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Met.O.11 Technical Note No. 263

Results from fine-mesh model trial using a modified evaporation scheme.

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RESULTS FROM FINE-MESH MODEL TRIAL USING A MODIFIED EVAPORATION SCHEME

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1. INTRODUCTION

a) DETAILS OF CHANGES.

During the last three years, a significant number of fine-mesh forecasts have under-estimated the extent of showers overland, especially in northerly or northwesterly airstreams. A small change, making the evaporation of rainfall dependent upon the rainfall rate Rowntree (1986), is proposed to try to alleviate this problem.

The current operational scheme is described in Met.O.2b Documentation Paper No.4. As a quick reminder, for dynamic precipitation, (ref.section 5.2) the new evaporation rate will apply at all levels, but for convective precipitation, the change will affect only those levels below the cloud base.

The current operational scheme for the evaporation of dynamicallly produced rain (and snow) and of convective rain (but *not* snow) is of the form:

$$E = \beta(q_s - q)$$

where the units are (Kg Kg^{-1})s^{-1} and q, q_s are the humidity and saturated humidty mixing ratios of the layer through which the precipitation is falling. There is a large disparity between the value of β for dynamic precipitation (2×10^{-5} s^{-1}) and that for convective rain (10^{-3} s^{-1}); following Kessler (1969) these values may be shown to correspond to rainfall rates near the ground of 0.1 mm hr^{-1} and ≈ 50 mm hr^{-1}, respectively. The large-scale value is only appropriate to very light rain whilst such large convective rain rates are experienced in middle latitudes only in the more intense thunderstorms. The proposed scheme therefore allows β to be rainfall rate dependent , following Kessler's (1969) approach.

For large-scale rain :

$$\beta = 1.34 \times 10^{-2} R^{0.6} \ s^{-1}$$

where R is the rainfall rate in Kg m^{-2} s^{-1} (≡ mm s^{-1}) .For simplicity the same formula is (at present) also applied to snowfall.

In the current operational scheme convective rainfall J (mm) is evaporated in each layer beneath cloud base according to :

$$J_k = J_{k+1} \exp\left(-\beta \Delta t \ 100 \ p_* \Delta\sigma \ (q_s - q) \ / \ (10 \ g \ J_b) \right)$$

where $J_b / \Delta t$ is the rainfall rate at cloud base. The new scheme replaces this with :

$$J_k = 10^{-3} \Delta t \left((J_{k+1} / \Delta t)^{0.2} - 10 \ p_* \ (q_s - q) \ 0.368 / g \right)^5$$

which comes from integrating the fractional change in rainfall rate over a layer :

$dR/d\sigma \propto \beta' \Delta q$ with $\beta' \propto R^{0.8}$, which allows for the variability of convective rain over a grid box.

After fall out of convective precipitation commences, some water is retained in the cloud by specifying a minimum liquid water content, which is the smaller of the local saturated specific humidity or an adjustable parameter . This used to be 1 g Kg^{-1} but has now been changed to 0.1 g k^{-1} in order to reduce the moistening and cooling when final detrainment occurs and the remaining cloud liquid water is re-evaporated.

In order to assess the impact of the changed evaporation rate upon the fine-mesh rainfall forecasts, eleven cases were rerun using:

i) a trial version including the modified evaporation rate. (This version became operational 22/7/87.)

ii) a control version, i.e the current operational version.

The eleven cases were selected from the last year to cover a wide range of synoptic situations. The eleven cases chosen were;

DT 00GMT 19/5/86 DT 00GMT 10/6/86 DT 12GMT 16/6/86 DT 12GMT 22/7/86
DT 00GMT 23/7/86 DT 12GMT 27/8/86 DT 00GMT 29/9/86 DT 00GMT 11/1/87
DT 12GMT 11/2/87 DT 00GMT 28/3/87 DT 00GMT 13/6/87.

In section 2, we will describe the main differences noticed between the old and new versions of the fine-mesh model in the eleven cases examined. Finally, in section 3 a brief summary of the results is given.

2. CASE STUDIES

a) DT 00GMT 19/5/86

An upper trough was positioned to the southwest with a southerly upper flow over the U.K. The weather remained sunny and warm in most places on the 19th, but isolated thunderstorms developed in the southwest later. During the night of the 19/20th, thundery outbreaks became more widespread ahead of a cold front approaching southwest England. Heavy rain and thunderstorms affected the remainder of England during the morning of the 20th.

The main interest in this case centres on a comparison of the T+24 forecasts, verifying at 00GMT 20/5/86. (see figures 1 a-c). The control version forecast isolated showers from convective cloud base 800mb, depth 6000m at two gridpoints only in southwest England (figure 1a) . In the trial version, showers were forecast to be widespread over Wales and southwest England from convective cloud base 800-700mb, depth 4000-7000m.(figure1b). The extra showers gave six-hour accumulations of 0.1mm to 1mm of rain. In the trial forecast, a slight reduction in medium layer cloud was noticed over Wales corresponding to the positions of the extra showers. In figure 1c , the radar picture for 00GMT shows the main rain area lying from Plymouth northwards to Bristol and the West Midlands. Although the trial version has forecast the showers too far west, it is still a better forecast since it indicates a faster eastwards movement of the thundery rain.

b) DT 00GMT 10/6/86.

This case was chosen as an example of a cool,wet,cyclonic period. During the 10th, a depression moved northeastwards from Southern Ireland to Northeast Scotland. An associated area of rain also moved northeast over the U.K during the morning, although the extreme southeast of England remained mostly dry. During the afternoon, thundery showers developed over Wales and Northern England, whilst Scotland had heavy rain with snow on the Cairngorms. This type of weather continued over Scotland for at least twenty four hours. During the 11th, a small wave depression developed in the Southwest Approaches and a further area of rain spread eastwards over Southern England. The trial version forecast more showers over Wales and Northwest England on the 10th and so was slightly more accurate than the control version. The extra showers added 0.1 - 1mm to the accumulations. In figures 2 a-c, we compare the T+36 rainfall forecasts verifying at 12GMT, 11/6/86 with the radar. The main difference between the forecasts occurs over Eastern England, where the trial version (figure 2b) has developed a slight trough with light showers. The radar picture, (figure 2c), shows some rain over Northern England, so the trial forecast is slightly better. Again , the extra showers have added 0.1-1mm to rainfall accumulations. There was very little difference between the two versions in the forecast rainfall accumulations associated with the depression in the south.

c) DT 12GMT 16/6/86.

This case was chosen as an example of a hot,humid period with the risk of thunderstorms developing. Throughout the period the weather was very warm and thundery over the continent with maximum temperatures ranging between 24 and 28 degrees Celsius. During the 17th, a weak cold front moved eastwards over the U.K. South-east England stayed mostly dry, but further west it was cooler and cloudier with thundery showers developing over Northwest England and Southern Scotland. Only minor differences occurred between the two versions in this case. In figures 3 a-c, we compare the T+30 rainfall forecasts verifying at 18GMT with the corresponding significant weather chart. The trial version (figure 3b) has forecast slightly more showers over Eastern England. These extra showers do not verify well when compared with the significant weather chart (figure 3c). The problem was a slight evolution error in the forecast with both versions maintaining a trough over Southeastern England too long. In reality the rain area had moved eastwards on to the continent.The trial forecast with more showers was worse than the control version in this case. Forecast temperatures were very similar.

d) DT 12GMT 22/7/86.

This case was chosen because the original operational model gave a poor forecast of showers over Southeast England for the Royal Wedding day on July 23rd. This was a cool day with heavy showers, some accompanied by hail and thunder, especially southeast of a line from Scarborough to Bristol. The trial version was marginally better since it forecast a few extra light showers over the Pennines and East Anglia but neither forecast predicted any showers at all over Southeast England.

e) DT 00GMT 23/7/86.

This case was also chosen because the original operational version gave a poor forecast of showers over Southeast England for the Royal Wedding day on July 23rd. This was a cool day with heavy showers, some accompanied by hail and thunder, especially southeast of a line from Scarborough to Bristol. In figure 4 a-c, we compare the T+18 rainfall forecasts verifying at 18GMT, 23/7/86 with the corresponding radar. The control version forecast no rain at all (see figure 4a). The trial version forecast a few light showers, which was better although still underdone. The extra showers over the U.K added 0.1-1mm to the six-hour accumulations. The trial version forecast local intensification of rain on the northern side of high ground over the continent. This also occurred in the previous case (DT 12GMT,22/7/86). However, the increase of rainfall in a six-hour period onlt amounted to 1-2mm. There was a slight reduction in the amount of medium cloud forecast by the trial version associated with the low pressure area over the North sea and continent. In figure 5 a-b, we compare the T+18 forecast tephigrams at the gridpoints corresponding to Hemsby and Crawley. The trial ascents are very slightly warmer and drier,with the maximum effect at 600mb.

f) DT 12GMT 27/8/86.

During this period, a depression in the North Sea moved slowly northeast, filling and a cool strong northerly airstream covered the U.K. On the 27th, northeast England remained cloudy with some heavy rain at times, whist the rest of the U.K had showers and isolated thunderstorms. During the 28th, showers developed again inland with the heaviest over Southern England. The main difference between the two forecasts in this case is the increase in the number of light showers forecast over the sea in the unstable northerly airstream. These showers contribute an extra 0.1-1mm in a six-hour period and typically fall from convective clouds, base 950mb, depth 2000-3000m. This can be seen in figures 6 a-b, where we compare the rainfall forecasts at T+12 and T+30. A comparison with satellite pictures indicate that the showers in the trial version are too widespread. Changes overland are much smaller. Over the U.K at 18GMT, scattered heavy showers were reported over Eastern England and both versions have under-forecast showers at this time. However, the trial version has forecast several more showers over France at 18GMT and this was a more accurate forecast.

g) DT 00GMT 29/9/86.

