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A further global trial of the Analysis Correction Scheme - Christmas 1987

by

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1. Introduction

The analysis correction scheme *(Lorenc and Dumelow , 1987)* underwent two extensive periods of testing during the Spring and Autumn of 1987 when detailed comparisons of the analyses and forecasts from a parallel run with the operational suite were made. The results from these trials *(Bell, 1987)* showed that considerable benefits were obtained from the new scheme in the early stages of a forecast which were retained throughout the forecast period in the southern hemisphere but lost in the later stages of the forecast in the northern hemisphere. Further investigations led us to suspect that too little weight was being attached to observations around the periphery of the data dense areas. A revision of the algorithm described in *Macpherson (1988)* attempted to combat this problem by using a pre-analysis of the observation density to modify the weights normalisation factor. The revised version of the scheme which was prepared for testing differed from that run in the August trial as follows :

a) A prior analysis of observation density was done each timestep and this was used to modify the weights normalisation factor so as to give better convergence rates to isolated data near a region of high data density. This substantial reformulation necessitated a complete reassessment of other tunable parameters. Some minor adjustments of other parameters were made in the light of these tuning experiments.

b) An error in the horizontal influence area which resulted in more elongated influence areas nearer the poles rather than a circular influence area was corrected.

This paper describes the results from a further trial of the analysis correction scheme which started just before Christmas 1987. The trial format followed along much the same lines as previous trials . A complete global data-assimilation cycle was run using exactly the same set of quality controlled observations as were used operationally , together with a fifth cycle which duplicated the 12GMT main forecast run. Forecasts from this repeat main run were initially run to T+72. The use of identical observation sets makes the evaluation task much easier since differences are restricted to the assimilation method , although we are not entirely mimicing what would happen if the new scheme were operational since we are not quality controlling the observations using first guess fields derived from the trial assimilations.

The trial ran from 23rd December 1987 to 4th January 1988, a period during which the weather over the North Atlantic was particularly disturbed, allowing a good opportunity to assess the scheme during a more mobile situation. The trial assimilation cycle was interrupted three times during the 12 day period, the 00GMT/06GMT runs were not run on the 30th and 2nd because of computer outages and the 00GMT run on the 1st failed. Thus the forecasts from 12GMT on the 30th, 1st and 2nd are based on only a one cycle AC assimilation after restarting from operational files and are not very useful for assessment. The one failure was traced to an overwriting problem which only occurred when the number of 250km resolution SATEMs was small; other runs were not contaminated by this error.

The objective assessment , the results of which are discussed in the next section, consisted mainly of a comparison of model analyses (at 00GMT and 12GMT) and forecasts against verifying surface and radiosonde reports. Results were meaned for three latitude bands as well as for the North Atlantic sector . The forecast verification was for T+12, 24, 48 and 72 from the 12GMT forecast run and also T+6 forecast first guess fields from the intermediate 06GMT and 18GMT analyses. Subjective assessment efforts were concentrated on the forecast evaluation in the northern hemisphere, since this aspect of the earlier trials had caused most concern. Some conclusions from this assessment are presented in section 3. The final section contains results of some of the trial forecasts which were continued for a further 2 days (to T+120).

2. Objective verification

All the tables in this section give a comparison of rms differences of model field from verifying surface reports and radiosondes reports for 11 fields. The trial result is followed by the operational result in parentheses. Results marked by (x) indicate the trial rms error worse by more than 1% whilst results marked (✓) indicates the trial result better by more than 1%. Results are presented for four verification areas. These are the northern hemisphere poleward of 30°N (area 200) , the tropics equatorward of 30° (area 300), the southern hemisphere poleward of 30°S (area 400) and the North Atlantic sector covering the eastern coastal area of North America and also Western Europe (area 2).

2.1 First guess verification

Table 1 contains results from 12 T+6 first guess fields verifying at 00GMT and 12GMT during the period 23rd to 29th December.

	Northern Hemisphere (90°N-30°N)	Tropics (30°N-30°S)	Southern Hemisphere (30°S-90°S)	North Atlantic (Area 2)
pmsl	2.53✓(2.60)	2.35✓(2.41)	2.69×(2.66)	2.05✓(2.23)
850ht	1.56✓(1.61)	1.36✓(1.44)	1.72✓(1.78)	1.21✓(1.36)
500ht	2.33✓(2.41)	2.74×(2.71)	2.90 (2.89)	2.20✓(2.25)
250ht	3.53✓(3.60)	4.63×(4.57)	4.15 (4.17)	3.12 (3.15)
850temp	2.28✓(2.38)	2.12✓(2.18)	2.35✓(2.55)	1.93✓(2.02)
500temp	1.58✓(1.68)	1.74×(1.70)	2.05✓(2.08)	1.44✓(1.53)
250temp	2.11✓(2.17)	2.02×(1.97)	2.45×(2.35)	1.93✓(2.01)
850wind	10.1✓(10.5)	10.1✓(10.5)	12.0✓(12.4)	8.7✓(9.0)
500wind	11.9✓(12.1)	11.2✓(11.4)	15.3 (15.4)	11.4✓(11.6)
250wind	15.8✓(16.4)	17.0 (16.9)	22.8✓(24.1)	14.8✓(15.7)
700rh	22.4✓(23.4)	21.0✓(21.2)	23.7✓(24.1)	22.5✓(23.0)

Table 1 Verification of T+6 forecasts from intermediate assimilations

The T+6 verification is probably a better measure of the quality of the assimilation than the T+0 verification since a close fit of the analysis to observations does not necessarily imply a good analysis. We see that the new scheme has out-performed the operational scheme everywhere except the upper tropospheric mass field in the tropics. This result is consistent with earlier trial results.

2.2 Verification of the analyses

The verification of the analyses are included for completeness. Little meaning can be attached to the results of the upper air verification since the verification assumes that all the radiosondes are valid at the synoptic hour (00GMT or 12GMT). The operational assimilation makes the same assumption, whereas the trial assimilation scheme assimilates the data at its true validity time which for almost 50% of the radiosondes is one hour before the main hour. In the southern hemisphere Australian observations are valid two hours before the main hour. At the surface only synoptic reports are included and here we see only very small differences between the two schemes. As anticipated, the operational scheme shows a slightly closer fit of analyses to observations, due to its use of a very much smaller sphere of influence for the observation increments.

	Northern Hemisphere (90°N-30°N)	Tropics (30°N-30°S)	Southern Hemisphere (30°S-90°S)	North Atlantic (Area 2)
pmsl	2.15×(2.09)	2.09 (2.09)	2.22×(2.04)	1.76 (1.75)
850ht	1.30 (1.30)	1.30✓(1.42)	1.45✓(1.50)	0.95✓(1.00)
500ht	1.91×(1.87)	2.35 (2.36)	2.49×(2.36)	1.70×(1.65)
250ht	2.95×(2.83)	4.19×(4.03)	3.51×(2.96)	2.64×(2.56)
850temp	1.83×(1.63)	1.83×(1.72)	2.05×(1.38)	1.61×(1.43)
500temp	1.24×(1.11)	1.51×(1.38)	1.64×(1.11)	1.18×(1.05)
250temp	1.70×(1.53)	1.70×(1.55)	1.98×(1.41)	1.59×(1.40)
850wind	8.1×(7.7)	8.2 (8.2)	9.8×(8.5)	7.2×(7.1)
500wind	9.2×(8.8)	8.3×(7.1)	11.3×(9.8)	9.1×(8.5)
250wind	12.2×(11.3)	12.7×(10.8)	17.7×(14.9)	11.8×(10.9)
700rh	19.2×(17.9)	16.4×(13.4)	17.6×(15.1)	19.1×(17.5)

Table 2 Verification of 00GMT and 12GMT assimilations

2.3 Forecast verification

The forecast verification results for each of the four verification areas are presented in tables 3-6 respectively. Results are available for four forecast periods T+12, 24, 48 and 72. For reasons of clarity only one decimal place has been retained when reproducing these tables, although the assignment of (×,✓) marks was based on a higher precision, which explains why apparently equal scores are marked as differing by more than 1%. These tables contain mean results for all 13 forecasts run from 12GMT data during the period 23rd December to 4th January. As has already been mentioned some of these forecasts were based on a short spinup because of various computer problems but it was decided that to exclude such cases from the results would give too small a number of cases and also the mean results could then only be computed with some difficulty. Tables 3-5 can be compared directly with results for the previous trial (Tables 4(a-c) in *Bell, 1987*).

	T+12	T+24	T+48	T+72
pmsl	2.8 ✓(2.9)	3.4 ✓(3.5)	4.6 (4.6)	6.1 ×(5.9)
850ht	1.7 ✓(1.7)	2.1 (2.0)	2.9 (2.9)	4.0 ×(3.9)
500ht	2.4 ×(2.3)	2.9 ×(2.8)	4.3 ×(4.2)	5.9 ×(5.8)
250ht	3.6 ×(3.5)	4.3 ×(4.2)	6.1 ×(6.0)	7.9 (7.8)
850temp	2.3 (2.3)	2.7 (2.7)	3.3 ×(3.3)	4.0 ×(3.9)
500temp	1.5 ✓(1.6)	1.9 (1.9)	2.5 (2.5)	3.1 ✓(3.1)
250temp	2.1 ✓(2.1)	2.4 ✓(2.4)	2.8 (2.8)	3.3 (3.3)
850wind	10.4✓(10.5)	11.2 (11.3)	13.3 (13.3)	15.6×(15.3)
500wind	12.2 (12.3)	14.0 (14.0)	18.0 (17.9)	22.2×(21.8)
250wind	16.1 (16.2)	18.7 (18.7)	24.3 (24.5)	29.8 (29.7)
700rh	22.8✓(23.4)	23.7✓(24.2)	26.6✓(26.9)	29.3 (29.1)

Table 3 Forecast Verification for Area 200 (N H)

In the Northern latitudes there is a small signal that the trial is better in the early stages of the forecast and marginally less good towards the later stages of the forecast. Taking the trial rms errors as a percentage of the operational comparison and meaning the percentages for the 11 variables specified in the table we find that the trial is 0.5% better in rms terms at T+12 and 0.1% better at T+24, but 0.4% worse at T+48 and 1.2% worse by T+72. Overall 11 of the above statistics show the trial to be better and 13 show the trial to be worse, with the remaining 16 being within 1%.

	T+12	T+24	T+48	T+72
pmsl	2.3 ✓(2.5)	2.5 ×(2.5)	2.8 ✓(2.9)	3.0 ✓(3.1)
850ht	1.4 ✓(1.5)	1.6 ×(1.5)	1.8 (1.8)	2.1 ×(2.0)
500ht	2.6 ×(2.6)	2.8 ×(2.7)	3.2 ×(3.1)	3.5 ✓(3.6)
250ht	4.4 ×(4.4)	4.9 ×(4.6)	5.4 ×(5.3)	5.9 (5.9)
850temp	2.2 ✓(2.3)	2.5 (2.5)	2.9 ✓(2.9)	3.1 (3.1)
500temp	1.7 ×(1.7)	2.0 ×(1.9)	2.3 ×(2.2)	2.5 ×(2.5)
250temp	1.9 (1.9)	2.2 ×(2.1)	2.3 ×(2.3)	2.6 ×(2.4)
850wind	10.4✓(10.7)	10.9✓(11.0)	11.4✓(11.7)	12.0 (12.0)
500wind	10.9✓(11.0)	12.4✓(12.6)	14.0 (14.0)	15.1 (15.1)
250wind	17.1 (17.1)	20.1 (20.2)	23.2 (23.1)	24.7 (24.6)
700rh	21.6 (21.4)	20.9✓(22.0)	24.1 (24.3)	26.1 (26.1)

Table 4 forecast verif for Area 300 (Tropics)

The results in the tropics show the trial scheme to have an overall neutral impact. The wind field ,which is of course more important in the tropics, verifies better in the trial runs, but this is balanced by slightly worse height statistics . Rather oddly, the trial shows up worse at T+24 , yet this deterioration from T+12 is not really sustained in the later forecast periods.

	T+12	T+24	T+48	T+72
pmsl	3.0 ✓(3.1)	3.7 ×(3.6)	4.5 ✓(4.6)	4.8 ✓(5.1)
850ht	2.1 ✓(2.1)	2.5 ×(2.5)	3.3 ×(3.2)	3.6 ✓(3.7)
500ht	3.2 ✓(3.3)	3.8 ×(3.7)	5.3 ×(5.2)	6.1 ×(5.9)
250ht	3.8 ✓(3.9)	5.3 ×(5.2)	7.0 (6.9)	8.3 ×(8.1)
850temp	2.2 ✓(2.2)	2.2 ✓(2.3)	2.8 ✓(2.9)	3.4 ✓(3.5)
500temp	1.8 ×(1.7)	2.2 (2.2)	2.7 ✓(2.7)	3.1 ×(3.0)
250temp	2.4 ×(2.3)	3.2 ×(3.0)	3.3 ×(3.3)	3.5 ×(3.4)
850wind	12.6✓(13.0)	13.1✓(13.4)	14.3✓(14.5)	14.8✓(15.2)
500wind	13.8✓(14.0)	16.7✓(17.5)	18.3✓(19.0)	20.3✓(20.7)
250wind	19.8✓(21.0)	24.5✓(25.4)	28.6✓(29.0)	32.6✓(33.6)
700rh	23.9×(23.6)	27.2×(25.5)	27.3✓(28.0)	27.9✓(29.7)

Table 5 forecast verif for Area 400 (S H)

As we have noted in previous trials, the results from southern hemisphere verification show a significant positive impact from the trial scheme. In table 5 , we see that 26 trial statistics are better and 16 worse. All 12 wind statistics show the trial to be better, with upper winds verifying about 1 knot better .

	T+12	T+24	T+48	T+72
pmsl	2.2 ✓(2.4)	3.1 ✓(3.2)	4.5 (4.5)	6.5 ×(6.1)
850ht	1.4 ✓(1.6)	1.9 ✓(2.1)	3.1 ✓(3.1)	4.5 ×(4.3)
500ht	2.2 (2.3)	2.9 ✓(2.9)	4.6 (4.6)	6.6 ×(6.3)
250ht	3.3 ×(3.2)	3.9 ✓(3.9)	5.7 ✓(5.9)	8.2 ×(8.1)
850temp	1.9 ×(1.8)	2.2 (2.1)	2.7 (2.7)	3.4 (3.4)
500temp	1.5 (1.5)	1.7 (1.7)	2.3 ✓(2.4)	3.1 ✓(3.2)
250temp	2.0 ✓(2.0)	2.3 ✓(2.3)	2.8 ×(2.7)	3.5 (3.5)
850wind	9.4 ✓(9.7)	10.7✓(10.8)	13.5 (13.6)	16.9×(16.4)
500wind	11.7 (11.7)	14.1✓(14.4)	18.3✓(18.5)	23.8×(23.2)
250wind	14.6✓(15.2)	17.2✓(17.5)	22.7✓(23.4)	30.8 (30.5)
700rh	23.2 (23.3)	23.9✓(24.5)	27.7✓(27.9)	30.6 (30.5)

Table 6 forecast verif for Area 2 (Atlantic sector)

Overall we see an improvement in forecast verification for Area 2 in the trial with 21 of the above statistics showing the trial to be better and only 9 showing the trial to be worse, with the remaining 14 being within 1%. There does appear to be some relative deterioration in trial results between T+48 and T+72 , as in the Area 200 results. Examining individual cases we see that the trial performed particularly badly for several cases based on analyses made around Christmas Day. For instance, if the forecasts from DT 25th and 26th are excluded , the remaining 11 cases taken together actually verify better than operational for T+72 500mb heights. These poor forecasts are considered further in the subjective assessment .

