MET.O.11 TECHNICAL NOTE No. 43

SOME EXAMPLES OF THE RAINFALL FORECASTS PRODUCED BY THE FINE-MESH VERSION OF THE 10-LEVEL MODEL.

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Summary

The rainfall forecasts over the British Isles, computed by the fine-mesh version of the 10-level model on four occasions during the summer of 1973, are displayed.

Current deficiencies in the formulation of certain physical processes in the model, notably the representation of convective rainfall processes and of topography, give rise to some substantial, but identifiable, errors in the rainfall accumulations forecast at individual grid-points. However, from a synoptic viewpoint the computed forecasts provide useful guidance on the character of the rainfall occurring in these situations.

The fine-mesh version of the 10-level model.

A detailed description of this model was published in 1971.[1] Since that date a number of changes in the formulation of the fine-mesh model have been introduced, notably the adoption of a semi-implicit integration scheme. However the modelling of the precipitation processes remains unchanged. At each time-step in the integration of the forecasting equations, equivalent to 12 minutes of real time, forecasts of the rate of rainfall at the bottom level of the model (1000 mb) are made at each point of a horizontal grid which has a mesh size of 100km. The accumulated rainfall total since the start of the forecast run is also recorded.

The forecast rainfall is produced in the model in two ways. Advection of water vapour by the three-dimensional motion of the model atmosphere may lead to the air at some level above a grid-point becoming supersaturated. The superfluous moisture then condenses, falls and, subject to possible evaporation into drier layers below its original level, reaches the surface as rain. Rainfall produced in this way is referred to as 'dynamic rain'.

A superfluity of moisture in a layer above a grid-point may also be produced as a result of the 'convective adjustment' process. This is a process, carried out after each time-step, in which the thicknesses of each successive pairs of layers above a grid-point are mutually adjusted so as to ensure that no unreasonable static instability develops at individual grid-points. Since, in the current formulation of the model, the relative humidities of the adjusted layers are kept unchanged, any moisture in excess of that required to conserve the relative humidities is condensed and may eventually reach the surface. This is referred to as 'convective rain'.

It has been found in practice that, while the 'convective rainfall' forecast by the model normally occurs in areas where it is synoptically reasonable to expect showers, the quantity of convective rain forecast is usually very much less than the quantity of forecast dynamic rain and also very much less than the actual rainfall which occurs through showers or other convective systems.

The 'total rate' of rain at any grid-point is the sum of the dynamic and convective rates. In this article it is the total rate of rain and the total rainfall accumulations that are displayed.

<u>General synoptic character of the early summer, 1973.</u>

For many months prior to June 1973 the weather in the British Isles was remarkably dry. During the first ten days of June this dry weather continued and led to public warnings, about the necessity of conserving water supplies, becoming increasingly frequent during this time.

Subsequently, during the following three weeks, there were four important frontal situations which affected the country. In terms of the actual rainfall accumulations, two of these situations were significantly wet in the southern half of England but dry elsewhere, while the other two were dry over England but brought rain to Scotland. Having regard to the nationwide water shortage at this time it was of some importance to be able to forecast correctly which of the fronts would produce a lot of rain and which would not.

An assessment of the synoptic value of the charts of forecast rates of rainfall.

In this section some brief comments are made on each of the forecast charts in Figures 1 - 4, to illustrate their value to forecasters engaged on general synoptic duties. Each chart has also been given an assessment letter which, being subjective, is not likely to command universal agreement. However, the point of these assessment letters is to provide an indication of the value of the forecasts as a whole, rather than individually. This is done in Table I, where the definitions of the letters may also be found.

Figures 1 - 4 illustrate the four frontal situations in turn. Each covers a 48-hour period, showing actual charts at 12-hour intervals. The isobars are drawn at 4mb intervals and the frontal positions have been taken from the Daily Weather Reports. The extent of the frontal rain has been sketched in from the reported synoptic observations, distinguishing areas of mainly slight rain (hatched), mainly moderate rain (cross-hatched) and showers (symbols). Beneath each of the actual charts are the 24-hour and 36-hour prognostic charts which verify at that time. On these, the forecast rainfall is shown at each grid-point by symbols (+, ◇, ✡)which distinguish slight, moderate and heavy rates of rain respectively. In order to keep the patterns of the main frontal rainbelts as clear as possible, forecast occurrences of very slight rain (less than 0.1mm/hr) have been omitted.

