

MET 0 11 TECHNICAL NOTE 204

SNOW FORECASTS FROM N.W.P. MODELS DURING THE
WINTER OF 1984/85

By

O. Hammon

Met 0 11 (Forecasting Research)

Meteorological Office

London Road

Bracknell

Berkshire

England RG12 2SZ

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1. Introduction

Due to the large number of snow situations during this winter, it was decided to limit this investigation to a four week period from December 26th to January 23rd.

On December 26th, the first significant snowfall of the winter occurred when a polar low moved southeastwards from Iceland across Ireland and the Scilly Isles, with several inches of snow falling over high ground in Wales, Southwest England and the Cotswolds. During the following four weeks, the weather remained predominantly cold with further periods of snow. The period ended with a deep depression centred just east of Aberdeen causing severe blizzards over Central and Eastern Scotland.

The fine-mesh model was the main model assessed in this investigation, but it was also compared with the mesoscale forecast model which was undergoing trials during the last two weeks of the period. The operational fine-mesh model has been described in detail by Dickinson (4) and the mesoscale model by Golding (3).

The fine-mesh prediction of snow is given by the 80%, 50% and 20% snow probability lines which are based upon the forecast 1000-850 mb thickness with a small correction for pressure. Snow prediction from the mesoscale model is not fully developed as yet and the only available parameter is the screen temperature. Precipitation is said to fall as snow if the screen temperature is below zero. (Golding, private communication).

This investigation is divided into two sections. In the first, the accuracy of the snow predictors is assessed, whilst in the second, some case studies, which highlight some model problems, are described.

2. Snow Predictors

The snow predictors considered are the 1000-850 mb thickness, the freezing level and the screen temperature.

a) The 1000-850 mb thickness

The 80%, 50% and 20% snow probability lines on the fine-mesh forecast are based upon the 1000-850 mb thickness, according to the figures derived by Boyden(1) (shown in table 1).

% Probability of snow	90	80	70	60	50	40	30	20	10
1000-850 mb thickness in gpm	1281	1285	1290	1291	1293	1295	1298	1300	1303

Table 1

Snow causes a good deal of anxiety and chaos, so it is important for the fine-mesh snow probability lines to be correct not only at T+12, but also at T+24 and T+36, so that ample warning of snow may be given to local authorities.

Table 1 shows that there is a difference of only 15 gpm between an 80% probability of snow and 20%, and only 7 gpm between a 50% probability of snow and 20%. Thus a high degree of accuracy (error < 1%) is demanded from the fine-mesh forecast of the 1000-850 mb thickness.

No official statistics are available for the verification of the 1000-850 mb thickness. Only the geopotential heights are verified separately at 1000 and 850 mb. To get some idea of the accuracy of the fine-mesh in predicting this thickness, we compared the forecast values at 00 and 12 GMT over the period Dec 26th to Jan 23rd at the positions of the

eight UK upper air stations with the observed values. By this method, values of the mean and r.m.s errors were calculated. The average values for the eight UK upper air stations are given in table 2.

Error in gpm.	T+12	T+24	T+36
Mean	1	2	2
R.M.S	5	7	9

Table 2: Fine-mesh 1000-850 mb thickness errors (Dec 26th - Jan 23rd)

The fine-mesh forecast needs to be accurate to within 8 gpm if it is to be a reliable guide for the prediction of snow. Table 2 shows that the fine-mesh mean and rms errors are in general <1% in the prediction of the 1000-850 mb thickness, but the r.m.s. errors increase with time.

Approximately 11% of the fine-mesh forecasts had an error greater than 10 gpm in the value of the 1000-850 mb thickness. Of this figure, 5.5% were at T+36 and 4.2% at T+24. Unfortunately the largest errors during the period of this investigation occurred at very critical points, ahead of a warm front in a rain-snow situation. The use of the 1000-850 mb thickness as a snow predictor in this situation is discussed in section 3 (case study for 20/21 January) and also in section 4.

The next important point to consider is whether the 1000-850 mb thickness is an accurate predictor of snow. Using the observed values from the 00, 12 GMT upper air ascents over the UK and Eire, the 80%, 50% and 20% snow probability lines were drawn as accurately as possible and compared with the relevant observations. Overall, the 50% snow probability line seemed to be a reasonably good guidance for the occurrence of snow,

provided that the height of a station above mean sea level was taken into account. Boyden(1) recommended that the following correction for mean sea level pressure and height above mean sea level should be added to the 1000-850 mb thickness value:

$$\text{Correction Factor} = \frac{P_0 - 1000}{4} - \frac{h}{30}, \text{ where } P_0 \text{ is the mean sea level pressure (mb) and } h \text{ is the station height above mean sea level (gpm).}$$

However, the point which corresponds to a switch from rain to snow depends upon whether the airmass is stable or unstable. Some light rain showers were reported in an unstable northerly or northeasterly airstream with 1000-850 mb thickness of 1295 gpm at low levels inland. In contrast, snow or sleet was reported at low levels in a stable airmass ahead of a warm front, with thickness values of approximately 1300 to 1306 gpm. The latter example is difficult to verify absolutely. Ahead of a warm front there is a strong gradient in the thickness lines and a wider coverage of observations is needed to be certain of the thickness value corresponding to the change from rain to snow. However this suggests that the 1000-850 mb thickness predictor may not be accurate enough to predict the boundary between rain and snow ahead of a warm front.

b) Freezing level

Boyden(1) also gave criteria for using the height of the freezing level above ground as a snow predictor. These are shown in table 3.

Height of freezing level above ground (mb)	12	25	35	45	61
Probability of snow as %	90	70	50	30	10

Table 3

Again, a high degree of accuracy is demanded. To be able to use these criteria as a snow predictor, we must have an accurate temperature structure in the lowest 50 mb of the atmosphere. To assess the accuracy of the fine-mesh freezing levels, values taken from the fine-mesh tephigrams at 00 and 12 GMT were compared with the actual radiosonde tephigrams. Errors were calculated as before and the results are given in table 4.

Station	Errors in mb	T+0	T+12	T+24	T+36
Lerwick	Mean	+13	+18	+21	+21
	R.M.S.	19	28	28	28
Stornoway	Mean	+8	+13	+13	+13
	R.M.S.	12	16	19	21
Hemsby	Mean	-9	-7	-10	-1
	R.M.S.	17	20	21	27
Aughton	Mean	-9	-6	-9	+5
	R.M.S.	18	26	28	43

Table 4: Errors in Fine mesh freezing levels for period

Dec 26th to January 23rd

Table 4 shows that the fine-mesh temperature structure below 900 mb was not accurate enough during this period. There is evidence of a cold bias overland in these figures for the temperature. This may be caused by a problem in the radiation scheme, leading to excessive overnight cooling and too slow a rise of temperature during the morning. The errors at T+0 are also rather worrying, but are probably due to the model having too coarse a resolution in the lowest 100mb.

The freezing level should be a better predictor of snow than the 1000-850 mb thickness in a frontal situation, because it assesses the temperatures of the lowest layer of the atmosphere. However, during the period considered, the fine-mesh did not have a sufficiently accurate low level temperature structure.

3. Case Studies

When the fine-mesh forecasts for T+12, T+24, T+36 were compared to the actual weather conditions during this period, three main 'snow' problems were noticed. These were connected with forecasting the following;

- i) the position of the boundary between rain and snow,
- ii) the extent and persistence of light snow over land;
- iii) the intensity of showers and their advection inland.

The following case studies were chosen to illustrate these problems.

a) Period 12 GMT 20/1/85 to 12 GMT 21/1/85

This example was chosen because it illustrates the problems of using the 1000-850 mb thickness to predict snow ahead of a warm front. The largest positive errors in the fine-mesh forecast values of this thickness occurred during this period. Errors of 1-2 dm occurred at T+12, increasing to 2-4 dm at T+36.

At 12 GMT 20/1/85, a warm front was lying from Valentia to Scillies, moving slowly northeastwards (see figure 1). Rain over southwest England was turning to snow or sleet even at low levels over South Wales, Bristol, and the Boscombe Down area, on the northern edge of the precipitation belt. If we verify the fine mesh snow probability lines at this time, then, at T+12, only the 20% probability line was in this position. At T+24 and T+36 all the snow probability lines were forecast to be north of this snow area (see figure 3). Unfortunately as it was on a Sunday, no 12 GMT Larkhill ascent was available, so we cannot verify the actual 1000-850 mb thickness over Boscombe Down at 12 GMT. However, assuming a strong gradient in the thickness lines ahead of the warm front, the 50% snow probability line (1293 gpm) could be drawn from Crawley to Larkhill to South Wales (see figure 2).

