Forecasting Research Division
Technical Report No. 36

REVISIONS
TO
THE OPERATIONAL DATA ASSIMILATION - NOV 1992

BY

R.S. BELL

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FORECASTING RESEARCH DIVISION

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Forecasting Research Division
Meteorological Office
London Road
Bracknell,
Berkshire, England

Outline of Report

1. Introduction

The analysis correction code was ported to the Cray Unified Model system without any significant retuning. Improvements over the Cyber205 version were noted in respect of resolution, more iterations and improved vertical analysis of multilevel data (Bell and Robinson,1991), however many features have remained unexamined since the scheme was first tuned for use within the Cyber205 15 level model.

Part of the impetus for this work came from a desire by the forecasters to see some improvements on the smaller scales, particularly in the vicinity of jets and rapidly developing features. The work reported here is one step in this direction. Other work in progress is also addressing this problem. Parrett (1992) has reported success in preliminary experiments aimed at giving higher weight to observations where we perceive the background errors to be large. A scheme for providing the observed wind increments with balanced surface pressure and temperature increments has also recently been developed, (see §7.3 of Bell et al,1992a), which it is hoped will improve the fit and retention of wind data.

Experiences with the development of the UARS configuration of the UM assimilation have also pointed to areas, particularly related to stratospheric analysis, where improvements might be sought.

During the past six months we have added a considerable amount of flexibility to the system, such that observations or groups of observations may receive different treatment (Bell et al,1992b). This we also intend to exploit.

2. Options for tuning

The following summarises the aspects of the assimilation which have been considered.

2.1 Vertical error correlation

The assimilation scheme has adopted a continuous vertical correlation model (μ^v) with a structure:

$$\mu^v = \exp\left(-b^2 \ln^2(p_i/p_j)\right)$$

for the correlation between pressure levels p_i and p_j on a scale determined by the constant b. A fixed value of $b^2=3$ has been used for all levels, latitudes and variables. This value is a carry over from the OI analysis used prior to the AC. It has been recognised for some time that the correlation is too broad and this has been compensated for operationally by a cut-off on the vertical correlation scale outside a range of one (density) scale height centred on the observation level, or in the case of surface data a cut-off at the fifth model level (870hPa), or uppermost boundary layer level.

A study of the vertical correlation of the (o-b) for radiosonde data has been carried out using data from the Observation Processing Database (OPD) during a six month period covering the first half of 1992. Correlations were calculated separately for 2 latitude bands (90°-30°N and 30°N-30°S) and for both temperature and wind variables. The model level OPD was used. The table below illustrates the results. It shows the correlations (scaled by 100 with negative lobes set to zero) for northern hemisphere radiosonde temperature data which is available at 18 model levels.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	100	100	72	29	11	05	05	05	03	02	00	00	01	03	20	18	22	18
2	100	100	75	33	16	12	11	06	06	07	06	06	04	02	03	02	02	07
3	72	75	100	64	28	11	08	06	07	07	07	06	04	03	04	00	00	00
4	29	33	64	100	58	15	05	06	07	07	07	06	04	04	03	00	01	00
5	11	16	28	58	100	50	21	14	15	13	12	12	08	05	00	00	00	00
6	05	12	11	15	50	100	63	27	22	18	15	16	12	08	00	00	00	00
7	05	11	08	05	21	63	100	58	34	24	18	17	15	10	00	00	00	00
8	05	06	06	06	14	27	58	100	63	37	24	17	13	08	00	00	00	00
9	03	06	07	07	15	22	34	63	100	71	39	24	12	05	00	00	00	00
10	02	07	07	07	13	18	24	37	71	100	73	38	12	03	00	00	00	00
11	00	06	07	07	12	15	18	24	39	73	100	60	17	03	00	00	00	00
12	00	06	06	06	12	16	17	17	24	38	60	100	45	08	00	00	00	00
13	01	04	04	04	08	12	15	13	12	12	17	45	100	42	00	00	00	00
14	03	02	03	04	05	08	10	08	05	03	03	08	42	100	30	00	00	00
15	20	03	04	03	00	00	00	00	00	00	00	00	00	30	100	26	41	29
16	18	02	00	00	00	00	00	00	00	00	00	00	00	00	26	100	46	33
17	22	02	00	01	00	00	00	00	00	00	00	00	00	00	41	46	100	47
18	18	07	00	00	00	00	00	00	00	00	00	00	00	00	29	33	47	100

Table 1
Radiosonde temperature (o-b) correlations (on model levels)
Data from Jan-May 1992 (sondes north of 30°N)

Although functions with a better fit to this data could be sought, we decided to keep the current function for simplicity and make the parameter, b, vary as a function of level, latitude and variable. The values of b which gave a best fit are given below. The code uses values of b interpolated from the values specified on a fixed set of pressure levels. These values for tropical and extratropical wind and non-wind variables are contained in Table 2. In addition, the effect of removing the cut-off, by increasing its value to 2, was examined.

Plevel⇒	1000	900	800	700	600	500	400	300	200	100
T,q poleward 30°	7.0	8.0	7.0	5.0	4.0	4.0	5.0	5.5	5.5	3.5
T,q tropical	8.0	8.0	7.0	5.5	4.5	3.5	3.0	3.0	3.5	2.5
u,v poleward 30°	6.0	5.0	5.0	4.0	3.5	3.0	2.5	2.5	2.5	2.0
u,v tropical	6.5	6.0	5.5	5.0	3.5	3.5	3.0	3.0	3.0	2.0

Table 2
Revised values of constant scaling factor b in μ^{v}

2.2 Horizontal error correlation and influence region

The current horizontal correlation scales are unchanged from Cyber205 model values when the model resolution was 50% coarser. Several alternative values for the correlation scale at observation time, start and end of time window were examined.

Much reduced correlation scales might also be more appropriate in the southern hemisphere than previously used, now that more high resolution satellite data is available. It had previously been argued that the data coverage was inadequate for the analysis of anything other than the largest scales. The previous operational values were 1.667 times the northern hemisphere correlation scale. The UARS configuration uses the same correlation scale everywhere.

Another option to try is the use of the alternative modified SOAR function which tapers to zero at the edge of the sphere of influence. This might avoid some noise. It has been successfully used in the UARS configuration.

The radius of influence (specified as a multiple of the correlation scale) was also considered. Previously lower values (than the standard 3.5) have been used in the LAM moisture assimilation and in tests of scatterometer wind assimilation.

2.3 Divergence

The assimilation diagnostics were not examined in a systematic way when the level of divergence diffusion was chosen for the UM. It is conventional to run with the minimum possible levels of diffusion. Several runs have been done to examine this.

The wind increments are currently non-divergent. A facility exists to relax this non-divergent constraint. Reduced values of the non-divergent correction coefficient have been tried.

2.4 Temporal weighting

The temporal weighting is governed by a time factor specified by its shape, time window, start and end points.The shape is currently triangular, starting from near zero at 5 hours before observation time and rising to 1 at the observation time before falling over the subsequent hour.

Two factors prompt a revision here. Firstly the often expressed concern that a 6 hour window was too broad in fast moving situations. The observations might be fitted in advance of the observation time and the analysis 'gets ahead of reality'. Secondly, a lot of time is spent computing extremely small increments at the extremes of the time window. To address these points a quadratic time ramp has been tested, as have smaller time windows and larger initial and final values.

2.5 Geostrophic wind increments

At present the scaling (both horizontally and vertically) of the geostrophic wind increments differ in the operational and UARS configurations. The operational version has different scalings in the two hemispheres and no increments are applied in the stratosphere, where one might expect the flow to be more geostrophic.

2.6 Iteration strategy

Macpherson (1990), showed some benefits for the wind analysis by changing the iteration strategy. He removed the asynoptic feature of the AC scheme for wind data and performed the multiple iterations at analysis time rather than interleaving them with the model forecast steps. Facilities now exist to do this quite flexibly (any number of iterations at any interval as a function of observation group).

It was not thought desirable to abandon the asynoptic feature completely. An intermediate approach would be to group the wind iterations (say 3 per timestep) and reduce the time window (say to 2hours).

2.7 Nudging coefficients

The UARS configuration has different nudging coefficients for mass and wind increments. However a full examination of the nudging coefficients awaits trials of the synoptic dependent background errors since the observation/background error ratio is likely to change at that time.

3. Results from the individual tests

3.1 Details of the experiments

Several specifications of each of the above aspects were assessed within the global model. The majority of tests were based on a 2 day assimilation period spinning off 3*12hour forecasts for verification. Some of the clearly inferior versions relative to the operational control were abandoned after a 1 day assimilation with single 12 hour forecast.

The tests were largely done with version 2.5 of the model. We identified all tuning options which gave improved verification of short period forecast. Additionally we identified those options which gave improved fit of analysis to data, particularly jets and small scale features even if overall verification of short period forecast is not improved. Although no overall deterioration in key fields was allowed.

Verification was based on 1 timestep runs using an ACOBs file. This generates (after meaning over levels) 28 values. These are for 10 observation types (P^*, T_{sonde}, T_{airep}, $T_{lass(NH\ only)}$, T_{sat500}, T_{sat120}, V_{sonde}, $V_{airep/ctw}$, V_{ship}, RH_{sonde}) at 3 latitude bands.

3.2 Discussion of the results

Only a summary of the objective verification will be given to illustrate the impact (in terms of number of statistics bettering the operational control).

3.2.1 Vertical error correlation

Three runs were done.

a) A revised vertical correlations as described in section 2.1 with a cut-off at 2 scale heights.
b) As (a) except correlation for surface data was unchanged.
c) As (a) except cut-off remained at 1 scale height.

These runs were clearly beneficial. Only run (a) was continued into the 2nd day. The scores were:

Run		better	same	worse
a)	1 f/c	18	5	5
b)	1 f/c	18	4	6
c)	1 f/c	16	6	6
a)	3 f/c	17	6	5

The tropical region scored best. The change over land, where most data is multilevel, (judging from sonde verification) was negligible. The surface changes (pressure and ship winds) were also not significant. However the improvement over sea (airep and satellite verification), presumably resulting from a better assimilation of single level winds was clear.

3.2.2 Horizontal error correlation and influence region

Twelve runs were done to assess the aspects of the assimilation discussed in section 2.2:

a) Adjusted SOAR tailing to zero at edge of influence.
b) Change ratio of SH/NH correlation scale to 1.
c) Change ratio of Tropics/NH correlation scale to 1.
d) Change ratio of SH/NH cor.scale to 1.25 and Tropics/NH cor.scale to 1.5
e) As (d) but use NH value of cor.scale for SAT120.
f) Change ratio of both SH/NH and Tropics/NH cor.scale to 1.5.
g) As (f) but use NH value of cor.scale for SAT120 and RH.
h) Reduce base correlation scale (NH) at start of time window to 300km.
i) As (h) plus reduced final base correlation scale to 200km.
j) As (h) plus reduced final base correlation scale to 150km.
k) Reduce RH radius of influence to 2.25 correlation scales.
l) Reduce radius of influence to 3 correlation scales.
m) Reduce final base correlation scale (NH) to 200km.

