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## TRIAL OF INCREASED VERTICAL RESOLUTION IN THE GLOBAL MODEL

by

C.A.Wilson and O. Hammon

MARCH 1995

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# TRIAL OF INCREASED VERTICAL RESOLUTION IN THE GLOBAL MODEL

CONTENTS



## 1. INTRODUCTION

This technical report contains the results of subjective and objective assessments of a test of extra vertical levels in the global forecast model compared to the standard 19 levels (**FIG 1.1, TABLE 1.1** ) used operationally. A parallel suite trial was performed from 12-31 July 1994 with a new sets of 31 levels. This was based on the levels as used at ECMWF , modified slightly to maintain the same top boundary as the current 19 levels; there are 7 levels below 800hPa, a more uniform resolution in the free atmosphere and increased resolution of ~25 to 30hPa at jet levels compared to the current resolution there of ~50hPa. The bottom layer thickness was also kept the same as operational rather than using the ECMWF first layer which is ~20m thicker. This is because the processing and assimilation of ship winds assumes the first model level is ~25m. Tests of extra vertical resolution with the limited area model had shown this set to improve upper level winds and temperatures, with a smaller improvement to surface pressure and a slight increase in low level cooling, see **Technical Report 113** (Wilson and Hammon, 1994). The increased cost of ~50% run time incurred with extra levels was partly offset by the use of a longer timestep of 20 minutes for the physics, see **Technical Report 112** (Wilson and Hammon, 1994), which had a largely neutral impact on the quality of the forecasts.

TABLE 1.1 UM 19 and 31 LEVELS (η)

| 19(UM) | 31(eculev) |
|---|---|
| .997 | .997 |
| | .983 |
| .975 | |
| | .959 |
| .930 | .928 |
| | .891 |
| .870 | |
| | .850 |
| .792 | .807 |
| ------------------------------------------ | ------------------------------------------boundary layer top |
| | .762 |
| .700 | .717 |
| | .671 |
| | .626 |
| .600 | |
| | .581 |
| | .537 |
| .505 | .495 |
| | .453 |
| .422 | .413 |
| | .374 |
| .355 | |
| | .337 |
| .300 | .302 |
| | .269 |
| .250 | |
| | .237 |
| .200 | .208 |
| | .181 |

| 19 (UM) | 31(eculev) |
|---|---|
| .150 | .155 |
| | .132 |
| .099 | .111 |
| | .090 |
| | .070 |
| .056 | .050 |
| .0296 | .0296 |
| .0147 | |
| | .0088 |
| .0046 | |

## 2. OBJECTIVE VERIFICATION

The analyses and forecasts were verified against observations (sondes and synops) for the period 12/07/94 to 31/07/94. Verification was also performed against analyses, each suite was verified against its own analyses for the same period. Time-mean results will mostly be discussed here . Results for forecast times T+0, T+24, T+72, T+120 and for areas "2", N. Hemisphere to 30N ("200"), Tropics 30N-30S ("300") and S. Hemisphere from 30S ("400") will be given.

### 2. 1 RMS ERRORS -OVERALL SUMMARY

**TABLE 2.1** summarises the objective scores for the N. Atlantic region (area 2) and extratropical N. Hemisphere. It shows the percentage changes in rms errors for heights, temperatures , vector winds (8 levels each) , relative humidity (3 levels) and 3 surface fields. A negative value shows the trial to be an improvement. Column and surface-means are also shown. **TABLE 2.2** summarises the objective scores for the Tropics and extratropical S. Hemisphere.

For all regions there is generally an improvement to heights, temperatures and surface parameters at T+0. The exception being the 100 and 50hPa temperatures in the southern Hemisphere. The winds at T+0 are generally similar to the operational model except at 100hPa where the errors are appreciably smaller for the trial. Southern hemisphere winds at T+0 are generally better than operational. For the N. Atlantic and extratropical N. Hemisphere the trial has bigger rms temperature errors at T+24 at 850hPa; these become worse into the forecasts and affect levels up to 500hPa by T+120; as a result progressively worse height errors are also found for the trial. This was a major drawback of the test and contributed to the decision to defer operational implementation of enhanced vertical resolution.

Forecast temperatures at upper levels above 250hPa are generally improved, except in the southern Hemisphere where the changed (decreased) resolution compared to the operational seems to have exacerbated the problems of the winter night stratosphere. The errors decrease with forecast range suggesting the cause of the problem is in the analysis.However for area2 and the N. Hemisphere the expected improved winds are found at 200 and 100hPa, but not at 250hPa.

Overall there are some large differences in rms errors with big improvements being counterbalanced by some large degradations. Taking changes greater than 1%, the number of scores from **TABLES 2.1 AND 2.2** for which the trial was better are given in **TABLE 2.3**. For changes less than 1% operational and trial were deemed equal. There is broadly an even spread between the trial and operational in all areas except the Southern Hemisphere where the trial is better. Although the trial comes out better overall in this simple count the relatively high counts for the operational better category rather than the equal category reflects the serious defects noted above. The impact of extra resolution is generally as expected from the earlier LAM tests (see **Technical Report 113** ). However the problem of increased cooling in the lower atmosphere has been found to be larger due to the trial being run in northern

%RMS CHANGE (TRIAL-OPERATIONAL) PERIOD 12/07/94-31/07/94

VERIFICATION AGAINST OBSERVATIONS

| | T+0 | T+24 | T+72 | T+120 |
|---|---|---|---|---|
| AREA | 2 | | | |
| HEIGHTS | | | | |
| 850 | -0.5 | 3.1 | 3 | -7.5 |
| 700 | -2.2 | -0.8 | 7.1 | -3.4 |
| 500 | -3 | 0.3 | 7.5 | 0.9 |
| 300 | -2.3 | -2.1 | 6.1 | 3.7 |
| 250 | -5.3 | -2.7 | 7.1 | 5.3 |
| 200 | -2 | -1.8 | 8.1 | 7.2 |
| 100 | -1 | 0.9 | 6.9 | 13.9 |
| 50 | 9.4 | 9.6 | 9.4 | 15.5 |
| MEAN | -0.9 | 0.8 | 6.9 | 4.4 |
| TEMPERATURES | | | | |
| 850 | -4.7 | 8.8 | 15.9 | 13.9 |
| 700 | -1.3 | -1 | 2.3 | 2.3 |
| 500 | 0 | -1.6 | 2.8 | 4.2 |
| 300 | -2 | -3.8 | 1.3 | 6.3 |
| 250 | 4.3 | -2.1 | -3.7 | -1.5 |
| 200 | -3.6 | -3.3 | -1.5 | -2.7 |
| 100 | -7.1 | -4.5 | 1.7 | -1.7 |
| 50 | -4.8 | -6.6 | -24.4 | -41.4 |
| MEAN | -2.4 | -1.8 | -0.7 | -2.6 |
| WINDS | | | | |
| 850 | -1 | -1.1 | -1.6 | -3.2 |
| 700 | -0.1 | 1 | 0.8 | -1.6 |
| 500 | 0.7 | 0.7 | 1.6 | -0.4 |
| 400 | 0.4 | 0.8 | 1.5 | 0.3 |
| 300 | 1 | 0 | 1.4 | 0.8 |
| 250 | 0 | -0.8 | 2 | 1.3 |
| 200 | -0.9 | -2.7 | 2.4 | 1 |
| 100 | -3 | -3.8 | -1.4 | -1 |
| MEAN | -0.4 | -0.7 | 0.8 | -0.3 |
| RH | | | | |
| 850 | -4 | 12.5 | 13.5 | 10.6 |
| 700 | -1.4 | 0.4 | 0.4 | -1.1 |
| 500 | -1.5 | 1 | 1.3 | 1.8 |
| MEAN | -2.3 | 4.6 | 5.1 | 3.8 |
| SURF | | | | |
| pmsl | 0.8 | 1.3 | 1.2 | -5.3 |
| temp | -2.6 | -1.2 | 5.4 | 7.5 |
| wind | 0.5 | 0.4 | 0.2 | -2.1 |
| MEAN | -0.4 | 0.2 | 2.3 | 0 |
| MEAN ALL | -1.2 | 0 | 2.6 | 0.8 |

| | T+0 | T+24 | T+72 | T+120 |
|---|---|---|---|---|
| N HEM | | | | |
| HEIGHTS | | | | |
| 850 | 2.2 | -1 | 1.3 | -2.5 |
| 700 | -1.9 | 0.8 | 4.7 | 0.4 |
| 500 | -1.9 | 1.8 | 6.1 | 3.4 |
| 300 | -2.3 | 1.2 | 6.5 | 6.4 |
| 250 | -3.3 | 1.1 | 7.8 | 8.1 |
| 200 | -1.8 | 1.6 | 7.6 | 8.1 |
| 100 | -1.9 | -1.1 | 2.7 | 5.8 |
| 50 | 7.9 | 4.8 | 8.1 | 8.6 |
| MEAN | -0.4 | 1.1 | 5.6 | 4.8 |
| TEMPERATURES | | | | |
| 850 | -3.1 | 4.8 | 13.8 | 14 |
| 700 | 0.3 | -0.3 | 0.6 | 3.6 |
| 500 | -1.6 | -1.6 | -0.8 | 4.3 |
| 300 | -3.6 | -2 | 3.2 | 6.4 |
| 250 | 0.2 | -4.7 | -2.9 | 0 |
| 200 | -5.1 | -3 | -2 | 0 |
| 100 | -10.4 | -1.9 | -0.4 | -3.6 |
| 50 | -9.5 | -13.9 | -16.3 | -30.1 |
| MEAN | -4.1 | -2.8 | -0.6 | -0.7 |
| WINDS | | | | |
| 850 | -0.6 | -0.5 | -1.7 | -2 |
| 700 | 0.2 | 0.9 | -0.1 | -0.7 |
| 500 | 0.4 | 0.3 | 0 | 0.2 |
| 400 | 0.3 | 0.5 | 0.6 | 1.3 |
| 300 | 0.8 | -0.1 | 0.3 | 1.3 |
| 250 | 0.7 | -0.5 | 0.6 | 1.4 |
| 200 | -0.9 | -2 | 0.6 | 1.2 |
| 100 | -7.8 | -5.3 | -5.6 | -4.8 |
| MEAN | -0.9 | -0.8 | -0.7 | -0.3 |
| RH | | | | |
| 850 | -2.5 | 9.2 | 10.6 | 8.9 |
| 700 | -1.1 | 0.3 | 0.3 | 0 |
| 500 | -1.4 | 0.9 | 0.2 | 0.3 |
| MEAN | -1.7 | 3.5 | 3.7 | 3.1 |
| SURF | | | | |
| pmsl | 2.7 | -1.2 | -0.2 | -2.7 |
| temp | -1.1 | 0.2 | 6.2 | 8.8 |
| wind | 0 | -0.2 | 0.2 | -0.8 |
| MEAN | 0.5 | -0.4 | 2.1 | 1.8 |
| MEAN ALL | -1.5 | -0.4 | 1.7 | 1.5 |