One further point noted when we examined statistics for individual cases was that the three cases which were based on only a one cycle spinup did not score as well as the others for upper winds. Leaving these cases out of the sample gives comparative rms 250mb vector wind errors of 17.0 knots for the trial against 17.8 knots operationally at T+24. This 1 knot advantage for the new scheme is probably a truer reflection of its performance.

3. Subjective Assessment

The outcome of the August trial , which suggested that the performance in the medium range merited further investigation, has led us to concentrate on T+72 northern hemisphere forecasts in this subjective assessment. The southern hemisphere pmsl forecasts and the northern hemisphere short period wind forecasts were also briefly examined for differences.

One feature of note in the southern hemisphere was a low near Southern Chile at 12GMT 29 December which was forecast consistently better by the trial at all forecast periods.

No differences of any significance were noted in the comparison of northern hemisphere upper winds at T+12 and T+24. The forecasts from trial analyses did appeared to be slightly smoother. There was also a slight tendency for the trial forecasts to have weaker winds. Out of 81 jets compared, the operational forecasts were stronger on 64 jets , with the trial being stronger on 15 jets. The differences were generally small, however, with even the strongest jets (>120kts) differing by no more than 5kts.

For the purposes of this subjective assessment, we shall concentrate on those trial forecasts which were based on AC assimilations of more than just a few cycles . Excluding from the total of 13 cases those cases which started within 1 day of the trial assimilation cycle being started (or restarted) , leaves us with 9 forecasts (data times 12GMT on 24th - 29th inclusive, 31st, 3rd and 4th). Figures 1-4 give a sequence of North Atlantic objective analyses of surface pressure from 27th December - 9th January which serve as a verification of the forecasts. The forecast comparison is presented in figures 5-13 with the trial T+72 North Atlantic surface pressure forecast at *(a)* and the comparable operational forecast at *(b)* in these figures. Note that the lower pair of figures *(c* and *d)* contain T+120 forecasts which are discussed in the next section.

A few brief comments on the main areas of difference between the pairs of T+72 forecast charts follows:

DT 24th No significant differences between the two forecasts, both are showing similar evolutions in the Atlantic which differ in substantial details from the actual evolution. The operational forecast has the main Atlantic low rather nearer to the actual depth of the low in mid-Atlantic but it is probably not the same low. *(compare figures 5a and 5b with verification in figure 1a).*

DT 25th The trial has a more accurate position for the upper vortex SW of Iceland and is correctly 2mb deeper with Atlantic low . The trial also has a better position, depth and shape of low complex over northern Scandanavia/NE Russia, whilst the operational run has correctly put rather less emphasis on the spurious feature in the southern Baltic. *(compare figures 6a and 6b with verification in figure 1b).*

DT 26th The trial is very much better with the Atlantic low south of 50°N, with the central pressure at 984 mb being almost exactly right compared with an operational value which was 19mb too deep. The trial forecast of the northernmost Atlantic low is not far enough west. *(compare figures 7a and 7b with verification in figure 1c).*

DT 27th The trial has a better shape, position and depth of the central Atlantic low . It is also better with the low east of the Baltic. The operational forecast is correctly slightly deeper with Newfoundland low. *(compare figures 8a and 8b with verification in figure 1d).*

DT 28th Both accurate forecasts, with the trial positioning the two main lows near Newfoundland and Scotland rather more accurately. Both forecasts of the low near Scotland are too shallow , but the operational forecast is marginally deeper and that together with its positional error gives it a better wind forecast for the North Sea. *(compare figures 9a and 9b with verification in figure 2a).*

DT 29th Both forecasts similar and fairly accurate. The trial has correctly retained a hint of the decaying low to the west of Norway. *(compare figures 10a and 10b with verification in figure 2b).*

DT 31st Both similar with the Baltic low, being slightly too far east. The low near south Norway is rather more accurate in the trial forecast which has therefore got a better portrayal of the wind flow in the sea areas around the UK. The extent of the northerly flow between 0° and 10°W in the operational run is slightly misleading. Both forecasts are more than 10mb out with a developing low at 52°N, 30°W, but the trial correctly puts less emphasis on the ridge between the two systems. *(compare figures 11a and 11b with verification in figure 2d).*

DT 3rd Both runs have the low near the UK much too far north, although the operational run is correctly deeper. Both have similar, good forecasts of the west Atlantic low. *(compare figures 12a and 12b with verification in figure 3c).*

DT 4th There are no obvious differences between the runs , both have the same minor positional errors. *(compare figures 13a and 13b with verification in figure 3d.*

Although the objective verification suggested that the trial was performing less well at the surface in the Atlantic sector at T+72, the charts do not confirm this impression. The forecasts are generally quite similar, perhaps more alike than we have come to expect from previous trials. Only three cases, if interpreted exactly, might result in a different emphasis being put on the UK forecast. The operational forecast from 27th, incorrectly advances the trough over Ireland (fig 8b); the trial forecast from 28th has insufficient gradient in the North Sea (fig 9a); the operational forecast from 31st suggests too much of a northerly flow (fig 11b). I have noted rather more plus points for the trial forecasts than for the operational forecasts, but of course the reader is free to make his own judgement. By far the largest error occurs in an operational forecast (19mb too deep with Atlantic low from DT 12GMT 26th).

4 Results from extended range forecasts

Although not part of the original trial, the 9 forecasts discussed above were continued for another 2 days to assess the impact which the trial assimilation scheme had upon the extended range forecasts, given the apparent relative deterioration in trial results for the northern hemisphere at T+72. The forecast comparison is also presented in figures 5-13 with the trial T+120 North Atlantic surface pressure forecast at *(c)* and the comparable operational forecast at *(d)* in these figures, below the 3 day forecasts. The verification given in figures 1-4 is also valid for this T+120 comparison. The assessment at T+120 mirrored that undertaken for T+72.

4.1 Subjective verification of T+120 North Atlantic PMSL charts

A brief summary of the subjective comparison between the T+120 surface pressure forecasts for the Eastern USA, North Atlantic and European sector follows:

DT 24th — Both forecasts have a major low to the south-west of Iceland. The trial forecast is marginally slow with this system. The new low at 36°W, 47°N is suggested rather better on the operational run, both forecasts are slow with this development , but the trial is worse. The pattern over the UK is identically forecast. *(compare figures 5c and 5d with verification in figure 1c).*

DT 25th — In reality there is a ridge in mid-Atlantic with lows either side at 60°W and 20°W. Neither forecast captured the developments to the west associated with a deep upper vortex over Newfoundland. The trial forecast was better with the low to the west of Ireland both on position and depth and correctly indicated a strong southwesterly in the west of Ireland and more of a ridge over the eastern parts of the UK. *(compare figures 6c and 6d with verification in figure 1d).*

DT 26th — The low near Scotland is better positioned in the operational run, thus a southwesterly flow still persists over the eastern

UK. Despite this , the flow round this low is still in some respects better in the trial forecast, with the trough correctly positioned down the Irish Sea and the northwesterlies getting into Ireland . The ridge in mid-Atlantic is better positioned in the trial run. Further west the operational run is clearly better, with a single low much closer to Newfoundland. A look at the upper pattern confirms that the trial forecast has the main features advanced by some 10° of longitude. *(compare figures 7c and 7d with verification in figure 2a).*

DT 27th Both forecasts are wrong with the low near Denmark, which is tracked too far south as it crossed the UK. There are comparable errors with the main Atlantic low , with the trial forecast 5mb too shallow and the operational forecast 7mb too deep. The operational model has the edge near the UK as the trial has made rather too much of the ridge between the two low pressure systems. *(compare figures 8c and 8d with verification in figure 2b).*

DT 28th The forecasts are similar for the UK and east Atlantic with both being rather slow. Both have an erroneous low east of the Baltic, but this is 8mb less deep in the trial. The trial is also successful in west Atlantic where it correctly indicates a low developing near Newfoundland. *(compare figures 9c and 9d with verification in figure 2c).*

DT 29th Both forecasts similar over Europe with the low pressure area too far south over Denmark, although the operational forecast has a marginally more correct flow to the west of this low. The detailed development in mid-Atlantic also follows a similar erroneous path, as both forecasts make too much of the upper ridge and have the next surface development too far north. *(compare figures 10c and 10d with verification in figure 2d).*

DT 31st The trial is better near the UK because it has some indication of the second low at 50°N ,west of Ireland and thus has a much better wind direction and strength over the UK and the North Sea. The trial also has a better depth for the Newfoundland low (987mb to 999mb compared with a verifying 976mb). *(compare figures 11c and 11d with verification in figure 3b).*

DT 3rd Both runs have comparable errors in the detail of the complex Atlantic low pressure area, resulting from the upper trough being too slow, although the trial has a better depth in that trough. The operational forecast makes too much of the ridge/trough pattern over the UK and North Sea which does not verify as the forecast is slow and out of phase with reality. *(compare figures 12c and 12d with verification in figure 4a).*

DT 4th Both good 5 day forecasts near the UK. The operational forecast of the Iceland low has a depth closer to verification but incorrectly weakens the gradient to the south of the low compared with the trial. The trial has a better position with the low near

Newfoundland. *(compare figures 13c and 13d with verification in figure 4b.*

On the evidence we have from these case studies , the subjective scores balance with no clear advantage at 5 days for either trial or operational runs during this period. For the UK area, the operational forecasts from the 26th, 27th and 29th receive more praise , whilst the trial forecasts from the 25th, 31st and 3rd gain higher marks.

4.2 Objective verification of extended range forecasts

Table 7 shows the pmsl and 500mb height rms errors for the 9 extended range forecasts , comparing the trial against both the operational forecasts and those from ECMWF. Looking first at the trial/operational comparison, we see that the trend which was established at T+72 is continued through T+96 and T+120. The trial is superior to the operational forecasts in the tropics and southern hemisphere but is giving worse results in the northern hemisphere during this period.

	T+96			T+120		
	AC	OP	EC	AC	OP	EC
Area 200						
pmsl	7.6	(7.3)	[7.6]	9.3	(8.6)	[8.7]
500ht	7.6	(7.5)	[7.4]	9.1	(8.5)	[9.1]
Area 300						
pmsl	3.3	(3.2)	[3.1]	3.3	(3.4)	[3.4]
500ht	3.8	(4.0)	[2.8]	3.9	(4.1)	[3.1]
Area 400						
pmsl	5.4	(5.9)	[5.2]	6.1	(6.9)	[6.0]
500ht	7.0	(7.0)	[5.3]	8.1	(8.5)	[6.4]
Area 2						
pmsl	8.1	(7.7)	[8.9]	10.5	(9.2)	[10.2]
500ht	8.5	(8.2)	[9.0]	10.3	(8.9)	[11.3]

Table 7 Forecast Verification at T+96, 120
for AC trial, operational and ECMWF

Several conclusions can be drawn from the comparison with ECMWF. Firstly, there is a clear signal that the trial results are midway between the operational and ECMWF results, with the trial taking second place in the three-way comparison for 11 of the 16 statistics in table 7. In the southern hemisphere where ECMWF has a clear lead during this period, the trial takes second place to ECMWF for 3 of the 4 statistics and approaches quite close to the ECMWF scores for pmsl. In the North Atlantic sector the operational forecasts are showing a clear lead over both the trial and ECMWF . Here we see the trial once again taking second place for 3 of the 4 statistics .

The second point of interest in table 7 is that it is unusual for the Met. Office operational model to score better than the ECMWF model in the North Atlantic sector. Monthly comparison of operational results during the past year show, for instance, that at T+96 over Area 2, ECMWF rms pmsl errors are lower than those of the Met. Office model for every month by margins varying between 1% and 15%. During the period January 1987-March 1988, comparative results for the operational and ECMWF forecasts were available on 307 occasions. Examining these results, it was noted that ECMWF rms errors were lower by more than 20% for both pmsl and 500mb heights over the North Atlantic at T+96 and T+120 on 39 occasions (13%), whereas the operational Met Office forecast was better by the same measure on only 9 occasions (3%).

Looking more closely at the results from individual T+120 pmsl forecasts, we see that the trial and operational forecasts in the northern hemisphere are closer than the overall rms error for all 9 cases suggests. Table 8 below notes the number of individual successes (measured as a lower rms error) . The trial forecasts are more successful relative to ECMWF than are the operational forecasts for all verification areas including the northern hemisphere and the North Atlantic.

	AREA 200	AREA 300	AREA 400	AREA 2
AC better than OP	3	5	8	4
AC worse than OP	5	2	1	5
AC better than EC	4	6	4	6
AC worse than EC	5	3	5	3
OP better than EC	3	3	2	5
OP worse than EC	5	4	6	4

Table 7

Summary of comparison of results for individual T+120 PMSL forecasts

The statistics for area 2 in Table 7 show a clear lead for the operational forecasts over the trial despite only a narrow lead 5 to 4 on a count of individual cases (as given in Table 8). Several of the poorer trial forecasts were substantially worse and it is interesting to note that 2 of the 9 occasions mentioned above when ECMWF scored much worse than the Met Office operational forecast fell during the trial period (DT 25th, 26th Dec) and on both these cases the trial performed poorly, when measured objectively, compared with the operational forecast and yet was comparable with ECMWF. The 26th December case has been the subject of a more in depth investigation *(Macpherson and Downton, 1988)*. Further confirmation of the relative behaviour of extended range forecasts from trial analyses of cases where substantial differences have occurred between the operational forecasts of the Met Office and ECMWF has been sought and the results of this study are documented in *Downton et. al. (1988)*

5. Conclusion

The most significant difference between these results and those for the previous trial is the relative improvement in wind errors which are better than operational for most levels/area/times. The wind results presented in Tables 3-5, favour the trial by a margin of 18 to 2 with the remaining results being within 1%. Comparable figures for the August trial period were 14 trial better/15 control better. We also see an overall change in the balance of the objective scores for surface pressure, with the trial having the advantage in 8 of the 12 statistics for pmsl in tables 3-5 compared with only 3 statistics where the operational version is better. Here the comparable figures in the August trial were 4 trial better/6 control better.

The improved results in the early stages of the forecast are the most obvious benefit to be derived from the new analysis scheme. Here we see an overwhelming advantage at T+6 (see table 1), which is clearly retained at least until T+48. Upper wind rms scores for aviation seem likely to improve by between ½-1 knot in these short term forecasts. The advantage to the trial continues to T+72 in the southern hemisphere . Several poor trial forecasts in the northern hemisphere give the operational run an overall advantage at T+72, but this advantage does not show in the subjective assessment.