These results from these runs were mixed. Runs (a),(f),(k) and a new run (m) [a slight variant of (i)] were continued for 2 days. The scores were:

Run		better	same	worse
a)	1 f/c	11	9	8
b)	1 f/c	7	15	6
c)	1 f/c	7	7	14
d)	1 f/c	10	11	7
e)	1 f/c	10	9	9
f)	1 f/c	9	11	8
g)	1 f/c	12	6	10
h)	1 f/c	9	8	11
i)	1 f/c	12	4	12
j)	1 f/c	11	3	14
k)	1 f/c	14	5	9
l)	1 f/c	8	8	12
a)	3 f/c	17	8	3
f)	3 f/c	12	11	5
k)	3 f/c	11	10	7
m)	3 f/c	9	15	4

With these changes, the differences between control and test are more marginal. However, we do see a more clear cut positive impact for those tests which were continued for 2 days to give 3 forecasts for verification. The modified SOAR (a) seems to have a slight edge.

The runs with reduced correlation scale factors in the tropics and southern hemisphere (b)-(g) show that a single global value as used by UARS (extra scaling factor 1) is inappropriate, particularly in the tropics. The time savings from reduced influence areas are substantial, so even a marginally positive impact is welcomed. A modest reduction of scaling from

1.667 to 1.5 was eventually preferred.
The runs with reduced correlation scale at start of time window, (h)-(j), did not seem very beneficial. However there did seem to be some gains from reducing the correlation scale at the end of the time window at least to 200km (see (i) relative to (h)).
A smaller influence radius appeared only beneficial when applied to RH, but in fact the benefits were not to the RH scores. This clearly demonstrates the potential damage that the inappropriate spreading of moisture increments has on the dynamic variables.

3.2.3 Divergence

Five runs were done to assess the points discussed in section 2.3.
a) Non-divergent coefficient set to 0.7.
b) Non-divergent coefficient set to 0.8.
c) Non-divergent coefficient set to 0.9.
d) Reduce divergence damping coefficient by factor 3.
e) Reduce divergence damping coefficient by factor 10.

The runs with reduced non-divergent coefficient were clearly beneficial. Reduced divergence damping is most clearly not a benefit. Run (b) was continued for a 2nd day. The scores were:

	Run	better	same	worse
a)	1 f/c	13	7	8
b)	1 f/c	14	6	7
c)	1 f/c	16	8	4
d)	1 f/c	1	11	16
e)	1 f/c	3	7	18
b)	3 f/c	11	10	7

Relaxing the non-divergent constraint had a particular benefit for wind scores and gave a better all round performance in the tropics. A value of 0.7 gave a best wind score outside the tropics but resulted in a worse score for surface pressure and temperature. In the tropics, a value of 0.7 gave the best score for all variables. A value of 0.8 was a compromise which kept the wind improvement without degrading other variables.

3.2.4 Temporal weighting

Five runs were done to assess the points discussed in section 2.4. All runs were with start and end points of time ramp set to 0.05.
a) quadratic time ramp for v only
b) quadratic time ramp for all variables
c) quadratic time ramp and 4 hour window for v only
d) quadratic time ramp for all variables and 4 hour time window for v only
e) quadratic time ramp and 4 hour time window for all variables

The runs with a quadratic time ramp are marginally better and more importantly give a substantially closer fit at analysis time. The 4 hour time window is not appropriate, presumably because despite the quadratic ramp the total effective number of iterations is reduced. Run (a) was continued for a 2nd day. The scores were:

	Run	better	same	worse
a)	1 f/c	10	11	7
b)	1 f/c	15	2	11
c)	1 f/c	11	12	5
d)	1 f/c	11	5	12
e)	1 f/c	8	6	14
a)	3 f/c	7	13	8

There is some indication that use of a quadratic time ramp for temperature as well as winds flips a nul NH impact to negative which implies that a lower nudging coefficient for temperature relative to winds might be appropriate.

3.2.5 Geostrophic wind increments

Four runs were done to assess the points discussed in section 2.5.

a) Increase horizontal scaling factor in NH to be same as SH (0.7).
b) Vertical scaling set to UARS values (1 in stratosphere).
c) As (b) but only increasing to scaling to 0.4 in stratosphere.
d) As (b) but scaling remains zero in stratosphere.

The scores were:

	Run	better	same	worse
a)	1 f/c	5	14	7
b)	1 f/c	15	2	9
c)	1 f/c	11	9	8
d)	1 f/c	14	8	6

The gross scores above suggest a nul impact of changing the horizontal scaling and a positive impact of changing the vertical scaling . However, a closer examination of individual levels shows that any increase in northern hemisphere weighting of geostrophic wind increments (either via horizontal or vertical scaling factors) degrades the verification against airep or radiosonde winds. In the tropics and southern hemisphere there is an improvement. It seems that geostrophic wind increments should only be used in the absence of observed winds.

3.2.6 Iteration strategy

Two runs were done to assess the points discussed in section 2.6.

a) Three wind iterations per timestep with a 2 hour window.
b) Two wind iterations per timestep with a 3 hour window.

The scores were:

	Run	better	same	worse
a)	1 f/c	4	9	15
b)	1 f/c	11	8	9

This did not look very promising, particularly for the northern hemisphere, and has not been pursued very far.

4 The combined package for parallel testing

The following points summarise the combined package which was put together for more extensive testing.

a) Narrower vertical error correlation which more accurately reflects that identified from radiosonde OPD studies, together with the removal of the cutoff at one scale height. This gives improved fit of upper winds from single level data. (see 3.2.1(a))

b) Relax the non divergent correction to give a marginal positive impact on analysed winds more particularly in the tropics. (see 3.2.3(b))

Three changes to the horizontal correlation scale tending to narrow the function and thus fit the observations more closely:

c) Adjust shape of horizontal correlation scale such that it tends to zero at edge of influence area. This implies slight narrowing of the correlation function and less noise induced at the edge of influence region (see 3.2.2(a))
d) Reduced horizontal correlation scale in southern hemisphere and tropics (from 1.667 to 1.5 of northern hemisphere value). As well as a clear improvement in scores, this has a significant time saving. (see 3.3.2(f))
e) Reduced correlation scale for all observation types at peak and end of time window. (from 225/250km to 200km; or to 150km for scatterometer winds and moisture). The lower value for moisture was chosen in preference to the reduced influence radius specification. As well as a marginal improvement in scores, this has a significant time saving. (see 3.2.2(m))

Changes (d) and (e) together imply an 18% saving.

Three changes impacting on the effective number of iterations. Which we define as the sum through the time window of the relaxation coefficient scaled by the time ramp factor.

f) Change time window from 6 hours to 5 hours. Thus improving temporal scale and lessening chance of inappropriate increments in fast moving situations. A reduction of assimilation costs by 17% was the prime motive for this change. A reduction to 4 hours (see 3.2.4) was thought be too much.
g) Change shape of time ramp from triangular to quadratic, together with larger initial and final values. This gives effectively bigger nudges away from observation time. (see 3.2.4b).
h) Small increase in the wind nudging coefficient and small reduction in the non-wind nudging coefficient.

The motive for changes (g) and (h) were primarily to achieve the time reduction implied by change (f), which on its own implies reduced forcing by the observations. The change in forecast scores due to the temporal weighting changes was negligible on the average although there is some expectation that improvements will occur in the analysis of rapidly moving or developing systems. The implication of changes (f),(g) and (h) is 10-20% increase in effective number of wind iterations and 5-10% reduction in effective number of temperature nudges. A modest improvement in analysis fit to winds results from this increase in the number of effective iterations.

5. Objective results from the parallel test

The changes discussed above were assessed by running a global assimilation in parallel with the operational assimilation. The parallel assimilation ran from the 19th Sept to 5th Oct and included a three day forecast from each 00z analysis. In this section we present the verification against observations (using the standard operational package) and a comparison of trial and operational OPD results.

5.1.Verification against observations

The following table gives a concise summary of the verification comparison. For four forecast areas (area 2-N Atlantic sector;areas 200,300,400-northern latitudes,tropics and southern latitudes respectively) and four forecast periods (analysis and daily forecast to 3 days), we give the difference in rms score for 26 fields. This is expressed as a percentage change (improvements are positive). The observations used for verification are radiosondes, synops and ships.