**TABLE 2.1**

%RMS CHANGE (TRIAL-OPERATIONAL) PERIOD 12/07/94-31/07/94

VERIFICATION AGAINST OBSERVATIONS

| | T+0 | T+24 | T+72 | T+120 | | T+0 | T+24 | T+72 | T+120 |
|---|---|---|---|---|---|---|---|---|---|
| TROPICS | | | | | S HEM | | | | |
| HEIGHTS | | | | | HEIGHTS | | | | |
| 850 | -1.6 | 1.4 | 0.9 | -2.9 | 850 | -2.1 | 0.4 | 1.4 | -2.4 |
| 700 | 0.7 | 3.1 | 2.9 | -0.7 | 700 | -2.9 | 0.2 | 0.8 | -1.1 |
| 500 | 0.9 | 2.4 | 3.6 | 1.1 | 500 | -1.3 | -0.8 | -2.5 | -1.1 |
| 300 | -0.7 | 2.8 | 4.7 | 7 | 300 | -3.9 | -2 | -3.5 | 0.6 |
| 250 | 0.4 | 4.8 | 6.6 | 10.5 | 250 | -4.4 | -1.7 | -3.6 | -0.4 |
| 200 | -0.6 | 3.5 | 7.9 | 11.2 | 200 | -7 | -3.3 | -3.1 | -1.7 |
| 100 | -3 | 0.8 | 4.1 | 8.1 | 100 | -7.7 | -2.7 | 1.7 | 1.8 |
| 50 | 4.6 | 1.1 | 6.1 | 10.8 | 50 | 2.2 | -2.3 | -2.4 | -2.1 |
| MEAN | 0.1 | 2.5 | 4.6 | 5.6 | MEAN | -3.4 | -1.5 | -1.4 | -0.8 |
| TEMPERATURES | | | | | TEMPERATURES | | | | |
| 850 | -1.7 | 0.2 | -0.7 | -2.9 | 850 | -6.8 | -3.5 | -2.5 | -0.1 |
| 700 | -4.1 | -3.8 | -4.3 | -1.3 | 700 | -0.3 | -4.4 | -5 | -4.4 |
| 500 | -1.2 | -1.4 | -1.4 | 1 | 500 | 4.3 | -1.2 | -1.9 | 0.7 |
| 300 | -0.8 | 3 | 4 | 9.4 | 300 | 1.7 | -3.3 | -4.6 | -0.7 |
| 250 | -0.6 | 2.7 | 5.2 | 9.3 | 250 | 1.5 | -2.4 | -4.8 | -3.4 |
| 200 | -0.6 | 0.4 | 5.3 | 8.5 | 200 | -1.7 | -1.7 | 0 | 1.8 |
| 100 | -18.1 | -12.4 | -12.6 | -9.6 | 100 | 27.3 | 17.3 | 3.9 | 6.5 |
| 50 | -2.6 | -2.6 | -11.1 | -19.7 | 50 | 100.2 | 67.6 | 19.2 | 13.9 |
| MEAN | -3.7 | -1.7 | -1.9 | -0.7 | MEAN | 15.8 | 8.6 | 0.5 | 1.8 |
| WINDS | | | | | WINDS | | | | |
| 850 | -1.1 | 1.2 | 1.6 | 3.5 | 850 | -1.9 | -0.4 | -0.4 | 2.5 |
| 700 | -0.1 | -1.4 | -0.3 | 1.5 | 700 | -0.8 | 2.3 | -0.9 | 1 |
| 500 | -1 | -0.8 | -1 | -0.5 | 500 | -3.4 | 0.4 | 0.3 | -0.1 |
| 400 | -2 | 0.1 | -1.8 | 1.6 | 400 | 0.2 | 1.5 | -0.2 | -0.7 |
| 300 | 0.9 | -1.2 | -3.3 | -0.1 | 300 | -2.3 | -0.7 | -3.7 | -3.5 |
| 250 | 0.9 | -1.3 | -5.2 | -0.8 | 250 | 1 | -1.1 | -2.2 | -1.3 |
| 200 | -0.5 | -0.6 | -3.8 | -1.2 | 200 | -2.1 | -2.2 | -4.5 | -2.7 |
| 100 | -11.2 | -4.5 | -4.6 | -4.9 | 100 | -7.2 | -0.7 | -2.6 | -2.9 |
| MEAN | -1.8 | -1.1 | -2.3 | -0.1 | MEAN | -2.1 | -0.1 | -1.8 | -1 |
| RH | | | | | RH | | | | |
| 850 | -4.2 | 1.5 | 0.5 | -0.2 | 850 | -5.8 | -0.4 | 2.8 | 1.7 |
| 700 | -1.7 | -1.3 | -3.9 | -3.7 | 700 | 0.9 | 0 | 0.4 | -0.2 |
| 500 | -3.1 | 0.8 | -1.7 | 1.5 | 500 | -2.4 | 2.2 | 3.7 | 0.7 |
| MEAN | -3 | 0.3 | -1.7 | -0.8 | MEAN | -2.4 | 0.6 | 2.3 | 0.7 |
| SURF | | | | | SURF | | | | |
| pmsl | 1 | -2.4 | -1.2 | -3.2 | pmsl | 1.5 | -0.4 | 0.2 | 1.4 |
| temp | 0.3 | 1.9 | 1.9 | -0.5 | temp | -2.1 | -1.1 | -3.1 | -0.3 |
| wind | 0.8 | -0.3 | -0.4 | -0.6 | wind | 0 | -0.2 | 1 | 1.1 |
| MEAN | 0.7 | -0.3 | 0.1 | -1.4 | MEAN | -0.2 | -0.6 | -0.6 | 0.7 |
| MEAN ALL | -1.7 | -0.1 | -0.1 | 1.1 | MEAN ALL | 2.5 | 1.8 | -0.5 | 0.2 |

**TABLE 2.2**

summer (see below) leading to significantly worse height errors and little improvement to surface pressure errors.

**TABLE 2.3** : Summary of objective verification scores from verification against observations (**TABLES 2.1 AND 2.2**)

| Area | Trial better | equal | operational better |
|---|---|---|---|
| N Atlantic ("2") | 47 | 33 | 40 |
| N Hemisphere | 38 | 44 | 38 |
| Tropics | 44 | 37 | 39 |
| S Hemisphere | 57 | 37 | 26 |

**TOTAL SCORE FOR EACH AREA=120**

**TABLES 2.4, AND 2.5**. summarise the percentage changes in rms errors for verification against analyses. NB each version is verified against its own analyses. The clearest benefit of increased vertical resolution is shown by the reductions in rms vector wind errors, especially at T+24, and particularly for area 2 and N Hemisphere. Partly this may be due to the longer timestep which had a beneficial impact at T+24 on winds ( see Technical Report 112)[1]. However the contrast with the small improvements shown by the verification against sondes is somewhat puzzling (see below).

For the N. Atlantic and extratropical N. Hemisphere the bigger temperature errors at 850hPa are evident, as for the verification against sondes. However the spread upwards of the temperature error and degradation of the 500hPa height with forecast time is less evident, but surface pressure errors are worse for the trial. The problem of top level temperatures in the southern Hemisphere from the reduced resolution of the new levels is again apparent ( **TABLE 2.5**.).

**TABLE 2.6** summarises the overall performance of the trial based on the scores in **TABLES 2.4, AND 2.5**. It shows the number of scores for which the rms changed by greater than 1% to decide whether the trial or operational were better in each area,with changes less than 1% deemed equal. The trial version is more clearly favoured in all regions in comparison with the verification against observations with the split between (trial better) : (operational better) being ~4:3. This is mainly due to the clear improvement in wind errors. However the deficiencies noted from verification against sondes and synops are still displayed and in some cases are so large as to be unacceptable. These deficiencies will require attention before the vertical resolution can be enhanced.

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[1]It appears that the extra adjustment steps for each physics increment results in a better balanced model with fewer spurious noisy increments and so generally smoother fields.

RMSE %CHANGE(TRIAL-OPER) PERIOD 12/07/94-31/07/94

VERIFICATION AGAINST ANALYSES

| | T+24 | T+72 | T+120 | | T+24 | T+72 | T+120 |
|---|---|---|---|---|---|---|---|
| AREA 2 | | | | N.HEM | | | |
| HEIGHT | | | | HEIGHT | | | |
| 850 | -4.3 | -0.7 | -5.6 | 850 | -1.6 | -1.1 | -3.1 |
| 700 | -4.2 | 0.7 | -4.7 | 700 | 0.0 | 0.4 | -1.7 |
| 500 | -2.9 | 1.6 | -2.9 | 500 | -1.5 | 1.2 | 0.5 |
| 300 | -2.9 | 1.7 | -0.7 | 300 | -1.0 | 2.0 | 3.4 |
| 250 | -1.3 | 4.9 | 2.0 | 250 | 0.9 | 4.7 | 5.9 |
| 200 | -0.5 | 6.3 | 3.9 | 200 | 0.9 | 5.8 | 7.0 |
| 100 | -1.2 | 12.0 | 11.8 | 100 | -3.3 | 6.0 | 11.5 |
| 50 | -5.5 | 3.0 | 13.9 | 50 | -11.2 | 1.6 | 9.7 |
| mean | -2.9 | 3.7 | 2.2 | mean | -2.1 | 2.6 | 4.2 |
| TEMP | | | | TEMP | | | |
| 850 | 10.9 | 14.1 | 13.4 | 850 | 4.8 | 11.7 | 14.3 |
| 700 | 3.5 | 1.7 | -0.4 | 700 | -1.0 | -1.1 | 1.6 |
| 500 | 2.4 | 0.0 | 0.4 | 500 | 1.2 | -1.2 | 2.1 |
| 300 | -10.1 | -2.6 | 1.4 | 300 | -6.5 | -1.9 | 2.2 |
| 250 | -11.6 | -4.1 | -4.3 | 250 | -9.8 | -5.0 | -3.5 |
| 200 | -9.4 | -4.3 | -5.3 | 200 | -4.8 | -3.2 | -1.6 |
| 100 | -5.0 | 0.0 | -3.3 | 100 | -4.3 | -4.4 | -5.0 |
| 50 | 2.8 | 28.3 | 4.5 | 50 | 1.2 | 0.0 | -14.8 |
| mean | -2.1 | 4.1 | 0.8 | mean | -2.4 | -0.6 | -0.6 |
| WIND | | | | WIND | | | |
| 850 | -3.7 | -2.3 | -3.8 | 850 | -3.7 | -3.2 | -2.5 |
| 700 | -3.1 | -3.1 | -5.3 | 700 | -3.1 | -3.4 | -3.2 |
| 500 | -3.7 | -2.6 | -4.7 | 500 | -4.4 | -3.4 | -2.5 |
| 400 | -3.9 | -2.9 | -4.4 | 400 | -4.3 | -3.1 | -1.7 |
| 300 | -5.9 | -2.8 | -3.7 | 300 | -5.8 | -2.5 | -0.8 |
| 250 | -7.0 | -1.9 | -2.7 | 250 | -6.5 | -1.7 | 0.1 |
| 200 | -6.7 | -2.0 | -2.9 | 200 | -6.4 | -1.9 | -0.1 |
| 100 | -9.7 | -2.2 | -5.9 | 100 | -7.1 | -6.7 | -6.6 |
| mean | -5.5 | -2.5 | -4.2 | mean | -5.2 | -3.2 | -2.2 |
| RELHUM | | | | RELHUM | | | |
| 950 | 0.2 | 5.0 | 5.2 | 950 | 0.6 | 5.0 | 5.3 |
| 850 | 12.1 | 12.5 | 10.8 | 850 | 9.6 | 9.7 | 9.3 |
| 700 | -0.5 | -0.4 | 0.2 | 700 | -1.3 | -0.8 | 1.2 |
| 500 | 0.5 | 0.8 | 0.9 | 500 | -0.8 | -0.8 | -0.1 |
| mean | 3.1 | 4.5 | 4.3 | mean | 2.0 | 3.3 | 3.9 |