Verification Time	Forecast Chart	Comments	Assessment Letter
00GMT 12.6.73	T+36	(Charts on Figure 1) The rain area over Scotland is too far south, but this is not a misleading forecast. The main fault is the weakness of the pressure gradients.	B
	T+24	The rain in Scotland is well placed, and the intensity seems about right.	A
12GMT 12.6.73	T+36	The cold front is correctly placed over Ireland, and the extensive area of moderate rain over N.Scotland is quite realistic	A
00GMT 13.6.73	T+24	The intensity of the narrow, weakening cold front is well forecast but it is a little slow, being about 1 grid-length too far north. No convection over Ireland was forecast.	B
12GMT 13.6.73	T+36 T+24	On both these forecasts the pressure trough over NW.Europe has been moved too slowly, but the rapid stabilisation of the air over the British Isles and transition from cyclonic to anticyclonic curvature of the isobars, coupled with the absence of any rain, was well forecast.	A A
00GMT 19.6.73	T+36	(Charts on Figure 2) The forecast rainfall pattern suggests an active warm front over NE.Scotland and a weaker cold front over W.Ireland. The cold front is too slow, by at least 1 grid-length, but is not totally misleading, for rain is forecast over Ireland as far south as 52°N.	C
	T+24	The location and intensity of the cold front rain are very well forecast.	A
12GMT 19.6.73	T+36	The frontal rain is well placed over E. Scotland but is some 2 grid-lengths misplaced over S.England.	B
	T+24	Apart from the premature clearance of rain in E.Scotland, this forecast is good.	A

Verification Time	Forecast Chart	Comments	Assessment Letter
00GMT 20.6.73	T+36 T+24	The forecasts for this particular time are not in fact too badly astray, but this is a lucky chance. The model is not getting the full extent of the low pressure development over Belgium, and there is no warning of the possible spread back of the rain from the North Sea into E.England.	B B
12GMT 20.6.73	T+36 T+24	These are incorrect and misleading forecasts. The model moves the rain trough slowly but steadily east - whereas the developing Belgian low remains stationary and its circulation brings extensive moderate or heavy rain back over a great part of the British Isles.	D D
00GMT 27.6.73	T+36	(Charts on Figure 3) With the development of a pressure trough in about the right place and some isolated grid-points giving rain, this forecast gets the correct 'weather type', but has only the poorest indication of the details.	C
	T+24	The location of the rain area over SE.England is remarkably good, though the intensity was under-forecast. The general line of the warm front in the English Channel and Biscay is discernible, though too far south.	B
12GMT 27.6.73	T+36	Not a very convincing forecast chart, although ill-defined pressure patterns are typical of this weather type. The forecast rain areas bear little relation to reality.	D
	T+24	A substantial rain area over Brittany is forecast, about 1 grid-length too far south.	B
00GMT 28.6.73	T+36	A remarkably good forecast, over both England and France, of the location of the frontal rain areas. The intensity over England is too weak.	A
	T+24	The northern boundary of the rain over England is about 1 grid-length too far south, but otherwise this looks a good forecast for England. Over France the cold front movement is too slow.	B

Verification Time	Forecast Chart	Comments	Assessment Letter
12GMT 28.6.73	T+36 T+24	Both these forecasts are quite good. Over England the location and intensity of the trailing rain area is well-handled, with the T+24 forecast being marginally more correct.	B A
00GMT 1.7.73	T+36	(Charts on Figure 4) Quite a good forecast, with some development of rain occurring in the pressure weakness to the SW of Ireland. Over Scotland the cold front is not clearly forecast, but over S.Ireland it is quite well placed.	B
	T+24	An unimpressive forecast. No specific developments are forecast in the area SW of Ireland and the frontal rainfall is too weak and disorganised to give any useful guidance.	C
12GMT 1.7.73.	T+36	Although the rain on this front progressively decreases, the complete lack of any significant rain at this stage is too premature a forecast.	C
	T+24	The ill-defined rain belt appears to be well placed but it is too weak, especially over the high ground of Scotland.	B
00GMT 2.7.73	T+36	Another forecast of a too rapid cessation to the rain. The positioning is fairly good.	B
	T+24	This has got the general impression right, of patchy outbreaks of rain on the weakening front, but details of the intensity and location are wrong.	B
12GMT 2.7.73	T+36	Evidence from the North Sea is sparse, but this appears to be a good forecast.	A
	T+24	A correct forecast of dry weather over the British Isles, but it is likely that some rain is still falling over the North Sea and this should have been shown.	B

In these assessments, the letters have the following meanings:

Letter	General character of the forecast chart	Forecast rain areas over the British Isles.
A	Very good	Substantially correct in location and intensity.
B	Good; gives useful forecast advice.	Slight errors in either location or intensity.
C	Fair; but not seriously misleading	Correct 'type' - but definite errors in both location and intensity.
D	Poor.	Major forecasting errors.

		Assessment letter				Total
		A	B	C	D	
Forecast	T+24	5	8	1	1	15
Chart	T+36	4	6	3	2	15
Total		23		7		30

TABLE I. Assessment of the synoptic value of the forecast charts.

Table I shows the frequency with which the various assessment letters occur on the four situations covered in this paper. The figures reflect a slight diminution in the overall usefulness of the prognoses as the forecast time increases from T+24 to T+36. But even at T+36 it is still possible to place two-thirds of the forecasts into Categories A or B. At T+24 the proportion of such forecasts is higher, and the overall figure of 23 out of 30 in Categories A and B shows that at least 75% of these individual forecast charts gave good, useful forecast advice.

The quantitative rainfall forecasts.