The forecasts at T+120 show that the trial scheme gives results intermediate between those from the present operational scheme and ECMWF, with the trial runs beating ECMWF more frequently than the operational runs. The trends noted at T+72 continue out to T+120, with the trial being superior in the tropics and southern hemisphere. However, two particularly poor trial forecasts result in the overall advantage going to the operational scheme in the northern hemisphere. Only one of those cases could be marked as a clear failure subjectively and this case , DT 12GMT 26th December, as has already been mentioned, is the subject of a more detailed study *(Macpherson and Downton, 1988)*. The poor cases have been shown to be cases when ECMWF also compared badly with the operational forecasts. Such events usually only occur with a frequency of 1 in 30, compared to the opposite situation of ECMWF being substantially better which occur 4 times more frequently. *Downton et al (1988)* have confirmed the usually desirable tendency of the new scheme to give results more like those of ECMWF in cases where substantial differences occur.

One objective of the new analysis scheme was to enable a larger sphere of influence to be given to observations, which would give smoother assimilation increment fields and also help make more effective use of observations in more data sparse areas. In these respects we are providing an analysis which is becoming more characteristic of the ECMWF analysis. Although the main difference between the two centres, the use of a repeated insertion technique at the Met Office compared with a more conventional statistical interpolation/normal mode initialisation at ECMWF, is maintained with the analysis correction scheme, with the additional sophistication of insertion of observations around their validity time. It should not be surprising that the forecast results from the trial are midway between the results from the two operational systems. *Downton and Bell (1988)* have documented one case study of a particularly poor operational forecast relative to ECMWFs forecast which was much improved when the AC assimilation was used.

Acknowledgements

The assistance of David Robinson, who provided the objective verification results ,and also that of Robin Downton, who undertook some of the subjective assessment, is appreciated.

List of Figures

References

Bell R.S.	1987	An assessment of the results of trials of a new analysis scheme for the operational global model *Met O 11 TN No 1*
Downton R.A., Bell R.S.	1988	A case study showing the impact of analysis differences on medium range forecasts *Met O 11 TN No 2*
Lorenc A.C., Dumelow R.K.	1987	Four dimensional Analysis by repeated insertion of observations in the Meteorological Office NWP model, *Met O 11 TN No 224*
Macpherson B.	1988	Development of the Analysis Correction scheme- Part II- inclusion of an observation density analysis, *Met O 11 TN No 3*
Macpherson B, Downton R.	1988	Sensitivity of a medium range forecast with the analysis correction scheme to data selection in the horizontal, *Met O 11 TN No 15*
Downton R., Bromley R.A., Ayles M.A.	1988	The 5 day forecast trial of the AC scheme *Met O 11 TN No 12*

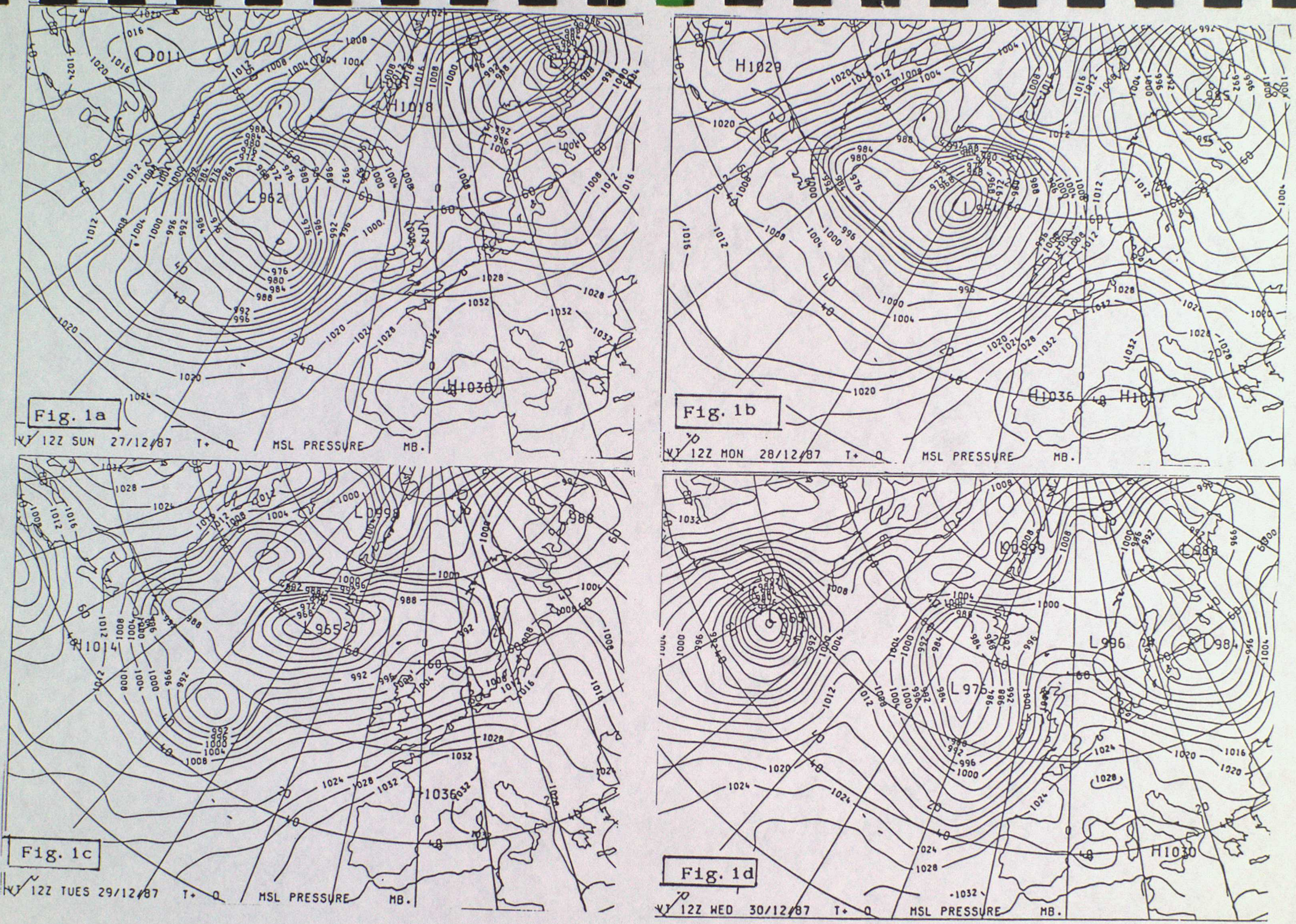


Figure 1 Verifying PMSL analyses

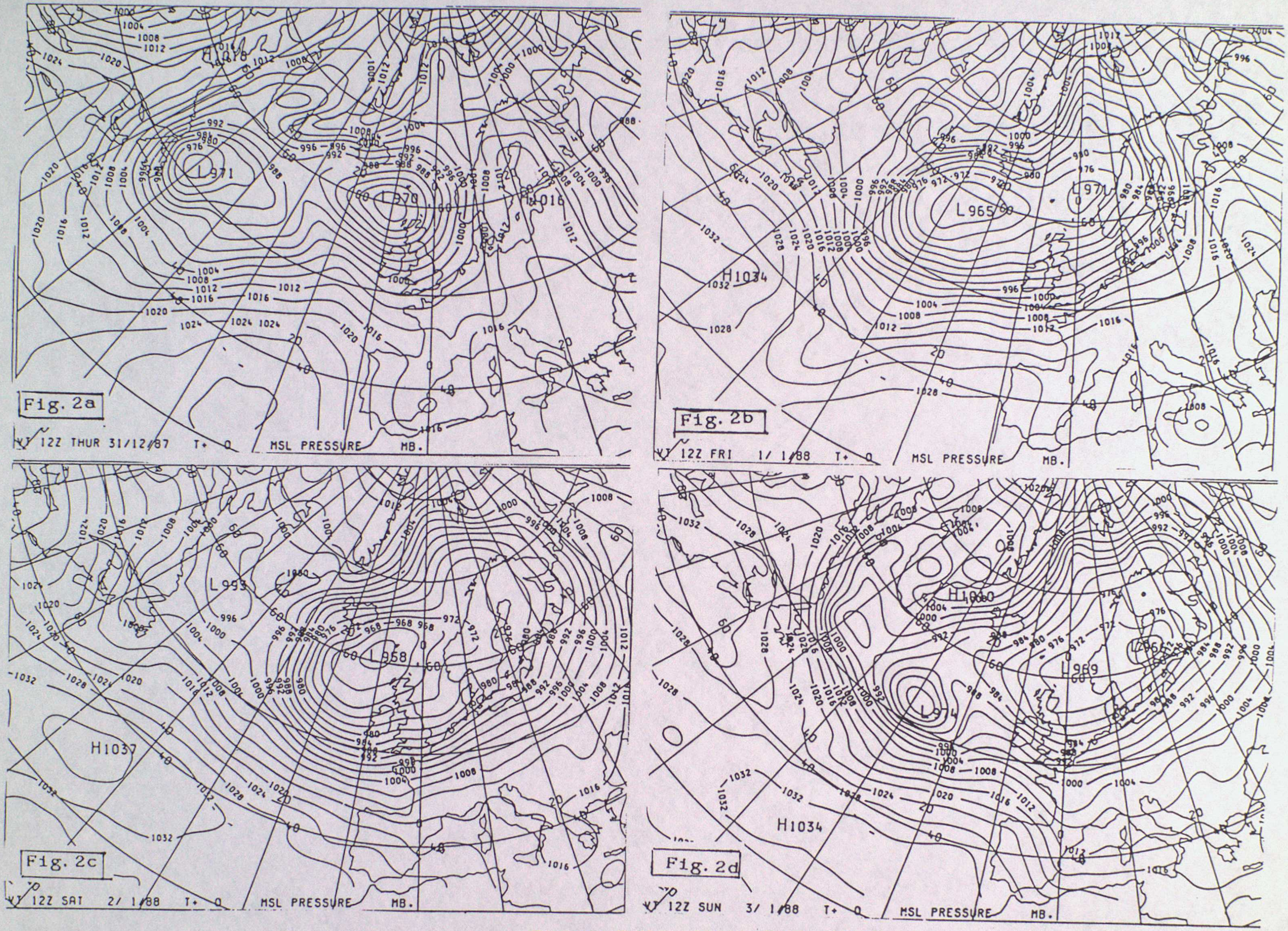
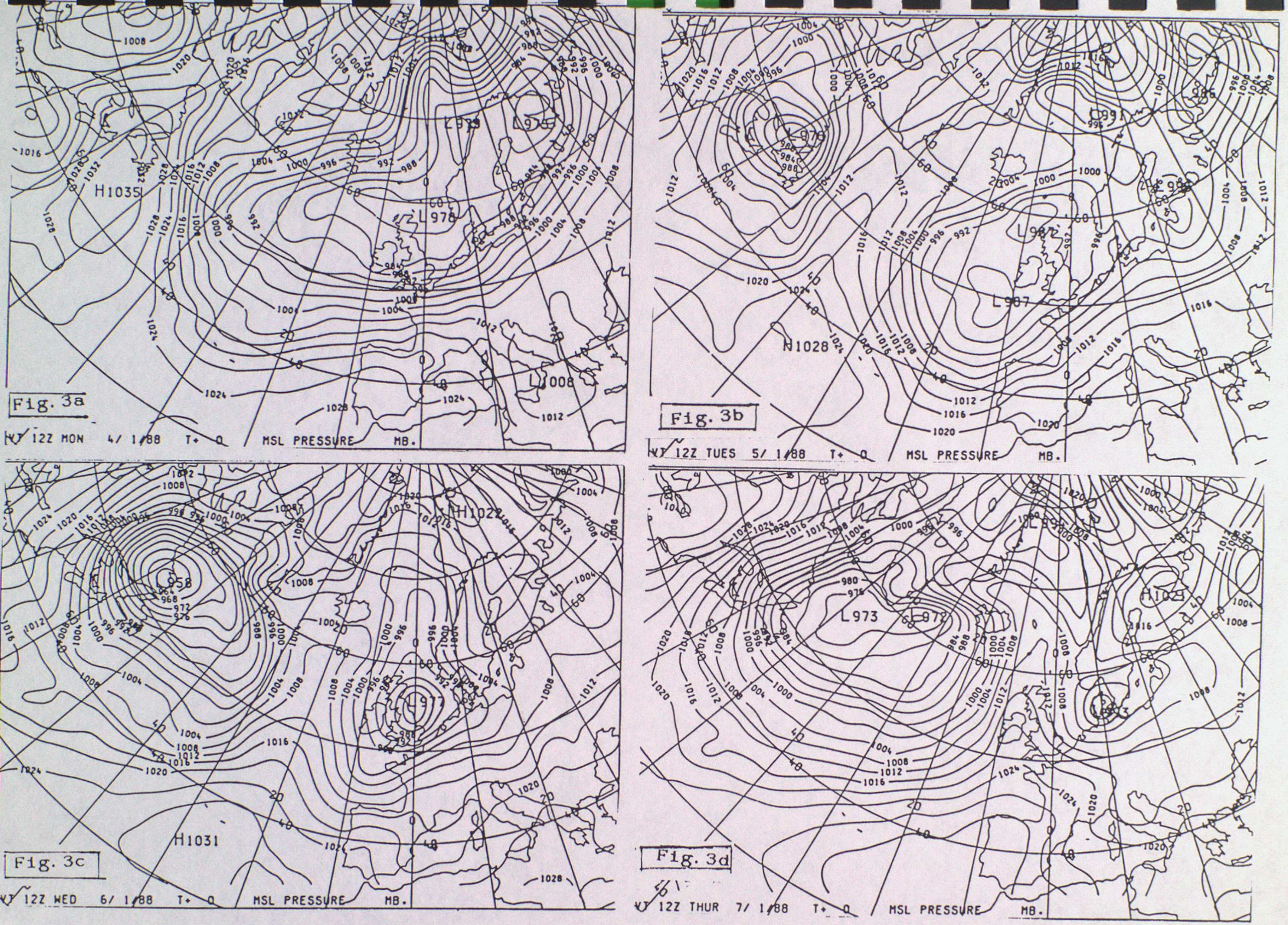