**TABLE 2.4**

RMSE %CHANGE(TRIAL-OPER) PERIOD 12/07/94-31/07/94

VERIFICATION AGAINST ANALYSES

| TROPICS | T+24 | T+72 | T+120 | S.HEM | T+24 | T+72 | T+120 |
|---|---|---|---|---|---|---|---|
| HEIGHT | | | | HEIGHT | | | |
| 850 | -5.5 | -6.4 | -8.1 | 850 | -3.2 | -2.4 | 1.8 |
| 700 | -4.6 | -4.8 | -6.8 | 700 | -3.3 | -2.8 | 1.1 |
| 500 | -5.8 | 0.7 | -1.6 | 500 | -3.4 | -3.6 | -0.2 |
| 300 | -0.9 | 9.5 | 14.2 | 300 | -2.6 | -2.5 | -1.1 |
| 250 | 0.0 | 10.7 | 18.2 | 250 | -2.3 | -2.1 | -1.2 |
| 200 | 5.7 | 16.1 | 23.6 | 200 | -0.9 | -1.6 | -2.0 |
| 100 | 8.9 | 16.9 | 25.2 | 100 | 1.4 | 3.1 | -4.6 |
| 50 | 1.4 | 14.4 | 23.6 | 50 | 2.6 | 5.2 | -7.7 |
| mean | -0.1 | 7.1 | 11.0 | mean | -1.5 | -0.8 | -1.7 |
| TEMP | | | | TEMP | | | |
| 850 | -1.2 | 1.4 | 2.9 | 850 | -0.6 | 1.8 | 3.5 |
| 700 | -8.8 | -13.9 | -15.2 | 700 | 0.6 | -1.2 | -0.2 |
| 500 | 0.0 | -1.7 | -1.9 | 500 | 0.7 | 1.0 | -1.4 |
| 300 | -1.4 | 4.4 | 10.5 | 300 | -2.6 | -3.8 | -1.9 |
| 250 | -4.9 | 4.8 | 10.8 | 250 | -9.0 | -4.9 | -4.9 |
| 200 | -3.9 | 4.2 | 6.6 | 200 | -2.6 | -0.3 | -0.7 |
| 100 | 9.2 | 11.9 | 16.6 | 100 | 17.0 | 23.5 | 15.5 |
| 50 | 48.2 | 64.5 | 72.1 | 50 | 92.2 | 80.1 | 62.9 |
| mean | 4.7 | 9.5 | 12.8 | mean | 12.0 | 12.0 | 9.1 |
| WIND | | | | WIND | | | |
| 850 | -0.2 | 0.3 | 0.9 | 850 | -3.2 | 0.1 | 1.7 |
| 700 | -3.2 | -3.1 | -2.2 | 700 | -3.3 | -0.9 | 0.8 |
| 500 | -1.5 | -0.3 | 1.4 | 500 | -3.7 | -2.0 | 0.3 |
| 400 | -2.4 | 0.9 | 2.1 | 400 | -3.7 | -1.4 | 0.3 |
| 300 | -7.4 | -2.1 | 0.0 | 300 | -4.8 | -2.4 | -0.6 |
| 250 | -10.1 | -5.5 | -2.1 | 250 | -5.2 | -2.8 | -0.8 |
| 200 | -9.3 | -5.2 | -1.6 | 200 | -4.1 | -3.5 | -1.7 |
| 100 | 4.4 | 4.0 | 5.8 | 100 | -3.7 | -2.7 | -4.4 |
| mean | -3.7 | -1.4 | 0.5 | mean | -4.0 | -2.0 | -0.6 |
| RELHUM | | | | RELHUM | | | |
| 950 | -7.3 | -8.6 | -6.1 | 950 | -7.2 | -5.1 | -5.4 |
| 850 | 2.4 | 1.3 | 1.3 | 850 | 0.7 | 1.8 | 2.5 |
| 700 | -4.9 | -7.0 | -6.7 | 700 | 0.6 | -1.0 | 0.1 |
| 500 | -0.1 | -2.6 | -3.2 | 500 | -1.8 | 1.1 | 1.0 |
| mean | -2.5 | -4.2 | -3.7 | mean | -1.9 | -0.8 | -0.5 |

**TABLE 2.5**

**TABLE 2.6** : Summary of objective verification scores from verification against analyses (**TABLES 2.4 AND 2.5** )

| Area | Trial better | equal | operational better |
|---|---|---|---|
| N Atlantic ("2") | 44 | 15 | 28 |
| N Hemisphere | 43 | 16 | 28 |
| Tropics | 41 | 11 | 35 |
| S Hemisphere | 46 | 23 | 18 |

**TOTAL SCORE FOR EACH AREA=87**

## 2.2 BIASES AND VERTICAL DISTRIBUTION OF ERROR

The verifications against surface observations and sondes will mostly be shown since the pattern from verification against analyses is very similar.

### PMSL

**FIGURE 2.1** shows the bias and rms errors (in hPa) ,verified against observations, from T+0 to T+120 for mean sea-level pressure for N Atlantic , N Hemisphere, Tropics and S. Hemisphere. The positive biases in the N. Hemisphere areas are slightly greater whilst in the tropics there is a slightly larger negative bias. Overall the changes are probably not significant.

### HEIGHT

**FIGURE 2.2** shows the bias (left) and rms (right) height error profiles for T+120 for area 2 (top) and N Hemisphere (bottom). **FIGURE 2.3** shows the same for the tropics and S Hemisphere. It is quite apparent that there has been a significant worsening of the negative height bias, particularly in extratropical regions.

### TEMPERATURE

**FIGURE 2.4** shows the bias (left) and rms (right) temperature error profiles for T+120 for area 2 (top) and N Hemisphere (bottom). **FIGURE 2.5** shows the same for the tropics and S Hemisphere. There is a larger cold bias at all levels up to 300hPa in the extratropics, and 200hPa in the tropics leading to the worse height biases. The cold bias is first evident at low levels (850hPa) at T+24 ( **FIGURE 2.6** area 2 (top) and N Hemisphere (bottom)). At other levels at this time the extra resolution has improved bias and rms scores generally. The cold bias gets progressively worse with forecast length and gradually affects higher levels.

### WINDS

**FIGURE 2.7** shows the bias (left) and rms vector (right) wind error profiles for T+0 for area 2 (top) and N Hemisphere (bottom). In distinction from the previous trial of longer physics timestep alone, there is not any evidence of the degradation of 2% in the analysed winds ( see **Technical Report 112** ). The biases are very similar with a very slightly larger underestimate of strength at 250hPa and better smaller underestimates at 200 and 100hPa. By T+24 ( **FIGURE 2.8** ) the biases are still very similar. More surprising the expected improvement in rms vector winds is not realised with only very small changes at 200 and 100hPa. Verification against analyses does show the expected improvements however ( **FIGURE 2.9** ), with the best change at 250hPa. The statistics are from different samples as shown by the absolute displacement of the data points in figure 2.9. The observations are sondes which are largely land based. The verification statistics for these takes no account of observation density, so that a large error in a small region can contribute excessively. Both verifications use the same output winds on standard pressure levels so the explanation for the discrepancy, apart from programming error, appears to be that the extra resolution benefits the winds over oceanic areas preferentially. This is unlikely. Verification against other observation types such as aireps might cast some light on the problem but these are not available at present from the operational verification packages. Some independent figures are available from the Observation Processing Database (OPD) for the background T+6 errors (see section 2.3). Similar results were found for the tropics and S Hemisphere (not shown).

## 2.3 OBSERVATION-BACKGROUND WIND ERRORS AGAINST AIREPS

To investigate further the discrepancy between wind verification against analyses and verification against sondes, the Observation Processing Database (OPD) from both trial and operational was used to look at background (T+6) errors against aireps. Ranking the O-B differences by speed bands the operational loss of speed compared to aireps is reduced with extra vertical resolution (**FIGURE 2.10, AND TABLE 2.7**, global region); background rms vector wind errors are similar or improved, particularly for 60-80ms$^{-1}$s and in excess of 80ms$^{-1}$ . The results from individual latitude bands for the N. Hemisphere (**FIGURE 2.11** ),tropics (**FIGURE 2.12** ) and S. Hemisphere (**FIGURE 2.13**) are broadly the same. The largest improvements are at higher wind speeds and for the winter(southern) hemisphere as expected. The bulk of the observations are for the North Atlantic and North Pacific (**TABLE 2.7**) and confirm the results of the verification against analyses. The impact of extra resolution appears to be greater over the oceanic areas and forecast wind speeds for aviation are improved. This is despite the use of the longer timestep for physics which gave a small reduction of wind speeds and increased background errors (see Technical Report 112).

## 2.4 OBJECTIVE VERIFICATION - SUMMARY

The verification scores have shown many of the expected benefits from extra vertical resolution. Whilst overall the rms errors are comparable to the operational errors the trial is marginally favoured. Verification against analyses and aireps shows the forecast winds to be better, particularly at upper flight levels. However against sondes there is no obvious improvement. A major drawback of the trial was increased low level cooling which lead to worse height errors at later forecast ranges. The cause of the cooling was increased low cloud amount, especially over N Hemisphere land (see **FIGURE 3.9**, below). Some worsening of problems due to lack of resolution at the topmost model levels for the winter stratosphere were also found. The deficiencies are in some cases so large as to be unacceptable and require attention before the vertical resolution can be enhanced.

# 3. SUBJECTIVE ASSESSMENT

Background errors (against aireps)

Jul13 - Jul 31

400-101hPa

| Operational | | | | 31 levels +long t/step | | | | |
|---|---|---|---|---|---|---|---|---|
| MEAN O&B SPEED m/s | MEAN O-B SPEED m/s | RMS O-B VECTOR m/s | No. OBS | MEAN O-B SPEED m/s | RMS O-B VECTOR m/s | No. OBS | %mean diff | %rms diff |
| 90-30S | | | | | | | | |
| Total no. Observations | | | 2382 | Total no. Observations | | 2382 | | |
| 0-3 | -0.32 | 3.21 | 2 | 0.48 | 2.81 | 2 | -250.0 | -12.5 |
| 3-20 | -0.02 | 5.92 | 513 | -0.11 | 5.98 | 510 | 450.0 | 1.0 |
| 20-40 | 1.18 | 6.62 | 1276 | 1.03 | 6.56 | 1278 | -12.7 | -0.9 |
| 40-60 | 2.78 | 7.70 | 449 | 2.26 | 7.40 | 446 | -18.7 | -3.9 |
| 60-80 | 3.67 | 8.98 | 124 | 2.98 | 8.63 | 125 | -18.8 | -3.9 |
| >80 | 3.44 | 7.89 | 18 | 1.99 | 7.55 | 21 | -42.2 | -4.3 |
| ALL | 1.37 | 6.85 | 2382 | 1.13 | 6.74 | 2382 | -17.5 | -1.6 |
| 30N-30S | | | | | | | | |
| Total no. Observations | | | 14860 | Total no. Observations | | 14858 | | |
| 0-3 | -0.52 | 3.27 | 386 | -0.61 | 3.14 | 370 | 17.3 | -4.0 |
| 3-20 | 0.88 | 5.28 | 8863 | 0.91 | 5.36 | 8898 | 3.4 | 1.5 |
| 20-40 | 1.31 | 6.08 | 4192 | 1.25 | 6.03 | 4163 | -4.6 | -0.8 |
| 40-60 | 0.79 | 6.92 | 1055 | 0.64 | 6.96 | 1058 | -19.0 | 0.6 |
| 60-80 | 1.39 | 7.55 | 355 | 0.90 | 7.57 | 359 | -35.3 | 0.3 |
| >80 | 3.84 | 5.32 | 9 | 3.64 | 5.58 | 10 | -5.2 | 4.9 |
| ALL | 0.97 | 5.66 | 14860 | 0.95 | 5.70 | 14858 | -2.1 | 0.7 |
| 30N-90N | | | | | | | | |
| Total no. Observations | | | 48122 | Total no. Observations | | 48127 | | |
| 0-3 | -0.85 | 3.12 | 815 | -0.87 | 3.11 | 836 | 2.4 | -0.3 |
| 3-20 | 0.39 | 5.37 | 26346 | 0.38 | 5.39 | 26313 | -2.6 | 0.4 |
| 20-40 | 1.06 | 7.36 | 17188 | 0.99 | 7.36 | 17188 | -6.6 | 0.0 |
| 40-60 | 2.56 | 8.62 | 3525 | 2.41 | 8.58 | 3536 | -5.9 | -0.5 |
| 60-80 | 4.04 | 9.80 | 245 | 3.58 | 9.60 | 251 | -11.4 | -2.0 |
| >80 | -2.43 | 4.35 | 3 | -2.91 | 4.40 | 3 | 19.8 | 1.1 |
| ALL | 0.79 | 6.42 | 48122 | 0.74 | 6.43 | 48127 | -6.3 | 0.2 |
| Global | | | | Global | | | | |
| Total no. Observations | | | 65364 | Total no. Observations | | 65367 | | |
| 0-3 | -0.75 | 3.17 | 1203 | -0.78 | 3.12 | 1208 | 4.0 | -1.6 |
| 3-20 | 0.51 | 5.36 | 35722 | 0.51 | 5.39 | 35721 | 0.0 | 0.6 |
| 20-40 | 1.11 | 7.10 | 22656 | 1.04 | 7.09 | 22629 | -6.3 | -0.1 |
| 40-60 | 2.21 | 8.21 | 5029 | 2.03 | 8.16 | 5040 | -8.1 | -0.6 |
| 60-80 | 2.67 | 8.62 | 724 | 2.17 | 8.49 | 735 | -18.7 | -1.5 |
| >80 | 2.97 | 6.91 | 30 | 2.04 | 6.79 | 34 | -31.3 | -1.7 |
| ALL | 0.85 | 6.27 | 65364 | 0.80 | 6.28 | 65367 | -5.9 | 0.2 |