A large anticyclone controlled the weather over most of Europe during this period,whilst further west in the Atlantic a depression was moving northeastwards towards Iceland. The reason for choosing this case was to check that the trial version wasnot predicting excessive low cloud amounts overland in comparison with the control version.In figures 7 a-b, we compare the six-hour forecast accumulations from both versions verifying at 12GMT 30/9/86. The main difference is noticed in the Atlantic between 30 and 40 degrees west, where the trial version has predicted more light rainfall. This is from light showers (local rate 1-2mm/hr) produced from convective cloud with a depth of 2000-3000m. There is also a reduction in the amount of medium cloud forecast to the south of the depression in the trial forecast. Changes in forecast amounts of low cloud over the U.K near the centre of the anticyclone were very small. Neither forecast gave a very good forecast of the amount and distribution of low cloud but the trial version was not any worse.

h) DT 00GMT 11/1/87.

This case was chosen from the coldest period of last winter, when strong easterly winds brought extremely cold weather from Siberia across the U.K, with temperatures remaining well below zero day and night. In figure 8, we compare the forecast rainfall rates at T+36. The main difference is the switch in the output from light dynamic rain (control version-figure 8a) to light convective rain (trial version-figure 8b) in the North Sea. Forecast accumulations are very similar.

i) DT 12GMT 11/2/87.

During most of the period of this forecast, a slack low pressure area persisted over the U.K. Initially, it was dull and wet in many parts, but the rain gradually died out and a ridge built over the U.K by T+36. This was one of the problem low cloud forecasts associated with the last fine-mesh trial. (The first trial package in February forecast excessive low cloud). This case was chosen in order to check the impact of the proposed evaporation changes on cloud amounts. In figures 9 a-d at T+12, verifying time 00GMT,12/2/87, we compare precipitation and medium cloud forecasts from the two versions. The main difference in the precipitation forecasts is the increased number of light showers forecast by the trial version (figure 9b)in the unstable north or northwesterly airstream over the sea in the Bay of Biscay. A comparison with satellite pictures indicate that the trial version has forecast too many showers. These extra showers add 1-3mm to the six-hour accumulations and fall from convective cloud of depth 2000-3000m. There is also a reduction of medium cloud amounts in the trial forecast (figure 9d) between Norway and Iceland on the outer edge of the depression. Changes in the amount and distribution of low cloud were small. Cloud amounts were unchanged in the frontal zone.

j) DT 00GMT 28/3/87.

A deep depression moved slowly northwards over Norway during the period of this forecast, and a strong northerly airstream covered the U.K. The interest in this case is concerned with the distribution of showers both over the sea and also inland over the U.K. In figures 10 a-b , we have compared the forecast precipitation from both versions at T+12 and T+36. The main difference in the T+12 forecasts lies in the increased number of light showers forecast by the trial version (figure 10b) over the sea in the cold unstable northerly airstream. These showers have added 0.1-2mm to the six-hour accumulations. At T+36, the main difference occurs over Wales and England, where the trial version has forecast many more light showers than the control version. The 29th March was a cold day with many places having wintry showers. At 12GMT however, most of the observed showers were in the west over Wales and the West Midlands. The trial version has predicted showers too far east (i.e too early) by 12GMT, but the forecast gives a better indication of the weather than the control version which predicted too few showers.

The trial version forecast less medium cloud in the unstable northerly airstream.

k) DT 00GMT 13/6/87.

The operational forecast failed to predict the heavy showers which occurred during the afternoon of Saturday, 13th June. In figure 11c, we show the significant weather chart for 18GMT 13/6/87, showing the distribution of showers mainly in the east. Figure 11a shows the T+18 forecast from the operational fine-mesh with only one isolated shower over Southern England. Figure 11b shows the corresponding forecast from the trial version showing a band of light showers from Northwest England to Eastbourne. The band of showers is a little too far west, probably because the model has too deep a low over Germany. However, the trial forecast of showers is much better guidance. The extra showers have added 1-3mm to the six-hour accumulations and the forecast convective depth was 4000.

3. CONCLUSION

A set of eleven cases were rerun using the current operational and trial versions of the fine-mesh model to compare the performance in a variety of situations. The main differences between the versions are shown in figures 1-11. The main conclusions from these cases are listed below.

1. Forecast mean sea level pressure was the same in both versions. Only one tiny difference was noticed in case (b) at T+36 over Northeast England. (see figure 2b.)

2. There is a significant increase in the number of light showers forecast over the sea. These showers fall from convective clouds of depth 2000m-3000m and add 0.1mm to 1mm to the six-hour accumulations. A comparison with satellite pictures for two of the cases (DT 12GMT 27/8/86, DT 12GMT 11/2/87) indicate that showers over the sea may be too widespread in the trial version

3. There is a slight increase in the number of light showers forecast over land also. In six cases out of 8 in which the forecast of showers over land was important, the trial version improved the forecast distribution of showers. The extra forecast showers were only light whereas the observed showers were occasionally heavy. In the other two cases, the trial version was worse in one (DT 12GMT 16/6/86) and equal in the other.

4. There was a slight decrease in forecast amounts of low and medium cloud. For low cloud, the decrease was very small. For medium cloud, the decrease was more noticeable but was mainly confined to unstable airstreams and the outer edges of depressions. Frontal cloud bands were mainly unaffected.

5. The output suggests a switch from dynamic to convective rain.

6. When the model ascents from the two versions differed. the trial ascents were very slightly warmer and drier. In most cases, the increase in temperature was only 0.1-0.2 degrees Celsius.

REFERENCES

Dickinson ,A . The Weather Prediction Model: Documentation Paper No.4

Kessler , E 1969 On the distribution and continuity of water substance in atmospheric circulation. Met. Monographs, 10 No 32, A.Met.Soc., 84pp

Rowntree , P R 1986 Proposals for modified treatment of the evaporation of rain. Manuscript (October).

Suggestions for changes to physical parametrizations. Manuscript (November).

SNOW PROB AT MSL DT 00Z MONDAY 19/5/1986 FINE MESH DYNAMIC LOCAL CONV

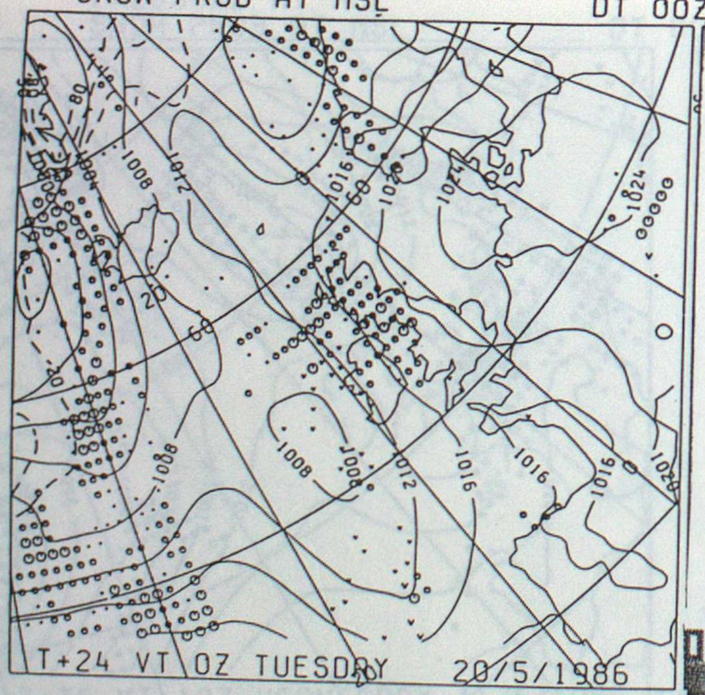


FIGURE 1a. CONTROL VERSION

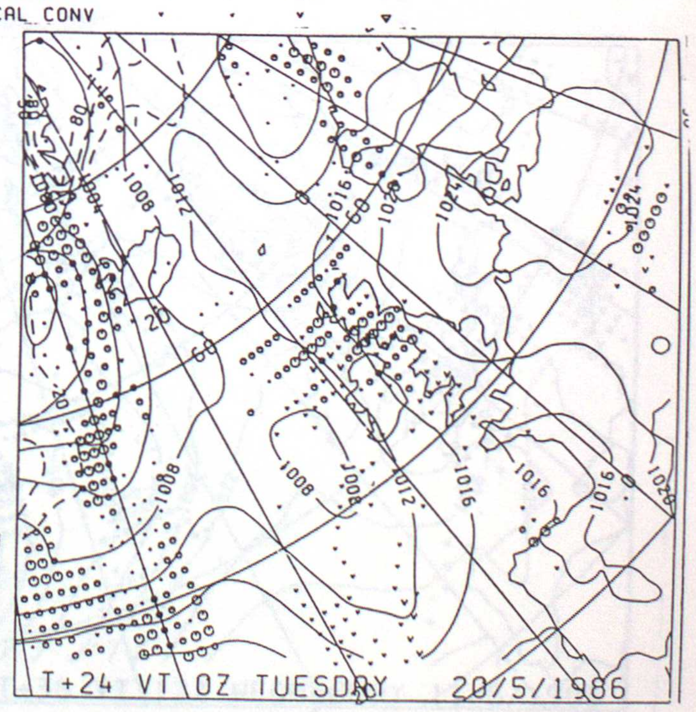


FIGURE 1b. TRIAL VERSION

FIGURE 1c. RADAR FOR 0000GMT 20/5/86.

RAINFALL RATE
PRESSURE AT MSL
SNOW PROB AT MSL

DT 00Z TUESDAY 10/6/1986 FINE MESH

DYNAMIC .01 .1 .5 4.0 MM/HR AT VT
LOCAL CONV

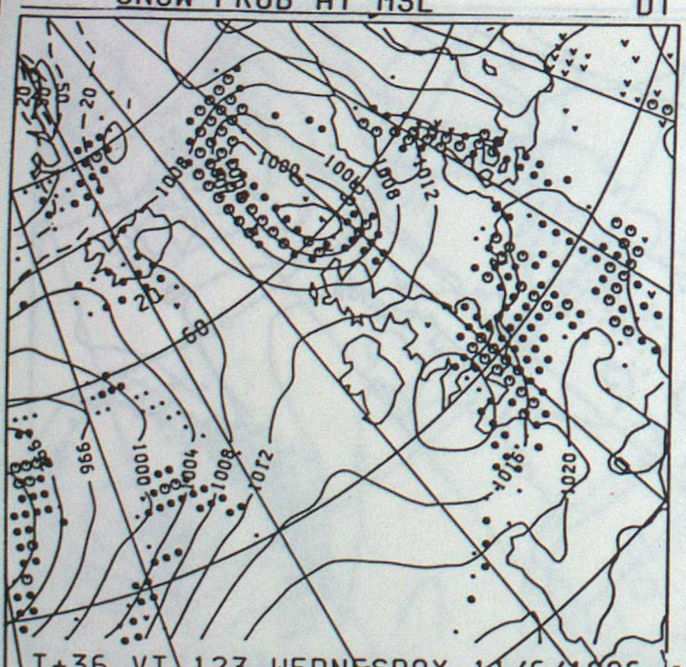


FIGURE 2a. CONTROL VERSION.

