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Results from Mesoscale Model Trial from November 1985 to January 1986

by R. S. Bell and O. Hammon

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Met O 11
London Road
Bracknell, Berks

1. Introduction

The mesoscale model has provided forecasts twice daily since April 1985 and this is the third in a series of reports on the model's performance. The report will consider the results of objective and subjective verifications for the three month period November 1985 to January 1986. The format of the trial has changed slightly from that described by Bell (1985a). The major change has been an extension of the overnight forecast, which now runs for 18 hours. This gives us an opportunity to assess the morning temperature and fog forecasts, when dawn occurs after 6z. The subjective assessment has also changed. The model is now marked according to how accurately it forecasts specific weather elements, frost, fog, low cloud, rain and snow. There are strict criteria being used to decide if the forecast is successful and these are detailed in section three.

Several changes to the model have occurred during recent months and some of the problems highlighted in the previous report (Bell, 1985b) have been alleviated. The main changes are as follows: On 26th November, a data assimilation scheme was introduced and from that date the first guess for each initialisation contains boundary layer and cloud information solely from a mesoscale forecast and remaining information from a mixture of mesoscale forecast and fine-mesh forecast. Although verification results from comparison runs with the assimilation scheme have been inconclusive, it was recognised that such a scheme would become crucial once parts of the country became snow-covered. Two other changes at the end of November were introduced to eliminate some of the problems which have been responsible for recent model failures. The boundary conditions were altered to specify values rather than gradients of potential temperature and the time smoothing coefficient was doubled. The first of these two changes also removed the erroneous advection of very cold air from the southeast boundary which had an adverse effect on temperature forecasts for south-east England. At the end of December, the turbulence scheme was tuned to give more realistic cloud fractions and a change was made to limit the moisture availability when the ground is wet as an interim measure to counteract the tendency to forecast an excessively moist surface. The more realistic cloud fractions from the model are also expected to have an indirect impact on the surface temperature forecasts. On the 7th January, a new convection scheme was introduced in which the response to the mass transport in the cloud is treated explicitly instead of being parametrized. It is also relevant to mention the fine-mesh changes which were made in December. The inclusion of divergence diffusion in the fine-mesh forecast would have provided the mesoscale model with smoother first guess and boundary information. Also, the parametrization of the deep soil heat flux improved fine-mesh surface temperature forecasts and this would have a beneficial impact on the mesoscale model.

One of the successes during this period was the dramatic reduction in the number of model failures following the improvements described above. There were 18 failures during November with all but two of those due to model instability. In both December and January there were 60 successful forecasts and of the four failures in that two month period, only one case was attributed to model instability.

2. Results of the Objective Verification

To provide some continuity between this report and the previous one, the results of the objective verification will be presented in the same way. As before, rather more attention will be paid to the last month in the three month period because it reflects the current status of the model. The model forecasts of each variable will be considered separately in the following sub-sections. Mention will be made of any significant change in model skill as a result of the modifications to the model. In particular, changes have had an impact on surface temperature forecasts and also on surface moisture forecsts, fog forecasts and low cloud forecasts. Special attention will be paid to several aspects of the weather during the period, including the large rainfall totals in December and January, the strong winds and the snow forecasts.

(a) Temperature forecasts

The r.m.s. temperature errors for mesoscale model forecasts and comparison fine-mesh model forecasts are shown in Figure 1. All available synoptic reports and all forecasts are included in the statistics.

	Data Time	6	6	6	6	18	18	18	18
	Verif Time	9	12	15	18	21	00	03	06
Model	Month								
mes	Nov	2.2	1.9	1.7	2.3	2.1	2.3	2.3	2.6
mes	Dec	1.7	1.7	1.7	2.0	1.6	1.8	2.0	2.1
mes	Jan	1.6	1.7	1.7	1.7	1.6	1.7	1.9	1.9
fm	Nov	4.3	3.3	2.4	2.5	2.7	2.9	3.3	3.5
fm	Dec	3.0	2.4	2.0	2.2	2.5	2.7	2.9	3.0
fm	Jan	2.3	1.9	1.8	1.9	2.1	2.1	2.2	2.3

Table 1 r.m.s. temperature errors

During the August to October period, mesoscale model temperature errors increased markedly for forecasts verifying at 6z. Minimum temperature prediction is, of course, more difficult in winter months. However part of the problem seemed to be related to contamination by the fine-mesh through the initialisation process and the lateral boundary updating in the south-east,because the fine-mesh forecast had large cold biases which increased with shortening day light period. November was even worse in this respect as can be seen from table 1. However, the changes to the fine-mesh model during December, the adjustment to the lateral boundary updating of the mesoscale model and the improvement in forecasts of fractional cloud cover which were discussed in the introduction have reversed the deteriorating trend. The improvements in fine-mesh temperature prediction between November and January has been quite dramatic, however mesoscale model predictions have also improved substantially and still show an appreciably greater level of skill.

Figures 1 and 2 show the geographical distribution of r.m.s. maximum and minimum temperature errors respectively for January 1986. The values for central England stations which are not influenced by complicating coastal and topographic effects are exceptionally low in both figures and significantly lower than the values in table 1. Typical r.m.s. maximum temperature errors are about 1°C over a large area of England and r.m.s. minimum temperature errors for the same areas are below 1.5°C. Mean temperature errors are now quite small; the significant cold bias having been removed at the end of November, a slight warming of less than 0.5°C is seen in statistics for December and January for both daytime and nighttime runs.

Range of Temperature Error (°C) (F/C - OB)	<-4	-4 to -3	-3 to -2	-2 to -1	-1 to 0	0 to 1	1 to 2	2 to 3	3 to 4	>4
Max. temps										
November	0.6	0.7	3.3	14.3	25.4	28.0	17.0	7.0	2.3	1.4
December	0.7	0.7	2.9	14.2	31.9	26.5	12.7	5.6	2.2	2.6
January	0.0	0.1	1.3	9.7	26.1	31.5	20.3	7.8	2.6	0.7
Min. temps										
November	5.4	3.5	7.1	11.6	16.9	21.6	13.2	8.6	5.4	6.7
December	1.0	1.5	3.4	7.3	17.4	25.8	19.8	11.9	6.2	5.9
January	0.5	0.6	2.2	7.5	19.0	25.8	21.5	12.3	6.0	4.6

Table 2 Frequency of occurrence of errors in extreme temperature forecasts expressed as % of total

Table 2 shows the percentage of forecasts of maximum and minimum temperature whose errors fall into given categories. There is a clear tendency for both maximum and minimum temperature to be too warm, rather more often than they are too cold. The table also shows the improvement during the three month period. The number of maximum temperature forecasts in error by more than 2°C has decreased over the period from 15.3% to 12.4%. The proportion of minimum temperature forecasts in error by 2°C has decreased even more noticeably from 36.7% to 26.2%. One aspect of November forecasts which was particularly worrying was the very large number of minimum temperature forecasts in error by more than 4°C (12.1%). The comparable figure for January is a much more acceptable 5.1%. Figures 3 and 4 show the number of forecast temperatures, for daytime maxima and nighttime minima respectively, whose errors exceed 2°C. It has already been pointed out, in reference to the rms errors, that low-lying inland station are forecast much better than coastal or high ground stations. The percentage figures from table 2 translate to an average of four forecasts each month being in error by 2°C during the daytime and an average of eight forecasts each month which are in error by 2°C or more overnight. In fact very few inland stations reach these average figures. In figure 3, we see that most stations in East Anglia, Yorkshire and Central Southern England have forecast daytime maximum within 2°C of the observed values on nearly every day during January. The problem of forecasting for a coastal station is highlighted by comparing Rhoose with 9 forecasts in error by 2°C or more with nearby Cardiff which is only in error once. In figure 4, we see that significant errors in nightime minimum temperatures are likely to be made on about four occasions during the month at the typical inland station, which is much lower than the average of eight taking all stations.

No direct comparison of extreme temperatures can be made with the fine-mesh model. We can however compare the frequency of gross errors at specific times. During January the mesoscale forecasts verifying at 18Z were in error by 2°C or more on 25% of occasions, whilst comparable fine-mesh forecasts were in error by 2°C or more on 30% of occasions. For forecasts verifying at 6z during January the equivalent figures are 30% of mesoscale forecasts in error and 35% of fine-mesh forecasts in error. These figures are higher than those quoted for the extremes because the number of stations reporting is substantially greater and many of the additional stations are coastal or hill stations.

The model skill on a day to day basis is demonstrated in Fig 5 which gives timeseries of forecast and observed maximum and minimum temperatures at Marham during January. A substantial forecast error only occurred once (minimum on 16th). The maximum temperature traces are very close and although several minimum temperature forecasts went slightly astray, the model very clearly identified the correct day to day trend on most occasions.

b) Wind forecasts

Table 3 gives the r.m.s. wind speed errors for both mesoscale model and fine-mesh model during the past three months. The fine-mesh figures are rather closer to those from the mesoscale model than they hve been in previous months because the forecast values have been scaled by 0.85 in a crude attempt to convert the 25 metre values into something which could be more reasonably compared with observations at 10 metres.

	Data Time	6	6	6	6	18	18	18	18
	Verif Time	9	12	15	18	21	0	3	6
Model	Month								
mes	Nov	5.1	5.1	4.8	5.4	5.3	5.1	5.0	5.4
mes	Dec	5.5	5.7	5.7	5.9	5.3	5.7	5.9	6.0
mes	Jan	5.7	5.9	6.1	6.2	5.7	5.7	5.7	5.8
fm	Nov	6.7	6.4	6.3	6.5	6.4	6.6	6.6	6.4
fm	Dec	6.7	6.6	6.5	6.7	6.4	6.6	6.8	6.8
fm	Jan	7.1	7.1	7.2	7.3	6.8	6.9	6.9	6.9

Table 3 r.m.s. wind speed error (knots)

The mesoscale model, in terms of rms errors, has about a 1 knot advantage over the fine-mesh model. The values in table 3 are somewhat higher than previous months but this probably reflects the more disturbed weather experienced in this later period. The geographical variation of wind errors is at least as large as for temperature errors. For inland stations rms wind errors during January were typically 3 knots which is considerably lower than the 6 knots in table 3 which is based on the full observing network. Figure 6 gives the rms windspeed error at 6z during January and we see figures ranging from 2.7 knots at Heathrow to 30.1 knots at Cairngorm. The following table gives the frequency of occurrence of particular wind speed error at 6z during January. Both observation and forecast are converted to Beaufort Force before the comparison and the forecast errors are partitioned in terms of number of Beaufort Force in error.

Error in Beaufort Force (F/C - OB)	<-3	-3	-2	-1	0	1	2	3	>3
mesoscale	0.5%	0.7%	5%	16%	34%	30%	11%	3%	0.2%
fine mesh	0.4%	2%	7%	19%	29%	25%	12%	4%	1%

Table 4 Frequency of occurrence of wind speed error
VT 6Z January

Table 4 shows that 80% of mesoscale forecasts verifying at 6Z during January were essentially correct (being no more than one Beaufort force in error). The comparable figure for fine-mesh forecasts is 73%. There is a clear bias in these results with forecast winds being too strong rather more often than they are too weak. The ratio of strong forecasts to weak forecasts is 2 for the mesoscale model and 1.5 for the fine-mesh model. Part of the problem relates to the incorrect model climatology in light wind regimes as table 5 indicates.

Beaufort Force	1	2	3	4	5	6	7	8	9
observed frequency (%)	14	11	16	26	16	10	4	2	0.6
mesoscale f/c freq. (%)	4	13	15	30	19	12	4	2	0.4
finemesh f/c freq. (%)	4	13	20	27	16	11	6	2	0.9

Table 5 observed and forecast wind speed climatology V.T. 6Z, January

Both models seriously underestimate the frequency of very light winds and this accounts for much of the bias. The mesoscale model also overestimates rather more than it underestimates when the observations are indicating Force 3 or 4, whereas no particular bias is evident for the fine-mesh at these wind speeds.

Figure 7 illustrates the geographical distribution of wind speed errors by showing the number of occasions when the error exceeded one Beaufort Force at 6Z during January. The average figure from table 4 is 20% of occasions or six times per month, however many stations have significant errors on much fewer occasions and values of three or less are more typical of low-lying inland stations, with some stations in East Anglia and Lincolnshire achieving correct forecasts throughout the month.

c) Precipitation Forecasts

In dramatic contrast to the last three month period, there has been no sign of a deficit in forecast rainfall during the November - January period. In fact, the mesoscale model has forecast more rain than was actually observed during December and January, and consistently more rain than the fine-mesh model.