**TABLE 2.7**

## 3. Subjective Assessment

### 3.1 Northern Hemisphere (north of 30N)

In comparison with the previous parallel suite trial (20 min timestep for physics, **Technical Report 112** ), it was soon apparent that increasing the vertical resolution was having a bigger impact on forecasts in the Northern Hemisphere. Differences were insignificant at T+24/48, but some changes in evolution developed by T+120.

**i) Mean sea level pressure and precipitation forecasts.**

Trial and operational depressions agreed closely at T+24/72 being generally within +/- 4mb. At T+120, differences were much larger, +/- 12mb, with changes in evolution. There were no systematic differences between trial and operational depressions. There were pluses and minuses but overall the subjective assessment slightly favoured the trial forecasts.

In most cases it was clear that the increased vertical resolution was having an impact on precipitation but the differences were not consistent. However, there was a tendency for showers to be less frequent but heavier over Europe. A comparison of rainfall statistics for 15 cases at T+72 indicated a slight increase in convective rainfall in trial forecasts and a slight decrease in dynamic rainfall. Overall impact was slight, (N.Hem +1.5%, Area 2 +3%).

The following three cases describe typical differences in mean sea level pressure and rainfall forecasts for T+72/120.

An important feature of the North Atlantic analysis for 12Z 24/07/94, (**Figure 3.1b**), was a complex area of low pressure to the west of Ireland, with two centres, 992mb at 58N 35W and 997mb at 53N 25W. The difference chart, (**Figure 3.1a**), indicates that the trial forecast mean sea level pressure at T+120 was significantly lower by 7-14mb in this area. A comparison of the individual trial and operational T+120 forecasts, (**Figures 3.2a/b** respectively) show that the trial forecast was much closer to the analysis, with centres 997mb at 58N 37W and 1002mb at 53N 30W. The operational forecast of the northern centre was very poor.

The next example shows a significant difference in timing over southern England between the trial and operational T+120 forecasts verifying at 12Z 19/07/94. The analysis, **Figure 3.3b**, shows a northeasterly airstream over southern England with a slack low pressure area over northeast France. The weather over southern England remained dry all day. The difference chart, **Figure 3.3a**, indicates a difference of 5-8mb between the two forecasts over southeast England. The individual trial and operational T+120 forecasts, compared in **Figures 3.4a and 3.4b** respectively, were very different over Southern England. The operational forecast was poor, with the timing too slow and the track of the low too far north. This forecast predicted a wet day for much of England and Wales incorrectly. The trial forecast had cleared the rain from the southeast and was much closer to the truth.

The analysis for 12Z 26/07/94 (**FIGURE 3.5a**) showed a frontal system over Wales moving eastwards, giving occasional rain or showers over most of England and Wales during the afternoon. The radar image, **FIGURE 3.5b**, shows the rainfall distribution at 12Z. The individual trial and operational T+72 forecasts for 12Z 26/07/94, compared in **FIGURES 3.6a/b** respectively), were very different for England and Wales. The trial timing was too fast, with the forecast showing a weak rainband over southeast England. The operational forecast was better in this case, with the forecast rainband further to the northwest.

**ii) 250mb jets**

The impact on T+24 jets was variable and there was no real sign of stronger jet cores, but the subjective assessment favoured the trial jets. Considering 20 jets which differed by more than 5 knots, 14 trial jets were closer to the analysis. Differences at T+24 were small, mainly between 2.5 and 5 $ms^{-1}$. One example is described below.

The 250mb wind analysis for 12Z 24/07/94 (**FIGURE 3.7a**) shows a northwesterly jet over America with core 42-44 $ms^{-1}$. The wind vector difference chart, **FIGURE 3.7b**, shows differences of 5-10$ms^{-1}$ between the T+24 trial and operational jets on the leading edge of the jet. A comparison of the trial and operational T+24 forecasts in **FIGURES 3.8a/b** respectively and the vector differences suggest that the operational jet was turning on to a more southerly direction than the trial forecast at this time. The trial forecast was closer to the analysis.

The subjective assessment favoured the trial forecasts at T+24/72 but the operational forecasts were better at T+120, suggesting a slight deterioration in the quality of the trial forecasts with time.

**iii) Cloud Amount.**

All individual trial forecasts showed a significant increase in low cloud when compared with the operational forecasts. The mean low,medium and high cloud fractions for T+24/72/120, calculated from forecasts run between 12Z 12/07/94 and 12Z 27/07/94, are listed below in **TABLE 3.1**. Both sets of forecasts show the spin-up problem, with low cloud increasing with time, but the trial forecasts had about 30% more low cloud than the operational forecasts.

**FIGURE 3.9a** shows the differences in mean low cloud fraction for 12Z, at T+120 verifying during the period 17th July-1st August. The increase in low cloud can be seen over Europe, especially Eastern Europe and in patches over the sea. The increase in low cloud did not appear to be a bottom level problem, although there was some extra low cloud near the centre of anticyclones. Low cloud statistics from two cases suggested that the increased low cloud was well distributed through levels 1-7.

All trial forecasts showed a small decrease in medium cloud of approximately 9% (**FIGURE 3.9b** ) and a small increase in high cloud of approximately 10% (**FIGURE 3.9c** ).

(**FIGURE 3.9b** ) and a small increase in high cloud of approximately 10% (**FIGURE 3.9c** ).

| MEAN CLOUD FRACTION | | | | | | |
|---|---|---|---|---|---|---|
| forecast time | LOW | | MEDIUM | | HIGH | |
| | trial | oper | trial | oper | trial | oper |
| T+024 | 0.41 | 0.33 | 0.15 | 0.16 | 0.27 | 0.24 |
| T+072 | 0.48 | 0.37 | 0.17 | 0.18 | 0.28 | 0.25 |
| T+120 | 0.51 | 0.39 | 0.18 | 0.20 | 0.28 | 0.25 |

**TABLE 3.1**. Mean cloud fractions in the Northern Hemisphere from T+24/72/120 forecasts run from DT12Z 12/07/94 to DT12Z 27/07/94

## 3.2 THE TROPICS (30N - 30S)

### (i) Subtropical Jets

There was an impact on the subtropical jets but it was variable rather than systematic. There was no advantage either way and the assessment was roughly 50-50.

### (ii) Precipitation

The overall impact was a small increase of 1%. Most cases showed a slight increase in convective precipitation and a small decrease in dynamic. There was a slight tendency for the shower distribution in the trial forecasts to be jerkier, with fewer but heavier showers, in comparison with the smoother, more widespread showers in operational forecasts.

### (iii) Impact upon Tropical Cyclones

The parallel suite trial forecasts had equal access to bogus observations added by CFO and generally differences between trial and operational tropical cyclone forecasts were small. The following example shows the difference between the T+72 forecasts of 'Emilia', a tropical cyclone which passed just to the south of Hawaii. **TABLE 3.2** below gives the position and maximum wind speed associated with 'Emilia' during the 21st and 22nd July.

| | | | | |
|---|---|---|---|---|
| 21st | 09Z | 125 | 14.4N | 155.3W |
| | 15Z | 125 | 15.1N | 155.8W |
| | 21Z | 115 | 15.8N | 156.6W |
| 22nd | 03Z | 105 | 16.6N | 157.1W |
| | 09Z | 85 | 17.3N | 157.5W |
| | 15Z | 65 | 17.7N | 158.7W |
| | 21Z | 65 | 18.2N | 159.4W |

**TABLE 3.2**. Position and maximum wind speed associated with tropical cyclone 'Emilia' on 21st/ 22nd July 1994.

The trial and operational T+72 forecasts for mean sea level pressure and 850mb wind,verifying at 12Z 22nd July, are compared in **FIGURES 3.10** and **3.11** respectively. The trial forecast (**FIGURE 3.10a**) predicted the cyclone to be centred at approximately 18N 158W at 12Z 22/7/94, just to the south of Hawaii, which was an accurate forecast. and slightly deeper and better positioned than the operational forecast shown in **FIGURE 3.10b**. The trial also predicted slightly stronger winds at the surface and 850mb around the cyclone. The 850mb T+72 wind forecasts are compared in **FIGURES 3.11a/b** respectively.

**(iv) Impact on Monsoon Forecasts**

A small impact was noticed on rainfall and low level winds forecast for the Indian monsoon. The rainfall accumulation differences shown in **FIGURE 3.12** were averaged from T+24 forecasts run during the period 12th - 27th July. The difference in total rainfall, **FIGURE 3.12c**, indicates an overall increase in rainfall over the sea but a small decrease over land. The increase over the sea was from convective rain, (**FIGURE 3.12b**), due to the trial showers being slightly heavier. The decrease over land was partly dynamic and partly convective (**FIGURES 3.12a/b**) and could be linked to an increase in low cloud.

The charts in **FIGURE 3.13** show the impact of the increased vertical resolution on the low level winds in the monsoon area. The verification winds shown in **FIGURE 3.13c** were from 850mb winds averaged from parallel suite analyses run during the period 17th -31st July. The 850mb forecast winds have been averaged from T+120 forecasts run during the period 12th - 27th July. The trial and operational forecasts, compared in **FIGURES 3.13 a/b** respectively, look very similar but the vector differences (**FIGURE 3.13c**) indicate that the trial has a weaker northerly component south of India and a stronger westerly flow across Southern India. Although the trial 15ms$^{-1}$ isotach verifies better when compared to the analysis, overall the increased westerly component was not correct.