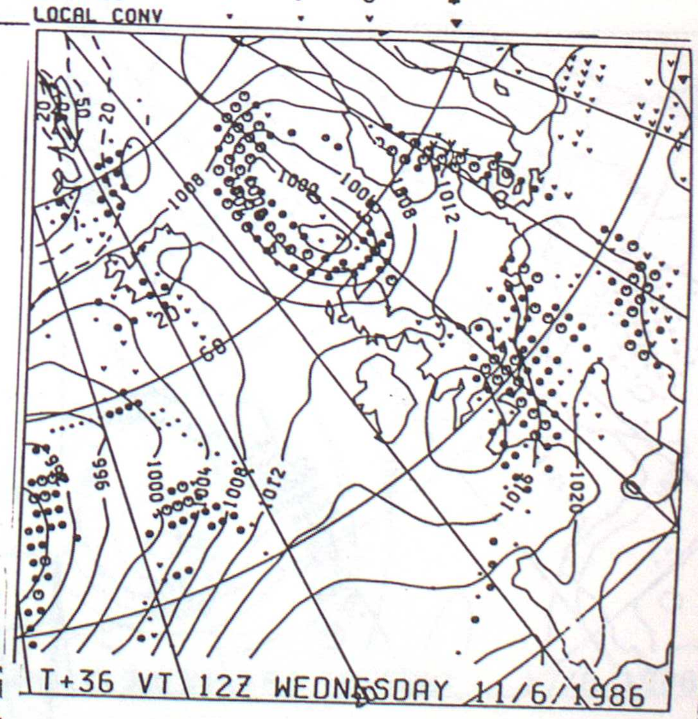
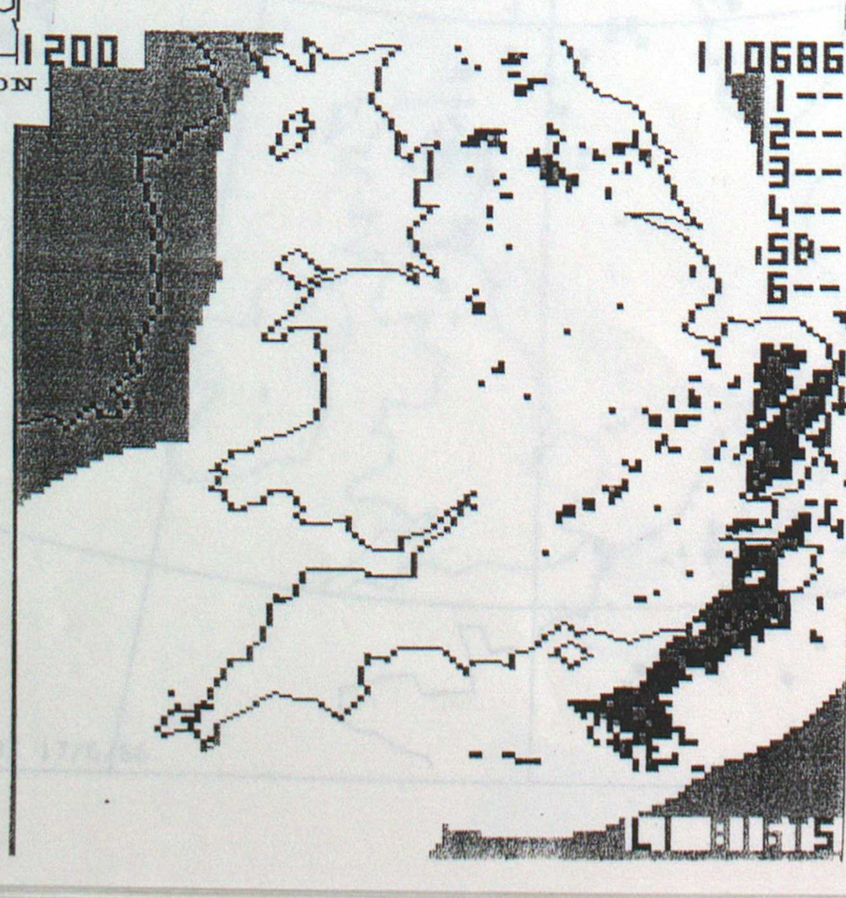


FIGURE 2b. TRIAL VERSION.

FIGURE 2c. RADAR FOR 0000GMT
20/5/86.



RAINFALL RATE
PRESSURE AT MSL
SNOW PROB AT MSL — DT 12Z MONDAY 16/6/1986 — FINE MESH — DYNAMIC / LOCAL CONV

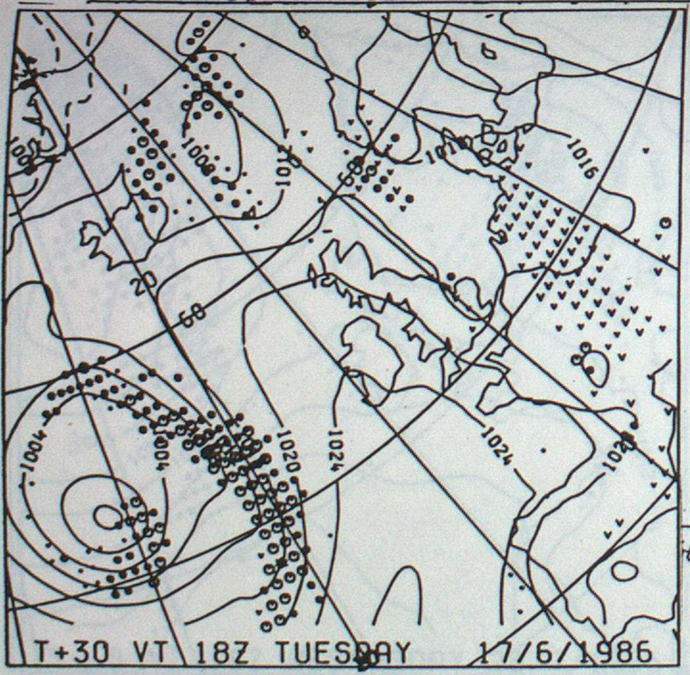


FIGURE 3a. CONTROL VERSION.

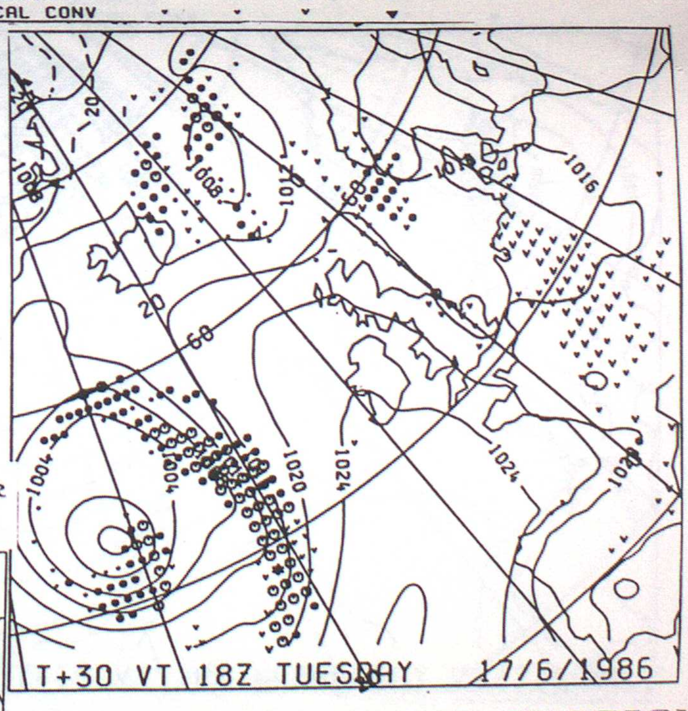
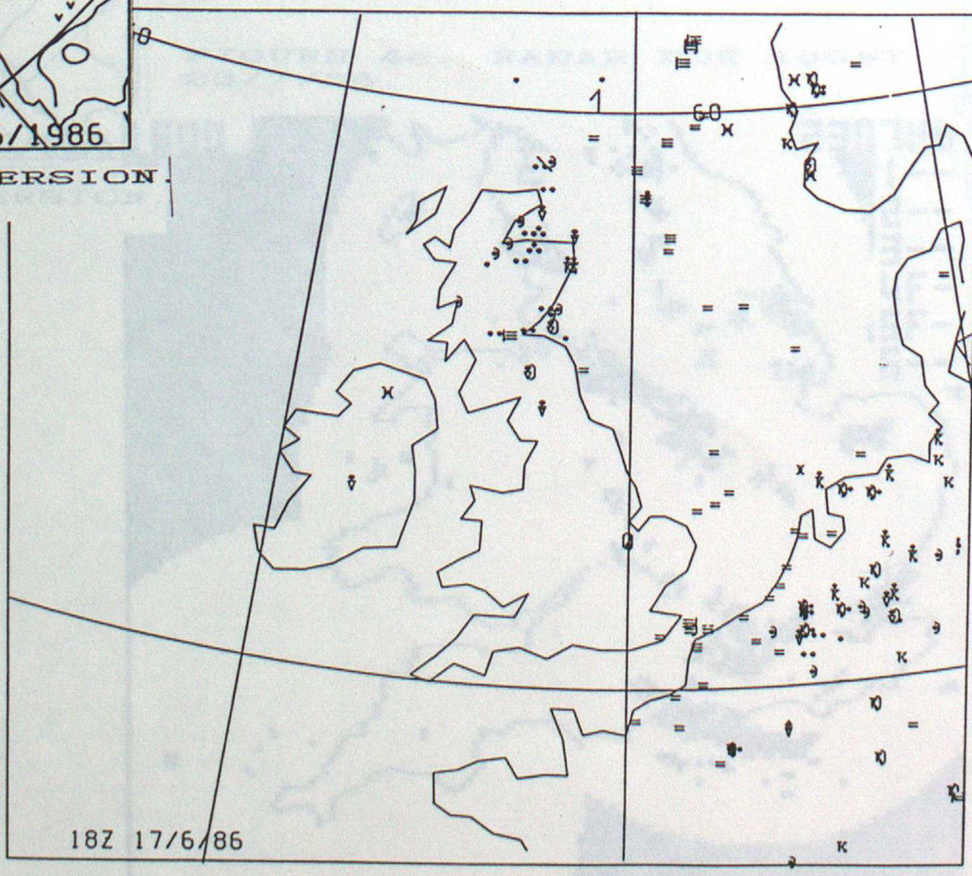


FIGURE 3b. TRIAL VERSION.

