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Verification of mesoscale model forecasts during the period August - October 1986.

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VERIFICATION OF MESOSCALE MODEL FORECASTS DURING THE PERIOD AUGUST - OCTOBER 1986

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1. INTRODUCTION

The aim of this report is to assess the accuracy of the mesoscale model forecasts, in comparison with the fine-mesh model forecasts, during the quasi-operational trial. It will describe results from the objective and subjective verification for the three month period August to October 1986.

A brief description of model performance and changes will be given in section 2, whilst the results from the objective verification of wind speed, weather, temperature and surface humidity are described in section 3. Essentially the format will be the same as in previous reports. The only difference is that rainfall accumulations and extreme temperatures have been assessed from the period 09-21 and 21-09 instead of 06-18 and 18-06.

Another important way of assessing the model is to see how well it performs in comparison with subjective forecasts. Three methods of subjective assessment will be described in section 4. These are as follows:

a. A detailed assessment of model (mesoscale, fine-mesh) temperature forecasts for selected stations has been made in comparison with those prepared at Weather Centres for issue to Gas Boards;

b. A daily forecast for the Bracknell local area for the period 09-24 is prepared by the British Isles forecaster in CFO and compared with a similar forecast made using mesoscale model output;

c. A comparison of significant cloud bases between those forecast by the mesoscale model and those forecast by Heathrow Met. Office.

The weather during the period was varied, providing a good test for the accuracy of both models. August was cool with above average rainfall as a succession of fronts and depressions crossed the UK. Although thunder was reported on thirteen days, unfortunately there was no hot, humid thundery spell to test the mesoscale model's deep convection scheme. An anticyclonic spell lasted from the middle of September to the 12 October, providing several fog and low cloud cases to assess. Finally, another spell of wet and windy weather occurred at the end of October.

2. MODEL PERFORMANCE AND CHANGES

During the period August to October, the mesoscale model forecast ran successfully on 95% of occasions. Out of the nine missed forecasts, only one could be attributed to a model failure. The rest were due to hardware problems.

A few small changes were made to the mesoscale model during the period. These were as follows:

a. The horizontal diffusion of thermodynamic variables was reduced by half (Aug 15/16). The aim was to confine hill fog to the hill tops only, rather than allowing it to spread across low ground as well;

b. S.V.P was reduced in the presence of ice crystals (Aug 15/16);

c. The emissivity and transmissivity of cloud was adjusted to allow more radiation through a partial cloud cover (Aug 15/16). This change was made to improve temperature forecasts on partially cloudy days;

d. Surface resistance to evaporation was increased to 500 s/m at night (Sep 16);

e. The derivation of soil moisture availability from MORECS was changed for moorland areas of Scotland (Oct 15).

Only one change affected the operational fine-mesh model during the period. During September, the resistance to surface evaporation was decreased from 60 s/m to zero. However, during October, a trial version of the fine-mesh model was tested in the verification scheme. Changes assessed included the implicit boundary layer scheme, split final detrainment, increased resistance to evaporation in winter and corrections to the interactive radiation scheme.

3. OBJECTIVE VERIFICATION RESULTS

In this section, mesoscale and fine-mesh model forecasts of wind speed, weather, cloud and humidity are compared for both forecast periods, 06-24 and 18-12. We will place most emphasis on the results for October, since these represent the latest status of the model. Particular attention will be given to the verification of fog and low cloud, which were significant features of the weather during the anticyclonic spell which lasted from mid-September to mid-October.

a. RAINFALL FORECASTS

During September, problems with the verification suite meant that rainfall accumulations could not be assessed. However, during August and October, the mesoscale model over-predicted rainfall amounts substantially, whereas the fine-mesh model was more accurate. The over-prediction of rainfall by the mesoscale model had three main causes:

i) Excessive rainfall during the first three hours of the forecast due to model instability. This is the reason why we decided to assess the periods 09-21 and 21-09 rather than 06-18 and 18-06.

ii) The model forecasts too much very light rain on occasions when none has been observed. During the anticyclonic spell in September and October, one third of this surplus rain could be attributed to small amounts of rain falling out of fog or low cloud.

iii) The major cause, however, is the over-prediction of convective rain. (This includes medium level instability in frontal systems). Table 1 shows the mean forecast accumulations for both models expressed as a percentage of the mean observed accumulations for October.

rainfall bias in models		Mesoscale model		Fine-mesh model	
rainfall period T+0 - T+12		06-18	18-06	06-18	18-06
August	(Fcst / Obs)x100	172	176	89	83
October	(Fcst / Obs)x100	204	190	93	90
rainfall period T+3 - T+15		09-21	21-09	09-21	21-09
October(all)	(Fcst / Obs)x100	181	154	110	93
October(con)	(Fcst / Obs)x100	95	69	23	14
October(dyn)	(Fcst / Obs)x100	86	85	87	79

TABLE 1. TOTAL MEAN FORECAST RAINFALL OVER A 12-HOUR PERIOD EXPRESSED AS A PERCENTAGE OF OBSERVED TOTALS

This table shows the improvement in the mesoscale rainfall obtained by using the period T+3 - T+15 in October, rather than T+0 - T+12. It also shows the high proportion of forecast convective rain. Figure 1 shows the observed accumulations for the whole of October for selected stations in the UK. Most rain fell in the west, with peak totals 241 at Fort William, 233 at Nantmor, 204 at Baastreet. The driest areas were over Eastern Scotland and Eastern England where less than 50 mm fell. Figure 2 shows the mesoscale forecast accumulations for October, based on 60 forecasts out of a possible 62. The daily totals for the periods 09-21 and 21-09 were added to obtain these totals. Although the mesoscale model predicted its highest totals in the west over high ground, forecast amounts were generally greater than those observed. This over-prediction of rain was widespread even over low ground in the east. Figure 3 shows the forecast convective rain accumulations, which appear to be at least two or three times too great. Figure 4 shows the forecast totals from the fine-mesh model and these are closer to the observed totals generally, except over Wales where the fine-mesh orography is too smooth.

Table 2 is a contingency table showing the forecast mesoscale model twelve-hour accumulations against observed accumulations in October. The figures given are an average for the periods 09-21 and 21-09.

acc (mm)	<0.05	0.05-1.0	1-5	5-10	>10
observed	42.6%	29.8%	18.5%	6.1%	2.7%
Mes fcst	41.9%	22.6%	19.6%	9.4%	6.2%
F.M fcst	37.5%	33.6%	19.7%	6.9%	1.9%

TABLE 2. Climatology of rainfall accumulations in a twelve-hour period

Table 2 shows a slight over-prediction of the larger amounts of rain by the mesoscale model. The test version of the fine-mesh has tended to forecast too much light rain, probably due to increased cloudiness.

b. FOG FORECASTS

Fog was an important feature of the anticyclonic period 15 September to 13 October. Figures 5 and 6 compare the observed and forecast percentages of fog for an specially selected subset of low-level inland stations in England for the periods September 15-30 and October 1-13 respectively.

The time interval verified is 19z-11z. The main features to be noticed are as follows:

i) Forecast period 06-24

The percentage of fog analysed by the model at 06z was substantially less than the percentage observed. Also the model fog depth was often too shallow. Due to these reasons, the model tended to clear the fog 1-2 hours too early in the morning. The model was slightly too moist at low levels and forecast fog to form too early (by 1-3 hours) during the evening. At 00z for example, the percentage of fog forecast was double the percentage observed.

ii) Forecast period 18-12

The rate of formation of fog during the night was approximately correct. The fog still tended to clear too quickly during the morning by 1-2 hours, probably due to the forecast fog depth being too shallow.

iii) The success rate (fog in the correct place at the right time) varied from 30 to 50 per cent during the peak fog time 03-08z.

It is also important for the model to be able to forecast the density of fog. Visibility tables for the period 15 September to 13 October are shown below for three verification times, 00z, 06z, 09z.

Table 4a.
D.T.06z Verification
time 00z.(T+18z)
(Sep 15-Oct 13)

V.T 00z	<250m	250-1050m	>1050m
OBS	2.7%	5.0%	92.3%
T+18 f/c	11.4%	4.6%	84.0%
% correct	0.5%	0.6%	78.7%

Table 4b
D.T.18z Verification
time 06z.
(Sep 15-Oct 13)

V.T 06z	<250m	250-1050m	>105m
OBS	11.8%	12.3%	75.9%
T+12 f/c	13.1%	6.8%	80.1%
% correct	3.0%	1.7%	65.0%

Table 4c
D.T.18z Verification
time 09z.
(Sep 15-Oct 13)

V.T 06z	<250m	250-1050m	>1050m
OBS	5.6%	6.5%	87.9%
T+12 f/c	2.8%	1.2%	96.0%
% correct	0.4%	0.1%	85.1%

The following points are worth noting from the above tables.

i) Much of the fog forecast by the mesoscale model is dense, ie vis <250m. The percentage of dense fog forecast at 06z compares well with the percentage observed.

ii) The percentage of forecast and observed fog at 06z were close, particularly for October. However, the success rate, ie fog in the correct position was only 25%. this means that the model guidance was good over an area rather than for a particular station.

iii) Fog was an obvious hazard during the period 15 September to 13 October and forecasters would have predicted it confidently without model guidance. To be useful, the model needed to predict the times of formation and clearance accurately. The forecast starting from D.T06z tended to form fog too early during the evening (see table 4a). Twice as much fog was forecast as observed at 00z. This is not serious. An early forecast is better than a later one. Of more importance is that the model tends to clear the fog too quickly during the morning. This problem can be attributed to the model forecasting too shallow a depth for the fog.

c. TEMPERATURE

During August, the fine-mesh model was more accurate in predicting screen temperatures. There was very little bias in the fine-mesh temperatures inland and the biggest errors were confined to coasts and hills. The mesoscale model r.m.s errors were mainly larger inland and there was a marked warm bias in the overnight forecast temperature.

During September, the two models were much closer in accuracy. This was due to a deterioration in the accuracy of the fine-mesh temperature forecasts rather than an improvement in the mesoscale model. The increased errors in the fine-mesh can be attributed to the reduction in the resistance to surface evaporation during September.

During October, there was an improvement in the mesoscale forecast temperatures. During the daytime, the mesoscale model was slightly more accurate than the fine-mesh, with little or no bias, and mainly small errors inland.

The fine-mesh forecast temperatures were good but there was a cold bias of 0.7C. However, during the evening and night, both models developed a warm bias. This warm bias was more marked in the mesoscale model.

Table 5 compares the r.m.s errors of the two models at three-hourly intervals for August, September and October.

	MES	F.M		MES	F.M
August			August		
DT6z VT09z	1.7	1.4	DT18z VT21z	1.4	1.8
DT6z VT12z	2.2	1.8	DT18z VT00z	1.7	1.9
DT6z VT15z	2.2	1.9	DT18z VT03z	2.0	2.0
DT6z VT18z	1.7	1.6	DT18z VT06z	2.1	2.0
DT6z VT21z	1.6	1.8	DT18z VT09z	2.0	1.9
DT6z VT00z	2.0	2.0	DT18z VT12z	1.5	1.7
September			September		
DT6z VT09z	1.6	1.6	DT18z VT21z	1.8	2.1
DT6z VT12z	2.0	1.9	DT18z VT00z	2.4	2.6
DT6z VT15z	2.0	1.9	DT18z VT03z	2.7	2.7
DT6z VT18z	1.4	1.5	DT18z VT06z	2.9	2.8
DT6z VT21z	1.9	2.3	DT18z VT09z	2.1	1.7
DT6z VT00z	2.4	2.7	DT18z VT12z	2.1	1.9
October			October		
DT6z VT09z	1.4	1.8	DT18z VT21z	1.5	1.8
DT6z VT12z	1.7	1.9	DT18z VT00z	1.9	1.9
DT6z VT15z	1.5	1.8	DT18z VT03z	2.1	2.1
DT6z VT18z	1.5	1.7	DT18z VT06z	2.3	2.1
DT6z VT21z	1.9	1.8	DT18z VT09z	1.9	1.8
DT6z VT00z	2.1	2.0	DT18z VT12z	1.8	1.9

TABLE 5. Comparison of overall r.m.s errors for the mesoscale model and fine-mesh model at 3-hourly intervals for Aug., Sept. and Oct.