A similar comparison of the 250mb winds in **FIGURE 3.14** indicated little change in the mean wind speed of the subtropical jet over the Caspian Sea but an increased northeasterly component south of India.

**(v) Stratospheric Winds and Temperatures in the Tropics.**

The largest impact on the winds in the Tropics was seen at 100mb in the mean easterly flow in the Indian Ocean. The vector difference chart ,(**FIGURE 3.15c**) , shows a decrease of 20-40 ms$^{-1}$ in the averaged easterly winds between Ethiopia and Sri Lanka. Again, these winds have been averaged from T+120 forecasts run during the period 12th - 27th July. The trial winds, shown in **FIGURE 3.15a**, had a much stronger gradient in the Indian Ocean but the operational forecast, (**FIGURE 3.15b**) , compared better with the analysis.

In the trial version, the lower boundary of the top model layer was lowered to 20mb so that the top level was placed at ~8.8mb. In the operational version, the top layer boundary is at 10mb with a top level at 4.6mb and the penultimate level is at 14.7mb (see **TABLE 1.1**). The relative positions of the levels used to interpolate to 10mb between the versions meant period 12th - 27th July, are compared in **FIGURE 3.16**, showing the trial analyses to be about 20C colder, due mainly to larger interpolation errors.

**(vi) Cloud in the Tropics**

As in the Northern Hemisphere, a marked increase of low cloud was seen in all forecasts (see **FIGURE 3.9a**) . The increase over the sea represents increased areas of stratocumulus, which may be realistic since a common fault of the unified model in climate and forecast versions is to underestimate subtropical stratocumulus. A similar sensitivity to extra vertical resolution has been found in climate simulations (Bushell, private communication). The increase over land was usually associated with a small decrease in dynamic rain. The mean low,medium and high cloud fractions for T+24/72/120, calculated from forecasts run beteen 12Z 12/07/94 and 12Z 27/07/94, are listed below in **TABLE 3.3**. There is more high cloud in the ITCZ and over the western Pacific (**FIGURE 3.9c**) .

MEAN CLOUD FRACTION

| forecast time | LOW | | MEDIUM | | HIGH | |
|---|---|---|---|---|---|---|
| | trial | oper | trial | oper | trial | oper |
| T+024 | 0.20 | 0.12 | 0.05 | 0.08 | 0.24 | 0.20 |
| T+072 | 0.19 | 0.10 | 0.06 | 0.10 | 0.25 | 0.22 |
| T+120 | 0.19 | 0.11 | 0.07 | 0.10 | 0.27 | 0.24 |

**TABLE 3.3**. Mean cloud fractions in the Tropics from T+24/72/120 forecasts run from DT12Z 12/07/94 to DT12Z 27/07/94.

**3.3 THE SOUTHERN HEMISPHERE (SOUTH OF 30S)**

Similar differences in mean sea level pressure were seen in the Southern Hemisphere to those already described in the Northern Hemisphere. Differences were variable rather than systematic and the assessment was fairly even.

All cases showed the same trends in cloud differences as seen in the Northern Hemisphere and Tropics; a significant increase in low cloud, a smaller decrease in medium cloud and increased high cloud (**FIGURE 3.9** ). The mean low,medium and high cloud fractions for T+24/72/120 for the Southern Hemisphere, calculated from forecasts run beteen 12Z 12/07/94 and 12Z 27/07/94, are listed below in **TABLE 3.4**.

MEAN CLOUD FRACTION

| forecast time | LOW | | MEDIUM | | HIGH | |
|---|---|---|---|---|---|---|
| | trial | oper | trial | oper | trial | oper |
| T+024 | 0.51 | 0.40 | 0.31 | 0.35 | 0.35 | 0.31 |
| T+072 | 0.51 | 0.41 | 0.31 | 0.38 | 0.36 | 0.33 |
| T+120 | 0.50 | 0.41 | 0.33 | 0.38 | 0.37 | 0.35 |

**TABLE 3.4**. Mean cloud fractions in the Southern Hemisphere from T+24/72/120 forecasts run from DT12Z 12/07/94 to DT12Z 27/07/94.

In operational forecasts generally, the jets tend to be strong and increase with time. There was a tendency overall for the trial jets to be slightly weaker and to verify better against the analysis. Differences of > 10 knots between trial and operational 250mb jet maxima were assessed against the respective analyses. Usually the weaker jet of the two verified better. Out of 134 jets which differed by more than 10 knots, the weaker jet was better for 116 . The subjective assessment favoured the trial jets, which were better for 67 occasions out of the 116.

All the trial forecasts showed a slight increase in both dynamic and convective precipitation. The overall increase was 2-7%.

### 3.4 ZONAL MEAN CROSS-SECTIONS

**Temperature**

The zonal mean cross-section, **FIGURE 3.17a**, shows the differences in temperature between the trial and operational analyses, meaned over the period 12Z 12/7/94 - 12Z 27/7/94. The shaded areas are negative, indicating a cold bias in the trial forecasts. The trial analyses have a slight cold bias at low levels, which is larger in the Southern Hemisphere and a marked cold bias in the stratosphere in the tropics.

The cross-section in **FIGURE 3.17b** shows the temperature differences at T+72. The cold bias at low levels has increased and extended to higher levels. This cold bias is due to the increase in low cloud in the trial forecasts.

The temperature cross-sections have been repeated in **FIGURE 3.18a/b**, using a contour of 3.0C in order to highlight the very large temperature differences above 100mb. The maximum temperature differences of 21C at 10mb are the same at T+00 and T+72 and are due to the changes made at the top of the model which means that the trial version has a poorer vertical resolution here.

### 3.5 SUBJECTIVE CONCLUSIONS

**NORTHERN HEMISPHERE (NORTH OF 30N)**

(i) CLOUD

All trial forecasts were consistent in showing a significant increase in low cloud (20-30%), a small decrease in medium cloud and a small increase in high cloud. The increased low cloud was mainly distributed in levels 2-5. Increased low cloud over the sea may be a better representation of stratocumulus around anticyclones but the increase overland was overdone at 12Z.

(ii) PRECIPITATION

Rainfall statistics showed a slight increase in convective precipitation and a smaller decrease in dynamic rainfall. The decrease in dynamic rainfall was linked to the increase in low cloud. The overall impact was slight (+1-3%).

(iii) DEPRESSIONS

There were no systematic differences between trial and operational depressions but the assessment favoured the trial forecasts at T+24/72.

(iv) 250MB JETS

There was no sign of the increased vertical resolution leading to a stronger jet core. Subjective assessment favoured the trial forecasts at T+24/72 but the operational forecasts were better at T+120, suggesting a slight deterioration in the quality of the trial forecasts with time.

(v) COLD BIAS

There was a small cold bias at low levels in the analysis which increased during the forecast and extended to higher levels. This cold bias may be linked to the increase in low cloud.

**TROPICS (30N - 30S)**

(i) CLOUD

As in the Northern Hemisphere.

(ii) PRECIPITATION

The overall impact was a very small increase in amounts of 1%. All individual forecasts showed a small increase in convective precipitation and a small decrease in dynamic. There was a slight tendency for the shower distribution in the trial forecasts to be jerkier, with fewer but heavier showers, in comparison with the smoother, more widespread showers in operational forecasts.

(iii) TROPICAL CYCLONES

Trial and operational forecasts similar.

(iv) MONSOON

Overall, there was a small increase in the westerly wind component at 850mb over Southern India, an increase in rainfall over the sea and a small decrease overland.

**SOUTHERN HEMISPHERE (SOUTH OF 30S)**

(i) CLOUD

As in the Northern Hemisphere.

(ii) PRECIPITATION

All individual cases showed an increase in both convective and dynamic precipitation. The overall increase was 2-8%.

(iii) DEPRESSIONS

There were no systematic differences between trial and operational depressions and the

(iv) 250MB JETS

In operational forecasts generally, the jets tend to be strong and increase with time. There was a tendency overall for the trial jets to be slightly weaker and to verify better against the analysis.

Hopes were high at the start of this trial that the increased vertical resolution would mean a noticeable improvement to the performance of the global model. This seemed to be the case at T+24 but the advantage was lost in later stages of the forecast. The main problem was the systematic increase in low cloud (20-30%).

## 4. CONCLUSIONS

From both the objective and subjective assessments it is clear that the enhanced vertical resolution is not ready for operational implementation at this stage. Whilst some of the expected benefits have been shown by the trial, such as generally smaller wind speed errors, other deficiencies have been revealed. The problem of too much low cloud, particularly over N Hemispheric land, which causes the cold bias to become worse needs to be investigated and addressed. Also the topmost levels should be reconsidered since there are larger interpolation errors and the problems of the polar night stratosphere have been exacerbated by the set used here.

## REFERENCES


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Trial of a longer timestep for physics in the global model. *FR Technical Report **112***

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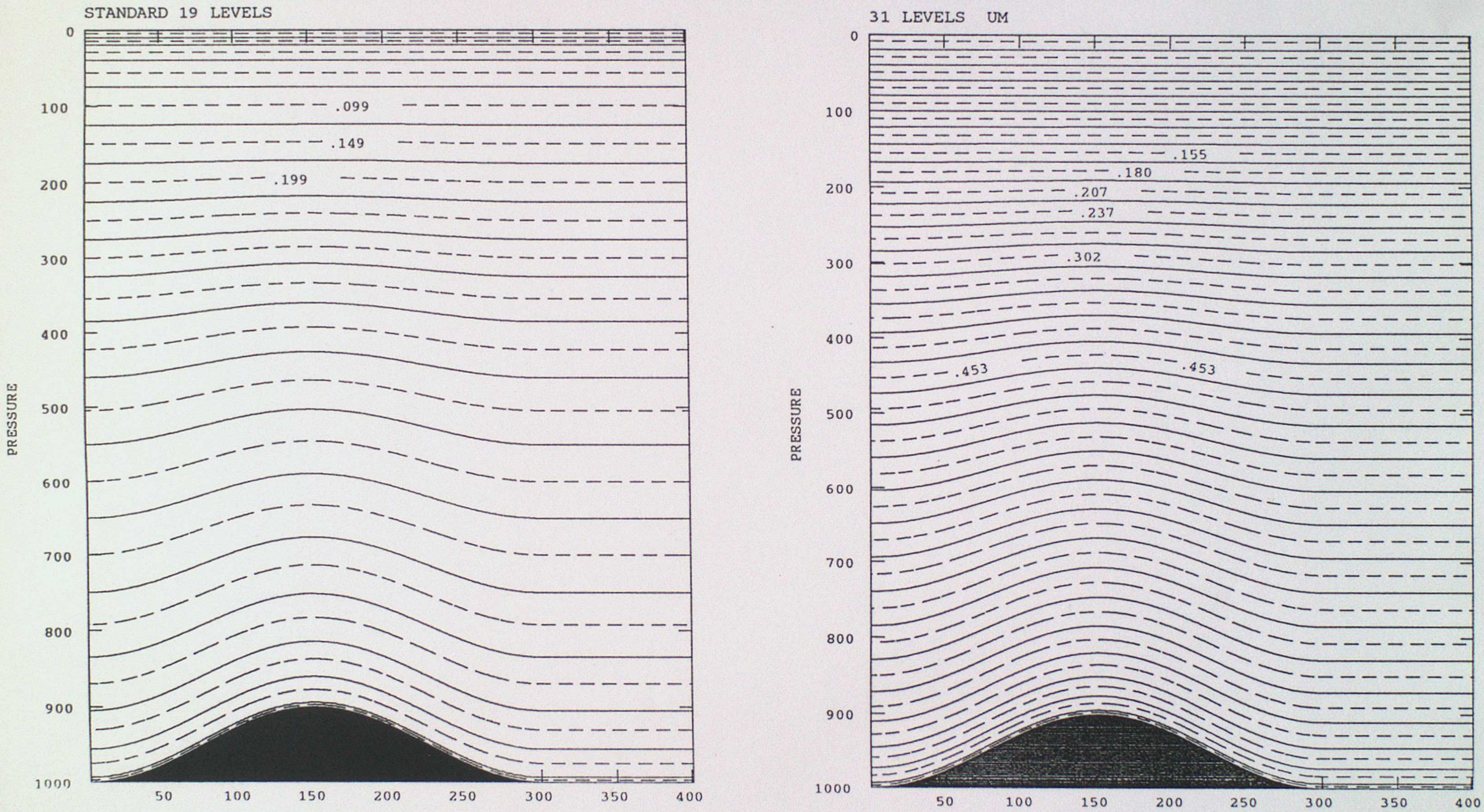