FIGURE 3c. SIGNIFICANT WEATHER CHART FOR 18GMT 17/6/86.



RAINFALL RATE
PRESSURE AT MSL
SNOW PROB AT MSL

DT 00Z WEDNESDAY 23/7/1986 FINE MESH

DYNAMIC
LOCAL CONV

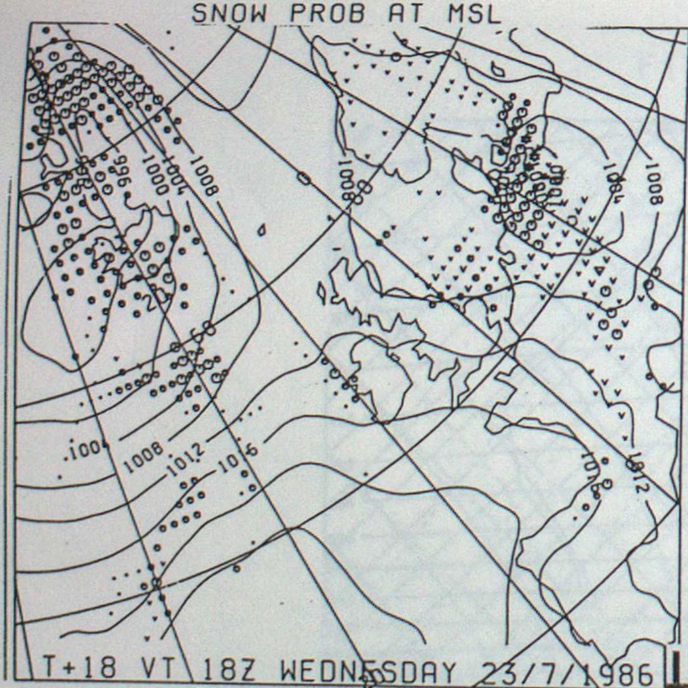


FIGURE 4a. CONTROL VERSION.

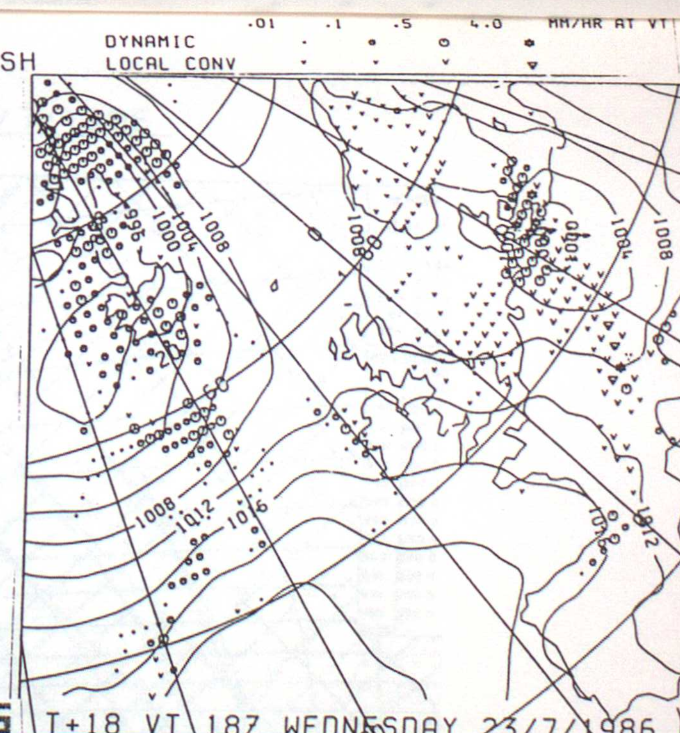
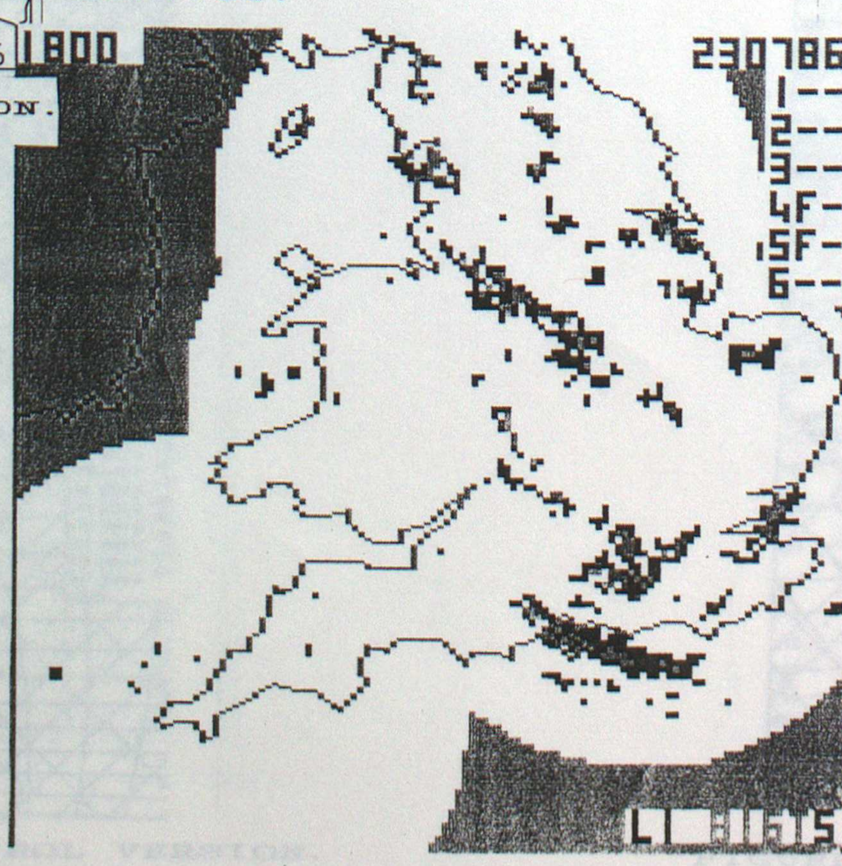


FIGURE 4b. TRIAL VERSION.

FIGURE 4c. RADAR FOR 18GMT 23/7/86.



FINE MESH TEPHIGRAMS T+18 VT 18Z 23/7/1986

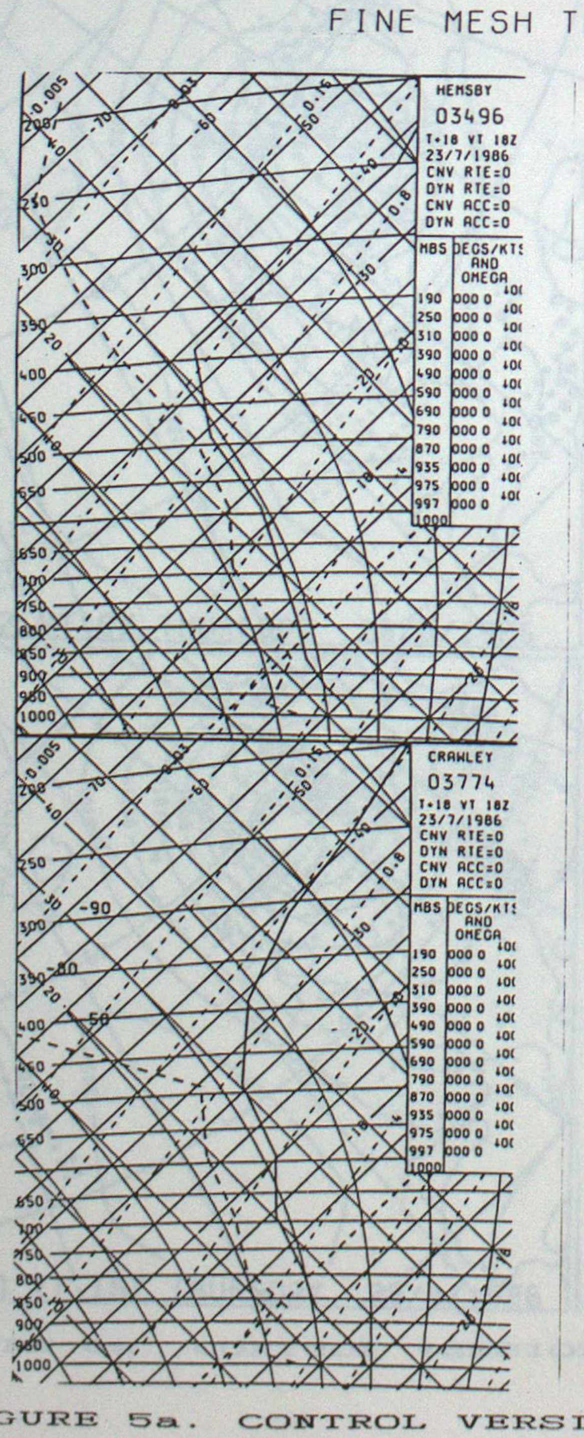


FIGURE 5a. CONTROL VERSION.

