LP

MET O 11 TECHNICAL NOTE NO. 126

A COMPARISON OF RAINFALL AMOUNTS PREDICTED FOR GREAT BRITAIN BY NUMERICAL MODELS

by

J. H. MINHINICK and J. FINDLATER

Met O 11 (Forecasting
Research Branch)
Meteorological Office
London Road
Bracknell
Berkshire
UK

May 1979

Introduction

The estimation of local rainfall, which may be modified by local topographical effects, is a major problem in the provision of short-period weather forecasts. The 10-level rectangle model with a grid length of 100 km is currently used for 36-hour forecasts. The effect of topographic height is included in the model in a limited way, but the resulting effect on the rainfall distribution is small. The topographic heights used in the model are average heights over 100 km squares and since these values are themselves smoothed the resulting topography is generally rather flat and featureless, as in Fig. 1. Another effect of the smoothing process is to spread the topography away from the actual mountains, and in some cases even out over the sea.

Recent work by Bell (1978) has shown that the 10-level model underestimates the rainfall over Wales, sometimes markedly, and Wickham (1977) has found a general deficiency in rainfall over the United Kingdom and adjacent continental areas. Also, it is known that the 10-level model is seriously deficient in rainfall accumulations for the first few hours of each forecast, and for this reason the tests reported here used rainfall accumulations for the period of nine to thirty-three hours after the beginning of each forecast.

One possible solution to the problem of improving the rainfall forecasts is to use the output from the 10-level model as the input to a separate model which has a grid size small enough to resolve the topography adequately, and which contains the essential physics of the orographic enhancement of rain. One such method has been developed by Bell (1978), hereafter referred to as B, in which information from the 10-level model is used to run an orographic model with a grid length of $3\frac{1}{3}$ km. The main drawbacks of B are:-

a) topography is not usually available on a $3\frac{1}{3}$ km grid.

b) there is no feed-back between the orographic model and the 10-level model.

Another, simpler, model has been developed by Riddaway (1978), hereafter referred to as R, where the effects of sub-gridscale topography are parametrized. R uses only one extra piece of information for each 100 km square, the standard deviation of the topography, whereas B uses 900 extra pieces of information for each square. R may also be developed to feed back to the larger-scale model. Initial tests of B and R in papers referred to earlier have indicated that for a short test period of two weeks over a limited area, Wales, both methods produced significantly better forecasts of rainfall accumulations than the 10-level model operational rectangle. In the R method the extra dynamic rain due to the sub-gridscale topography is calculated and added to the dynamic rain calculated during the forecast. In the B method the dynamic rain from the rectangle is ignored and the dynamic rain is calculated entirely by the B scheme. Thus R never forecasts less rain than the operational rectangle, hereafter referred to as OR, whereas in a few cases B will produce a forecast of less rain than OR.

These initial tests suggested a more extensive test of the models, over a wider area and over a longer period.

The experiment

The two models, B and R, were run daily during the six-month period from August 1978 to January 1979. The input data for the orographic models were extracted every six hours from the 10-level model fine-mesh forecast based on a midnight analysis. The data from T + 12 to T + 30 were used to arrive at forecast total accumulated rainfall for the period T + 9 to T + 33, which corresponds to a rainfall day, i.e., the period over which rainfall is measured. Because the topography data set on a $3\frac{1}{3}$ km grid length is aligned along the National Grid the rectangle data were re-orientated on the National Grid axes.

The total forecast area is shown in outline in Fig. 1. For grid squares that lay entirely or mostly over the sea both models used the OR rainfall amounts for computational economy. For the analysis of results thirty-seven

100 km squares were chosen to cover most of Great Britain, as shown in Fig. 2.

The forecast rainfall amounts for each 100 km square were compared with mean actual rainfall amounts over the 100 km squares. These latter data were obtained from the official raingauge network as held in the Met O 8 data sets. One point of note is that the observed rainfall is the sum of convective and dynamic rainfall. The orographic models cater only for dynamically-induced ascent and it follows that the amount due to convection must be added before comparing with actual rainfall. The convective contribution was derived from the OR deep convective scheme (Hayes, 1977) which adds on average about 20% to the low-lying area rainfall totals.

Since the accuracy of the forecasts from the orographic models depends directly on the quality of the forecast input data from OR, the results which follow compare forecasts from all three models.

The comparison

Basic statistics were calculated for all three models for each of the 100 km squares shown in Fig. 2. Whilst basic statistics such as correlation coefficients, mean errors and root mean square errors do not completely describe the accuracy of forecasts they can be used to draw attention to areas in which forecasts are generally good or bad, and to the relative performance of differing models. An overview of the results from the three models is given in Table 1.

The correlation coefficients should have little weight placed upon them since relatively high values can occur when a model consistently over- or under-forecasts rainfall. However, the mean errors ($\overline{E}$) in Table 1 indicate that the B model produces too much rain, the OR model too little rain, whilst the R model has a very small overall error. The root mean square errors are greatest in the B model and least in the R model.

The overall values in Table 1 may be sub-divided into the thirty-seven 100 km squares over which the forecasts were compared with the actual rainfall. Figs. 3, 4, 5 and 6 show the actual mean daily rainfall, the B forecast, the R forecast and the OR forecast respectively. It is noticeable that whereas the actual rainfall was greatest in west Scotland and the OR forecast matched this, albeit with smaller amounts, the B and R forecasts both placed the maximum rainfall over the Scottish highlands. The B forecast produced too much rain but the R forecast rainfall amounts were in good agreement with the actual values.

It is noteworthy that the OR model forecasts well the rainfall amounts in the non-mountainous areas of Great Britain (c.f. Figs. 3 and 6) and it follows that the B and R models, being based on the OR model, will do equally well in these areas. This implies that the problem of underforecasting rainfall in the OR model is linked to the problem of representing the topography adequately.

The root mean square errors, shown in Figs. 7, 8 and 9 reveal the serious over-forecasting of Scottish highland rainfall by the B model. The R model shows a small but consistent improvement in most highland areas over the OR model.

Mean forecast errors, as in Figs. 10, 11 and 12 show again the serious fault in the B model over the Scottish highlands, whilst the OR model produces too little rain (except in southern and eastern England). The best forecasts are from the R model, but it produces too little rain in western Scotland and too much over the Scottish highlands, though the errors are not large.

The results above are, of course, mean values for the 158 daily forecasts made during the six-month test period, but they suffice to highlight some of the more important characteristics of the models. To examine the performance of these models on a daily basis scatter diagrams of actual against forecast rainfall for each of the three models have been prepared for selected 100 km squares. Only those for square number 8 (Scottish highlands) are reproduced here.

Figs. 13, 14 and 15 represent the daily forecasts by the B, R and OR models respectively for a mountainuous area. The correlation coefficient and the line of best fit calculated by the method of least squares are included in each figure. In Fig. 13 it is obvious that the B model frequently predicted rainfall when little or no rain actually fell, and this tendency to overforecast was marked up to actual amounts of about 15 mm. For the larger amounts which fell, more than about 15 mm, the B model showed a slight tendency to underforecast rainfall.

The R model (Fig. 14) has a tendency to overforecast small amounts of rainfall but not to the extent that the B model does. For moderate amounts, of about 10 mm, the correspondence between actual and forecast amounts is good, but larger amounts are underforecast.

The OR model (Fig. 15) generally underforecasts rainfall amounts.

The characteristics of each model deduced from the analyses of Figs. 13, 14 and 15 are generally applicable to other elevated areas of Great Britain.

Conclusions

a) It is confirmed that the OR model predicts too little rainfall, especially over mountains. Over flat and low-lying areas such as south and southeast England its performance is good.

b) The B model predicts too much rainfall over all hilly areas, especially over Scotland. In the period investigated the B model predicted the greatest rainfall amounts over the central highlands of Scotland whereas the greatest actual amounts occurred on the west coast of Scotland. Also, the B model tendency to overforecast rainfall is marked up to actual amounts of about 15 mm. For the larger amounts which fell a slight tendency to underforecast rainfall was evident.

c) The R model overforecasts small amounts of rainfall, but not serviously, and underforecasts the larger amounts. In general, however, the R model predicts just about the right amount of rainfall. Over mountainous regions such as Scotland the greatest amounts are predicted to be over the highest ground whilst the greatest actual rainfall occurred over western Scotland.

d) The fact that both the B and R models place the greatest rainfall over the highest ground instead of on the west (and mostly windward) coast of Scotland, suggests that neither model takes adequate account of the effects of the general wind direction and topography. It is recommended that the most promising model, R, be made inter-active with the OR model and that topographic influences in the R model be more sensitive to the general wind direction so that windward and leeward effects are included.