Figure 2 Verifying PMSL analyses



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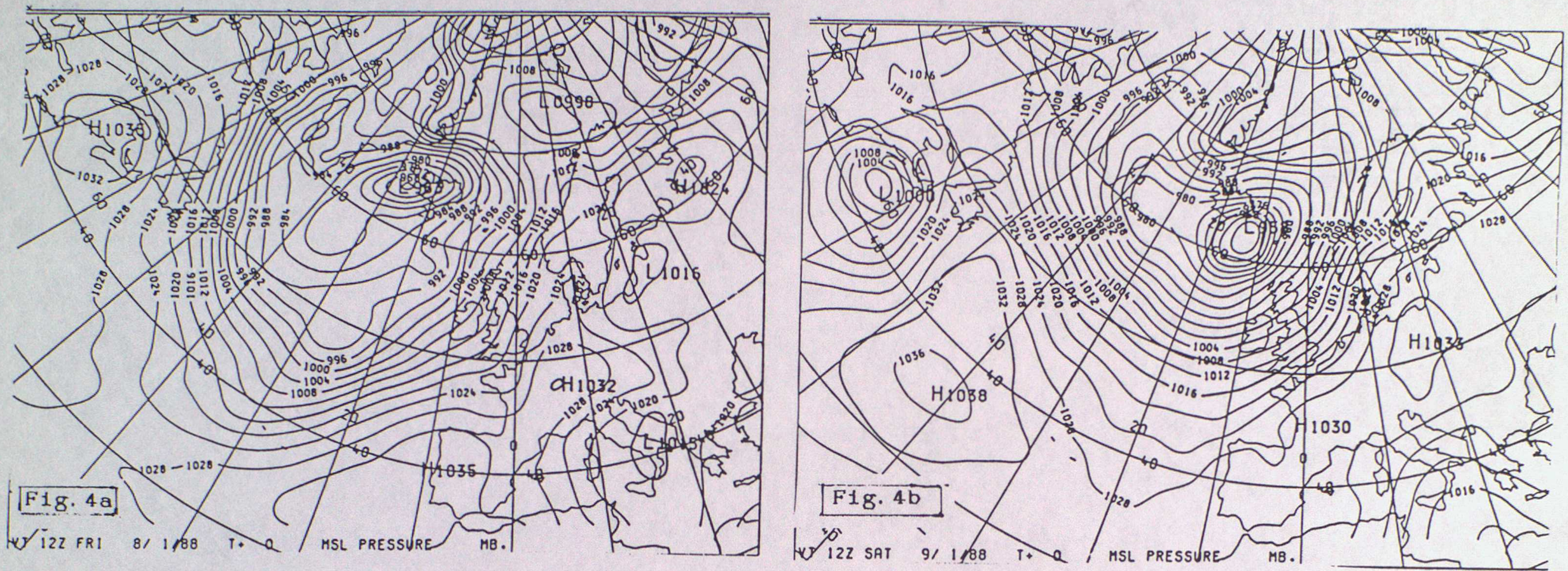