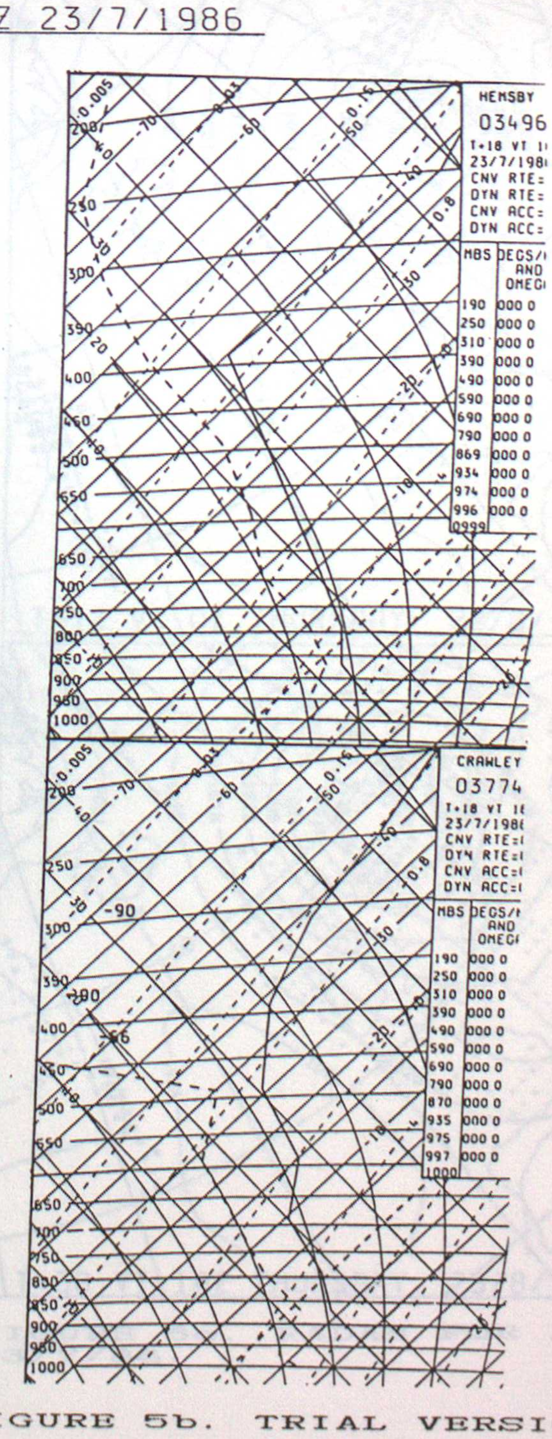


FIGURE 5b. TRIAL VERSION.

RAINFALL RATE
PRESSURE AT MSL
SNOW PROB AT MSL DT 12Z WEDNESDAY 27/8/1986 FINE MESH

DYNAMIC .01 .1 .5 4.0 MM/HR AT VT
LOCAL CONV

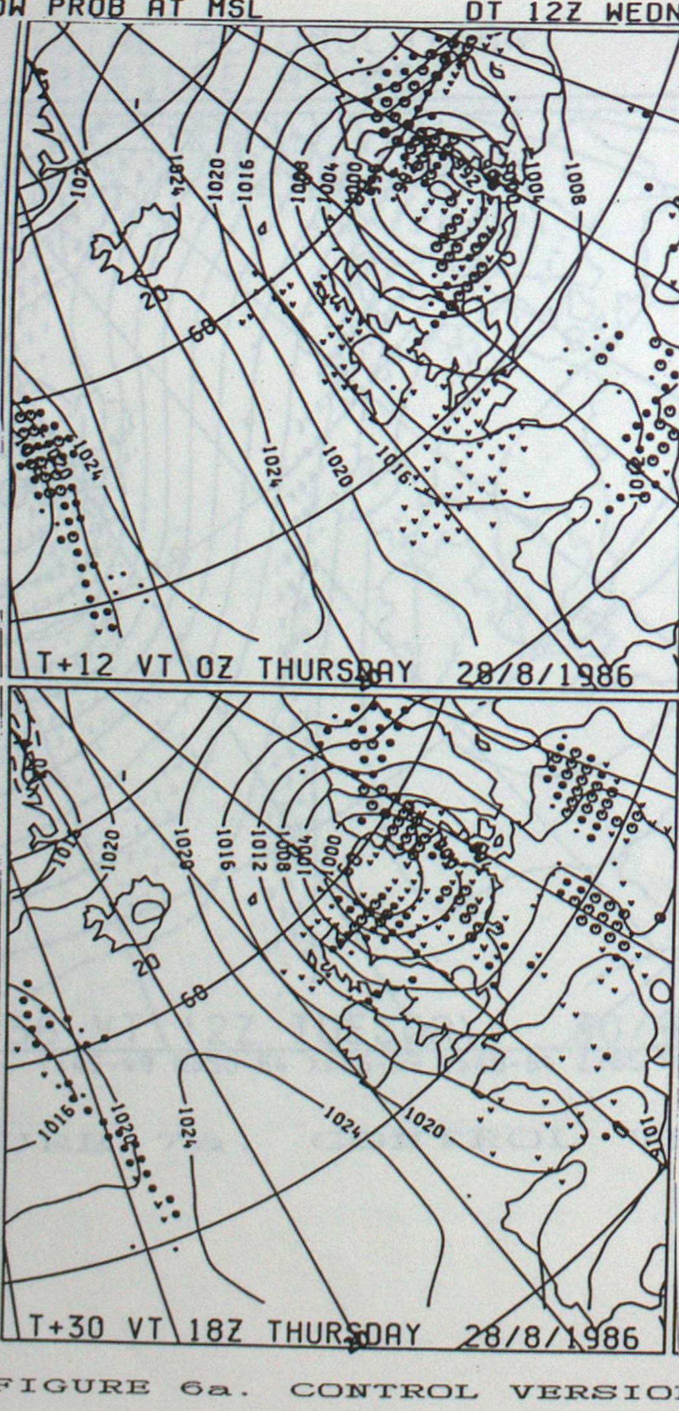


FIGURE 6a. CONTROL VERSION.

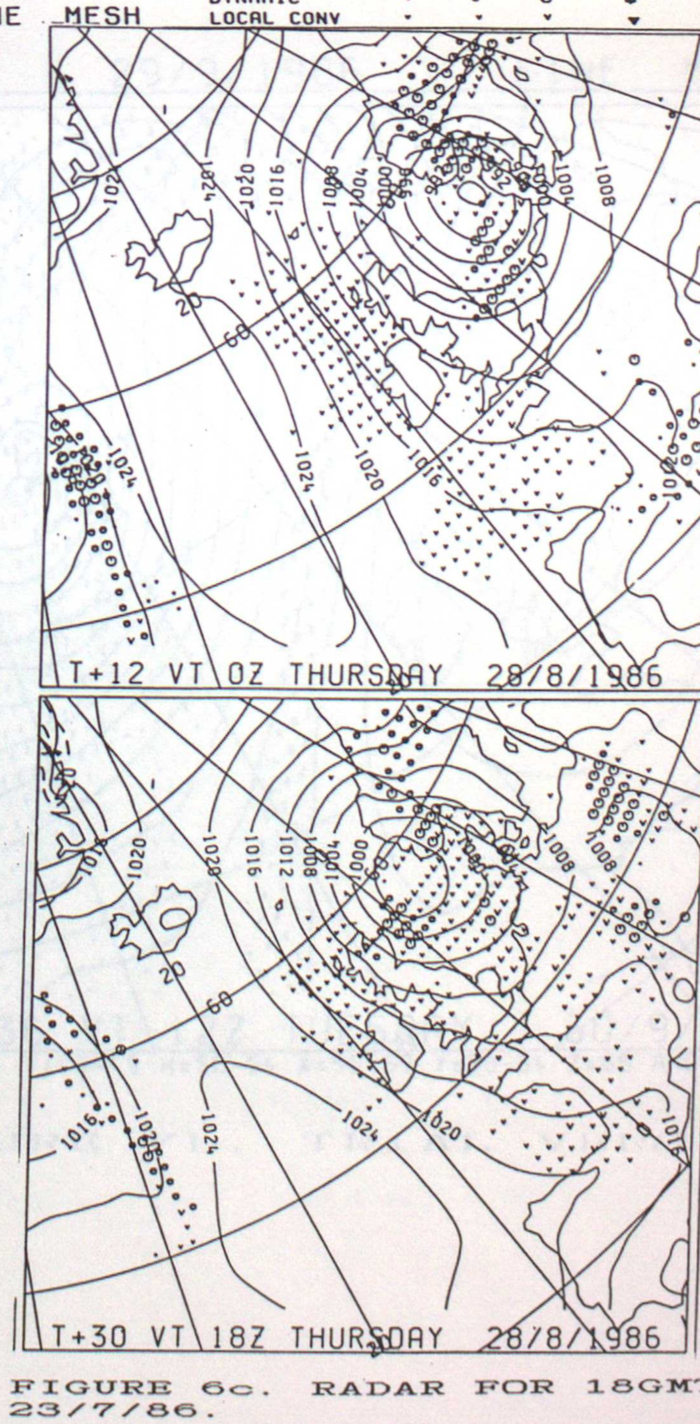


FIGURE 6c. RADAR FOR 18GMT 23/7/86.