Table 6 shows the mean forecast rain totals expressed as a percentage of the observed means for the three months.

	Mesoscale Model	Fine-Mesh Model
November Fc/obs	103	77
December Fc/obs	112	92
January Fc/obs	149	83

Table 6 Total Mean Forecast Rain Expressed as Percentage of Observed

The switch from under-estimation to over-estimation can be mainly attributed to the major change to the model made at the end of September. This change involved the advection of total water instead of the separate advection of humidity mixing ratio and cloud water, and also a different treatment of ice-phase precipitation, in which ice precipitate is assumed to fall as snow. The change of synoptic type from mainly anticyclonic in September and October to a predominance of mild wet westerlies also played an important role in the change.

The effect of the enhanced rainfall in the model can be seen clearly by comparing a chart showing the December total forecast 24 hour accumulations by the mesoscale model with the December rainfall chart produced from MORECS data. (See figures 8 and 9). The orographically enhanced rainfall peaks over Wales and Western Scotland have been forecast well by the model, together with the rain-shadow effect to the lee of the Welsh mountains, and the smaller totals over Eastern England. However, it has tended to over forecast amounts of rain over East Anglia and the London Area. When we compare similar charts for January we can see that the model has overforecast rainfall accumulations considerably. (see figures 10 to 12). Although the peak forecast of 410 mm over Western Scotland is backed up by the chart produced from MORECS data, nevertheless accumulations forecast elsewhere seem to be 1.5 to 2 times the observed amounts. Figure 13 shows the excess rain forecast for Trawscoed in Wales for January.

The reason for this overestimation of rainfall in January is not clearly understood. Eighteen cases which overestimated rainfall amounts significantly during December and January were analysed for their synoptic type. The criteria used for selection was that the mean forecast accumulation in 12 hours should be more than 1.5 times the observed mean total. Twelve of these were particularly interesting because the rainfall evolution differed markedly from that of the fine-mesh forecast run from the same initial data for verification purposes. Of these twelve cases, ten were frontal/cyclonic which were split evenly between mild southwesterly types and cooler northwesterly types with rain preceded by snow and the remaining two were unstable northwesterlies with snow showers. This suggests two possible explanations for the excess rainfall: A general over-estimation of rainfall in mild southwesterly frontal situations which has been an occasional fault of the fine-mesh model but seems to be worse in the mesoscale model. The peaks in forecast rainfall at Trawscoed (Figure 13) coincide with the warmer days in the month as identified by the timeseries of maximum temperature at nearby Aberporth. A problem with the treatment of the ice-phase precipitation is also suspected.

The contingency tables below show how well the models forecast rain on a simple yes-no basis for rain occurring in the 12 hour forecast period.

	Mesoscale Model				Fine Mesh Model		
(a) November	Obs →	NO	YES		Obs →	NO	YES	
F/C NO		38	7	45		37	12	48
F/C YES		15	40	55		16	35	51
		53	47			53	47	
(b) December	Obs →	NO	YES		Obs →	NO	YES	
F/C NO		27	7	34		32	11	43
F/C YES		22	44	66		17	40	57
		49	51			49	51	
(c) January	Obs →	NO	YES		Obs →	NO	YES	
F/C NO		19	5	24		21	10	31
F/C YES		21	55	76		19	50	69
		40	60			40	60	

Table 7 - Contingency tables of Rain Occurrence

Considering the three months together, then the mesoscale model is very marginally better with a success rate of 74% comapred to 72%. However, the tendency of the mesoscale model to forecast too many wet periods is evident in the above contingency tables. Errors are three times more likely ot be rain forecast/nil observed than the reverse. More than half of the excessive rainfall consists of very small amounts. If we consider just the incorrect rainfall forecasts in the 12-hour accumulation contingency tables, than on average 63% falls into the 0.1-1 mm class. One possible way to improve the problem might be to use a slightly larger cut-off than the present rate of 0.01 mm/hour.

Too large a proportion of the rain falls in the first hour. Table 8 compares the mean rainfall accumulations at T+1 and T+12 for December and January.

Month		06-18 F/C	18-06 F/C
Dec	T+1	0.37	0.43
	T+12	2.01	2.06

Month		06-18 F/C	18-06 F/C
Jan	T+1	0.47	0.41
	T+12	2.97	2.71

Table 8 Mean Rainfall Total from Mesoscale Model Forecast

Table 8 shows that on average 19.6% of the forecast rainfall fell in the first hour in December, decreasing to 15.5% during January. This is much larger than the figure which might be expected (8.3%). The lower figure in January might be due to improvements in the fine-mesh model during December.

A close examination of the correctly forecast wet periods reveals that the mesoscale model is slightly more successful in forecasting the correct amount. In this context, the correct amount is deemed to have been forecast if the model prediction of 12 hour rainfall at an individual station falls within the same category as that observed. The four categories used are .1 to 1 mm, 1 to 5 mm, 5-10 mm and 10 mm and above. A summary for the three month period is given below in table 9.

Mesoscale Model

Month	% Correct Forecasts	% too little F/C	% too much F/C
Nov	48	26	26
Dec	45	29	26
Jan	48	18	34
Average	47	24	29

Fine-Mesh Model

Month	% correct Forecasts	% too little F/C	% too much F/C
Nov	47	33	20
Dec	40	38	22
Jan	47	32	21
Average	45	34	21

Table 9 Verification of forecast accumulation in 12 hr period for correctly Forecast Wet Periods

In November and December there was very little bias in the model between forecasting too much or too little, but in January, errors were twice as likely to be too much rain forecast than too little. The fine-mesh model consistently forecast too little rainfall rather than too much.

If we consider just the occasions of significant rainfall (> 5 mm in 12-hour), then tables 10 and 11 below compare the success rate of the two models, also the false alarm rate.

	Mesoscale	Fine Mesh
November	48.5%	42.2%
December	44.7%	32.5%
January	67.0%	39.3%

Table 10 Success Rate in Forecasting >5mm accumulation in 12 hours, as a percentage of observed totals >5mm

	Mesoscale	Fine Mesh
November	45.1	39.0
December	48.5	48.3
January	51.9	42.5

Table 11 False Alarm Rate in Forecasting >5mm Accumulation in 12 hours as a percentage of forecast totals >5mm

As tables 10 and 11 show, the mesoscale model had a much higher success rate in forecasting the larger accumulations, but it also had a higher false alarm rate (except in December).

It is very important that the mesoscale model should be able to forecast the type of precipitation accurately. The mesoscale model is more ambitious than the fine mesh model in that it aims to forecast the exact dividing line between rain and snow. The criterion used is that snow will be predicted at the surface if the temperature at level 3 (310m) is less than zero. The definition is precise; as small a difference as 0.02°C in the level 3 temperature forecast could mean the difference between a successful snow forecast and a failure. This contrasts with the looseness of the fine-mesh model snow forecasts, which may be considered successful if the forecast probability of snow is 20%. During January, snow was added to the verification program. Observations of sleet are included with snow for the purposes of verification.

The contingency tables below show how well the mesoscale model forecast snow on a simple yes/no basis at T+2 and T+12 during January.

T+2
VT 20z

Obs →		Snow	Dry	Rain
F/C	Snow	1.9	1.8	1.0
	Dry	0.5	59.6	3.9
	Rain	1.1	18.7	11.4

Table 12 % of snow, rain forecast and observed at T+2 (To represent early stage in forecast)

T+12
VT 18z

Obs →		Snow	Dry	Rain
F/C	Snow	1.1	1.1	0.2
	Dry	0.8	57.0	6.0
	Rain	1.7	22.4	9.7

Table 13 % snow, rain forecast and observed at T+12 (To represent late stage of forecast)

Tables 12 and 13 indicate that the percentage of snow forecast declines during a forecast from 4.7% at T+2 to 2.4% at T+12. Also errors in the type of precipitation forecast are more likely to be snow observed/rain forecast at T+12 than at T+2. Both forecasts verify at a similar time of day, so they should compare closely in terms of percentages of snow or rain. These figures suggest that the mesoscale model may be warming up slightly too much during the course of a forecast. On some occasions, the mesoscale model was following the evolution of the fine mesh model forecast. However, some cases indicated that an additional warming in the mesoscale model was occurring. This may be connected with the excessive moisture in the model at low levels. Overall, the chosen criterion was successful, but sleet tended to be forecast as rain instead of snow by the model. It is difficult to come to a firm conclusion from the above figures and individual forecasts are being investigated further.

d) Cloud, humidity and fog forecasts

Forecasts of cloud, surface relative humidity and fog are closely related and will be considered together in this sub-section. Table 14 gives the percentage of forecasts of surface relative humidity as a function of their difference from observations for both models over the past three months. The verifying time is 12z in each case and the figures are expressed as a percentage of the total number of forecasts made in that month.

R.H. error (%) (f/c-ob)		[<-20]	[-20 - -10]	[-10-0]	[0-10]	[10-20]	[20-30]	[>30]
model	month							
mes	Nov	1%	5%	19%	39%	26%	8%	2%
mes	Dec	1%	1%	19%	44%	25%	8%	1%
mes	Jan	1%	4%	24%	43%	22%	5%	1%
f.m.	Nov	1%	5%	17%	29%	25%	14%	7%
f.m.	Dec	2%	5%	25%	39%	21%	7%	1%
f.m.	Jan	1%	5%	22%	35%	24%	11%	3%

Table 14 Frequency of occurrence of relative humidity error
DT6z VT 12z

The mean observed relative humidity at 12z for the three months was 78%, 85% and 82% respectively. Both models were much moister with mean values around 6% greater than those observed. There seemed to be much less variability in the forecast surface relative humidities, when the observed relative humidity was high the forecasts were good but when observed relative humidities were low the forecasts were often very poor. The mesoscale model forecasts do show marginally more skill than fine-mesh forecasts; over the three month period 63% of mesoscale model forecasts are within 10% of the observations whereas only 57% of finemesh forecasts fall within that same limit. The mesoscale model shows relatively more skill on the two drier months and there is some indication of an improving trend during the period. Figure 14 gives the mean relative humidity errors at each station for forecast verifying at 12Z during January. There are positive biases at almost every stations with some mean errors in excess of 10% (eg. Heathrow).

The tendency of the model to be too moist is clearly going to have an impact on the fog forecasts. As might be expected the model gave fog too frequently. Table 15 summarises the results for the past three months.

	Nov	Dec	Jan
Frequency of Fog F/C	7.9%	8.0%	5.8%
Frequency of Fog obs.	1.9%	4.2%	1.7%
Frequency of correct fog f/c	0.4%	1.2%	0.4%

Table 15 Fog Forecasting Results - verifying time 06Z

In this table, all visibilities below 1 kilometre are considered to be fog, although similarly results are obtained if a lower threshold is taken. A threshold of 200 metres gives frequencies of 4%, 2% and 0.4% at 6z during December for forecast, observed and correctly forecast respectively, however such a small sample size makes objective verification at an individual station rather difficult for what was not a particularly foggy period. Looking at individual stations for December the most obvious problems were an excess in hill fog forecasts (23 at Eskdalemuir compared with 2 observed) and estuaries (6 at Shannon compared with 1 observed). Inland the model forecast fog most frequenty at Gatwick (7 occasions where none were observed). Curiously, Yorkshire which was the foggiest part of the country in December was underforecast, Fig 15 illustrates the frequency of forecast fog at 6Z during December, with areas where observations of fog occurred more than twice in the month superimposed.

The cloud amount forecasts are summarised in Table 15, which gives the percentage of correct and incorrect, cloudy and clear forecasts verifying at 6z and 18z from both fine-mesh and mesoscale models over the three month period. In this context clear skies are defined as 4 octas or less and cloudy skies 5 octas or more.

model	month	v.t.	Correct Clear f/c	Correct Cloudy f/c	Incorrect clear f/c	Incorrect Cloudy f/c
mes	Nov	18z	16%	54%	19%	10%
fm	"	"	19%	46%	27%	8%
mes	Dec	"	8%	69%	10%	13%
fm	"	"	13%	61%	17%	9%
mes	Jan	"	16%	58%	17%	9%
fm	"	"	14%	59%	16%	11%
mes	Nov	6z	18%	52%	18%	12%
fm	"	"	20%	44%	26%	10%
mes	Dec	"	12%	61%	10%	17%
fm	"	"	14%	57%	14%	15%
mes	Jan	"	18%	53%	16%	13%
fm	"	"	18%	55%	14%	13%

Table 15 Cloud amount forecast summary Nov-Jan

Over the three month period, taking both 18z and 6z forecasts together, the mesoscale model gave correct cloud amount forecasts on 72% of occasions compared with 70% for the fine-mesh model. The mesoscale model was substantially better than the fine-mesh model in November, but in January there was little difference between them. This result might be a reflection of recent fine-mesh improvements or it could be due to the fact the situation in January was a very mobile and the mesoscale model forecast would be dominated by the large scale forcing from the fine-mesh model. Both models have difficulty with forecasts of clear skies, which are just as likely to be wrong as they are to be right (comparing column 1 and 3 of Table 15). The table also shows that, although there was a tendency to forecast clear skies too often (comparing columns 3 and 4) December was peculiar in having more cloud forecast than was observed.