period	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
area	2				200				300				400			
pmsl	3.8	0.8	1.2	-0.4	2.7	0.8	1.4	0.6	2.0	2.1	0.9	0.4	10.0	3.4	2.4	0.7
heights																
850hPa	-1.1	-0.7	2.2	0.8	1.9	0.0	2.5	1.4	0.0	4.9	3.4	0.6	4.3	3.6	3.0	-0.7
700hPa	-1.0	0.0	2.6	1.8	0.0	0.6	2.9	2.0	-0.8	3.5	2.5	2.3	3.0	-2.0	3.7	2.9
500hPa	0.0	2.3	2.7	3.1	0.0	0.9	2.5	2.3	0.0	1.3	1.6	1.9	6.0	1.5	6.5	4.7
300hPa	0.0	2.2	3.0	2.2	1.2	2.1	2.9	3.1	0.4	3.0	1.9	0.5	5.4	2.9	4.7	1.4
250hPa	0.4	2.8	2.8	2.1	0.7	1.7	2.3	2.8	1.9	3.6	2.3	0.6	2.5	2.9	4.2	2.7
200hPa	0.4	2.2	2.4	2.1	0.0	1.3	1.6	2.5	0.5	2.2	0.5	-0.7	2.0	3.5	5.0	4.9
100hPa	0.0	0.6	1.5	1.1	0.2	0.3	0.3	1.2	0.4	0.0	-1.0	-1.3	2.5	3.9	3.0	7.2
temperatures																
850hPa	4.9	1.1	2.2	0.0	4.7	0.6	1.7	0.7	6.1	3.1	1.7	1.0	3.9	5.4	6.6	1.8
700hPa	6.0	1.9	1.0	2.5	5.6	0.6	1.0	1.5	3.4	0.0	1.3	0.6	5.0	3.2	8.4	1.7
500hPa	2.3	-1.3	2.5	2.6	4.2	2.0	2.1	3.7	2.6	2.2	2.0	3.7	8.5	3.9	7.4	2.2
300hPa	6.3	-0.6	0.9	-0.8	7.4	1.7	1.4	1.2	1.6	1.3	0.0	-1.1	14.4	2.8	4.5	7.4
250hPa	5.6	1.1	1.2	-0.9	3.8	0.5	1.6	1.3	2.4	0.0	1.5	0.9	9.0	0.0	1.0	0.3
200hPa	4.6	2.2	2.8	1.2	4.5	2.1	1.7	1.6	3.6	0.0	-0.5	0.9	10.1	4.4	1.2	-1.4
100hPa	1.0	1.5	2.0	4.7	0.7	1.8	1.6	1.9	0.6	0.8	0.8	-0.5	1.4	-2.7	-1.6	0.8
winds																
surface	1.3	0.7	0.2	0.5	1.6	0.6	0.9	0.6	1.9	0.7	0.8	1.1	-0.1	0.1	0.7	3.5
850hPa	3.9	-0.1	-0.1	0.4	4.6	0.4	1.1	1.2	5.9	1.6	0.8	1.0	-0.9	-1.9	-2.1	0.7
700hPa	4.4	0.2	1.1	1.5	4.8	1.5	2.3	2.4	9.0	3.8	4.0	3.1	2.1	0.2	1.0	1.3
500hPa	4.1	1.6	1.9	3.5	3.8	2.9	3.1	4.0	5.6	2.9	3.4	3.4	-0.3	-0.7	4.9	4.9
300hPa	4.7	0.9	3.0	2.4	4.9	1.1	3.8	3.3	8.3	2.5	4.2	3.1	4.8	5.8	7.7	3.1
250hPa	4.1	0.4	1.7	2.5	5.3	0.3	3.0	3.1	8.4	3.4	4.5	3.6	-1.9	2.7	4.5	4.7
200hPa	5.9	2.9	2.7	3.1	6.8	3.3	4.1	3.9	7.6	3.9	4.5	3.9	3.8	7.1	6.4	4.3
100hPa	3.3	2.8	2.0	2.8	3.8	5.6	4.1	5.4	2.6	5.4	3.9	1.5	-0.6	8.1	7.6	4.1
relative humidity																
850hPa	6.2	-0.4	0.2	-0.1	7.0	-0.1	0.4	0.1	7.1	1.0	1.0	0.4	6.2	0.0	-4.7	-3.6
700hPa	8.3	-2.0	-0.9	-0.4	9.4	-0.7	0.2	0.9	9.7	0.5	0.6	0.3	11.3	5.0	3.2	2.3
500hPa	8.8	-0.6	-0.7	0.0	9.1	-0.3	0.3	0.0	9.5	0.6	0.2	0.8	6.8	-1.2	0.9	2.7

Table 3
VERIFICATION AGAINST OBSERVATIONS
% IMPROVEMENT of TRIAL RELATIVE TO OPERATIONAL

It should be noted that the wind comparison beyond analysis time is of unscaled winds from the parallel run against scaled winds from the operational run. *[The scaling being a bias correction to model output]* It might be presumed that the scaling used in the operational run represents and improvement so the comparison above favours the operational run.

In the table, we see 90 % of the figures represent an improvement. The few negative figures can be easily explained. FIrstly, the humidity forecasts are no better despite a better fit to observations because the current model error has a large scale bias component. Secondly, the southern hemisphere wind scores at analysis time are worse because the Australian sondes are swamped by Asdars. Thirdly, the improvements in temperature analysis don't filter through into height verification until day 1 of the forecast.

Over all the fields and areas, the analysis is improved by 4%. Excluding the humidity fields, It seems that 75% of this improvement is still evident in the short to medium range forecast scores. For example, at day 2 the average improvements (over all levels) are:

height fields :2.5%,2.1%,1.6% and 4.3% for the four areas.

wind fields :1.7%,3.1%,3.6% and 4.3% for the four areas.

There is no indication that the signal is being lost as the forecast period increases (day 3 improvement is similar to that at day 1).

Figures 1 and 2 show the same results as Table 3 in graphically form, for two of the key upper air fields: 500hPa height and jet level winds. In these charts, the rms error (difference from verifying observation) during the trial period is plotted as a function of forecast period for both the control operational run (solid line) and the trial run (pecked). The improvement is clear in all four verification areas.

5.2.OPD results

The OPD contains (observation-background) and (observation-analysis). The latter duplicates the above verification to a large extent. It does however contain data for observing systems other than radiosonde and surface. The airep data is of particular interest.

Speed Category	Number of obs	Mean speed (o-b)		rms vector (o-b)	
		Trial	Oper	Trial	Oper
0-3	552	-0.9	-0.7	3.1	3.2
3-20	23897	-0.3	-0.3	6.8	6.9
20-40	24536	0.9	1.0	7.4	7.6
40-60	7583	1.7	1.9	8.4	8.7
60-80	1596	2.5	2.6	9.4	9.7
>80	129	3.4	4.1	10.5	10.8

Table 4

Trial and operational (Airep-Background) wind differences
North of 30°N: 20Sept-5Oct:100-400hPa

For the strongest jets the background bias has reduced from over 4m/s to less than 3.5m/s. The rms vector wind difference is 0.3m/s lower for the trial or 3-4% which is consistent with the verification results for radiosondes in the previous section.

Speed Category	Number of obs	Mean speed (o-b)		rms vector (o-b)	
		Trial	Oper	Trial	Oper
0-3	513	-1.3	-1.3	3.4	3.4
3-20	10569	0.9	1.0	5.1	5.5
20-40	3703	1.6	1.7	6.4	6.7
40-60	972	1.8	1.9	7.3	7.8
60-80	109	3.9	4.2	8.2	8.6

Table 5

Trial and operational (Airep-Background) wind differences
Tropics: 20Sept-5Oct:100-400hPa

Speed Category	Number of obs	Mean speed (o-b)		rms vector (o-b)	
		Trial	Oper	Trial	Oper
3-20	675	0.5	0.6	5.9	6.2
20-40	1102	0.8	1.0	7.2	7.5
40-60	500	1.6	1.9	8.2	8.7
60-80	93	3.7	4.0	8.6	9.2

Table 6

Trial and operational (Airep-Background) wind differences
South of 30^{o}S: 20Sept-5Oct:100-400hPa

The improvement in rms vector wind difference of airep-background is even more marked in the tropics and southern hemisphere (0.4-0.5m/s or 7%).

6 Subjective assessment of trial

It is extremely difficult to do a subjective assessment of analysis differences, particularly when such differences are small. The bulk of the subjective assessment comprised an examination of those two and three day forecasts (of surface pressure and upper wind) where the (trial-control) difference charts showed a noticeable difference (albeit often small). This subjective forecast assessment serves to illustrate the scale of the differences, rather than provide a thorough and convincing case for the trial. The assessment will concentrate on the North Atlantic during the second week of the trial, aside from one southern hemisphere example and one tropical example. In all the figures, the pair of forecasts (trial and control) are in the upper panels with a difference chart and verifying analysis in the lower panels. The difference contours are 2hPa for surface pressure and 10knots for wind.

6.1 Southern Hemisphere

Large surface pressure differences were noted on every forecast. These were not usually verifiable because there were also differences in the two analyses and in many cases the forecasts were so different from the verification that it was difficult to choose which was closer. Figure 3 shows one example of a 3 day forecast valid at 27 Sept. At the scale of these charts, features tend to be rather confused near the Antarctic. The low near New Zealand is clearly better forecast by the trial run and there is not much evidence for the trough southwest of South Africa in the operational run.

6.2 Tropics

No tropical charts were actually studied. The one low latitude feature which attracted some attention was in the Pacific to the west of Mexico, where a low pressure system was objectively analysed at 1000hPa on 2nd Oct. The trial forecast at T+72 made a much better attempt at the depth but could be criticised for a slight displacement error. (see Figure 4)

6.3 North Atlantic

The North Atlantic pattern was blocked during the first week of the trial and only a little more mobile during the second week. Most of the features were fairly large scale and thus it was not an ideal time to test changes which focused on smaller scales. We concentrate on a four day period from the 29th Sept to 2nd Oct. Emphasis is placed on the 2 day forecasts where differences were more significant. More differences were noted in the jets than at the surface. Where surface pressure charts are not discussed, the differences were negligible. A brief comment follows for each set of forecast charts:

Figure 5: T+24 wind forecast from 29th
The main difference is in the sharp upper trough near the UK, which is correctly further back in the trial as judged from the wind contours near Valencia and the difference contours over Ireland.

Figure 6: T+48 wind forecast from 29th
A day later the same trough was near Shetland and again the trial positioned it correctly further south. The trial was also better with the forward position of the 120knot contour of the mid-Atlantic jet.

Figure 7: T+48 pmsl forecast from 29th
Both forecasts were not deep enough with the double low system near 60°N but the trial was deeper by more than 2hPa

Figure 8: T+48 wind forecast from 30th
The main difference here is to the west of the UK where the trial is incorrectly slow.

Figure 9: T+48 wind forecast from 1st
Here we see the northwesterly winds are correctly weaker over the UK in the trial, with the jet core a few degrees further west. Around the upper high, the trial correctly places the northerly jet, in the west Atlantic, a little further east. It is also more correct in the position of the northern most extent of the jet in the Denmark Strait.

Figure 10: T+48 pmsl forecast from 1st
Several features in the surface pressure chart are all better in the trial; the trough at 45°W, the lows south of Greenland, the ridge in mid-Atlantic to the south of Iceland and the trough over Brittany.

Figure 11: T+24 wind forecast from 2nd
Here the trial is probably not correct with the positioning of the jet to the west of Scotland, but is better with the strength of the southwesterly flow at 30°W and also with the northerly extent of the jet over Greenland.

Figure 12: T+48 wind forecast from 2nd
By day 2 of the same forecast, the strength on the easterly side of the northerly jet near the UK is better in the trial, however the next jet coming out of the US is better in the control run.

In summary, of the 17 noticeable differences in the 8 charts over this 4 day period, 14 were better in the trial.

6.4 Jet speeds

The analyses of the North Atlantic jets were compared through the entire trial period. This showed that of 32 identifiable maxima (in the 00Z 250hPa analyses), 23 were stronger in the trial. In the T+24 charts, 20 jet maxima could be identified and of these 14 were stronger. The table below contains the histogram of (trial-operational) differences at T+24, which confirms the tendency for slightly stronger trial jets.

(trial-oper)	-5	-4	-3	-2	-1	0	1	2	3	4	5	10
Number in bin	0	0	1	1	4	7	4	3	2	2	2	1

Table 7
Histogram of T+24 250hPa wind speed differences (knots)
over North Atlantic during trial period

7 Conclusion

The settings of a large number of tunable parameters have been re-examined, and revisions of some of these parameters have been demonstrated to be worthwhile in the global model. The main changes are: a narrowing of the vertical error correlation; a relaxation of the non divergent constraint; a reduced horizontal correlation scale (especially in southern latitudes); a reduced time window with associated changes in observation increment weighting. Full details are given in section 4.