A similar problem occurred during the morning, 21/1/85. By 06 GMT, the warm front was lying from Ipswich to Prestwick, with sleet and snow reported over Lincolnshire and Northern England even at some low level stations. The fine-mesh snow probability lines were again forecast to be too far north.

This example shows the tendency of the fine-mesh model to push warm air too quickly northwards ahead of a warm front, especially at T+24 and T+36, and also the inadequacy of the 1000-850 mb thickness as a snow predictor in this situation. Ahead of a warm front there is a strong gradient in the thickness lines and the fine mesh only has to be one gridpoint in error for the forecast thickness to have a large error. It is also possible for snow to occur in a stable airmass with thickness values as high as 1305 gpm even at low levels.

Figure 4 shows the difference between the actual ascent for Aughton at 21/00 GMT and the fine-mesh forecasts for Aughton at T+12, T+24 and T+36.

b) Period 14/1200 to 15/1200 GMT January 1985

This period was chosen to illustrate points (ii) and (iii) mentioned in the first paragraph of section 3. During this period the fine-mesh underestimated the area and intensity of showers.

The main feature of the synoptic situation was a ridge of high pressure over Scotland with an unstable northeasterly airstream over England and Wales. The isobars were curved cyclonically over the Southern North Sea, and on both the 14th and 15th, small shallow depressions formed over Holland and moved southwestwards through the Dover Straits into the Channel. The associated troughs increased and intensified showers over the relatively warm North Sea. Moderate, locally heavy snow showers fell along the east coast and an area of showers spread inland.

At 15/06 GMT, (see figure 6), the area of mainly light snow over Lincolnshire, Northern England and the Midlands originated from showers over the North Sea. As the showers spread inland, the intensity diminished but the area of snow persisted many hours. These conditions were poorly forecast by the fine-mesh as shown by figure 7.

The fine-mesh is not able to forecast this type of situation accurately in winter. Even if it forecasts showers correctly over the North sea, there is no mechanism in the model to advect the showers inland, and temperatures are too low over land to develop showers. Another problem is that the fine mesh underestimates the intensity of convection, due to incorrect modelling of the inversion. Figure 8 compares the 12 GMT 15/1/85 ascent for Hemsby with the fine-mesh forecasts. At 12 GMT, moderate snow was reported at a number of stations along the East Coast, just ahead of a

trough approaching from the east (see figure 7). Temperatures over the North sea were high enough to set off very vigorous convection to 10000 feet. With a temperature of -21°C at 9000 feet, this depth of cumulus cloud was sufficient to give at least moderate snow showers. Figure 8 shows how the fine-mesh smoothes out the sharp inversion. The best fine-mesh forecast at T+12 would give convection to only 6000 feet, which would give only light showers. The ascents at T+24 and T+36 were too dry and stable at low levels.

The mesoscale model is able to advect showers inland, and so was able to improve the forecast for 18 GMT on the 14th, but amounts were still underestimated.

4. Discussion

This investigation has shown that there are problems in choosing to use the 1000-850 mb thickness as a snow predictor. The critical value corresponding to a change from rain to snow depends upon the stability of the layer. In a stable flow ahead of a warm front, the temperature may be isothermal at zero to minus 01°C from the surface to 850 mb, giving snow even at low levels from a relatively high thickness of ≥ 1300 gpm, which corresponds to a probability $\leq 20\%$. No allowance is made for this in the Boyden criteria. The predictor is biased too much by the warming occurring in the top half of the layer, whereas in reality the type of precipitation is determined more by the low level temperatures.

The freezing level would be a better predictor to use in this case but the fine mesh freezing levels were not accurately enough forecast during the period investigated.

Figure 5 shows the mesoscale forecast observations for Glasgow Weather Centre on 21st January, compared with the actual observations. The figure shows that snow can be reported even with screen temperatures $> 1^{\circ}\text{C}$. The mesoscale model's snow prediction capabilities can only be assessed in clear cut cases where screen temperature is below freezing. Borderline rain-snow cases tend to be badly predicted because of the inadequacy of the predictor. Better criteria could be provided by the following;

- a) Height of dry bulb freezing level above ground (i.e. ≤ 35 mb);
- b) Height of wet-bulb freezing level above ground (i.e. ≤ 10 mb)
- c) screen temperature $< 1.5^{\circ}\text{C}$ and dewpoint $\leq 0^{\circ}\text{C}$.

Overall the mesoscale forecasts were similar to the fine mesh. However, there were a few occasions in which the amount of precipitation was intensified over high ground to a greater extent than in the fine mesh. Also the mesoscale model should provide extra useful detail in an unstable northeasterly airstream, due to its ability to advect showers. There is also a mechanism in the mesoscale model for estimating snow depth if the temperature is below zero. However there would be great difficulties in providing the model with a realistic snow cover at the initial analysis.

5. Conclusion

- a) The 1000-850 mb thickness is accurately forecast by the fine mesh on most occasions. However this thickness is not the best predictor to use when determining the boundary between rain and snow. Firstly, snow can occur in a stable airmass with actual thickness values > 1300 gpm ($< 20\%$ probability). Also the fine mesh has a tendency to push warm air too quickly northwards. These two factors will affect critically the forecasting of snow or rain ahead of a warm front.

- b) The freezing level should be a more accurate snow predictor since low level temperatures are more important than layer thickness in this situation.
- c) Light snow areas and convection were often underestimated by the fine mesh due to the models inability to advect showers and model the inversion correctly, and also due occasionally to relative dryness at low levels.
- d) The mesoscale model showed some improvement to the short range forecast in the advection of showers and orographic intensification of precipitation.

Lowndes, Beynon and Hawson (reference 2) carried out a detailed investigation into the accuracy of four snow predictors, (the 1000-850 mb and the 1000-900 mb thicknesses, adjusted for surface pressure and station height, the dry-bulb freezing level and the wet-bulb freezing level) in forecasting snow over Wales and the West Midlands during the three winters 1966-67, 1967-68, 1969-70. The main conclusions of this investigation were;

- a) The wet-bulb freezing level was the most efficient snow predictor, with the other three predictors being similar but slightly less accurate.
- b) The value of the 1000-850 mb adjusted thickness was not significantly different for showery and non-showery precipitation.

Our investigation covered a four-week period only, from December 26th to January 23rd, and it was concerned mainly with the verification of fine-mesh and mesoscale model forecasts of snow. However, the results did indicate that snow could occur at a higher value of the 1000-850 mb thickness in a stable airmass, and that this difference could be

significant ahead of a warm front. The wet-bulb freezing level was not verified in this investigation due to the cold bias of the fine-mesh forecast tephigrams over land during this period.

References

1. C J Boyden; A comparison of snow predictors, Met. Mag, Dec 1964.
2. C A S Lowndes, A Reynon, C L Hawson; An assessment of the usefulness of some snow predictors, Met Mag Dec 1974.
3. B W Golding, The Meteorological Office mesoscale model: its current status, Met Mag Oct 1984.
4. A Dickinson and C Temperton; The Operational Numerical Weather Prediction model. Met O 11 Technical Note No 183.

Figures

1. Surface analysis for 12 GMT, 20/1/85.
2. The 1000-850 mb thickness for 12 GMT, 20/1/85.
3. Fine-mesh forecasts of precipitation rate for 12GMT, 20/1/85.
4. Fine-mesh forecast temperature profiles compared with the actual radio-sonde temperature profile for Aughton for 00 GMT, 21/1/85.
5. Mesoscale forecast observations for Glasgow Weather Centre, compared with the actual observations, for 21/1/85.
6. Surface analysis for 06 GMT, 15/1/85.
7. surface analysis for 12 GMT, 15/1/85.
8. Fine-mesh forecast temperature profiles for Hemsby at 12 GMT, 15/1/85 compared with actual radio-sonde temperature profile.
9. Fine-mesh forecasts of precipitation rate for 06 GMT, 15/01/85.

