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Met O 11 Technical Note No 6

Assessment of HERMES soundings processed using the New Cloud-Clearing Scheme

by
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1. Introduction

High resolution satellite temperature soundings from the TIROS operational vertical sounder are now available at the Met Office for use in the operational data assimilation scheme. These data are received via Lasham and are processed locally by the Met O 19 HERMES computing system.

Two case studies (Adams 1984, Bell and Hammon 1985) have shown that the HERMES temperature profiles were likely to have errors that would degrade the analysis produced by the operational data assimilation. Various developments are in hand to improve the processing of the HERMES satellite sounding data. This paper assesses HERMES data produced with the New Cloud-Clearing Scheme (NCCS; Watts 1985, Eyre and Watts 1987). This scheme has been developed by Met O 19 with the capability of producing a greater number of temperature soundings, particularly in areas that are contaminated by cloud. A subsequent innovation is the use of forecast data for first-guess temperature profiles in the retrieval process, as opposed to using climatological first-guess profiles. It is intended to investigate this scheme (known as TOVFFG) once the new cloud-clearing scheme has been accepted.

Concurrently with this work by Met O 19, Met O 11 is developing a new operational data assimilation scheme (the analysis correction, or AC, scheme - Lorenc 1984). It is planned that techniques for assimilating the HERMES data should be developed further within the AC scheme (eg. Adams 1986, Lorenc et al 1985).

In this study NCCS and the former cloud-clearing scheme (which we will refer to as 'LASS') are compared by running pairs of fine-mesh analysis and forecast experiments. Each experiment consists of two (3-hour) cycles of data assimilation (using the current operational analysis scheme), followed by a thirty hour forecast. This procedure was adopted in preference to the operational method (using four assimilation cycles) because only NOAA-9 soundings were available, and the observations times were within 0-6Z (or 12-18Z); if four cycles had been run (starting from 0Z or 12Z) the effect of the HERMES data would have been diluted by subsequent observations. The three initial times for the case studies were 0Z 27th January, 12Z 10th February and 0Z 12th February 1987. These cases were chosen by Met O 19 to be representative of the data that would be available operationally.

2. HERMES data

The HERMES system receives radiances measured by the TIROS Operational Vertical Sounder (TOVS), which are converted to brightness temperature measurements. Atmospheric temperature profiles are constructed from these brightness temperature data via a statistical inversion scheme. However the inversion process assumes that the brightness temperatures have been measured for a field of view (FOV) that is free of cloud. Consequently an important part of any retrieval process is the cloud-clearing scheme.

In the LASS scheme the MSU channel 2 data is used to compare with the HIRS data to check for cloud. For partly cloudy FOVs the N* method is used to derive clear column data from HIRS data for an adjacent pair of FOVs. If the FOVs are too cloudy for the N* method, soundings can be derived from the MSU data alone, although the errors will be larger. The first part of the new cloud-clearing scheme is analogous (but not identical) to the former scheme. However NCCS includes a subsequent step (the 'sequential estimator' step) in which information is filtered so that the resulting sounding at a particular FOV takes into account data from the surrounding area, weighted according to the estimated errors.

The resolution of the HIRS data is 40 km at nadir. With the LASS cloud-clearing scheme the maximum resolution of HERMES data is half this (because pairs of FOVs are used for cloud-clearing). NCCS is capable of producing data at the full HIRS resolution. In this study the LASS data was used at the maximum resolution, but the NCCS was on a 3x3 grid (relative to the original HIRS resolution); as a result the two schemes gave a similar number of soundings (see Table 1). The data distribution obtained is indicated by Figs 1 and 2, which show the 250 mb observations for the 3Z and 6Z assimilations on 27th January, using the two cloud-clearing schemes.

The HERMES soundings are passed to the analysis scheme as sets of temperature data at standard pressure levels (1000, 850,... 50, 30 mb). In the current experiments (as in operational use) the 1000 mb level is not used. When used operationally, HERMES data are omitted over land (when the ground elevation is over 5m); in these experiments the data is used except where the ground elevation is greater than 1000m. These experiments also used HERMES data from the edge of each swath, which was omitted when used operationally.

3. The case studies

As mentioned above, Met O 19 have provided NCCS data for three cases - 27th January, 10th February and 12th February. The times of each pass and the number of soundings available are shown in Table 1. The equivalent data for the LASS cloud-clearing scheme were restored from the Met O 19 tape archive of HERMES data.

a. Synoptic differences

In this section we shall describe the synoptic situation in each of the three case studies, and the differences made to the analyses and forecasts by changing the cloud-clearing scheme. The figures in this section are mostly in a similar 'four up' format: the first two maps (a and b) show the results for the NCCS and LASS experiments respectively; differences are given on the third map (c); the fourth map (d) shows either the NCCS data distribution (to indicate the position of the satellite passes used in the analyses) or the verifying operational analyses (to compare with forecast fields).

For the first case the initial analysis (6Z 27/1/87) represents a blocked situation in the eastern N. Atlantic. The sea level charts (Fig 3a,b) show an anticyclone in the vicinity of Iceland, with a ridge extending across the British Isles towards Greece, and a depression off the W coast of Spain; the block is also very clear at 500 and 250 mb (Figs 4a, 5a). To the west, the surface chart shows a weak ridge in mid-Atlantic and a developing low-pressure system near Newfoundland. To the north, there is an area of low pressure near the tip of Greenland, and, to the east of the main anticyclone, there is a complex low pressure system over Scandinavia. During the forecast period (Fig 6) the anticyclone that was centred over Iceland shifts towards Britain, while the low to the west of Spain remains stationary and gradually fills. The depression in the western Atlantic progresses somewhat further east, eroding the weak mid-Atlantic ridge.

The differences between the two experiments are not large enough to alter the over-all synoptic patterns. The sea-level difference map (Fig 3c) shows that the NCCS analysis deepens the Scandinavian low, and weakens the ridge which extends across Britain. The map also shows that NCCS has a lower surface pressure in the Denmark Straits and also over a strip further south in mid-Atlantic; this line approximately coincides with the western limit of the HERMES data (Fig 3d), indicating that there may be a problem associated with high zenith angles. Comparing the differences with satellite images (taken from the same passes), there is a tendency for the positive NCCS-LASS differences to be correlated with areas where cloud cover is less, or where clouds are convective in nature, for instance in the northerly flow to the NE of Iceland. At 500 mb (Fig 4c) a similar pattern can be seen with opposite sign. (The cloudy areas are also indicated by a low density of soundings derived using the LASS cloud-clearing scheme - see Fig 1). Apart from this instance, 500 mb differences do not seem to be related in general to surface pressure differences. The differences at 250 mb (Fig 5c) resemble those at 500 mb, but are larger in magnitude. They clearly show that significant, mainly negative, differences are associated with the western-most satellite pass, particularly towards the edge of the swath. (Data from the other passes have only been used in the 3Z analysis; their effect will have been diluted by any land-based observations used in the 6Z analysis.) The 250 mb height fields are quite noisy, particularly in the LASS experiment (Fig 5b), in which there are unrealistic multiple high and low centres; this may be due to edge of swath data problems. The forecast difference maps at T+30 (Fig 6c) shows that NCCS has higher surface pressure over the ocean to the west of Britain, while pressure is less over Europe and over the Atlantic from Norway across to Iceland and Greenland. (A similar pattern of differences is found at T+18). The effect of these differences is to shift the anticyclone centred near Britain somewhat to the north in LASS, relative to NCCS. The verifying operational analysis is in Fig 6d; it is evident that the LASS forecast gives a better position to the anticyclone, although the two experiments are more similar to one another than either is to the analysis. The analysis has a ridge extending north-eastwards from the anticyclone; this is also better represented in the LASS experiment. The low at 45N, 15W is quite well forecast in both experiments. Both also treat the low to the south of Greenland in a similar way, though it should be slightly shallower and further to the east.

Maps showing the forecast rainfall rates at T+6, T+18 and T+30 are shown in Fig 7. The top line of the figure (parts a, b and c) show the forecast charts from the NCCS experiment and the bottom line (parts d, e and f) show the results from the LASS experiment. For verification purposes, the observed rainfall areas are also indicated by hand-drawn symbols. The observed rainfall is taken from reports from the Synoptic Data Bank and is available for the

British Isles and the near continent only. There are only minor differences between the NCCS and LASS forecasts, few of which can be verified by comparison with observations. The most noticeable difference is that the observations show a much more extensive and persistent area of showers over Scotland and the North Sea than is given by either of the forecasts. The area of rainfall in the south-western approaches appears to be quite well simulated. At T+18 the rain extends into Cornwall; this is better represented in the LASS experiment. This ties in with the higher PMSL values over Brest in the NCCS run.

Since the second two cases are only a day and a half apart, the synoptic situations will be described together. At the analysis time for the second case (18Z 10th February; Fig 8a,b) there is a complex low pressure area near the British Isles, with three separate centres - in the North Sea, near Rockall and just off Cape Finisterre. From the 500 mb flow (Fig 9) it can be seen that the southern depression is associated with an cut-off low in the height field, while the other two are linked with a complex upper trough. To the west there is a surface ridge stretching from Greenland towards the Azores high, with an anticyclonic centre at 50N, 30W. Further west there is an intense depression centred near Nova Scotia. In the forecast the two lows near the UK rotate cyclonicly around one another, so that by 0Z on 12th February (Fig 11), one centre is over southern Norway and the other over the Irish Sea. The third centre shifts south-eastwards across Spain to the western Mediterranean. On the western side of the Atlantic the other main depression deepens further and a marked trough associated with it develops in mid-Atlantic. There are some significant synoptic differences between the forecast fields and the corresponding operational sea level pressure analysis. The developing low in mid-Atlantic is more marked in the analysis and there is a further distinct centre to the south of Newfoundland (just off the edge of the maps). The depressions near western Europe are not very well forecast; the depression that was forecast to be near southern Norway has in fact shifted further north, though there is a minor centre near the forecast position. There is an indistinct low pressure centre analysed in the Bristol Channel which may correspond to the forecast low in the Irish Sea, but there is also a slightly deeper low over Belgium.

The T+30 forecast time for the second case is just six hours before the analysis time for the third case and the analyses for the experiments (Fig 13a, b) are very similar to Fig 11d. During the third forecast (Fig 16a), the depression in mid-Atlantic extends its influence across to the south of Ireland, so there is a sequence of several low pressure centres strung out across the Atlantic. Across the UK there is a weak ridge, and to the east the main low pressure centres are over Denmark and off the coast of Norway (this centre is virtually stationary throughout the forecast).

At the analysis time for the second case the differences between the two experiments are as shown on Fig 8c. The LASS analysis has a slightly deeper low to the north of Ireland, and a less intense anticyclone in mid-Atlantic, otherwise the differences are are small. In this case the negative NCCS-LASS differences are correlated with lower cloud cover (the opposite way round to the first case - possibly related to the different time of day). At both 500 and 250 mb the geopotential heights in the NCCS analysis are slightly lower than with LASS over most of the map area (Fig 9c ,10c), probably associated with the areas covered by satellite data (Figs 9d, 10d). The differences are quite large considering that the HERMES data was only used in the 15Z analysis (Table 1). During the period of the forecast (Fig 11) the sea level pressure differences evolve such that NCCS is more negative south of Greenland and east of Iceland (corresponding to slightly deeper troughs in these two positions). Further south there is an increase in pressure in the northern North Sea and across Norway, implying a shift in the depression off Norway (though this shift was a lot smaller than the forecast error).

The rainfall forecasts for the two experiments are compared in Fig 12, which has the same layout as Fig 7. The evolution of the rainfall areas over N. Scotland and S. Norway is quite well captured in both experiments. The rainfall area over SW England is too extensive in the NCCS experiment at T+6, and is better represented in the LASS run; through the forecast this extends to the north-east and remains too extensive in the NCCS experiment, but better in LASS.

For the third case (6Z 12/2/87) the sea level pressure difference maps (Fig 13c) show that NCCS has a lower surface pressure over the UK and surrounding areas, increased pressure in mid-Atlantic and decreases further west, most noticeably near Greenland. Once again these differences are quite small and are correlated with the cloud cover. The differences at sea level and also at upper levels (Figs 14c, 15c) again clearly reflect the satellite data coverage, especially over the Atlantic. As in previous cases, the NCCS analysis tends to have lower geopotential heights over the area covered by the HERMES data, though there are some positive differences near the edge of the data swath (again indicating possible inconsistencies at high zenith angles). The sea level differences are rather larger at the end of the forecast period (Fig 16c). The centre of the depression is again further north in the NCCS experiment, agreeing well with the verifying analysis (Fig 16d), except that the central value is too high. The negative differences in the Atlantic near 55N, 20W show that the trough extends slightly further east in the NCCS experiment compared to LASS. The low to the south of Ireland is well represented in both forecasts.

The rainfall maps for the third case are given in Fig 17. At T+6 the observations show showers around the Scottish coast that do not occur in the forecasts, and an area of rain over E. England that is also not captured in the experiments. At later stages in the forecasts, both experiments correctly show an area of showers over Scotland, but the rain associated with the depression to the south of Ireland does not extend far enough north-east.

b. Verification against radiosondes

The results have been assessed by comparing the analyses and the forecasts with radiosonde observations. Figs 18, 19 and 20 show the mean and RMS temperature differences for the three cases. In all three cases both the LASS and NCCS data gave broadly similar statistical results.

In the first case (27th January) both the LASS and NCCS show biases of about 0.5K in the upper troposphere (with the analyses cold relative to the radiosonde observations); above 200 mb the bias is in the opposite sense. The RMS differences are largest (about 2.0K) in the top layer (0-99mb), and a minimum in mid-troposphere. Through most of the profile the LASS analysis agrees better with the observations than does the NCCS analysis. Through the forecast period the differences grow, until at T+18 there is a cold bias of nearly 2K near the tropopause in the NCCS analyses, and a warm bias in the layer above. For the T+30 forecast, the differences at upper levels are less, but in mid-troposphere they are greater. The RMS differences are large near the tropopause as well as in the top layer. All four profiles show that the verification scores are generally worse with NCCS data than LASS.

In the second case (10th February; Fig 19) the verification scores for NCCS and LASS are very similar at analysis time; the analyses have a warm bias relative to the sondes at every layer below 300 mb, and a cold bias above. The maximium RMS values again occur in the top layer. As the forecast proceeds, the pattern of warm bias at lower levels (generally below 200 mb) and cold bias above grows more marked. The RMS diffences increase, particularly at low levels and near the tropopause. Comparing the two cloud-clearing schemes, the results show that in this case NCCS gives a better fit to the observations in the upper troposphere, with little to choose between the experiments at other levels.

The third case (12th February; Fig 20) gives similar vertical profiles of mean and RMS differences to those in the second case, both at analysis time and during the forecast period (possibly because of the closeness of the two dates). Once again the results tend to favour NCCS over LASS, although the differences are marginal. To summarise, the first case gives generally worse results with NCCS, but the other two cases give slightly better results.

Because of the poor results for the 27th January case, a parallel experiment was also run without any HERMES data, in order to find whether the results were better without HERMES data. Figure 21 compares the NCCS run with the no-HERMES experiment (designated CTRL). This shows clearly that the analyses agree better with the sondes when HERMES data is omitted. The forecast profiles also show a better fit for CTRL; the improvement is particularly noticeable at T+18. For the second case (Fig 22), the differences are much smaller, and throughout the forecast HERMES has a positive impact in the troposphere (except at the highest levels). Thus, in this case, HERMES data (using NCCS) has a positive impact on the analyses, at least in the troposphere. A no-HERMES experiment has not been run for the 12th February case.

c. Data rejected at the analysis step

The data assimilation scheme consists of two basic stages - the analysis and the assimilation. The first stage comprises the calculation of weights to interpolate observations to model grid points; this incorporates a step to quality control the data. A measure of the quality of observational data can be obtained from the proportion of the data that fail this automatic quality control step. Table 2 gives the percentage of HERMES data used at each analysis time which fail this check. (Note that some of the upper levels are grouped together, since these results are calculated over 100 mb layers.)

These figures show that, in the second and third cases, most of the HERMES retrievals passed the quality control check; in virtually all instances less than 10% of the data were rejected, and in many cases the proportion was less than 1%. As might be expected, the highest rejection rates occurred at the highest and lowest levels, and also near the tropopause. In contrast, the results for the 27th January case show very high rejection rates, of around 50% at the top levels. In this study HERMES data predominates at these levels, so the buddychecking step in the analysis will have had minimal impact (HERMES data is not buddy-checked against other HERMES data); thus the high rejection rates come about because the data are more than 5° different from the first-guess. It is likely that a large amount of data with significant (but smaller than 5°) biases has been used. The results for the 3Z analysis generally show more rejections than the corresponding 6Z figures; this is probably because HERMES data which is used in the 3Z analysis alters the background fields used in the 6Z analysis, so that they are closer to the HERMES data. These results confirm the results of the previous sections, in that they imply poorer quality retrievals for the 27th January case, as compared to the February. There is no obvious systematic difference between the rejection rates for NCCS and LASS retrievals.

d. Differences between HERMES data and background fields

An indication of the effect of the HERMES data on the analyses can also be obtained by comparing the temperature soundings with the background used in the relevant assimilations. This is more instructive for the first assimilation cycle, since the background fields on subsequent cycles will already be affected by the HERMES data.

Figure 23 shows the profiles of the differences for the first case for both NCCS and LASS soundings. The biases in the HERMES data are very striking, particularly for the 3Z analysis, though qualitatively similar biases are also shown in the 6Z data. In layer 3 (which in fact only includes the observations at 300 mb) both the LASS and NCCS soundings are about 3K colder than the background data, for the 3Z analysis. This large bias is probably attributable to a poor representation of the tropopause in the soundings. In layer 1 (including both the 100mb and 150 mb levels) there is a strong positive bias of about 2K. The RMS differences are typically 2K in the troposphere, peaking at layer 3 (related to the large bias), and decreasing to about 3K for the higher layers. The results from The NCCS experiment show generally greater negative bias, consistent with the poorer results for this run, as shown in the previous sub-section. The geographical distributions of observed minus background differences show that the largest negative biases tend to occur where the HERMES data at a particular level do not show a temperature maximum which is in the background field (rather than the observations showing a minimum where the background field is flat). For the 27th January case, the bias is also strongly negative at high latitudes (typically -8K at 75N and 300mb for LASS, and rather less at neighbouring levels).

Similar profiles for the February cases are given in Figs 24 and 25 (note that HERMES data were only used at 15Z for the 10/2/87 case). It is very noticeable that the profiles are similar for both cases, and at both analysis times for the 12/2/87 case. At the lowest levels the HERMES data are colder than the background, higher in the troposphere they are warmer, becoming colder again around layers 2 and 3 (near the tropopause), warmer in layer 1 and colder in layer 0. The profiles also show that the NCCS data is generally colder than LASS in the troposphere (up to layer 3) and warmer in the stratosphere. The profiles for the 10th February case show generally smaller differences than the 12th February case; this is true both of the mean and RMS differences. Comparison of the NCCS and LASS experiments shows that the NCCS observation minus background differences tend to be smaller in magnitude than the LASS values, both in the troposphere and stratosphere.

4. Conclusions

The results of this study shows that, for two of the three cases examined, the differences between HERMES data processed by the two cloud-clearing schemes does not cause significant differences in the fine-mesh analyses. The verification scores imply that the new cloud-clearing scheme is slightly better than the earlier LASS scheme. However the results for the 27th January case show a clear negative impact of the new cloud-clearing scheme, offsetting the two February cases. The subjective rainfall verification for the UK and near continental areas favours the old LASS scheme over NCCS for two of the three cases. In order to investigate that case further, the results were also compared with an experiment in which HERMES data was omitted; this showed that both the LASS and NCCS HERMES data degraded the forecast significantly. The poor quality of the HERMES retrievals for the January case is also shown by the fact that a large proportion of the data failed the analysis quality control check. Thus the poor results for this case cannot be attributed to the new cloud-clearing scheme as such (though it is concerning if HERMES data is likely to have a negative impact on the analyses and forecasts). In considering these results it should be borne in mind that the impacts shown in these studies are likely to be larger than any changes that would be seen operationally, firstly because the analysis times were chosen to maximise the effect of the HERMES data, and secondly because HERMES data were used over both land and sea, rather than just sea.