Figure 4 Verifying PMSL analyses

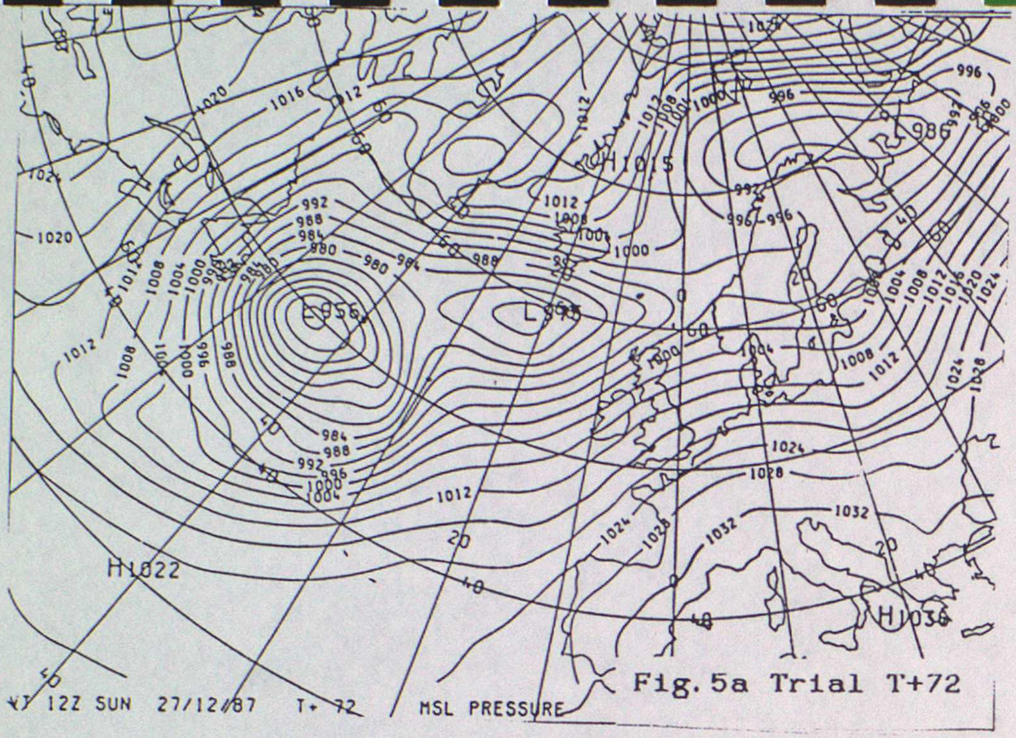


Fig.5a Trial T+72

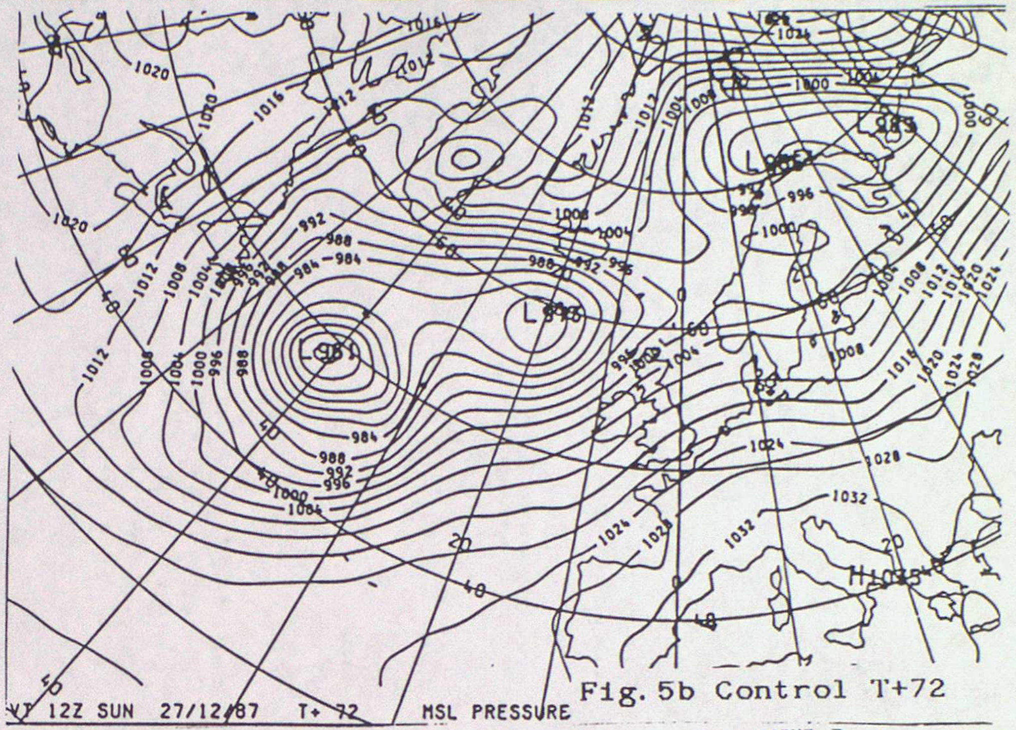


Fig.5b Control T+72

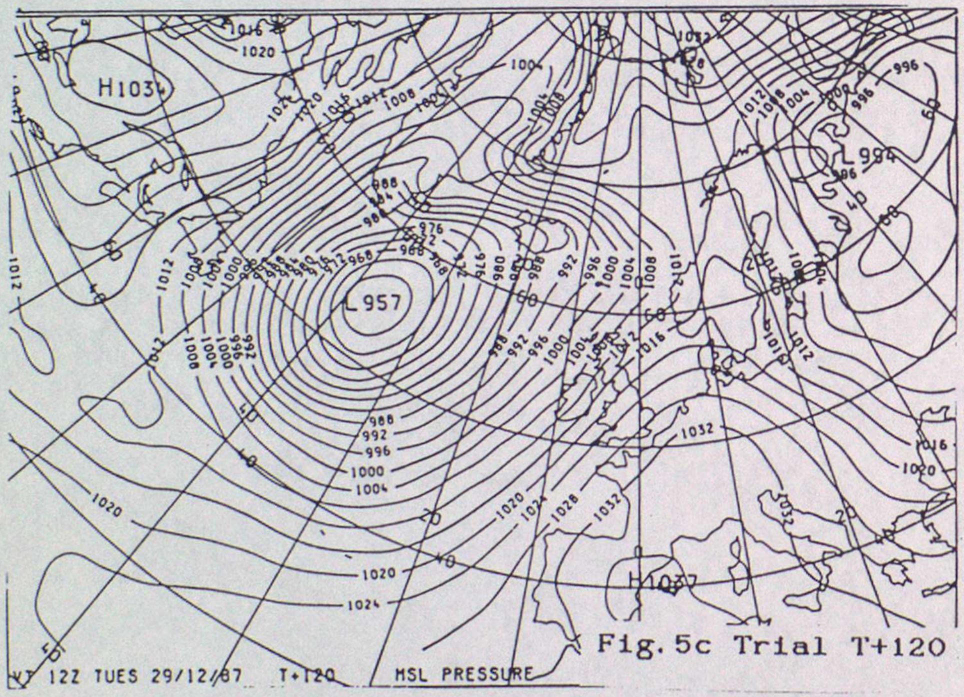


Fig.5c Trial T+120

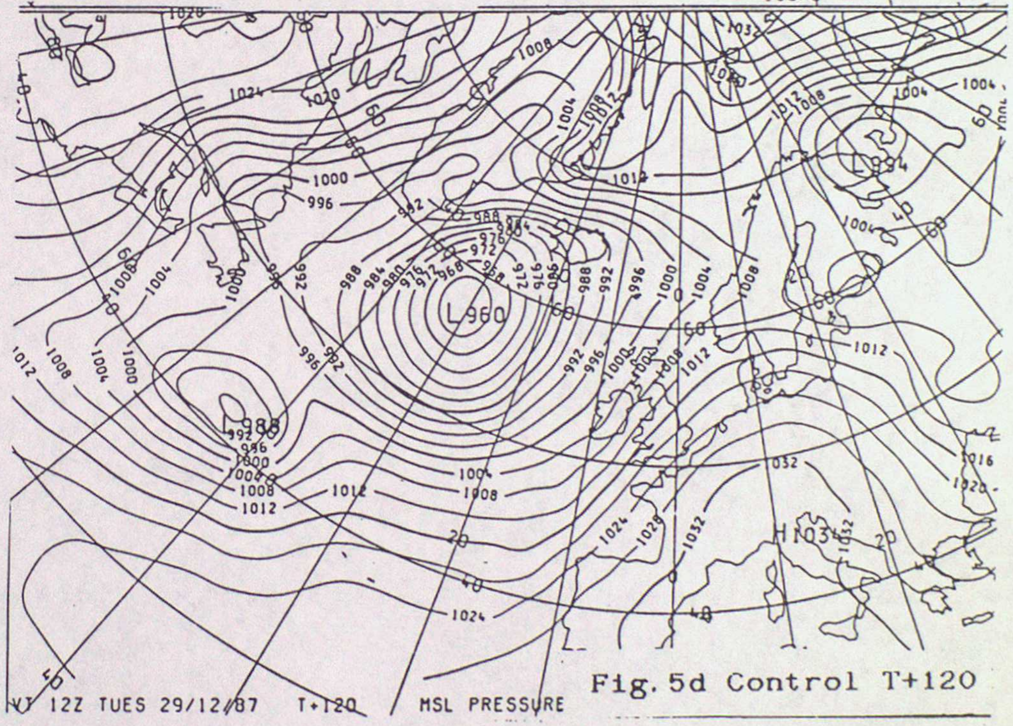


Fig.5d Control T+120

Figure 5 Comparison PMSL forecasts from DT 12GMT 24/12/87

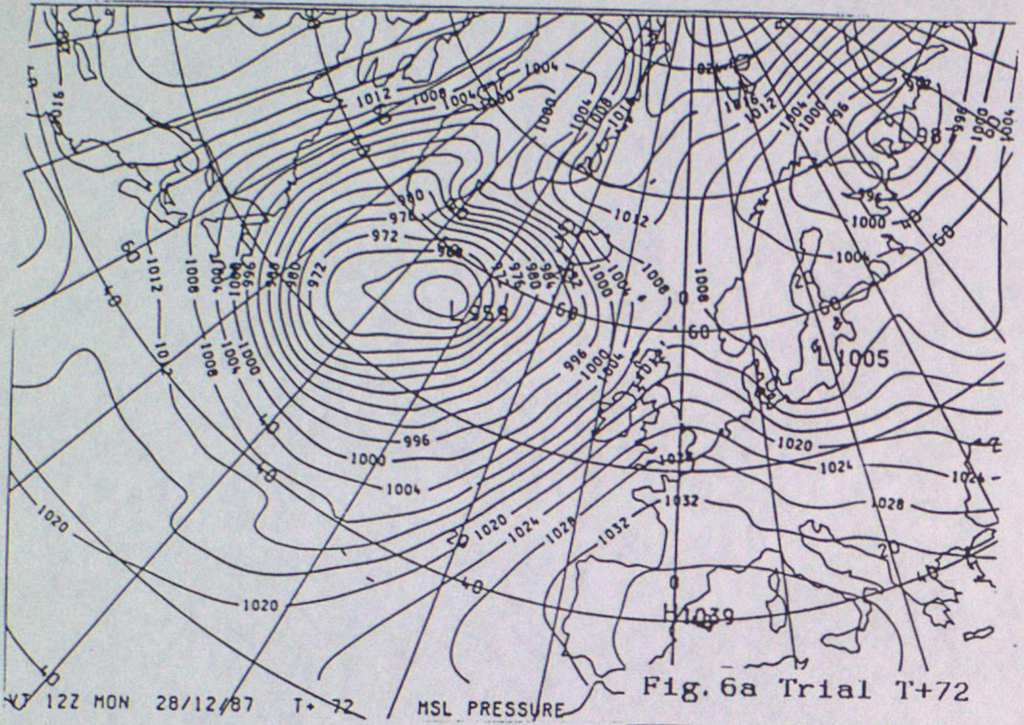


Fig. 6a Trial T+72

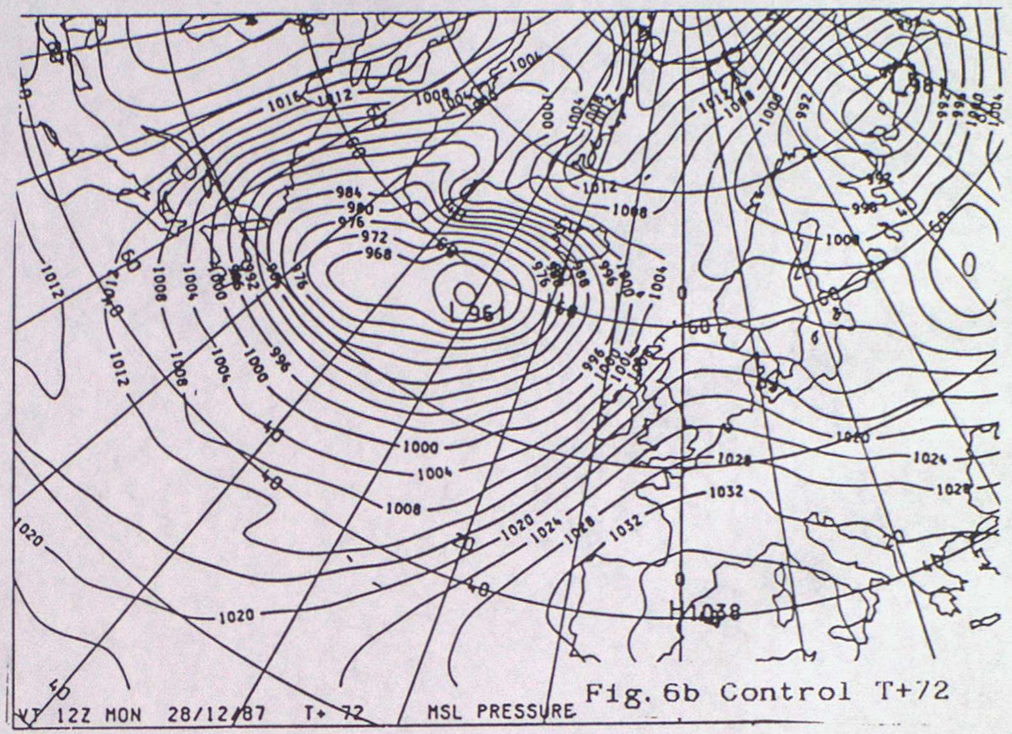


Fig. 6b Control T+72

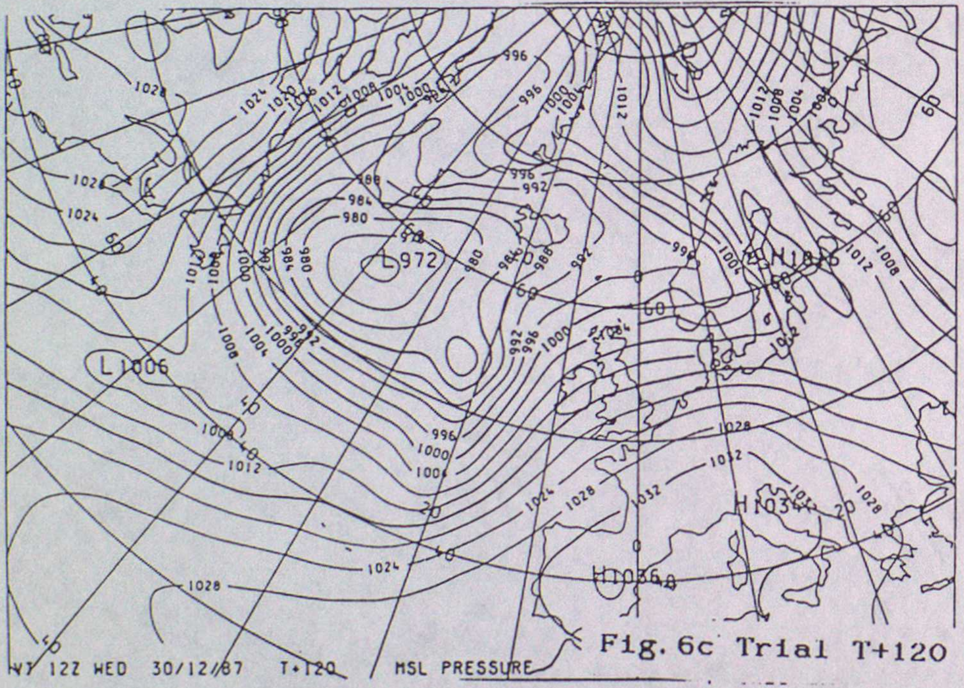


Fig. 6c Trial T+120

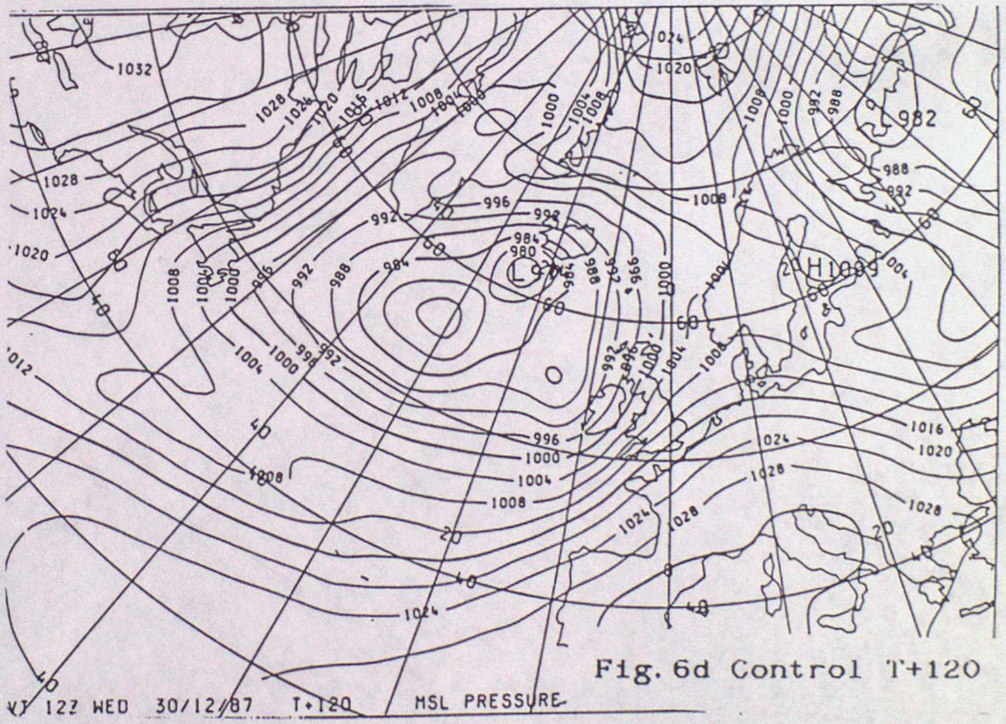


Fig. 6d Control T+120

Figure 6 Comparison PMSL forecasts from DT 12GMT

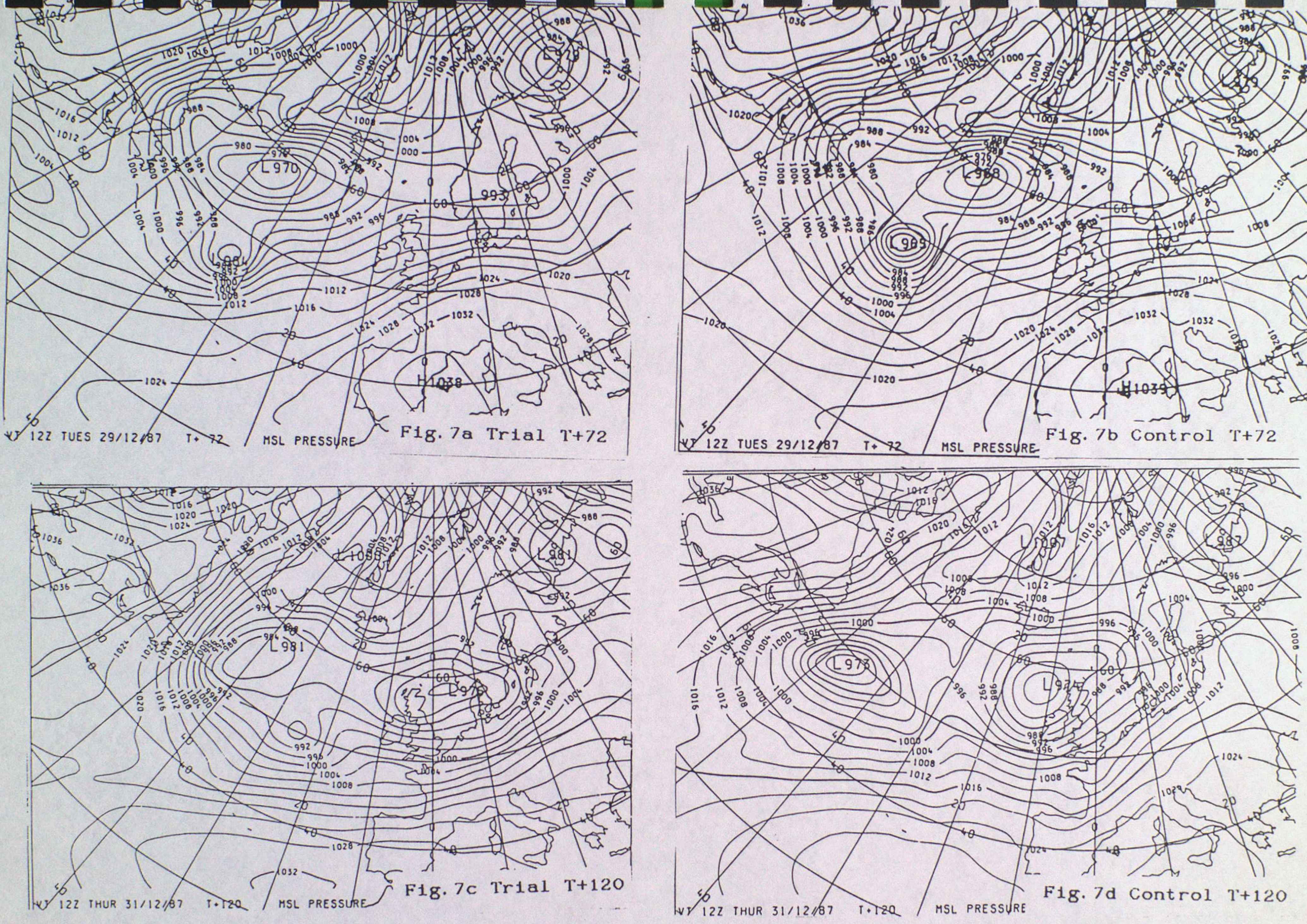


Fig. 7a Trial T+72

Fig. 7b Control T+72

Fig. 7c Trial T+120

Fig. 7d Control T+120

Figure 7 Comparison PMSL forecasts from DT 12GMT 26/12/87

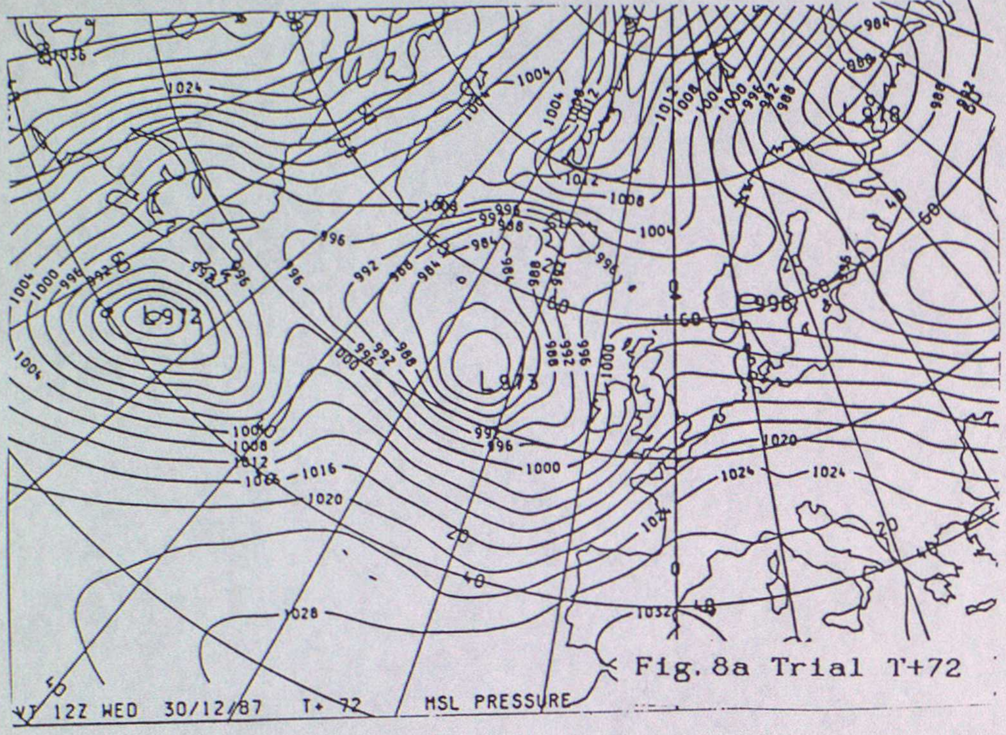


Fig. 8a Trial T+72

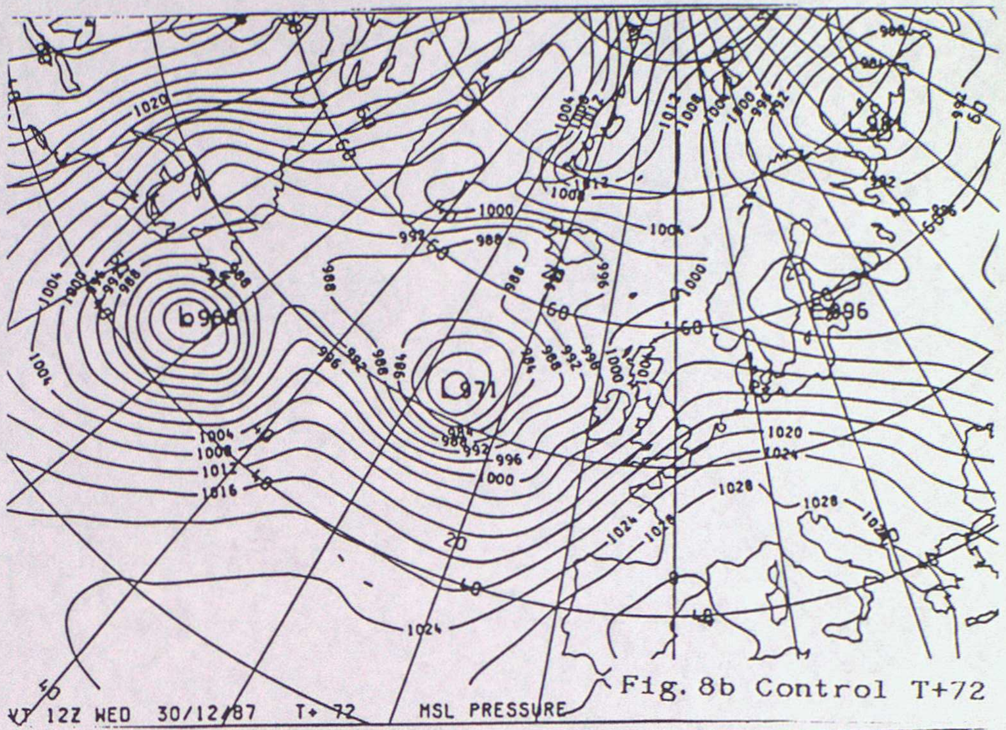
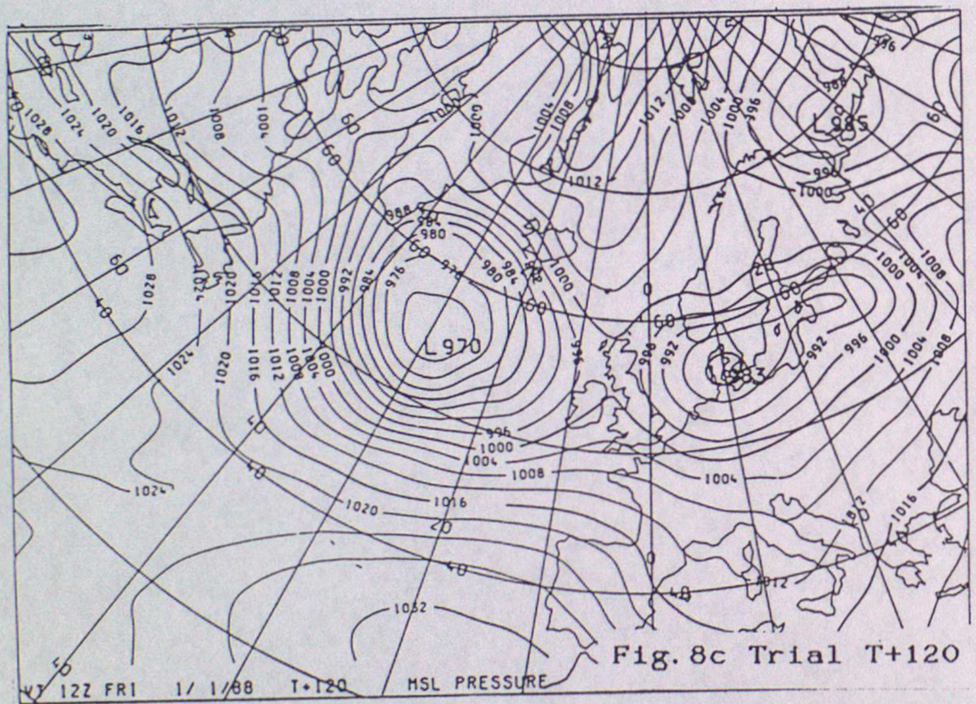