During the past nine months the mesoscale model has given prediction of partial cloudiness, but the success rate was small because there was a very large bias towards forecast of 0 or 8 octas. Recent changes have increased the frequency of partially cloudy forecasts and Table 16 summaries the January 12 hour forecast results of cloud amount, in terms of a 4*4 contingency table with catagories 0-1 octa, 2-4 octa, 5-7 octa, 8 octa. The results are expressed as a percentage of all forecasts (≈11000 forecasts verifying at 6z and 18z).

Obs	0-1	2-4	5-7	8	
FC					
0-1	7	4	5	3	19
2-4	2	4	5	4	15
5-7	2	4	7	7	20
8	1	4	12	29	46
	12	16	29	43	100

Table 16 Contingency table - cloud amount - January T+12

The model's climatology of partial cloudiness is now quite good. The two most significant errors are a slight excess in the forecast frequency at both ends of the cloudiness spectrum. The excess of cloudy forecasts are generally when observations are indicating mostly cloudy, but incorrect clear forecasts (0-1 octa) are likely to occur at any observed cloud amount.

The above results for cloud amount give full credit for the cloud forecast even if the cloud base is completely wrong. Table 17 provides details of the observed and forecast cloud base climatologies during the past three months. The six cloud base categories given in table 17 include four categories for low cloud which are appropriate to mesoscale model levels 2-5, then two categories for medium and high cloud the latter of which includes occasions of no cloud. The fine-mesh cloud base forecasts are based on an interpolation of the relative humidities to the mesoscale model grid; high values of relative humidity are then interpreted as cloud. All forecasts verifying at 18z are included in the table.

Cloud Base (feet)		0-600	601-1500	1501-2600	2601-4100	4101-18000	>18000
Nov	mes	26%	18%	14%	3%	8%	30%
	f.m	25%	3%	7%	8%	18%	39%
	obs	6%	15%	28%	23%	23%	5%
Dec	mes	45%	20%	8%	2%	7%	18%
	f.m	34%	5%	8%	4%	17%	32%
	obs	9%	21%	29%	16%	16%	8%
Jan	mes	28%	27%	13%	4%	11%	18%
	f.m	31%	7%	6%	5%	26%	24%
	obs	8%	23%	33%	14%	16%	7%

Table 17 Climatology of forecast and observed cloud bases
Nov - Jan verifying time 18z

The trend towards excessive frequency of very low cloud forecasts which was established in October has continued throughout the winter month. Both models exhibit the same problem which must be related to the surface relative humidity bias. Excluding the lowest cloud layer, the distribution of cloud bases in the two models is quite different. The mesoscale model has a large number of forecasts with cloud base in the second category. The proportion is in fact similar to that observed, but when added to the percentage at the lowest level it gives far too much cloud below 1500 feet. The frequency of cloud bases in the third and fourth categories in Table 17 is deficient in both models. Taking all four levels, the mesoscale model has about the right number of occasions with cloud base below 4200 feet whereas the fine-mesh model has many fewer forecasts of such low cloud.

Tables 18a and 18b provide a little more detail of the January mesoscale model cloud base forecast verifying at 18z. Table 18a is a contingency table of cloud base with two categories (above and below 4100 feet). Table 18b is a contingency table of cloud base for those occasions when cloud below 4100 feet was successfully forecast by the mesoscale model, it has four categories corresponding to the model levels.

obs	<4100	>4100	
f/c <4100	60%	13%	73%
>4100	17%	10%	27%
	77%	23%	100%

Table 18a Contingency table - Cloud Base - January - VT18z

obs	0-600	601-1500	1501-2600	2601-4100	
f/c 0-600	8%	15%	12%	5%	40%
601-1500	3%	12%	14%	6%	35%
1501-2600	0%	5%	9%	3%	17%
2601-4100	0%	1%	3%	1%	5%
	11%	33%	38%	15%	97%

Table 18b Contingency Table of successful low cloud forecast - January VT18z

Clearly it does not take much skill to forecast an event which occurs on 77% of occasions. However the mesoscale model has correctly forecast three quarters of these low cloud occasions. Considering only those successful forecasts of cloud base below 4100 feet, we see that 30% of those successful forecast were of the correct cloud base and a further 46% are within one model level of the correct base. The bias towards cloud base being too low is very apparent in Table 18b where we see that cloud base is likely to be forecast too low nearly five times as often as it is forecast to be too high. The tendency to forecast cloud bases too low is further highlighted by Figure 16 which shows the number of occasions of forecast cloud base below 1500 feet at 18z in January. On this figure the contours represent those areas where the observed occurrence exceeded 12 during the month. This contour encompasses most of the high level stations where in fact the forecast frequency is only slightly greater than that observed (eg Exton 19 occasions forecast, 17 observed). Forecast frequency is also high in the central Highlands of Scotland but the stations there don't verify well because they tend to lie in valleys which are too small to be identified by the model (eg Foyer 21 occasions forecast, 1 observed). The west facing coasts also had forecast occurrences of low cloud which were only marginally greater than those observed (eg Scillies 8 forecast, 7 observed). The largest number of incorrect forecasts occurred at low lying stations which were not exposed to the prevailing westerly winds. The area between the Thames and the Wash, encompassing East Anglia and the East Midlands has forecast occurrences of low cloud on average 16 times compared with 7 observed occurrences.

3. Subjective Assessment

Objective assessment by itself does not give any measure of the difficulty of a particular forecast. An important way of assessing the model is to see how well it performs in comparison with a subjective forecast. This comparison was carried out in two ways, which are described below.

a) Bracknell Forecast

A Bracknell local area forecast for the period 10-18 GMT, based entirely on the mesoscale model run from 06 GMT data, was compared with a similar forecast issued by CFO just prior to receiving the mesoscale model forecast. Wind, weather and temperature forecasts are scored using the following criteria:

Score 2 if the mesoscale model forecasts provide extra correct detail
Score 1 if both forecasts are similar
Score 0 if the mesoscale model gives extra information which is incorrect

	Month	Score 2	Score 1	Score 0
Wind	Nov	6	16	3
	Dec	6	20	5
	Jan	8	12	7
	Overall	24%	58%	18%
Weather	Nov	1	15	9
	Dec	3	13	15
	Jan	1	16	10
	Overall	6%	53%	41%
Temp	Nov	4	13	8
	Dec	5	20	6
	Jan	5	14	8
	Overall	17%	57%	26%

Table 19 Subjective Assessment Scores of the Bracknell Local Area Forecast

	% Correct within 2°C		% Correct within 3°C		Mean Error		RMS Error	
Month	MES	CFO	MES	CFO	MES	CFO	MES	CFO
Nov	85	96	96	100	-0.4	-0.2	1.5	1.1
Dec	84	84	93	90	-0.2	0.4	1.6	1.4
Jan	97	97	100	100	0	0.1	1.0	1.2
Overall	88	92	96	96	-0.2	0.1	1.4	1.2

Table 20 Maximum Temperature Forecast for Bracknell

Table 19 summarises the results of the subjective assessment of the Bracknell local area forecast. Overall, the mesoscale model was slightly better in forecasting the wind speed and direction. During strong wind periods in January the model tended to forecast slightly lower speeds than CFO, but each was correct on an equal number of occasions. CFO were slightly more accurate in forecasting the maximum temperature for Bracknell, with the mesoscale model having a slight cold bias. However, table 20 shows that overall there was little to choose between CFO and the mesoscale model. Results in January were particularly accurate.

CFO were clearly better in forecasting the weather for Bracknell, which includes cloud, precipitation and fog. The results from the mesoscale model were worse than the August-October period. The reasons for the 34 zero scores for weather can be analysed as follows;

6 Fog -	Fog forecast but not observed	
11 Cloud -	Too little	4
	Too much/Base too low	7
	precipitation forecast but not observed	9
17 Precipitation -	dry forecast but precipitation observed	3
	Intensity incorrect	4
	Rain forecast/sleet observed	1

These results demonstrate the tendency of the model during this period to forecast too much low cloud and also to forecast rain, usually small amounts during observed dry periods.

b) Temperature forecasts for the Gas Industry

Weather Centres issue daily forecasts to Gas Boards, which include temperature forecasts for up to 48 hours ahead. We decided that a useful way of testing the reliability of the mesoscale model's temperature forecasts would be to see how well they compared with the forecasts issued by selected Weather Centres over a 12 to 18 hour period.

Two verification times were chosen; 15 and 09 GMT. The mesoscale model temperature forecasts for 15 GMT were drawn from the forecast run from 06 GMT data and compared with the forecasts issued by chosen Weather Centres at 0800 GMT. This was a fair comparison, since both forecasts would be based on the 06 GMT analysis. The mesoscale model forecast temperatures for 09 GMT were drawn from the forecast run from 18 GMT data and compared with the forecast issued by the chosen Weather Centres at 00 GMT. In this case, the forecaster's held a few hours advantage. Results of the comparison are only available for December and January. To ensure a fair comparison, the model forecast temperatures and the observed temperatures were rounded to the nearest degree (with .5 rounded to the odd). Temperatures were verified only on those days when forecasts were available both from the Weather Centre and the mesoscale model. The results are summarised in table 21.

Verification Time	Station	Number Forecasts Compared	% Correct to 1°C		% Correct to 2°C		% Correct to 3°C	
			MES	FCR	MES	FCR	MES	FCR
15 GMT	LWC	55	80	84	95	95	100	98
	Southampton	56	78	69	95	94	96	98
	Watnall	50	74	74	93	88	98	96
	Manchester	59	78	68	93	94	100	99
	Newcastle	30	70	77	90	93	97	93
	Glasgow	30	70	80	93	100	100	100
	Average		76	75	93	94	99	98
09 GMT	Southampton	41	69	71	83	98	90	100
	Watnall	40	51	62	80	92	90	95
	Manchester	44	64	66	81	86	95	98
	Newcastle	28	71	64	86	79	89	89
	Glasgow	28	79	61	89	82	93	96
	Average		66	65	83	88	92	96

MES - Mesoscale model Forecast
FCR - Weather Centre Forecast

Table 21 Gas Board Forecast Temperatures

The mesoscale model forecast temperatures were as accurate as those issued by forecasters at the Weather Centres for 15 GMT. The forecasters were slightly better at forecasting the temperature at 09 GMT, but this may be due to the fact that they issue their forecast at 00 GMT, 6 hours later than the data time of the mesoscale model forecast.

Verification Time	Nr Fcsts Compared	% Correct to 1°C		% Correct to 2°C		% Correct to 3°C	
		MES	FCR	MES	FCR	MES	FCR
15 GMT	31	71	65	100	87	100	97
09 GMT	50	54	56	82	82	94	94

Table 22 Occasions when Persistence ≥ 3°C in error in January

It is important that the model should be able to predict temperatures accurately on those days when there is a marked change of temperature from the previous day. Table 22 shows that the model was better than the forecasters at 15 GMT (T+9 forecast) and equally good at 09 GMT (T+15) during January.

c) Subjective Assessment of British Isles weather

During the period November 7th to January 31st, the British Isles Forecaster in CFO carried out a detailed subjective assessment of the mesoscale model's three-hourly forecast charts of precipitation, cloud, fog and frost. The main details are summarised in table 23 for verification times T+12 and T+18.

	BT 06 GMT VT 18 GMT (T+12)	DT 18 GMT VT 06 GMT	DT 18 GMT VT 12 GMT
Area of forecast precipitation good	64%	73%	65%
Intensity well forecast	77%	87%	85%
Type of precipitation well forecast	81%	84%	77%
Occasions rain forecast/nil obs.	23%	24%	22%
Area of cloud forecast - good	48%	47%	47%
% Cloud base forecast too low	72%	63%	65%
Occasions Fog Forecast/none observed	23%	30%	30%

Table 23 Main results of subjective assessment of mesoscale model forecasts

A good precipitation forecast is defined as one in which the main precipitation areas are mainly correct with only one or two positional errors >50 km. For both the 06-18 GMT and the 18-12 GMT forecast runs, the accuracy of the precipitation areas decreased gradually during the period of the forecast.

