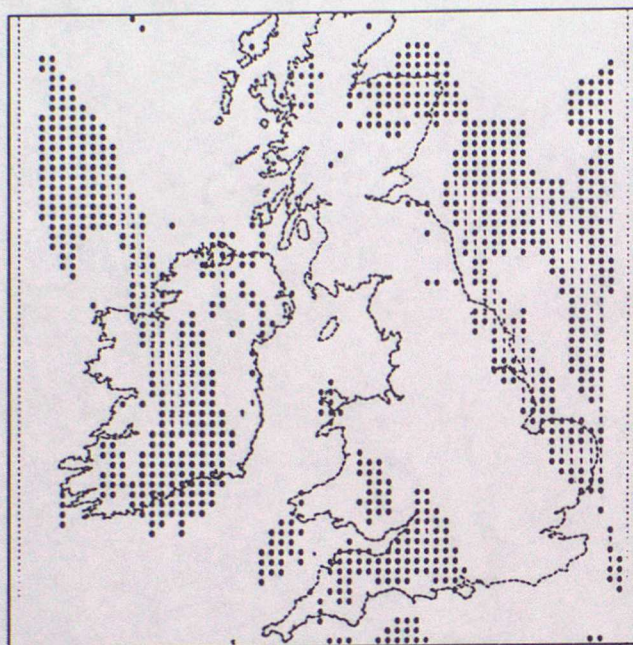


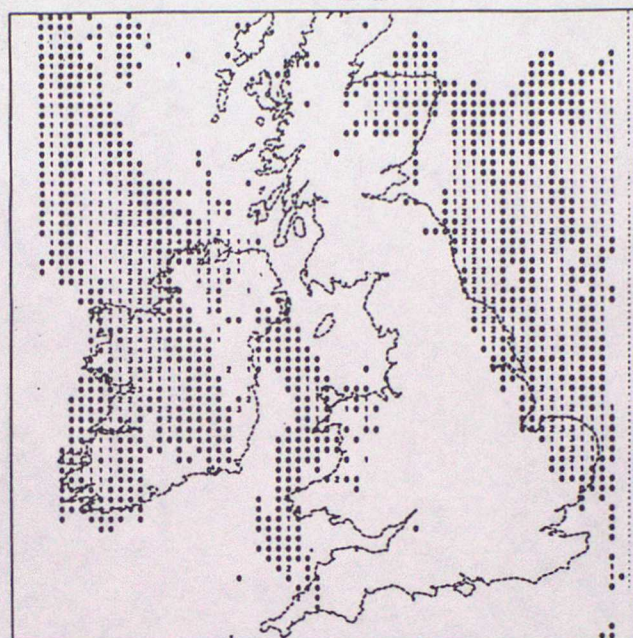
Figure 15. Forecast accumulations of total (dynamic and convective)
precipitation between 21z and 24z 29/2/88 and 00z and 03z 30/2/88 from
forecasts starting at 12z 29/2/88

accumulations are given in mm



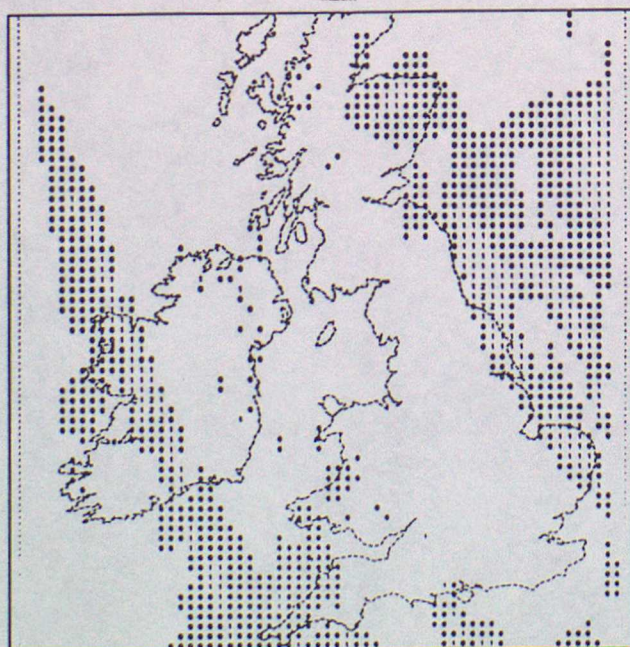
(a) accumulated precipitation 21z-24z

February 1988 version



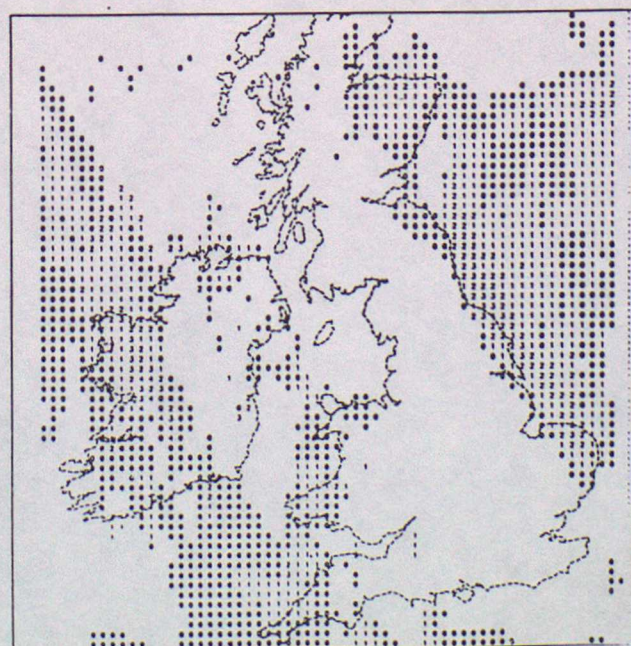
(b) accumulated precipitation 21z-24z

March 1988 version



(c) accumulated precipitation 00z-03z

February 1988 version



(d) accumulated precipitation 00z-03z

March 1988 version

Figure 16. Areas of precipitation taken from surface observations at hourly intervals between 21z 29/2/88 and 03z 30/2/88

(a) 21z-24z 29/2/88

. 21z
 - . - . 22z
 - - - - 23z
 ——— 24z



(b) 00z-03z 30/2/88

. 00z
 - . - . 01z
 - - - - 02z
 ——— 03z