The over-all conclusion is that changing the cloud-clearing scheme is likely to have only a marginal impact on the fine-mesh analyses and forecasts. However, it also indicates further problems with the data, which means that more radical changes may have to be made to the HERMES system before soundings can be produced with satisfactory reliability.

Postscript

HERMES data processed using the new cloud-clearing scheme (NCCS) have been produced operationally by Met O 19 since 23rd June 1987. Although the data are not used in the operational analyses, their quality is being monitored by Met O 2b. Since 7th November 1987, the data have been derived using forecast first-guess profiles (TOVFFG), rather than climatological profiles.

Table 1

Satellite Pass Data

Date	Start Time	End Time	Analysis Time(s)	Ascending/ Desc'g Node	No. NCCS Retrievals	No. LASS Retrievals
27/1/87	1.23	1.32	0/3	D	569	608
	3.02	3.18	3	D	930	1064
	4.43	4.58	6	D	892	1230
10/2/87	12.07	12.18	12	A	-	-
	13.45	14.00	15	A	916	949
	15.26	15.41	15	A	809	911
12/2/87	1.51	2.03	3	D	759	972
	3.31	3.47	3	D	930	1064
	5.13	5.26	6	D	835	944

Table 2

Percentage of data failing Quality Control check

Analysis	3Z 27/1		6Z 27/1		15Z 10/2		3Z 12/2		6Z 12/2	
	NCCS	LASS	NCCS	LASS	NCCS	LASS	NCCS	LASS	NCCS	LASS
Level(s)										
850	20.0	10.0	4.1	2.0	2.3	0.7	4.3	2.0	0.1	0.6
700	6.0	0.0	0.5	0.5	2.1	0.5	0.0	0.0	0.3	0.0
500	0.4	1.3	0.2	0.8	0.8	0.2	0.0	1.5	0.1	2.4
400	10.2	9.6	6.4	4.1	0.2	0.5	0.5	0.4	0.0	0.5
300	23.5	28.8	3.7	2.3	2.8	0.6	0.0	0.9	0.4	0.0
250, 200	10.7	10.2	6.8	8.9	8.4	10.3	1.7	3.5	3.6	5.1
150, 100	22.3	15.4	5.1	5.3	1.1	1.1	0.0	0.1	0.0	0.0
70, 50, 30	47.7	43.9	53.5	54.1	10.1	8.5	4.5	4.6	4.8	2.9

References

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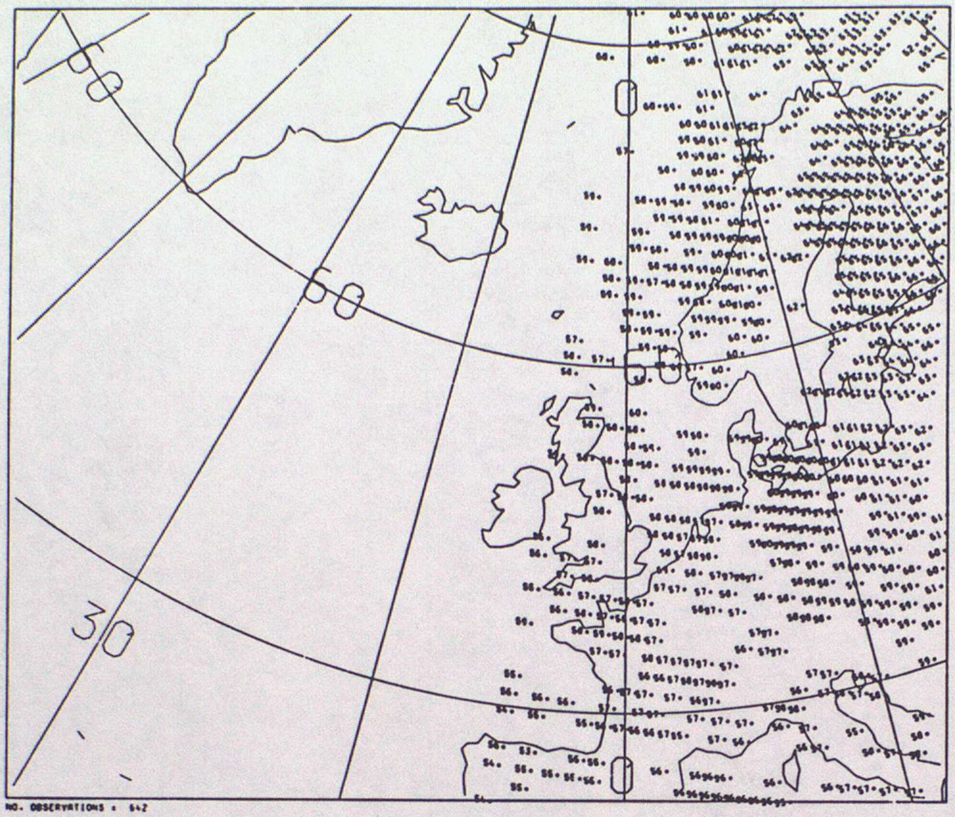
A. Lorenc 1984 The design of an analysis correction routine for assimilating observations into a forecast model. Met O 11 Working Paper 72.

A. Lorenc, W. Adams and J. Eyre 1985 The analysis of high resolution satellite data in the Met Office. Met O 11 Tech Note 212.

P.D. Watts 1985 An improved TOVS cloud clearing scheme - preliminary report. Met O 19 Branch Memorandum 81.

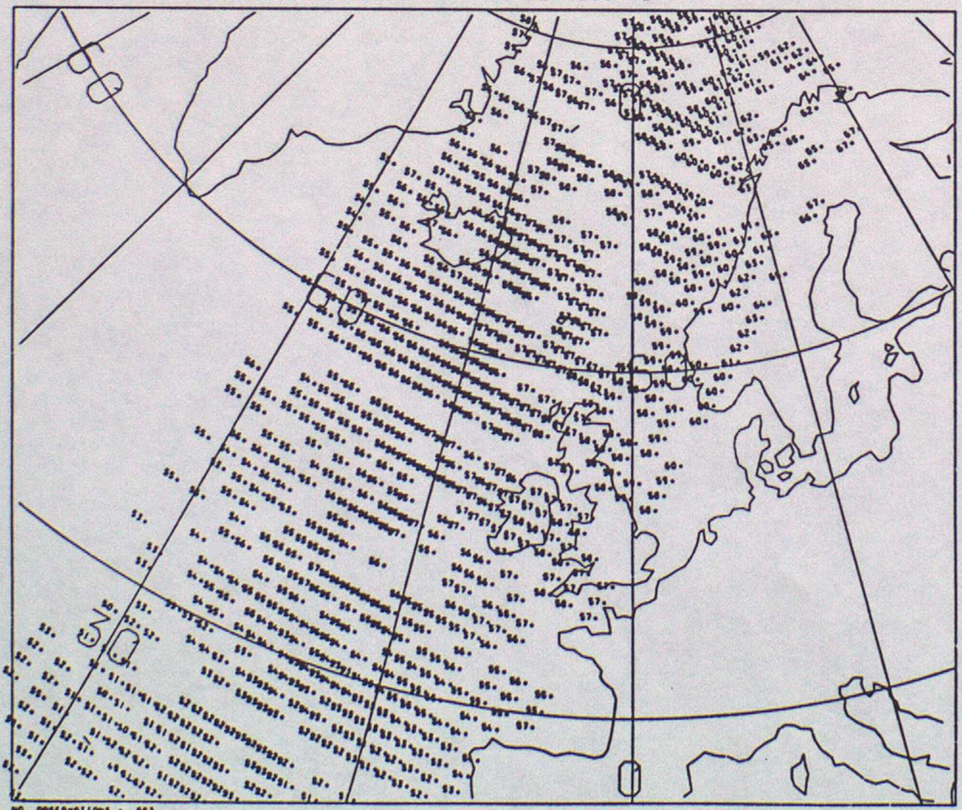
FIGURE 1

HERMES ORIGINAL LASS DATA
OBSERVATIONS FOR 03Z ON 27/01/1987   LEVEL= 250 MB



NO. OBSERVATIONS = 642

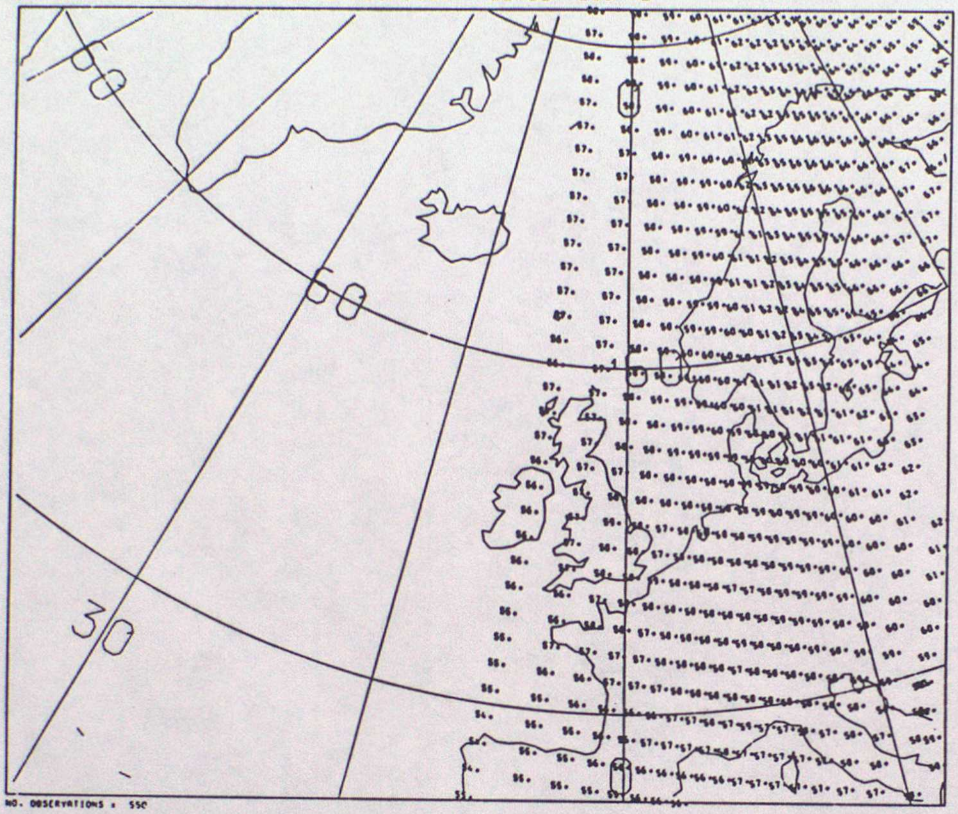
HERMES ORIGINAL LASS DATA
OBSERVATIONS FOR 06Z ON 27/01/1987   LEVEL= 250 MB



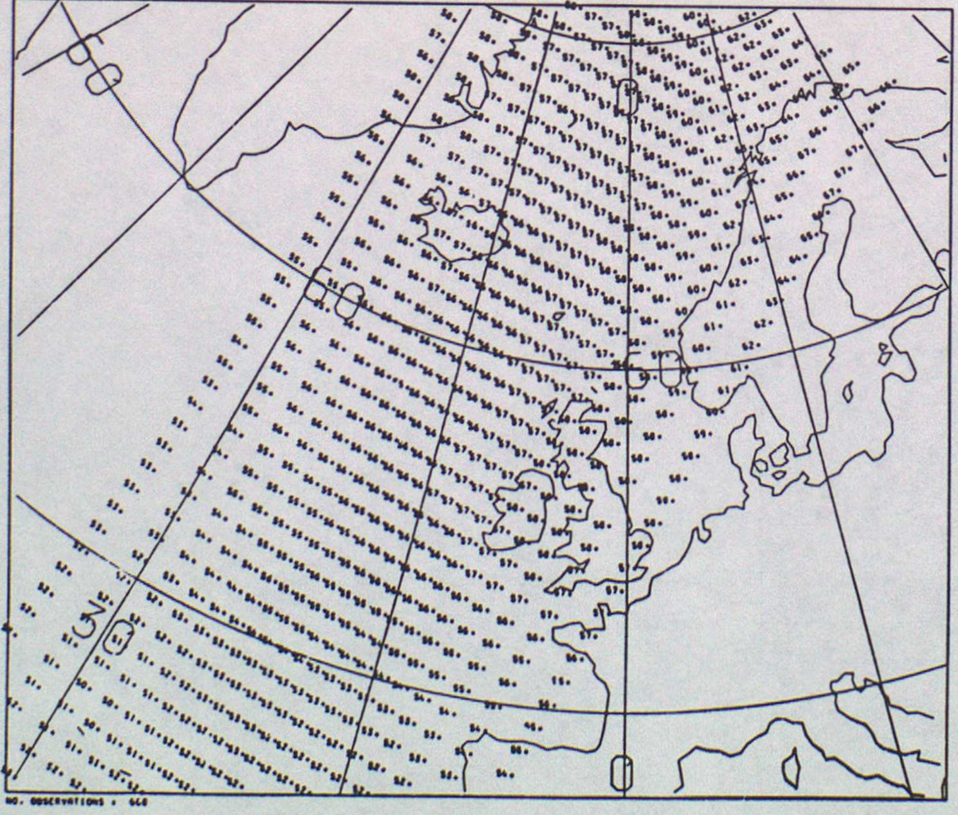
NO. OBSERVATIONS = 882

FIGURE 2

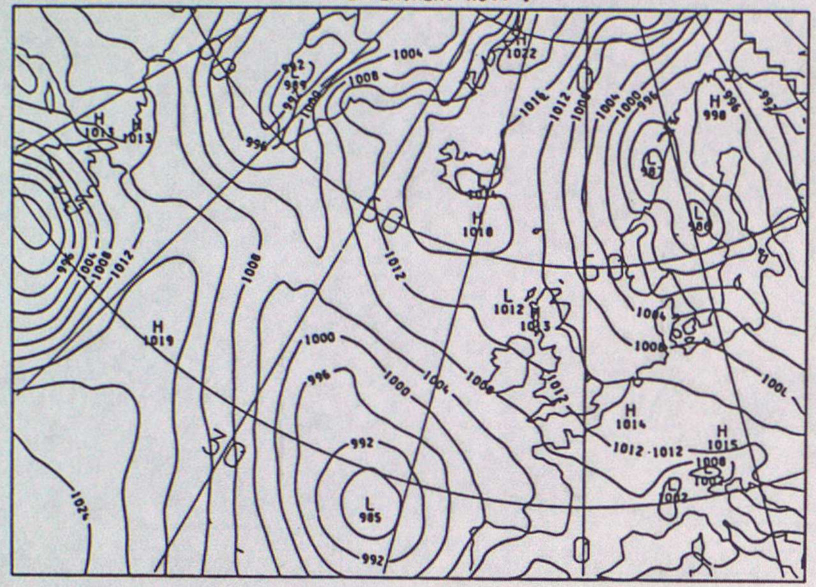
HERMES NEW CLOUD-CLEARING SCHEME DATA
OBSERVATIONS FOR 03Z ON 27/01/1987 LEVEL= 250 MB



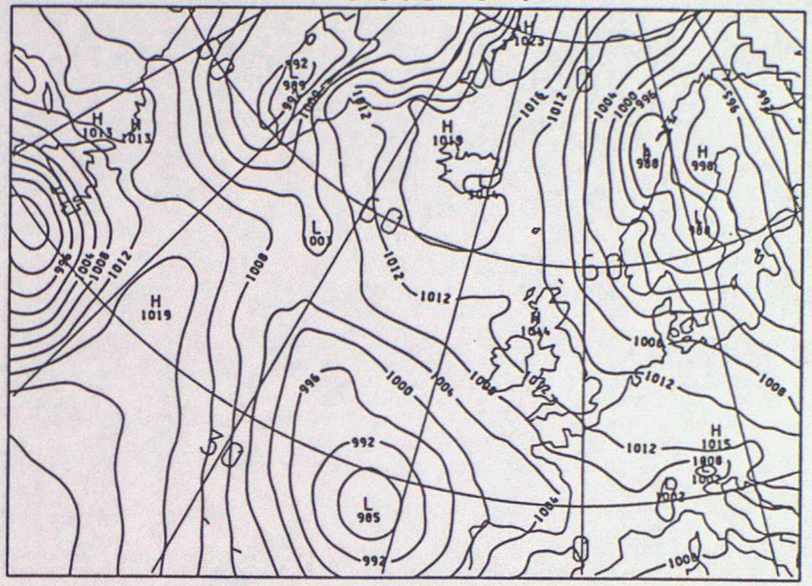
HERMES NEW CLOUD-CLEARING SCHEME DATA
OBSERVATIONS FOR 05Z ON 27/01/1987 LEVEL= 250 MB



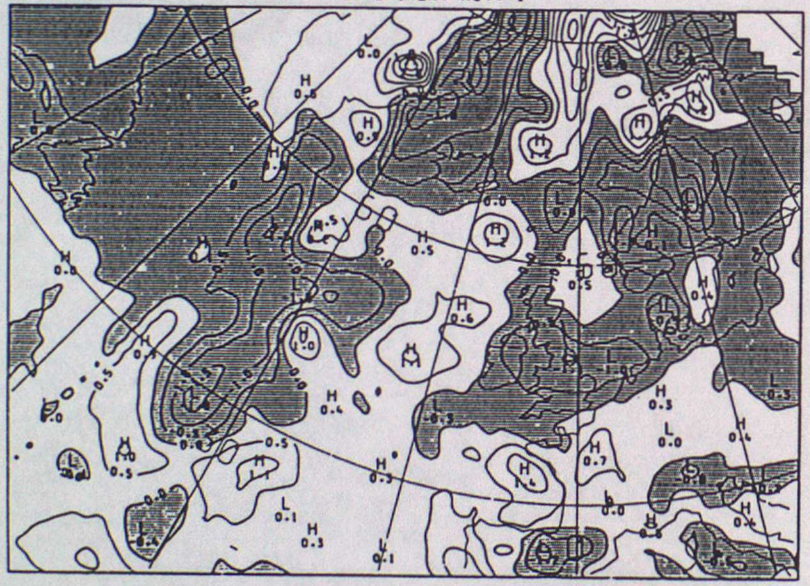
NEW CLOUD CLEARING SCHEME EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 6Z ON 27/1/1987
SEA LEVEL EXPERIMENT NO.: 1



ORIGINAL LASS EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 6Z ON 27/1/1987
SEA LEVEL EXPERIMENT NO.: 1



NCCS MINUS ORIGINAL LASS EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 6Z ON 27/1/1987
SEA LEVEL EXPERIMENT NO.: 1