Figure 1

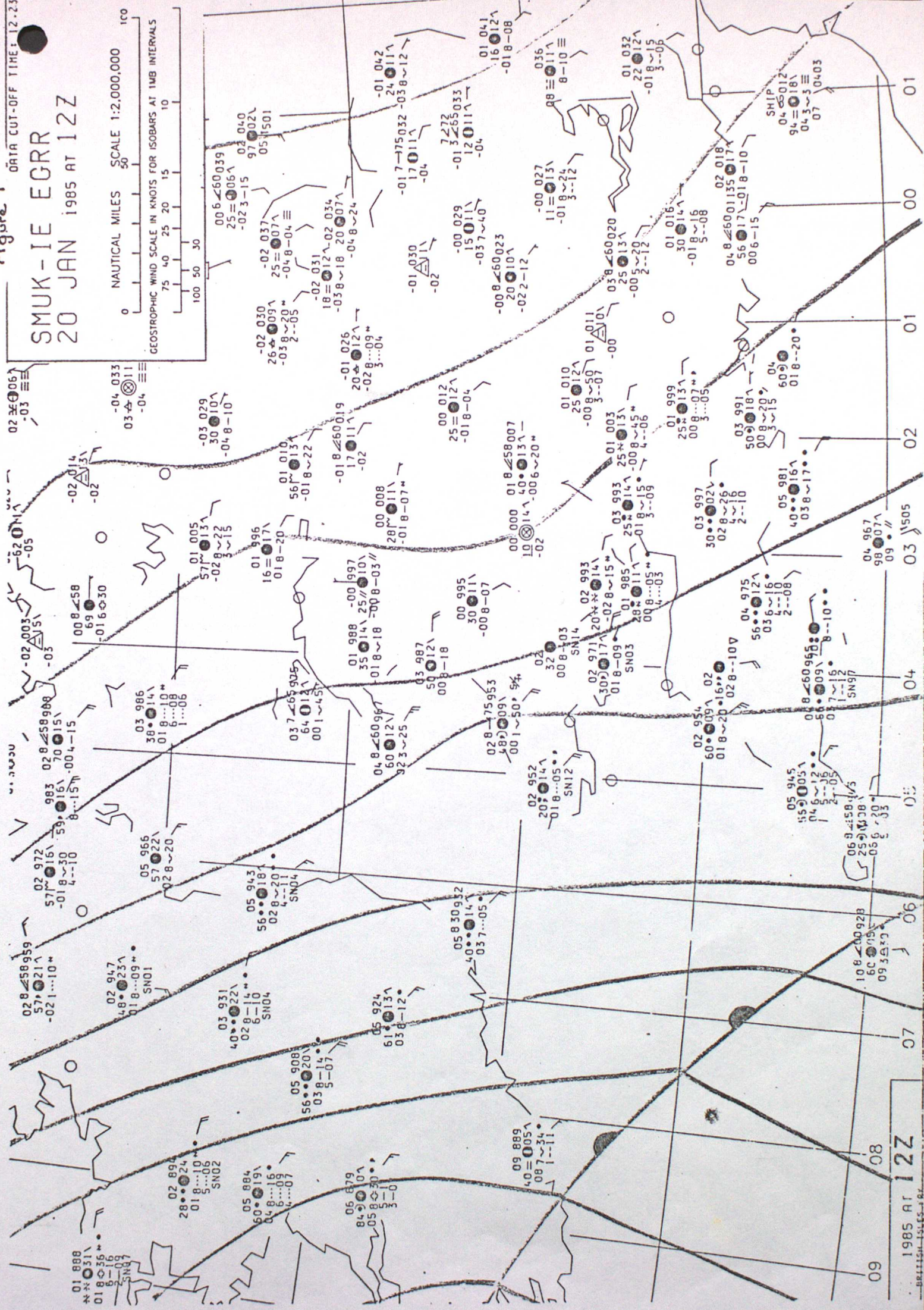
DATA CUT-OFF TIME 12Z

SMUK-IE EGR

20 JAN 1985 AT 12Z

NAUTICAL MILES SCALE 1:2,000,000

GEOSTROPHIC WIND SCALE IN KNOTS FOR ISOBARS AT 1MB INTERVALS



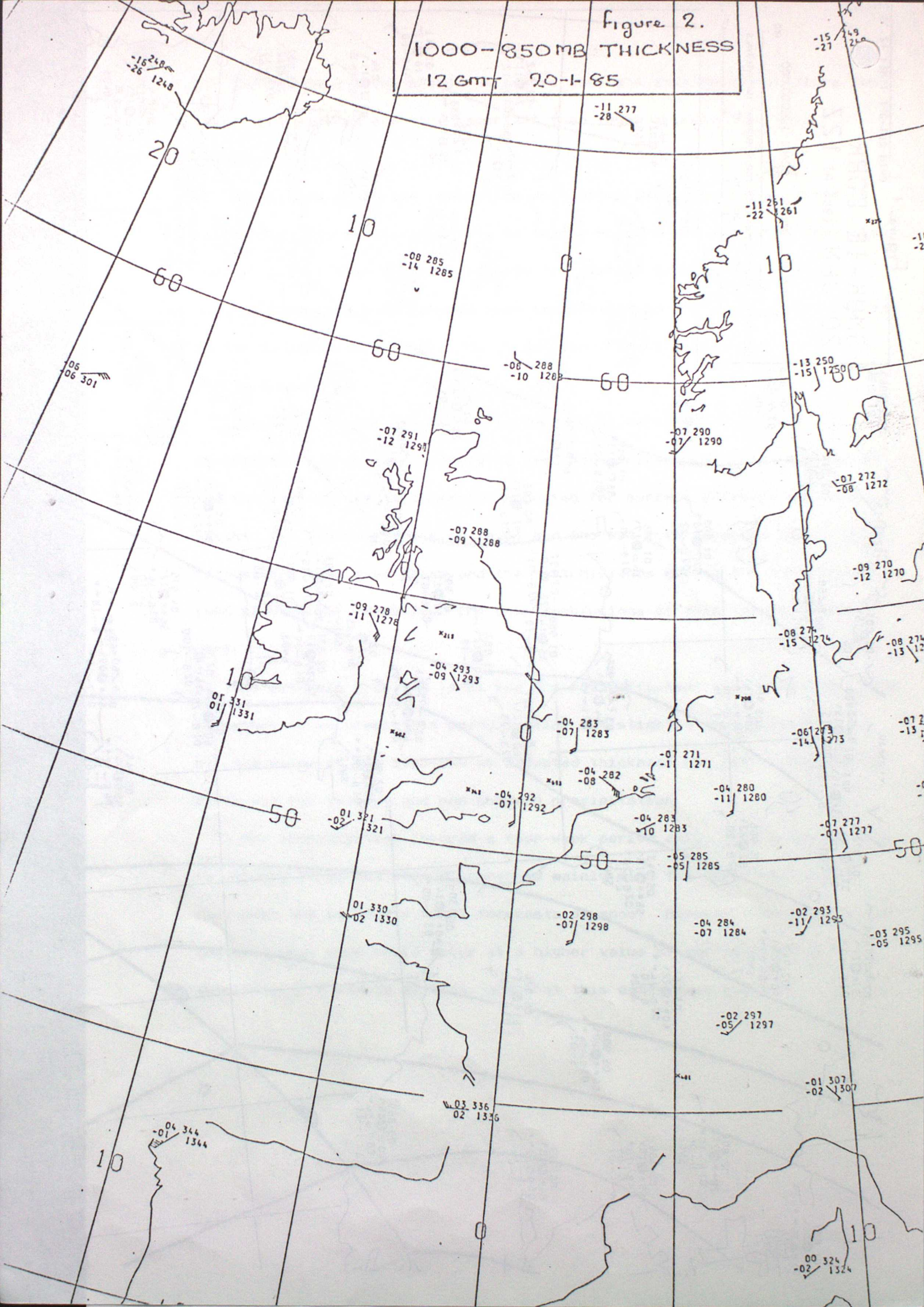
1985 AT 12Z

BRITISH ISLES

Figure 2.