Figures 5 - 8 show, for each occasion, the actual and forecast accumulations of rain during the 'rainfall day' extending from 0900z on Day 1 to 0900z on Day 2. The forecast values are plotted, in mm, from an array of 72 grid points covering the area of the British Isles. They are values computed during the forecast runs based on 0001z data on Day 1, and are the predicted accumulations between the (T+09) and (T+33) hours of these forecasts.

The actual accumulations are the average areal rainfall amounts over 100km squares centred on the model's grid-point locations. These values were produced by computer using the Comprehensive Areal Rainfall Program (CARP)[2] developed by Met.O.8, in which an analysis is made of the daily rainfall totals from over 6000 rain gauges covering England, Scotland and Wales. Since no measurements are available over the sea, the only grid-squares for which reliable estimates of the actual accumulations can be made are those which lie entirely, or very largely, over land. There are only 17 such grid-squares.

There can be little doubt that in the broadest terms these four situations were more or less correctly handled by the model. Figures 6 and 7 show the two occasions when wet weather was forecast for the south of the country, while Scotland remained dry. This was correct. Figures 5 and 8 show the two occasions when the pattern was reversed; Scotland getting the rain while England remained dry. On these two occasions the forecasts were broadly correct, though Figure 8(b) is the least convincing of the four forecast charts.

However, when attention is transferred from the broad sweep of the synoptic scale features discussed above, and is concentrated on individual grid-points it is clear that a very different order of forecasting accuracy is attainable. A visual comparison of the forecast and actual values at corresponding grid-points in Figures 5 - 8 is enough to convince one that the correlation is very small. Not only is the general level of the forecast rainfall below that of the actuals but there is also, in each case, an error in the location of the rain areas. These positional errors, though they may amount to only one or two grid-lengths, are quite enough to produce large rainfall errors at individual grid points.

So far as it is possible to do so, with the limited information available on the actual charts, the most meaningful assessment of the value of Figures 5 - 8 is to list the errors occurring in the forecast location and magnitude of the maximum 24-hour rainfall total:

Figure	Date	Highest rainfall at a grid-point(mm)		Approx: distance between forecast & actual maxima (km)
		Actual	Forecast	
5	12/6/73	36 (mm)	14	140
6	19/6/73	39	22	180
7	27/6/73	30	28	220
8	1/7/73	27	7	50
	Mean Values	33mm	18mm	150Km

<u>Conclusion</u>

The results show that, on the current performance of the 10-level model, the synoptic value of the rainfall forecasts is considerable. But as regards quantitative forecasting on the scale of one grid-length the forecasts are of lower reliability. Errors in location of forecast rain areas are frequently of the order of 1 - 2 grid-lengths and the quantity of rain forecast by the model is generally only ½ - 2/3 of the actual values.

The reasons for particular forecasting errors are often quite difficult to pinpoint with certainty. Sometimes an obvious fault can be traced, but usually it is the complex result of a number of factors whose effects are inter-related. At times there may be a lack of initial data; or there may be slight errors in the analysis of some crucial observations, or in their quality control. There are errors due to the approximations which have to be made when using finite difference methods to solve the mathematical forecasting equations. And there are errors due to the fact that most of the physical processes which occur in the real atmosphere are only modelled in an incomplete and approximate way in the computer programs. Some obvious indications of this are apparent in the charts displayed here, where the lack of a sufficiently detailed representation of topography in the model leads to serious underestimates of the rainfall over Scotland. It is also clear from the rainfall totals that the convective rainfall in the current formulation of the model is not sufficiently realistic.

The four actual charts in Figures 5 - 8 show that, even in these quite average frontal situations, rainfall gradients of over 1 inch (per rainfall day) per 100km are not infrequent. With actual gradients of this magnitude it is clear that the misplacement of a rainbelt by as little as one grid-length on a forecast chart can result in large errors at some grid-points. The achievement of high accuracy and reliability at this level of spatial resolution is a very formidable task.

REFERENCES

1. BENWELL, G.R.R., GADD, A.J., KEERS, J.F., TIMPSON, Margaret S., and WHITE, P.W.; - The Bushby- Timpson 10-level Model on a Fine Mesh. Met.O. London, Sci.Paper No.32, 1971.