HERMES NCCS DATA DISTRIBUTION
27/1/87 CASE STUDY

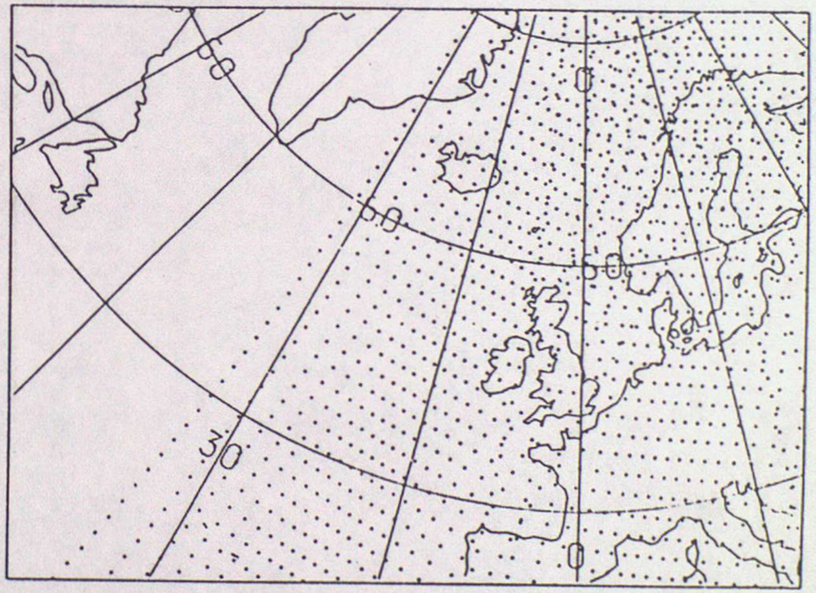
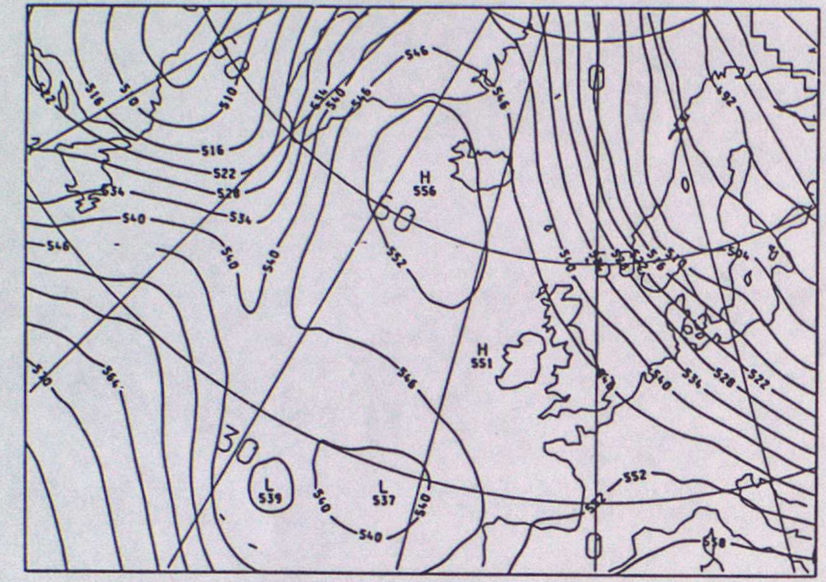
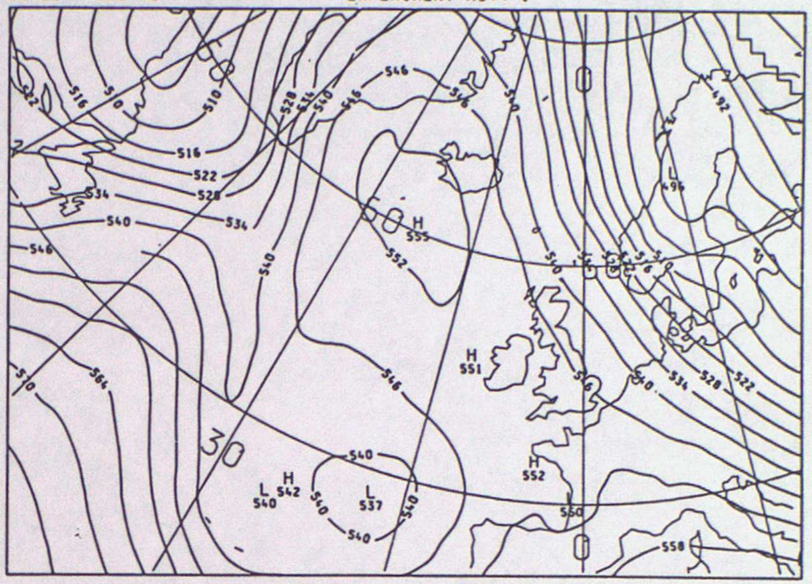


FIGURE 4

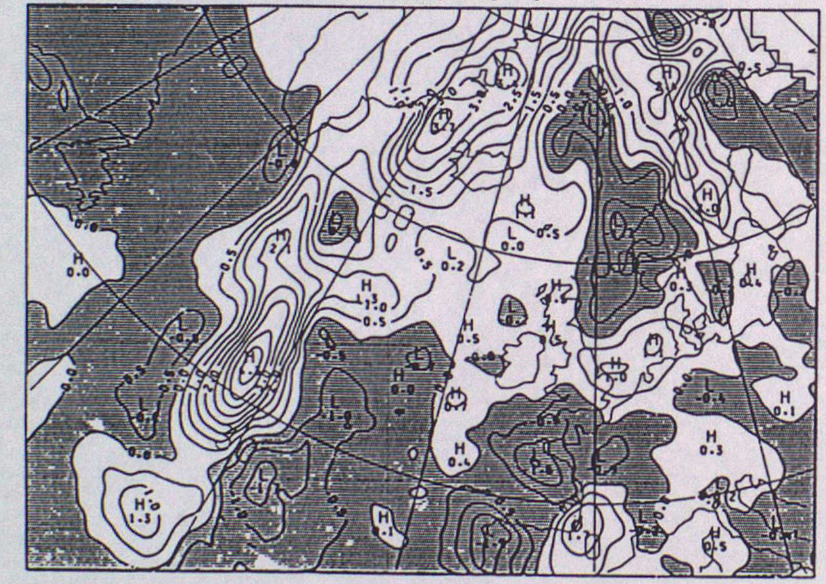
NEW CLOUD CLEARING SCHEME EXPERIMENT
500 MB HEIGHT
VALID AT 6Z ON 27/1/1987
LEVEL: 500 MB EXPERIMENT NO.: 1



ORIGINAL LASS EXPERIMENT
500 MB HEIGHT
VALID AT 6Z ON 27/1/1987
LEVEL: 500 MB EXPERIMENT NO.: 1



NCCS MINUS ORIGINAL LASS EXPERIMENT
500 MB HEIGHT
VALID AT 6Z ON 27/1/1987
LEVEL: 500 MB EXPERIMENT NO.: 1



HERMES NCCS DATA DISTRIBUTION
27/1/87 CASE STUDY

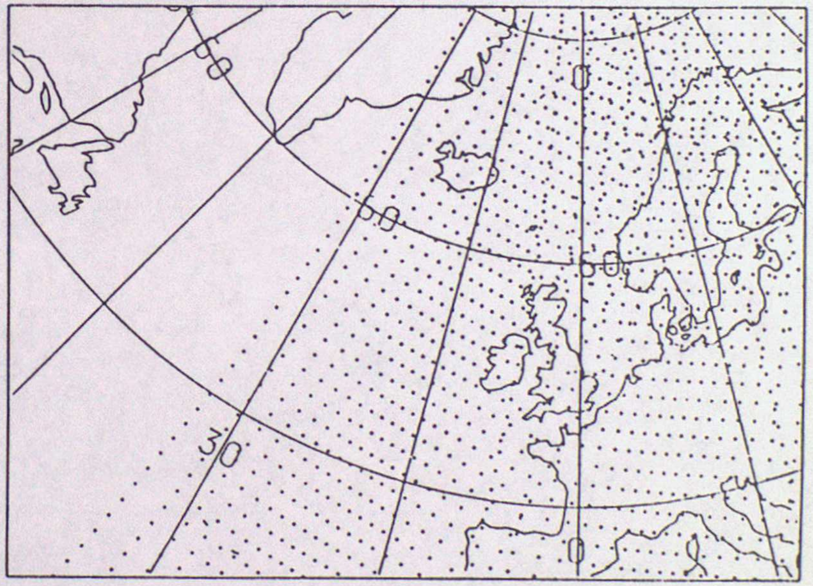
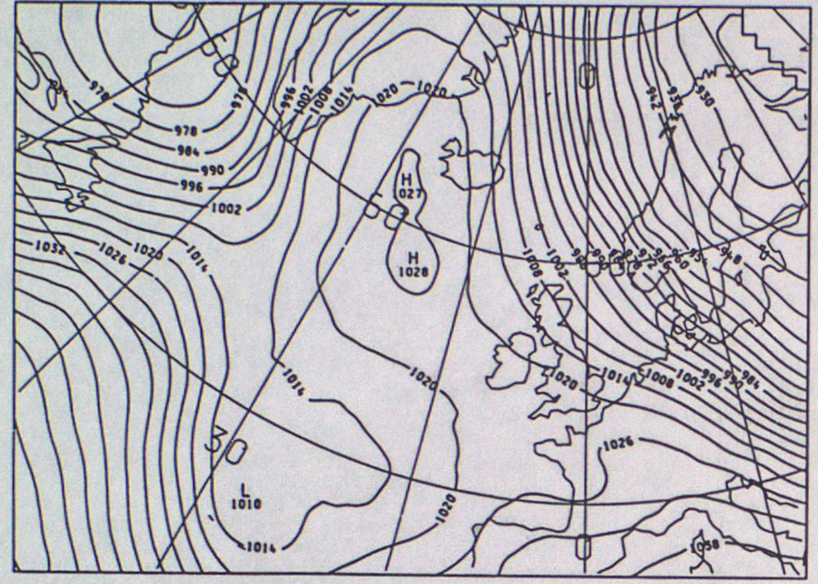
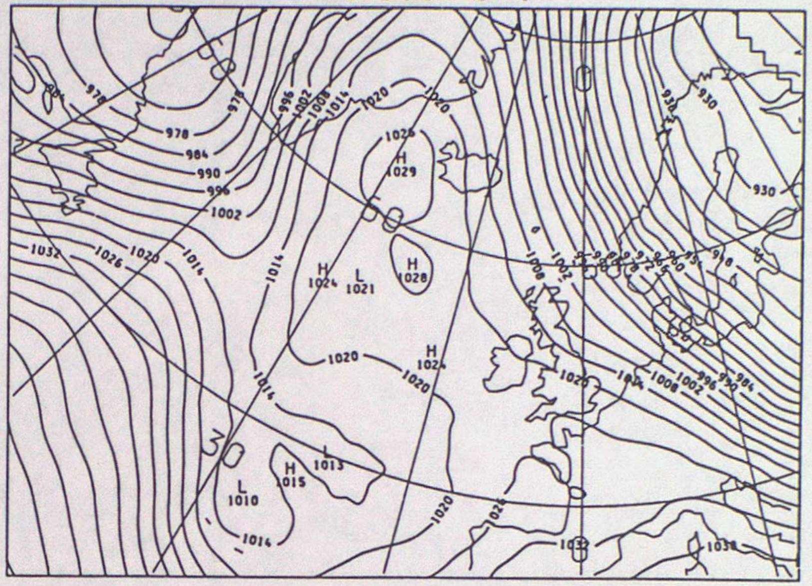


FIGURE 5

NEW CLOUD CLEARING SCHEME EXPERIMENT
250 MB HEIGHT
VALID AT 6Z ON 27/1/1987
LEVEL: 250 MB EXPERIMENT NO.: 1



ORIGINAL LASS EXPERIMENT
250 MB HEIGHT
VALID AT 6Z ON 27/1/1987
LEVEL: 250 MB EXPERIMENT NO.: 1



NCCS MINUS ORIGINAL LASS EXPERIMENT
250 MB HEIGHT
VALID AT 6Z ON 27/1/1987
LEVEL: 250 MB EXPERIMENT NO.: 1

HERMES NCCS DATA DISTRIBUTION
27/1/87 CASE STUDY

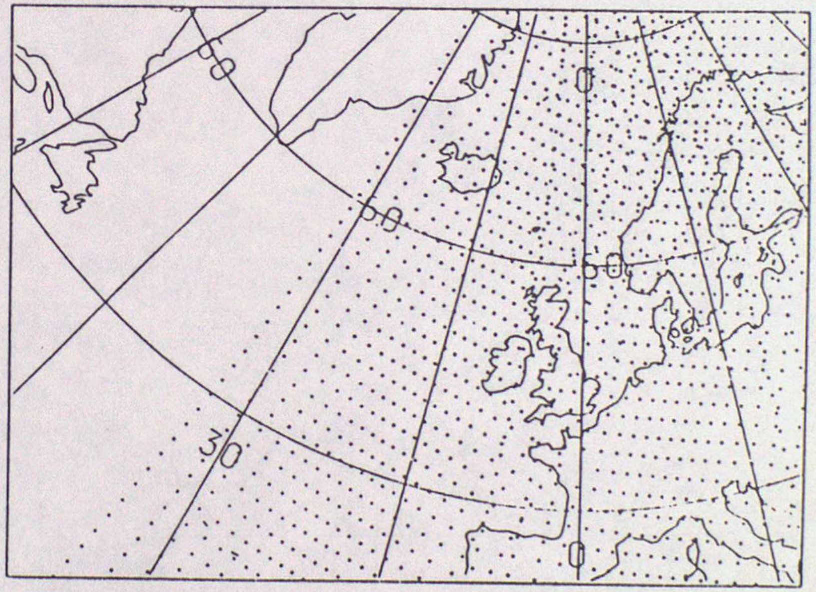
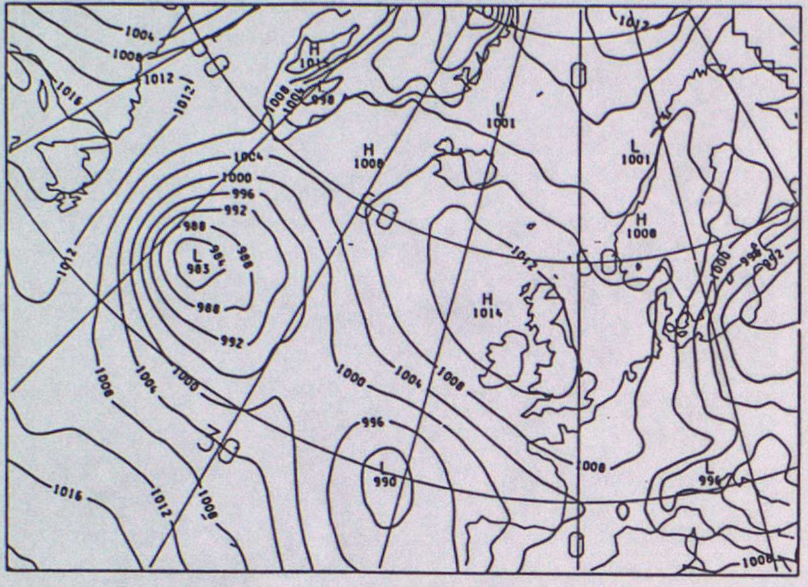
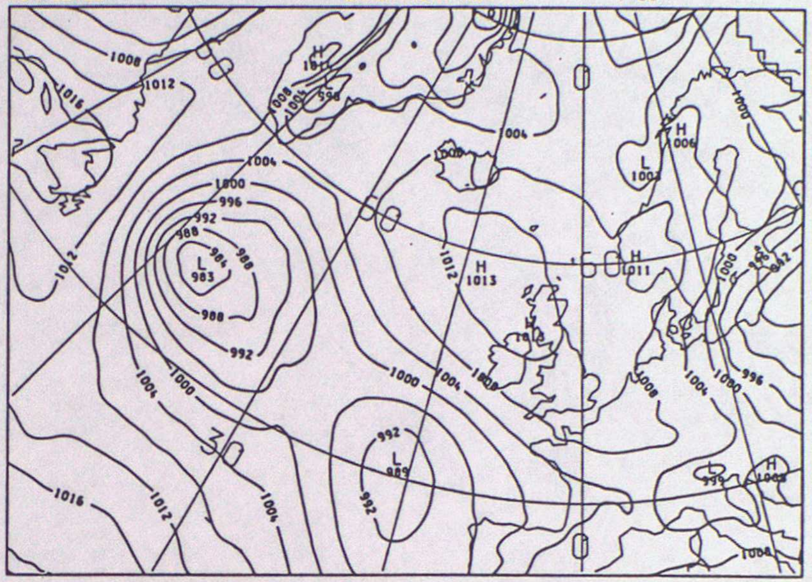


FIGURE 6

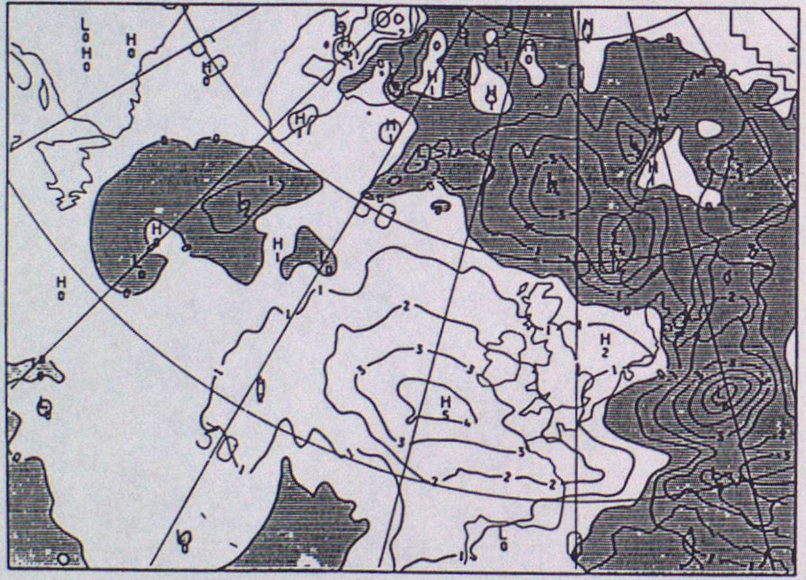
NEW CLOUD CLEARING SCHEME EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 12Z ON 28/1/1987 DATA TIME 6Z ON 27/1/1987
SEA LEVEL EXPERIMENT NO.: 1 T+30



ORIGINAL LASS EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 12Z ON 28/1/1987 DATA TIME 6Z ON 27/1/1987
SEA LEVEL EXPERIMENT NO.: 1 T+30



NCCS MINUS ORIGINAL LASS EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 12Z ON 28/1/1987 DATA TIME 6Z ON 27/1/1987
SEA LEVEL EXPERIMENT NO.: 1 T+30



VERIFYING OPERATIONAL ANALYSIS
MEAN SEA LEVEL PRESSURE
VALID AT 12Z ON 28/1/1987 DAY 28 DATA TIME 12Z ON 28/1/1987 DAY 28
SEA LEVEL