STANDARD 19 LEVELS
PRESSURE
0
100
200
300
400
500
600
700
800
900
1000
50
100
150
200
250
300
350
400
.099
.149
.199
31 LEVELS UM
PRESSURE
.155
.180
.207
.237
.302
.453
.453

**FIGURE 1.1**

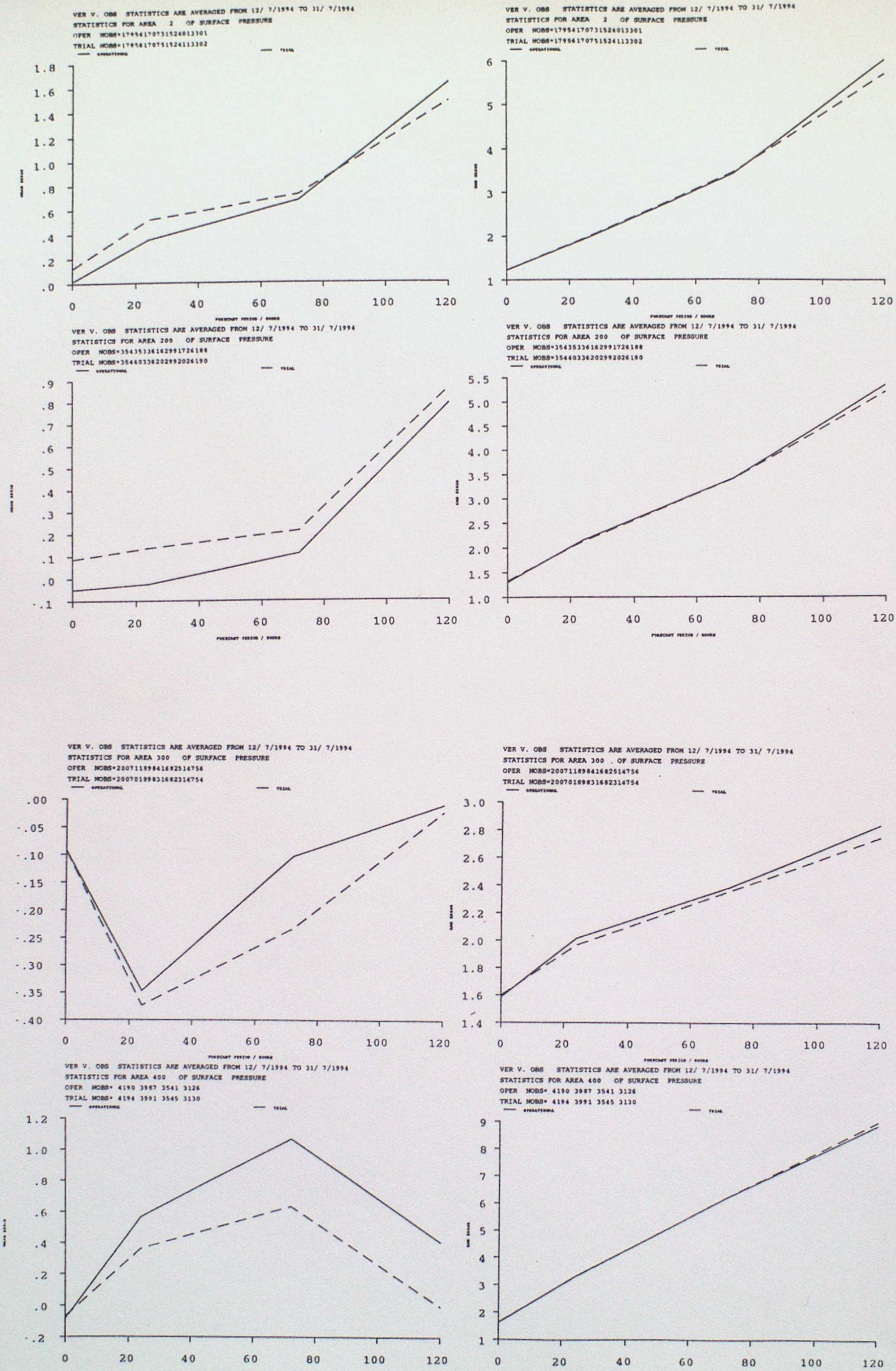

VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
STATISTICS FOR AREA 2 OF SURFACE PRESSURE
OPER NOBS=1795417073152401301
TRIAL NOBS=1795617075152411302
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
STATISTICS FOR AREA 2 OF SURFACE PRESSURE
OPER NOBS=1795417073152401301
TRIAL NOBS=1795617075152411302
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
STATISTICS FOR AREA 200 OF SURFACE PRESSURE
OPER NOBS=3543533616299172618
TRIAL NOBS=3544033620299202619
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
STATISTICS FOR AREA 200 OF SURFACE PRESSURE
OPER NOBS=3543533616299172618
TRIAL NOBS=3544033620299202619
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
STATISTICS FOR AREA 300 OF SURFACE PRESSURE
OPER NOBS=2007118984168251475
TRIAL NOBS=2007018983168231475
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
STATISTICS FOR AREA 300 OF SURFACE PRESSURE
OPER NOBS=2007118984168251475
TRIAL NOBS=2007018983168231475
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
STATISTICS FOR AREA 400 OF SURFACE PRESSURE
OPER NOBS= 4199 3987 3541 3126
TRIAL NOBS= 4194 3991 3545 3130
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
STATISTICS FOR AREA 400 OF SURFACE PRESSURE
OPER NOBS= 4190 3987 3541 3126
TRIAL NOBS= 4194 3991 3545 3130

**FIGURE 2.1**

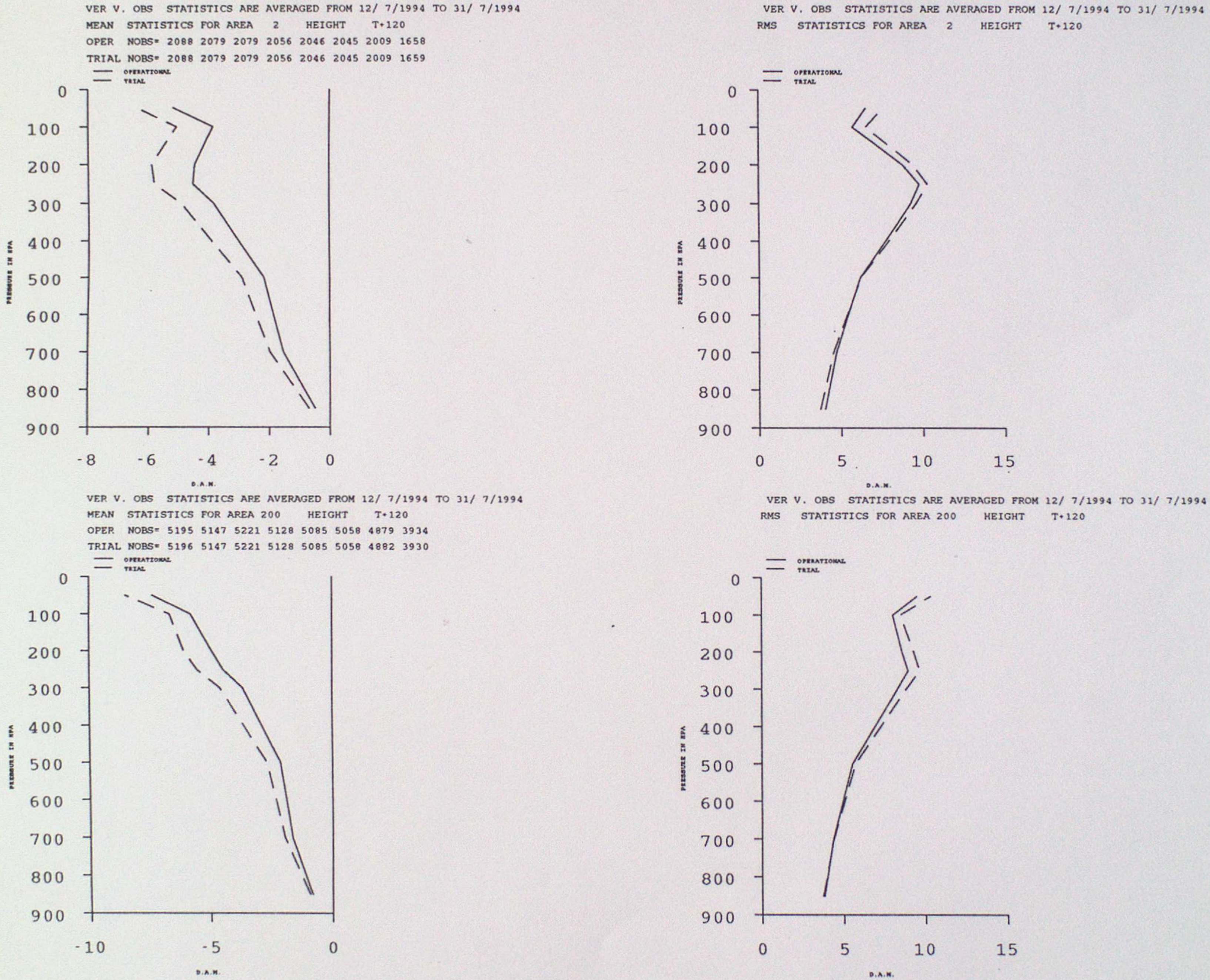

VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
MEAN STATISTICS FOR AREA 2 HEIGHT T+120
OPER NOBS= 2088 2079 2079 2056 2046 2045 2009 1658
TRIAL NOBS= 2088 2079 2079 2056 2046 2045 2009 1659
OPERATIONAL
TRIAL
PRESSURE IN HPA
D.A.M.
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
RMS STATISTICS FOR AREA 2 HEIGHT T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
D.A.M.
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
MEAN STATISTICS FOR AREA 200 HEIGHT T+120
OPER NOBS= 5195 5147 5221 5128 5085 5058 4879 3934
TRIAL NOBS= 5196 5147 5221 5128 5085 5058 4882 3930
OPERATIONAL
TRIAL
PRESSURE IN HPA
D.A.M.
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
RMS STATISTICS FOR AREA 200 HEIGHT T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
D.A.M.