Fig. 8b Control T+72



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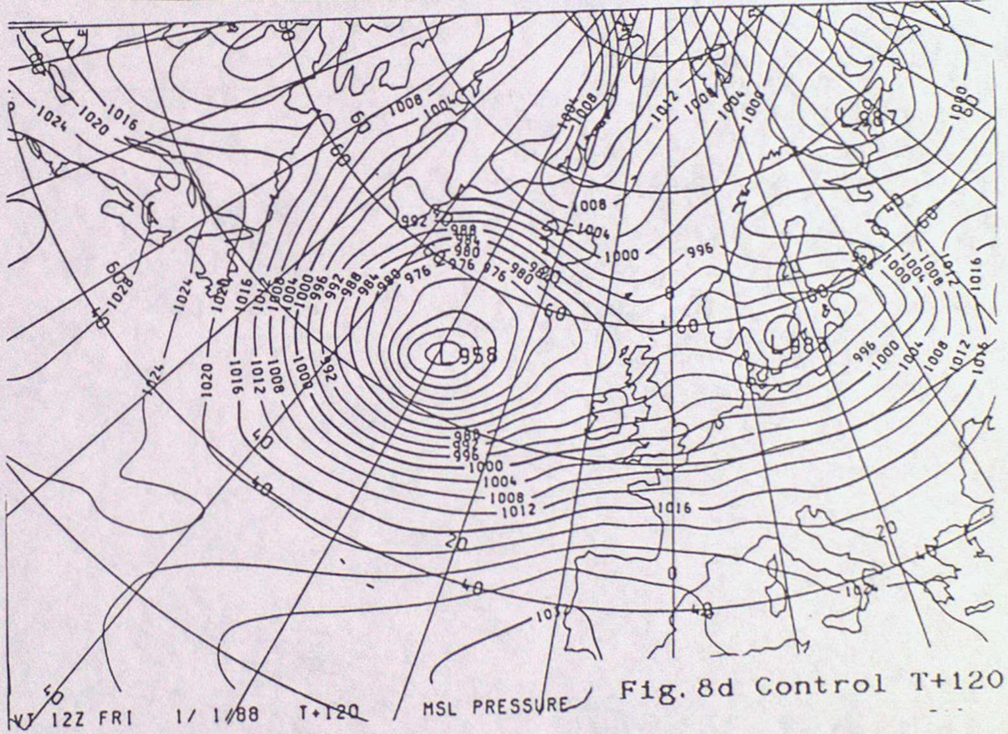