During November and December, errors in the type of precipitation forecast were mainly snow forecast/rain observed. However, during January errors were twice as likely to be rain forecast/snow or sleet observed than the reverse. It is not possible to say from these results whether this was due to the inaccuracy of the snow predictor (snow is forecast if the temperature at level 3 < 0°C) or due to a warm bias in the model at level 3. One forecast in every 4 or 5 had an area of spurious rain. This occurred most frequently in Southeast and Central Southern England and East Anglia.

A good cloud forecast is defined similarly to a good precipitation area, i.e. the main areas are correct and there are only 1 or 2 positional errors >50 km. The percentage of good cloud areas increased during the period at T+12 from 31% in Nov to 66% in Jan (DT 06z) and from 41% to 61% (DT 18z). This may be due to the improved forecasts of partial cloudiness. Similarly the percentage of forecasts with cloud bases too low decreased from 81% in November to 58% in January (DT 06 GMT) and from 75% in November to 68% in January (DT 18 GMT). Areas most likely to be affected by spurious areas of low cloud were Southeast and Central Southern England, East Anglia and the Midlands.

From table (23), one in every 3 or 4 forecasts at T+12 were likely to have patches of spurious fog. Areas most often affected were East and Northeast England, Southeast and Central Southern England and the Midlands.

4. Summary

The mesoscale model has provided forecasts throughout the period with increased reliability. The standard of the temperature forecasts has remained high despite the increased difficulty of forecasting temperature dirng the winter months. The temperature forecasts were significantly better than those produced by the fine-mesh model at the start of the period and have remained marginally better despite the improved fine-mesh temperatures. They have also been proven to be comparable with the subjective forecasts issued by CFO and the weather centres. Wind forecasts from the mesoscale model have also proved to be superior to those both from the fine-mesh model and from CFO.

The model has continued to have difficulty in forecasting the weather and has lagged far behind in the comparison with subjective forecasts for the Bracknell area. There has been a marked tendency for the model to be too moist at low levels giving rise to an excessive frequency of fog and low cloud forecasts. There has also been too many occasions of spurious rain. The retention of stratocumulus which was noted in the previous report remains a significant problem. In general, the model did not show any appreciable skill at forecasting fog or cloud base during the period. The rainfall and cloud amount forecasts were only very marginally better than those produced by the fine-mesh model, with the exception of orographically induced features which are handled rather better by the mesoscale model.

5. References

Bell R.S.	1985 (a)	A critical appraisal of the Mesoscale Model Forecast Results - April to July 1985. Met O 11 TN213, Met Office, Bracknell.
Bell R.S.	1985 (b)	A verification of the Mesoscale Model performance during August to October 1985. Met O 11 TN221, Met Office, Bracknell.

List of Figures

Figure 15. Number of occasions when forecast visibility was below 1 kilometre at 6Z during January. (A contour superimposed on this chart encloses stations where a similar visibility was observed on more than two occasions at 6Z).

Figure 16. Number of occasions when forecast cloud base was below 1500 feet at 18Z during January. (A contour superimposed on this chart encloses stations where similar cloud bases were observed on more than 12 occasions at 18Z).

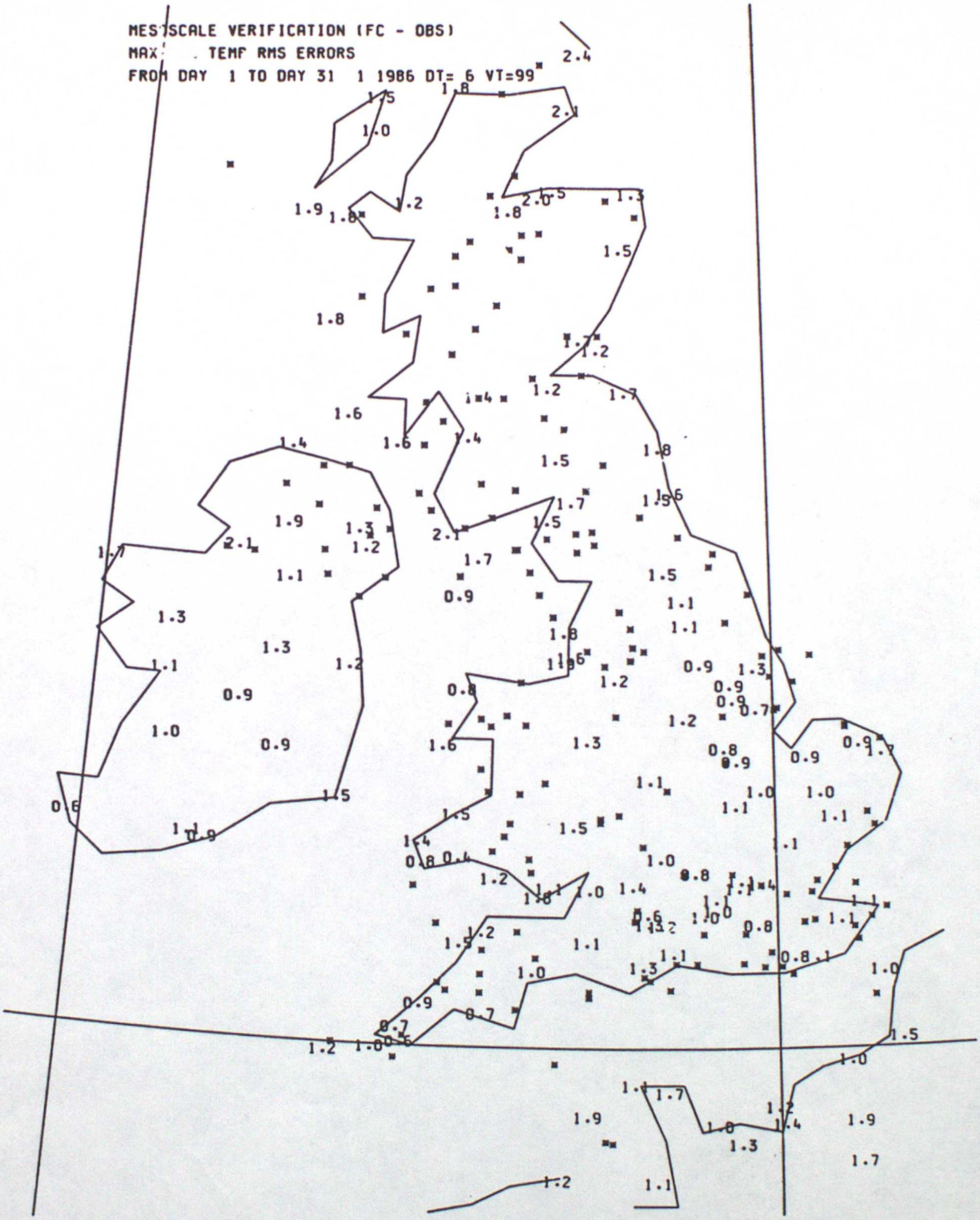


Figure 1. Root mean square errors of maximum temperature from mesoscale model forecasts based on 6Z data time during January 1986.

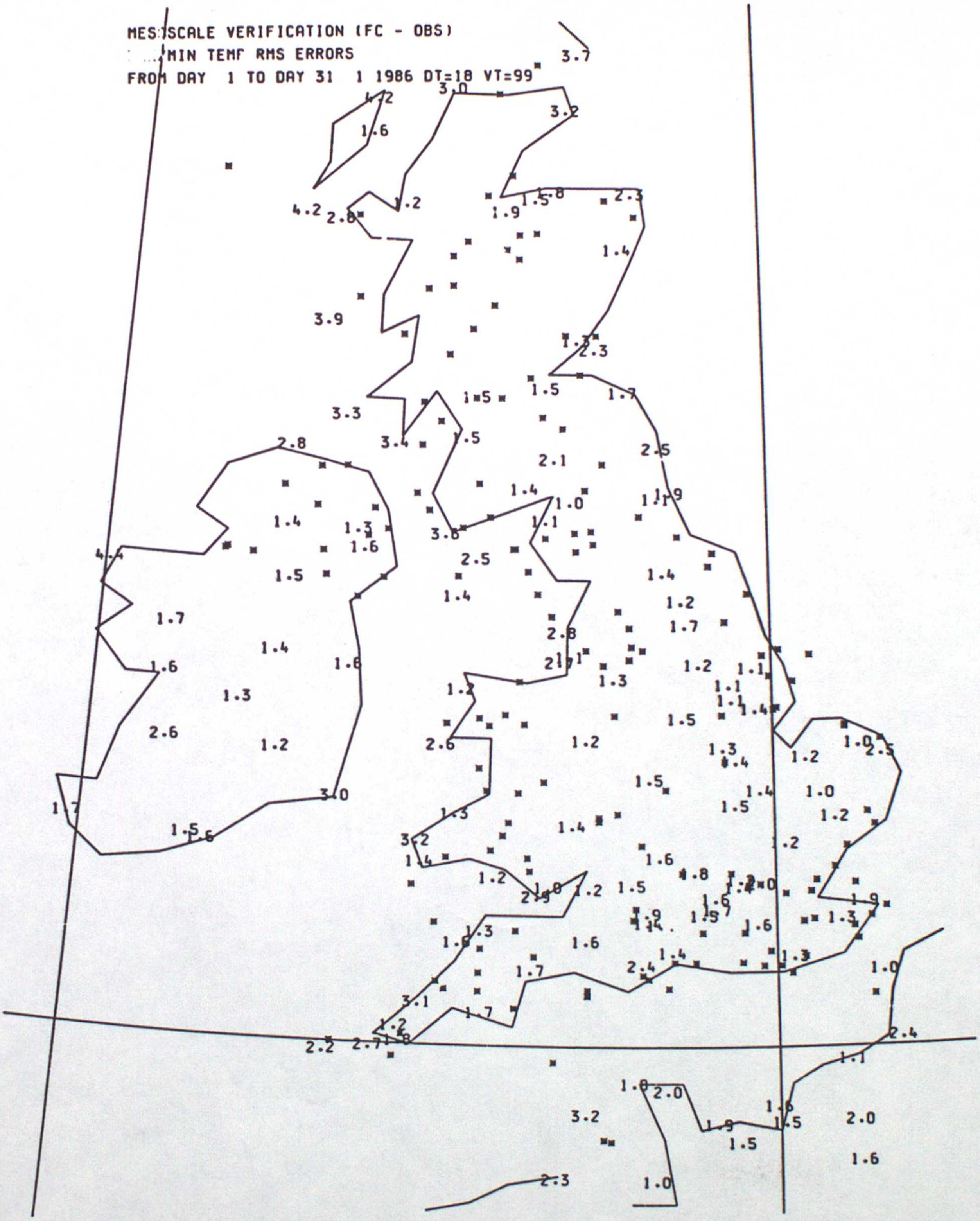


Figure 2. As Figure 1, but for minimun temperature from forecasts with an 18Z data time.

Figure 3. Number of occasions when mesoscale model maximum temperatures were in error by more than 2°C - January 1986.