TOTAL ACCUMULATION
PRESSURE AT MSL
DT 00Z MONDAY 29/9/1986 FINE MESH

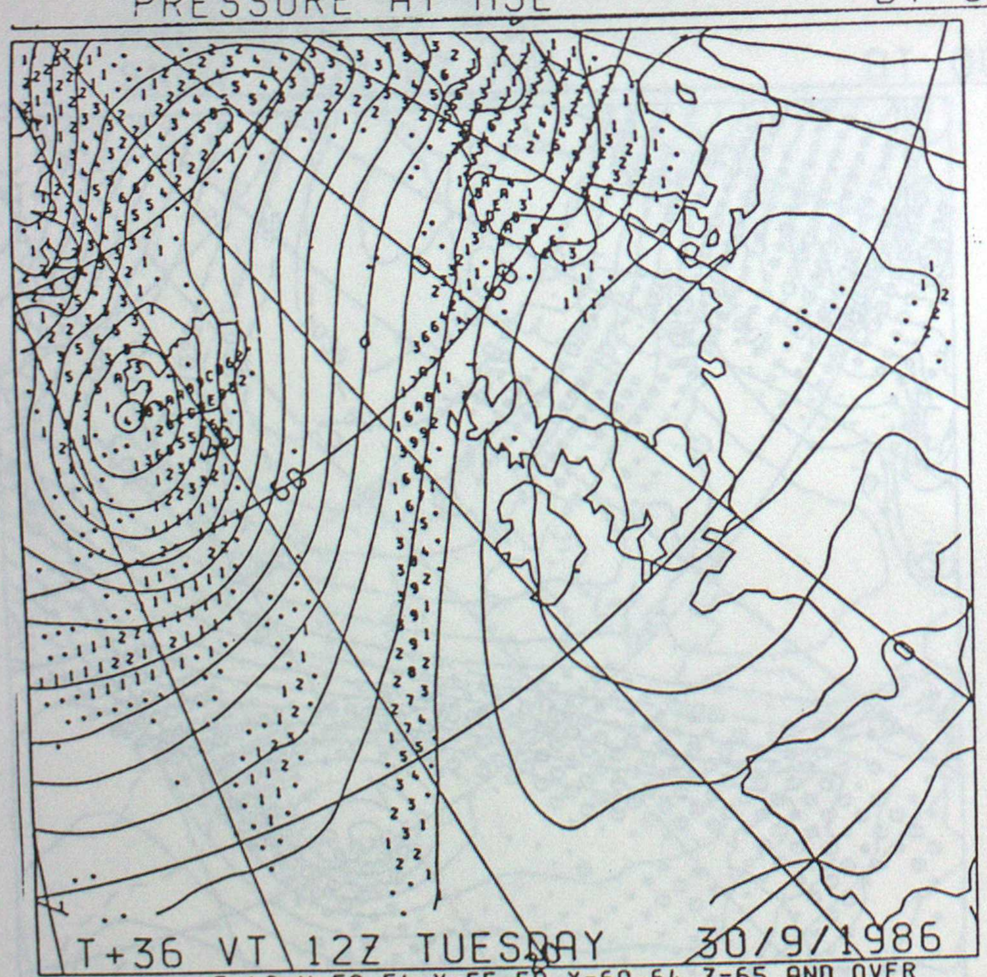


FIGURE 7a. CONTROL VERSION.

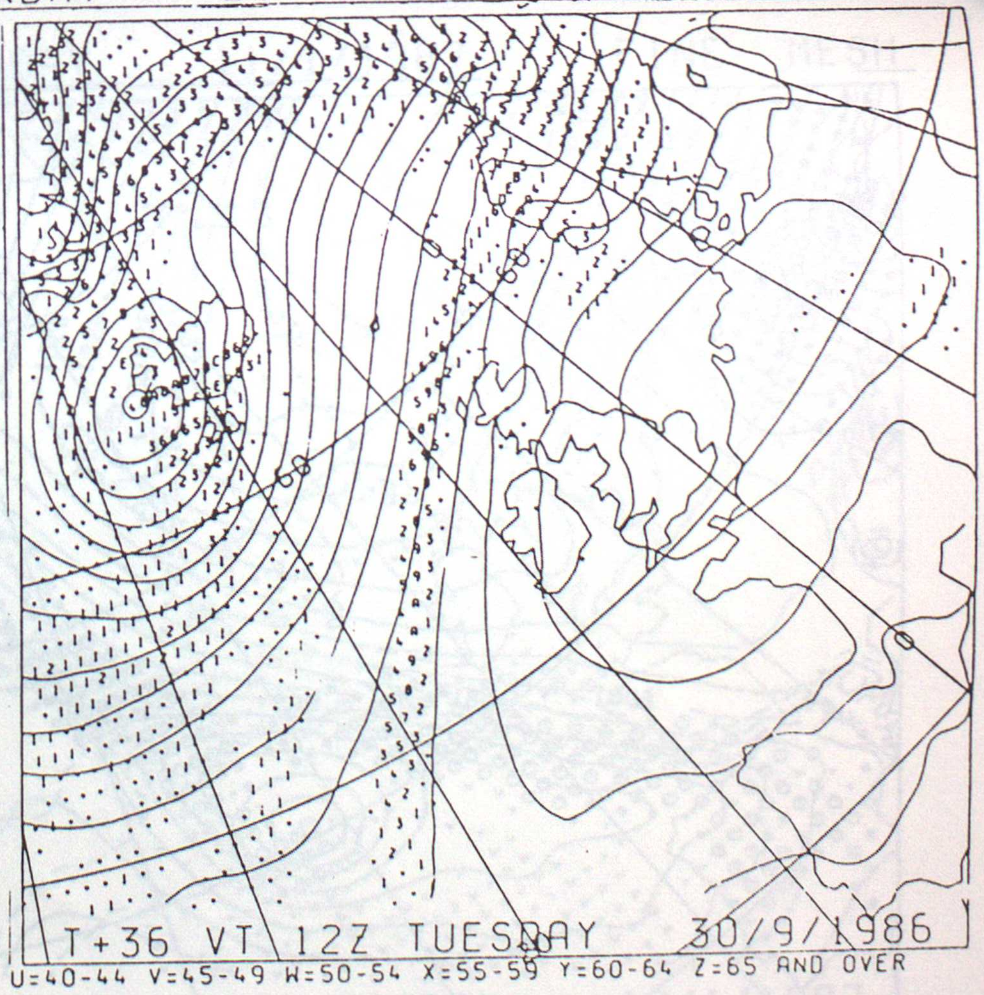
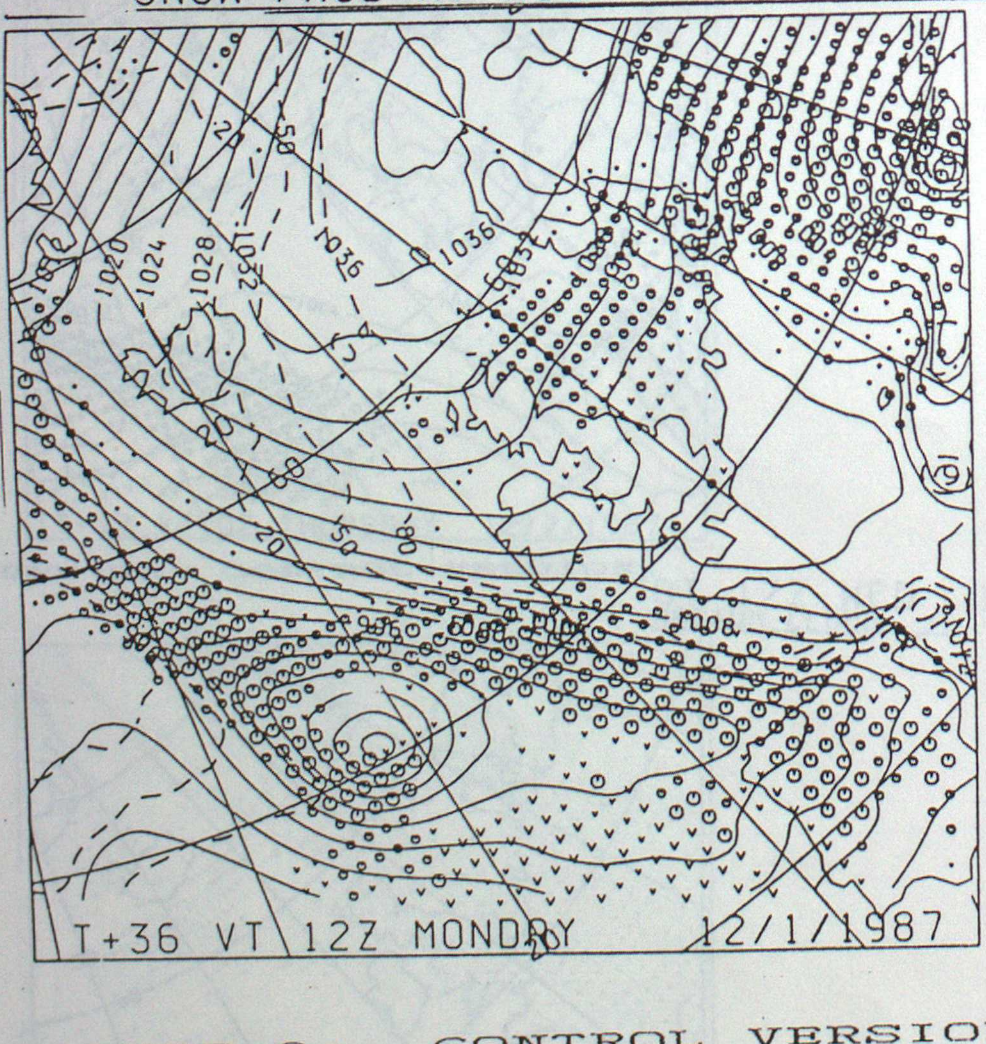


FIGURE 7b. TRIAL VERSION.