1000-850MB THICKNESS

12 GMT 20-1-85



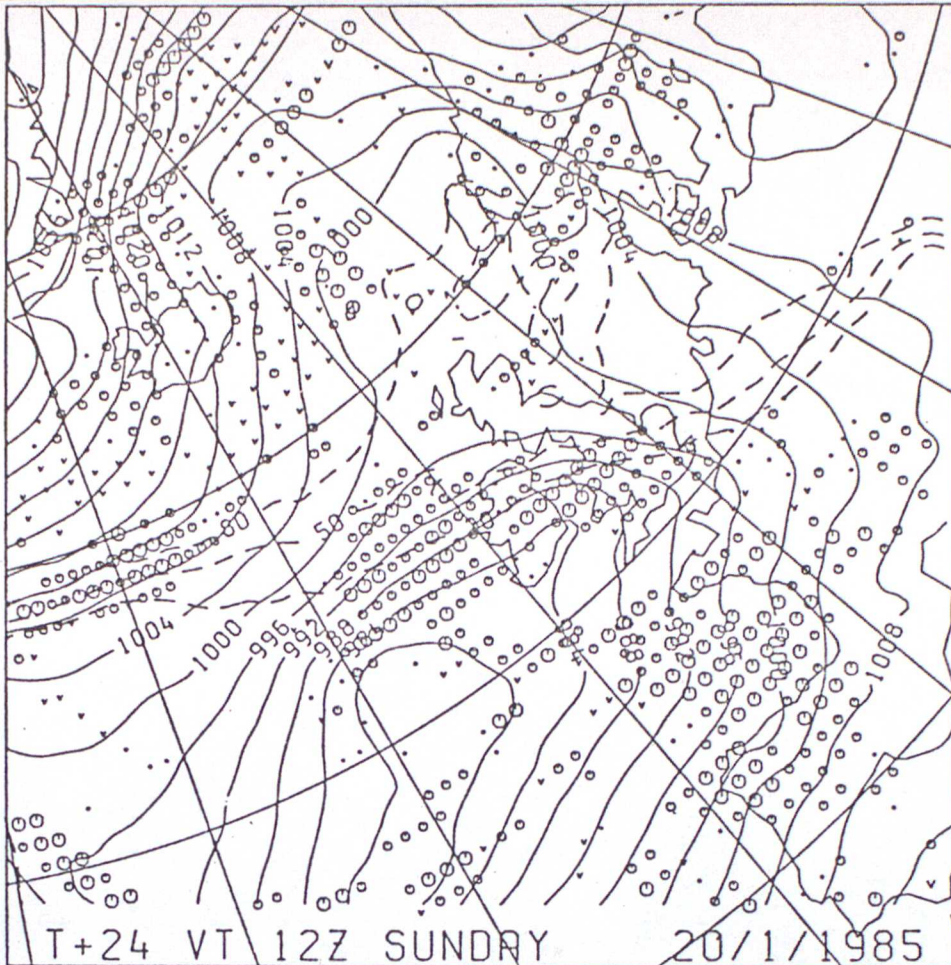
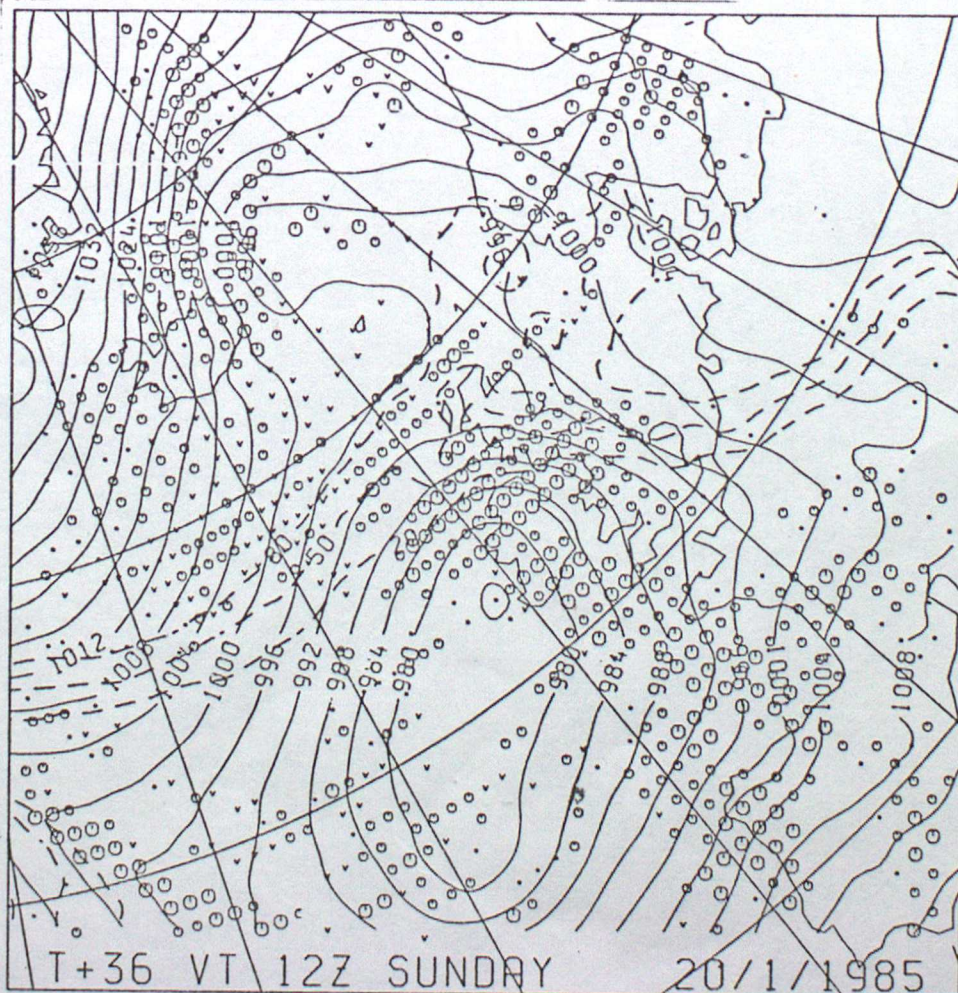
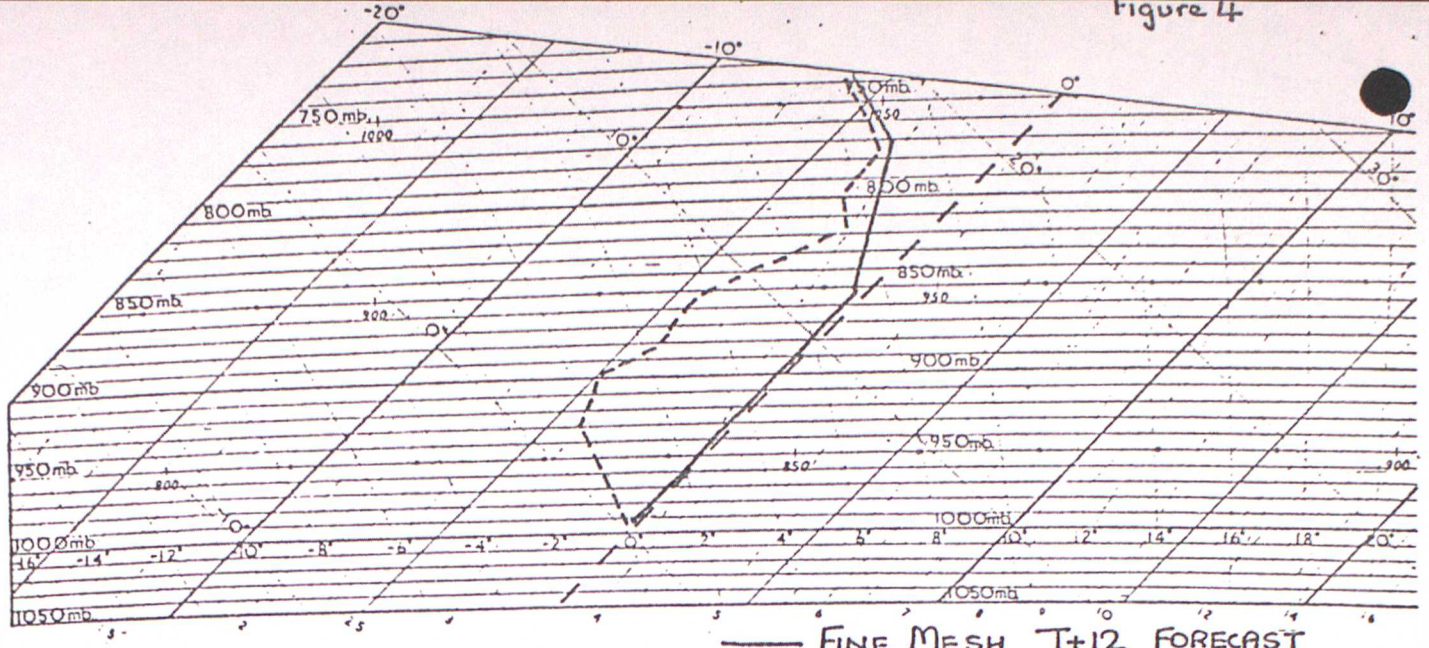