The objective verification (using surface and radiosonde reports) from a parallel trial has shown a useful reduction in rms scores. On average a 4% reduction in rms fit at T+0 and 3% reduction in rms fit in the short to medium range forecast. Similar results were obtained from a comparison of airep winds with model background. Full details are given in section 5.

The subjective impact in the southern hemisphere was substantial but largely unverifiable. In the northern hemisphere the impact was small but some positive benefits were noted. During the 4 day period discussed in section 6, 14 out of 17 features were considered superior in trial forecasts.

Similar changes are planned for the LAM (without a reduction in time window but with the equivalent reduction in horizontal correlation scale ie. 85% of current value).

An important by-product of this tuning exercise is the 30% reduction in cost of the assimilation component of the global version of the unified model. This translates into a reduction in operational suite usage of 4 minutes per day.

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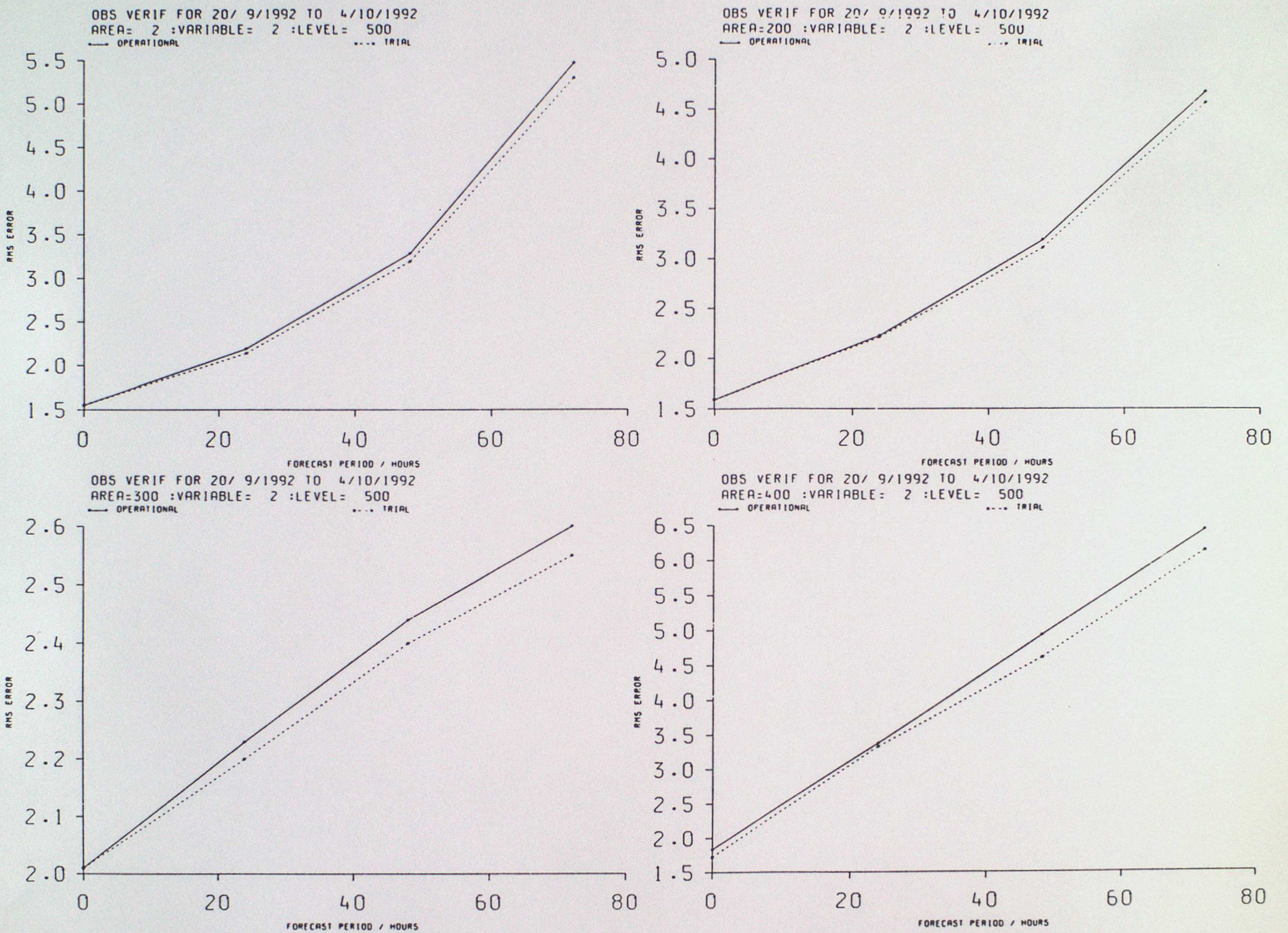


FIG 1: RMS ERROR 500HPA HEIGHT FOR TRIAL AND OPER (4 AREAS)

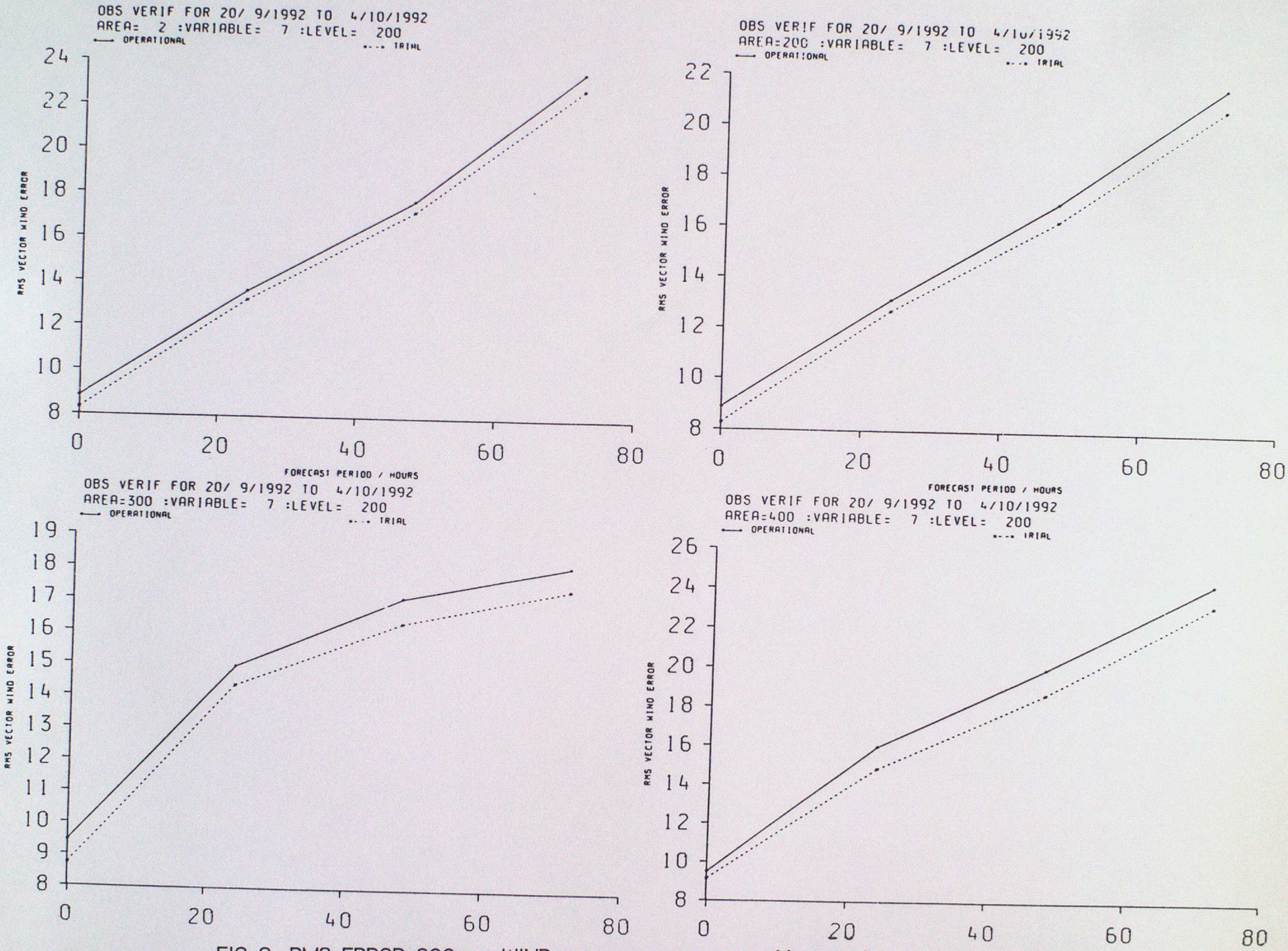


FIG 2: RMS ERROR 200HPA WIND FOR TRIAL AND OPER (4 AREAS)