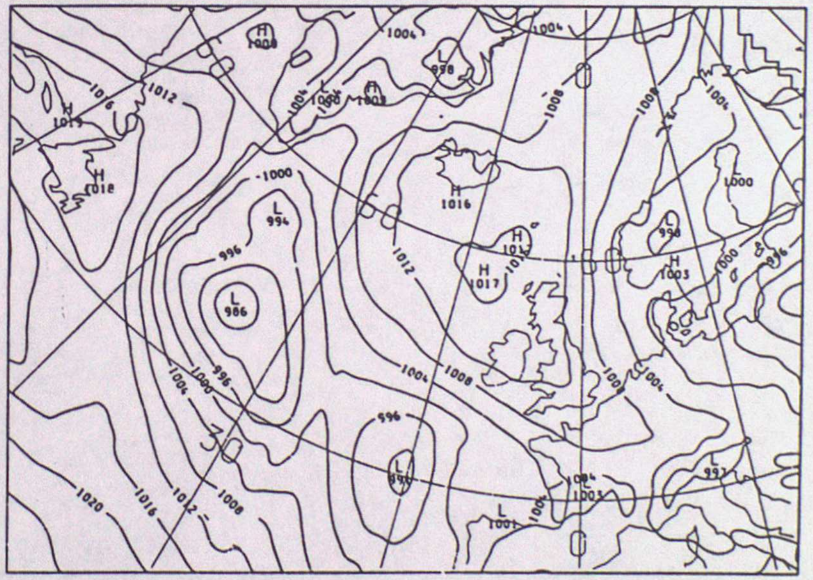


FIGURE 7

RAINFALL RATE
PRESSURE AT MSL
SNOW PROB AT MSL

DT 12Z TUESDAY 27/1/1987 FINE MESH

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

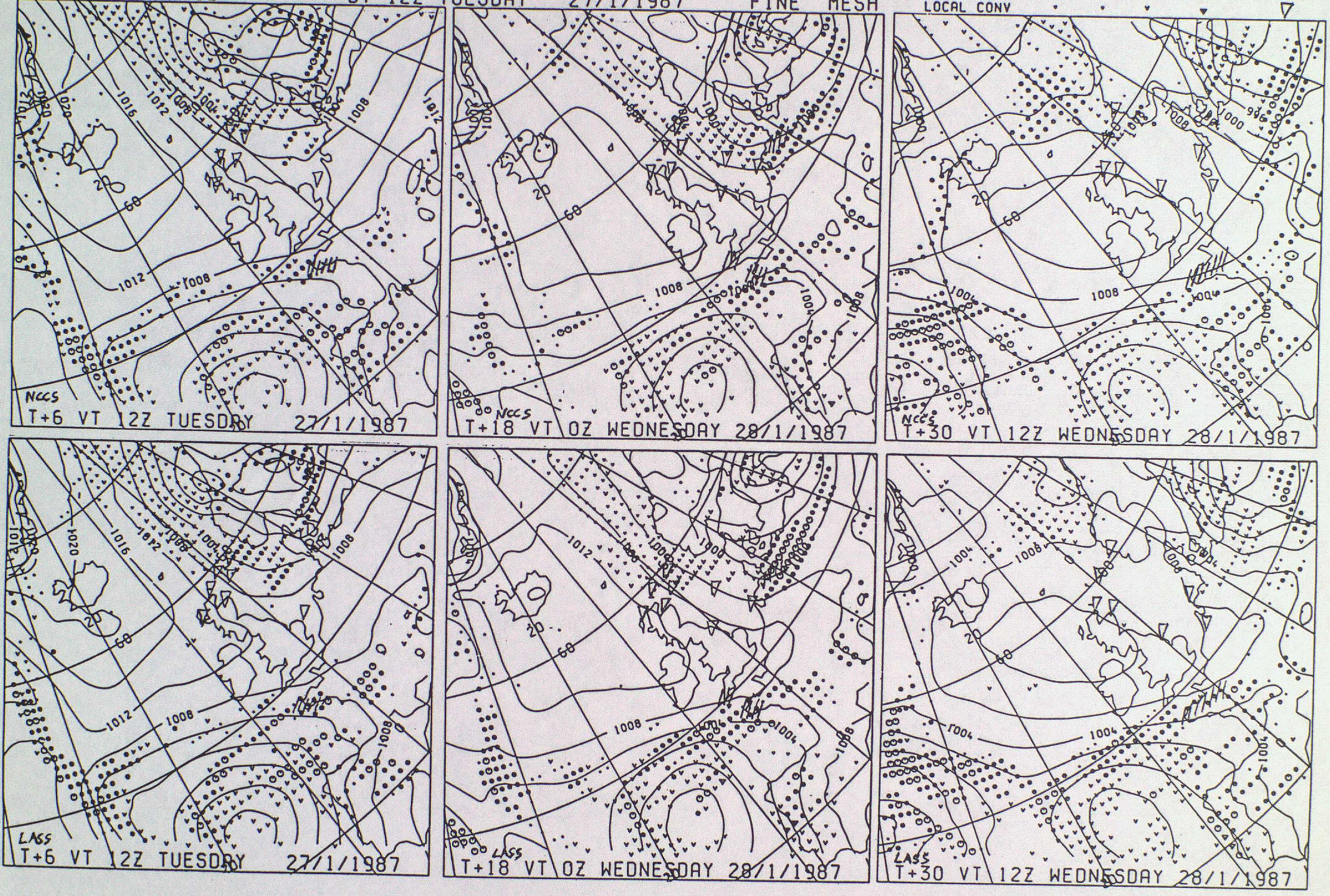
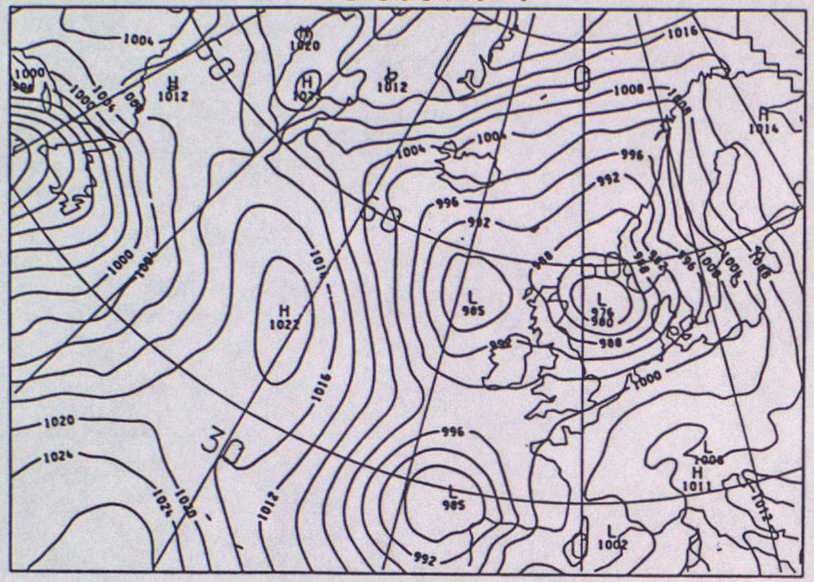
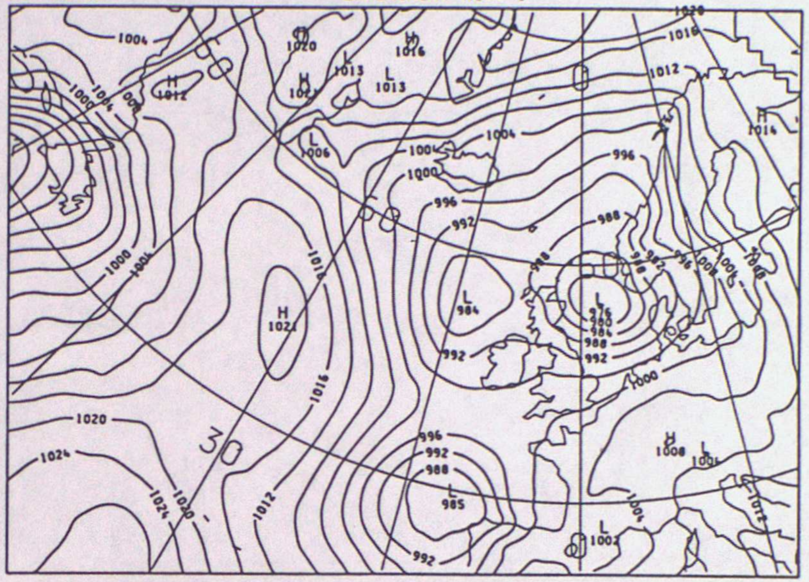


FIGURE 8

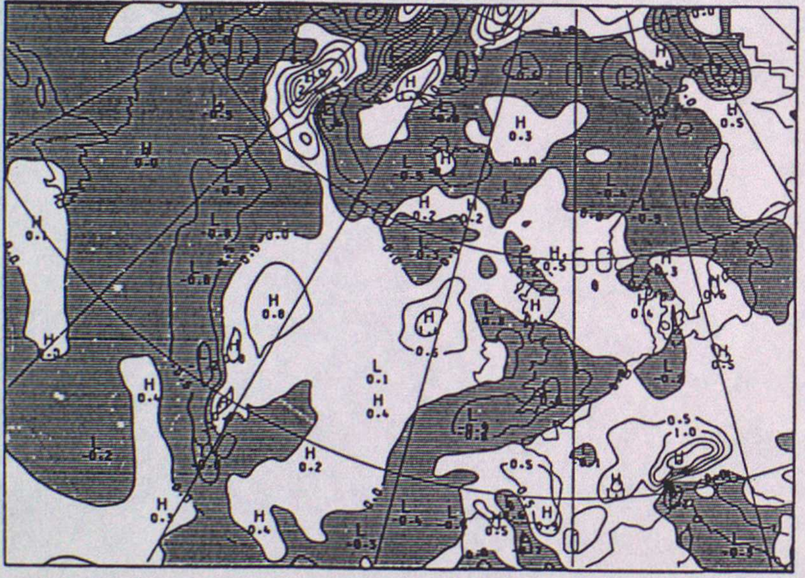
NEW CLOUD CLEARING SCHEME EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 18Z ON 10/2/1987
SEA LEVEL EXPERIMENT NO.: 1



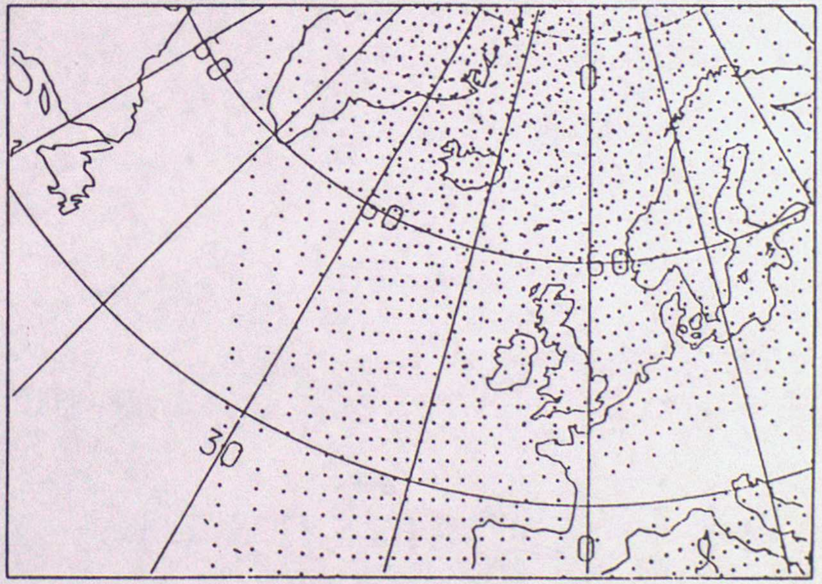
ORIGINAL LASS EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 18Z ON 10/2/1987
SEA LEVEL EXPERIMENT NO.: 1



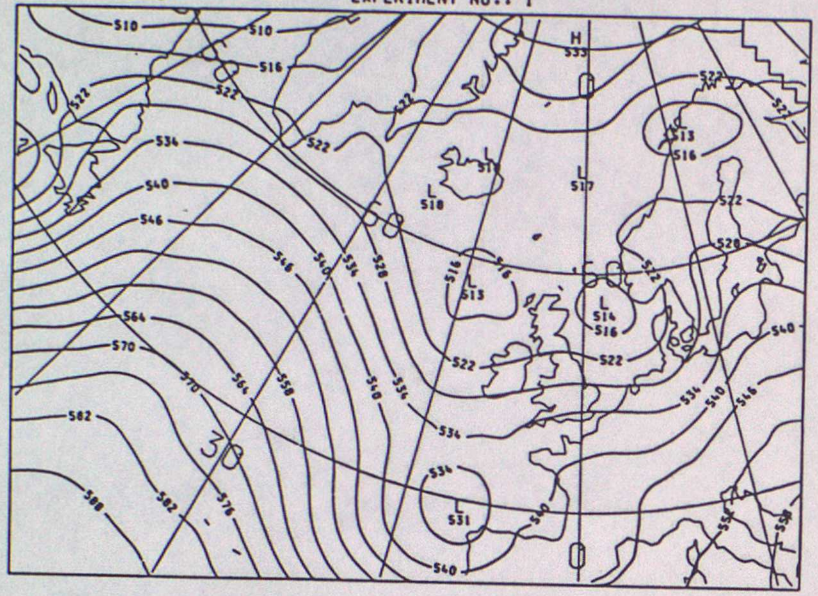
NCCS MINUS ORIGINAL LASS EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 18Z ON 10/2/1987
SEA LEVEL EXPERIMENT NO.: 1



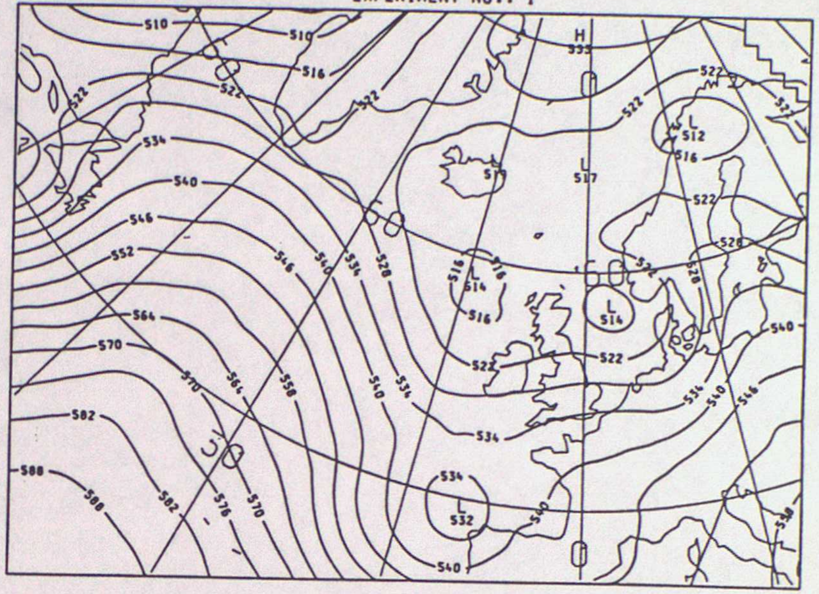
HERMES NCCS DATA DISTRIBUTION
10/2/87 CASE STUDY



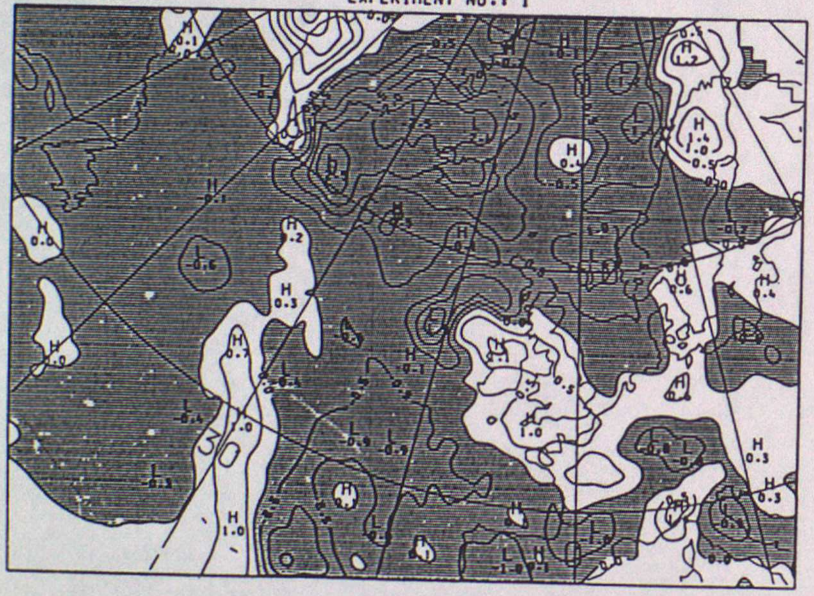
NEW CLOUD CLEARING SCHEME EXPERIMENT
500 MB HEIGHT
VALID AT 18Z ON 10/2/1987
LEVEL: 500 MB
EXPERIMENT NO.: 1



ORIGINAL LASS EXPERIMENT
500 MB HEIGHT
VALID AT 18Z ON 10/2/1987
LEVEL: 500 MB
EXPERIMENT NO.: 1



NCCS MINUS ORIGINAL LASS EXPERIMENT
500 MB HEIGHT
VALID AT 18Z ON 10/2/1987
LEVEL: 500 MB
EXPERIMENT NO.: 1



HERMES NCCS DATA DISTRIBUTION
10/2/87 CASE STUDY

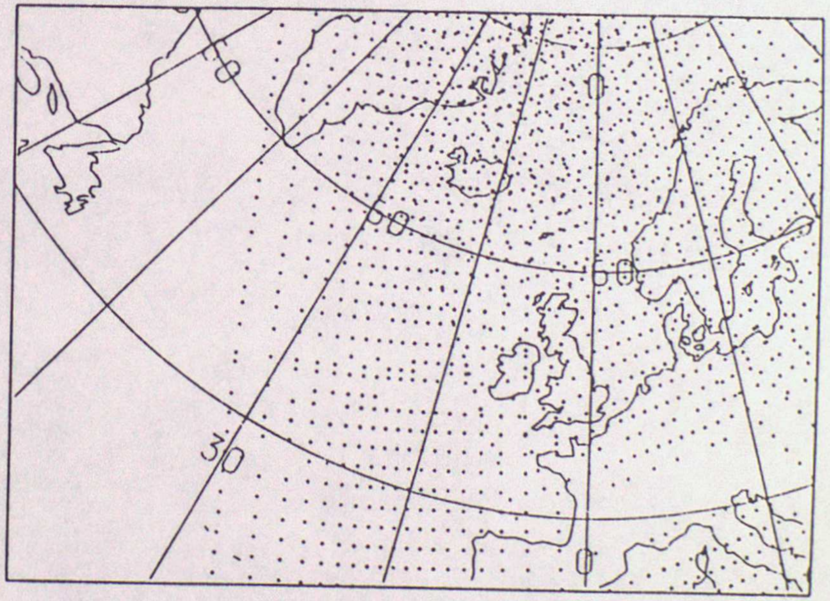
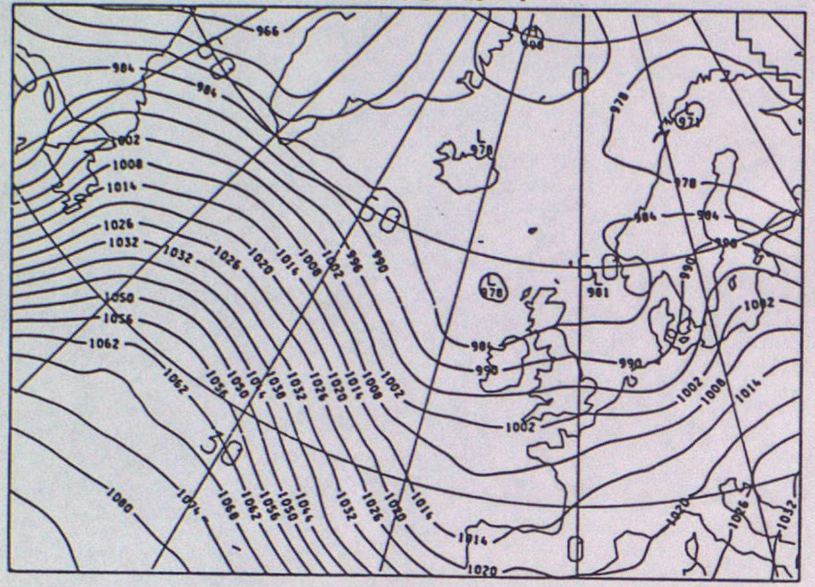
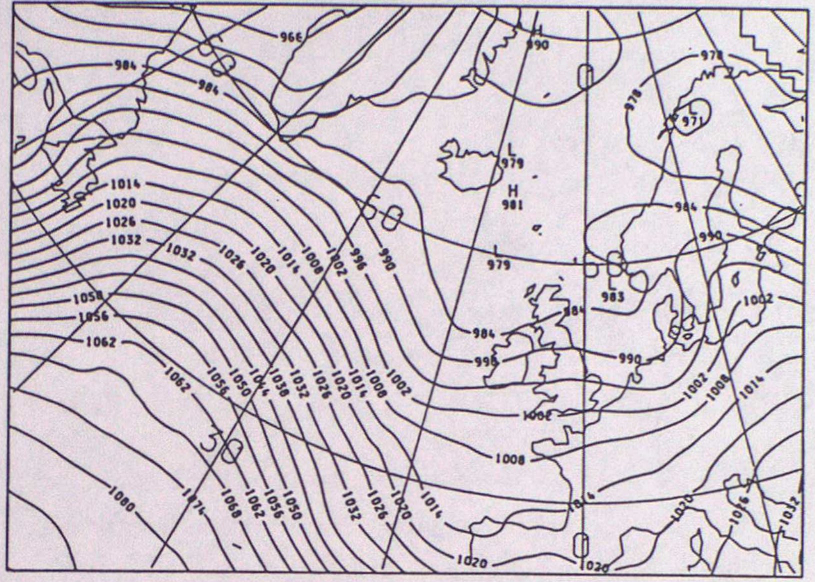