RAINFALL RATE
PRESSURE AT MSL
SNOW PROB AT MSL

DT 00Z SUNDAY 11/1/1987 FINE MESH



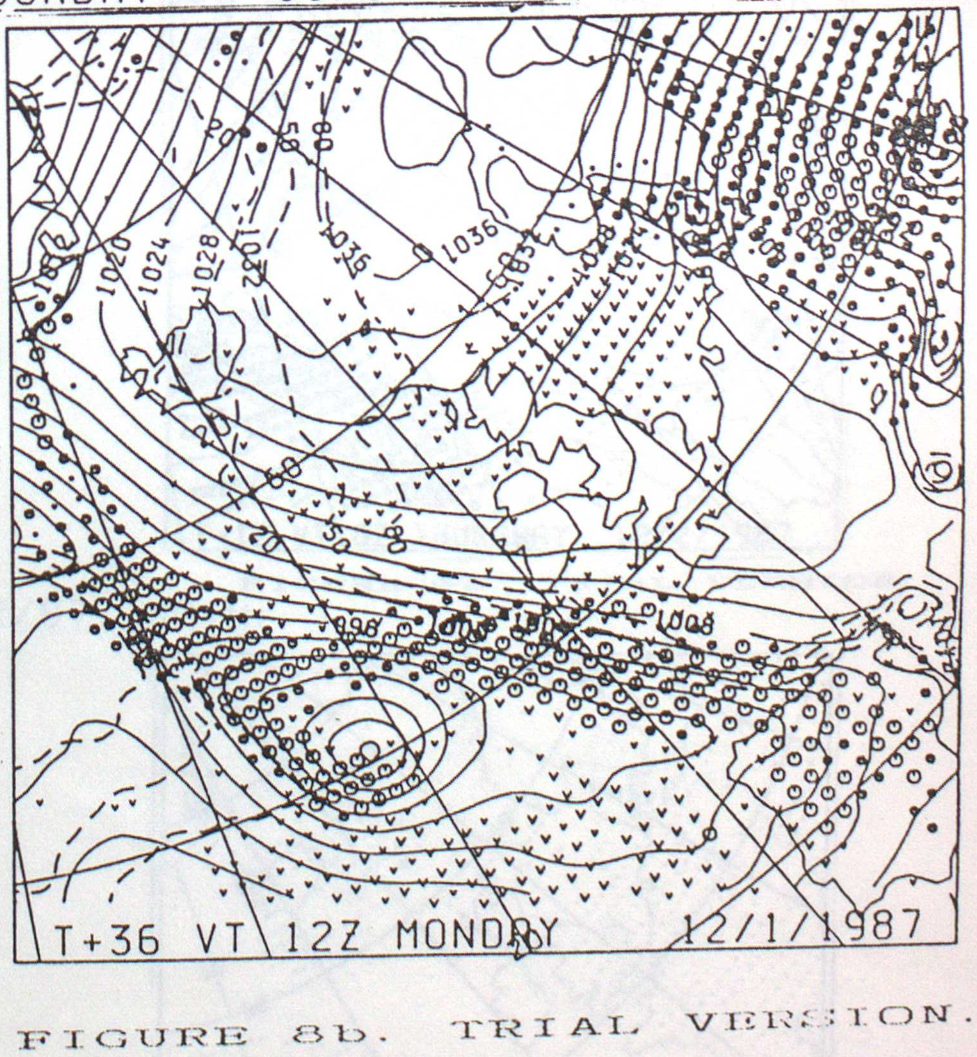


FIGURE 8a. CONTROL VERSION. FIGURE 8b. TRIAL VERSION.

RAINFALL RATE
PRESSURE AT MSL
SNOW PROB AT MSL

DT 12Z WEDNESDAY 11/2/1987 FINE MESH

DYNAMIC / LOCAL CONV: .01 .1 .5 4.0 MM/HR AT VT

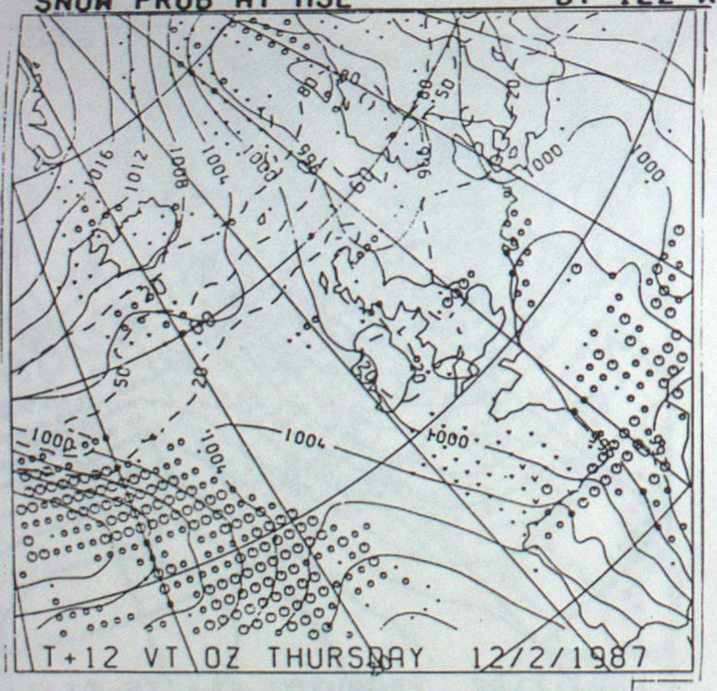


FIGURE 9a. CONTROL VERSION

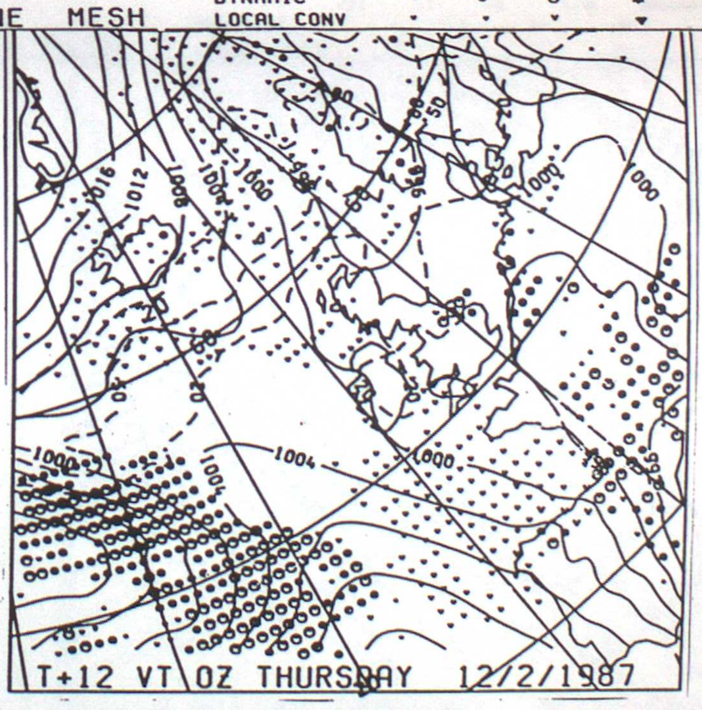
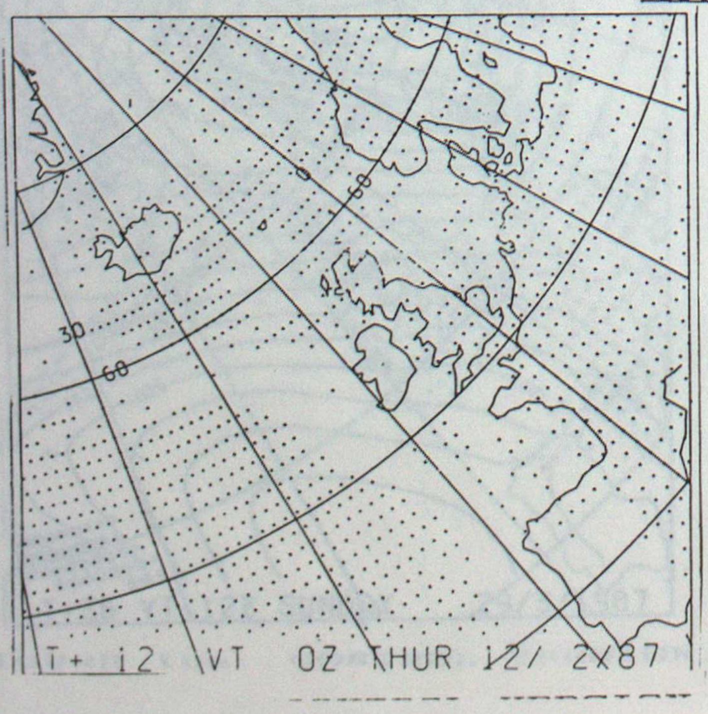
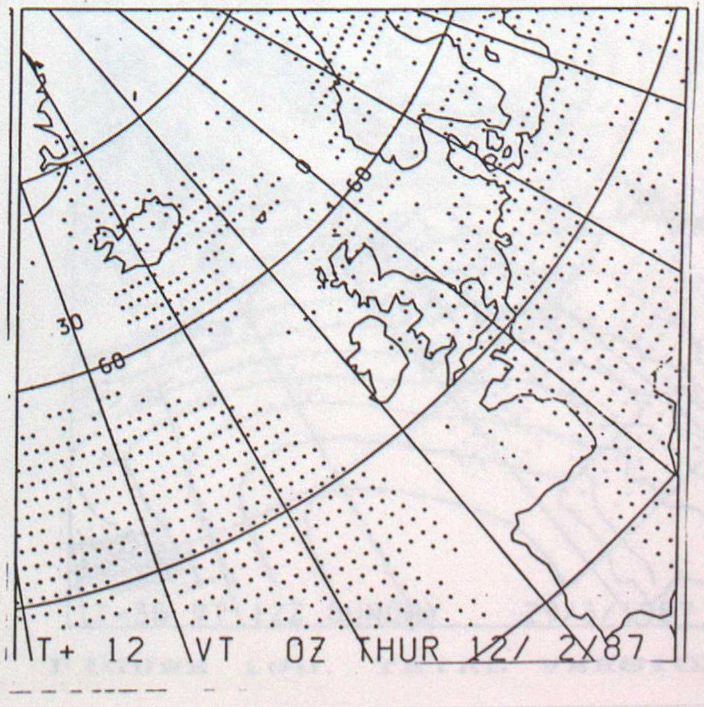


FIGURE 9b. TRIAL VERSION.