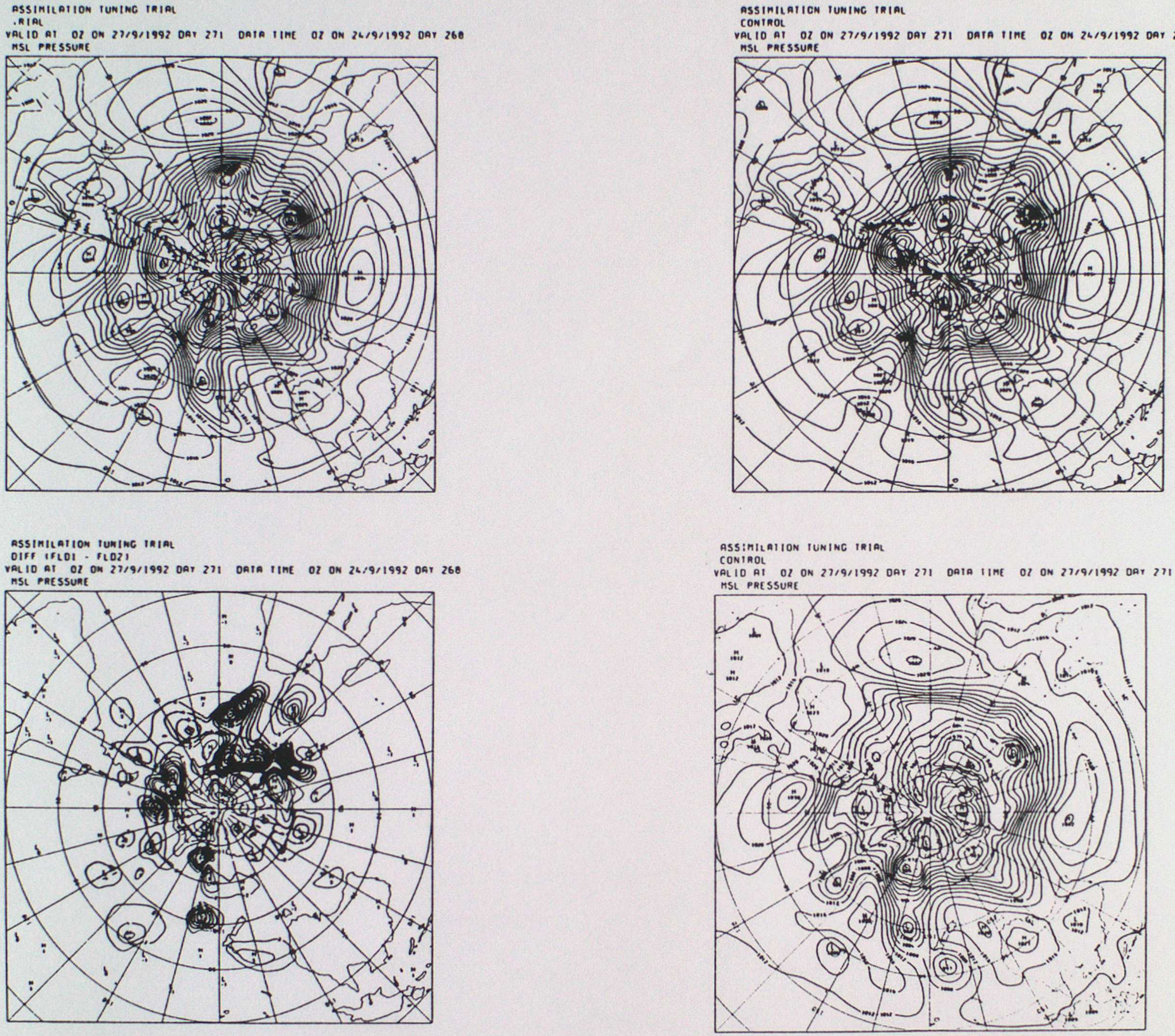
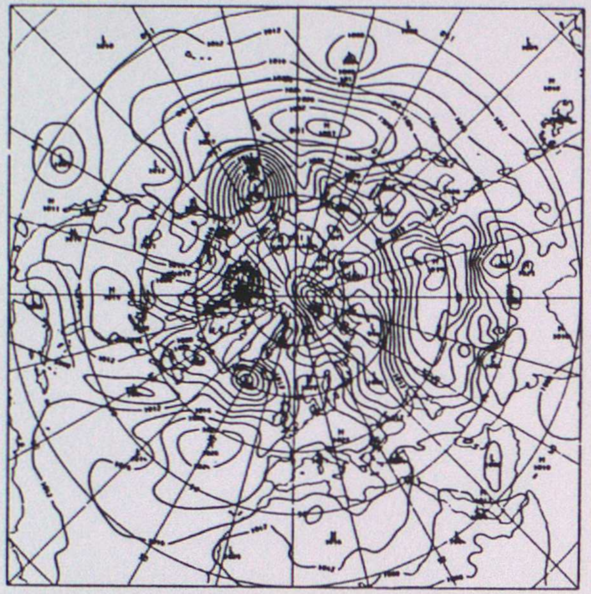
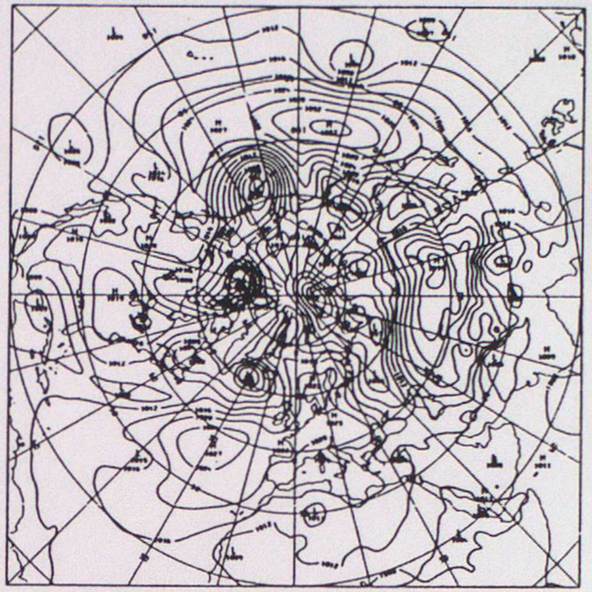


FIG 3: T+72 PMSL FORECAST COMPARISON WITH DIFFS AND VERIF

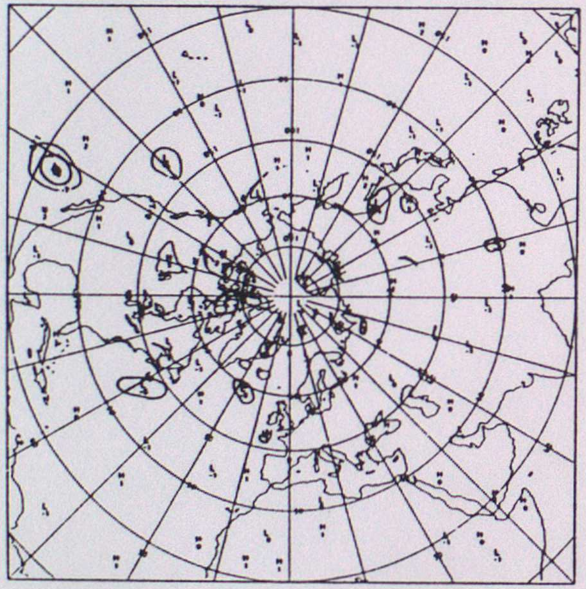
ASSIMILATION TUNING TRIAL
TRIAL
VALID AT 0Z ON 2/10/1992 DAY 276 DATA TIME 0Z ON 29/9/1992 DAY 273
MSL PRESSURE



ASSIMILATION TUNING TRIAL
CONTROL
VALID AT 0Z ON 2/10/1992 DAY 276 DATA TIME 0Z ON 29/9/1992 DAY 273
MSL PRESSURE



ASSIMILATION TUNING TRIAL
DIFF (FLD1 - FLD2)
VALID AT 0Z ON 2/10/1992 DAY 276 DATA TIME 0Z ON 29/9/1992 DAY 273
MSL PRESSURE