FIGURE 10

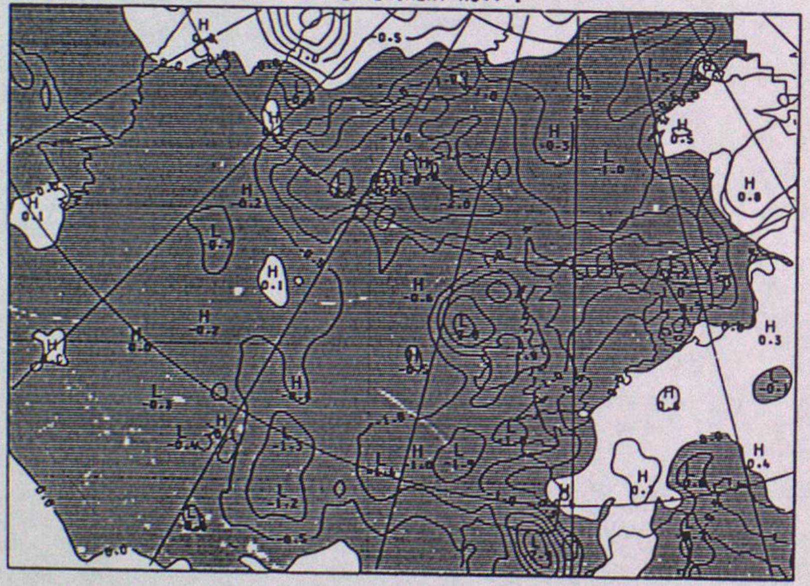
NEW CLOUD CLEARING SCHEME EXPERIMENT
250 MB HEIGHT
VALID AT 18Z ON 10/2/1987
LEVEL: 250 MB EXPERIMENT NO.: 1



ORIGINAL LASS EXPERIMENT
250 MB HEIGHT
VALID AT 18Z ON 10/2/1987
LEVEL: 250 MB EXPERIMENT NO.: 1



NCCS MINUS ORIGINAL LASS EXPERIMENT
250 MB HEIGHT
VALID AT 18Z ON 10/2/1987
LEVEL: 250 MB EXPERIMENT NO.: 1



HERMES NCCS DATA DISTRIBUTION
10/2/87 CASE STUDY

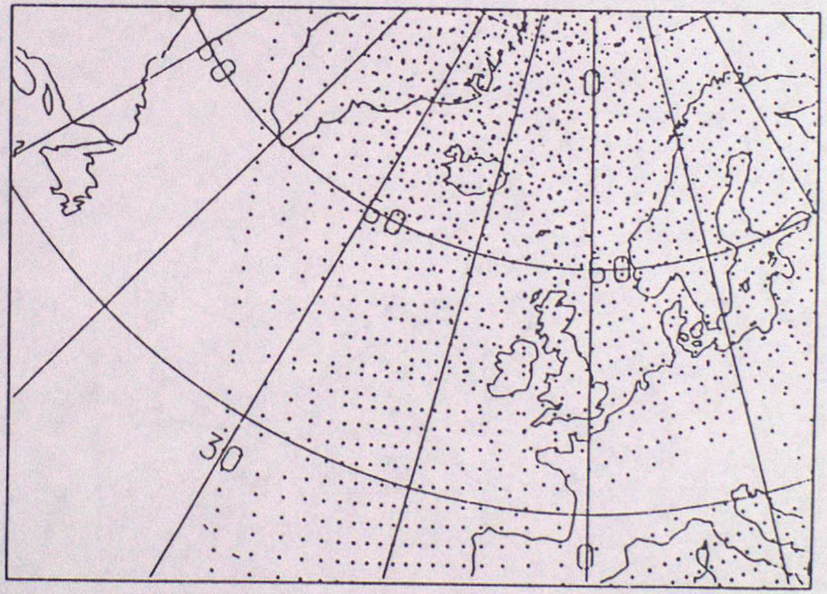
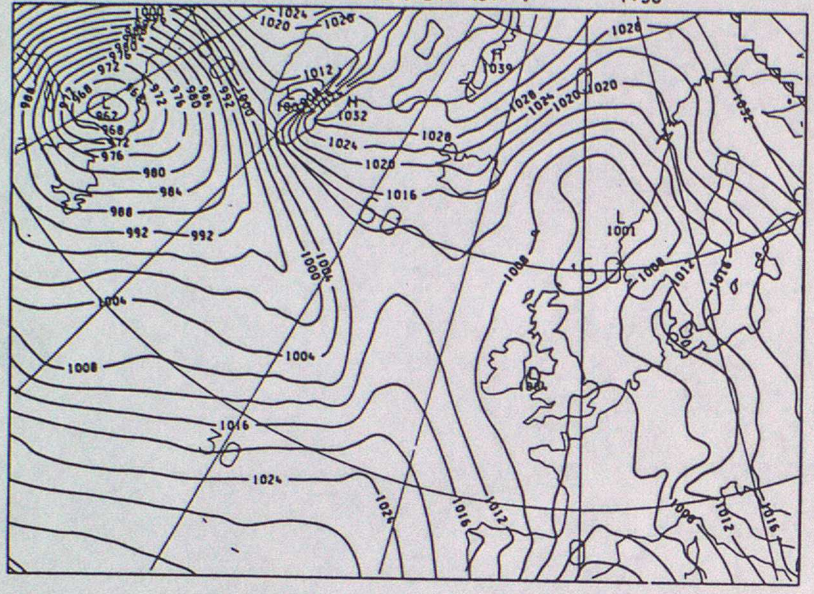
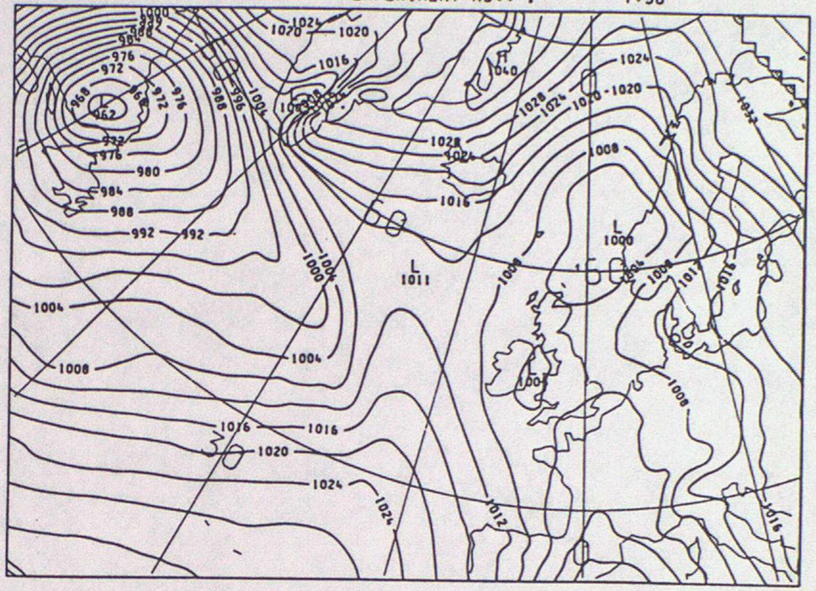


FIGURE 11

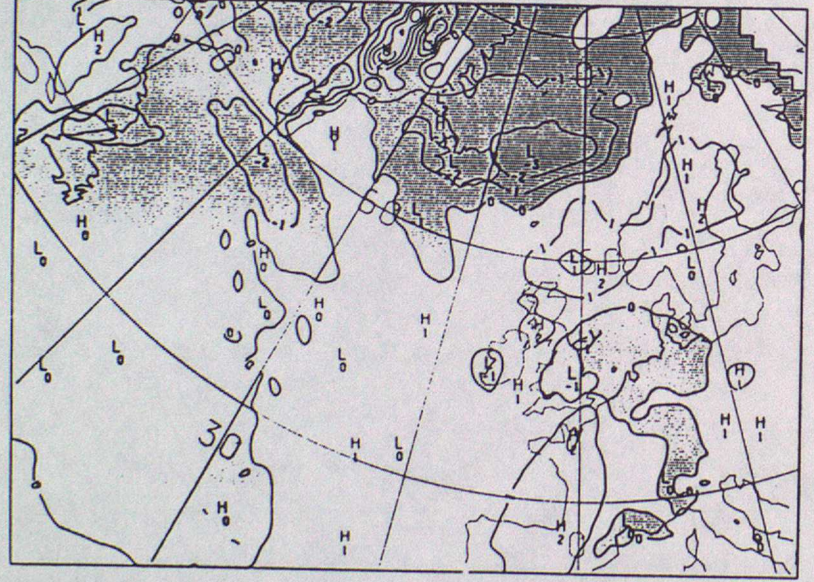
NEW CLOUD CLEARING SCHEME EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 0Z ON 12/2/1987 DATA TIME 18Z ON 10/2/1987
SEA LEVEL EXPERIMENT NO.: 1 T+30



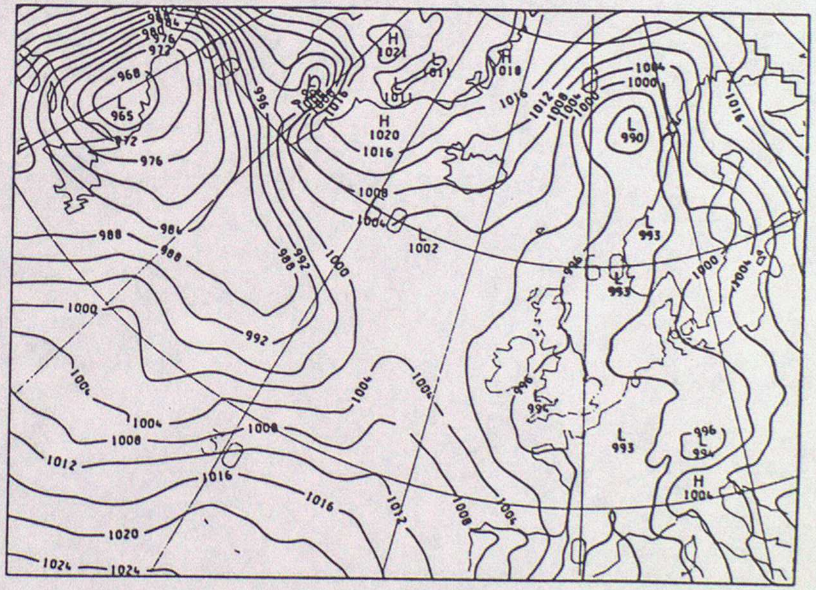
ORIGINAL LASS EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 0Z ON 12/2/1987 DATA TIME 18Z ON 10/2/1987
SEA LEVEL EXPERIMENT NO.: 1 T+30



NCCS MINUS ORIGINAL LASS EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 0Z ON 12/2/1987 DATA TIME 18Z ON 10/2/1987
SEA LEVEL EXPERIMENT NO.: 1 T+30



VERIFYING OPERATIONAL ANALYSIS
MEAN SEA LEVEL PRESSURE
VALID AT 0Z ON 12/2/1987 DAY 43 DATA TIME 0Z ON 12/2/1987 DAY 43
SEA LEVEL



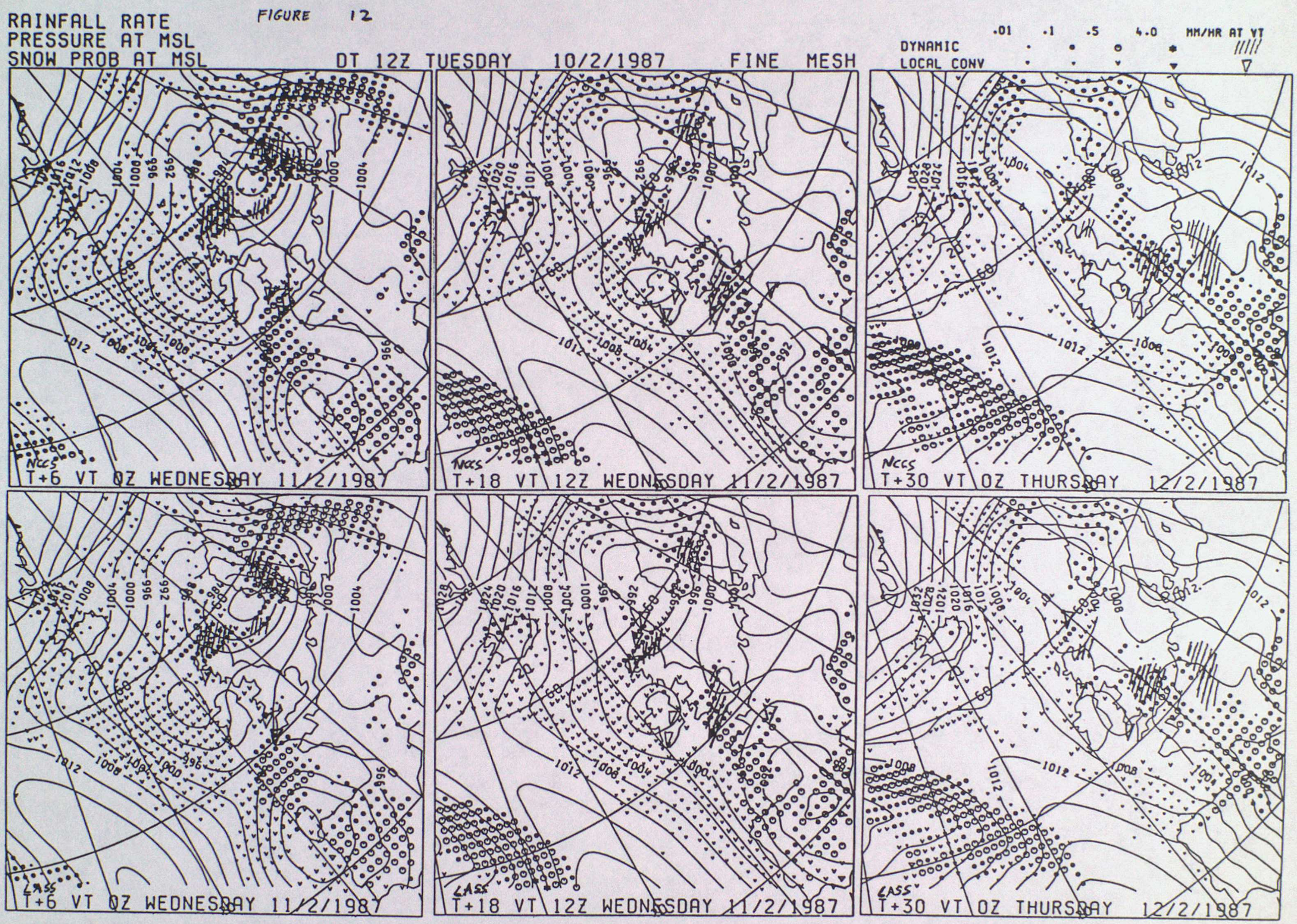
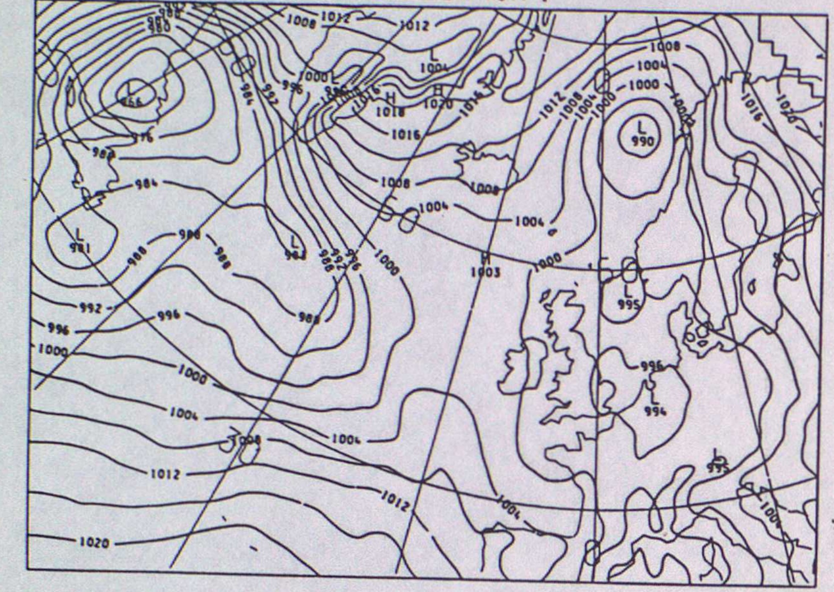


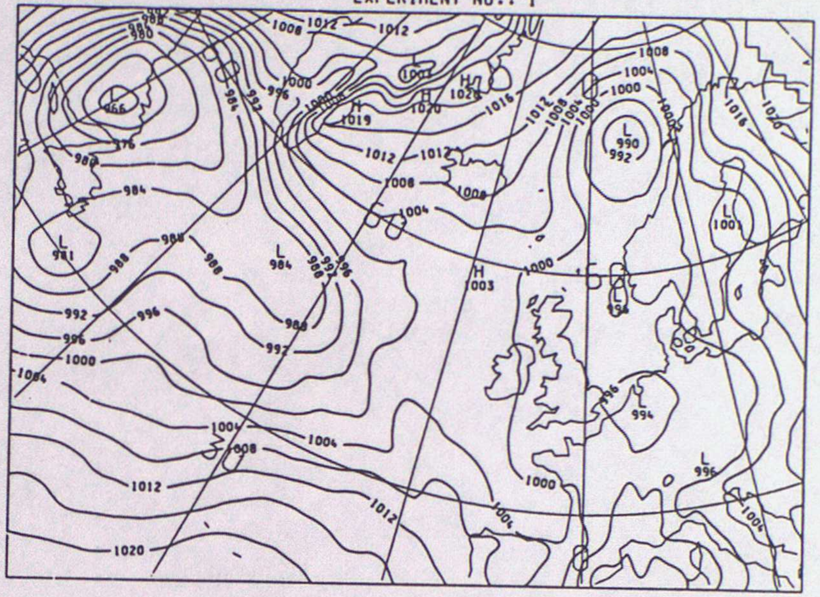
FIGURE 12
RAINFALL RATE
PRESSURE AT MSL
SNOW PROB AT MSL
DT 12Z TUESDAY 10/2/1987 FINE MESH
DYNAMIC
LOCAL CONV
.01 .1 .5 4.0 MM/HR AT VT
NCCS
T+6 VT 0Z WEDNESDAY 11/2/1987
T+18 VT 12Z WEDNESDAY 11/2/1987
T+30 VT 0Z THURSDAY 12/2/1987
LASS
T+6 VT 0Z WEDNESDAY 11/2/1987
T+18 VT 12Z WEDNESDAY 11/2/1987
T+30 VT 0Z THURSDAY 12/2/1987

FIGURE 3

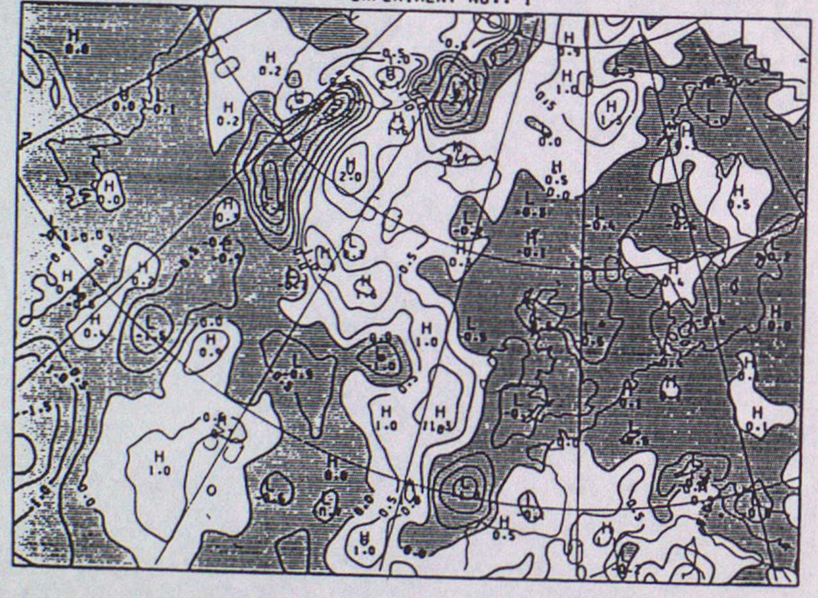
NEW CLOUD CLEARING SCHEME EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 6Z ON 12/2/1987
SEA LEVEL
EXPERIMENT NO.: 1



ORIGINAL LASS EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 6Z ON 12/2/1987
SEA LEVEL
EXPERIMENT NO.: 1



NCCS MINUS ORIGINAL LASS EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 6Z ON 12/2/1987
SEA LEVEL
EXPERIMENT NO.: 1