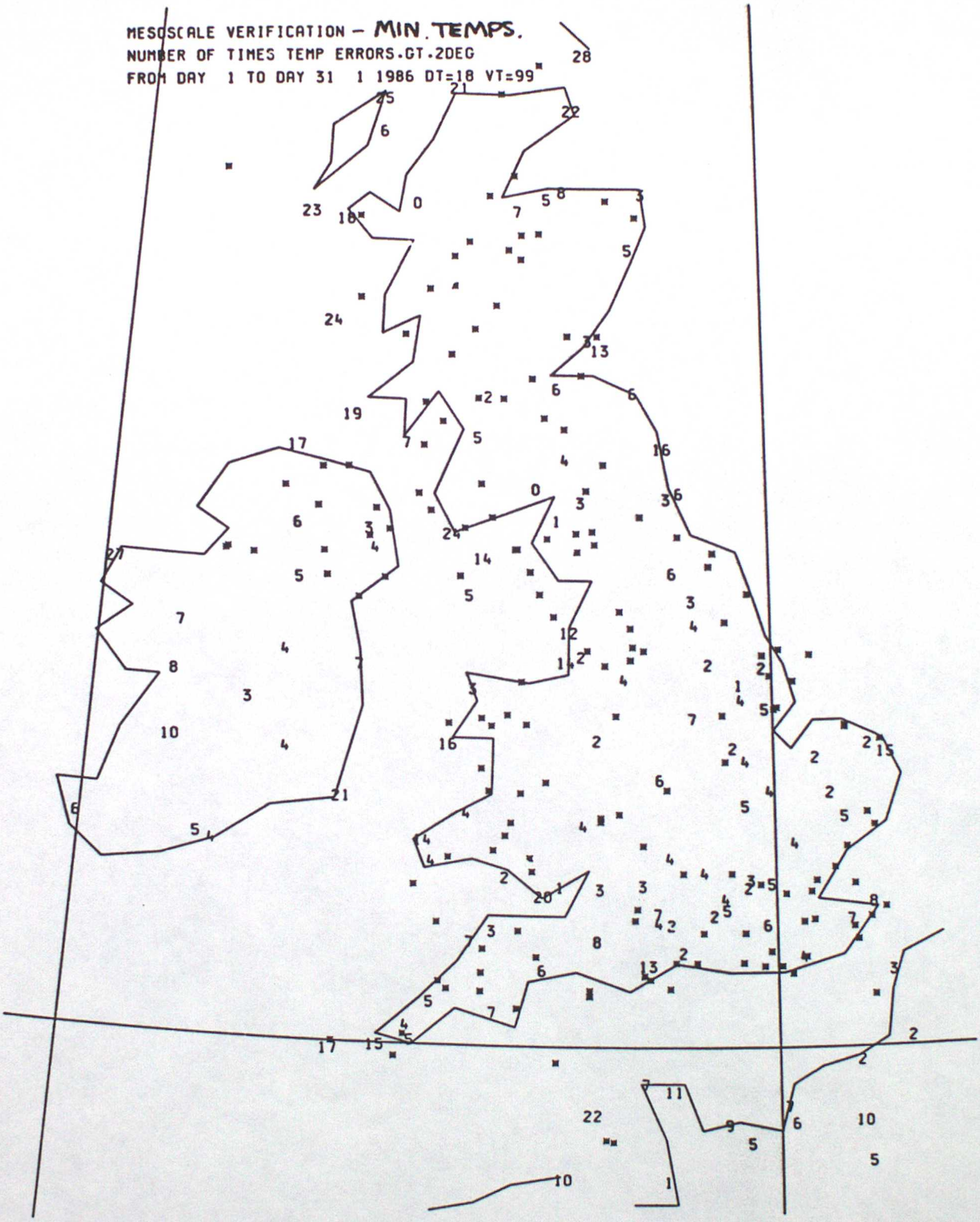


Figure 4. As Figure 3, but for minimum temperature forecasts.

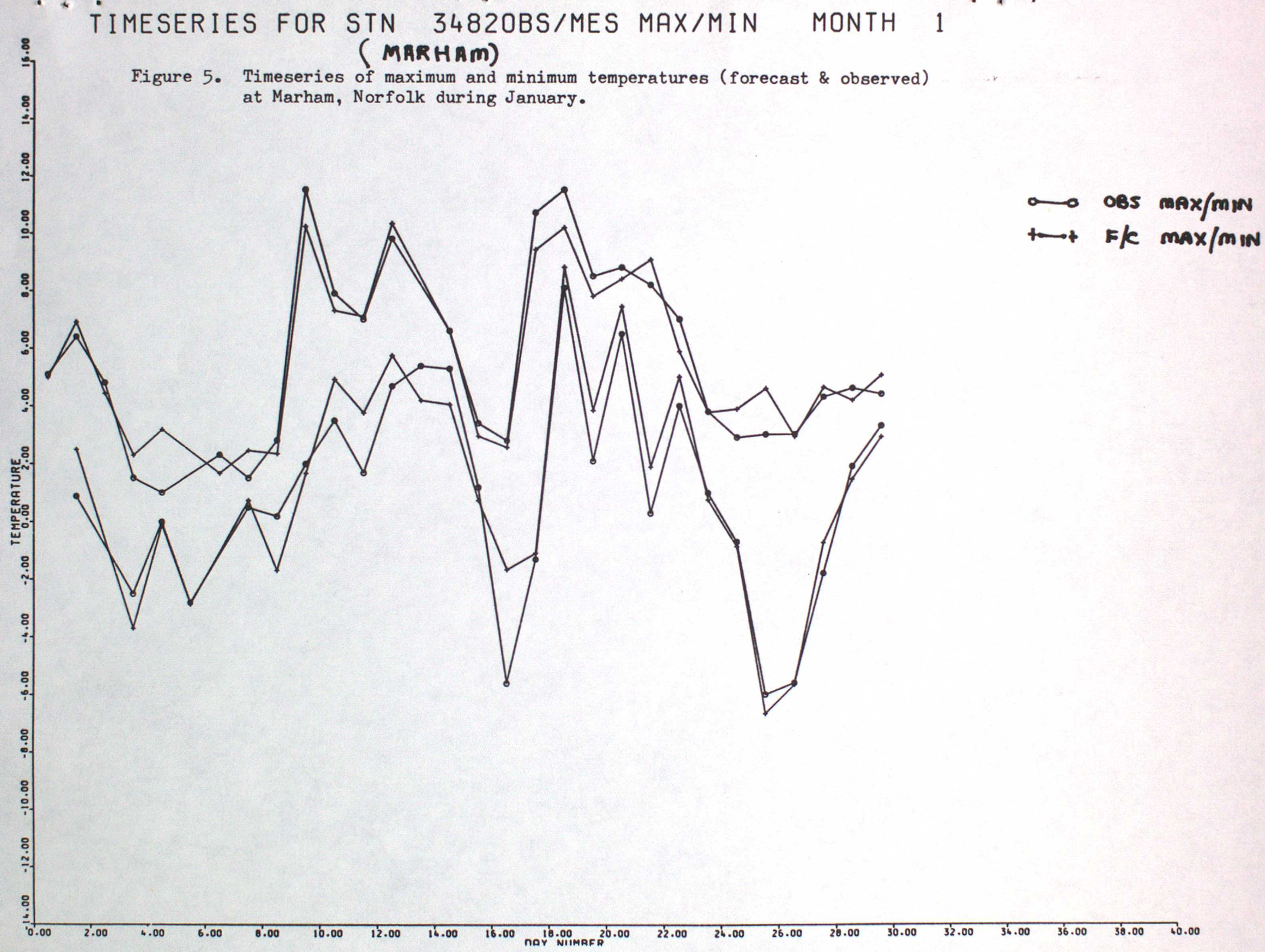


Figure 5. Timeseries of maximum and minimum temperatures (forecast & observed) at Marham, Norfolk during January.

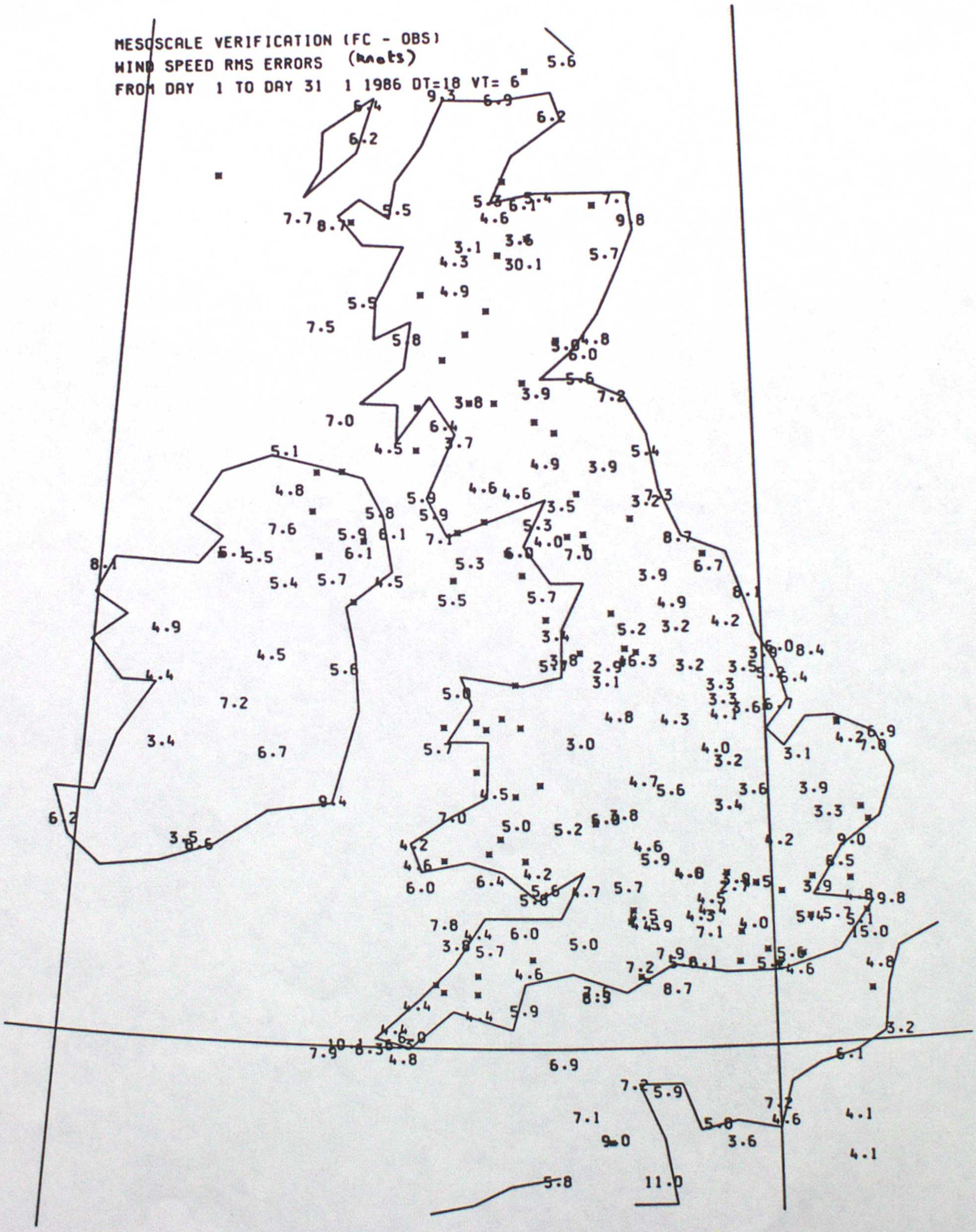


Figure 6. Root mean square errors of wind speed (knots) for January forecasts verifying at 6Z.