References

Bell, R.S.	1978	The forecasting of orographcally-enhanced rainfall accumulations using 10-level model data. Met. Mag., 107, pp 113-124.
Wickham, P.G.	1977	Errors in rainfall forecasts by the 10-level model, 1973-77. Met O 11 Tech. Note No. 99.
Riddaway, R.W.	1978	The parameterization of subgridscale topography. Met O 11 Tech. Note No. 117.
Hayes, F.R.	1977	A new parameterization of deep convection for use in the 10-level model. Q.J.R. Met. Soc. Vol. 103, pp 359-367.

Model	$\overline{r}$	$\overline{E}$	RSME
B	0.618	0.889	4.856
R	0.602	-0.011	4.167
OR	0.583	-1.224	4.298

Table 1. Correlation coefficients ($\overline{r}$), mean error ($\overline{E}$) in mm, and root mean square error (RSME) in mm for the three models. All areas of Great Britain combined.

Fig.1 Smoothed topography as used in the 10-level operational rectangle model. The frame encloses the area used in comparing forecasts from differing models

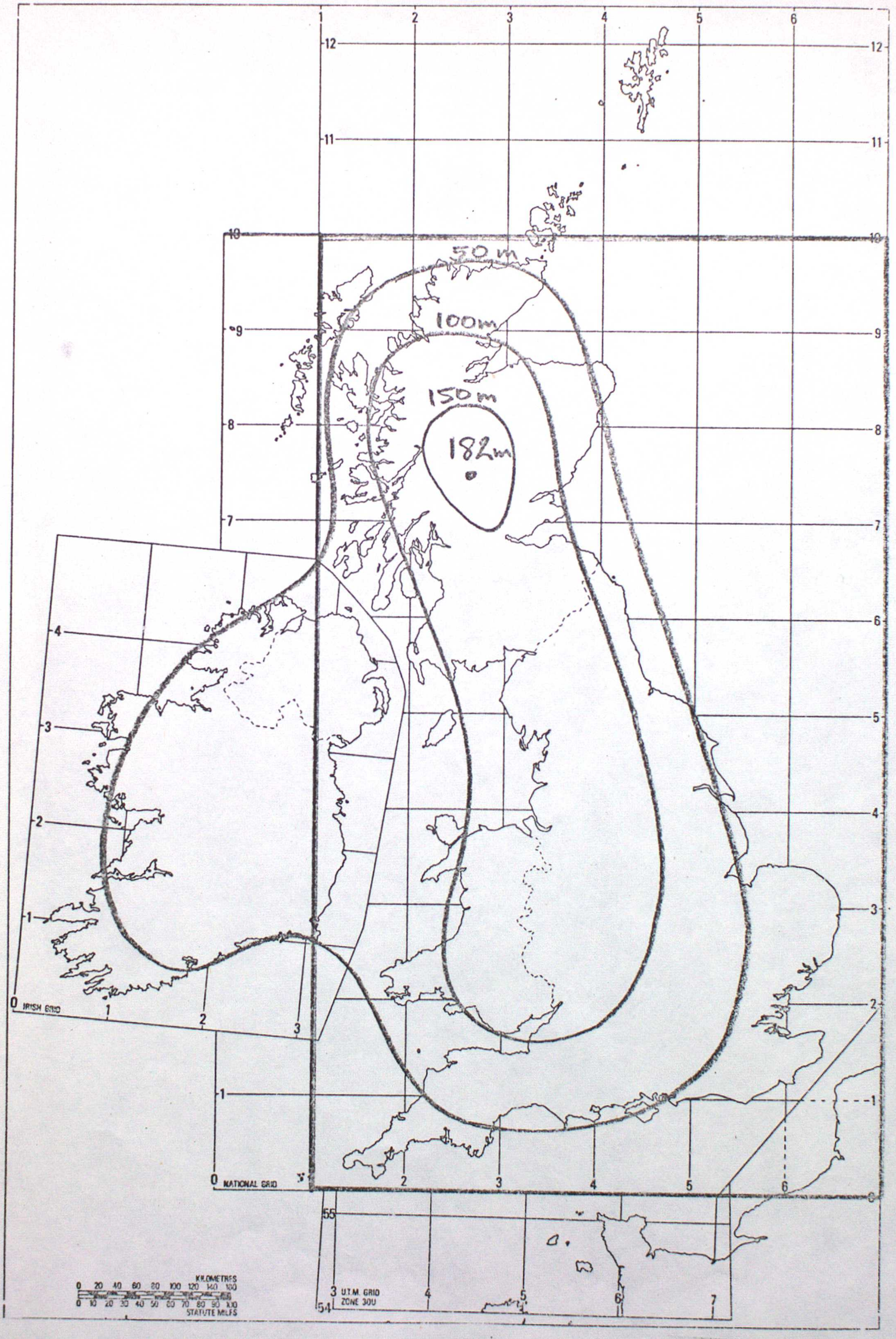


Fig.2. 100km grid squares used in comparing forecast rainfall with actual rainfall.