Figure 3

T+24

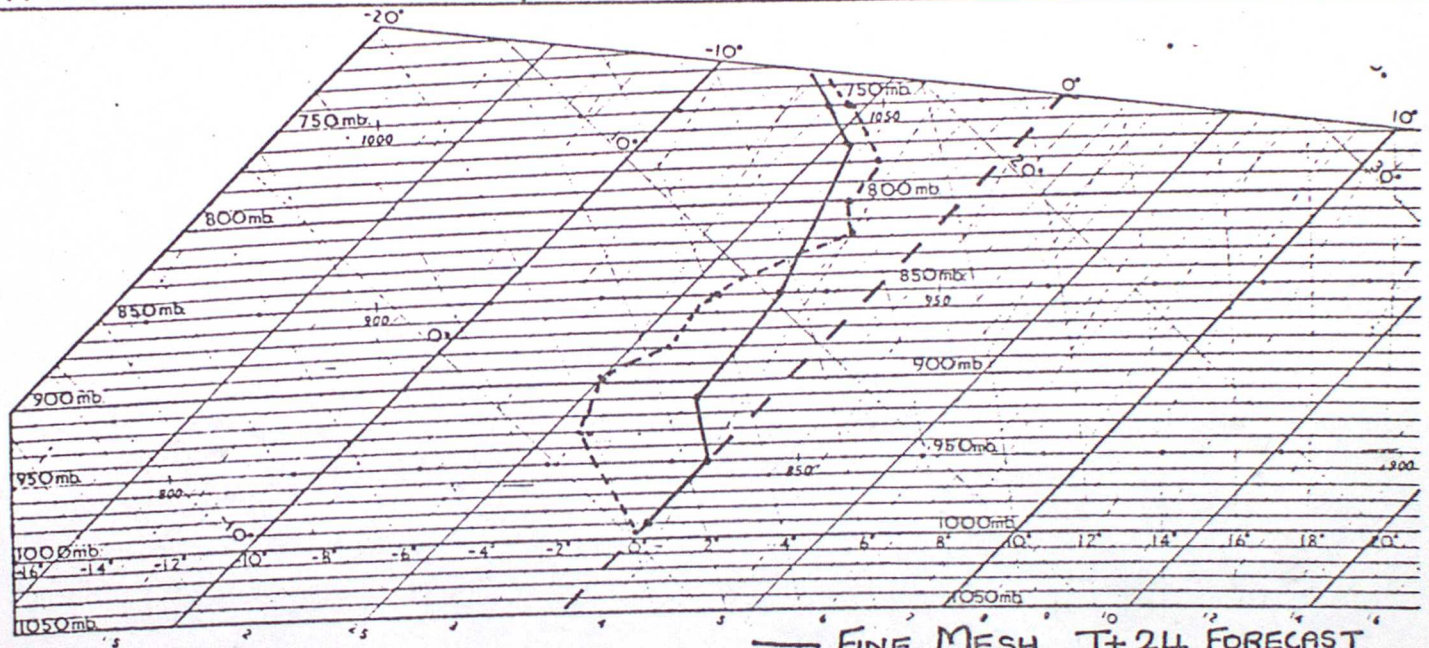


T+36



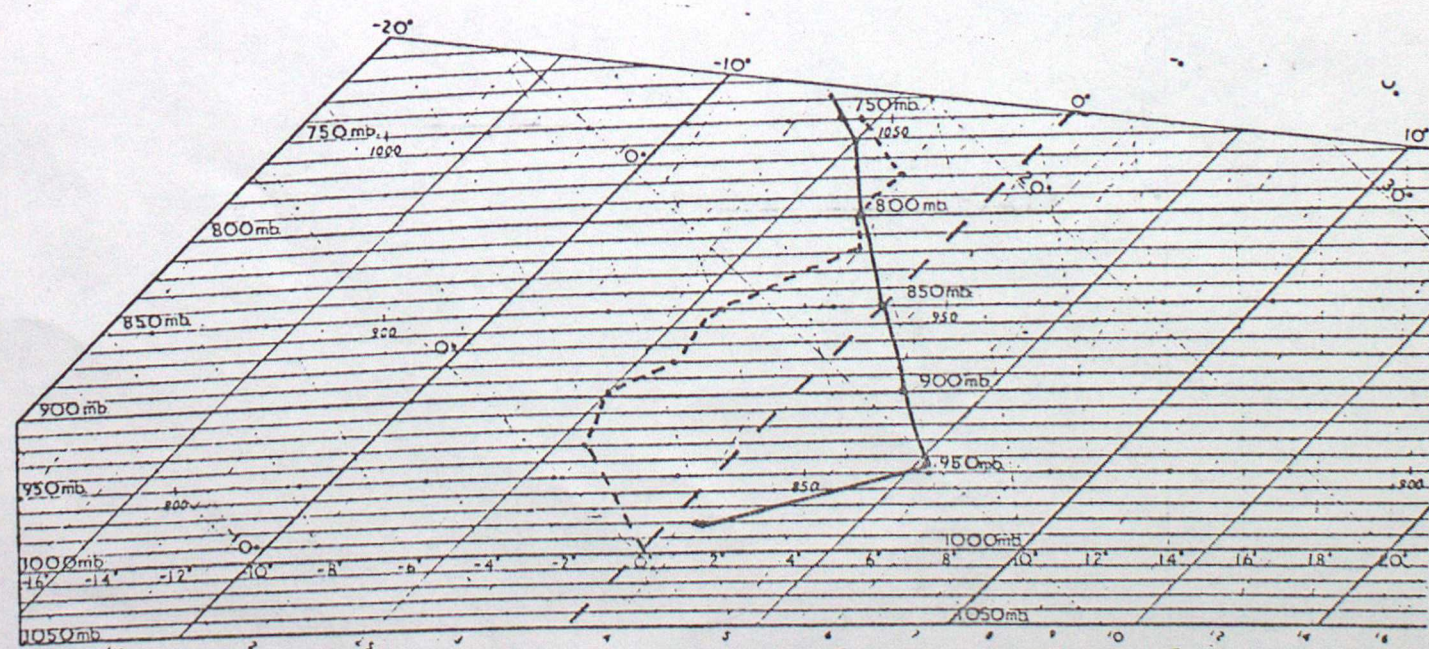
AUGHTON TEPHIGRAMS 00z 21/01/85

— FINE MESH T+12 FORECAST
 --- RADIOSONDE ASCENT.



AUGHTON TEPHIGRAMS 00z 21/01/85

— FINE MESH T+24 FORECAST
 --- RADIOSONDE ASCENT



AUGHTON TEPHIGRAMS 00z 21/01/85

— FINE MESH T+36 FORECAST
 --- RADIOSONDE ASCENT

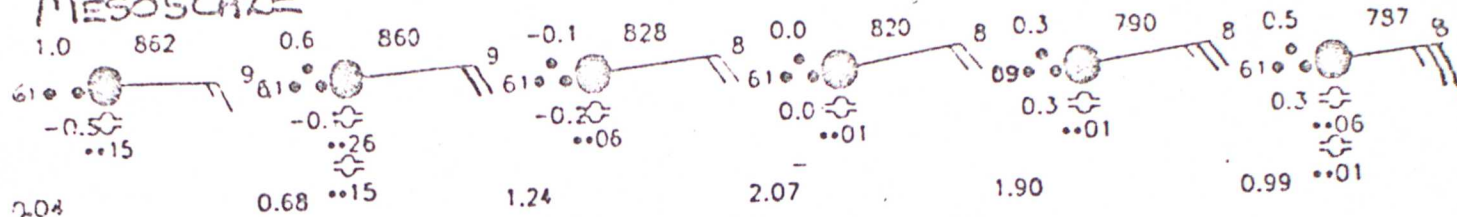
MESOSCALE FORECAST FOR GLASGOW WEATHER CENTRE 21/01/85

COMPARED WITH ACTUAL OBSERVATIONS.