Figures 7 and 8 show the mean errors for the mesoscale model maximum and minimum temperatures respectively. The errors in the maximum temperature forecast are biggest over high ground and small elsewhere. In the minimum temperature forecasts there is a distinct warm bias of 2 degrees C or more for most stations. This warm bias is due partly to inaccurate output (screen temperature is taken to be halfway between the temperatures at the surface and level 1) and also due to excess cloudiness. Figure 9 shows the effect of this warm overnight bias for one station, Marham during October. Although maximum temperatures forecast by the mesoscale model are generally correct to within 2C, minimum temperatures are consistently too high. It is important that this persistent warm bias should be corrected since it will spoil forecasts of frost in the winter.

We cannot assess fine-mesh maximum and minimum temperatures since we have only three hourly output. However, we can compare model forecasts at 15z and 06z. Figures 10-13 show the distribution of r.m.s errors for the mesoscale and fine-mesh models at 15z,06z respectively.

Frost was not an important feature of the weather during September or October. Both models produced identical contingency tables for the occurrence of frost at 06z. The results are given in Table 6.

Table 6. DT18z Verification of frost at time 06z. (Oct. 1986 T+12 f/c)

	F.M /MES	Observed: Frost	Observed: No Frost	
F/C	Frost	0.1	0.0	0.1
F/C	No Frost	0.7	99.2	99.9
		0.8	99.2	100.0

This table gives an indication that both models miss occasions of slight frost.

d. CLOUD AMOUNT

i) Initial conditions

The model cloud amounts changed considerably during the first timestep. The analysis during October had a sight deficit in cloud, but, after one time-step, the proportion of 7-8 octas cloud increased from 25% to 68%. Th ese results are shown in table 7 below.

Table 7 contingency table for mesoscale model cloud amounts (combined 06, 18) at initial time and after one time-step

MES INIT	0-1 octas	1-4 octas	4-6 octas	7-8 octas
OBS	15	18	16	51
INIT	16	32	27	25
T+1 ts	10	12	10	68

ii) Cloud bias during period 06-24

Cloud amounts were well predicted by the mesoscale model during daylight hours, and forecast errors were mainly in the category 6 octas observed/8 octas forecast. However, too much cloud was predicted during the evening and night, with errors in the category 6 octas or less observed/8 octas forecast. The operational version of the fine-mesh model tended to forecast too little cloud generally during August and September. However, the trial version used in October forecast substantially more cloud and was more accurate as table 8a shows.

TABLE 8a. Cloud Contingency table at T+12, VT 18z, October 1986

dt06 vt18	B (0-4)	P (5 6)	C (7-8)	MES F/C	dt06 vt18	B (0-4)	P (5-6)	C (7-8)	F.M F/C
B	14%	3%	7%	24%	B	21%	8%	14%	43%
P	3%	2%	4%	9%	P	4%	2%	5%	11%
C	15%	12%	40%	67%	C	7%	7%	32%	46%
OBS	32%	17%	51%	100	OBS	32%	17%	51%	100%

iii) Cloud bias during period 18-12

The mesoscale model forecast too much cloud throughout this period with a maximum overall bias of 1-1.5 octas between 00z and 06z. The fine-mesh model forecast too little cloud at night during August and September but approximately the correct amount during October. This increase of cloudiness in the fine-mesh was due to the introduction of the implicit boundary layer scheme and split final detrainment in the fine-mesh trial. Table 8b compares the model's cloud amount forecast at T+12 with the observed amount during October.

TABLE 8b. Cloud Contingency table at T+12, VT 06z, October 1986

d+18 vt06	B (0-4)	P (5-6)	C (7-8)	MES F/C	dt18 vt06	B (0-4)	P (5-6)	C (7-8)	F.M F/C
B	12%	2%	5%	19%	B	16%	4%	8%	28%
P	3%	1%	3%	7%	P	6%	2%	7%	15%
C	17%	11%	46%	74%	C	10%	8%	39%	57%
OBS	32%	14%	54%	100	OBS	32%	14%	54%	100%

The main error in the mesoscale model is the over-prediction of cloudy periods. The main error for the operational fine-mesh model during August and September was the over-prediction of clear periods. Cloud amounts were more accurately predicted by the trial version of the fine-mesh model in October.

e. CLOUD BASE

i) INITIAL CONDITIONS

Table 9 below shows the percentage of cloud analysed by the model in the five lowest levels compared with the observed amounts. It also shows how the cloud base changes and lowers during the first model timestep.

MES F/C CLD BASE	LEVEL 110m	LEVEL 310m	LEVEL 610m	LEVEL 1010m	LEVEL 1510m	LEVEL >1510m
OBS	4.3%	9.6%	14.1%	10.6%	7.4%	21.0%
INIT	3.7%	8.1%	10.5%	6.9%	5.2%	11.7%
T+1 t/s	10.3%	3.2%	4.9%	3.3%	1.5%	21.4%

Table 9. Climatology of initial cloud base (average of 06z, 18z) during October.

ii) Multi-layer cloud analysis during October

Table 10 a-d give a comparison between the model cloud analyses and forecasts. The tables show the differences as a percentage between the forecast and analysed amount of cloud in the lowest five model levels. Positive values mean that the model has a surplus of cloud, whilst negative values imply a cloud deficit. Tables 10 (a) and (c) show the sharp increase of cloud during the first timestep in the mesoscale forecast. The mesoscale forecasts too much cloud at level 610 and below with a deficit at level 1510. Tables 10b and d show that the fine-mesh has too little cloud

at levels 610 and above, with an excess at levels 310 and 110. Thew fine-mesh forecast is generally closer to the observed values except at level 110. In the operational fine-mesh forecast, this would be interpreted as too much mist and fog.

	init	06z	09z	12z	15z	18z	21z	00z
1510	-1.8	13.7	-5.3	-7.2	-12.1	-11.5	-12.4	-10.8
1010	-2.3	17.2	-0.5	-4.2	- 4.2	- 2.3	0.1	- 0.8
610	-1.9	19.7	15.9	16.7	17.7	16.0	19.3	18.8
310	-0.6	12.6	23.1	21.6	22.6	17.2	21.6	21.8
110	-0.9	5.7	14.6	11.0	9.5	11.8	14.1	15.6

TABLE 10a. Mesoscale model low cloud base forecast and analysis from 06-24 F/C (% F/C minus % OBS plotted in table)

	init	06z	09z	12z	15z	18z	21z	00z
1510	-12.3	-12.4	-11.9	-13.2	-14.0	-12.1	-10.6	-7.7
1010	-10.9	-10.9	-10.8	-14.3	-12.7	-11.9	- 7.9	-5.5
610	-11.2	-11.2	-10.4	-10.8	- 6.0	- 3.9	- 0.3	0.0
310	- 2.4	- 2.5	5.2	8.3	13.0	7.7	11.7	12.4
110	12.3	12.3	16.5	10.7	9.6	11.8	19.6	21.6

TABLE 10b. Fine-mesh model low cloud base forecast and analysis from 06-24 F/C (% F/C minus % OBS plotted in table)

	init	18z	21z	00z	03z	06z	09z	12z
1510	-2.0	15.9	-6.1	-5.0	-6.7	-10.4	-12.7	-13.7
1010	-3.6	22.3	3.2	4.1	3.1	2.2	-2.3	4.6
610	-2.2	19.5	20.3	20.1	20.2	18.7	14.7	13.1
310	-1.0	9.8	21.2	22.9	24.6	25.3	25.5	20.3
110	-0.6	3.1	10.8	12.3	16.5	18.9	17.8	9.7

TABLE 10c. Mesoscale model low cloud base forecast and analysis from 18-12 F/C (% F/C minus % OBS plotted in table)

	init	18z	21z	00z	03z	06z	09z	12z
1510	-12.5	-11.8	-11.5	-9.7	-9.2	-9.8	-10.1	-11.1
1010	-11.2	-10.7	-9.1	-7.8	-8.3	-6.7	-8.2	-11.1
610	-10.5	-9.7	-6.6	-5.1	-4.5	-5.8	-8.8	-11.1
310	-2.8	-3.0	3.0	6.2	9.5	12.7	10.5	10.6
110	5.6	5.4	12.6	17.8	22.0	27.0	26.6	15.6

TABLE 10d. Fine-mesh model low cloud base forecast and analysis from 18-12 F/C (% F/C minus % OBS plotted in table)

Table 11 compares the forecast and observed cloud base climatologies for both models for verification time 15z (T+9 f/c) for the three months, August to October. This verification uses only a subset of airfields all with cloud base recorders. Significant cloud amounts of 5 octas or more have been used. The table shows that the mesoscale model consistently forecast the cloud base to be too low. During August and September, the excess cloud occurred in model levels 310, 610 and 1010. In October, excess cloud was also forecast at 110 m.

	110	310	610	1010	1510	month
OBS	0.7%	3.7%	7.9%	7.4%	25.4%	AUGUST
MES	5.3%	11.9%	18.6%	20.1%	10.7%	"
F.M	0.4%	1.7%	3.2%	5.5%	3.4%	"
OBS	1.1%	4.3%	6.4%	9.1%	15.2%	SEPTEMBER
MES	3.8%	12.3%	13.3%	14.8%	6.8%	"
F.M	2.2%	7.2%	7.9%	6.5%	2.8%	"
OBS	3.5%	9.6%	14.1%	11.4%	6.9%	OCTOBER
MES	11.4%	17.4%	17.0%	6.1%	1.8%	"
F.M	9.8%	9.8%	4.9%	2.6%	1.2%	"

TABLE 11. Cloud base climatology for verification time 15z (cloud amounts 5 octas or more verified, using a subset of 30 stations)

f. WIND VERIFICATION

Table 12 (a) and (b) show the forecast wind errors for both models for both models for the period August to October 1986. The fine-mesh wind speed forecasts for level 1 (25 m) have been multiplied by a factor of 0.85 so that they can be compared fairly with the mesoscale model winds at 10 m and also wind observations.

DATA TIME 06 GMT		VERIFICATION TIME					
MODEL	PERIOD	9	12	15	18	21	00
MES	AUG-OCT	4.8	4.8	5.0	5.3	5.6	5.6
F.M	AUG-OCT	5.1	4.7	5.0	5.5	5.8	5.8

TABLE 12a. R.M.S wind speed errors in knots at 3-hourly intervals during the 06-24 forecast.

DATA TIME 18 GMT		VERIFICATION TIME					
MODEL	PERIOD	21	00	03	06	09	12
MES	AUG-OCT	5.0	5.1	5.3	5.5	5.4	5.2
F.M	AUG-OCT	5.2	5.1	5.3	5.4	5.5	5.1

TABLE 12B. R.M.S wind speed errors in knots at 3-hourly intervals during the 18-12 forecast.

Tables 12 show how close the models are in terms of accuracy. Figure 14 shows the geographical distribution of mesoscale model wind speed errors for T+9, VT 15 GMT during October. The shaded areas represent r.m.s errors greater than 5.0 kt, which is the average value from table 12b. The largest errors occur mainly over the coast or high ground, whilst many inland stations have r.m.s errors less than 4 kt. Figure 14 shows the number of occasions during October when the forecast wind speed error exceeded two Beaufort force.