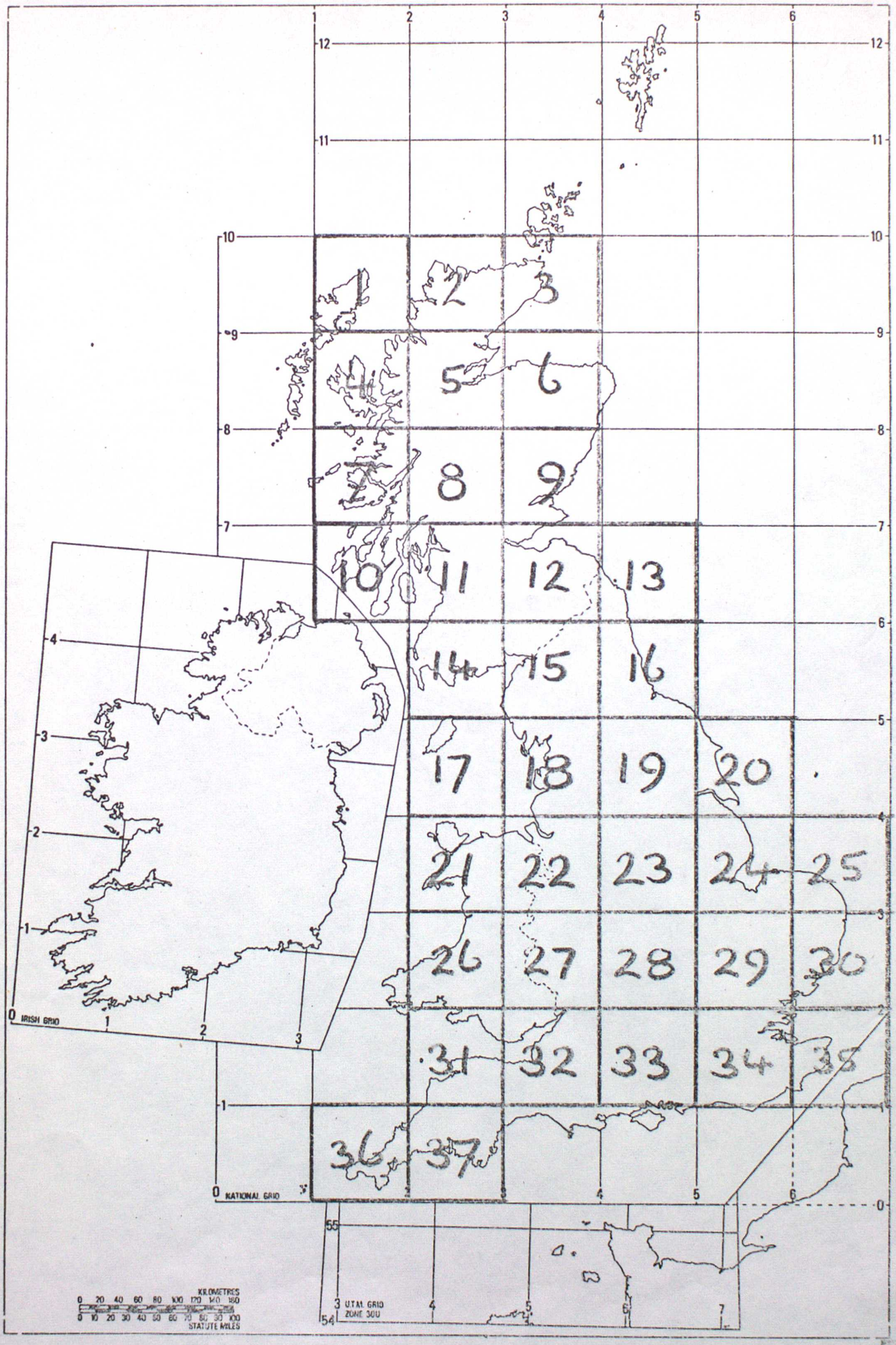


Fig.3. Mean Daily Rainfall (mm). August 1978 - January 1979

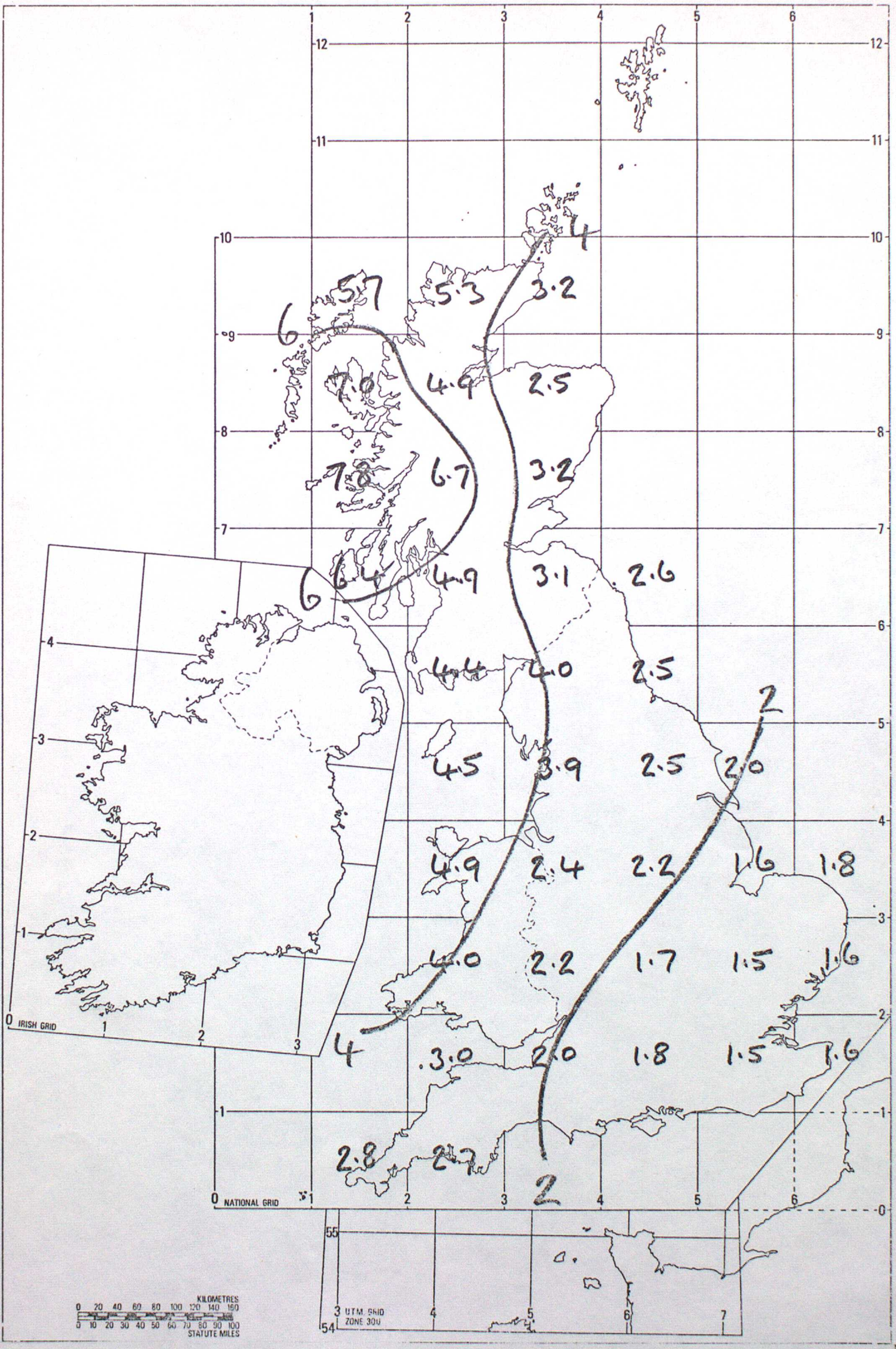


Fig.4. Mean Forecast Daily Rainfall (mm). Bell Model, August 1978 - January 1979.

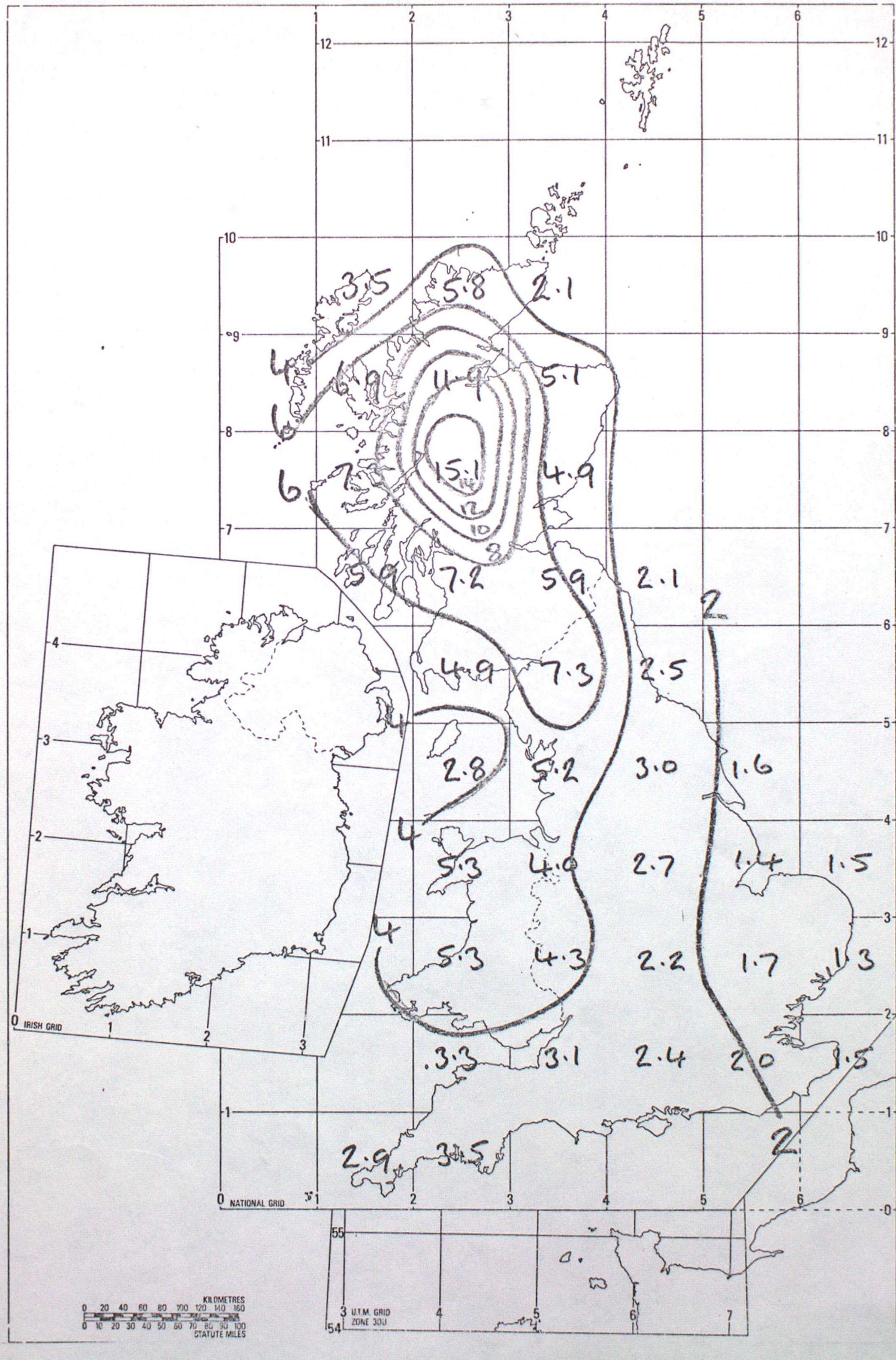


Fig. 5. Mean Forecast Daily Rainfall (mm), Riddaway Model, August 1978 - January 1979.