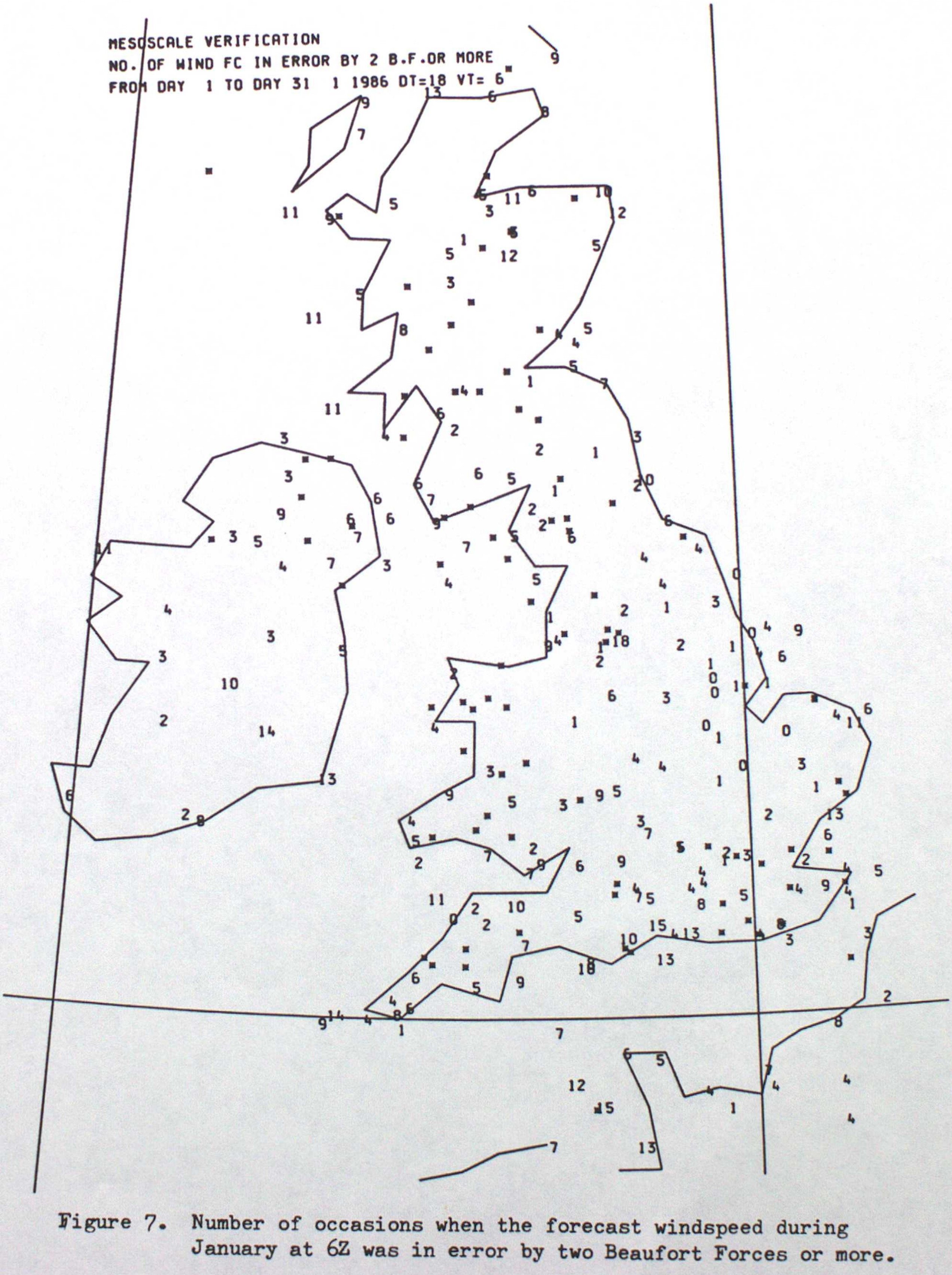


Figure 7. Number of occasions when the forecast windspeed during January at 6Z was in error by two Beaufort Forces or more.

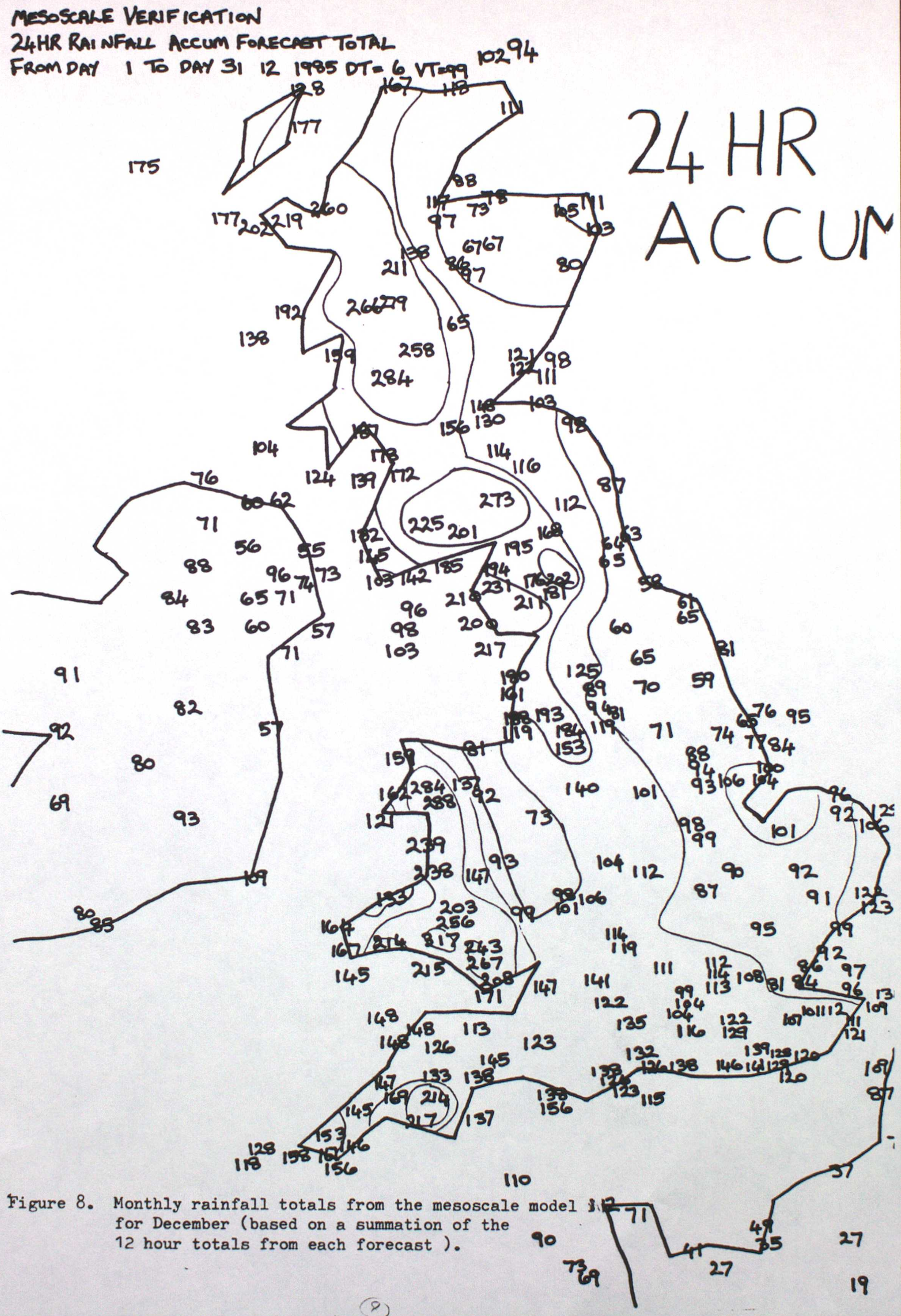


Figure 8. Monthly rainfall totals from the mesoscale model for December (based on a summation of the 12 hour totals from each forecast).

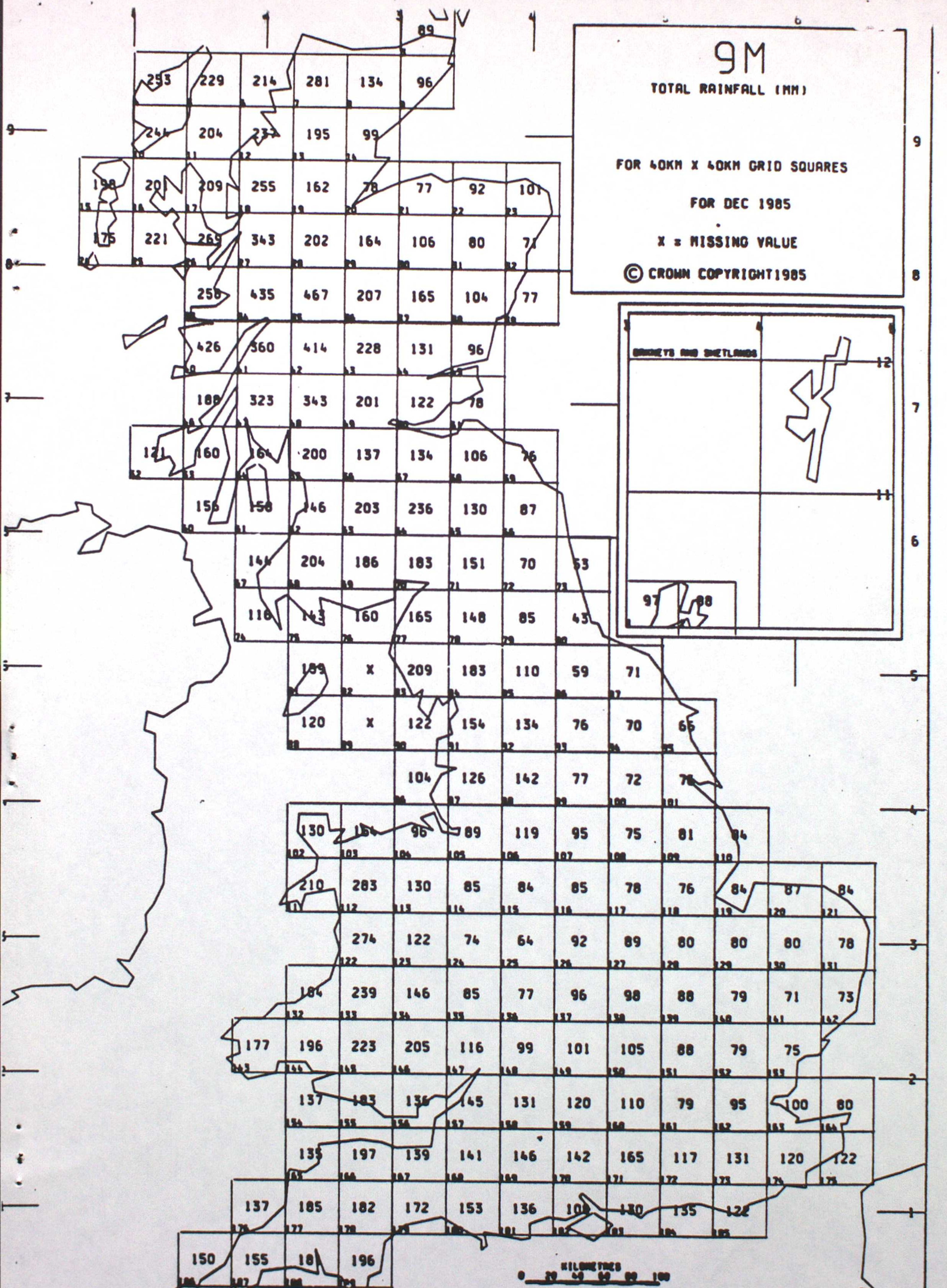


Figure 9. Monthly observed rainfall total for December (from the Met O 3 MORECS analysis).

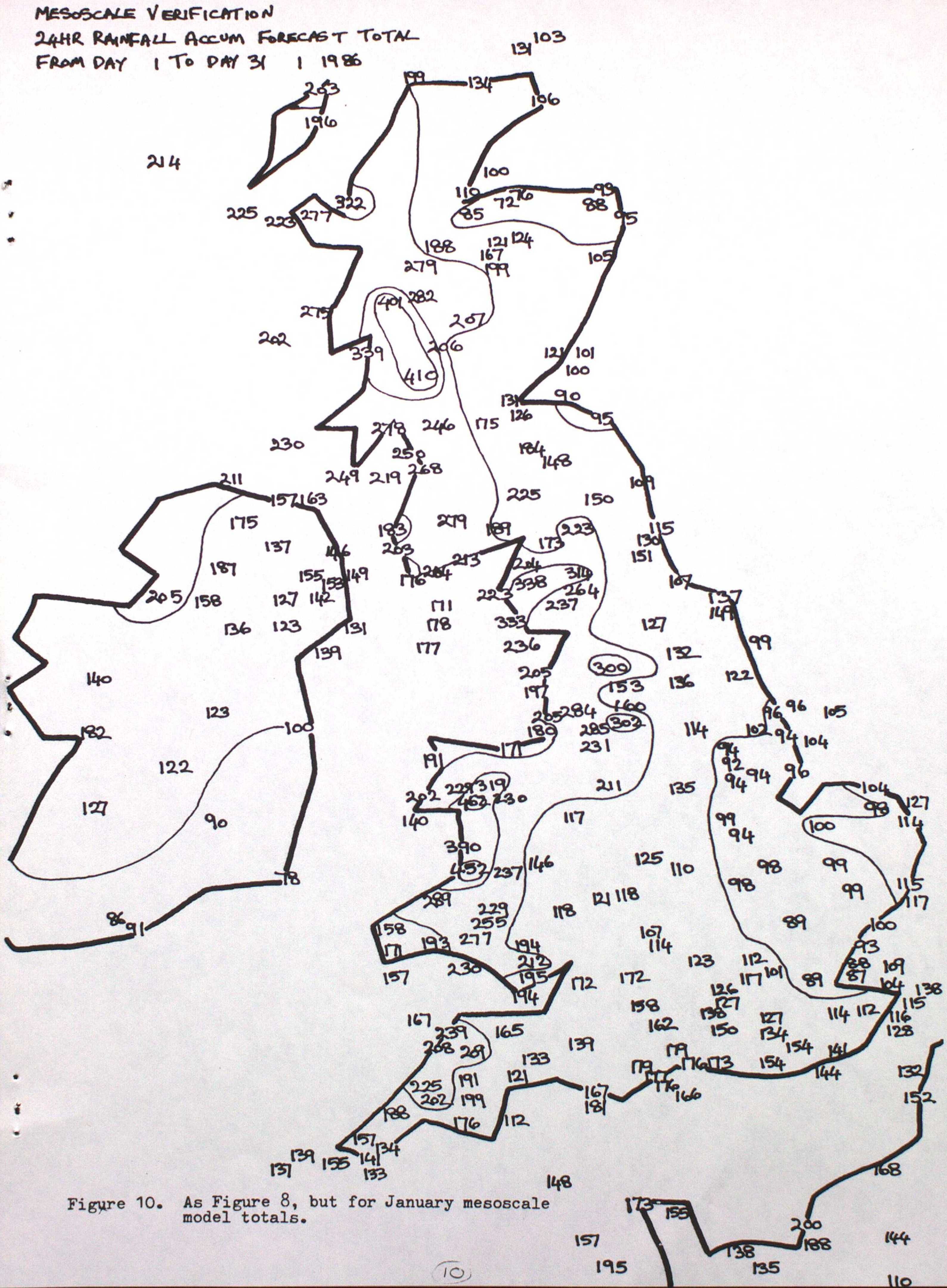


Figure 10. As Figure 8, but for January mesoscale model totals.