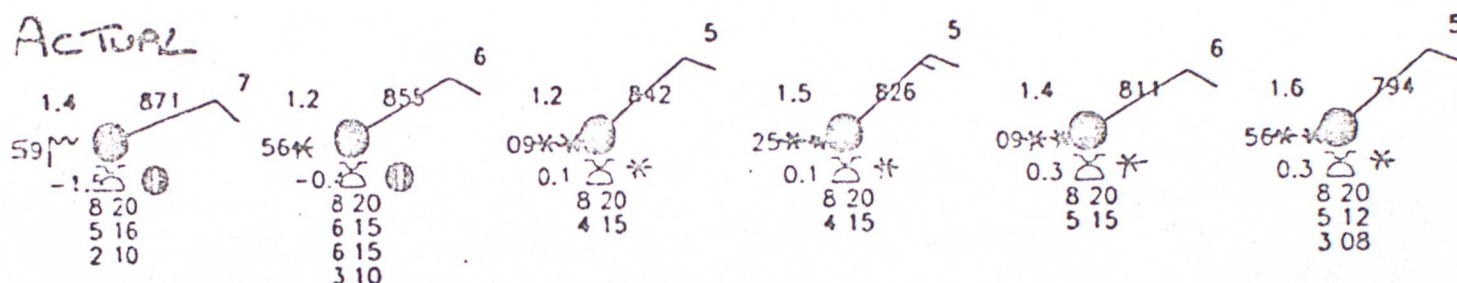
[MESOSCALE 'WEATHER' ASSUMED TO BE SNOW IF TEMPERATURE $< 0^{\circ}\text{C}$]