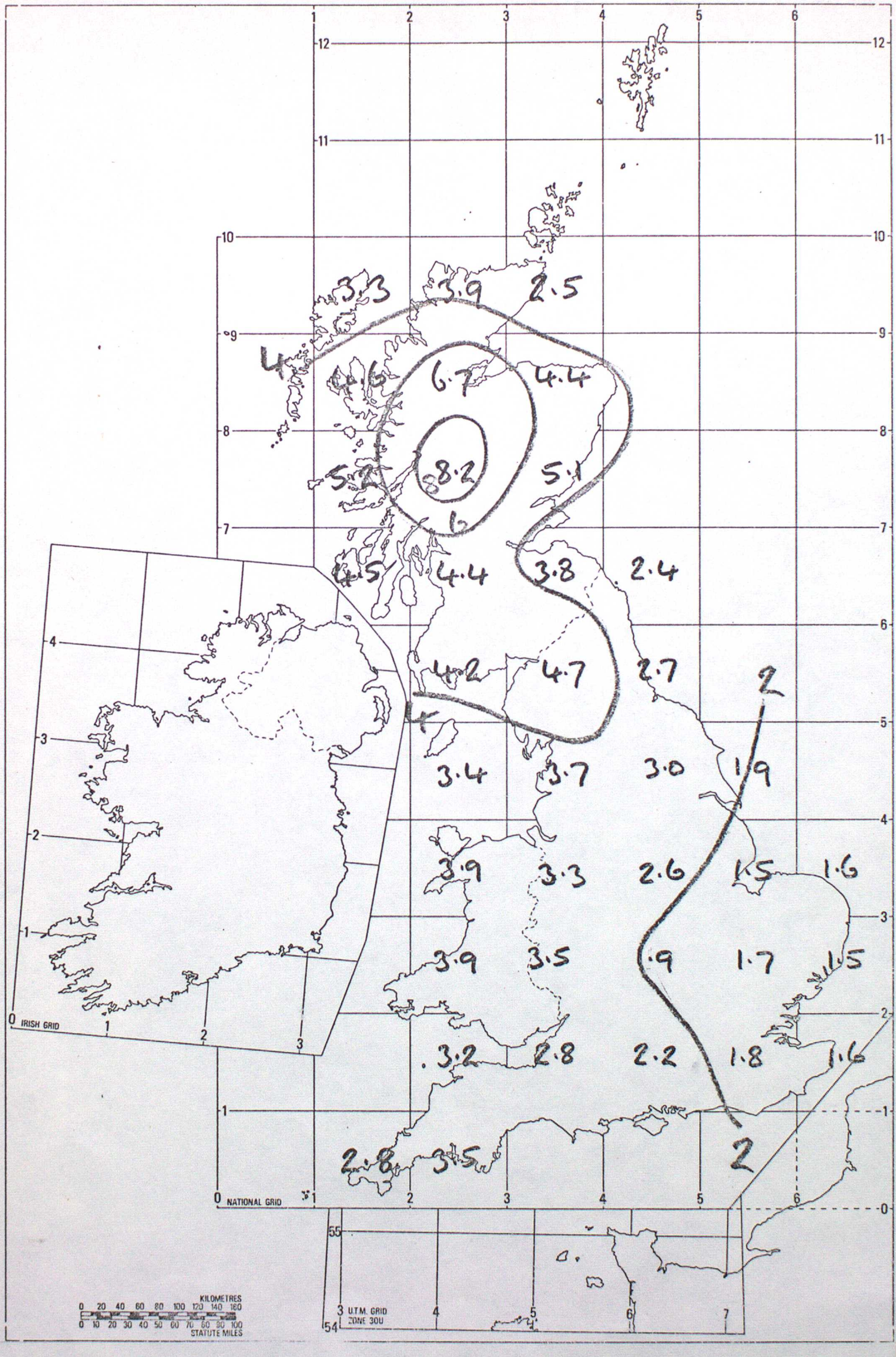


Fig.6. Mean Forecast Daily Rainfall (mm). Rectangle Model, August 1078 - January 1979.