2. SALTER, Pauline M.; Areal rainfall analysis by computer. WMO. No.326. VolII p.497, 1972.

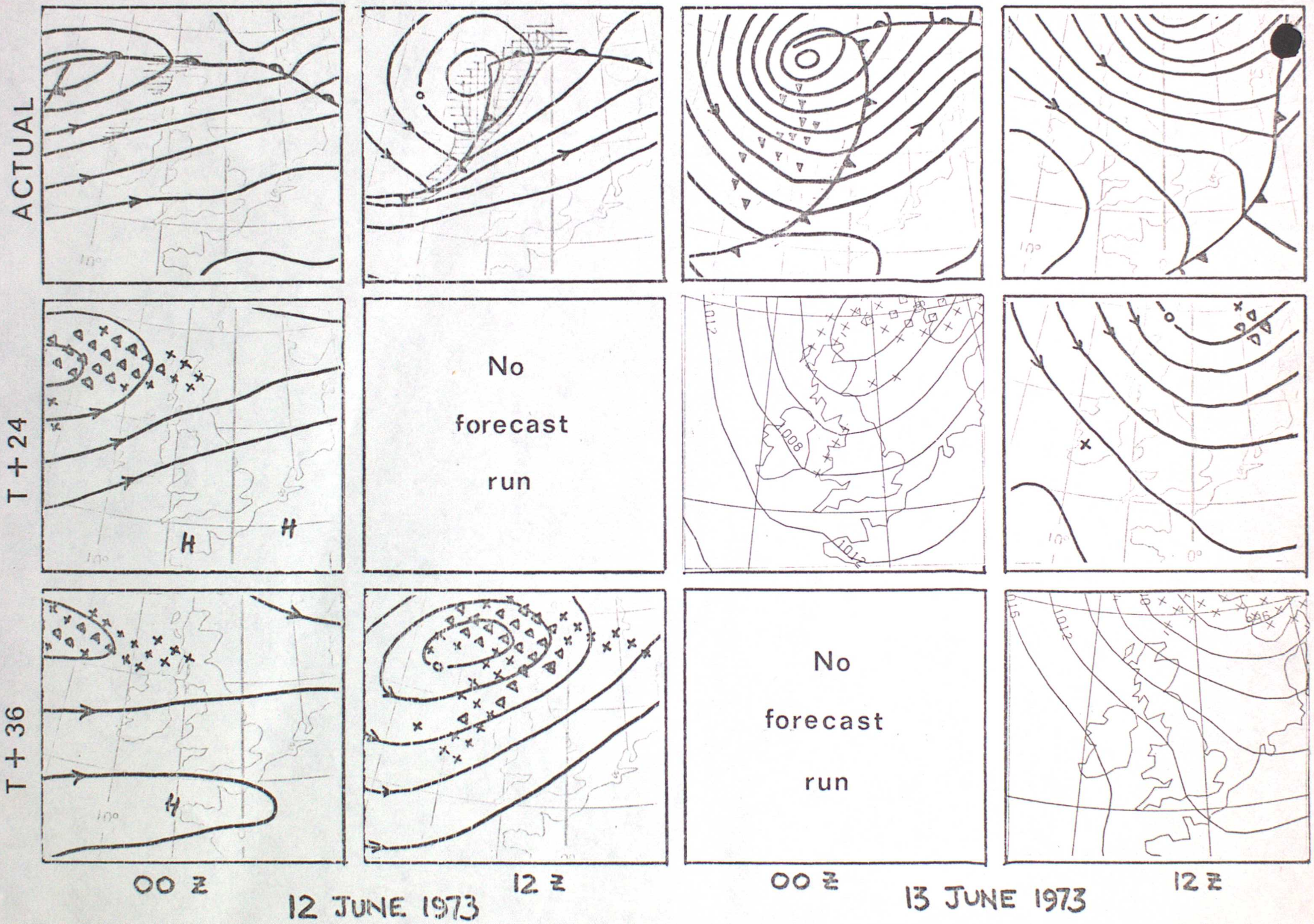
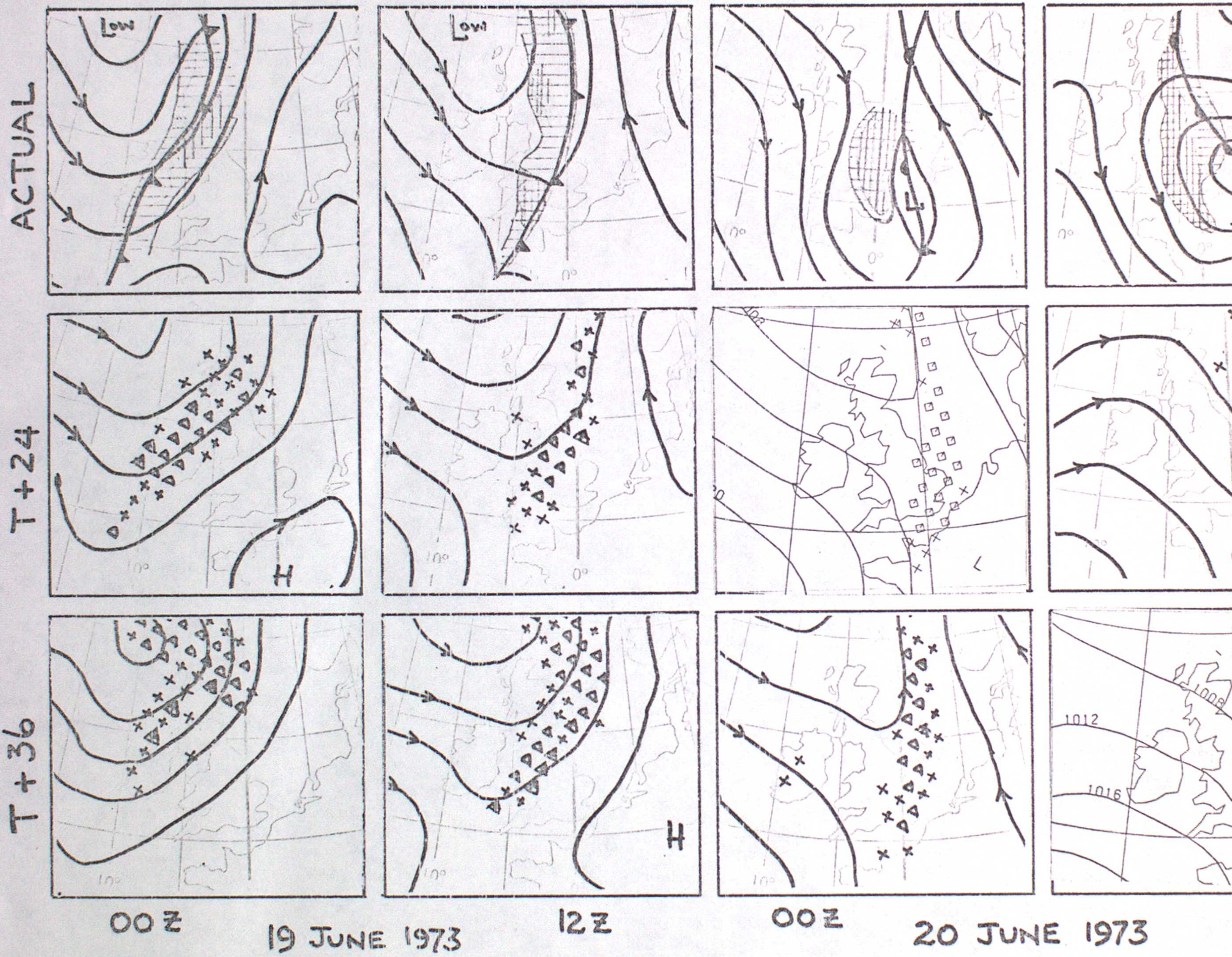