Table 13 shows the frequency of occurrence of wind speed errors at 06z and 15z during this three month period. Observations and forecasts have been converted into Beaufort forces and errors are partitioned in terms of the number of Beaufort force.

ERROR IN BEAUFORT FORCE (FORECAST - OBSERVED) AUGUST - OCTOBER 1986

VERF. TIME		-3	-2	-1	0	1	2	3
VT06z	(T+12) % MES FCSTS	0.6	2.6	10.8	30.7	34.7	16.3	3.8
VT06z	(T+12) % F.M FCSTS	0.8	4.2	11.8	32.2	36.1	11.5	4.0
VT15z	(T+9) % MES FCSTS	1.2	4.1	16.1	36.5	29.5	10.4	2.1
VT15z	(T+9) % F.M FCSTS	1.0	5.1	18.7	37.7	25.7	9.3	2.6

TABLE 13. Frequency of occurrence of wind speed errors at 06z and 15z during period August to October 1986

Table 13 shows that 76% of mesoscale wind speed forecasts verifying at 06z were correct to within one Beaufort force, compared to 82% for the fine-mesh model. There is a definite tendency for the winds to be too strong. The ratio of strong forecasts to weak forecasts at 06z was 4:1 for the mesoscale model, 3:1 for the fine-mesh. At 15z, the models were very similar with 82% of forecasts correct within one Beaufort force.

Table 14 shows the observed and forecast wind speed climatology for 06z and 15z during the period August to October.

VT	BEAUFORT FORCE	1	2	3	4	5	6	7	8	9
06z	OBS FREQUENCY %	31.6	20.7	20.9	16.2	5.8	3.0	1.0	0.4	0.3
06z	MES FREQUENCY %	9.3	24.8	26.1	24.2	8.9	4.5	1.7	0.3	0.1
06z	F.M FREQUENCY %	9.5	34.0	23.8	19.4	7.4	4.0	1.4	0.4	0.1
15z	OBS FREQUENCY %	14.6	19.9	26.4	24.6	8.7	3.0	1.0	0.4	0.3
15z	MES FREQUENCY %	8.0	17.8	27.4	28.5	8.9	4.5	1.7	0.3	0.1
15Z	F.M FREQUENCY %	10.3	17.6	26.4	28.2	7.4	4.0	1.4	0.4	0.1

TABLE 14. Observed and forecast wind speed climatology VT 06z and 15z for period August to October 1986

Table 14 shows that light wind speeds (Beaufort forces 1 and 2) are underestimated, particularly by the mesoscale model at 06z.52.3% of observed winds at 06z were Beaufort force 1 or 2 compared to 34.1% for the mesoscale model.

Figure 14 shows the number of occasions of mesoscale model wind errors at 06Z greater than two Beaufort force. A significant number of inland stations have errors greater than 2 Beaufort force on more than five occasions.

4. SUBJECTIVE VERIFICATION

Subjective verification is important since it shows how useful the model is in a particular situation. Three ways in which the mesoscale model has bveen compared with subjective forecasts are described in this section.

a. Bracknell Local Area Forecast

A special Bracknell local area forecast for the period 09-24z is prepared daily in CFO using mesoscale model output alone. This is compared with a similar forecast issued by the British Isles Forecaster in CFO prior to receiving the mesoscale model output. The period is divided into five sections, 09-12, 12-15, 15-18, 18-21 and forecasts of weather, cloud, wind and temperature are assessed. The results are described below.

i) Temperature Forecasts

The accuracy of the CFO and mesoscale temperature forecasts are compared in Table 15a, which shows the percentage of forecasts correct within 2 degrees C.

MONTH	VT 12z		VT15z		VT18z		VT21z		VT00z	
	MES	CFO	MES	CFO	MES	CFO	MES	CFO	MES	CFO
AUGUST	69	83	76	83	76	90	76	86	55	72
SEPTEMBER	80	90	77	77	80	83	55	62	34	65
OCTOBER	87	87	87	90	84	81	65	68	61	71

TABLE 15a. Percentage of Bracknell Temperature forecasts correct within 2 degrees C.

August was the worst month for the mesoscale model overall and CFO were better at all verifying times. In September, the forecasts verifying at 21z and 00z were the least accurate issued by both CFO and the mesoscale model. These forecasts reflect the problems of low cloud and fog. The mesoscale model was equally accurate in October during the period 09-18z but developed a warm bias of 1-2C during the evening due to too much cloud. In general, CFO forecast the temperature better on clear evenings, since the forecasters could allow for the coldness of Beaufort Park. However, the mesoscale model was sometimes better on cloudy evenings, due to a tendency for CFO to forecast partial cloudiness.

VERIFICATION TIME	12	15	18	21	00	OVERALL
CFO BETTER BY >2C	19%	19%	10%	26%	38%	22%
CFO BETTER BY 1C	23%	16%	24%	18%	17%	20%
FORECASTS SAME	27%	34%	30%	24%	16%	26%
MES BETTER BY 1C	21%	19%	21%	13%	13%	17%
MES BETTER BY >2C	10%	11%	14%	18%	16%	14%

TABLE 15B. Subjective assessment of the accuracy of CFO and mesoscale model temperature forecasts for Bracknell during the period August to October 1986

Table 15b confirms the superiority of CFO temperatures during the evening.

ii) Wind Forecasts

The comparison between the CFO and mesoscale model wind forecasts for Bracknell is shown in Table 16. The criteria used to judge which forecast was more accurate is described below:

CFO forecast was more accurate if the magnitude of the mesoscale model wind vector error >5 kt larger than the magnitude of the CFO wind vector error, and vice-versa.

FORECAST PERIOD	09z-12z	12z-15z	15z-18z	18z-21z	21z-00z
CFO MORE ACCURATE	40%	31%	21%	16%	30%
FCSTS SAME	37%	30%	59%	66%	53%
MES MORE ACCURATE	23%	28%	20%	18%	17%

TABLE 16. Subjective assessment of the accuracy of CFO and mesoscale model wind forecasts for Bracknell during the period August to October 1986.

Overall, there was little to choose between the wind forecasts issued by CFO and the mesoscale model.

ii) Forecasts of Cloud Amount

Forecast Period	09z-12z	12z-15z	15z-18z	18z-21z	21z-00z
CFO MORE ACCURATE	31%	36%	34%	30%	36%
FORECASTS SAME	42%	33%	23%	34%	27%
MES MORE ACCURATE	27%	31%	42%	36%	36%

TABLE 17A. Subjective assessment of the accuracy of CFO and mesoscale model cloud forecasts for Bracknell during the period August to October 1986

MONTH	AUGUST	SEPTEMBER	OCTOBER	OVERALL
MESOSCALE MODEL (% correct forecasts)	57%	43%	57%	52%
CFO (% correct forecasts)	63%	55%	63%	60%
CLOUD AMOUNTS. RATIO OVER TO UNDER PREDICTED				
MESOSCALE MODEL	0.82	2.35	2.58	1.92
CFO	0.59	0.67	0.68	0.64

TABLE 17B. The accuracy of CFO and mesoscale model cloud amount forecasts for Bracknell during the period August-October 1986

TABLE 18. Climatology of Cloud Amounts-Observed and Forecast-for Bracknell during the period August to October 1986.

	AUGUST			SEPTEMBER			OCTOBER		
OCTAS	B	P	C	B	P	C	B	P	C
FCST	0-4/8	5-6/8	7-8/8	0-4/8	5-6/8	7-8/8	0-4/8	5-6/8	7-8/8
OBS	17%	32%	52%	36%	32%	32%	32%	25%	43%
MES	20%	31%	50%	20%	33%	47%	19%	29%	52%
F.M	25%	34%	41%	38%	42%	20%	36%	29%	35%

August was the best month for the mesoscale model, with forecast errors of too little cloud balancing forecast errors of too much cloud. In September, the problems of fog/low cloud formation and clearance proved difficult for both forecasters and model and this was the least accurate month. The mesoscale model tended to forecast too many cloudy periods, whilst CFO forecast too many occasions of partial cloudiness.

PERIOD	MES F/C ACCURACY	CFO F/C ACCURACY
09-12	76%	63%
12-15	71%	81%
15-18	52%	45%
18-21	50%	55%
21-24	40%	67%

TABLE 19

Accuracy of cloud forecasts during the period 09-24

Table 19 shows the decrease in the accuracy of mesoscale model forecasts of cloud amounts with time. The least accurate time for the mesoscale model is the period 21-24, and for CFO 15-18. Tables 20 (a) and (b) below compare the forecasts at these two times.

	PERIOD 15-18				PERIOD 21-24		
	B	P	C		B	P	C
FCST	0-4/8	5-6/8	7-8/8	FCST	0-4/8	5-6/8	7-8/8
OBS	37%	16%	47%	OBS	45%	25%	30%
MES	24%	29%	47%	MES	13%	28%	59%
CFO	32%	37%	31%	CFO	50%	17%	34%

Table 20a, b. Climatology of cloud amount forecasts from CFO and mesoscale model during the periods 15-18 and 21-24, for October

Both CFO and the model forecast too many occasions of partial cloudiness (P) during the period 15-18. However the errors differed. The mesoscale model tended to over-predict cloud amounts, whereas CFO tended to under-estimate the amount.

iv) Weather forecasts

	09z-12z	12z-15z	15z-18z	18z-21z	21z-00z
CFO MORE ACCURATE	19%	9%	11%	11%	23%
FCSTS SAME	60%	79%	79%	79%	64%
MES MORE ACCURATE	12%	12%	10%	10%	12%

TABLE 21. Subjective assessment of the accuracy of CFO and mesoscale model weather forecasts for Bracknell during the period August to October 1986

In general, the mesoscale model rain forecasts were similar to those from CFO during the period 09-18z. However, CFO were better during the evening, due to the mesoscale model forecasting fog too early on some occasions.

b. Temperature Forecasts for Gas Boards

A useful way of assessing the quality of model temperature forecasts is to see how well they compare with temperature forecasts issued by Weather Centres for a 12-18 hour period. Temperatures taken from the fine-mesh and mesoscale model forecasts for five stations were compared with those issued by forecasters at the respective Weather Centres to the Gas Board industry. Three verification times were chosen, 08z, 12z and 18z. The results are summarised in Table 21 below.

VERIFYING TIME 08Z D.T18Z	AUGUST			SEPTEMBER			OCTOBER		
STATION	MES	W.C	F.M	MES	W.C	F.M	MES	W.C	F.M
GLASGOW	85	92	-	52	87	-	79	71	-
SOUTHAMPTON	88	83	-	-	-	-	83	83	-
MANCHESTER	77	96	-	52	91	-	86	79	-
WATNALL	69	100	-	52	69	-	62	70	-
RHOOSE	96	93	-	26	88	-	59	83	-

VERIFYING TIME 12z D.T18z	AUGUST			SEPTEMBER			OCTOBER		
STATION	MES	W.C	F.M	MES	W.C	F.M	MES	W.C	F.M
GLASGOW	41	89	54	74	96	63	65	87	41
SOUTHAMPTON	56	87	61	-	-	-	65	83	62
MANCHESTER	59	93	89	81	92	78	69	87	72
WATNALL	59	86	65	67	72	70	76	87	69
RHOOSE	63	93	81	89	71	89	90	87	86

VERIFYING TIME 18z D.T06z	AUGUST			SEPTEMBER			OCTOBER		
STATION	MES	W.C	F.M	MES	W.C	F.M	WES	W.C	F.M
GLASGOW	54	86	64	71	96	93	84	92	77
SOUTHAMPTON	86	83	82	-	-	-	87	92	93
MANCHESTER	68	86	82	75	100	82	93	92	90
WATNALL	68	86	86	75	100	82	84	80	71
RHOOSE	89	93	96	89	93	79	81	84	74

TABLE 22. Comparison between model temperature forecasts for 08z, 12z, 18z and corresponding subjective temperature forecasts issued by weather centres to the Gas Industry. Figures quoted give the percentages of forecasts correct within 2C.