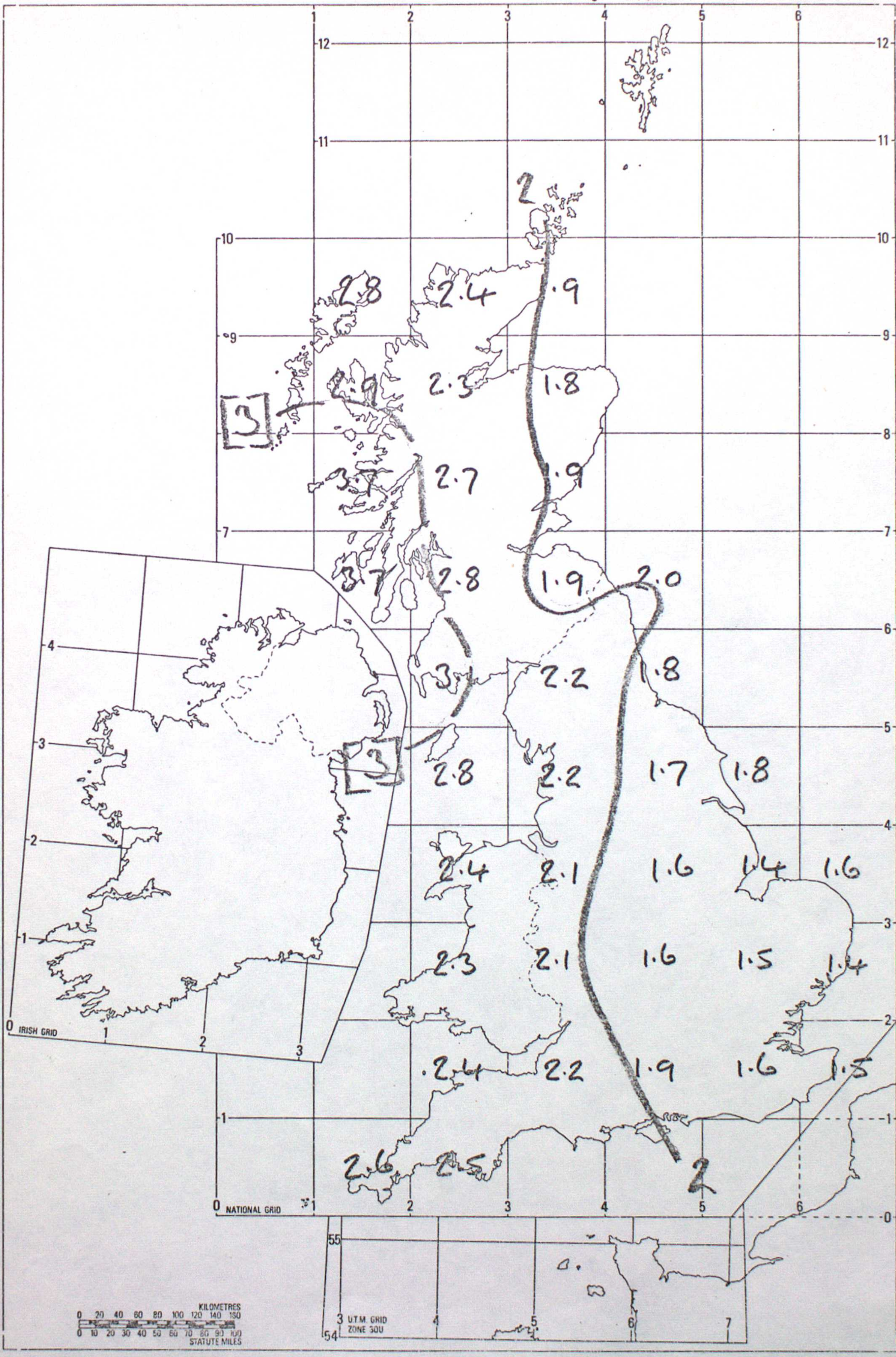


Fig.7. Root Mean Square Error (mm) Bell Model, August 1978 - January 1979

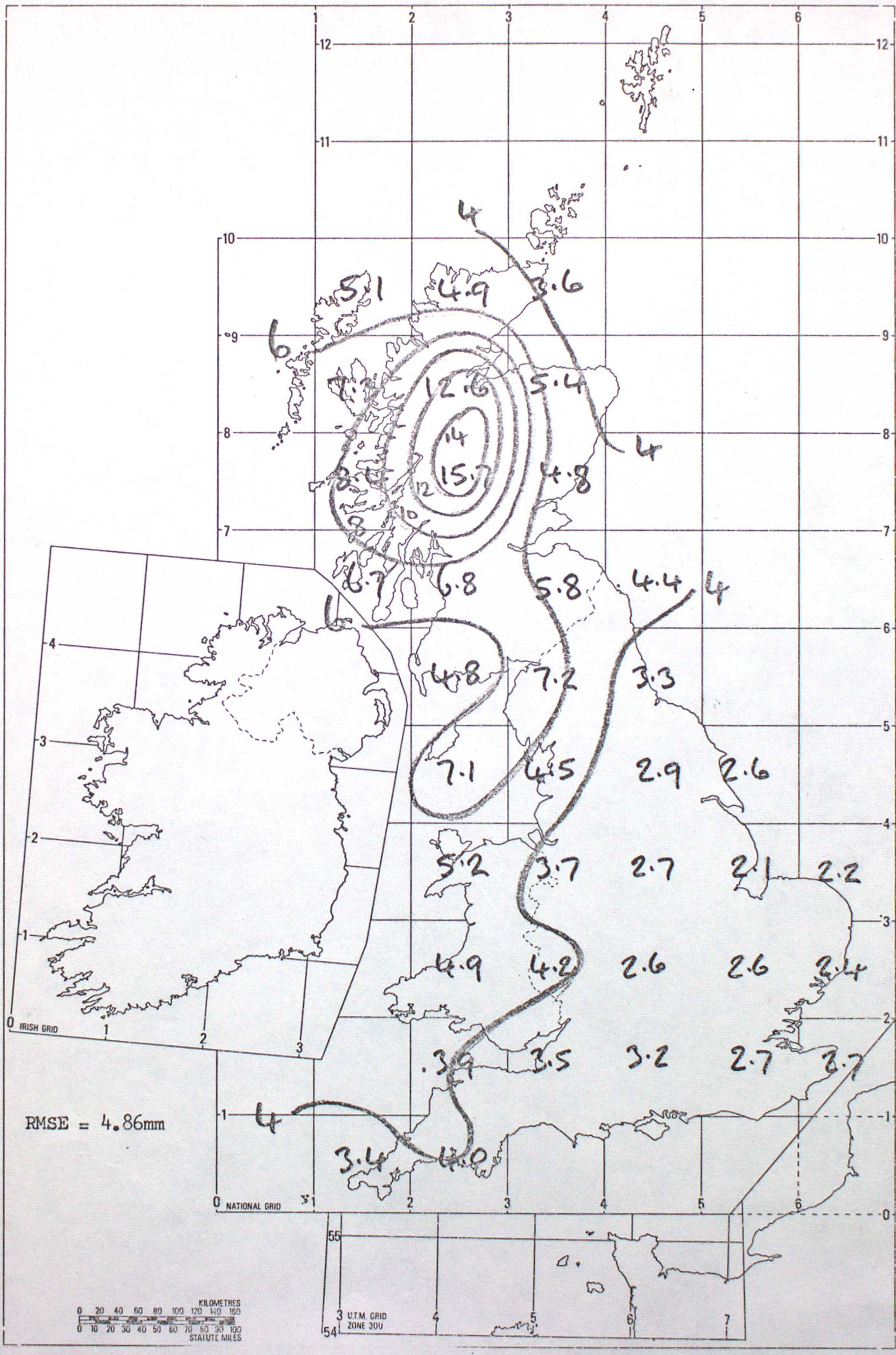
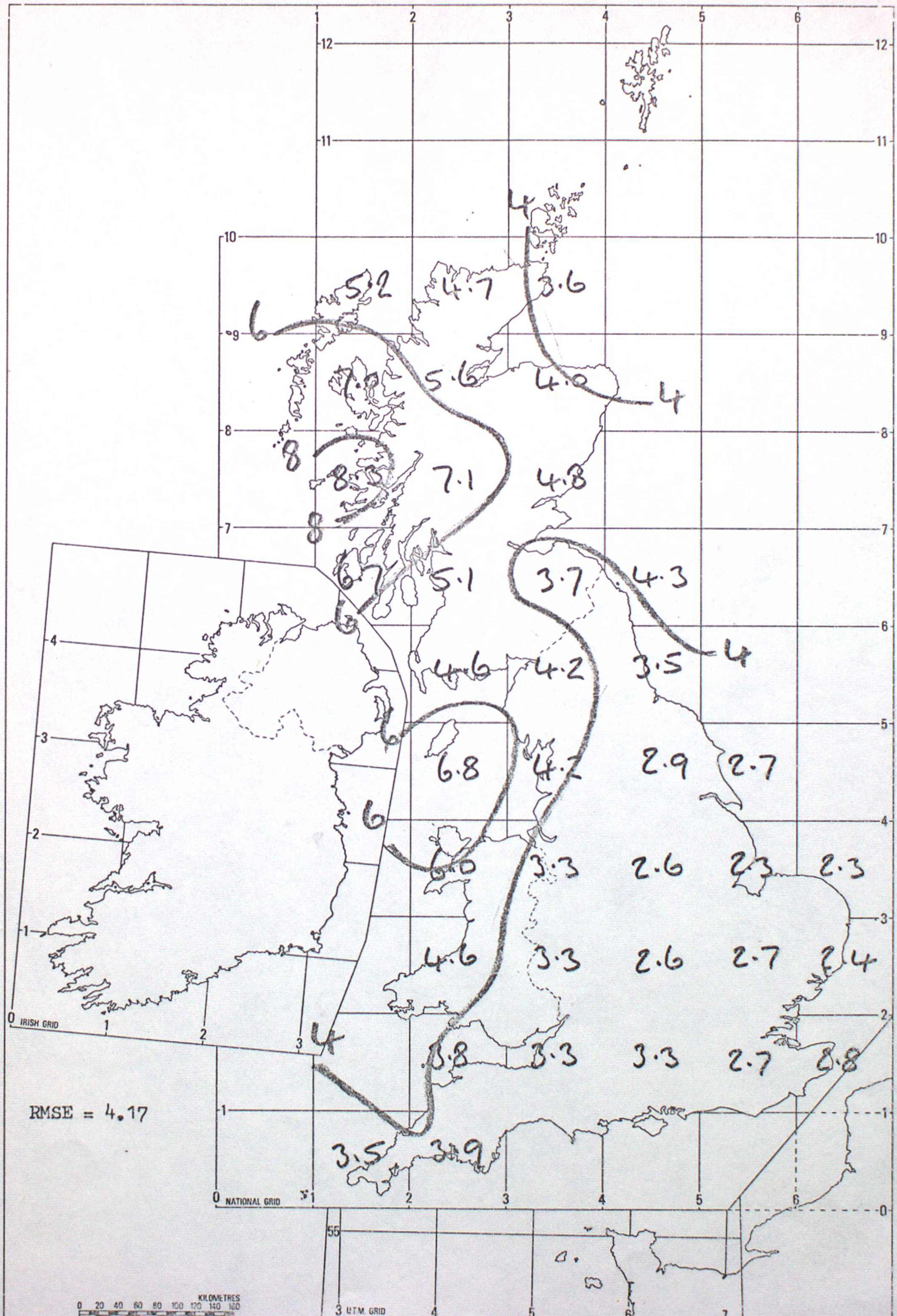