Fig. 8d Control T+120

Figure 8 Comparison PMSL forecasts from DT 12GMT 27/12/87

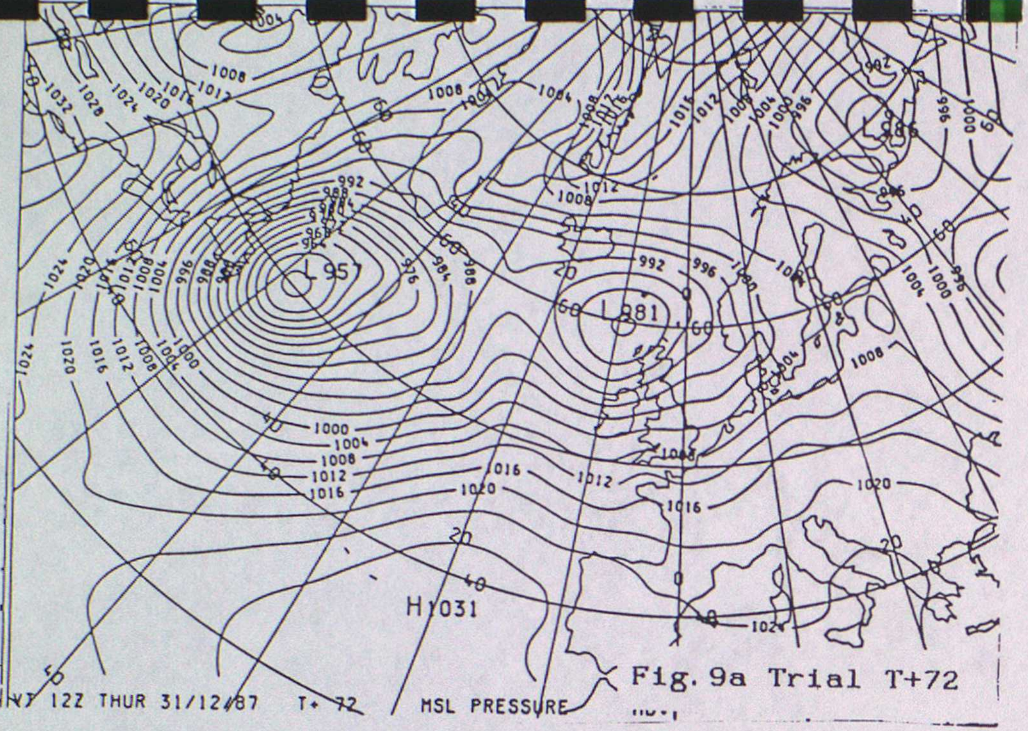


Fig. 9a Trial T+72

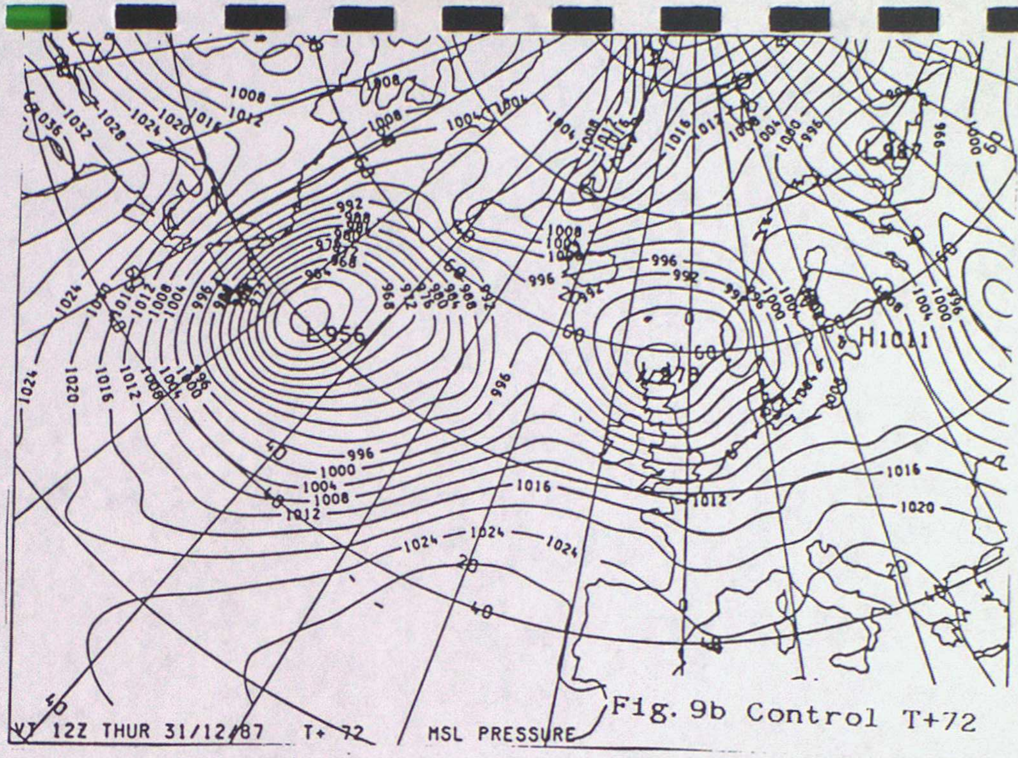


Fig. 9b Control T+72

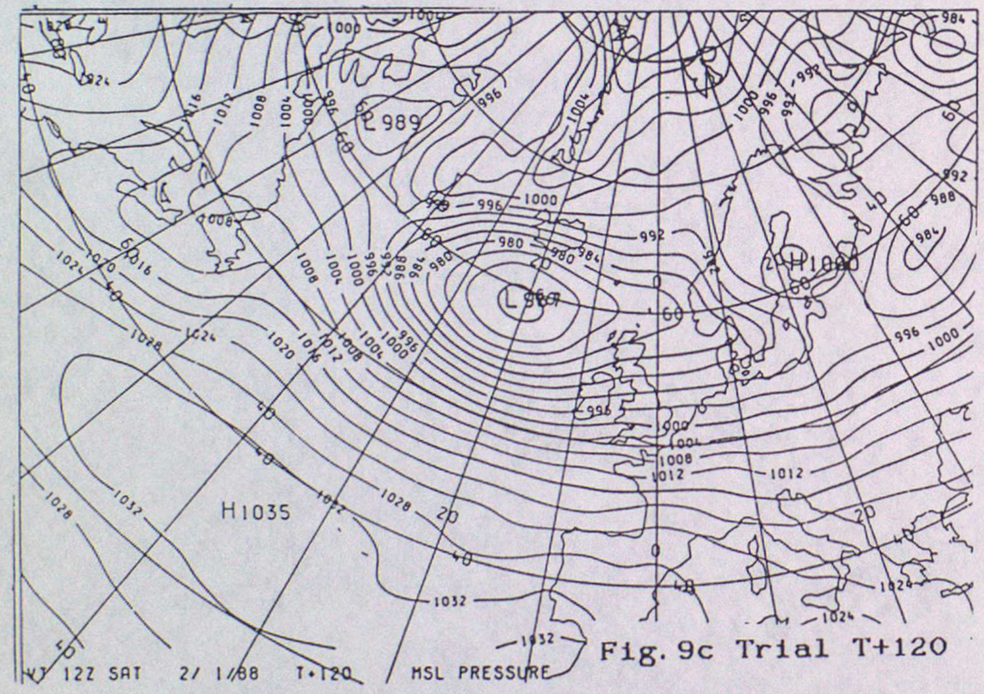


Fig. 9c Trial T+120

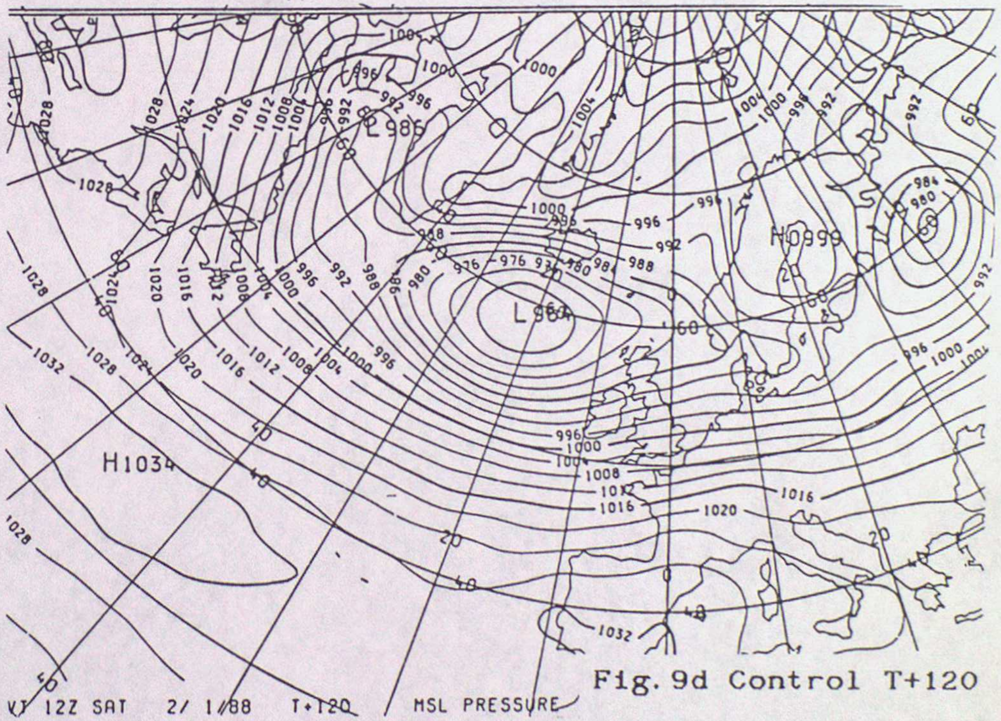


Fig. 9d Control T+120

Figure 9 Comparison PMSL forecasts from DT 12GMT 28/12/87

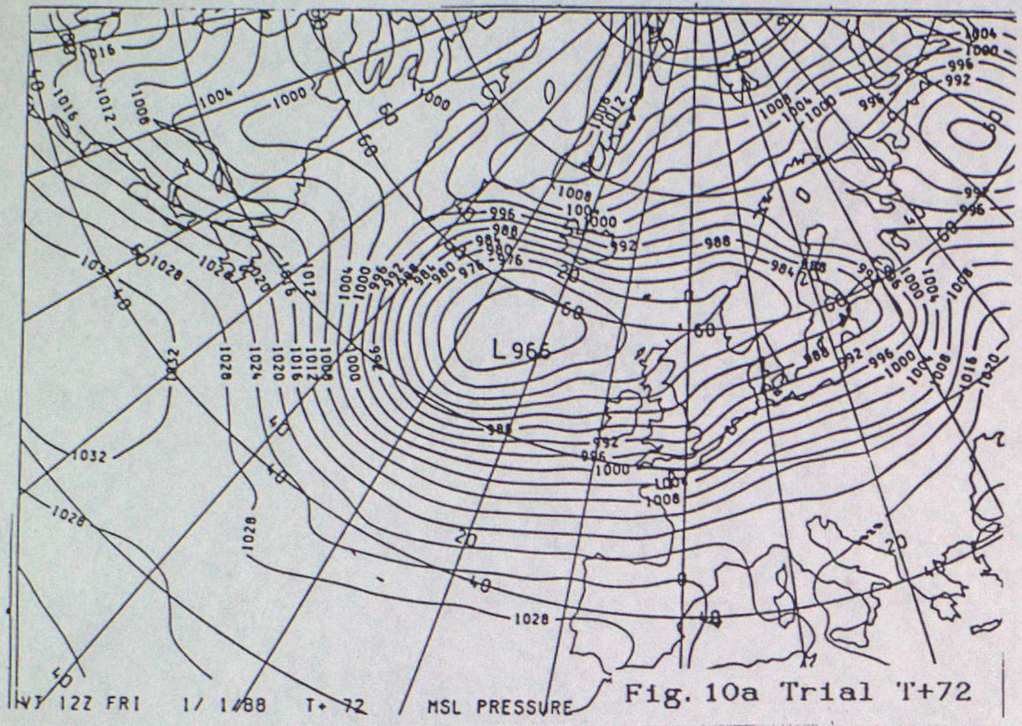
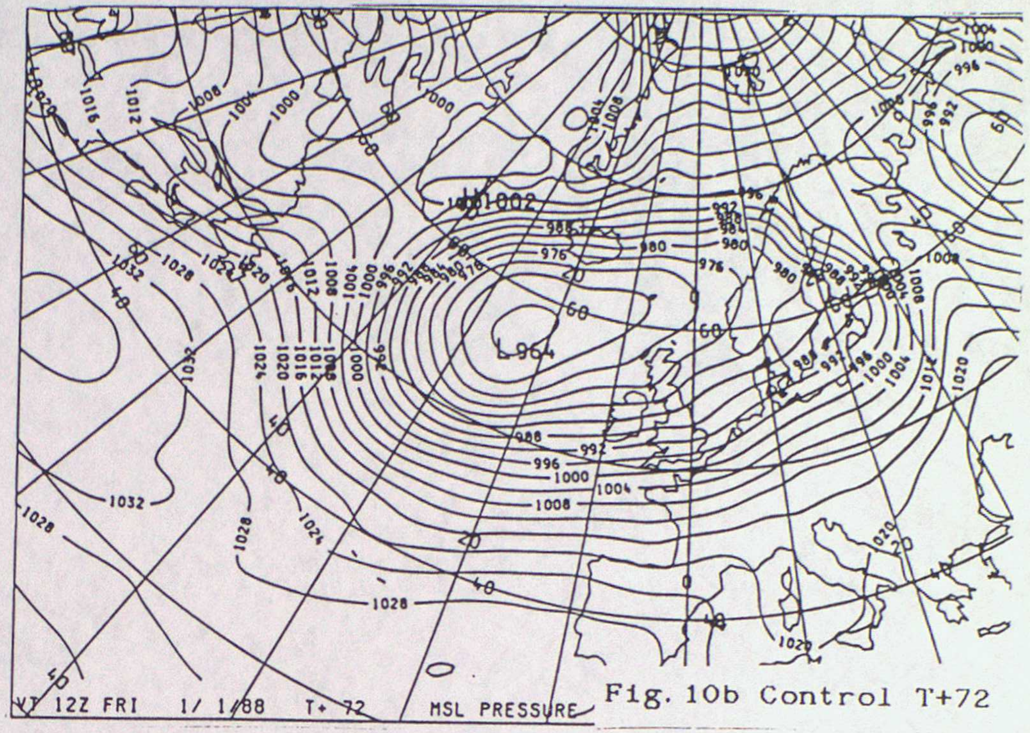


Fig. 10a Trial T+72



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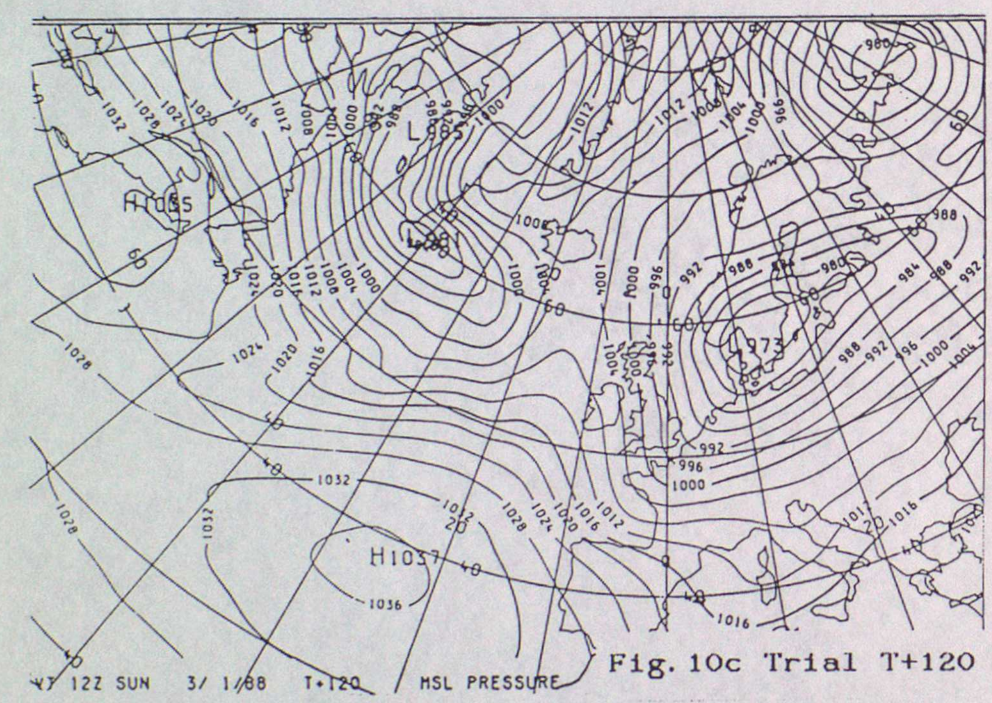


Fig. 10c Trial T+120

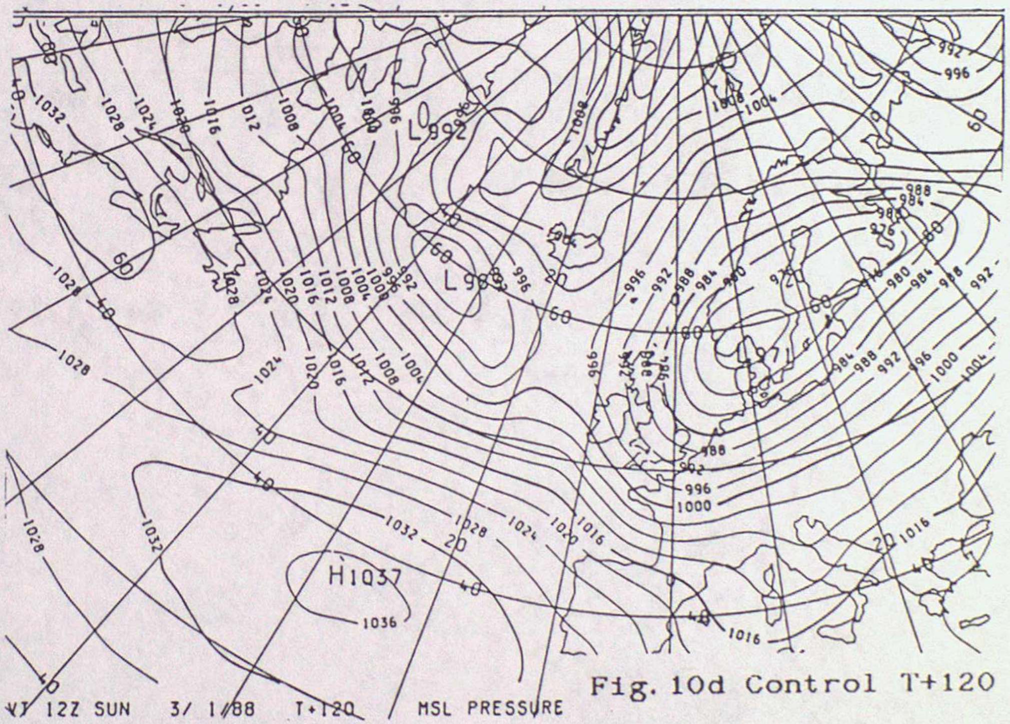


Fig. 10d Control T+120

Figure 10 Comparison PMSL forecasts from DT 12GMT 29/12/87

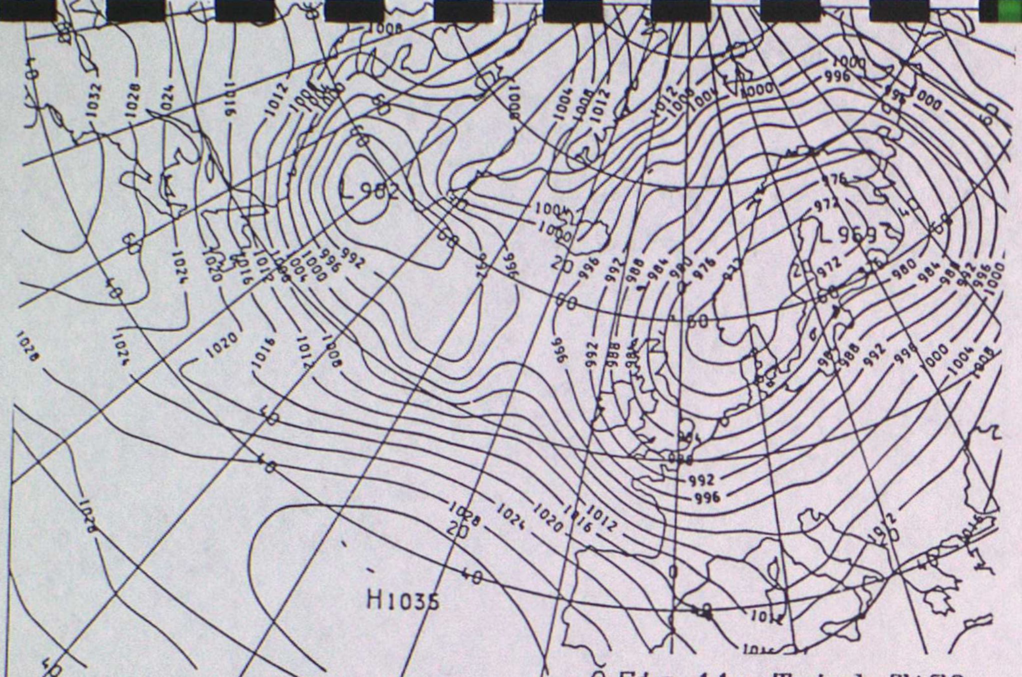
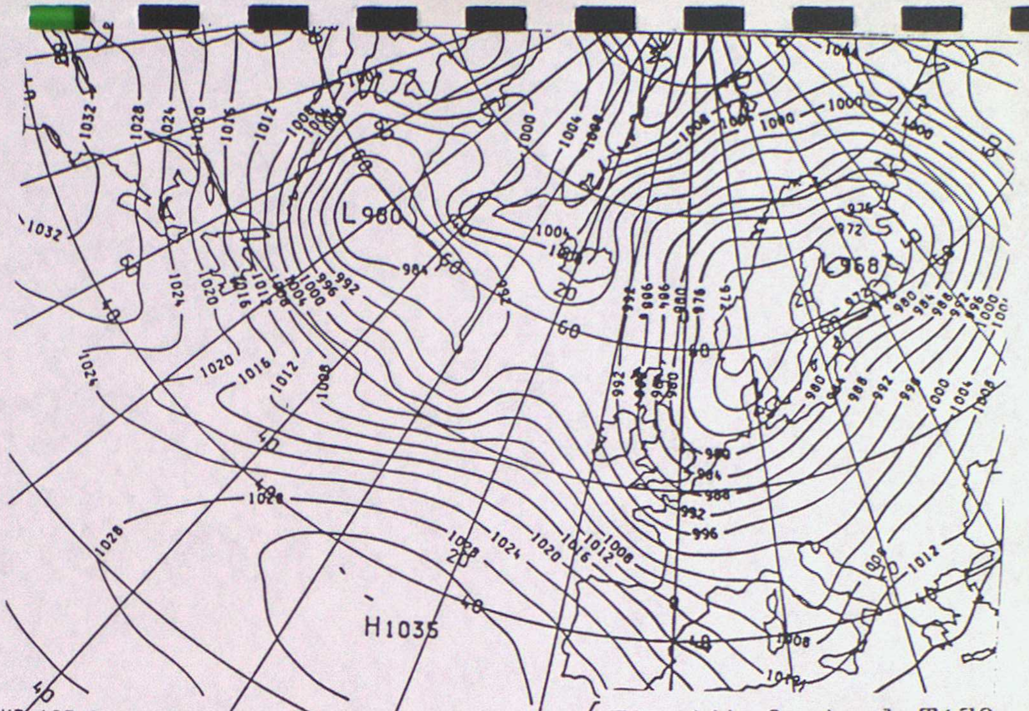


Fig. 11a Trial T+72



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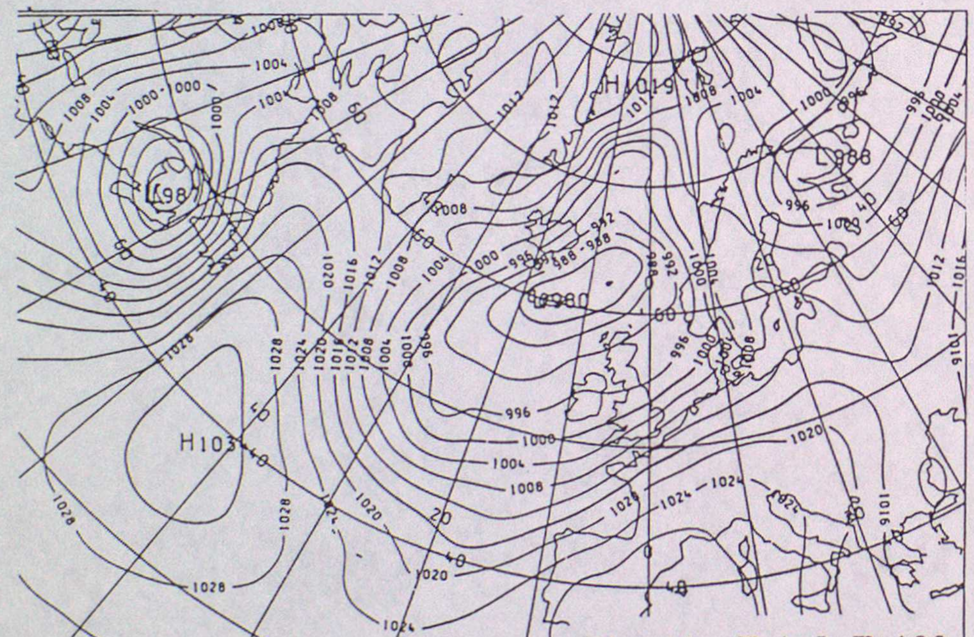