% OVERALL CORRECT	MESOSCALE MODEL		WEATHER CENTRE		FINE-MESH MODEL	
WITHIN 2C/3C	2C	3C	2C	3C	2C	3C
D.T 18z V.T 08z	69%	82%	85%	94%	-	-
D.T 18z V.T 12z	68%	87%	86%	96%	70%	87%
D.T 06z V.T 18z	79%	92%	90%	96%	64%	95%

TABLE 22. Comparison of the accuracy of CFO and model temperature forecasts for five stations for the period August-October 1986

In this intercomparison, temperatures were verified only on those days when forecasts were available from the Weather Centres as well as from both models. The most reliable forecasts were those issued by the Weather Centres, with an average accuracy within 2C of 87% for the five stations, compared to 72% for the mesoscale model and 67% for the fine-mesh model.

c. Cloud Base Forecasts for Heathrow Airport

Cloud base forecasts from the mesoscale model for the period 10-19 (F.T 06z) were compared with those taken from the routine 10-19.

Heathrow TAF Cloud base forecasts below 1500 feet only were verified. There were some obvious problems involved with using model output to forecast significant low cloud. First, the model's vertical resolution is too coarse. Change groups are used in TAFS whenever the cloud base is forecast to move over the levels 200 ft, 500 ft, 1000 ft, and 1500 ft. The mesoscale model can only forecast bases of 300 ft, 1000 ft and 2000 ft. Model cloud base changes tend to be abrupt rather than gradual, i.e from 8 octas at 300 ft to 8 octas at 1000 ft in one hour. There is also the problem of the best way to interpret change groups such as tempo and prob from model output. The results are shown in Table 23 below. Significant cloud amounts (5 octas or more) only have been verified.

D.T 06z V.T 15z				TAF ISSUE 09z			
MES	OBSERVED			FCR	OBSERVED		
FCST	110m	310m	above	FCST	110m	310m	above
110m	0%	4%	13%	110m	0%	0%	0%
310m	0%	4%	4%	310m	0	9%	13%
above	0%	4%	70%	above	0%	4%	74%

Table 24a

Comparison between cloud base forecasts issued by the mesoscale model and by forecasters at Heathrow. (Note: No Tempos included)

Within the limitations described above, the mesoscale model forecasts of cloud base compared quite well with the base given by the Heathrow TAFs for 15 GMT, but note that on 13% of occasions the model forecast the cloud base at 110 m incorrectly.

D.T 18z V.T 06z				TAF ISSUE 21z			
MES	OBSERVED			FCR	OBSERVED		
FCST	110m	310m	above	FCST	110m	310m	above
110m	4%	9%	30%	110m	9%	0%	4%
310m	4%	0%	4%	310m	0	13%	4%
above	4%	9%	35%	above	4%	4%	61%

Table 24b

Comparison between cloud base forecasts issued by the mesoscale model and by forecasters at Heathrow. (Note: no Tempos included)

Using the model output to forecast the cloud base for Heathrow at night was much more difficult due to the model tendency to forecast excessive cloud at the lowest level 110 m. (See table 24b, 12% cloud observed at 110 m, 43% forecast by the mesoscale model, 13% forecast by Heathrow.)

5. SUMMARY

The mesoscale model produced forecasts on 95% of possible occasions during the period August to October 1986. Only one missed forecast was due to a model failure. However, there were no hot, humid, thundery spells to test the model's deep convection scheme.

The model is still over-predicting rainfall accumulations. The main cause is the over-prediction of convective rain by a factor of two to four. However, peak totals over high ground in Scotland, Wales and South-west England are very well forecast by the model.

The model was fairly successful in predicting fog during the anticyclonic spell 15 September-13 October. However, in that situation, forecasters would have predicted fog confidently without any model guidance. To be useful, the model needed to predict times of formation and clearance fairly accurately.

In general, the model predicted fog too early during the evening and dispersed the fog too quickly during the morning. (Error 1-3 hours for both.)

During August and September, the mesoscale model was slightly less accurate in predicting temperatures than the fine-mesh. This position altered in October, with the mesoscale model becoming more accurate in predicting daytime temperatures. However, the main problem is the systematic warm bias in the mesoscale model's night-time temperatures, caused by the over-prediction of low cloud.

During the summer months, daytime cloud amounts and bases were reasonably well predicted by the model. However, the model predicts too much cloud, too low, generally overnight.

LIST OF FIGURES

OBSERVED RAINFALL ACCUMULATIONS FOR OCTOBER.