HERMES NCCS DATA DISTRIBUTION
12/2/87 CASE STUDY

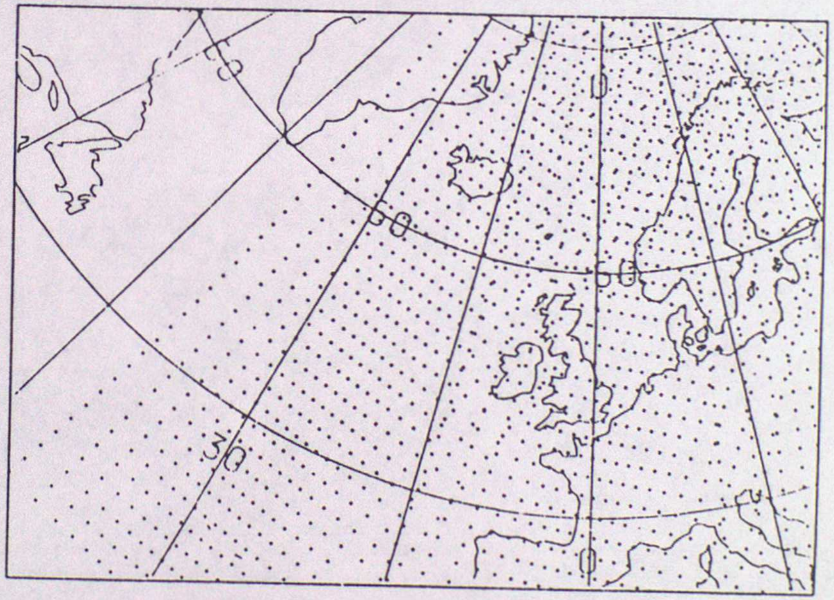
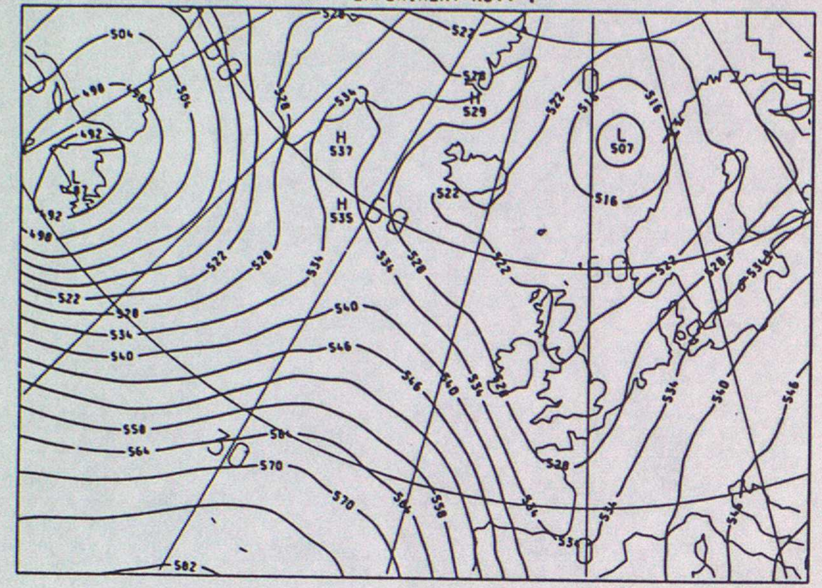
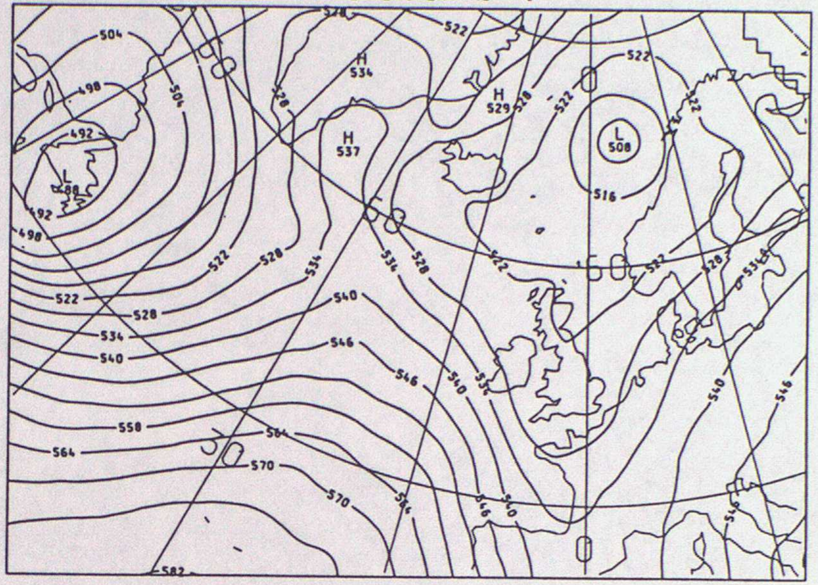


FIGURE 14

NEW CLOUD CLEARING SCHEME EXPERIMENT
500 MB HEIGHT
VALID AT 6Z ON 12/2/1987
LEVEL: 500 MB EXPERIMENT NO.: 1



ORIGINAL LASS EXPERIMENT
500 MB HEIGHT
VALID AT 6Z ON 12/2/1987
LEVEL: 500 MB EXPERIMENT NO.: 1



NCCS MINUS ORIGINAL LASS EXPERIMENT
500 MB HEIGHT
VALID AT 6Z ON 12/2/1987
LEVEL: 500 MB EXPERIMENT NO.: 1

HERMES NCCS DATA DISTRIBUTION
12/2/87 CASE STUDY

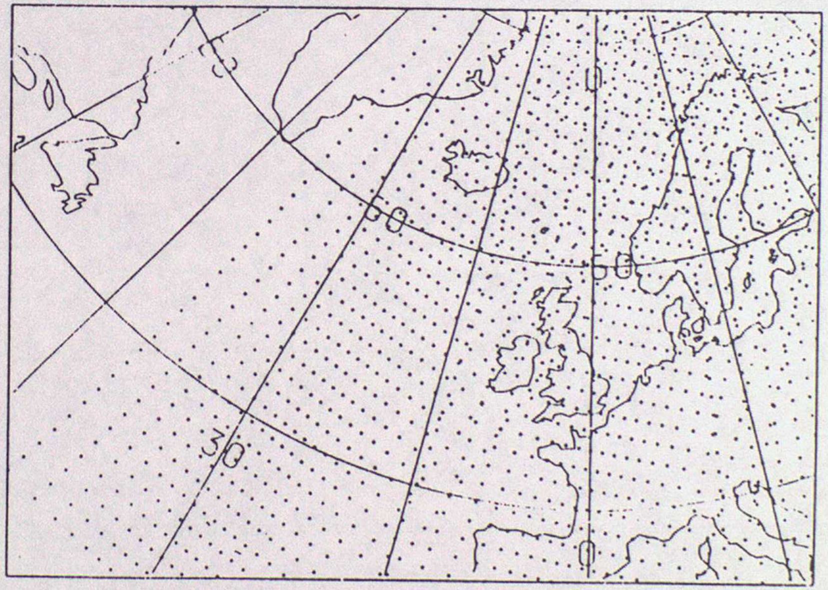
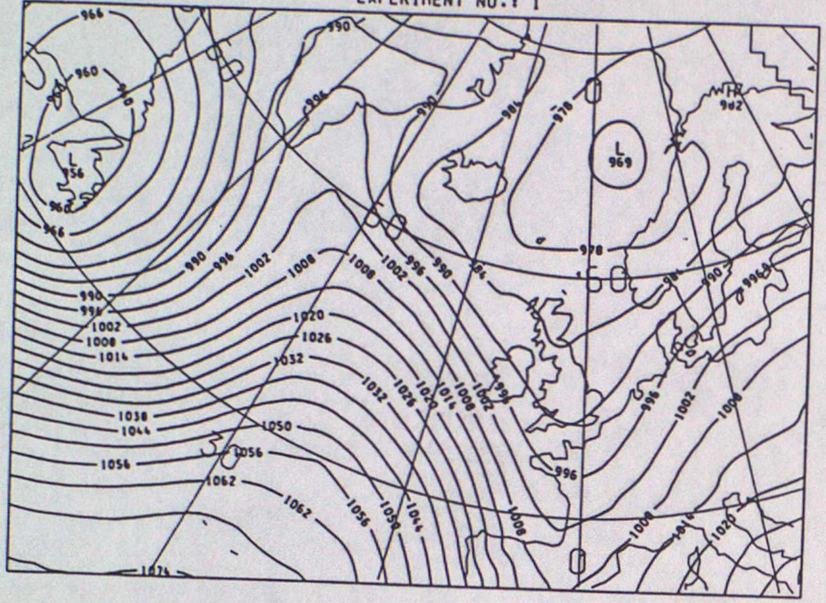
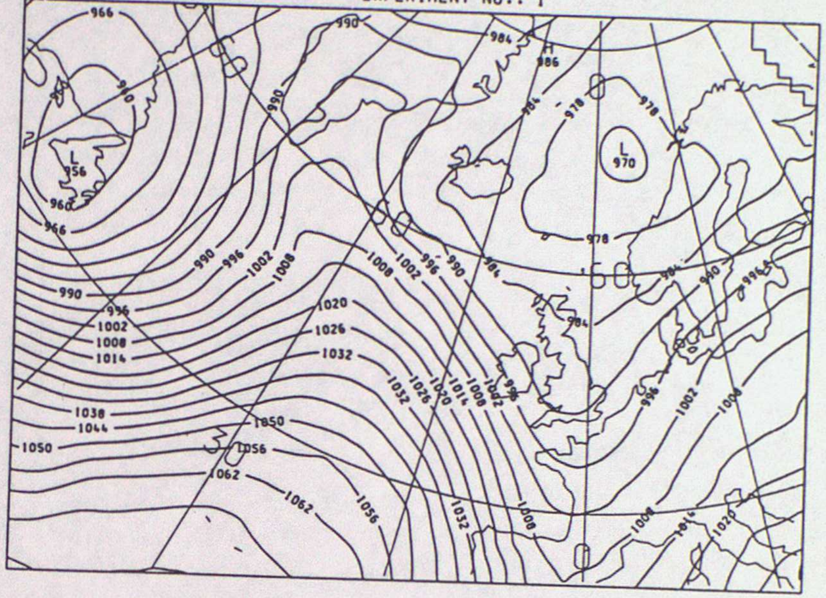


FIGURE 13

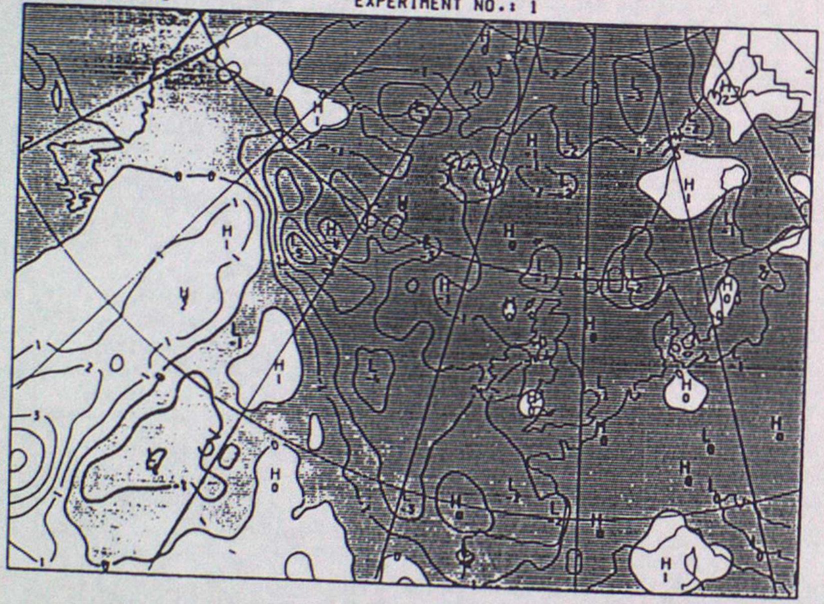
NEW CLOUD CLEARING SCHEME EXPERIMENT
250 MB HEIGHT
VALID AT 6Z ON 12/2/1987
LEVEL: 250 MB
EXPERIMENT NO.: 1



ORIGINAL LASS EXPERIMENT
250 MB HEIGHT
VALID AT 6Z ON 12/2/1987
LEVEL: 250 MB
EXPERIMENT NO.: 1



NCCS MINUS ORIGINAL LASS EXPERIMENT
250 MB HEIGHT
VALID AT 6Z ON 12/2/1987
LEVEL: 250 MB
EXPERIMENT NO.: 1



HERMES NCCS DATA DISTRIBUTION
12/2/87 CASE STUDY

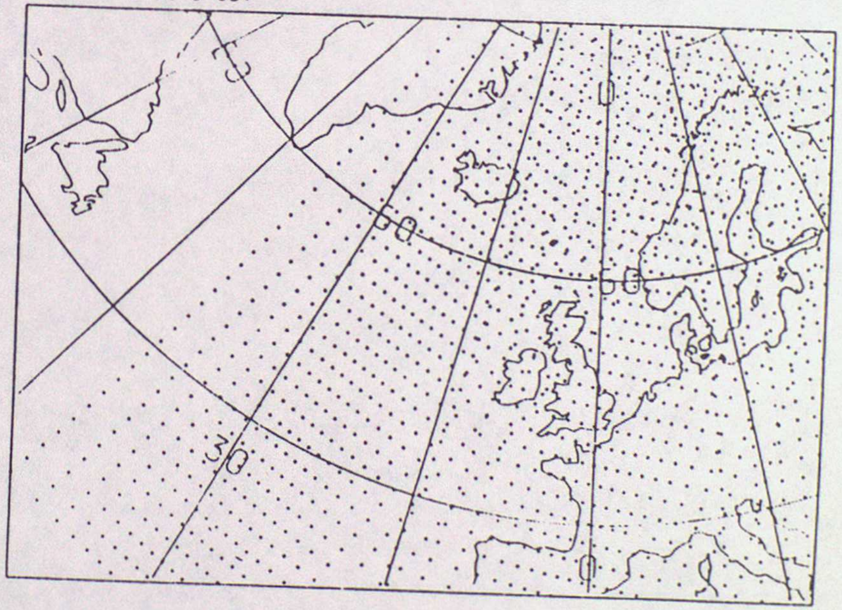
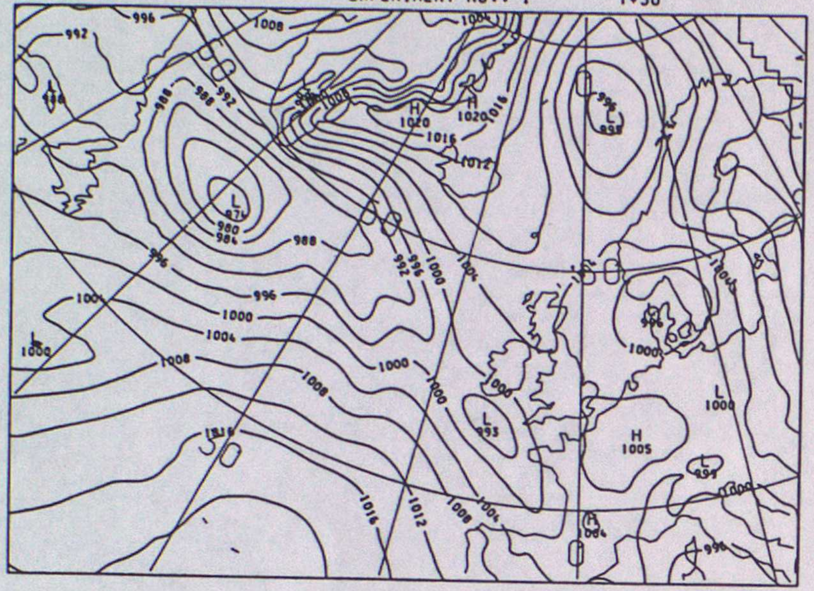
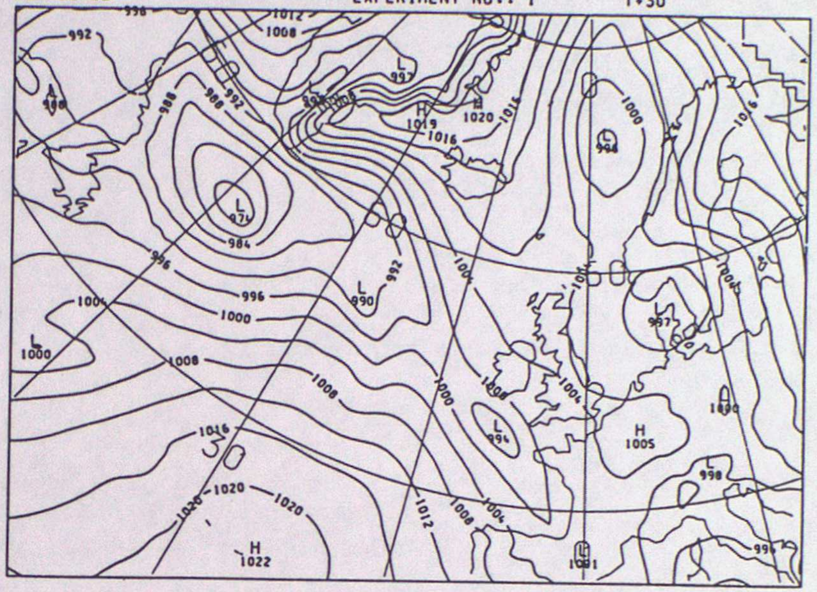


FIGURE 16

NEW CLOUD CLEARING SCHEME EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 12Z ON 13/2/1987 DATA TIME 6Z ON 12/2/1987
SEA LEVEL EXPERIMENT NO.: 1 T+30



ORIGINAL LASS EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 12Z ON 13/2/1987 DATA TIME 6Z ON 12/2/1987
SEA LEVEL EXPERIMENT NO.: 1 T+30



NCCS MINUS ORIGINAL LASS EXPERIMENT
MEAN SEA LEVEL PRESSURE
VALID AT 12Z ON 13/2/1987 DATA TIME 6Z ON 12/2/1987
SEA LEVEL EXPERIMENT NO.: 1 T+30

VERIFYING OPERATIONAL ANALYSIS
MEAN SEA LEVEL PRESSURE
VALID AT 12Z ON 13/2/1987 DAY 44 DATA TIME 12Z ON 13/2/1987 DAY 44
SEA LEVEL