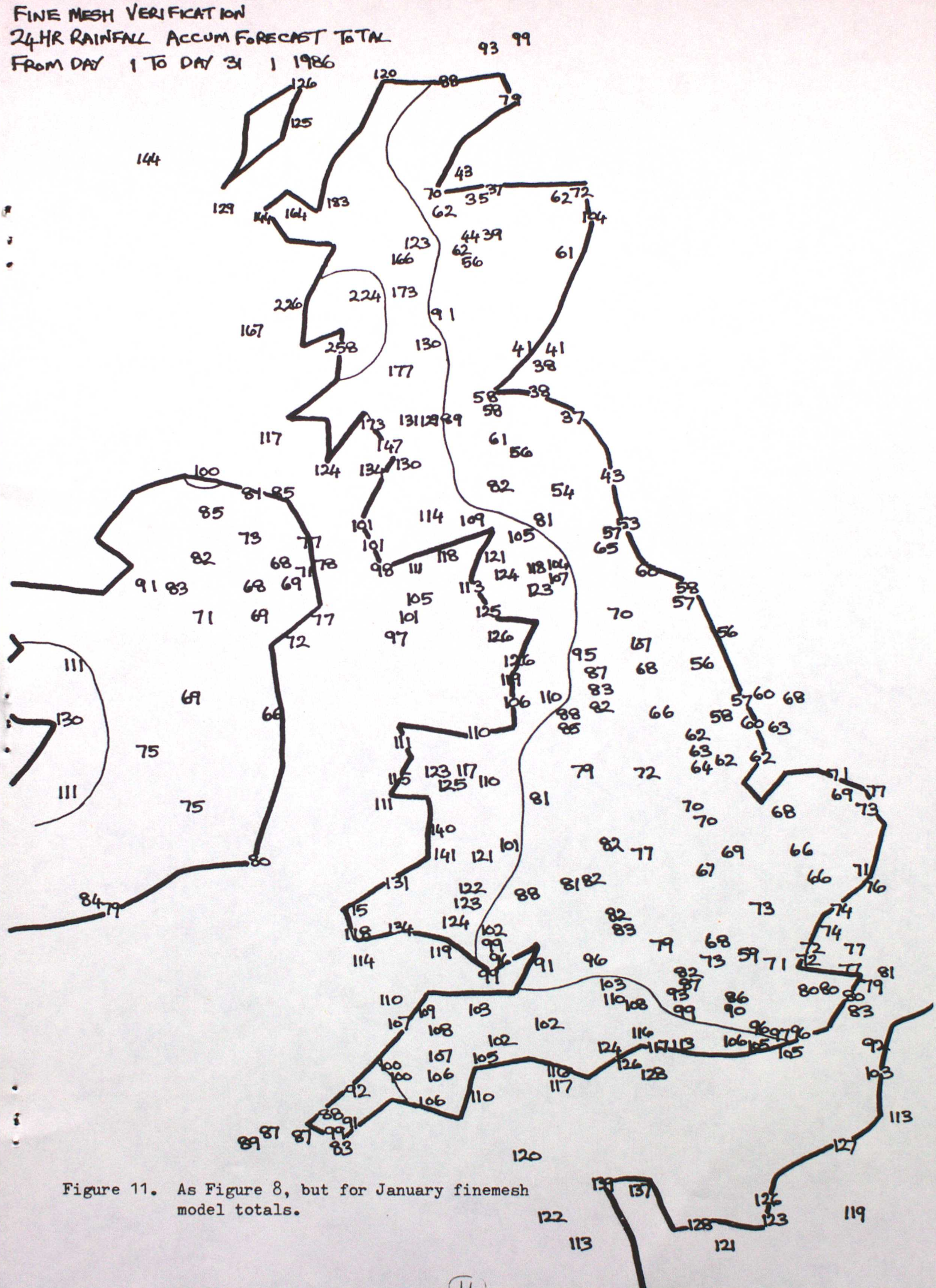


Figure 11. As Figure 8, but for January finemesh model totals.

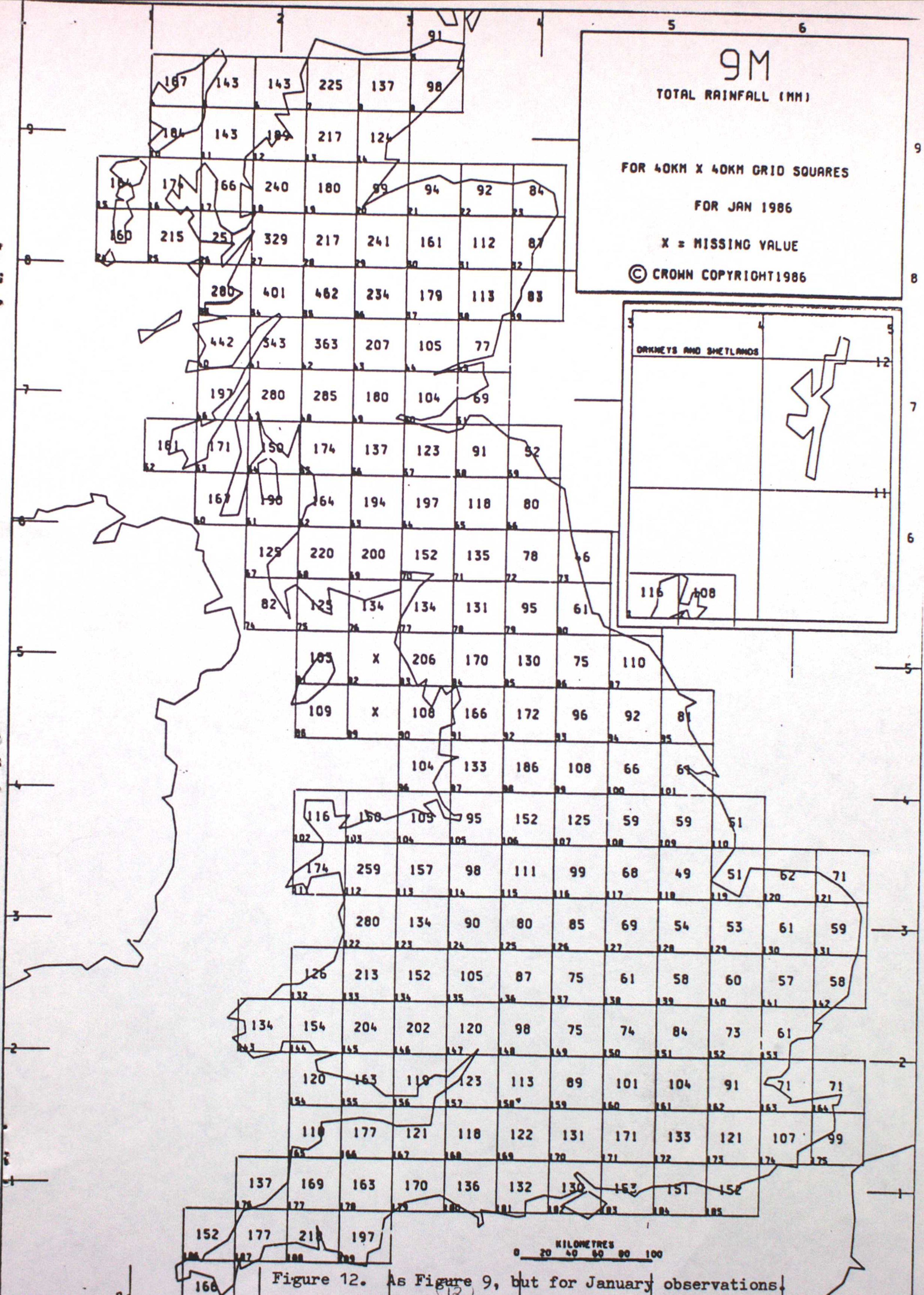
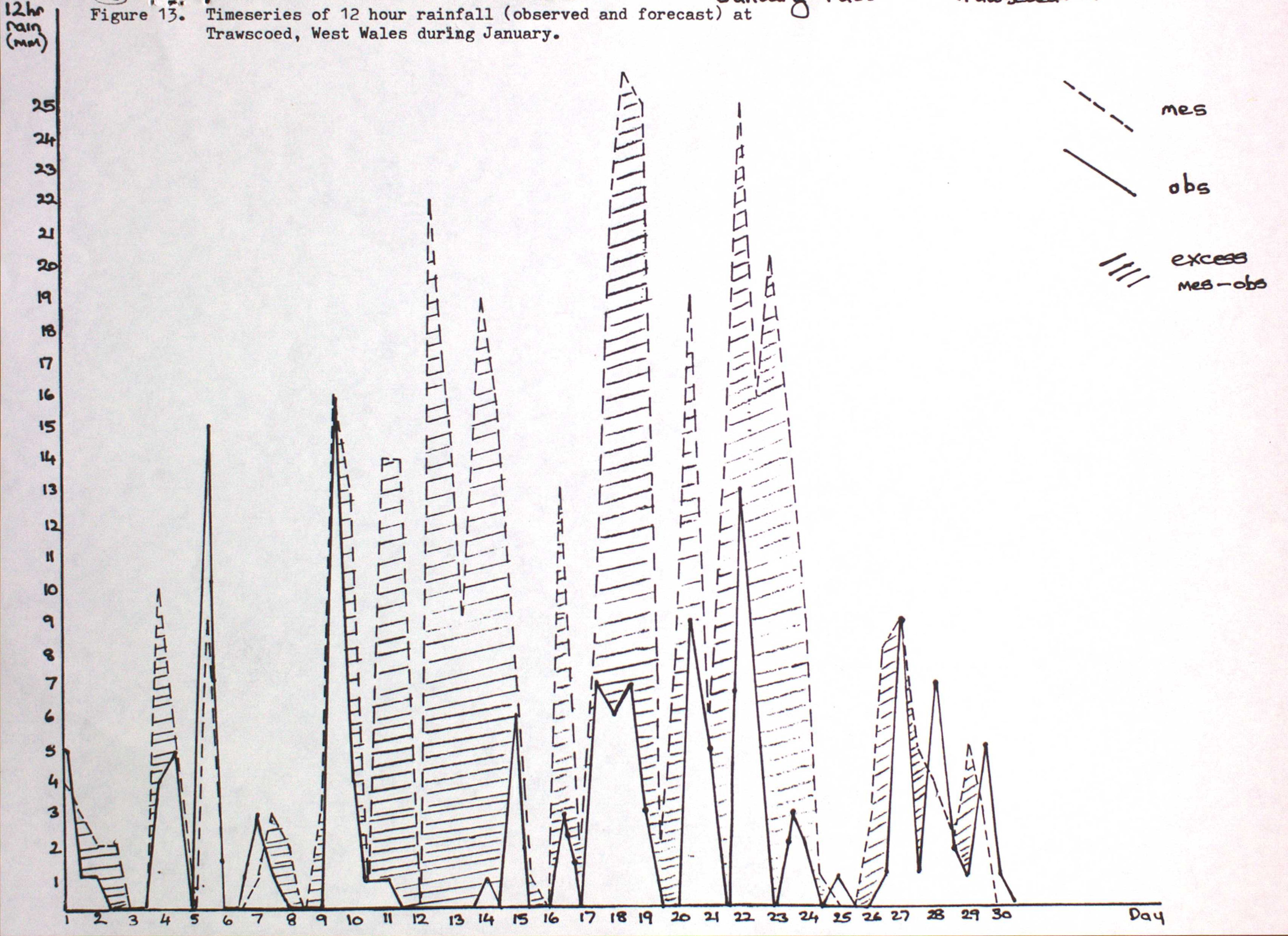


Figure 12. As Figure 9, but for January observations.