03145 21/01/85

MESOSCALE



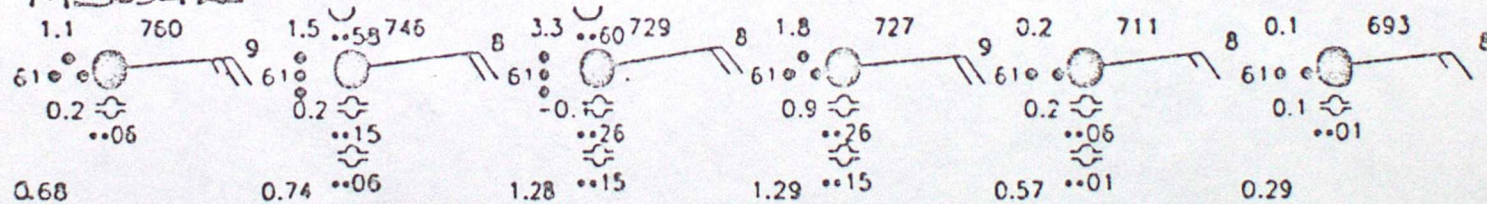
ACTUAL



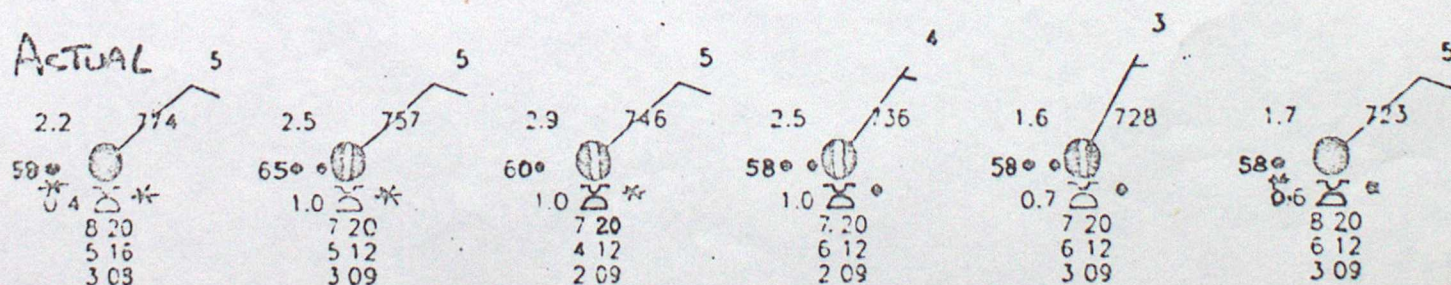
07Z 08Z 09Z 10Z 11Z 12Z

STATION 03145 21/01/85

MESOSCALE



ACTUAL



13Z 14Z 15Z 16Z 17Z 18Z

Figure 6

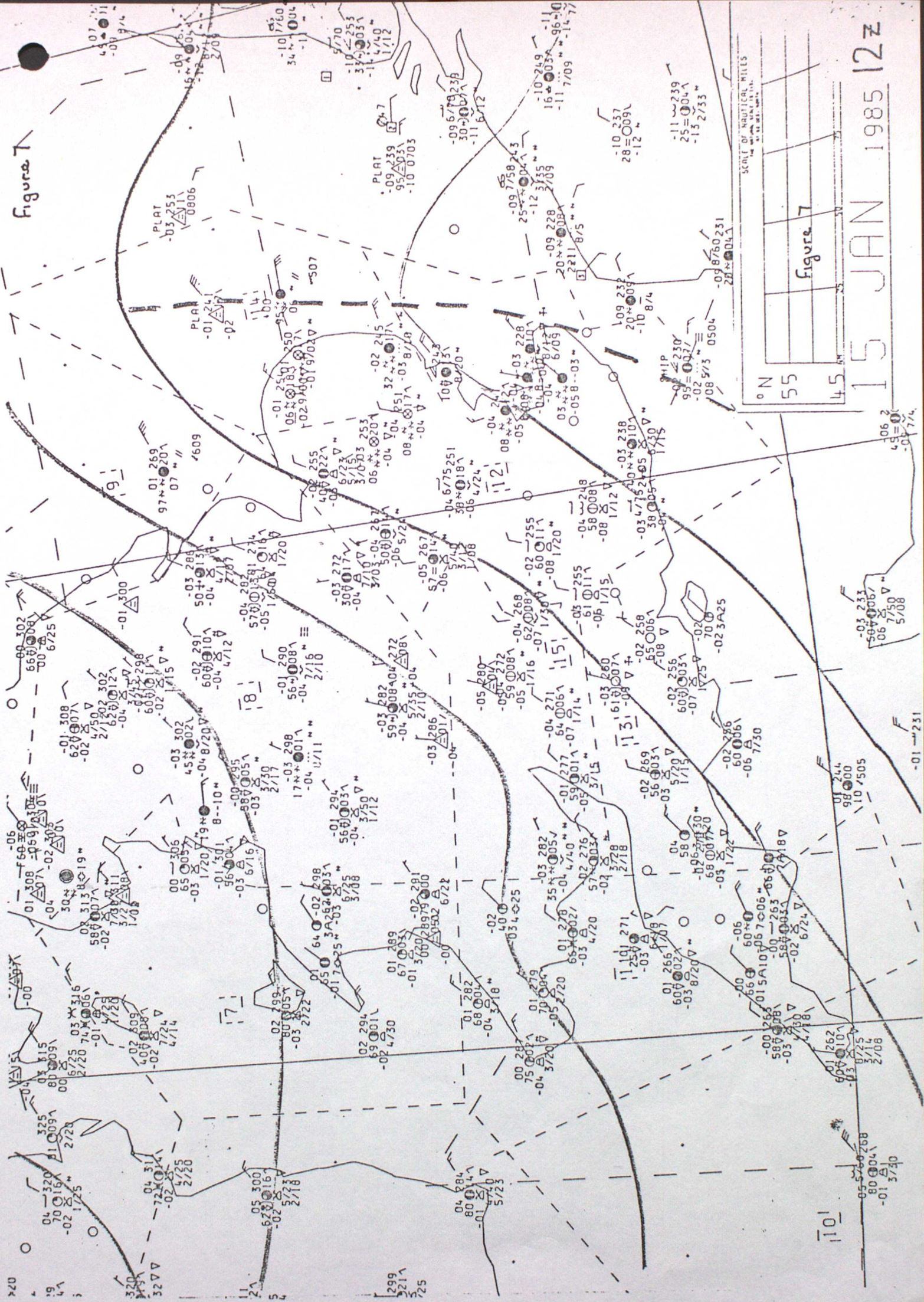
15 JAN 1995 AT 06Z

DATA CUT-OFF TIME: 0600Z

Figure 6

15 JAN 1985 AT 06Z

Figure 7



SCALE OF NAUTICAL MILES
1" = 10 MILES

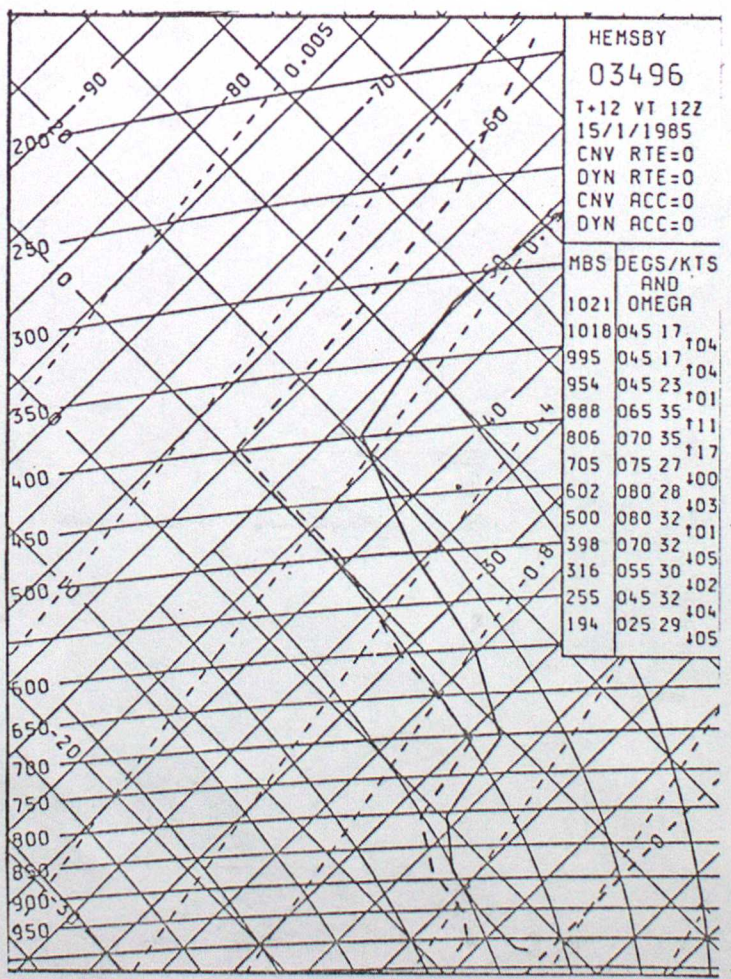
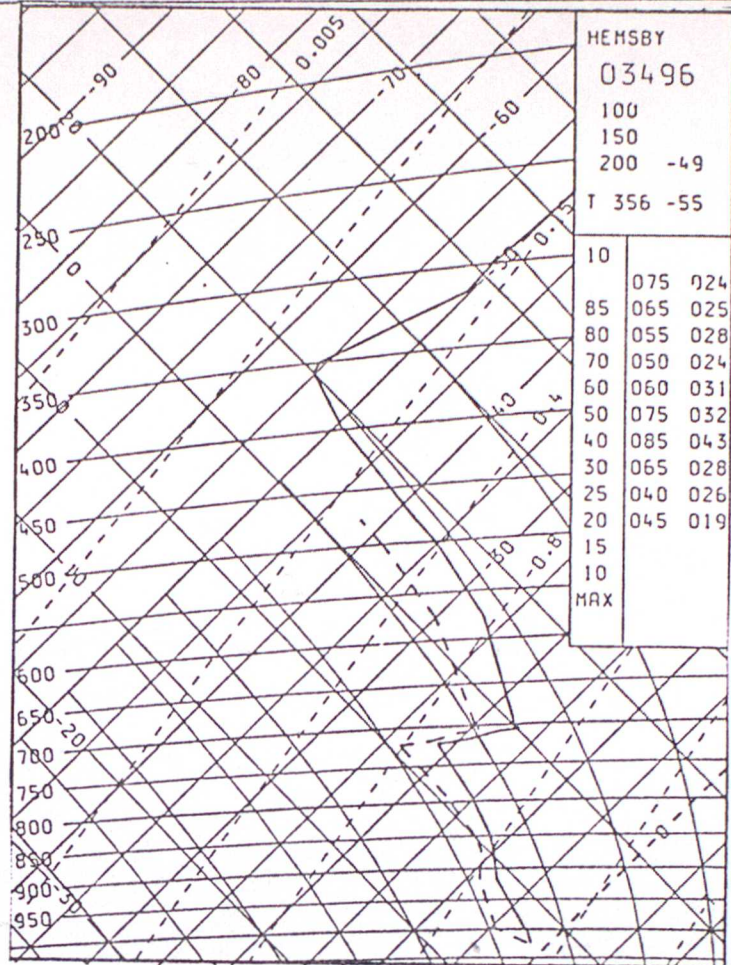
Figure 7