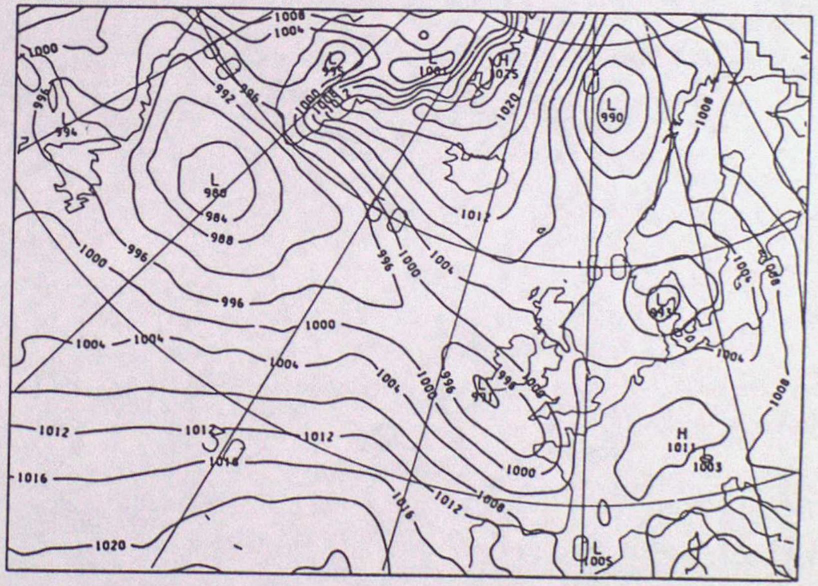


FIGURE 17

RAINFALL RATE
PRESSURE AT MSL
SNOW PROB AT MSL

DT 12Z THURSDAY 12/2/1987 FINE MESH

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

FIGURE 1B

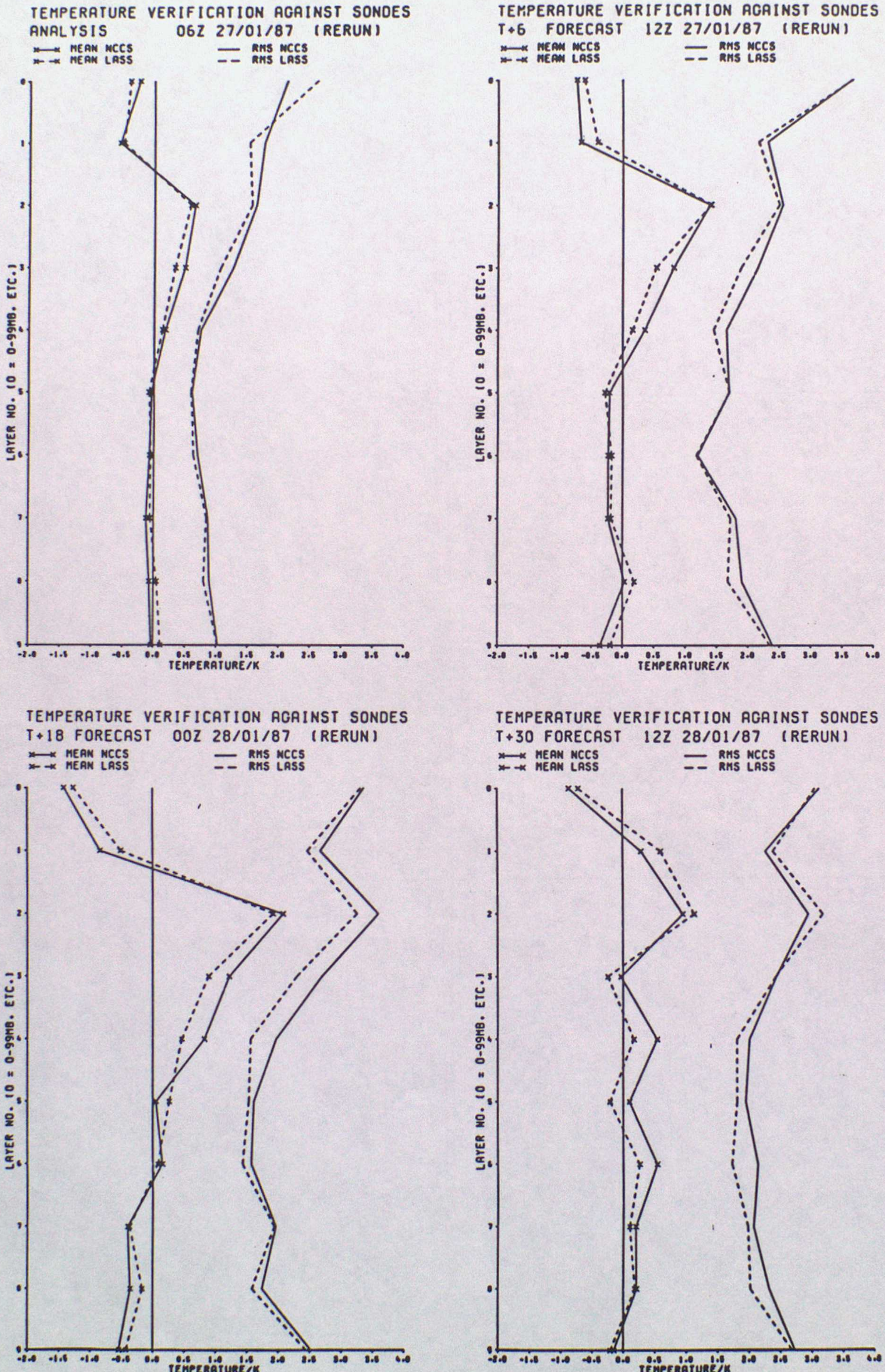

TEMPERATURE VERIFICATION AGAINST SONDES
ANALYSIS 06Z 27/01/87 (RERUN)
MEAN NCCS
MEAN LASS
RMS NCCS
RMS LASS
LAYER NO. (0 = 0-99MB. ETC.)
TEMPERATURE/K
TEMPERATURE VERIFICATION AGAINST SONDES
T+6 FORECAST 12Z 27/01/87 (RERUN)
MEAN NCCS
MEAN LASS
RMS NCCS
RMS LASS
LAYER NO. (0 = 0-99MB. ETC.)
TEMPERATURE/K
TEMPERATURE VERIFICATION AGAINST SONDES
T+18 FORECAST 00Z 28/01/87 (RERUN)
MEAN NCCS
MEAN LASS
RMS NCCS
RMS LASS
LAYER NO. (0 = 0-99MB. ETC.)
TEMPERATURE/K
TEMPERATURE VERIFICATION AGAINST SONDES
T+30 FORECAST 12Z 28/01/87 (RERUN)
MEAN NCCS
MEAN LASS
RMS NCCS
RMS LASS
LAYER NO. (0 = 0-99MB. ETC.)
TEMPERATURE/K

FIGURE 19

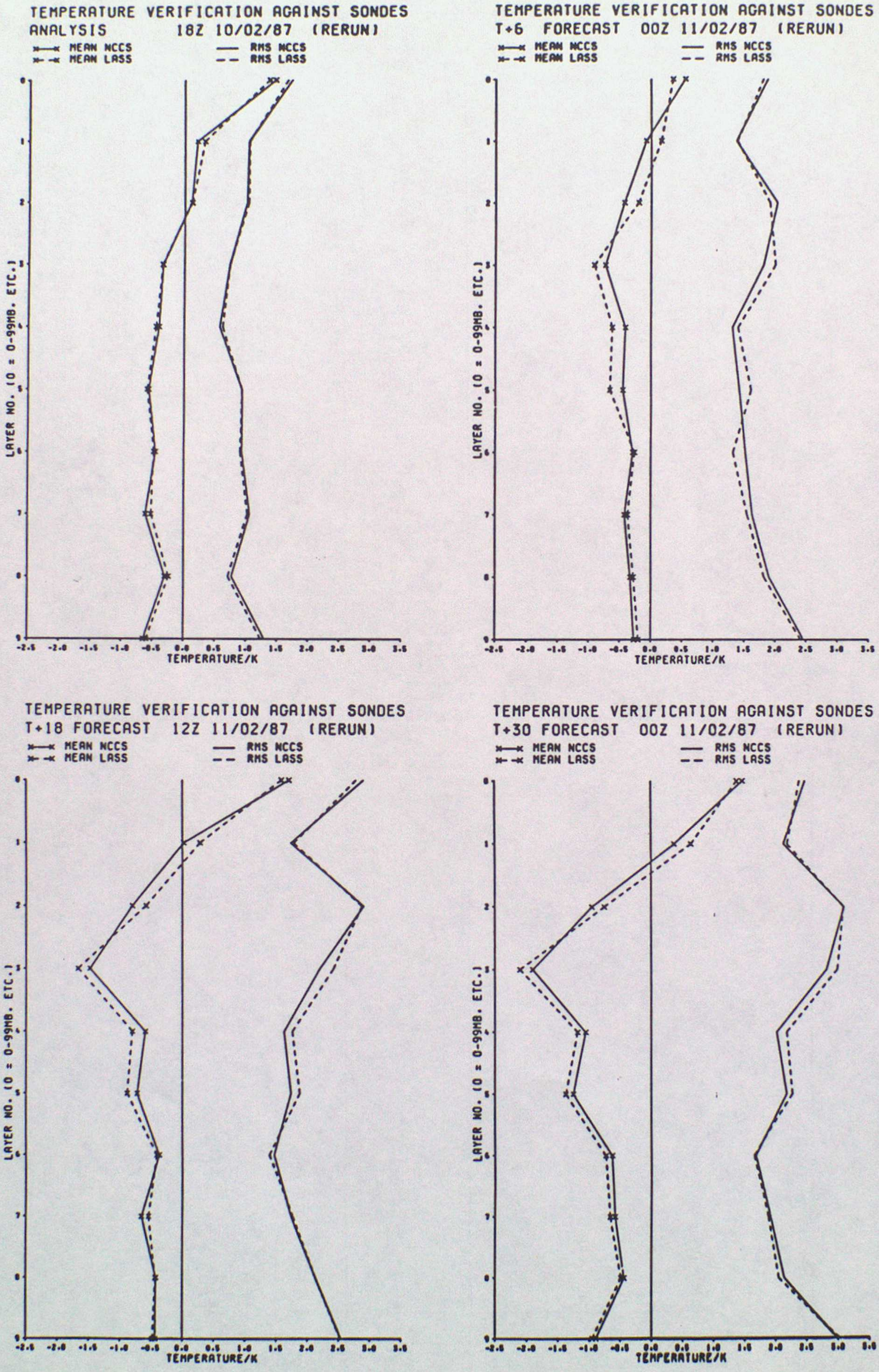

TEMPERATURE VERIFICATION AGAINST SONDES
ANALYSIS 18Z 10/02/87 (RERUN)
MEAN NCCS
MEAN LASS
RMS NCCS
RMS LASS
LAYER NO. (0 = 0-99MB. ETC.)
TEMPERATURE/K
TEMPERATURE VERIFICATION AGAINST SONDES
T+6 FORECAST 00Z 11/02/87 (RERUN)
MEAN NCCS
MEAN LASS
RMS NCCS
RMS LASS
LAYER NO. (0 = 0-99MB. ETC.)
TEMPERATURE/K
TEMPERATURE VERIFICATION AGAINST SONDES
T+18 FORECAST 12Z 11/02/87 (RERUN)
MEAN NCCS
MEAN LASS
RMS NCCS
RMS LASS
LAYER NO. (0 = 0-99MB. ETC.)
TEMPERATURE/K
TEMPERATURE VERIFICATION AGAINST SONDES
T+30 FORECAST 00Z 11/02/87 (RERUN)
MEAN NCCS
MEAN LASS
RMS NCCS
RMS LASS
LAYER NO. (0 = 0-99MB. ETC.)
TEMPERATURE/K

FIGURE 20

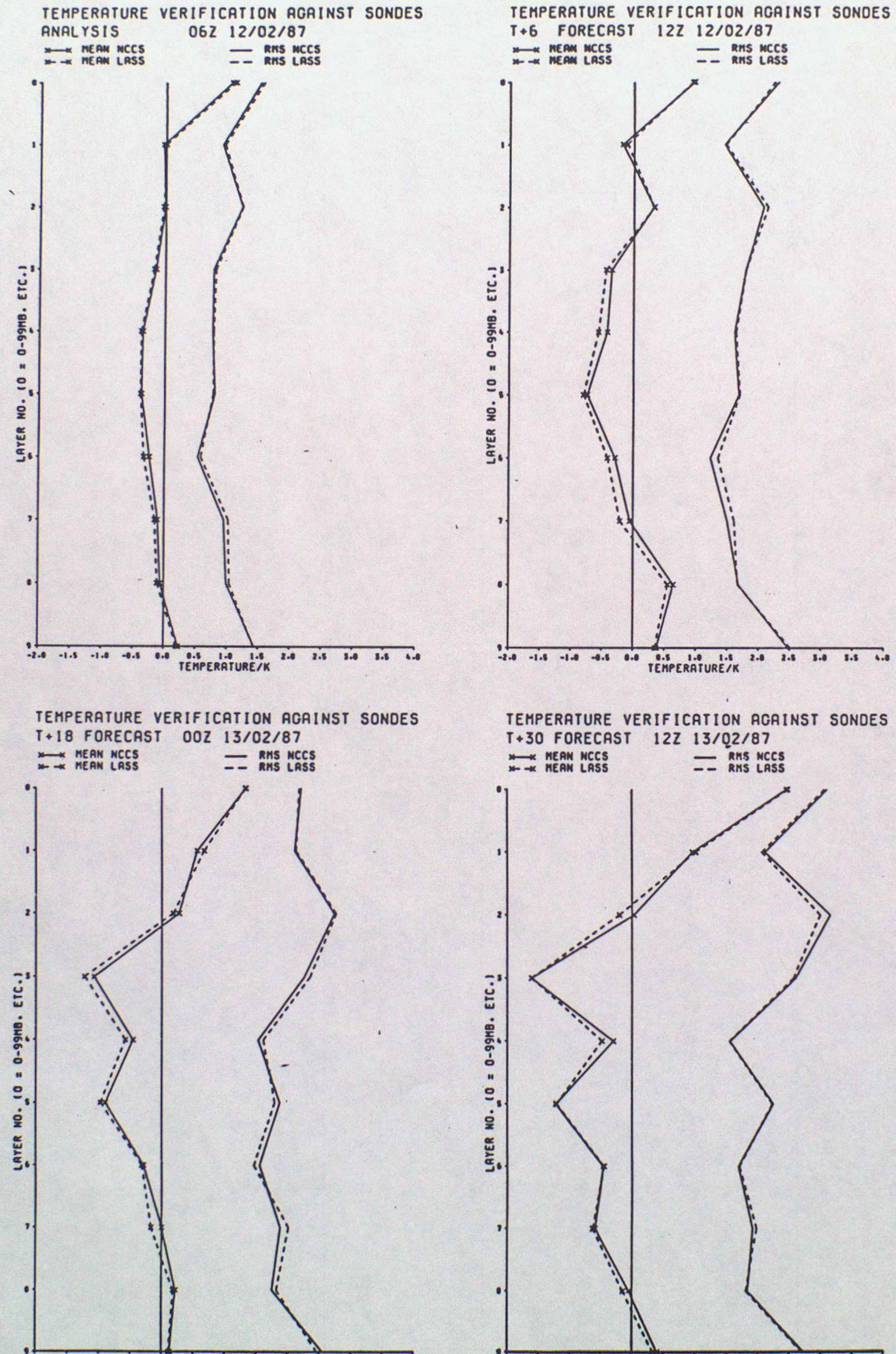
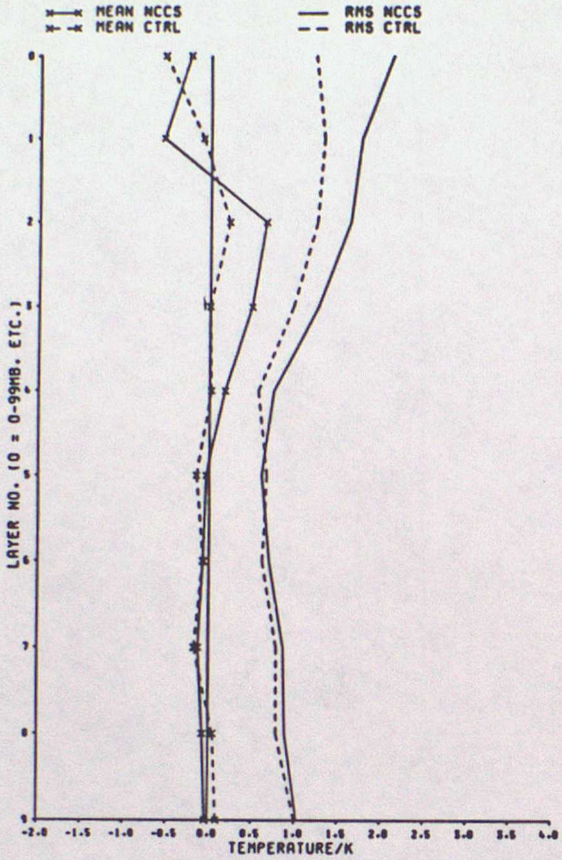
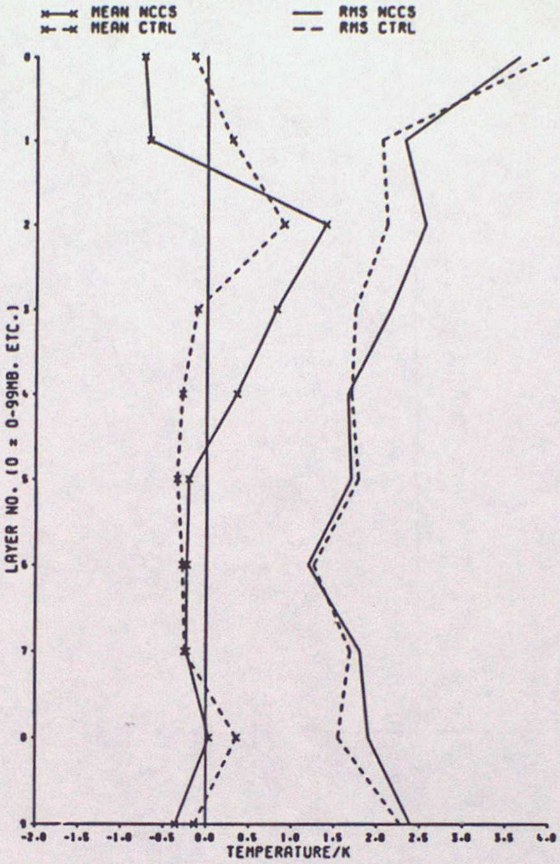

TEMPERATURE VERIFICATION AGAINST SONDES
ANALYSIS 06Z 12/02/87
MEAN NCCS
MEAN LASS
RMS NCCS
RMS LASS
LAYER NO. (0 = 0-99MB. ETC.)
TEMPERATURE/K
TEMPERATURE VERIFICATION AGAINST SONDES
T+6 FORECAST 12Z 12/02/87
MEAN NCCS
MEAN LASS
RMS NCCS
RMS LASS
LAYER NO. (0 = 0-99MB. ETC.)
TEMPERATURE/K
TEMPERATURE VERIFICATION AGAINST SONDES
T+18 FORECAST 00Z 13/02/87
MEAN NCCS
MEAN LASS
RMS NCCS
RMS LASS
LAYER NO. (0 = 0-99MB. ETC.)
TEMPERATURE/K
TEMPERATURE VERIFICATION AGAINST SONDES
T+30 FORECAST 12Z 13/02/87
MEAN NCCS
MEAN LASS
RMS NCCS
RMS LASS
LAYER NO. (0 = 0-99MB. ETC.)
TEMPERATURE/K

FIGURE 21

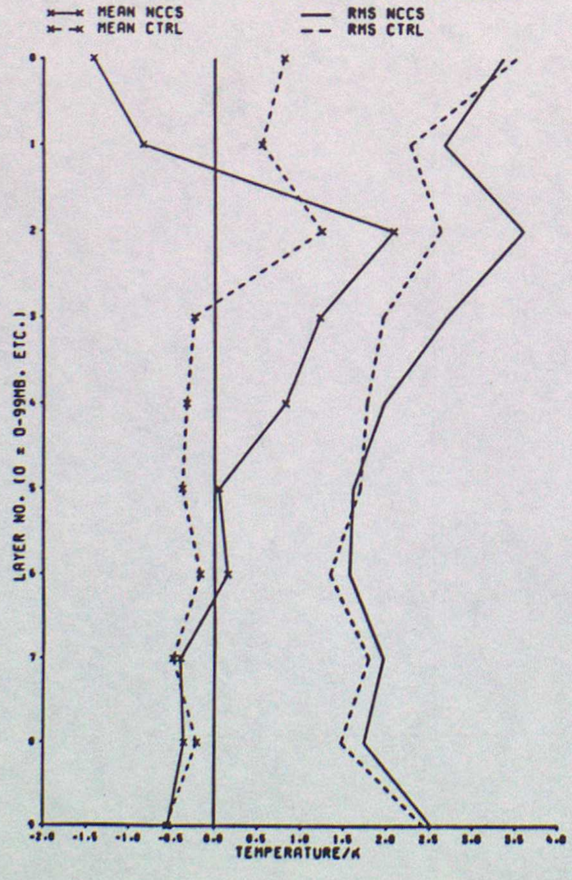
TEMPERATURE VERIFICATION AGAINST SONDES
ANALYSIS 06Z 27/01/87 (RERUN)



TEMPERATURE VERIFICATION AGAINST SONDES
T+6 FORECAST 12Z 27/01/87 (RERUN)



TEMPERATURE VERIFICATION AGAINST SONDES
T+18 FORECAST 00Z 28/01/87 (RERUN)