//SUITE VERIF
ANALYSIS
VALID AT 0Z ON 2/10/1992 DAY 276 DATA TIME 0Z ON 2/10/1992 DAY 276
MSL PRESSURE

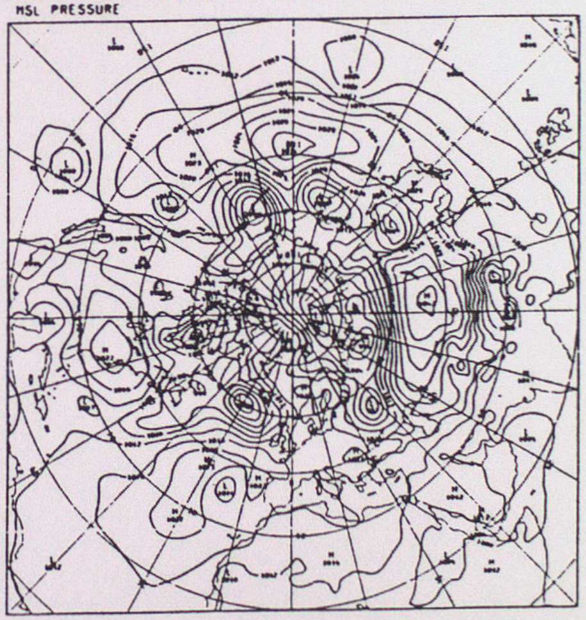


FIG 4: T+72 PMSL FORECAST COMPARISON WITH DIFFS AND VERIF

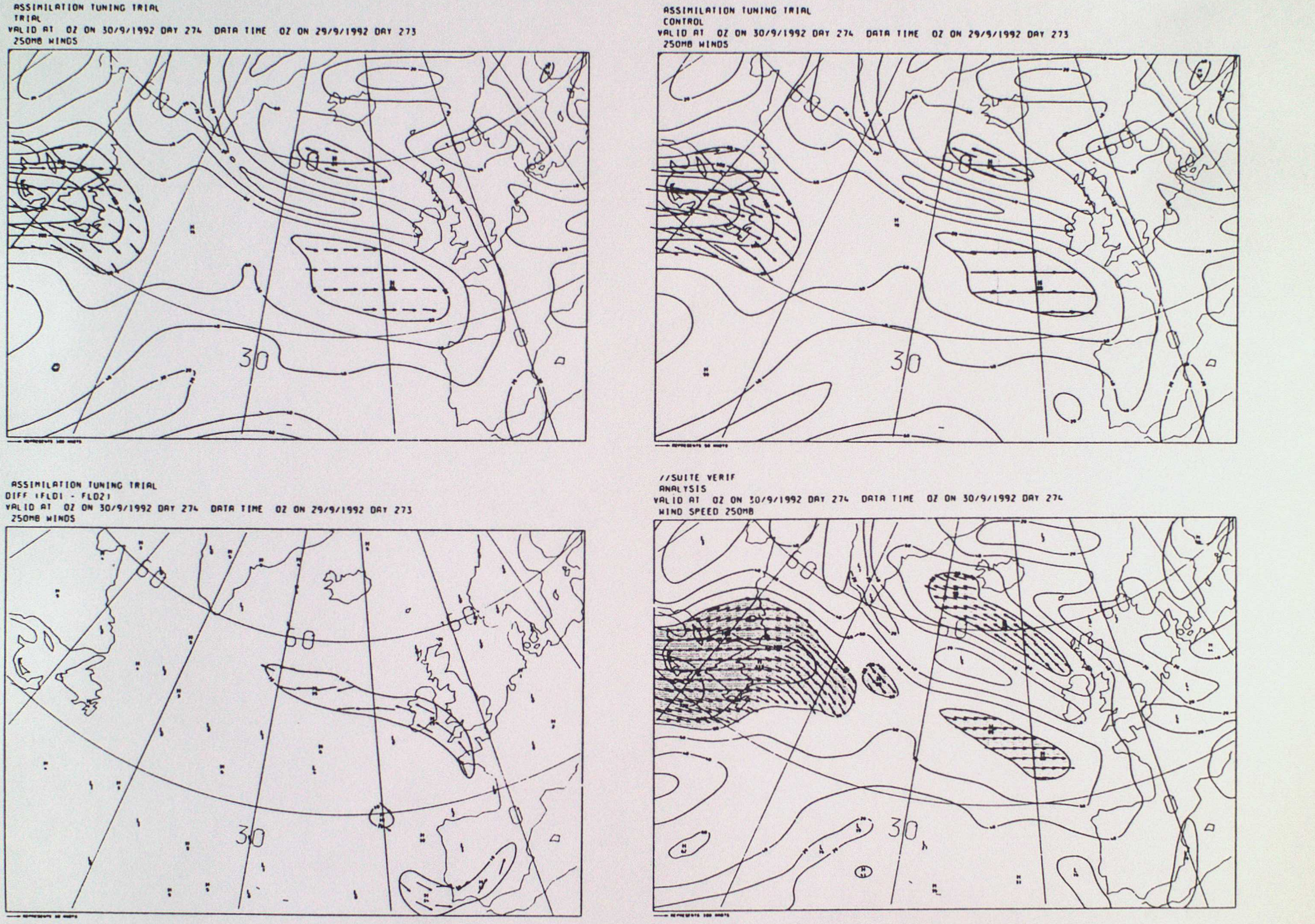


FIG 5: T+24 250HPA WIND FORECAST COMPARISON WITH DIFFS AND VERIF

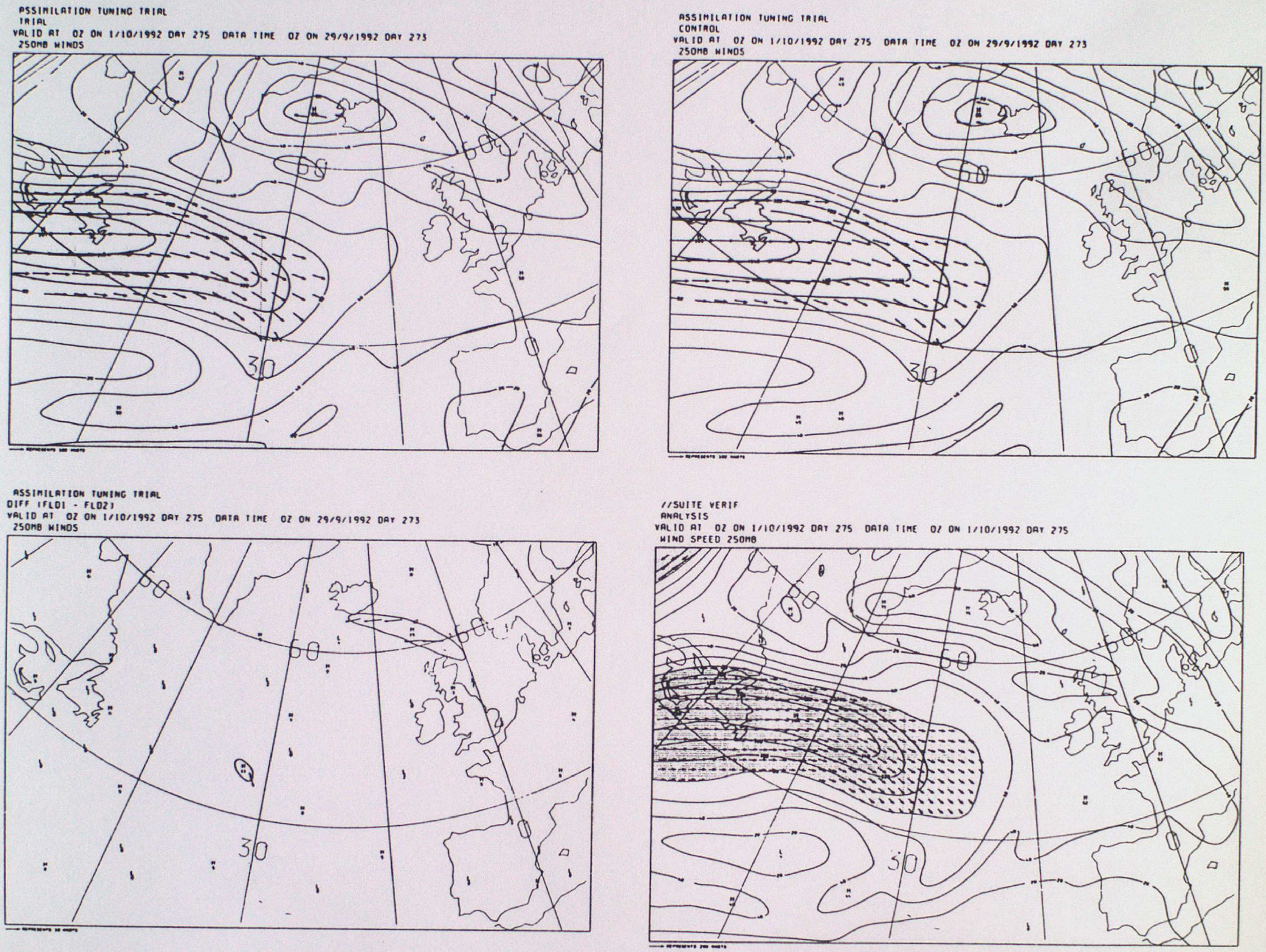


FIG 6: T+48 250HPA WIND FORECAST COMPARISON WITH DIFFS AND VERIF

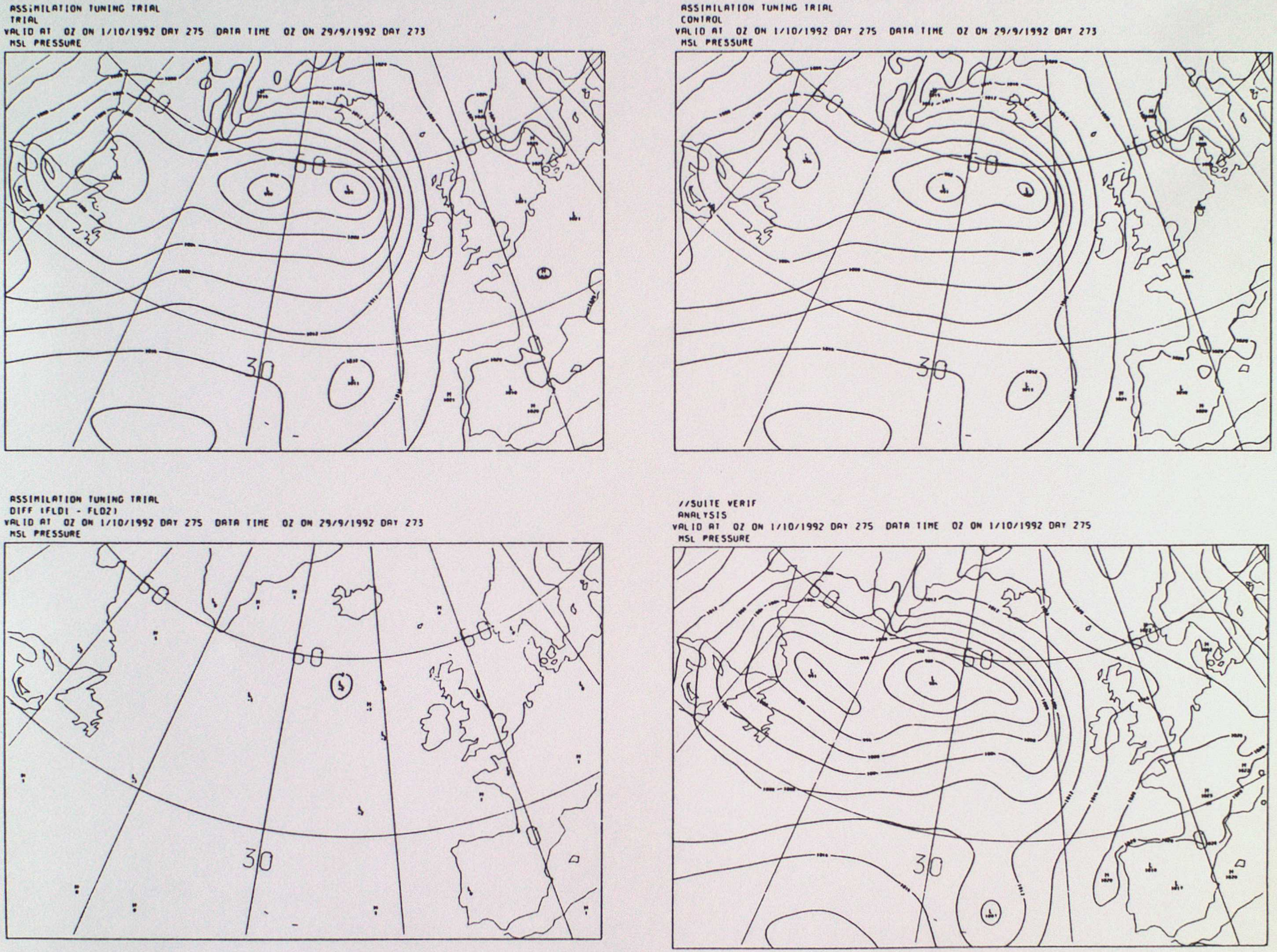