**FIGURE 2.2**

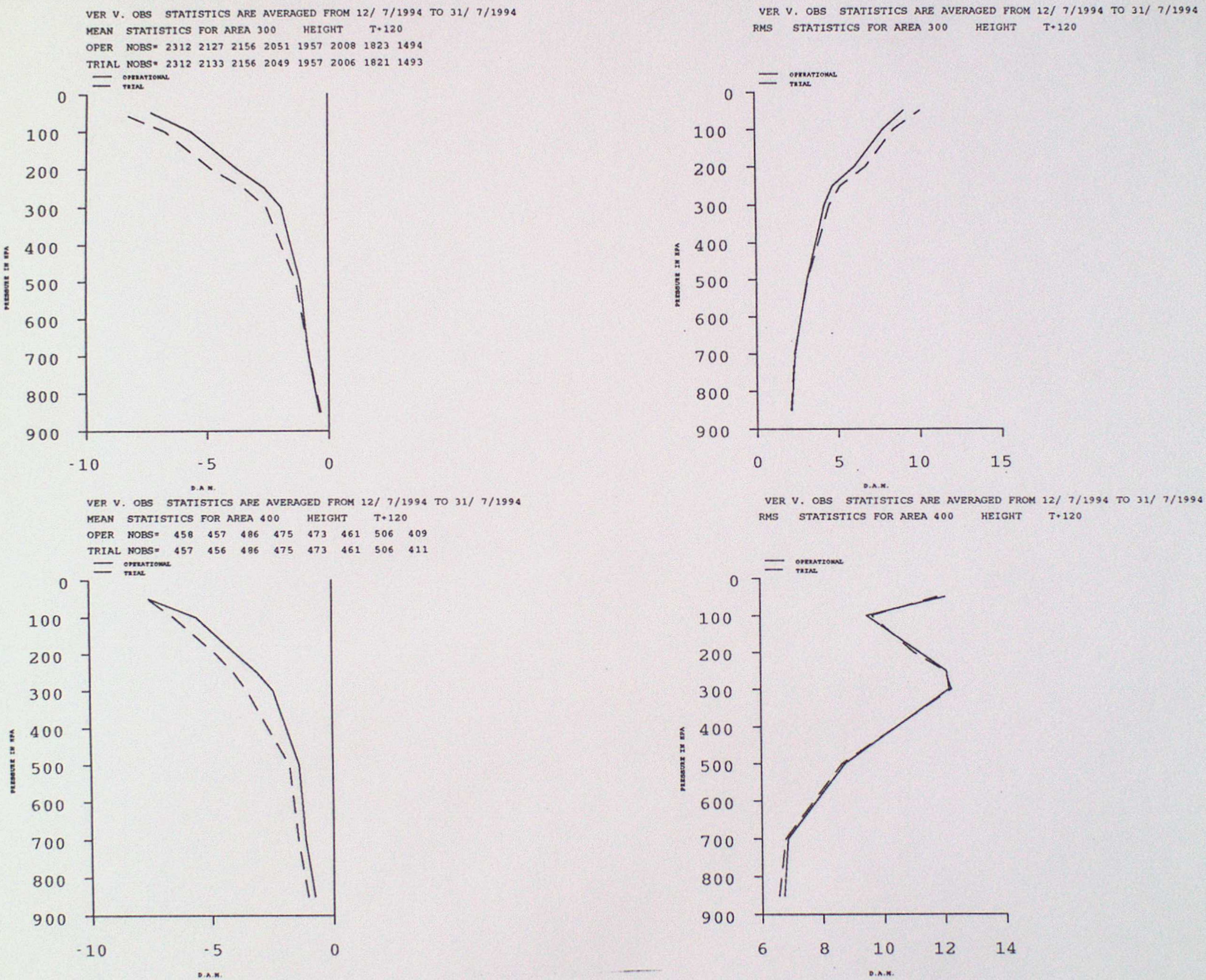
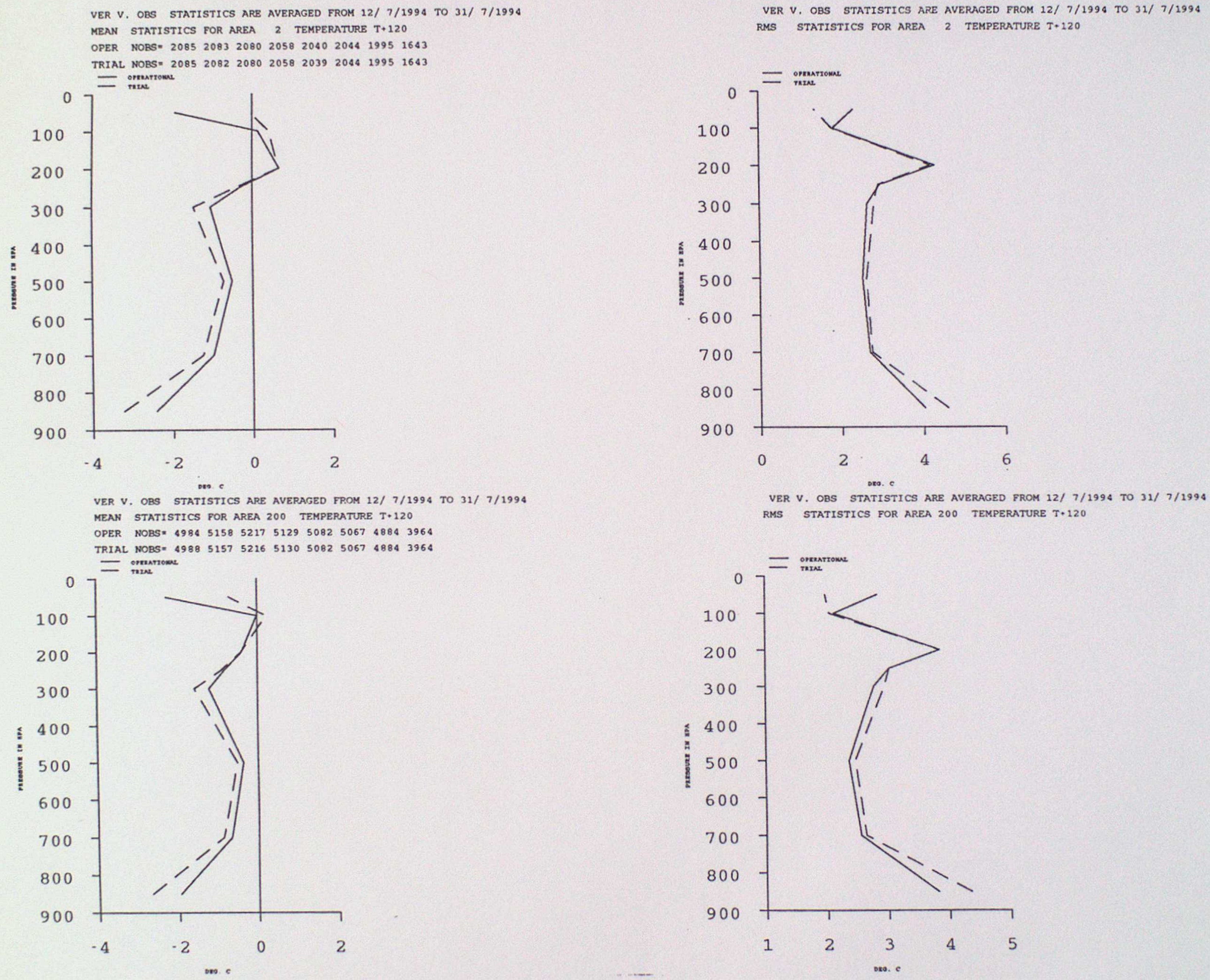

VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
MEAN STATISTICS FOR AREA 300 HEIGHT T+120
OPER NOBS= 2312 2127 2156 2051 1957 2008 1823 1494
TRIAL NOBS= 2312 2133 2156 2049 1957 2006 1821 1493
0
100
200
300
400
500
600
700
800
900
-10
-5
0
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
RMS STATISTICS FOR AREA 300 HEIGHT T+120
0
5
10
15
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
MEAN STATISTICS FOR AREA 400 HEIGHT T+120
OPER NOBS= 458 457 486 475 473 461 506 409
TRIAL NOBS= 457 456 486 475 473 461 506 411
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
RMS STATISTICS FOR AREA 400 HEIGHT T+120
6
8
10
12
14

FIGURE 2.3



VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
MEAN STATISTICS FOR AREA 2 TEMPERATURE T+120
OPER NOBS= 2085 2083 2080 2058 2040 2044 1995 1643
TRIAL NOBS= 2085 2082 2080 2058 2039 2044 1995 1643
OPERATIONAL
TRIAL
PRESSURE IN HPA
DEG. C
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
RMS STATISTICS FOR AREA 2 TEMPERATURE T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
DEG. C
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
MEAN STATISTICS FOR AREA 200 TEMPERATURE T+120
OPER NOBS= 4984 5158 5217 5129 5082 5067 4884 3964
TRIAL NOBS= 4988 5157 5216 5130 5082 5067 4884 3964
OPERATIONAL
TRIAL
PRESSURE IN HPA
DEG. C
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
RMS STATISTICS FOR AREA 200 TEMPERATURE T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
DEG. C