TEMPERATURE VERIFICATION AGAINST SONDES
T+30 FORECAST 12Z 28/01/87 (RERUN)

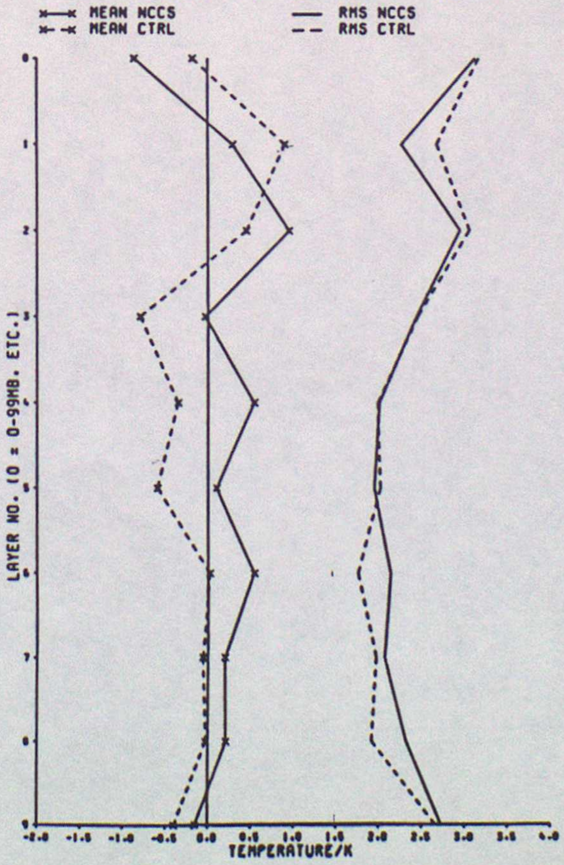
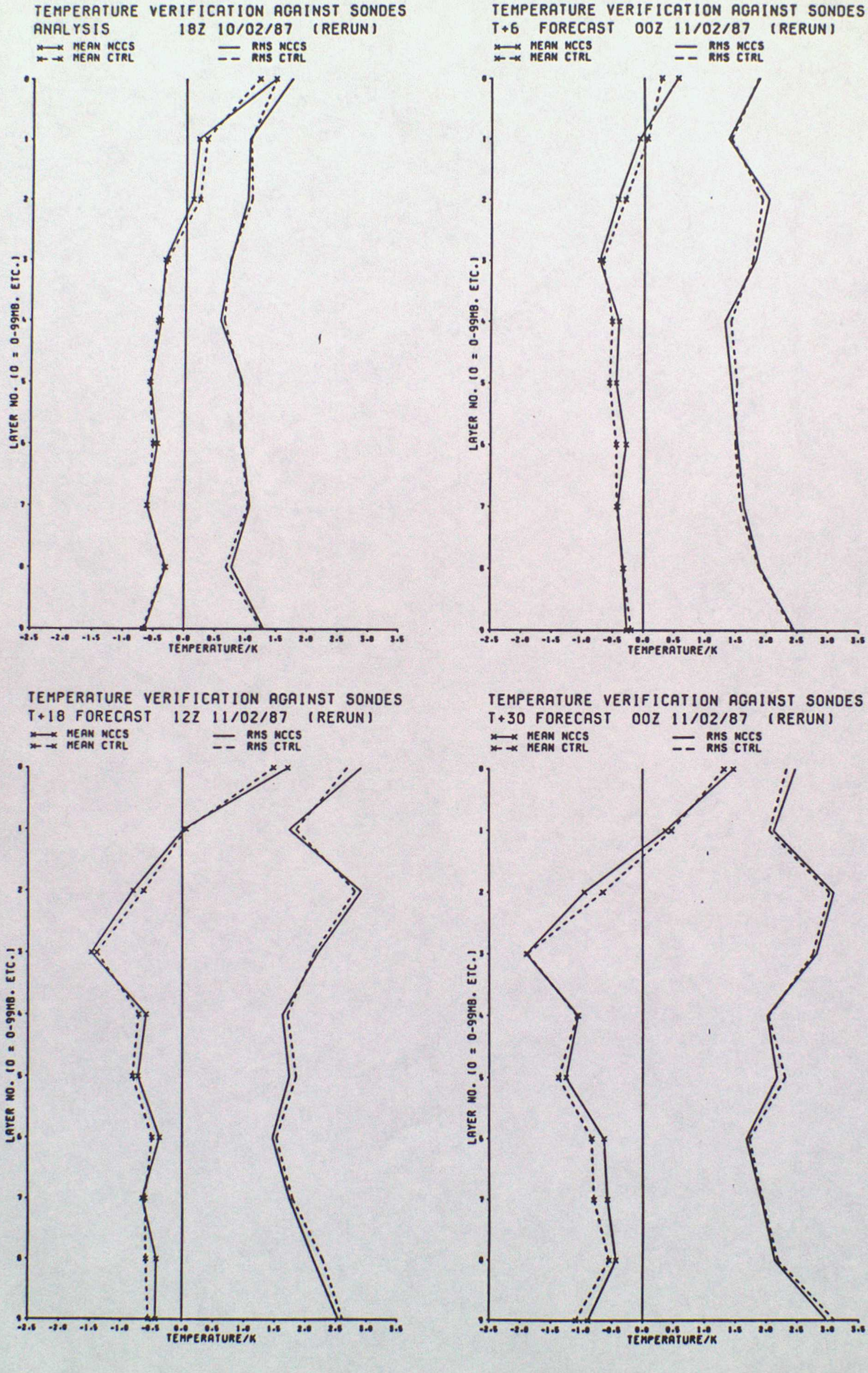


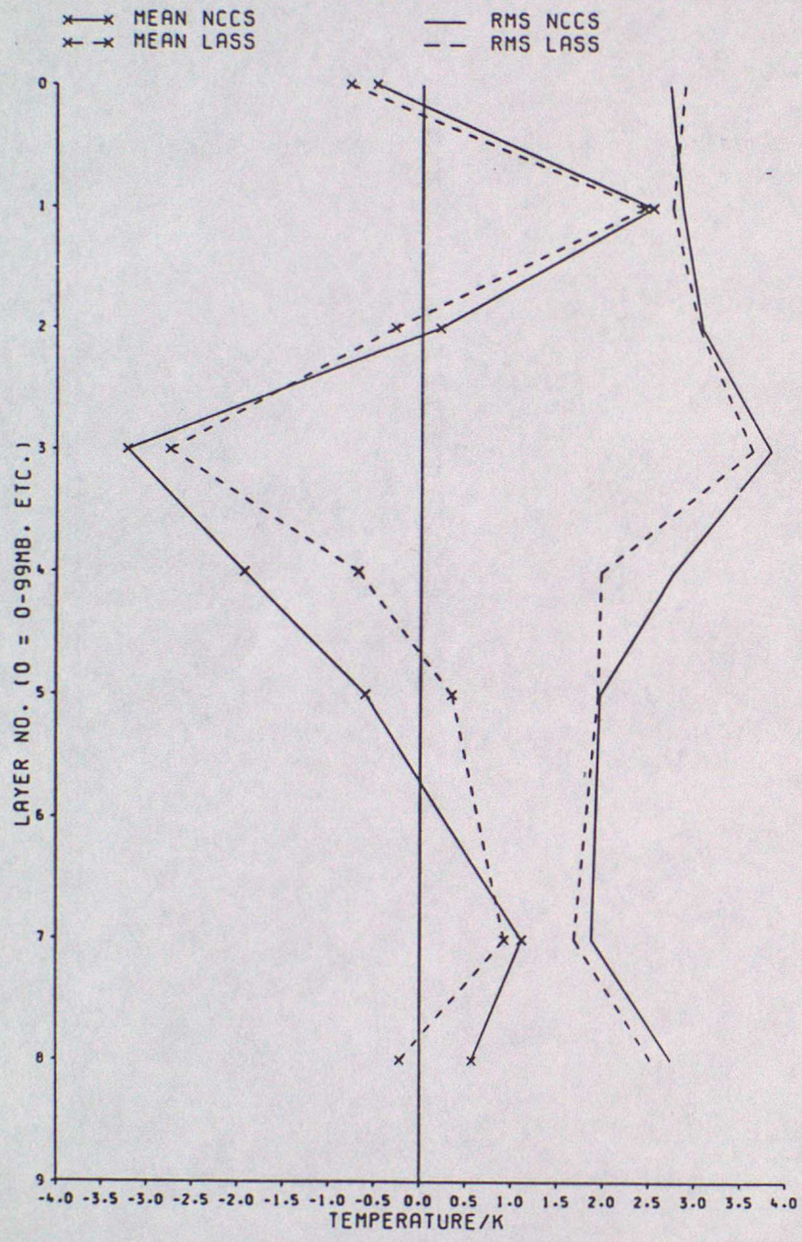
FIGURE 22



TEMPERATURE VERIFICATION AGAINST SONDES
ANALYSIS 18Z 10/02/87 (RERUN)
MEAN NCCS
MEAN CTRL
RMS NCCS
RMS CTRL
LAYER NO. (0 = 0-99MB. ETC.)
TEMPERATURE/K
TEMPERATURE VERIFICATION AGAINST SONDES
T+6 FORECAST 00Z 11/02/87 (RERUN)
MEAN NCCS
MEAN CTRL
RMS NCCS
RMS CTRL
LAYER NO. (0 = 0-99MB. ETC.)
TEMPERATURE/K
TEMPERATURE VERIFICATION AGAINST SONDES
T+18 FORECAST 12Z 11/02/87 (RERUN)
MEAN NCCS
MEAN CTRL
RMS NCCS
RMS CTRL
LAYER NO. (0 = 0-99MB. ETC.)
TEMPERATURE/K
TEMPERATURE VERIFICATION AGAINST SONDES
T+30 FORECAST 00Z 11/02/87 (RERUN)
MEAN NCCS
MEAN CTRL
RMS NCCS
RMS CTRL
LAYER NO. (0 = 0-99MB. ETC.)
TEMPERATURE/K

FIGURE 23

MEAN & RMS HERMES DIFFERENCES FROM BACKGROUND ANALYSIS 03Z 27/01/87 (RERUN)



MEAN & RMS HERMES DIFFERENCES FROM BACKGROUND ANALYSIS 06Z 27/01/87 (RERUN)

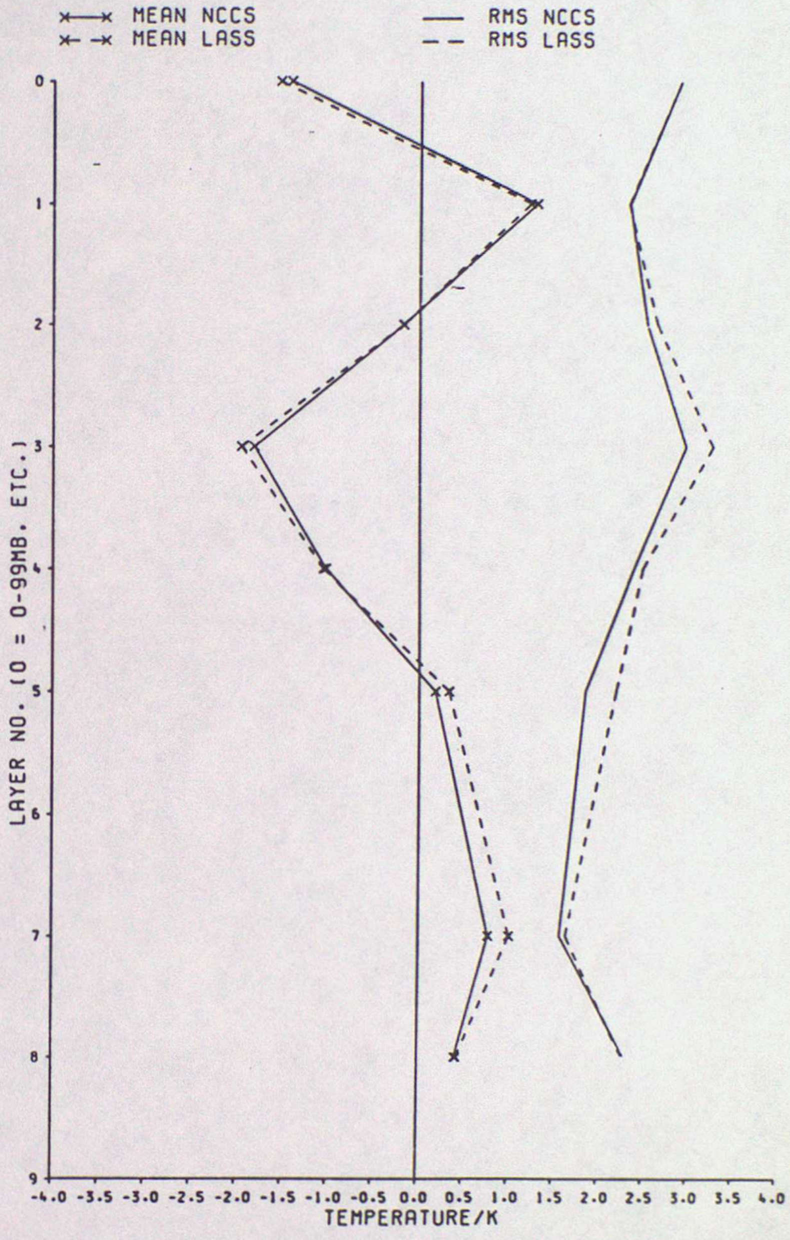


FIGURE 24

MEAN & RMS HERMES DIFFERENCES FROM BACKGROUND ANALYSIS 15Z 10/02/87 (RERUN)

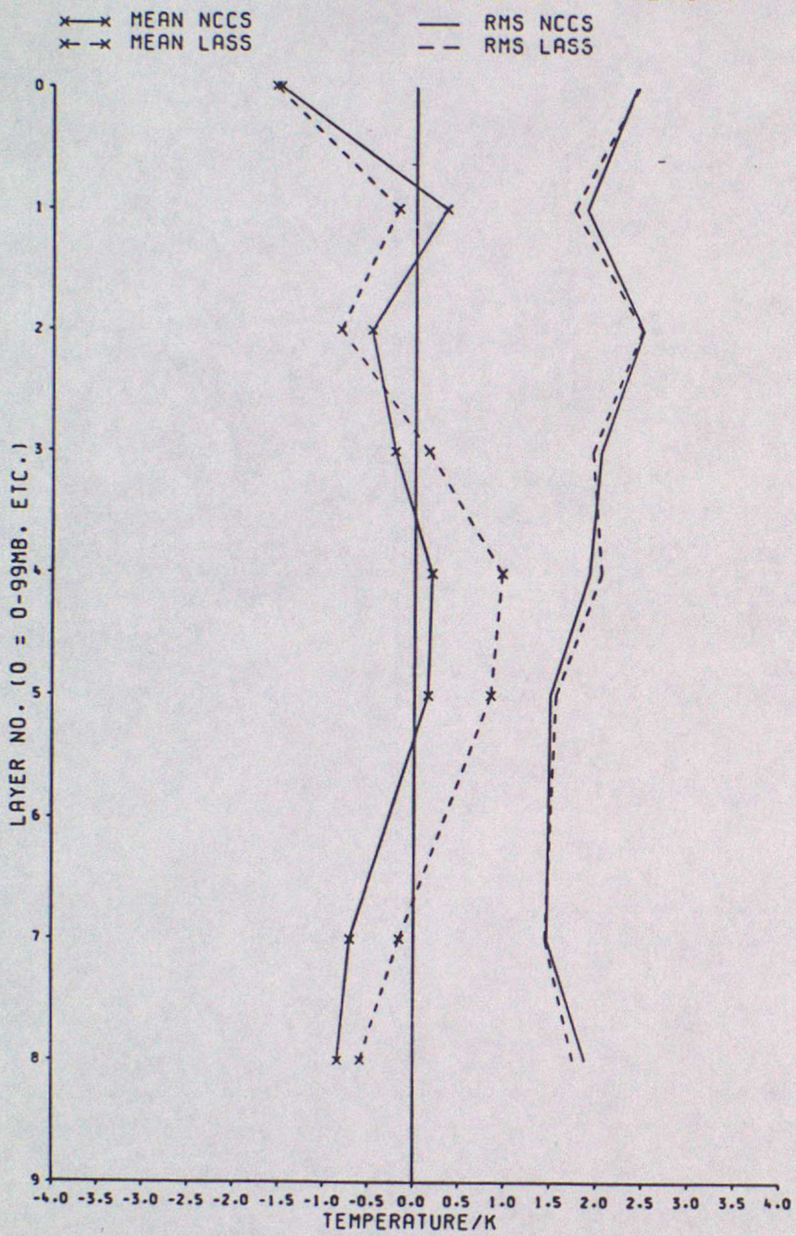
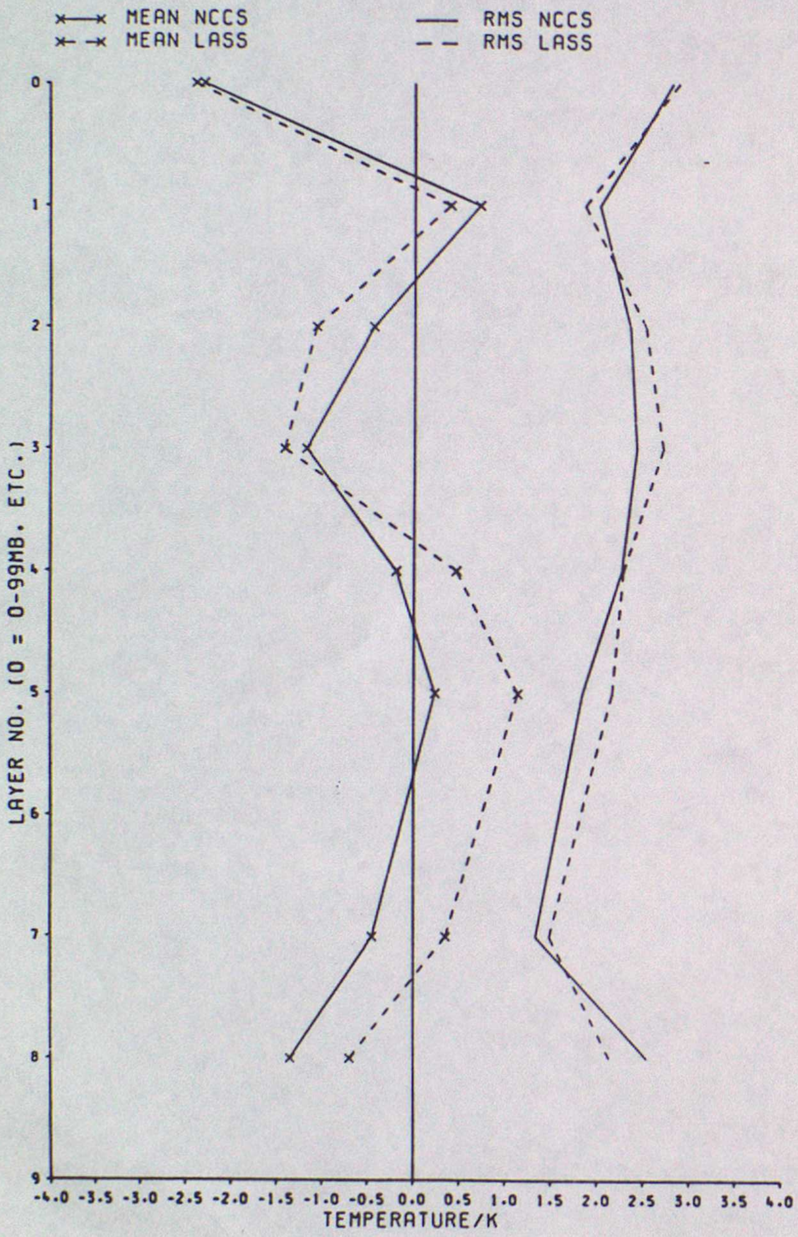


FIGURE 25

MEAN & RMS HERMES DIFFERENCES FROM BACKGROUND ANALYSIS 03Z 12/02/87



MEAN & RMS HERMES DIFFERENCES FROM BACKGROUND ANALYSIS 06Z 12/02/87