Fig. 8. Root Mean Square Error (mm). Riddaway Model, August 1978 - January 1979



RMSE = 4.17

Fig. 9. Root Mean Square Error (mm). Rectangle Model, August 1978 - January 1979

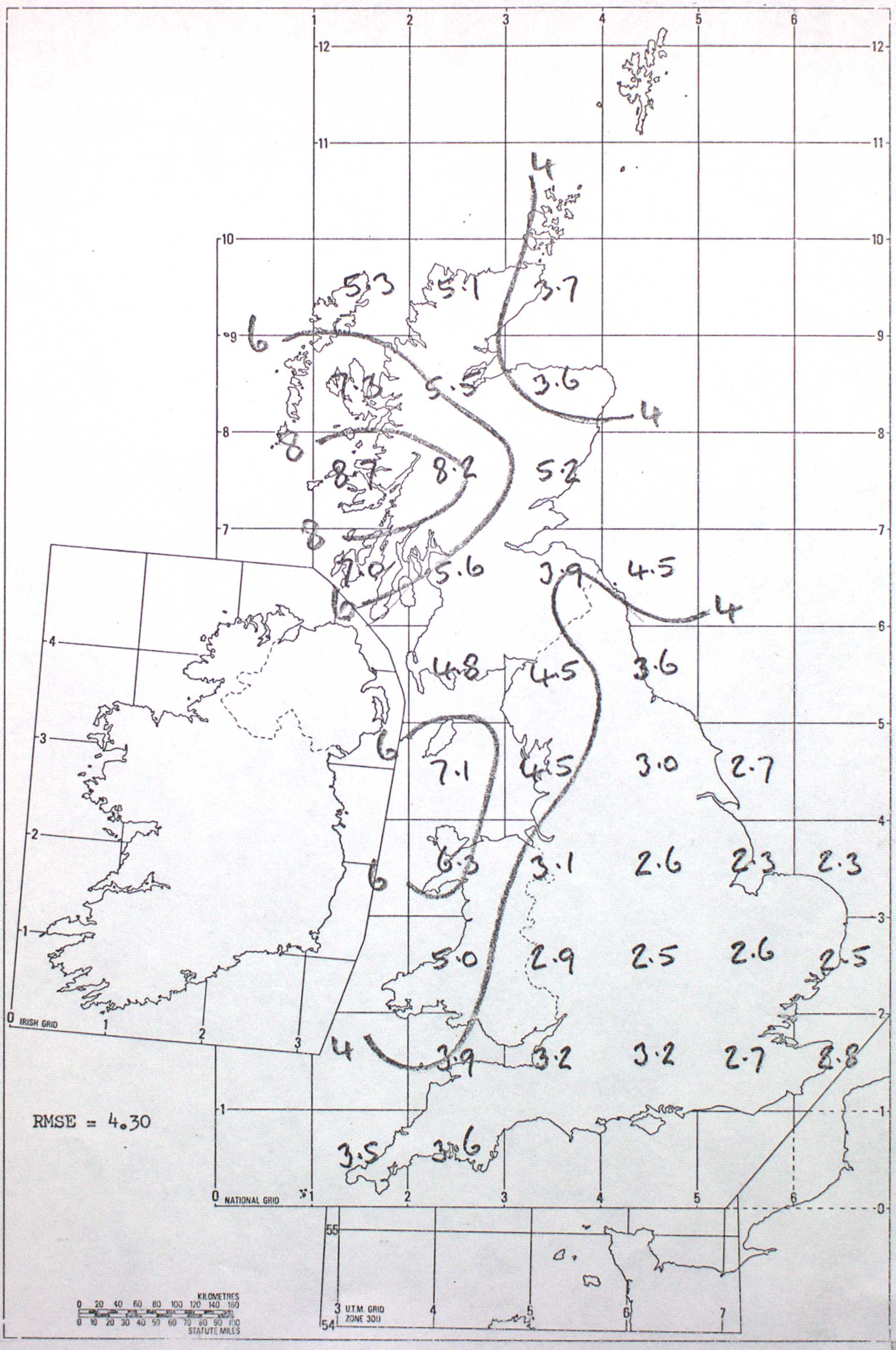


Fig. 10. Mean Forecast Error (mm). Bell Model, August 1978 - January 1979.