FIG 7: T+48 PMSL FORECAST COMPARISON WITH DIFFS AND VERIF

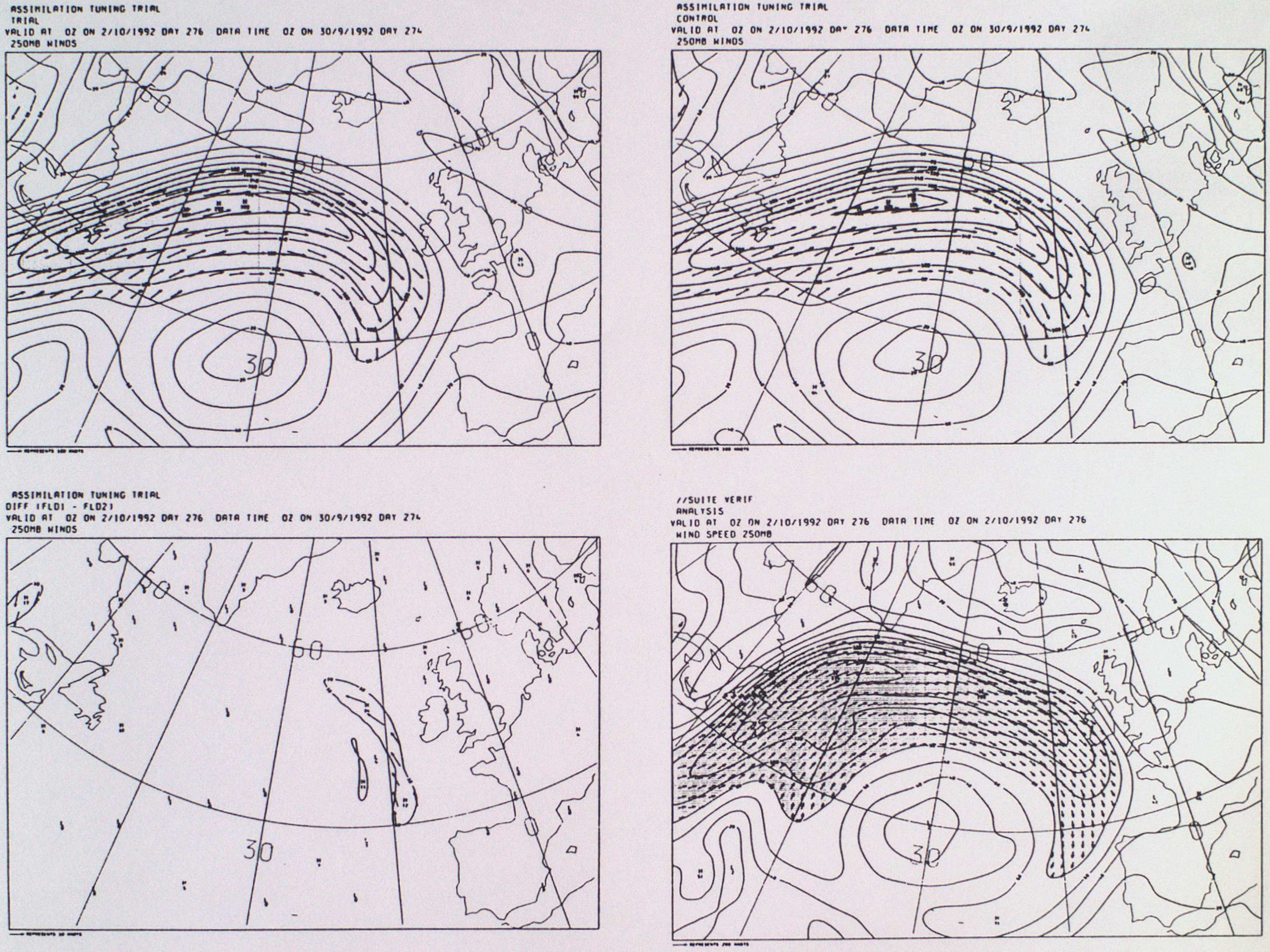


FIG 8: T+48 250HPA WIND FORECAST COMPARISON WITH DIFFS AND VERIF

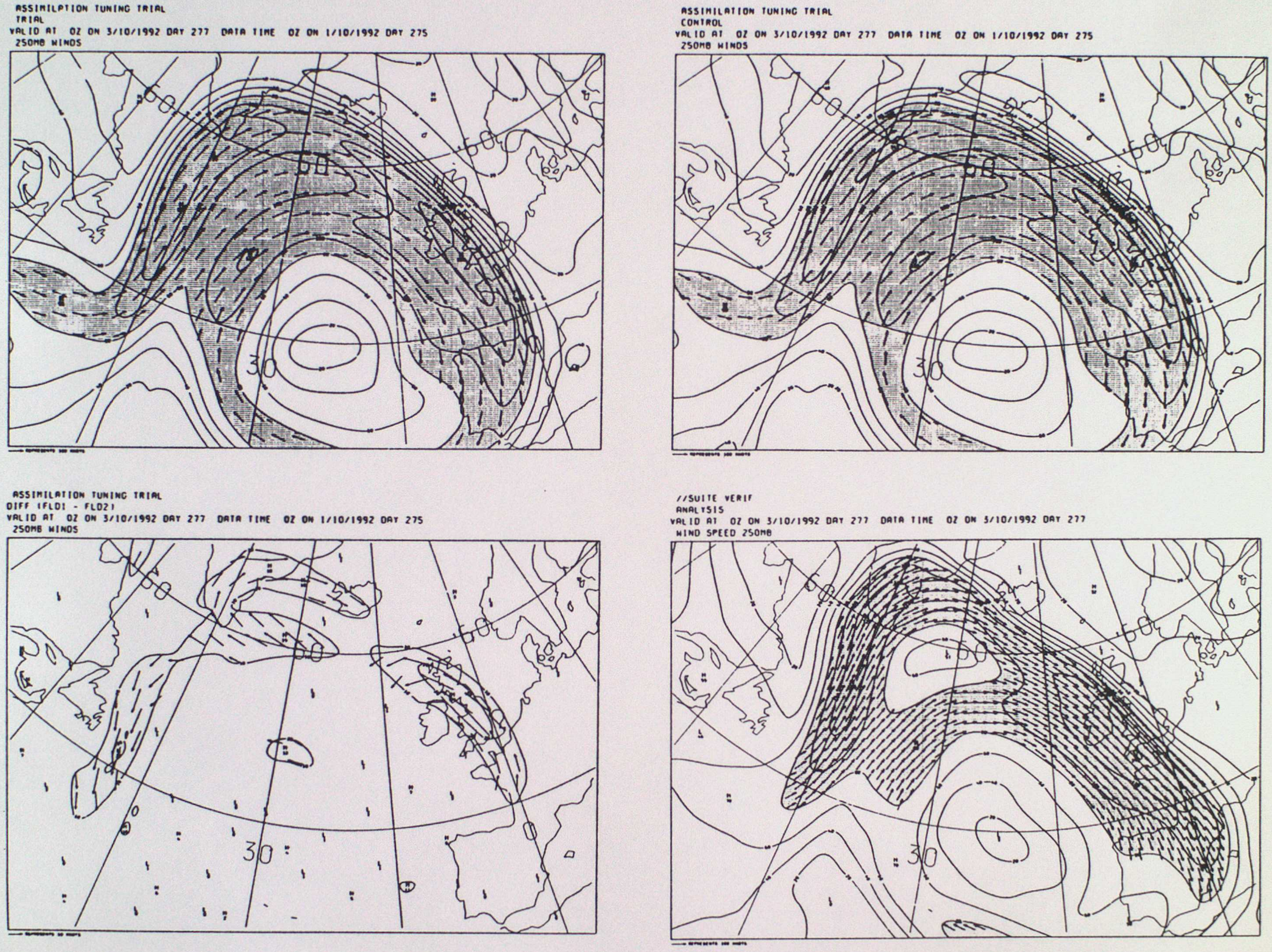
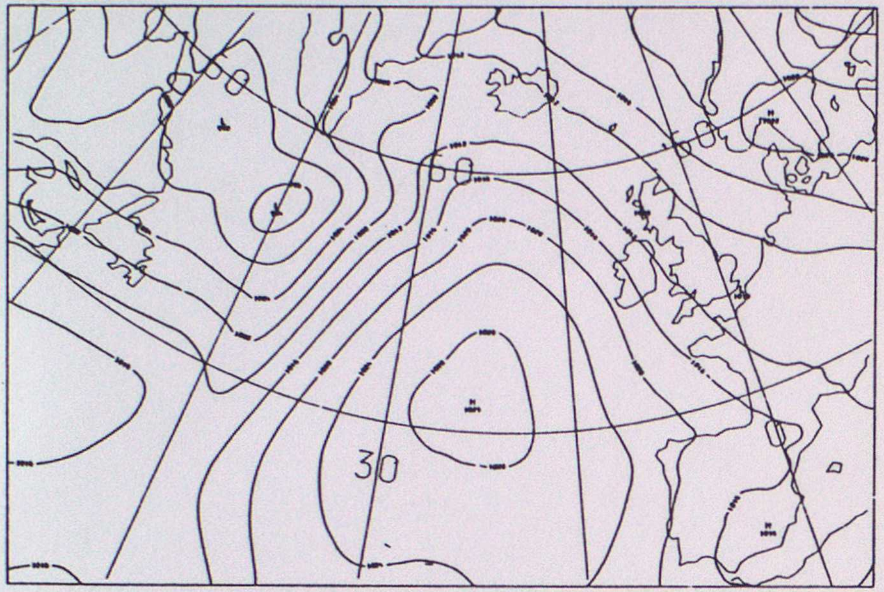
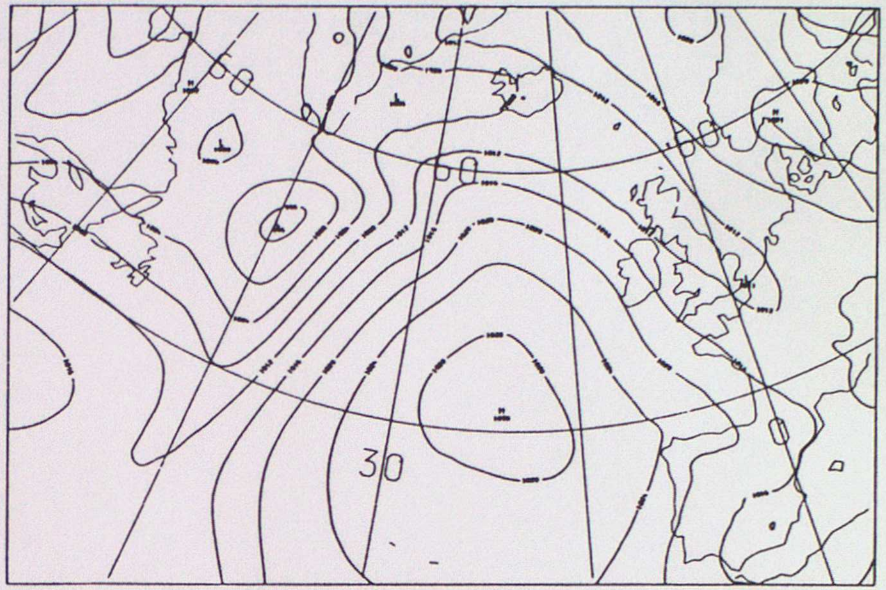


FIG 9: T+48 250HPA WIND FORECAST COMPARISON WITH DIFFS AND VERIF

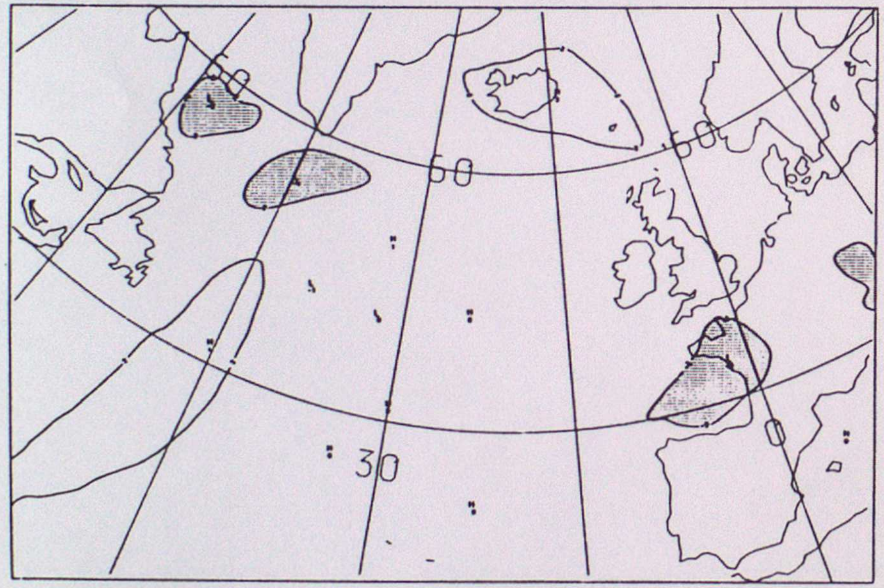
ASSIMILATION TUNING TRIAL
TRIP'
VALID AT 0Z ON 3/10/1992 DAY 277 DATA TIME 0Z ON 1/10/1992 DAY 275
MSL PRESSURE