15 JAN 1985 12Z

55
45

101

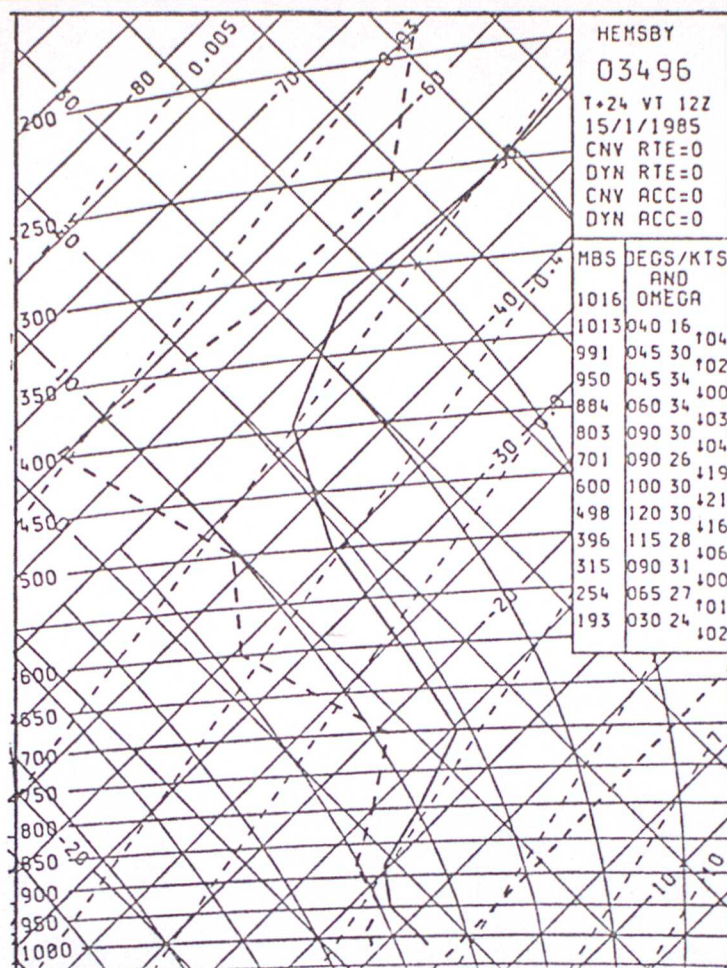
HEMSBY UPPER AIR ASCENT 12z 15/01/85



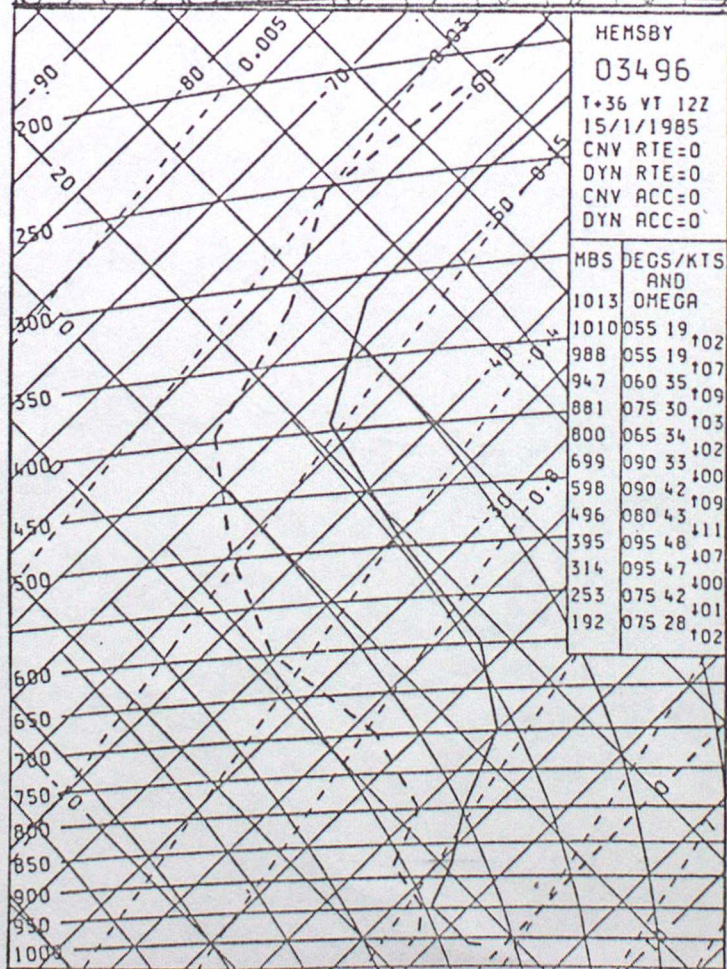
T+12

Figure 8

FINE-MESH FORECAST UPPER AIR ASCENTS FOR HEMSBY 12z 15/01/85



T+24



T+36

Figure 8

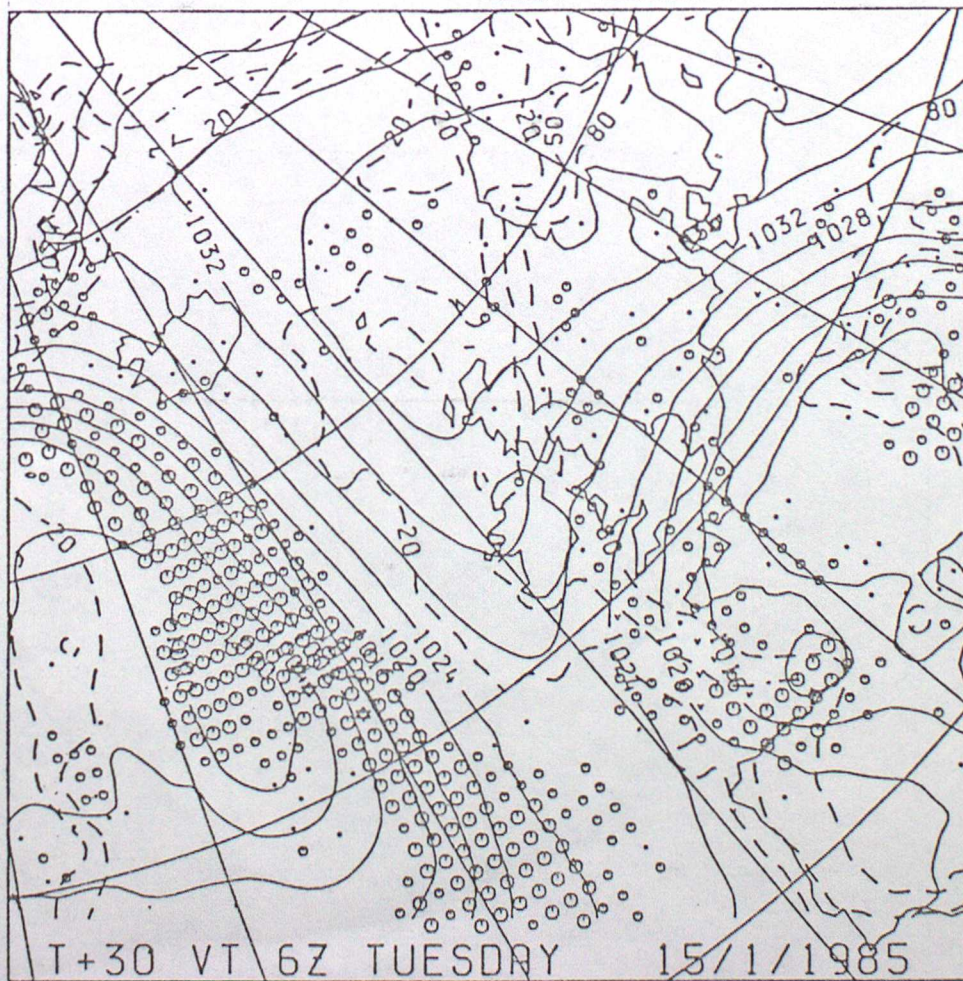
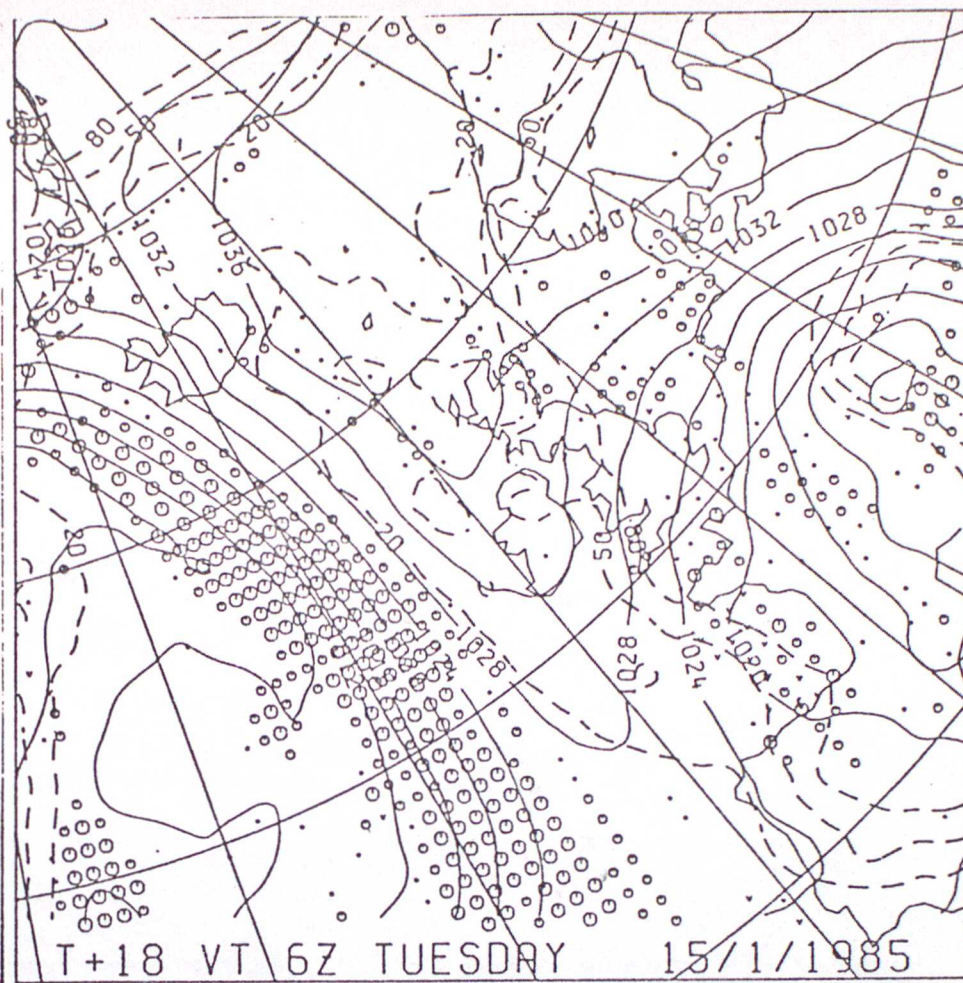


Figure 9