ACTUAL
T + 24
T + 36
No forecast run
No forecast run
1008
1012
00 Z
12 Z
12 JUNE 1973
00 Z
12 Z
13 JUNE 1973

FIG: 1

FIG:2



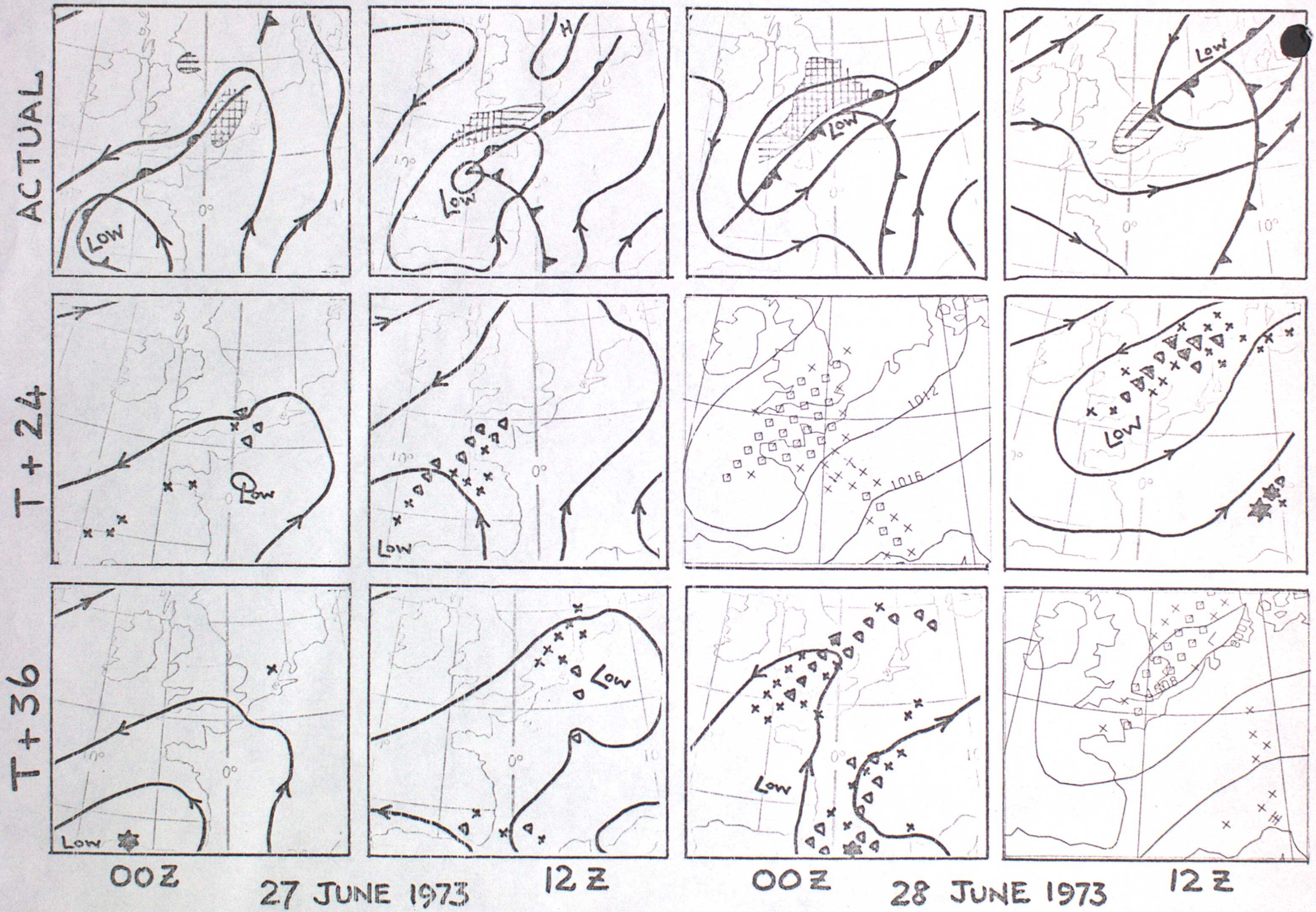