ASSIMILATION TUNING TRIAL
CONTROL
VALID AT 0Z ON 3/10/1992 DAY 277 DATA TIME 0Z ON 1/10/1992 DAY 275
MSL PRESSURE



ASSIMILATION TUNING TRIAL
DIFF (FLD1 - FLD2)
VALID AT 0Z ON 3/10/1992 DAY 277 DATA TIME 0Z ON 1/10/1992 DAY 275
MSL PRESSURE



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ANALYSIS
VALID AT 0Z ON 3/10/1992 DAY 277 DATA TIME 0Z ON 3/10/1992 DAY 277
MSL PRESSURE

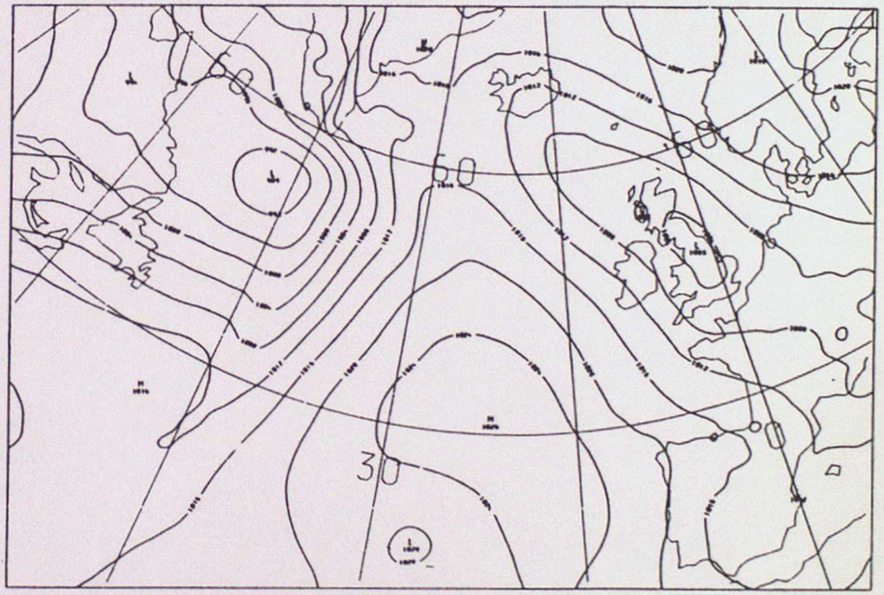

FIG 10: T+48 PMSL FORECAST COMPARISON WITH DIFFS AND VERIF

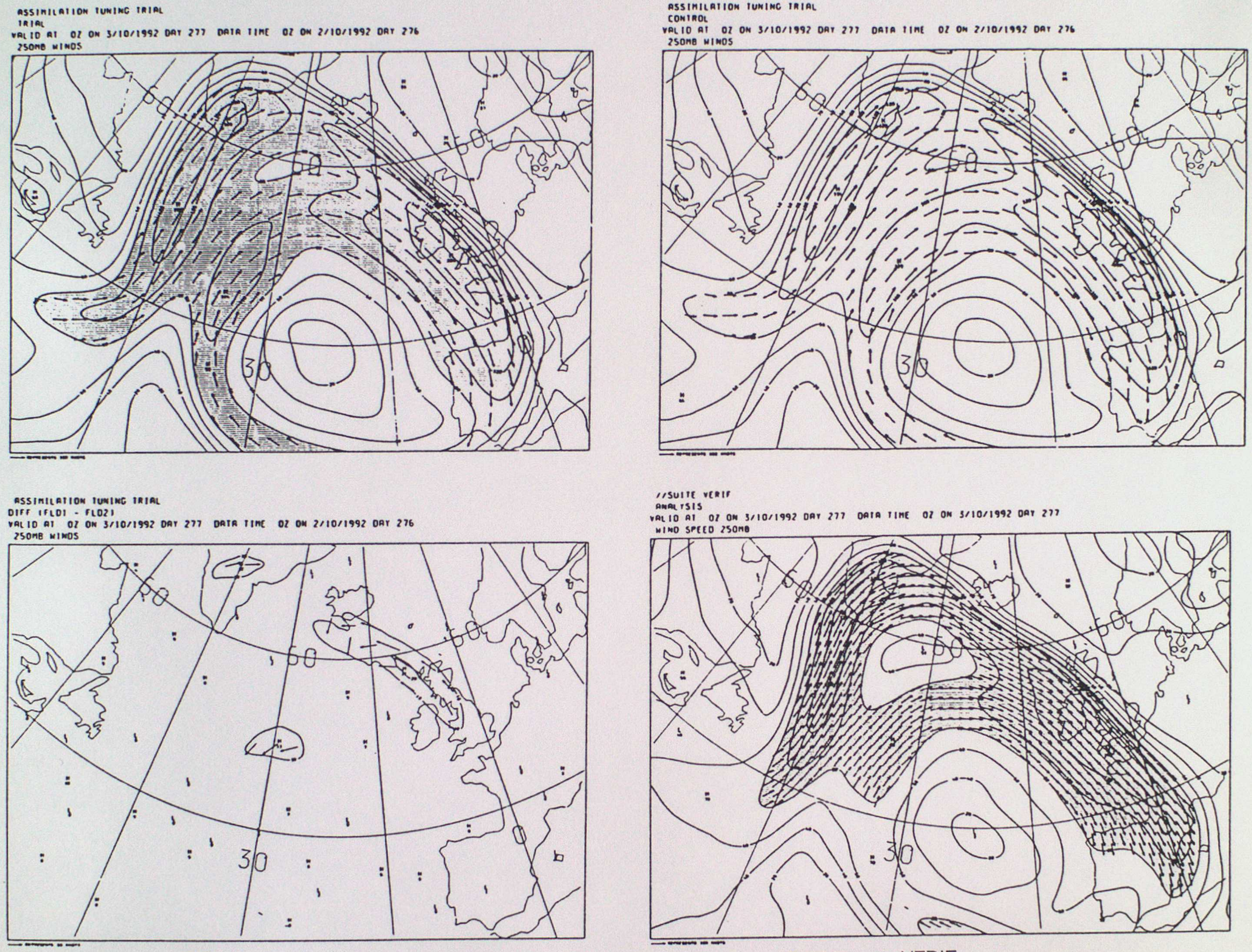

FIG 11: T+24 250HPA WIND FORECAST COMPARISON WITH DIFFS AND VERIF

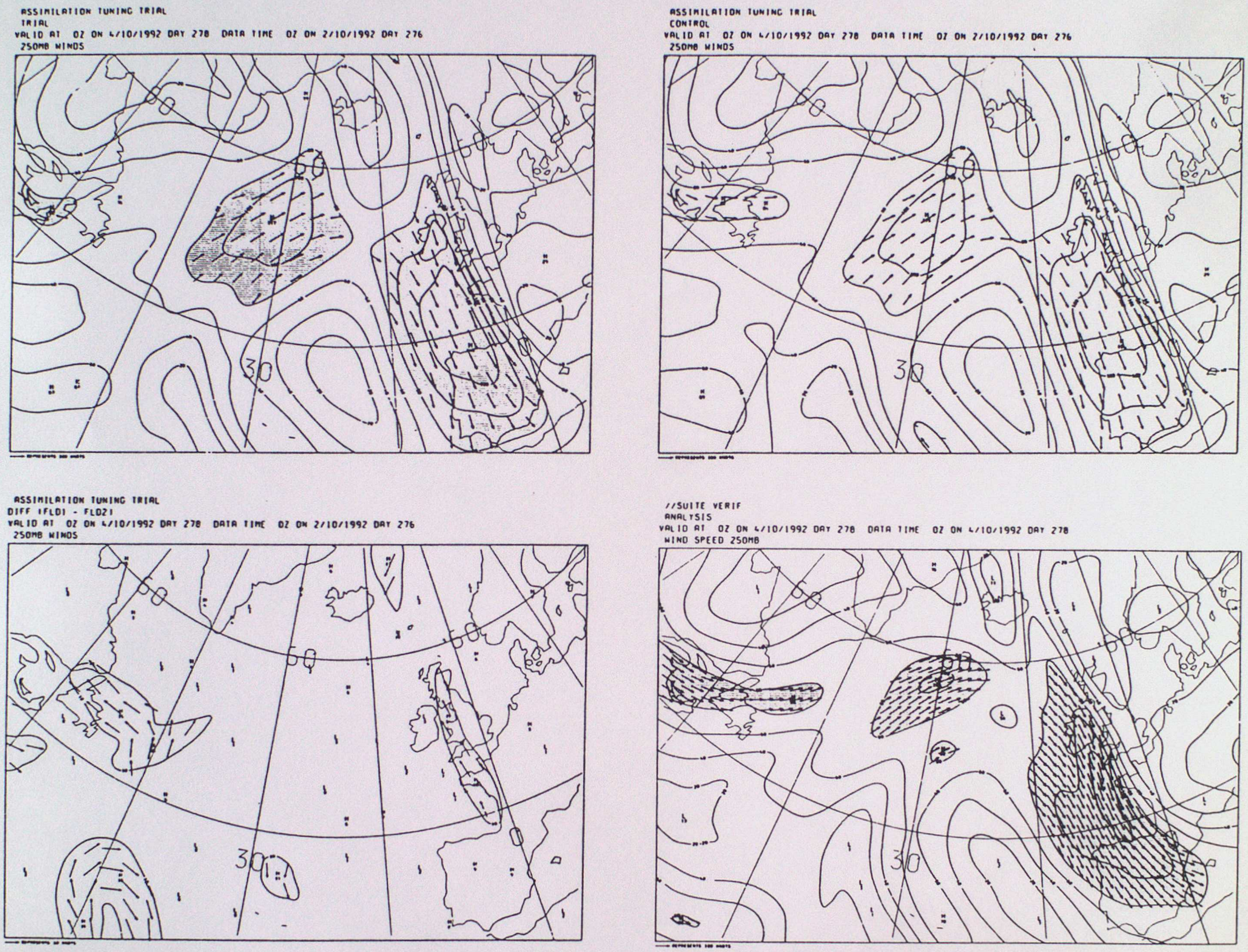

FIG 12: T+48 250HPA WIND FORECAST COMPARISON WITH DIFFS AND VERIF

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