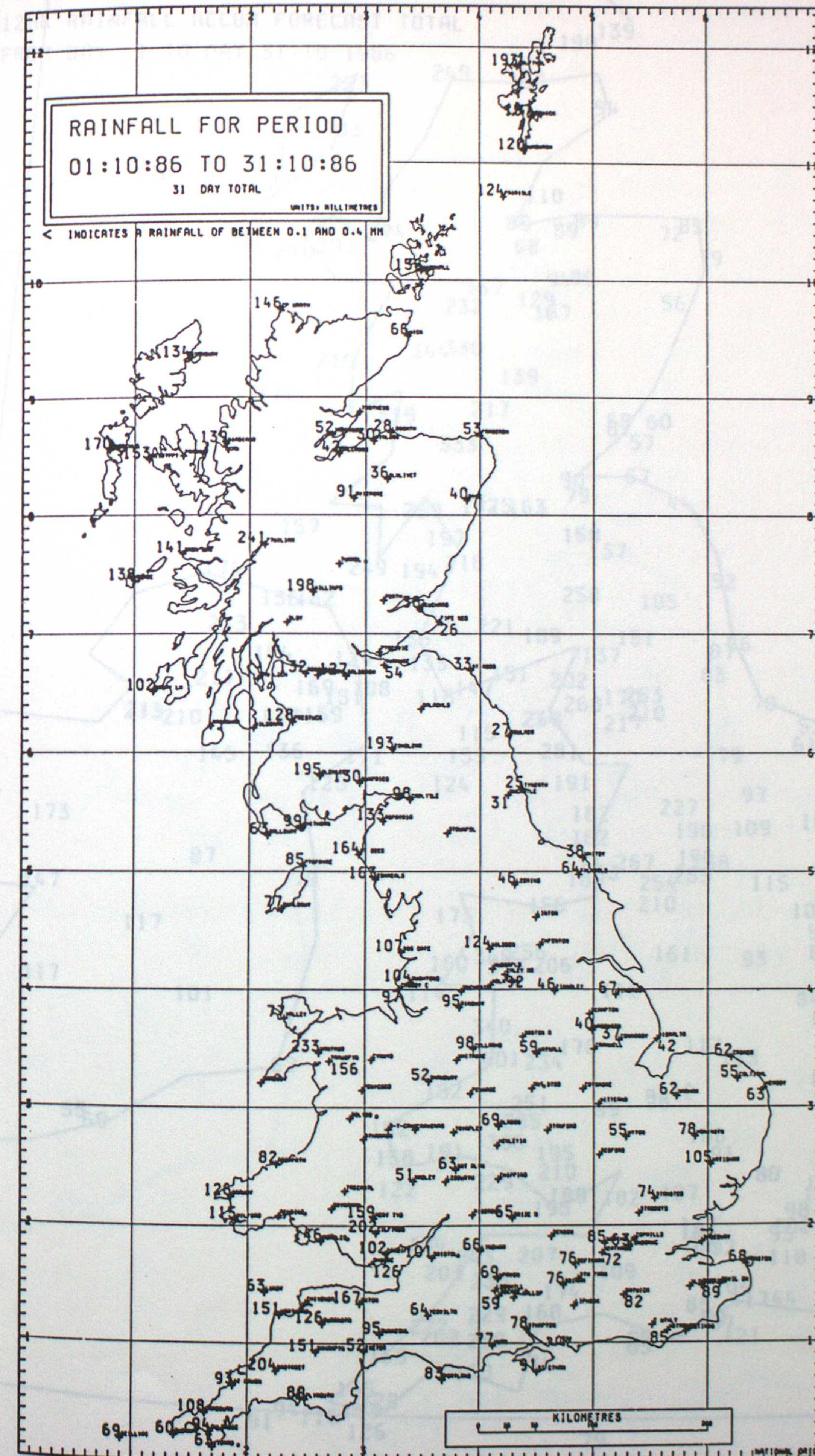


figure 1

MESOSCALE MODEL FORECAST TOTAL RAINFALL ACCUMULATIONS FOR OCTOBER

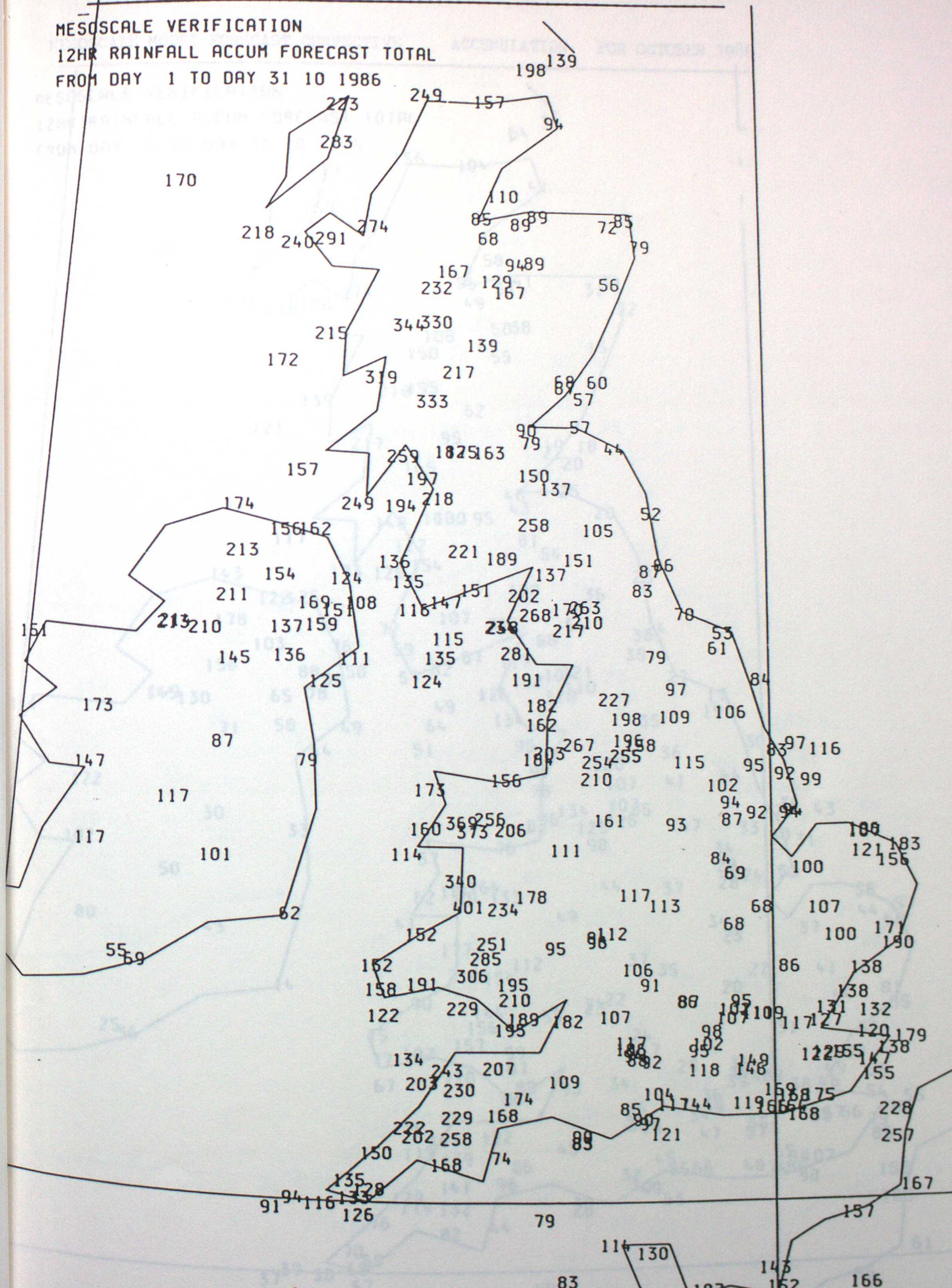


figure 2

MESOSCALE MODEL FORECAST CONVECTIVE ACCUMULATION FOR OCTOBER 1986

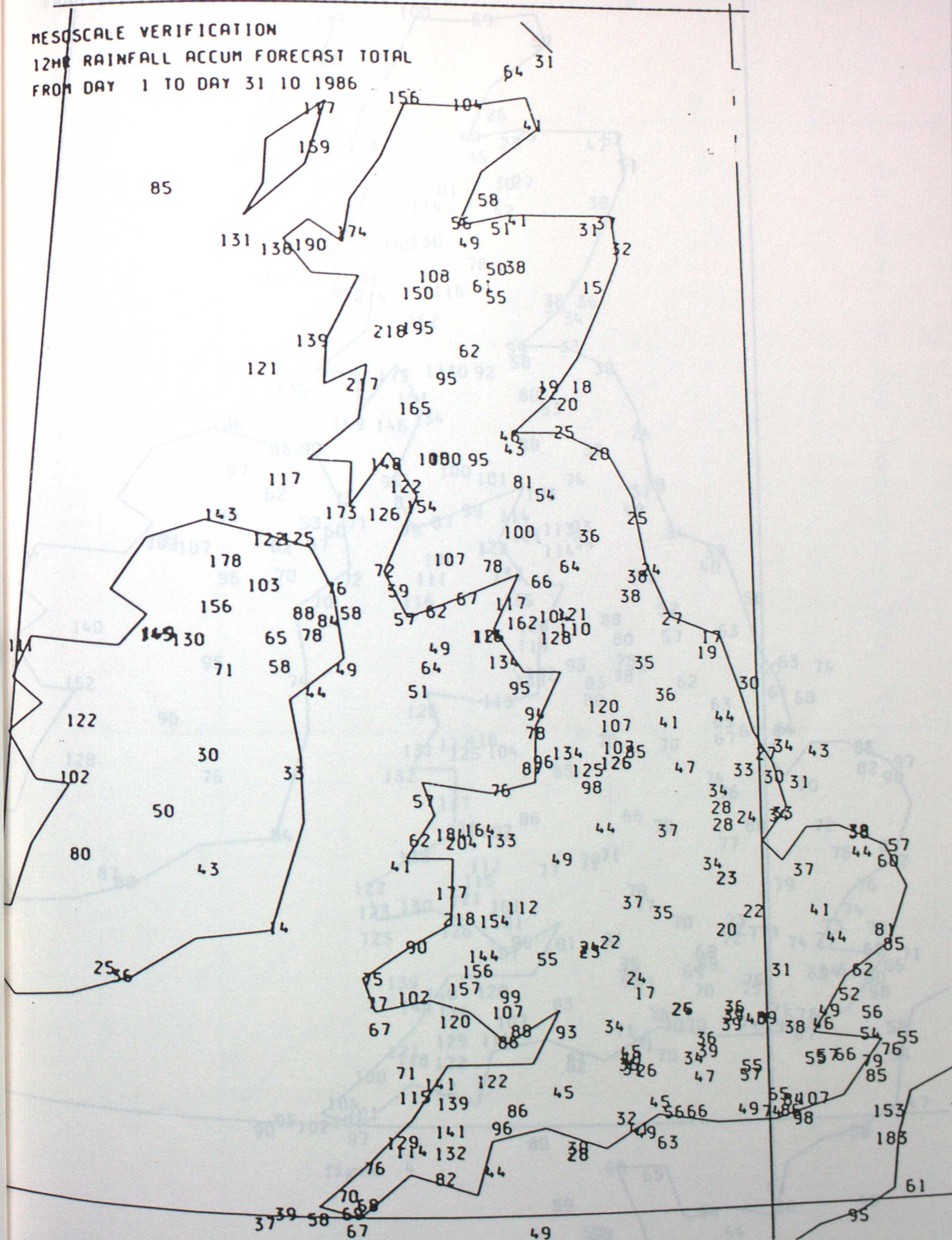


FIGURE 3

FINE MESH MODEL FORECAST TOTAL RAINFALL ACCUMULATIONS FOR OCTOBER1986

FINE MESH VERIFICATION

12HR RAINFALL ACCUM FORECAST TOTAL

FROM DAY 1 TO DAY 31 10 1986

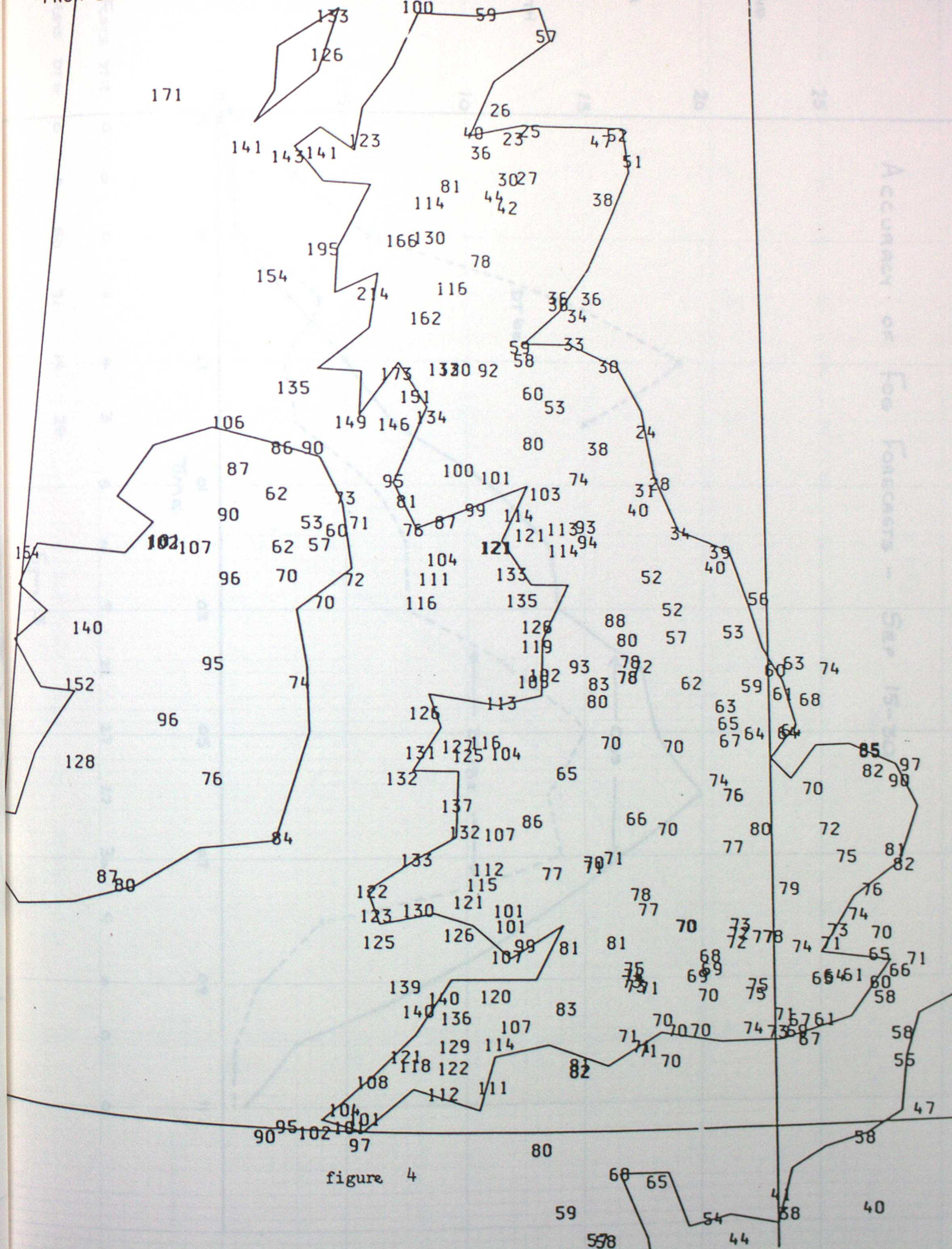
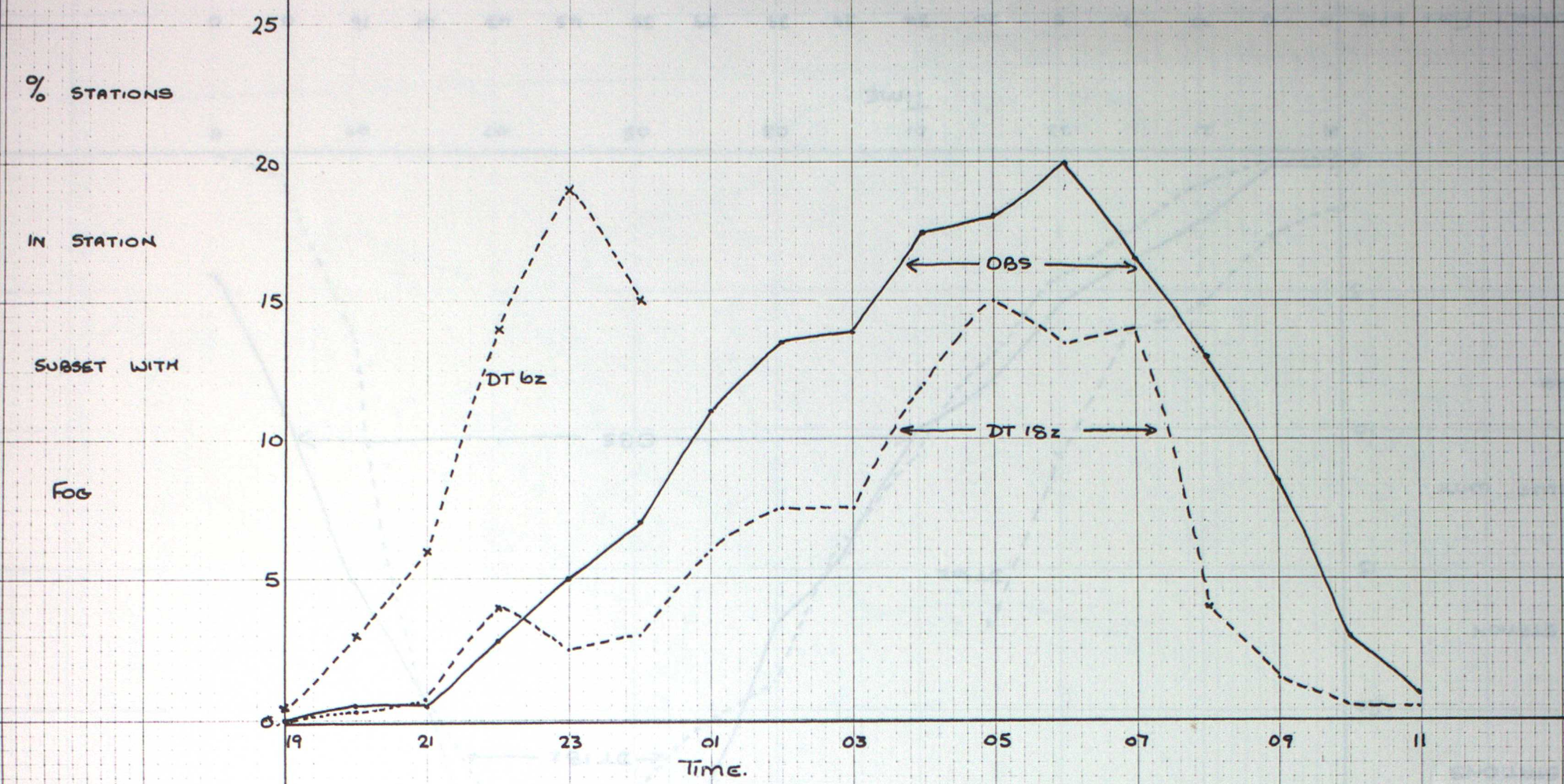