ACTUAL
T + 24
T + 36
00Z
12Z
27 JUNE 1973
28 JUNE 1973
LOW
H
1012
1016
1008

FIG:3

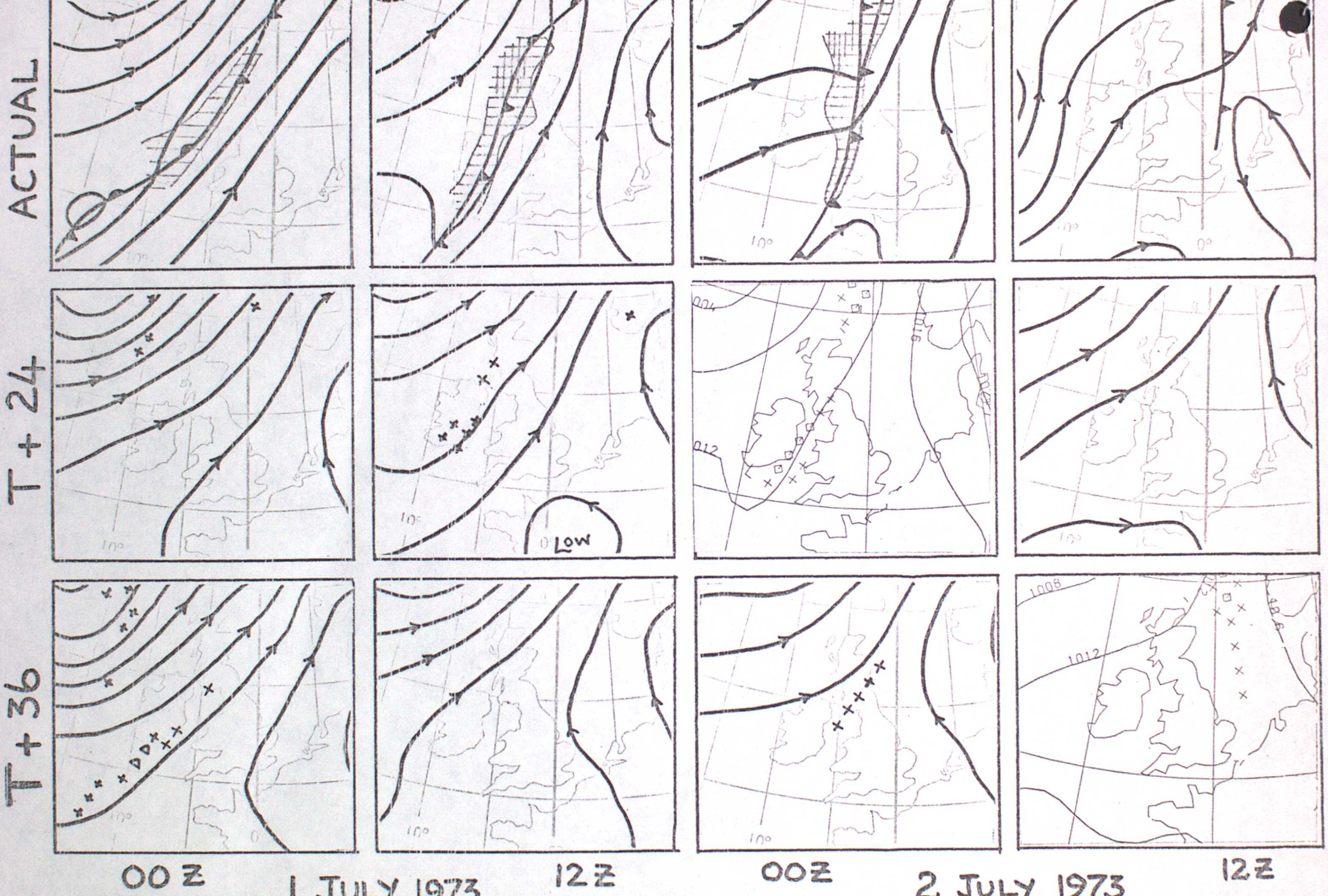
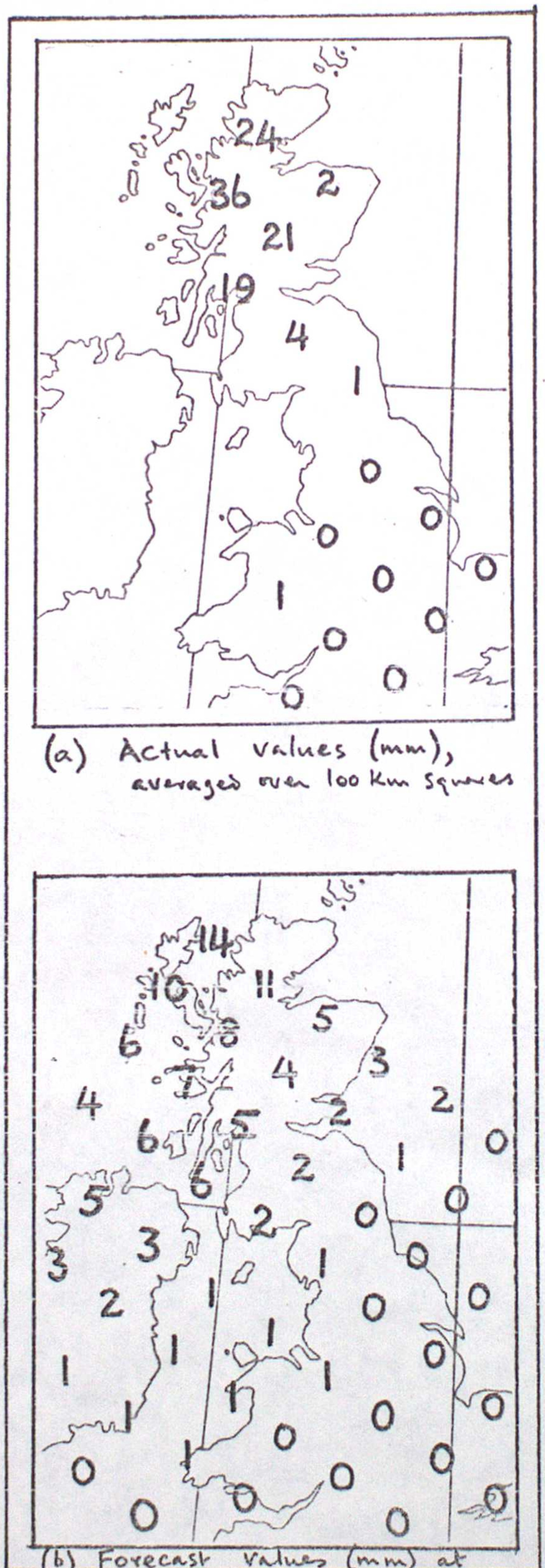