(13)

January Rain Trawscoed.

Figure 13. Timeseries of 12 hour rainfall (observed and forecast) at Trawscoed, West Wales during January.



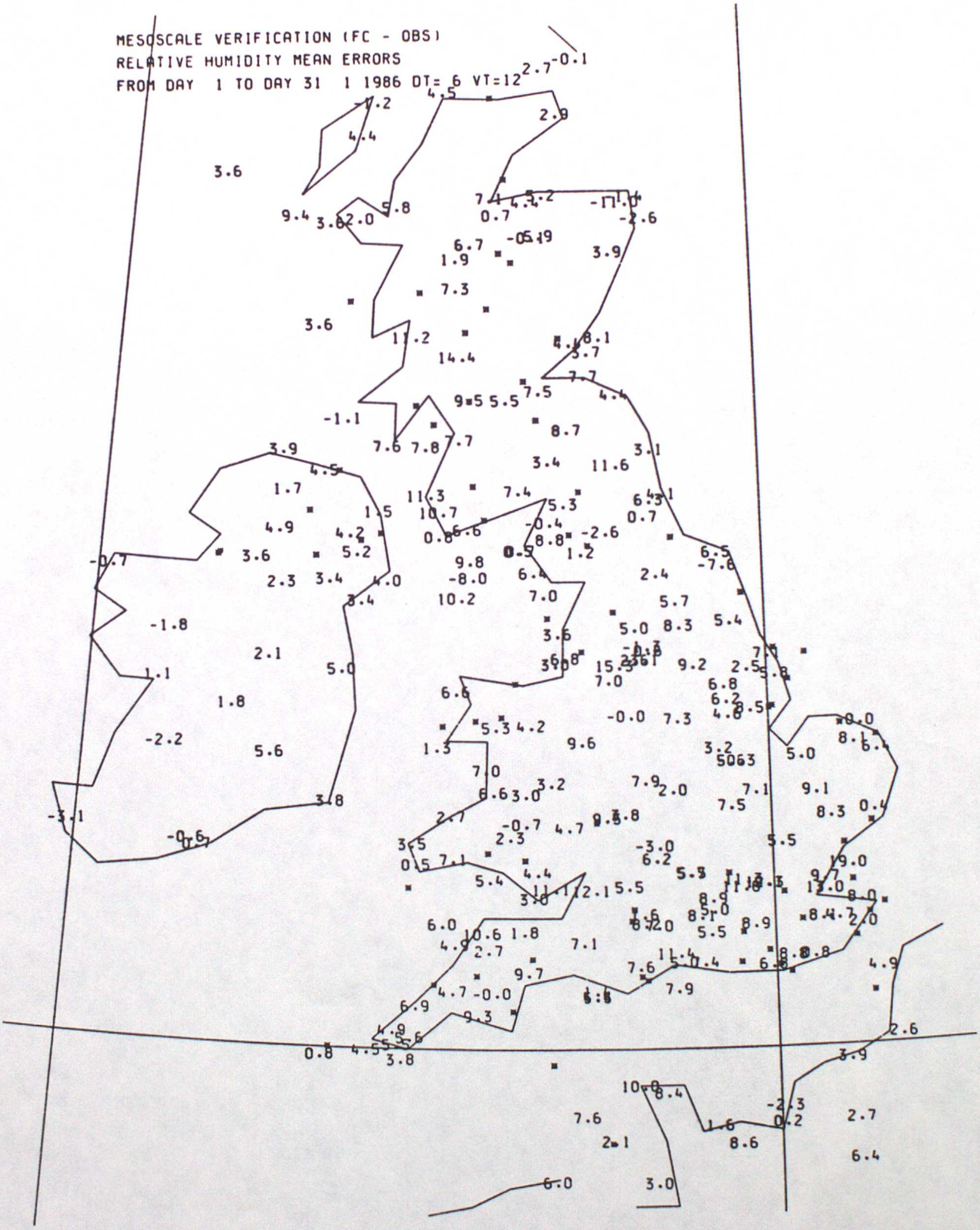


Figure 14. Mean errors of relative humidity for January forecasts verifying at 12Z.

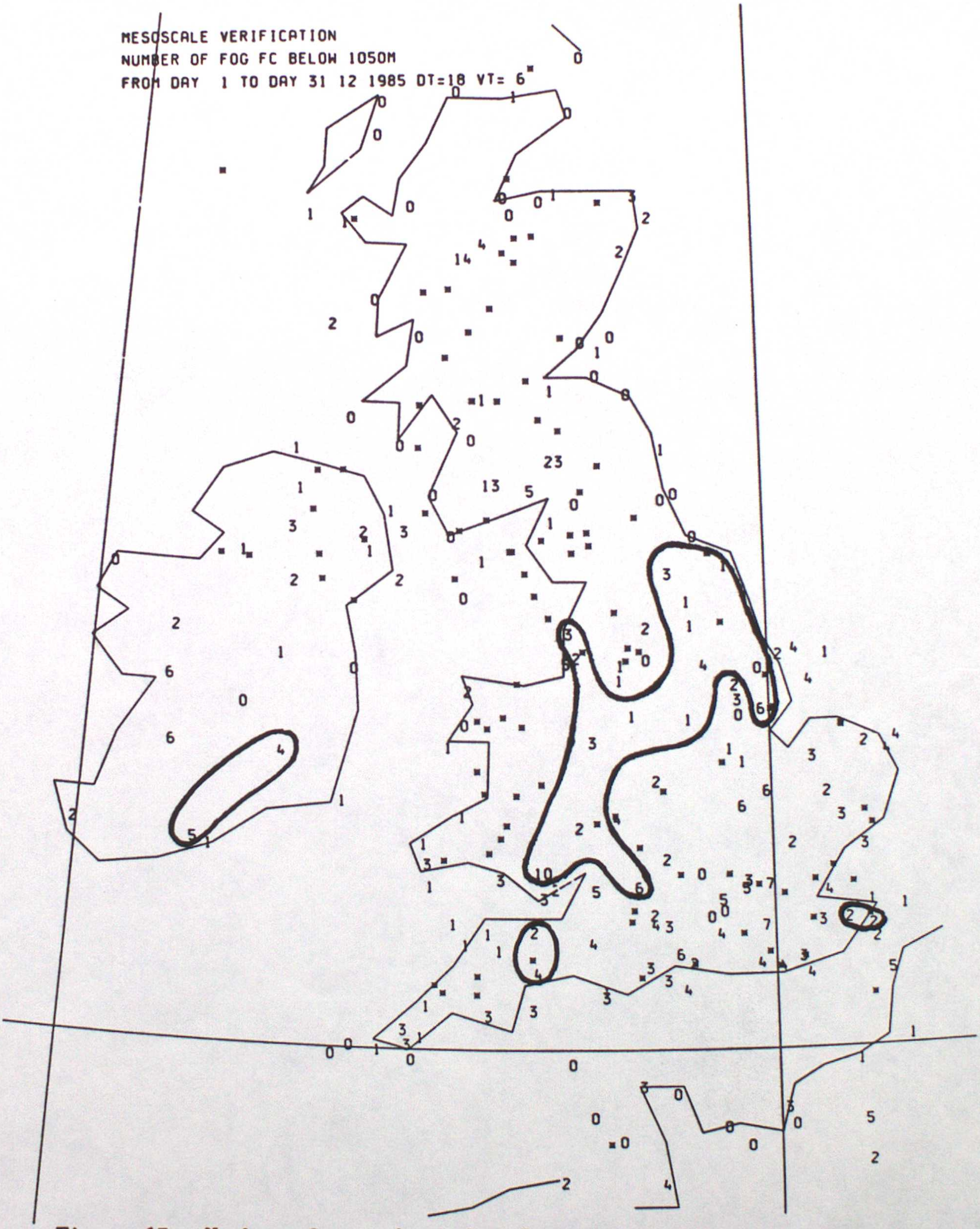


Figure 15. Number of occasions when forecast visibility was below 1 kilometre at 6Z during January. (A contour suprimposed on this chart encloses stations where a similar visibility was observed on more than two occasions at 6Z).

contour where ob fog freq > 2

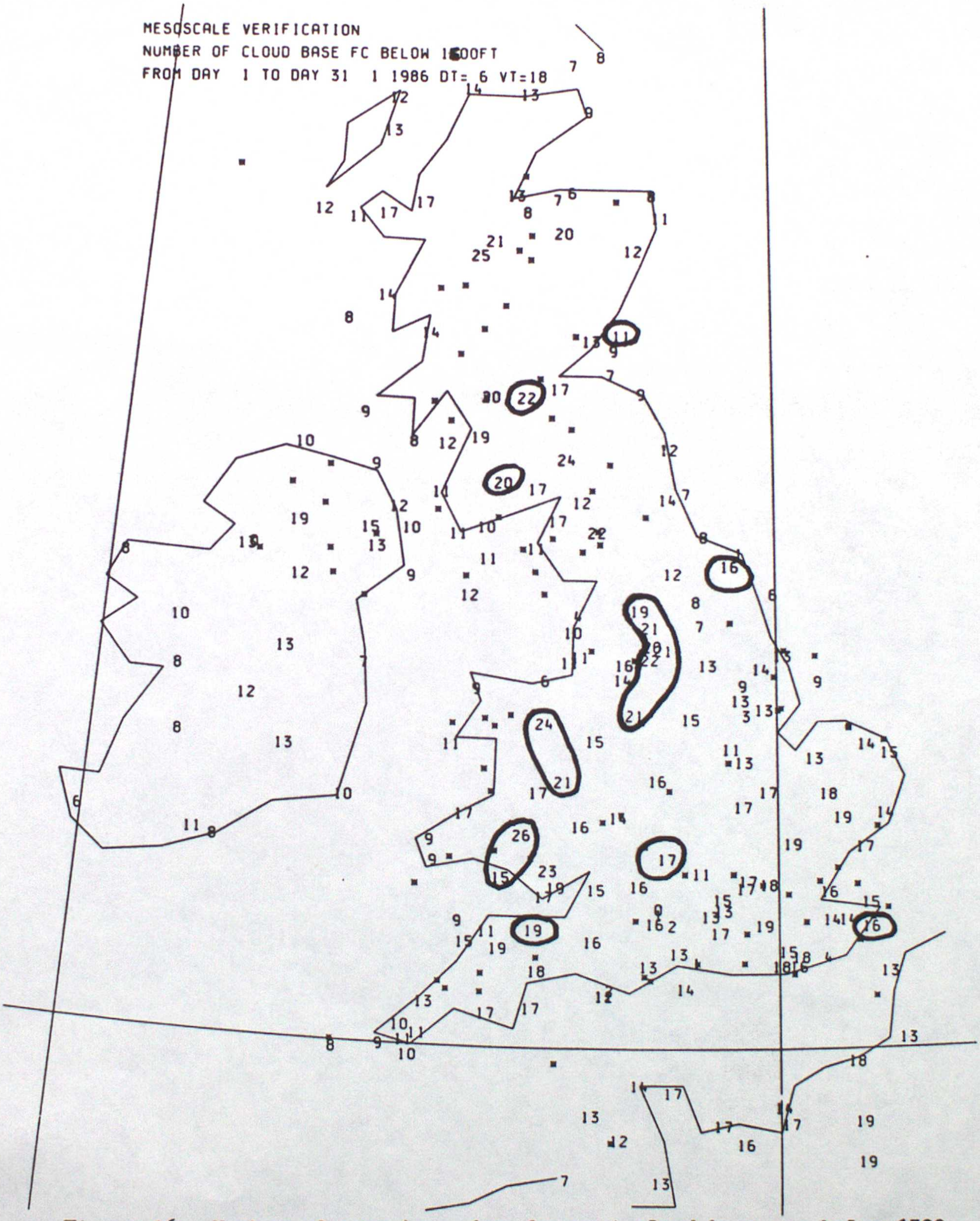


Figure 16. Number of occasions when forecast cloud base was below 1500 feet at 18Z during January. (A contour superimposed on this chart encloses stations where similar cloud bases were observed on more than 12 occasions at 18Z).

Contour where obs low cloud freq >12