figure 4

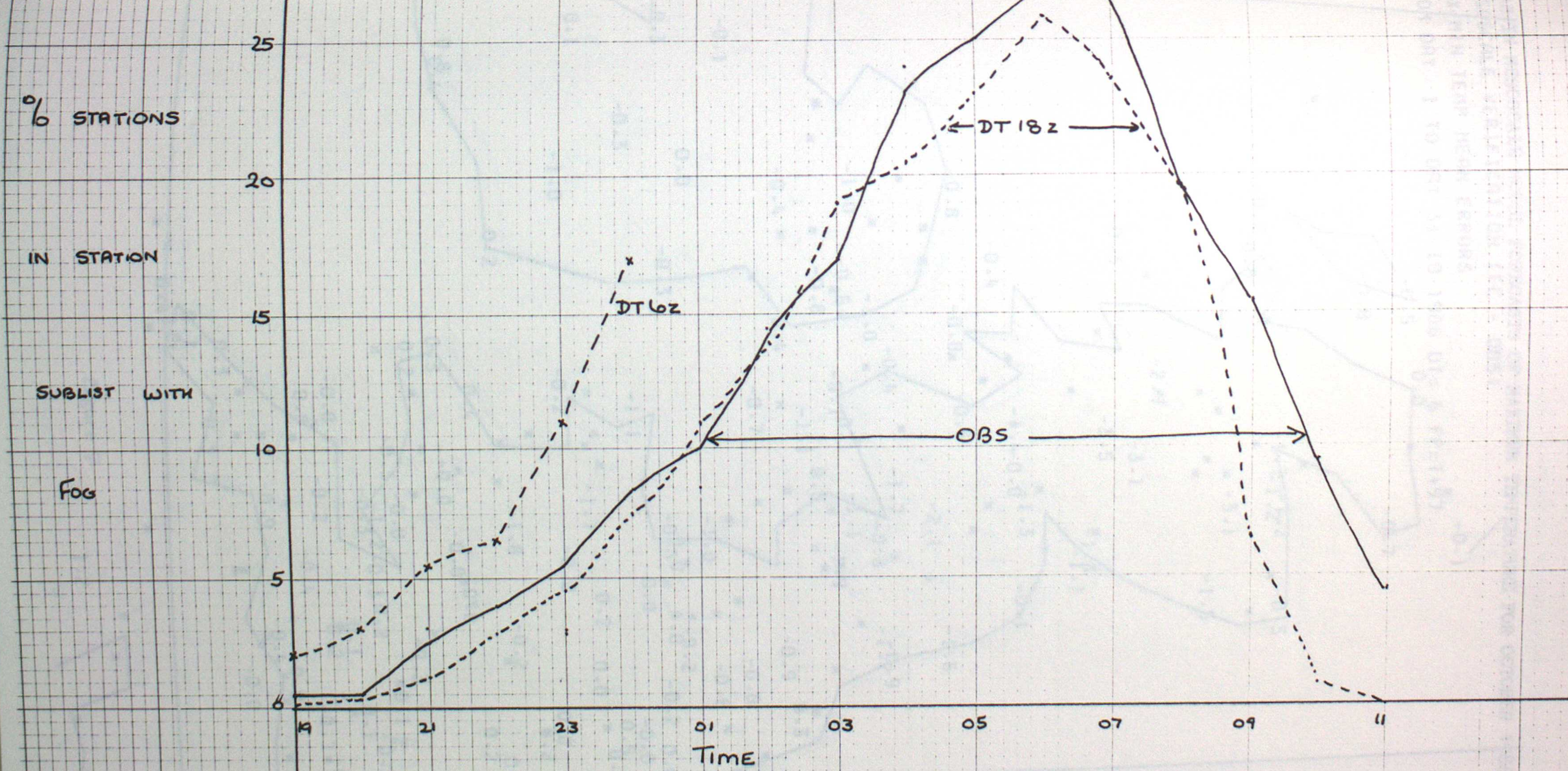
Accuracy of Fog Forecasts - Sep 15-30



% Correct Fcsts DT18	0	0	0	11	4	3	5	4	9	22	27	27	30	9	0	0	0
% Correct Fcsts DT6	0	0	50	31	19	28											

Figure 5

Accuracy of Fog Forecasts - Oct 1-13



% Correct Fcsts DT18	0	0	0	7	5	20	34	29	39	39	38	45	43	41	16	0	0
% Correct Fcsts DT 6	0	50	13	22	31	33											