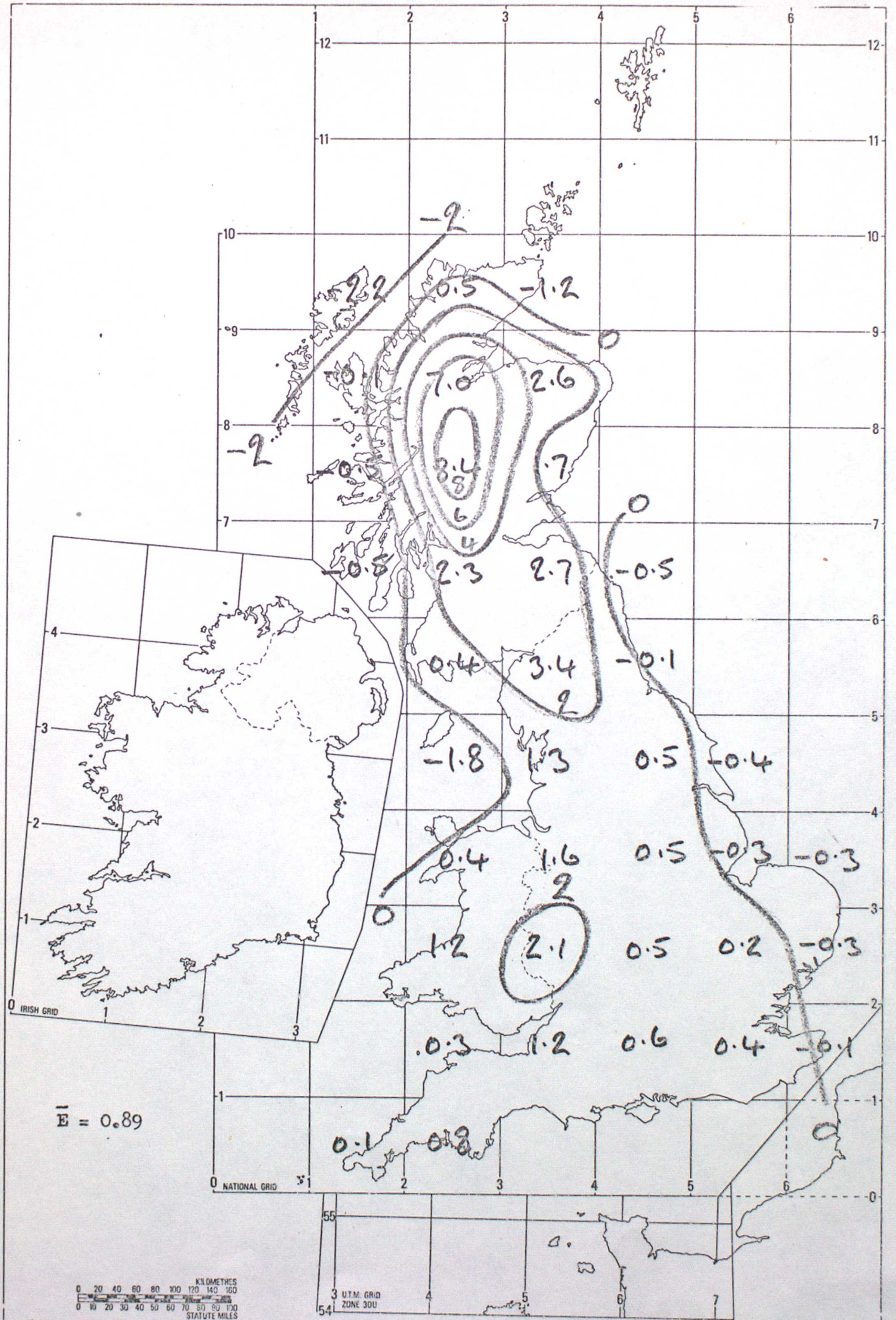


Fig.11. Mean Forecast Error (mm). Riddaway Model, August 1978 - January 1979

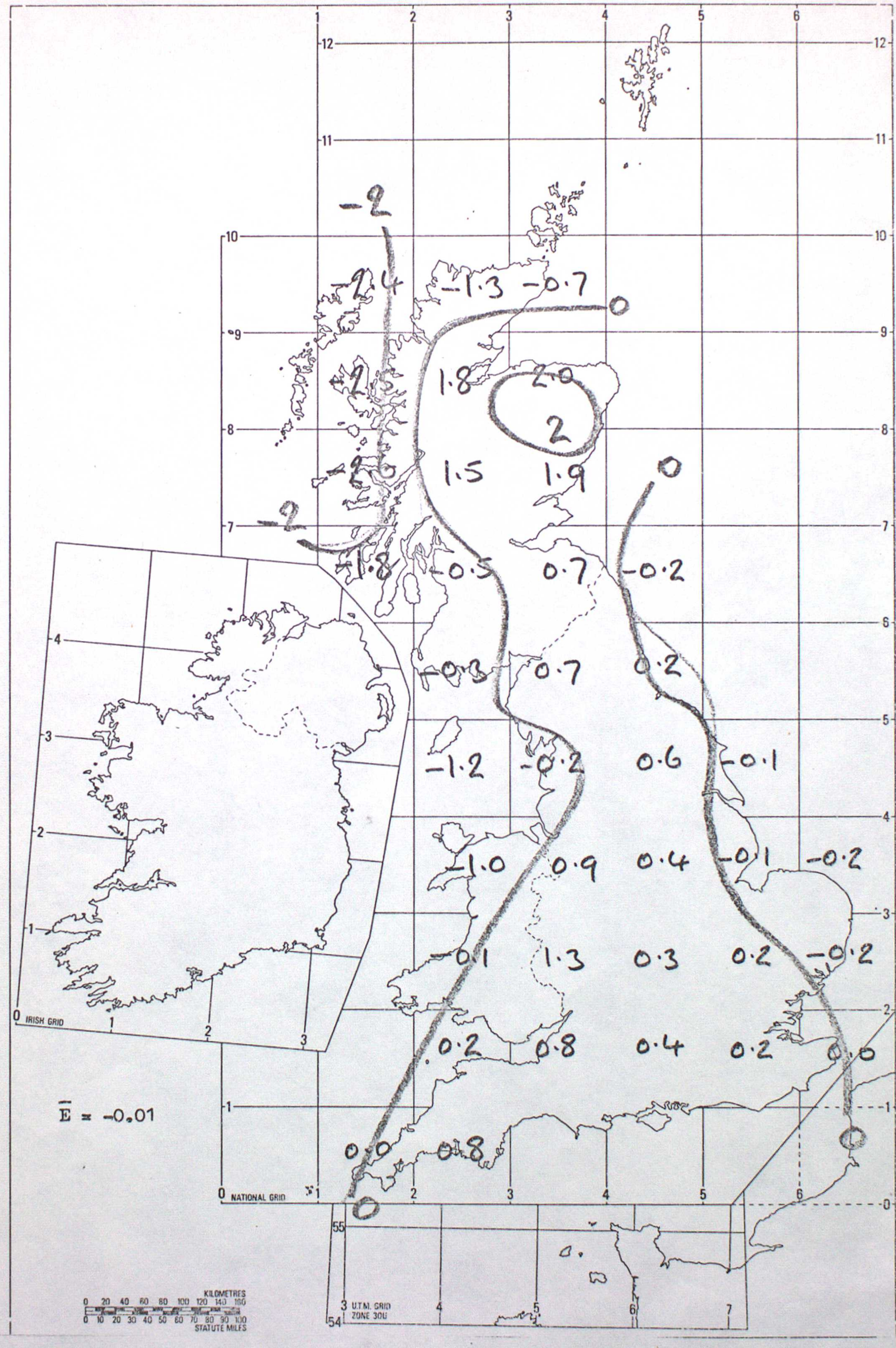
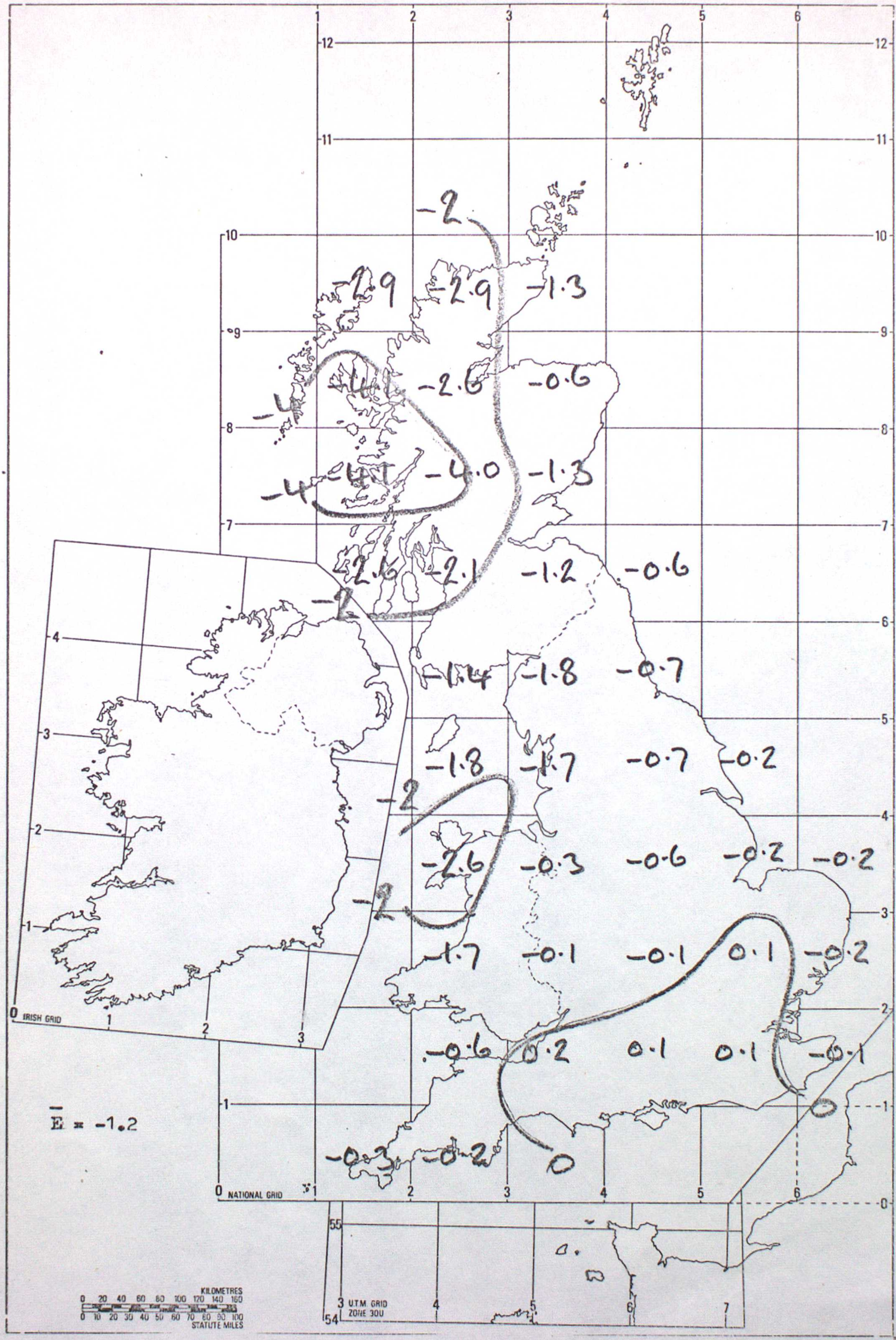


Fig.12. Mean Forecast Error (mm). Rectangle Model, August 1978 - January 1979



ACTUAL RAINFALL (mm)

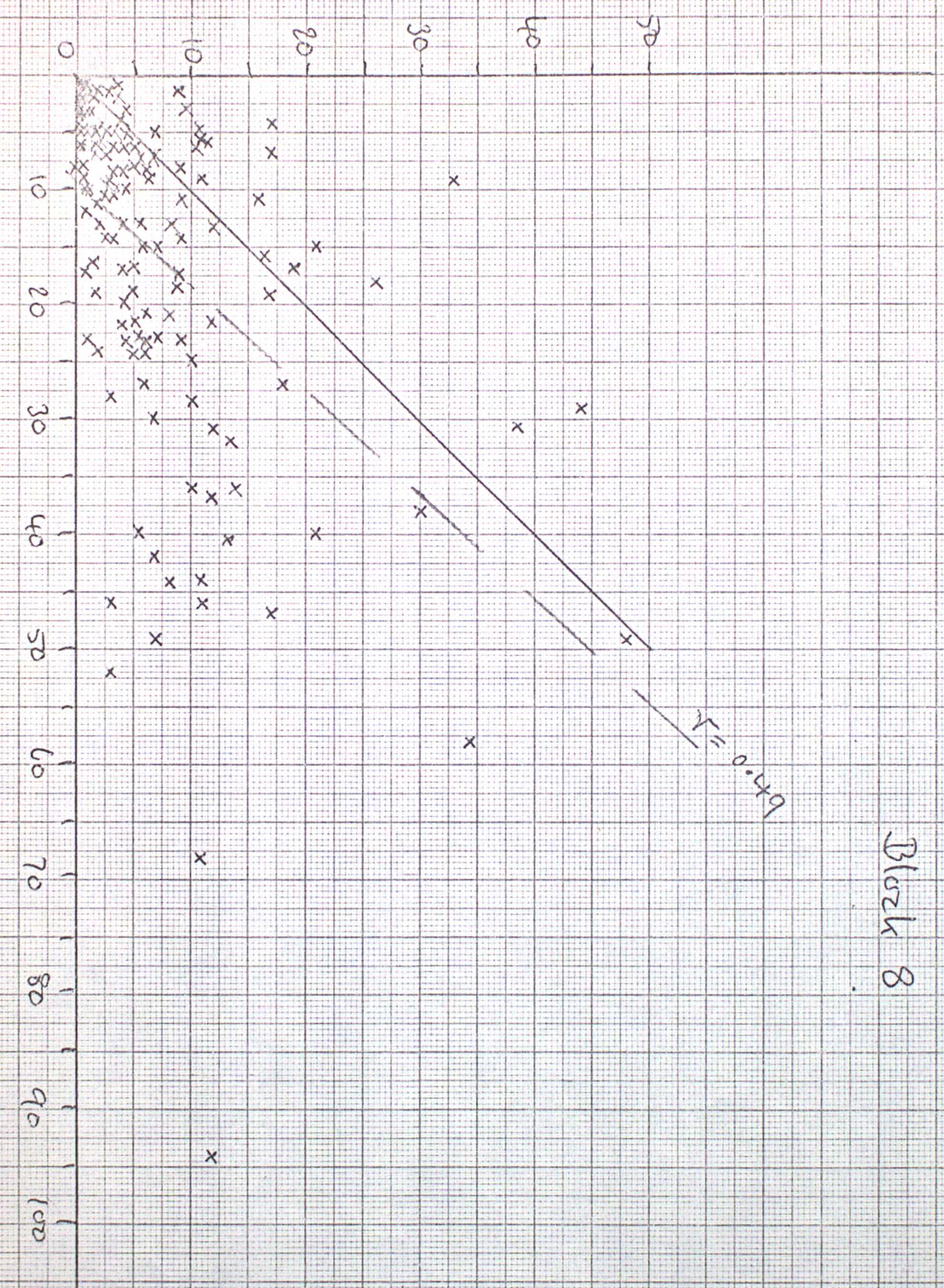


Fig. 13.