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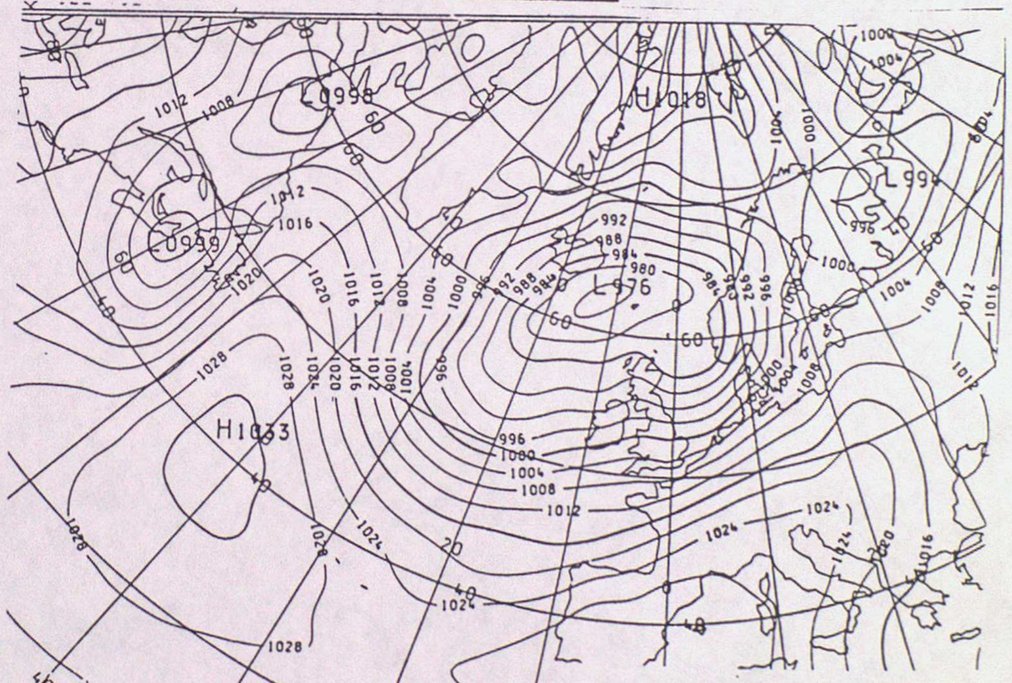

Fig. 11d Control T+120

Figure 11 Comparison PMSL forecasts from DT 12GMT 31/12/87

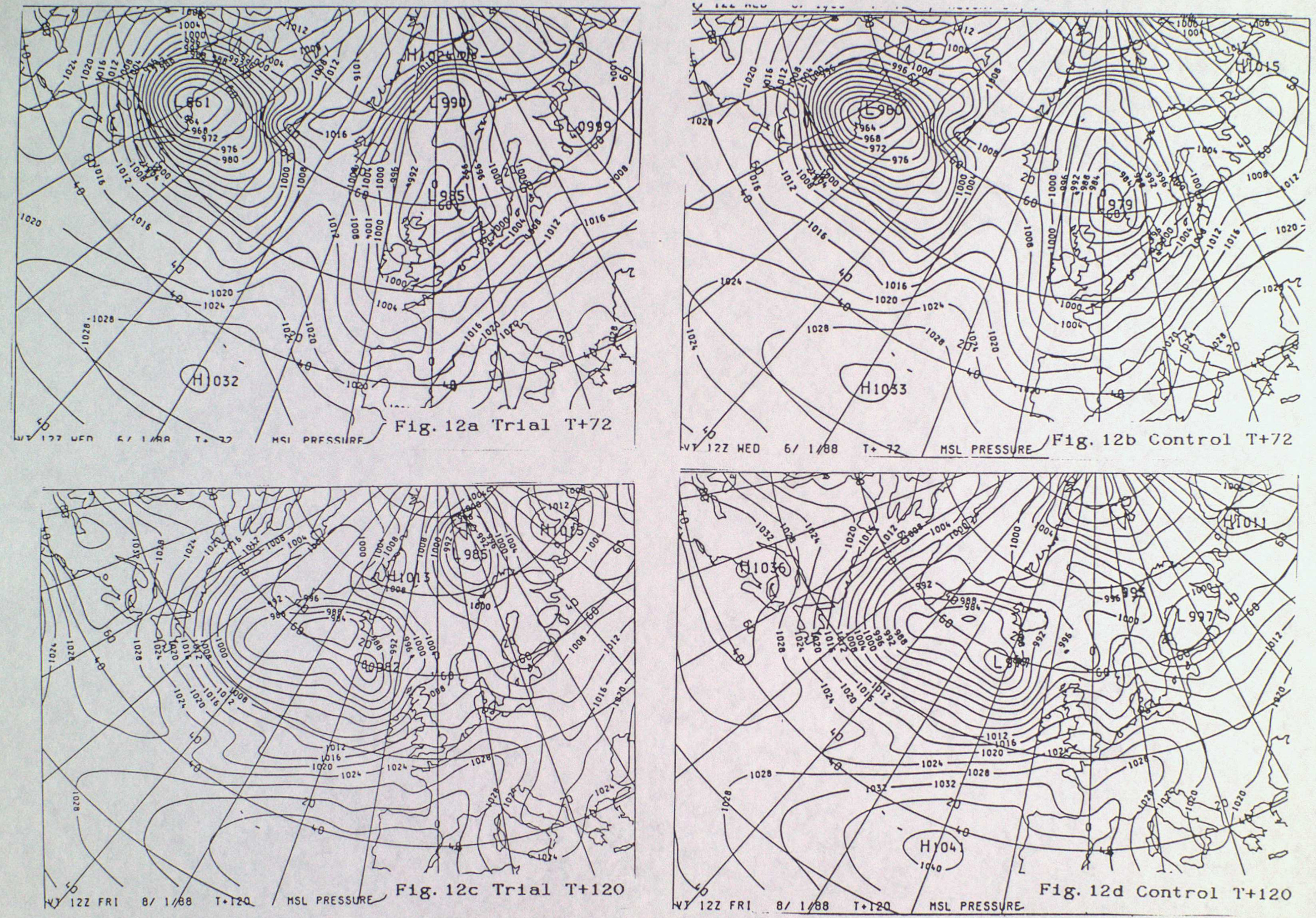

Figure 12 Comparison PMSL forecasts from DT 12GMT 3/1/88

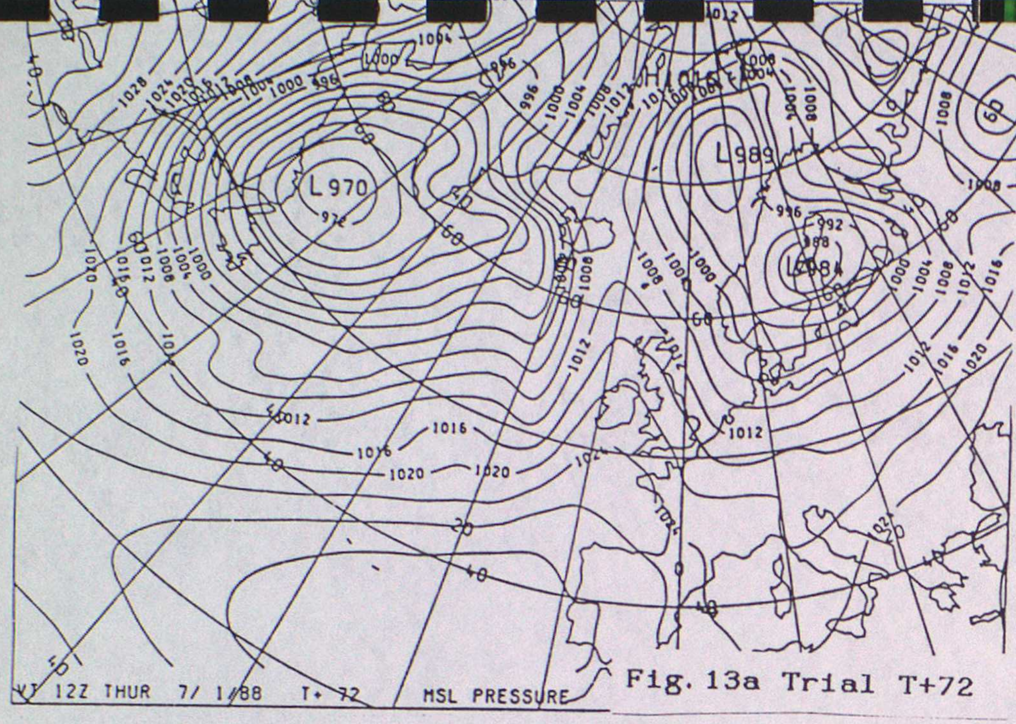

Fig. 13a Trial T+72

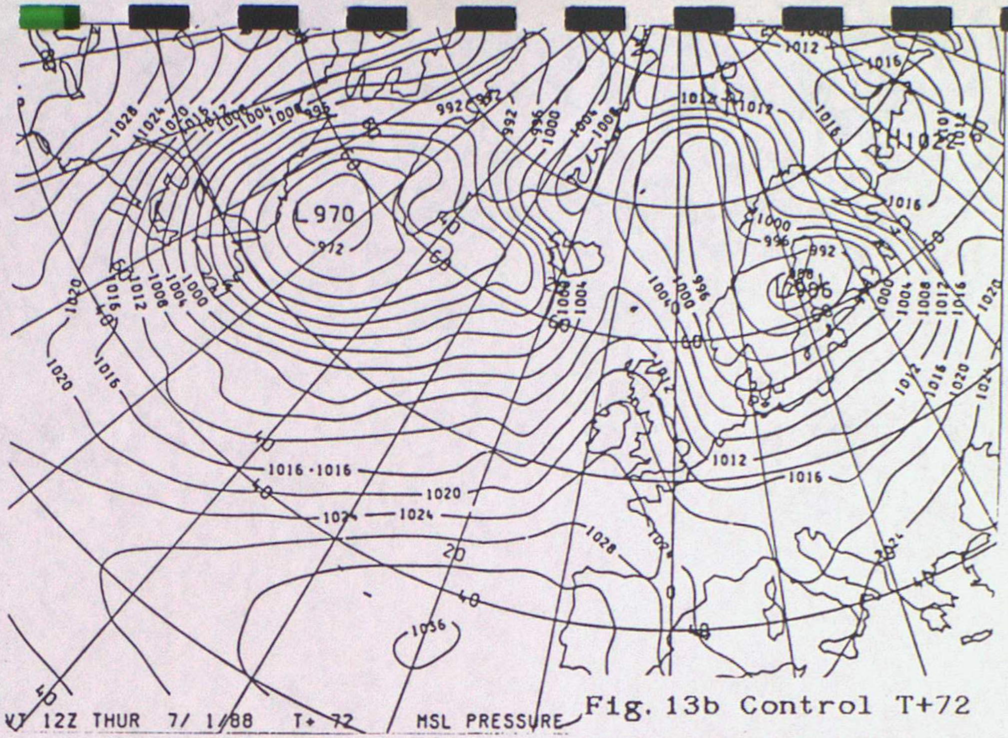

Fig. 13b Control T+72

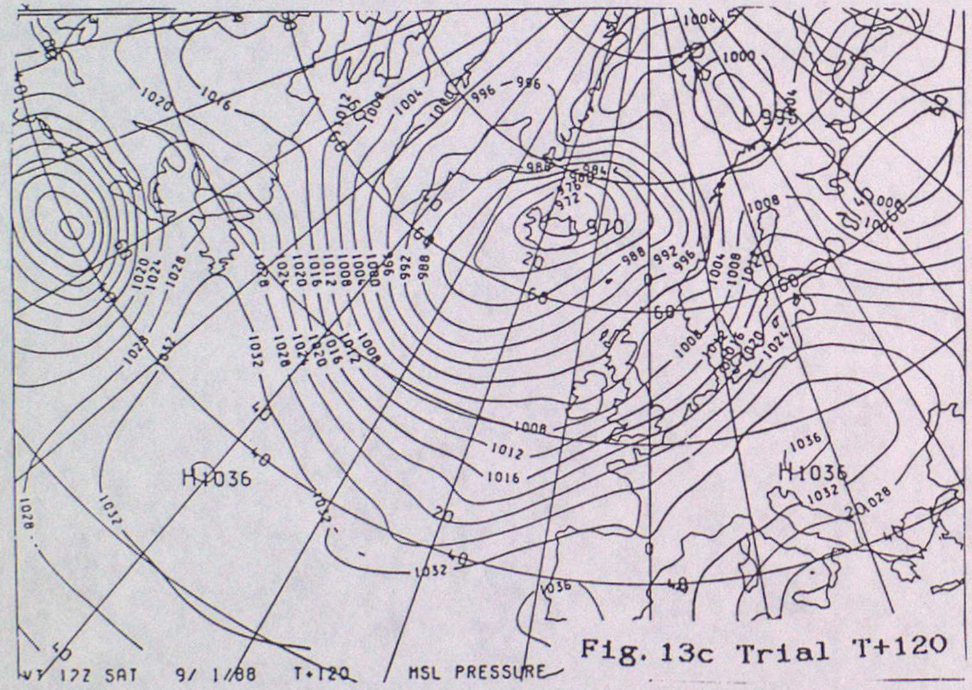

Fig. 13c Trial T+120

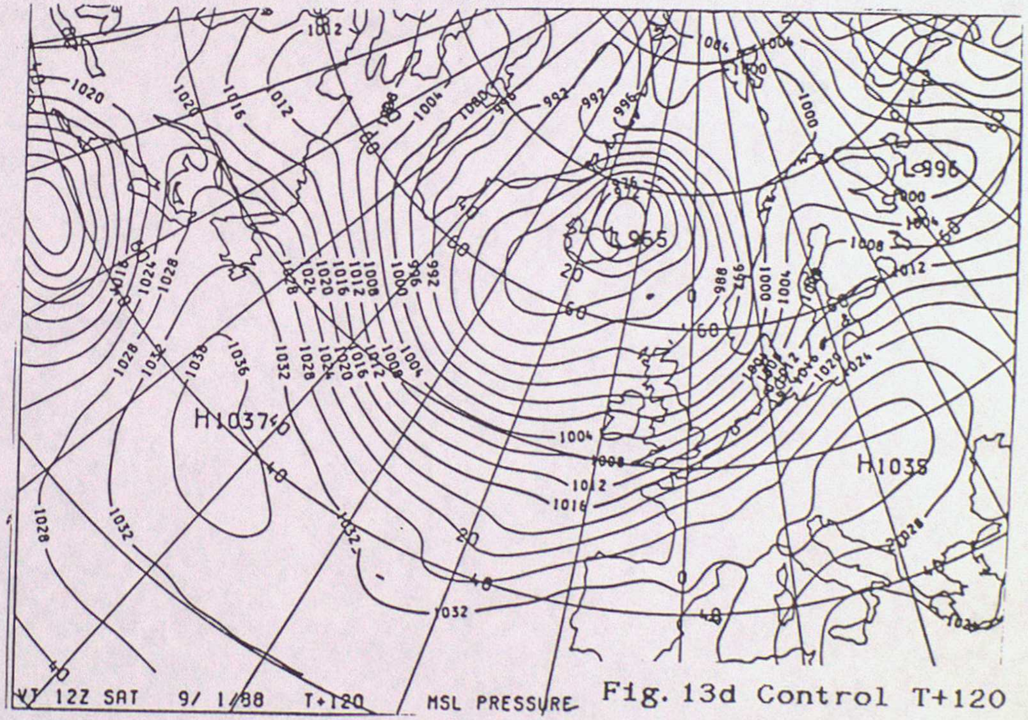

Fig. 13d Control T+120

Figure 13 Comparison PMSL forecasts from DT 12GMT 4/1/88