Figure 6

BIAS IN MESOSCALE MODEL FORECASTS OF MAXIMUM TEMPERATURE FOR OCTOBER 1986

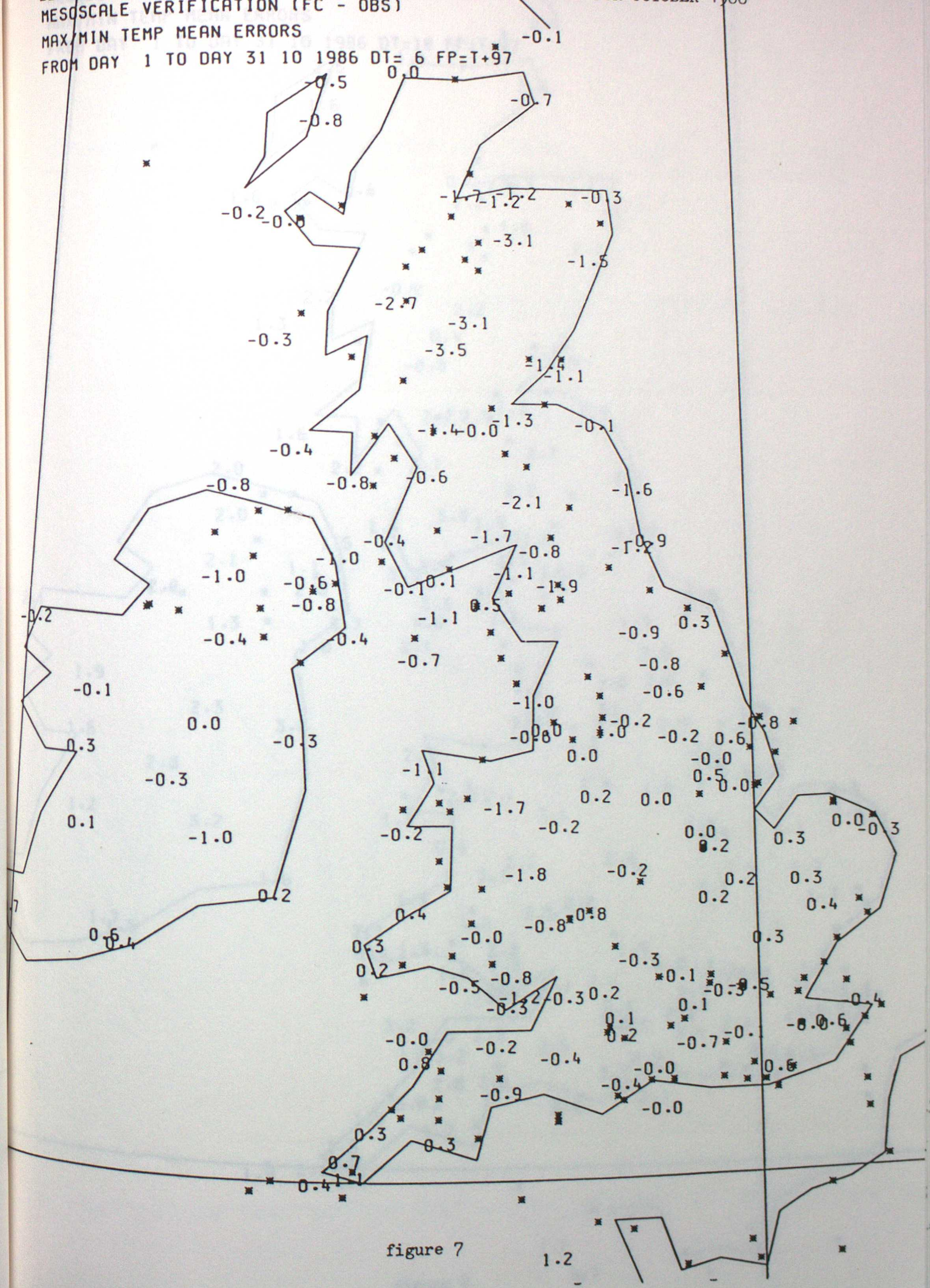


figure 7

BIAS IN MESOSCALE MODEL FORECASTS OF MINIMUM TEMPERATURE FOR OCTOBER 1986

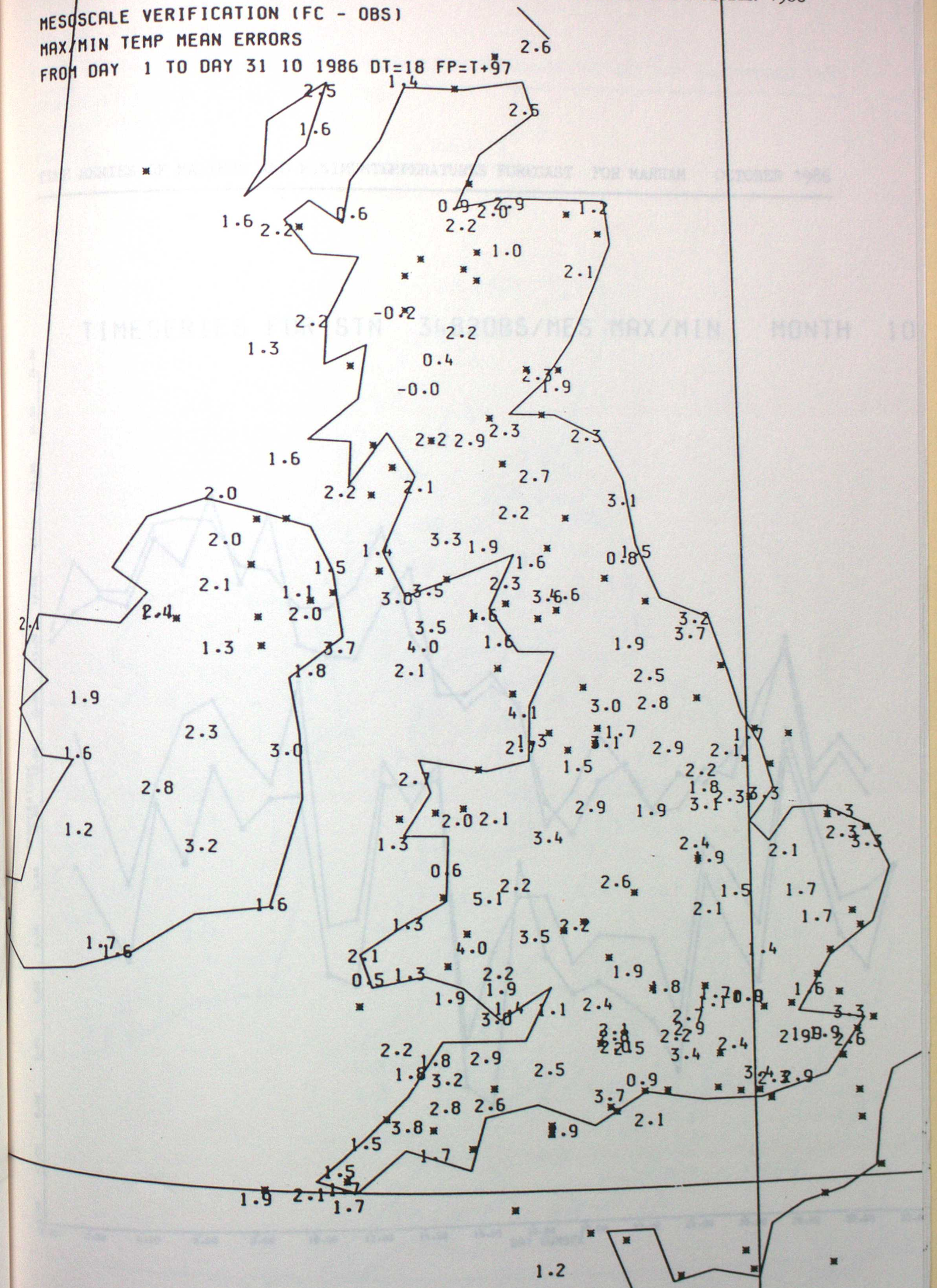


figure 8

TIME SERIES OF MAXIMUM AND MINIMUMTEMPERATURES FORECAST FOR MARHAM OCTOBER 1986

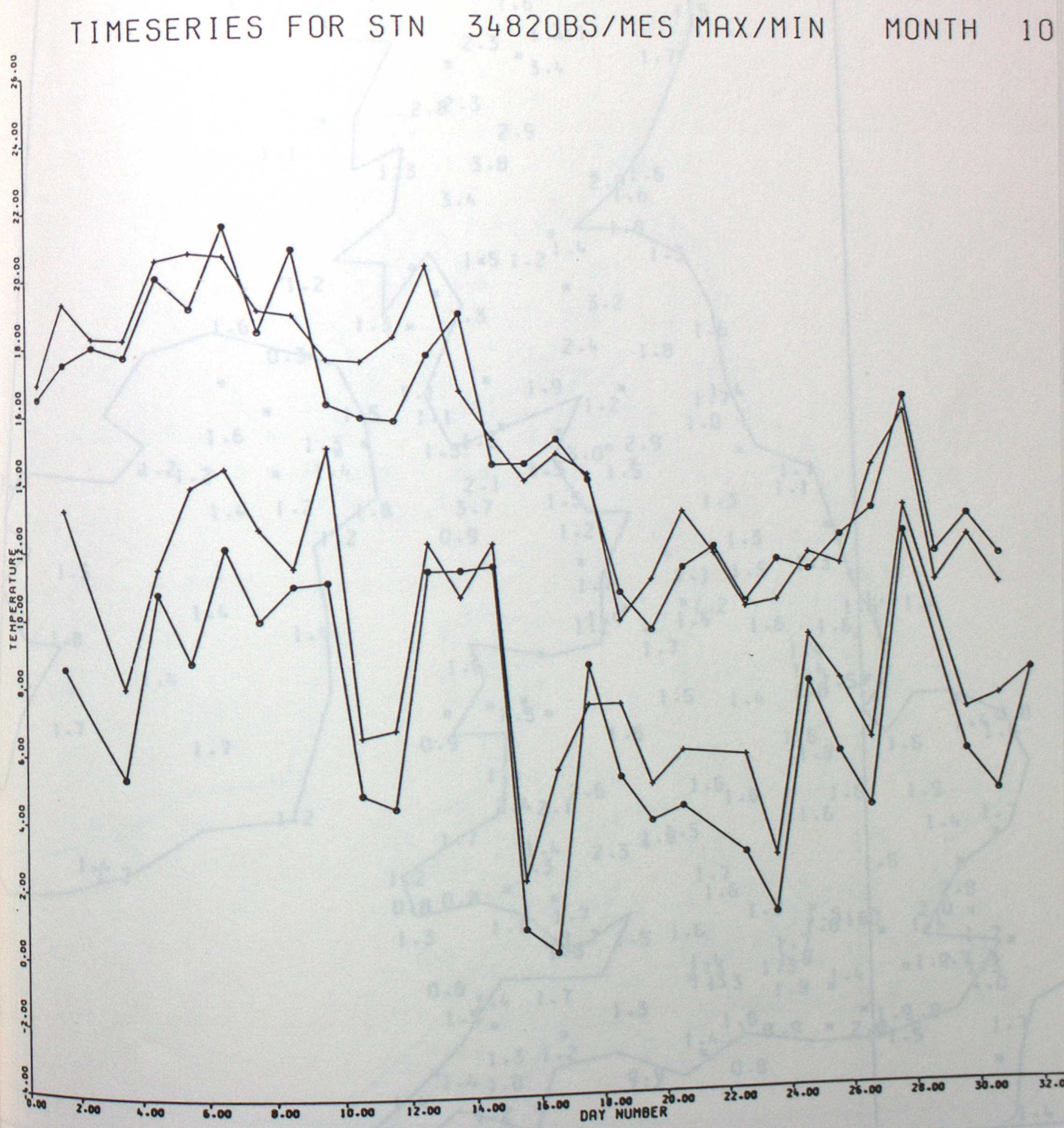


figure 9

R.M.S ERRORS FOR MESOSCALE MODEL TEMPERATURES FORECASTS.D.T 06Z V.T 15z.OCTOBER 1986

FIGURE 10

R.M.S ERRORSFOR FINE MESH MODEL TEMPERATURES FORECASTS D.T 6Z V.T15Z OCTOBER 1986

FINE MESH VERIFICATION (FC - OBS)

TEMPERATURE RMS ERRORS

FROM DAY 1 TO DAY 31 10 1986 DT= 6 FP=T+ 9

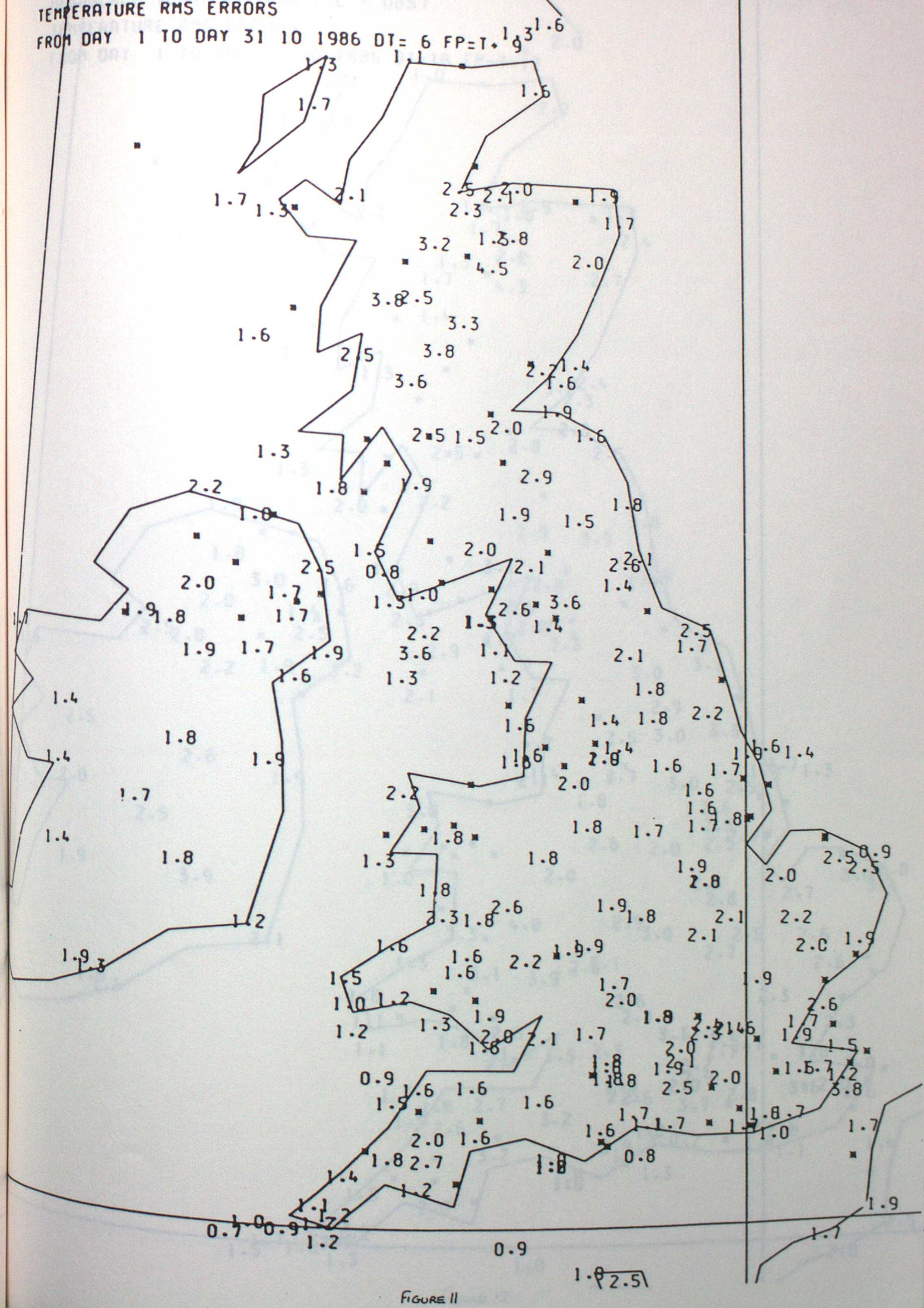


FIGURE 11

RMS ERRORS FOR MESOSCALE MODEL TEMPERATURES FORECASTS D.T 18z VT06Z OCTOBER 1986

FIGURE 12

R.M.S. ERRORS FOR FINE MESH MODEL TEMPERATURE FORECASTS D.T 18Z V.T 06Z OCTOBER 1986

FINE MESH VERIFICATION (FC - OBS)