Forecast Rainfall - Bell Model (mm)

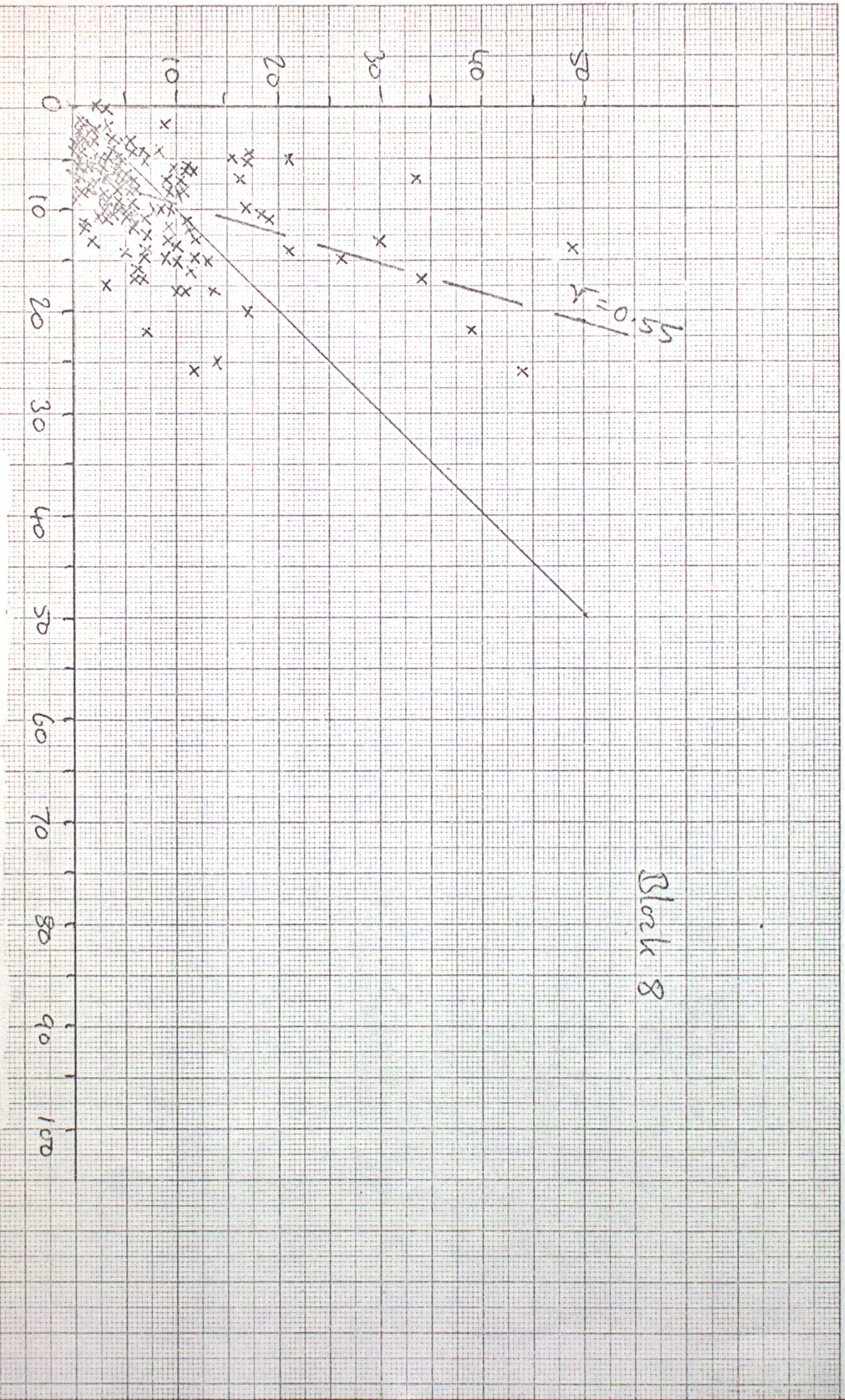

ACTUAL RAINFALL (mm)
0
10
20
30
40
50
60
70
80
90
100
r = 0.55
Block 8
Forecast Rainfall - Riddaway Model (mm)

Fig.14.

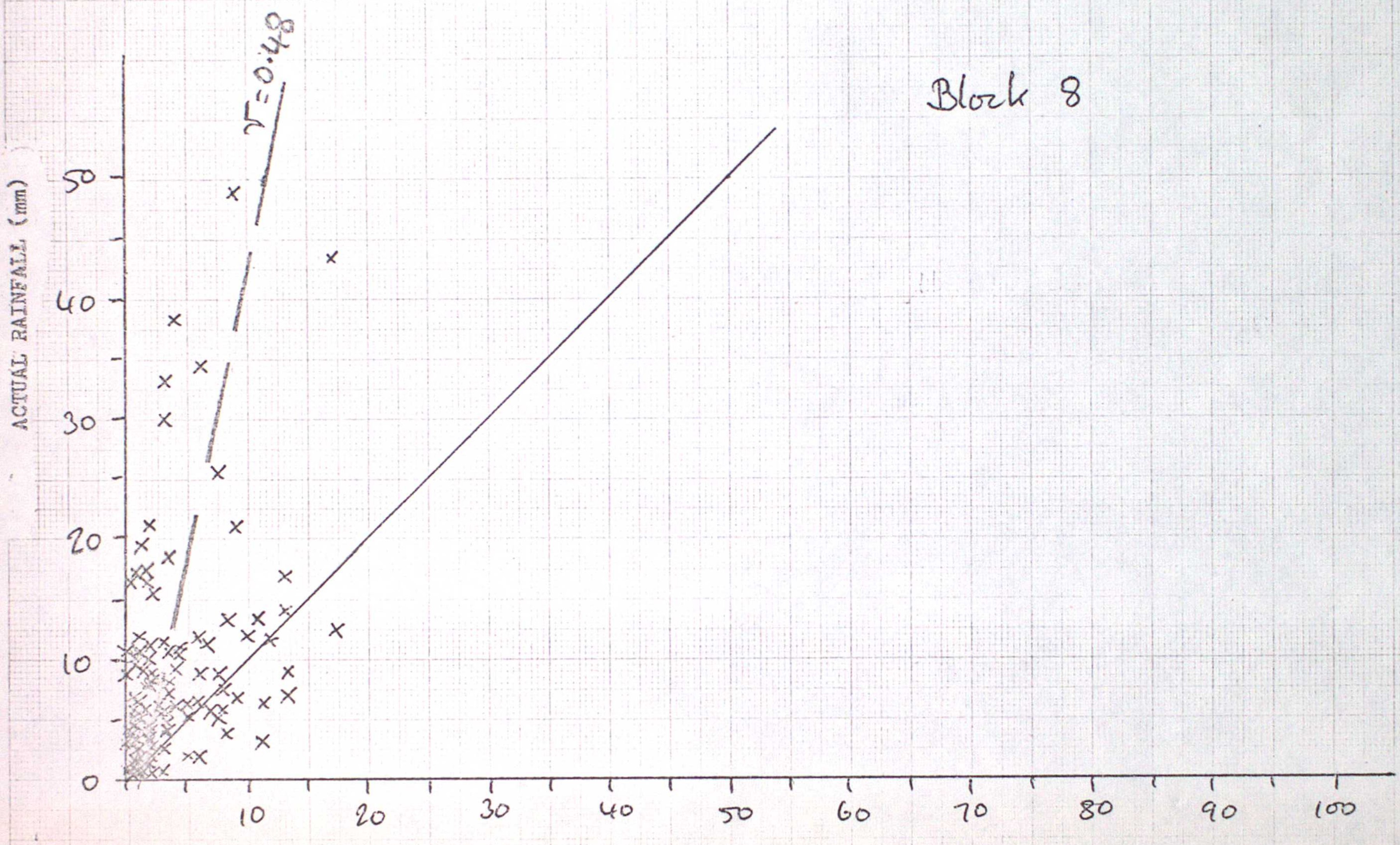


Fig. 15. Forecast Rainfall - Rectangle Model (mm)