ACTUAL
T + 24
T + 36
LOW
1004
1008
1012
1016
10°
0°
00Z
1 JULY 1973
12Z
00Z
2 JULY 1973
12Z

FIG: 4

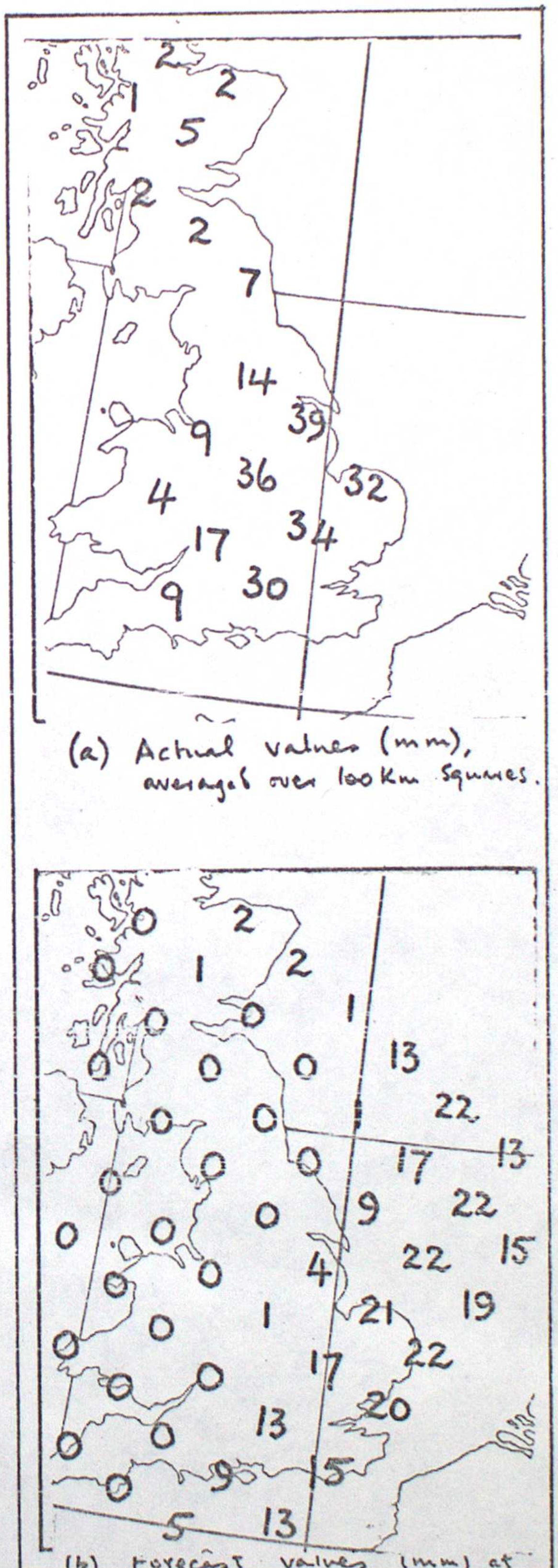


(a) Actual values (mm), averaged over 100 Km squares

(b) Forecast values (mm) at grid-points

FIG: 5

24-HOUR RAINFALL TOTALS FROM 0900 GMT 12 June 1973.

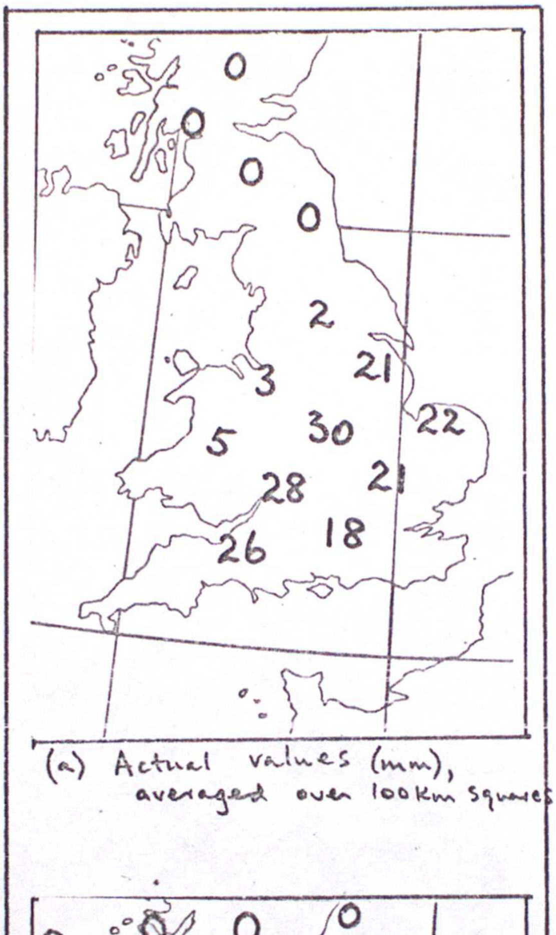


(a) Actual values (mm), averaged over 100 Km squares.

(b) Forecast values (mm) at grid-points

FIG: 6

24-HOUR RAINFALL TOTALS FROM 0900 GMT 19 JUNE 1973

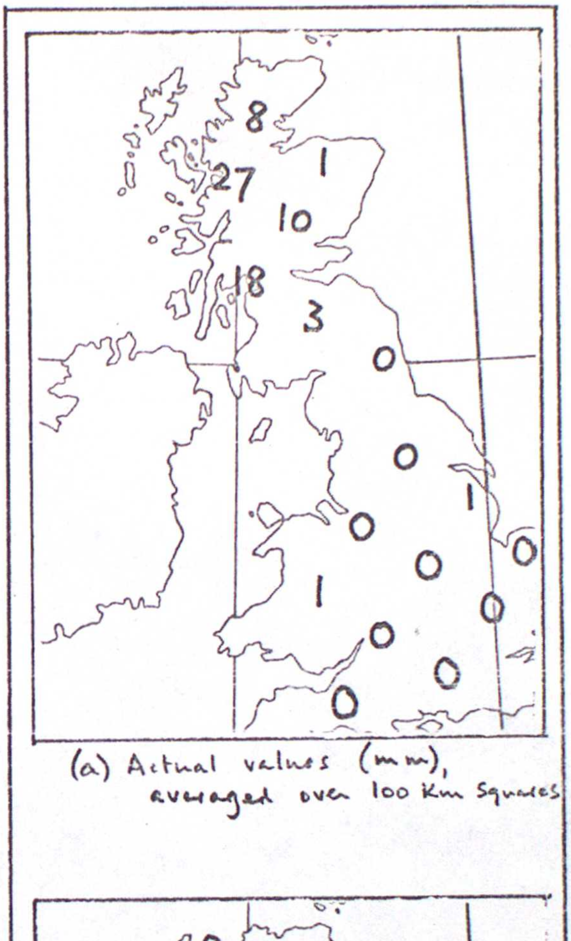


(a) Actual values (mm), averaged over 100 km squares

(b) Forecast values (mm) at grid-points

FIG: 7

24-HOUR RAINFALL TOTALS FROM 0900 GMT 27 JUNE 1973



(a) Actual values (mm), averaged over 100 km squares

(b) Forecast values (mm) at grid-points

FIG: 8

24-HOUR RAINFALL TOTALS FROM 0900 GMT 1 JULY 1973