TEMPERATURE RMS ERRORS

FROM DAY 1 TO DAY 31 10 1986 DT=18 FP=T+12

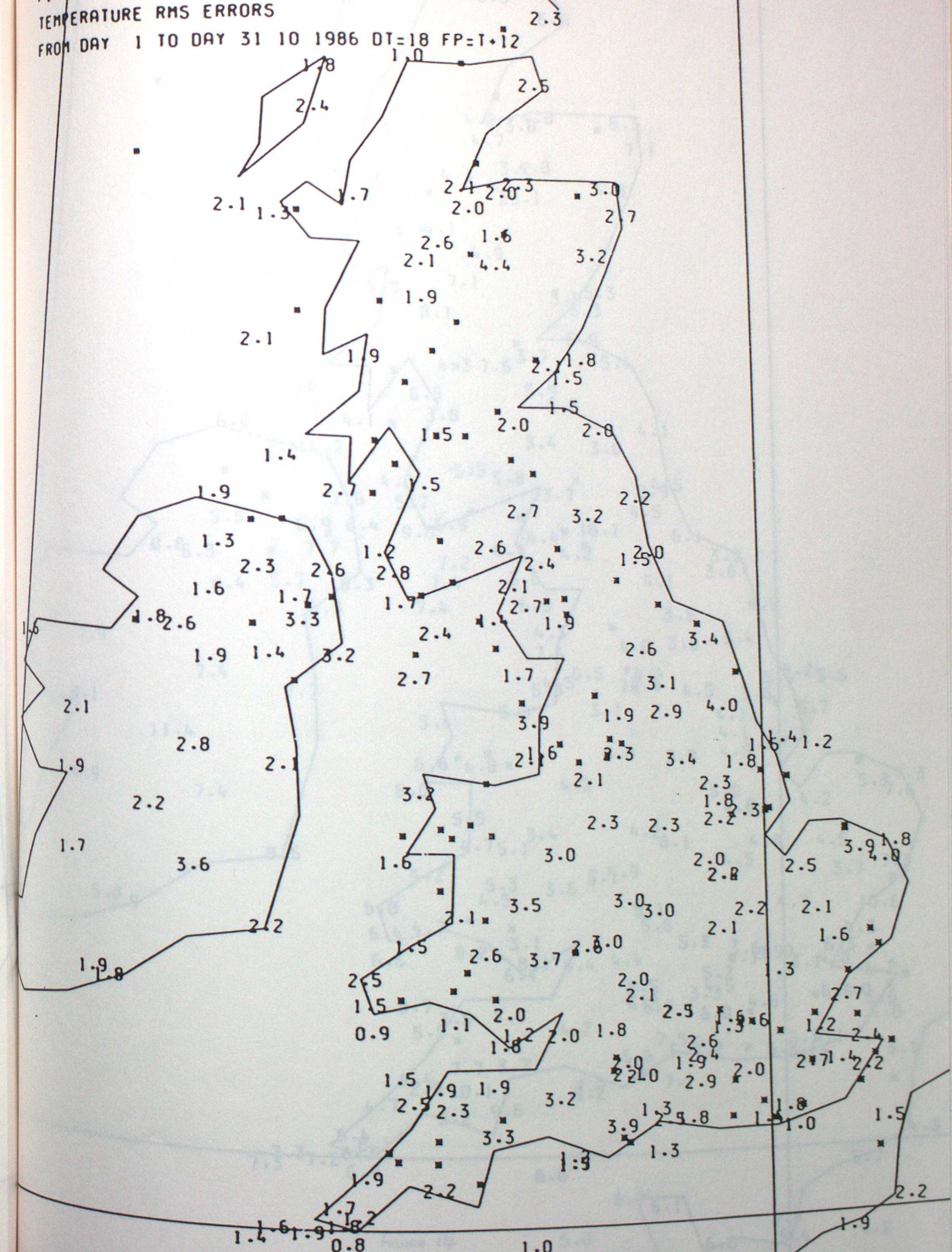


Figure 13

R.M.S. ERRORS FOR MESOSCALE MODEL WIND SPEED FORECASTS D.T 06Z V.T 15Z OCTOBER 19

MESOSCALE VERIFICATION (FC - OBS)

WIND SPEED RMS ERRORS

FROM DAY 1 TO DAY 31 10 1986 DT= 6 FP=T+ 9

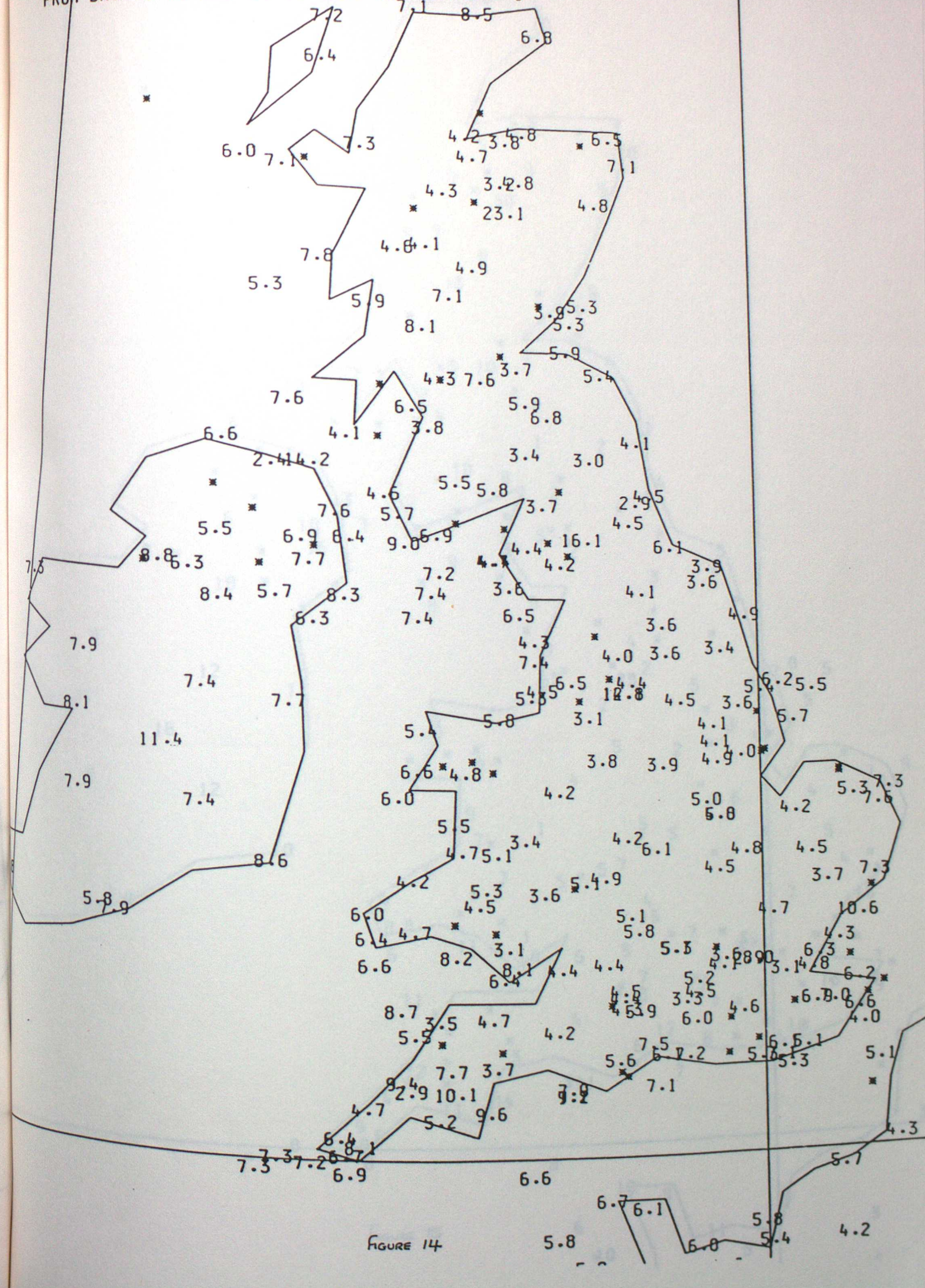


FIGURE 14

NUMBER OF OCCASIONS DURING OCTOBER, WHEN THE MESOSCALE MODEL FORECAST WIND SPEED ERROR EXCEEDED 2 BEAUFORT FORCE

MESOSCALE VERIFICATION

NO. OF WIND FC IN ERROR BY 2 B.F.OR MORE

FROM DAY 1 TO DAY 31 10 1986 DT= 6 FP=T+ 9

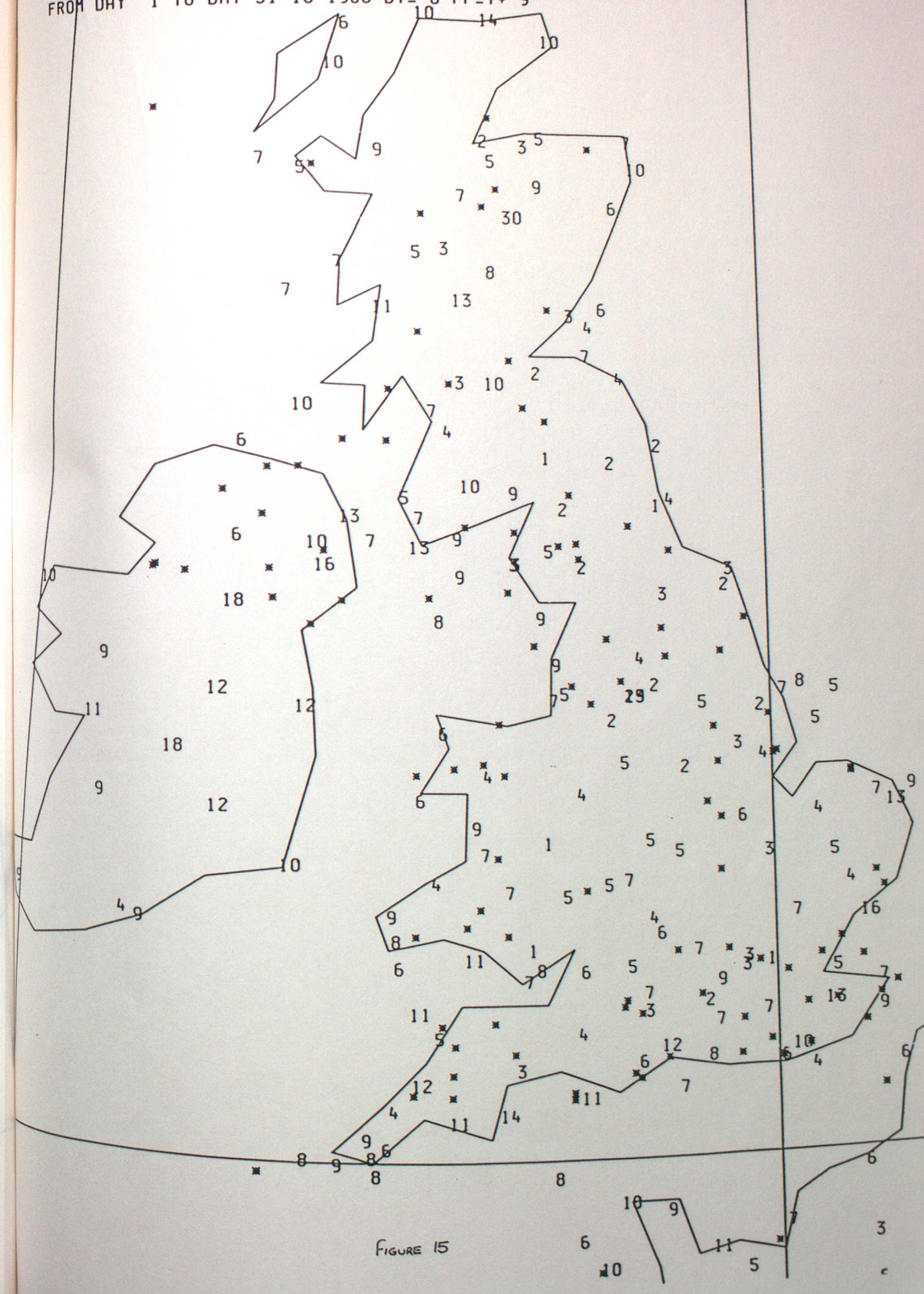


FIGURE 15