DT 12Z WED 11/ 2/87 MAIN
MEDIUM CLOUD





RAINFALL RATE
PRESSURE AT MSL
SNOW PROB AT MSL

DT 00Z SATURDAY 28/3/1987 FINE MESH

	.01	.1	.5	4.0	MM/HR AT VT
DYNAMIC	·	•	⊙	*	
LOCAL CONV	·	·	˅	▾	

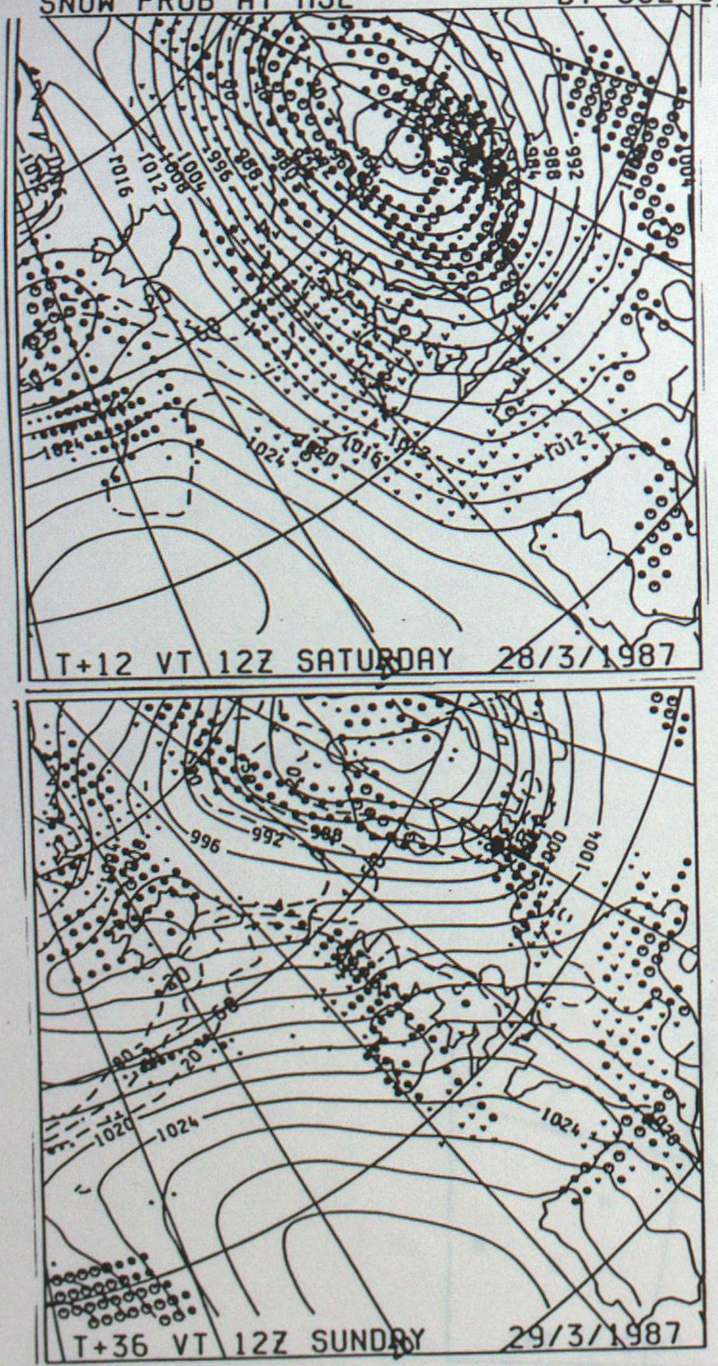


FIGURE 10a. CONTROL VERSION.

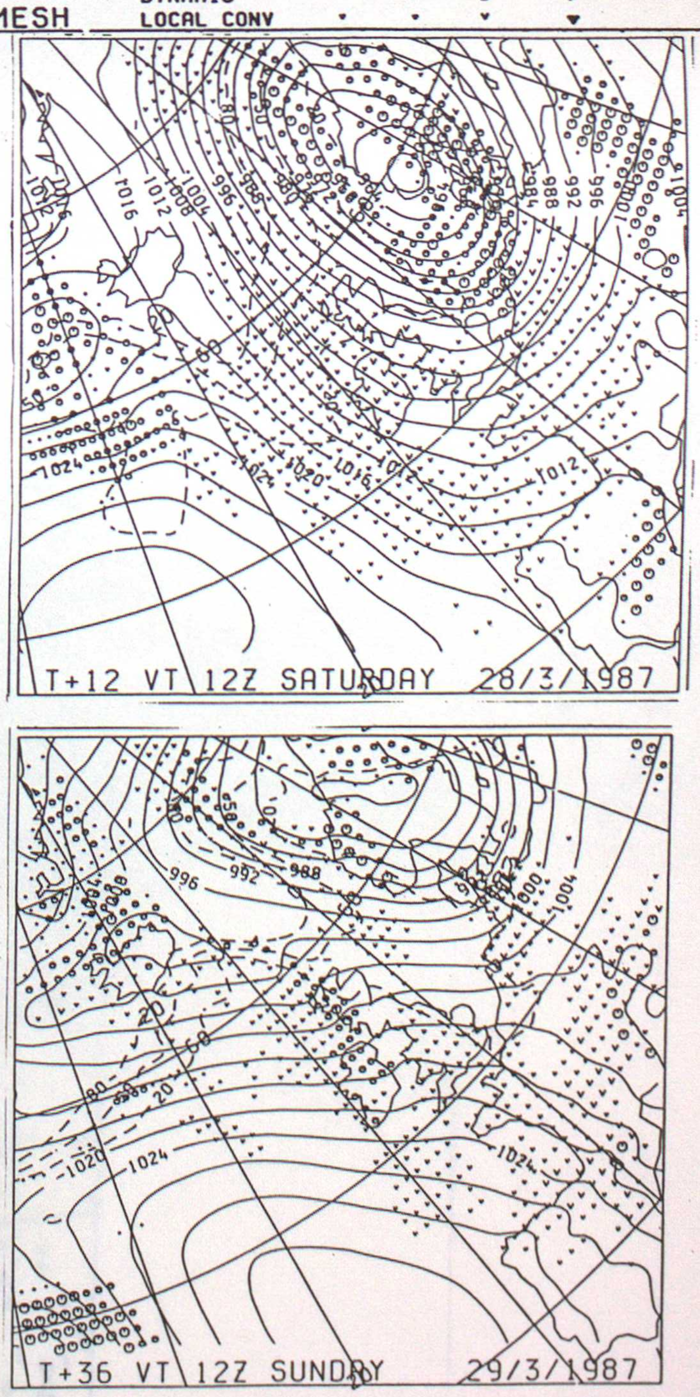


FIGURE 10b. TRIAL VERSION.

RAINFALL RATE
PRESSURE AT MSL
SNOW PROB AT MSL

DT 00Z SATURDAY 13/6/1987 FINE MESH

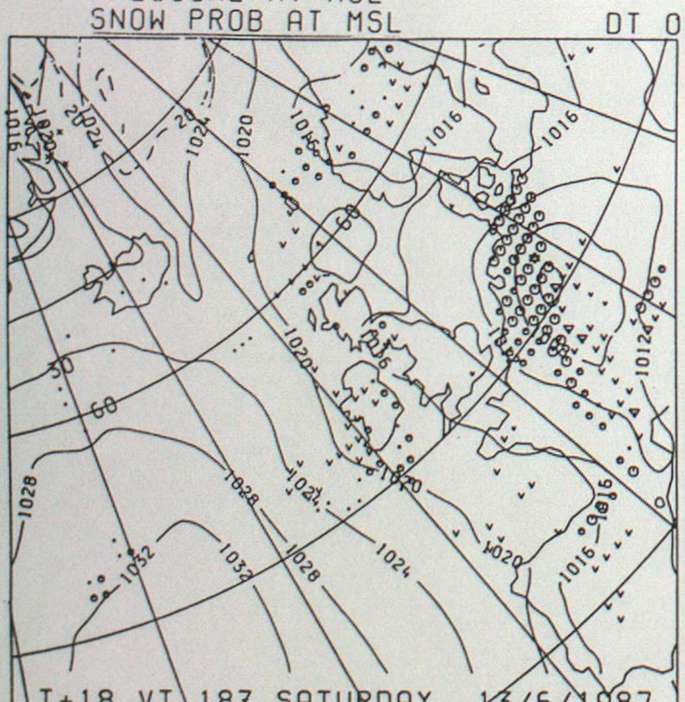


FIGURE 11a. CONTROL VERSION.

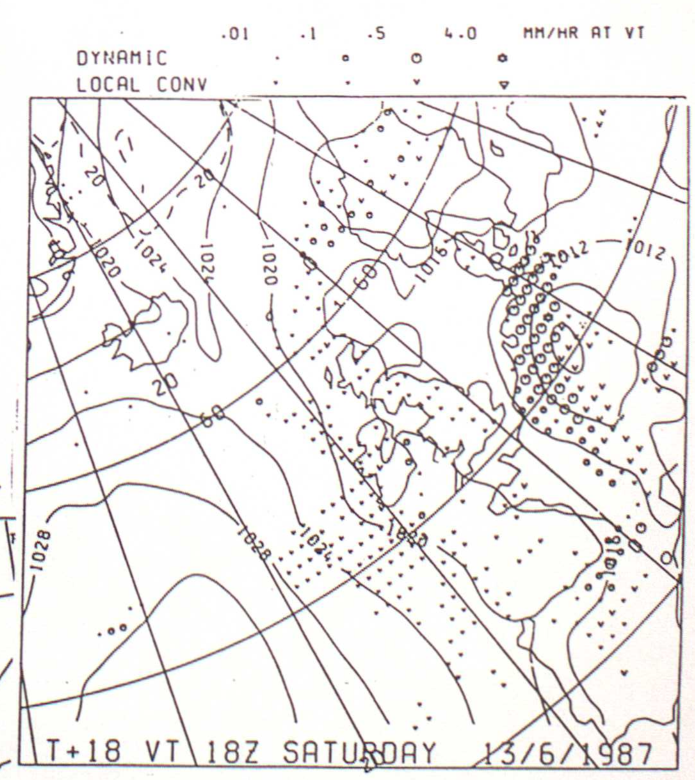


FIGURE 11b. TRIAL VERSION.

FIGURE 11c. SIGNIFICANT WEATHER CHART 18GMT 13/6/87.