**FIGURE 2.4**

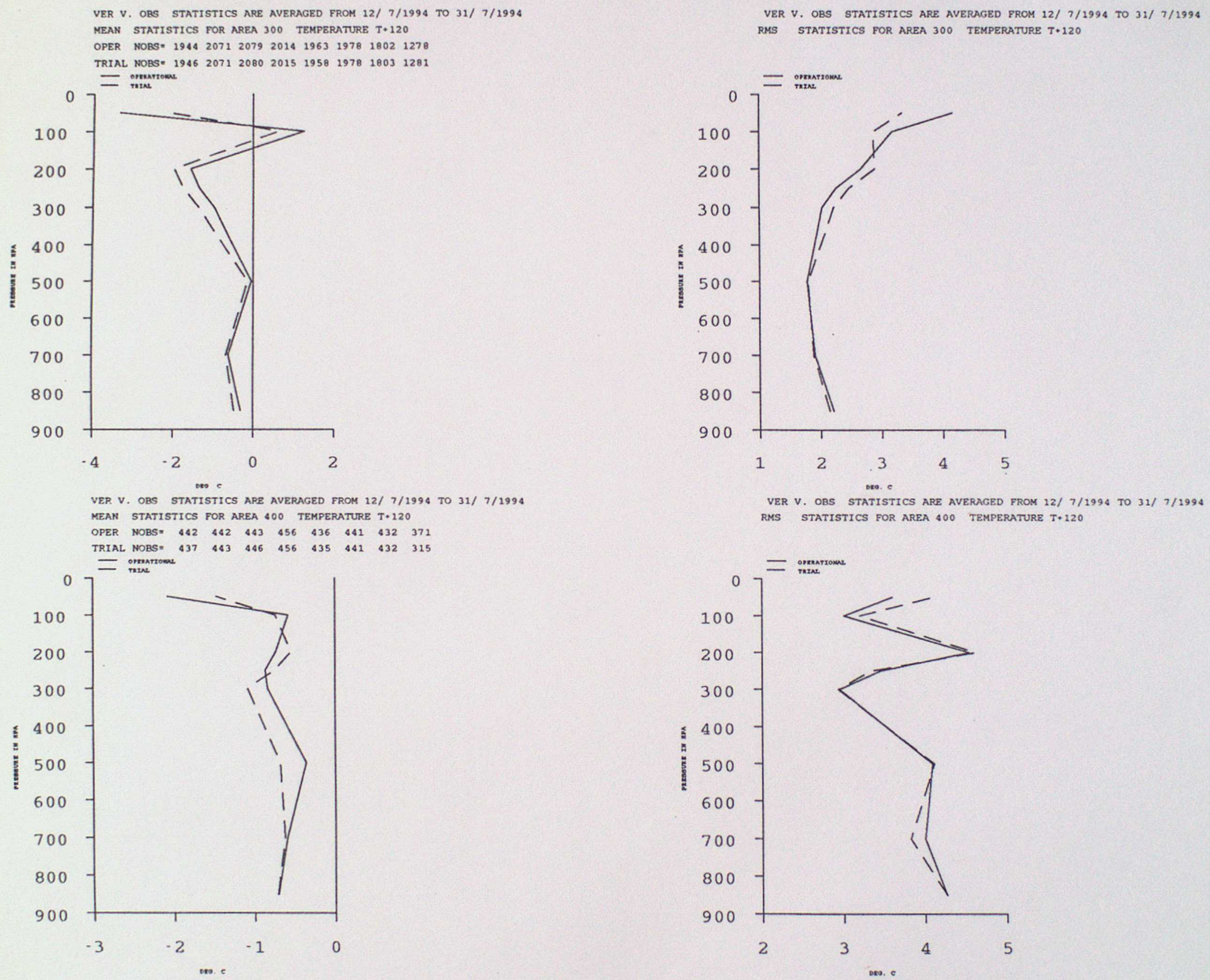

VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
MEAN STATISTICS FOR AREA 300 TEMPERATURE T+120
OPER NOBS= 1944 2071 2079 2014 1963 1978 1802 1278
TRIAL NOBS= 1946 2071 2080 2015 1958 1978 1803 1281
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-4
-2
0
2
DEG C
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
RMS STATISTICS FOR AREA 300 TEMPERATURE T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
1
2
3
4
5
DEG. C
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
MEAN STATISTICS FOR AREA 400 TEMPERATURE T+120
OPER NOBS= 442 442 443 456 436 441 432 371
TRIAL NOBS= 437 443 446 456 435 441 432 315
OPERATIONAL
TRIAL
PRESSURE IN HPA
-3
-2
-1
0
DEG. C
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
RMS STATISTICS FOR AREA 400 TEMPERATURE T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
2
3
4
5
DEG. C

FIGURE 2.5

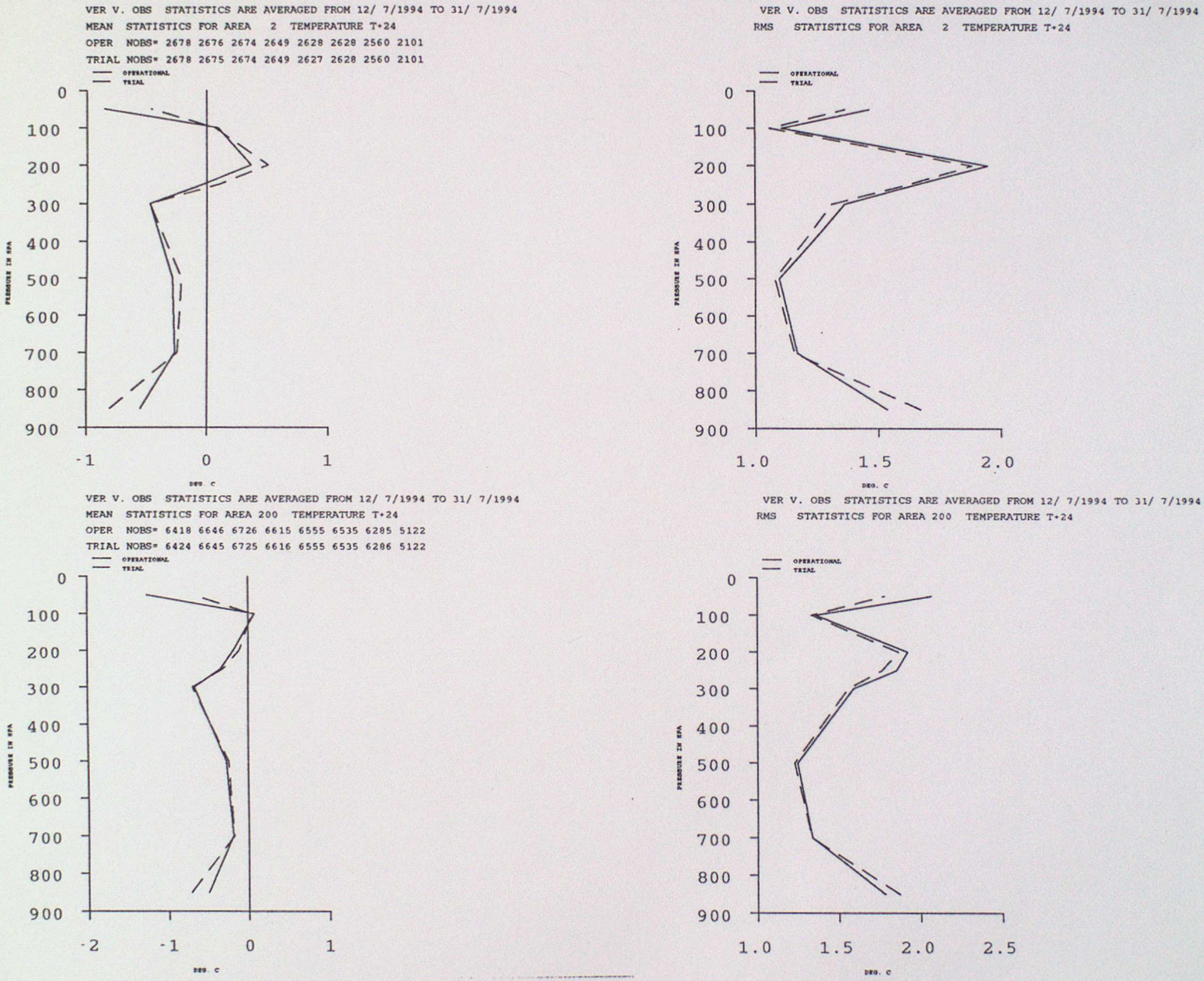

VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
MEAN STATISTICS FOR AREA 2 TEMPERATURE T+24
OPER NOBS= 2678 2676 2674 2649 2628 2628 2560 2101
TRIAL NOBS= 2678 2675 2674 2649 2627 2628 2560 2101
OPERATIONAL
TRIAL
PRESSURE IN HPA
DEG. C
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
RMS STATISTICS FOR AREA 2 TEMPERATURE T+24
OPERATIONAL
TRIAL
PRESSURE IN HPA
DEG. C
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
MEAN STATISTICS FOR AREA 200 TEMPERATURE T+24
OPER NOBS= 6418 6646 6726 6615 6555 6535 6285 5122
TRIAL NOBS= 6424 6645 6725 6616 6555 6535 6286 5122
OPERATIONAL
TRIAL
PRESSURE IN HPA
DEG. C
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
RMS STATISTICS FOR AREA 200 TEMPERATURE T+24
OPERATIONAL
TRIAL
PRESSURE IN HPA
DEG. C

**FIGURE 2.6**

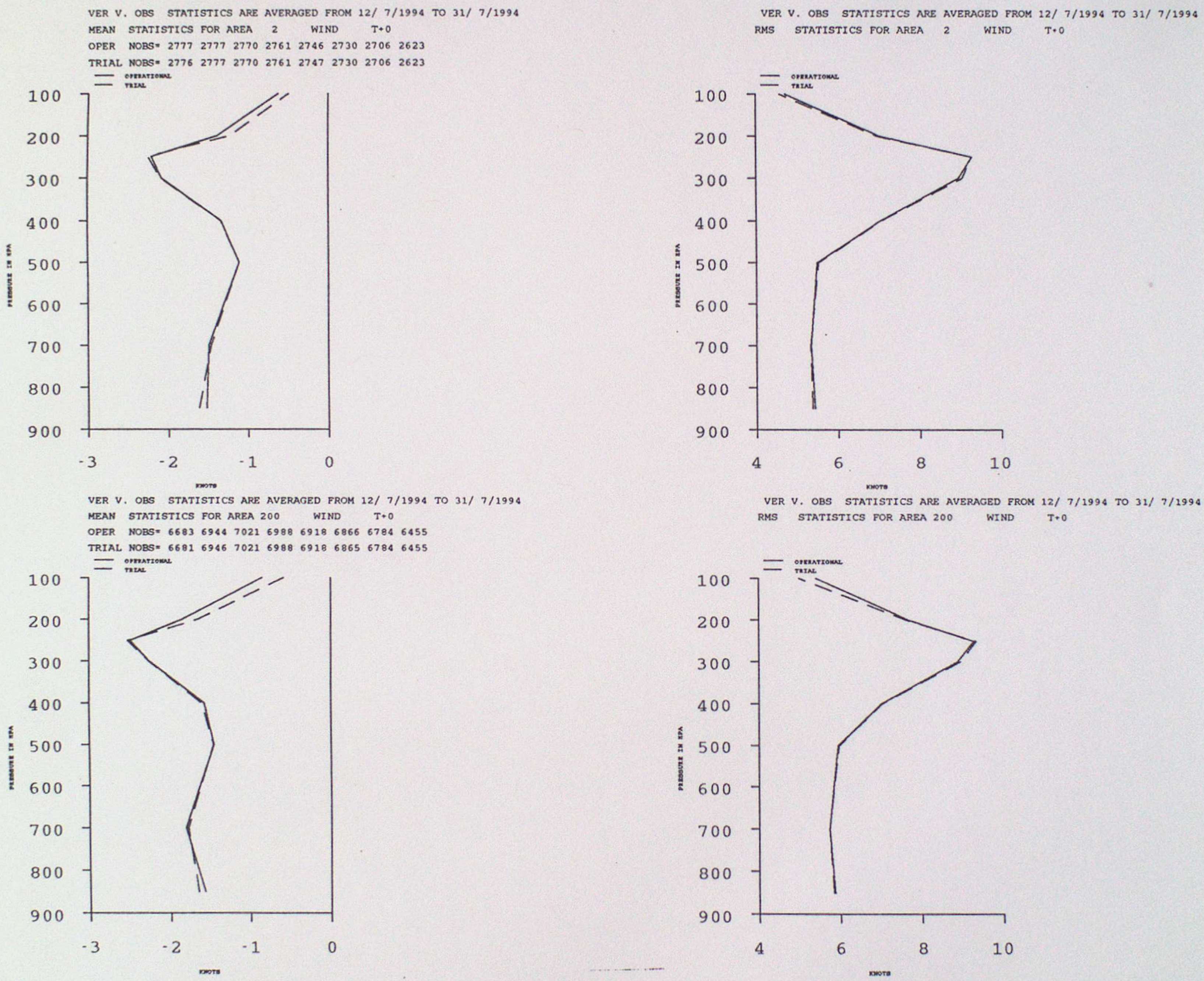

VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
MEAN STATISTICS FOR AREA 2 WIND T+0
OPER NOBS= 2777 2777 2770 2761 2746 2730 2706 2623
TRIAL NOBS= 2776 2777 2770 2761 2747 2730 2706 2623
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
-3
-2
-1
0
KNOTS
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
RMS STATISTICS FOR AREA 2 WIND T+0
OPERATIONAL
TRIAL
PRESSURE IN HPA
4
6
8
10
KNOTS
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
MEAN STATISTICS FOR AREA 200 WIND T+0
OPER NOBS= 6683 6944 7021 6988 6918 6866 6784 6455
TRIAL NOBS= 6681 6946 7021 6988 6918 6865 6784 6455
OPERATIONAL
TRIAL
PRESSURE IN HPA
KNOTS
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
RMS STATISTICS FOR AREA 200 WIND T+0
OPERATIONAL
TRIAL
PRESSURE IN HPA
KNOTS

**FIGURE 2.7**

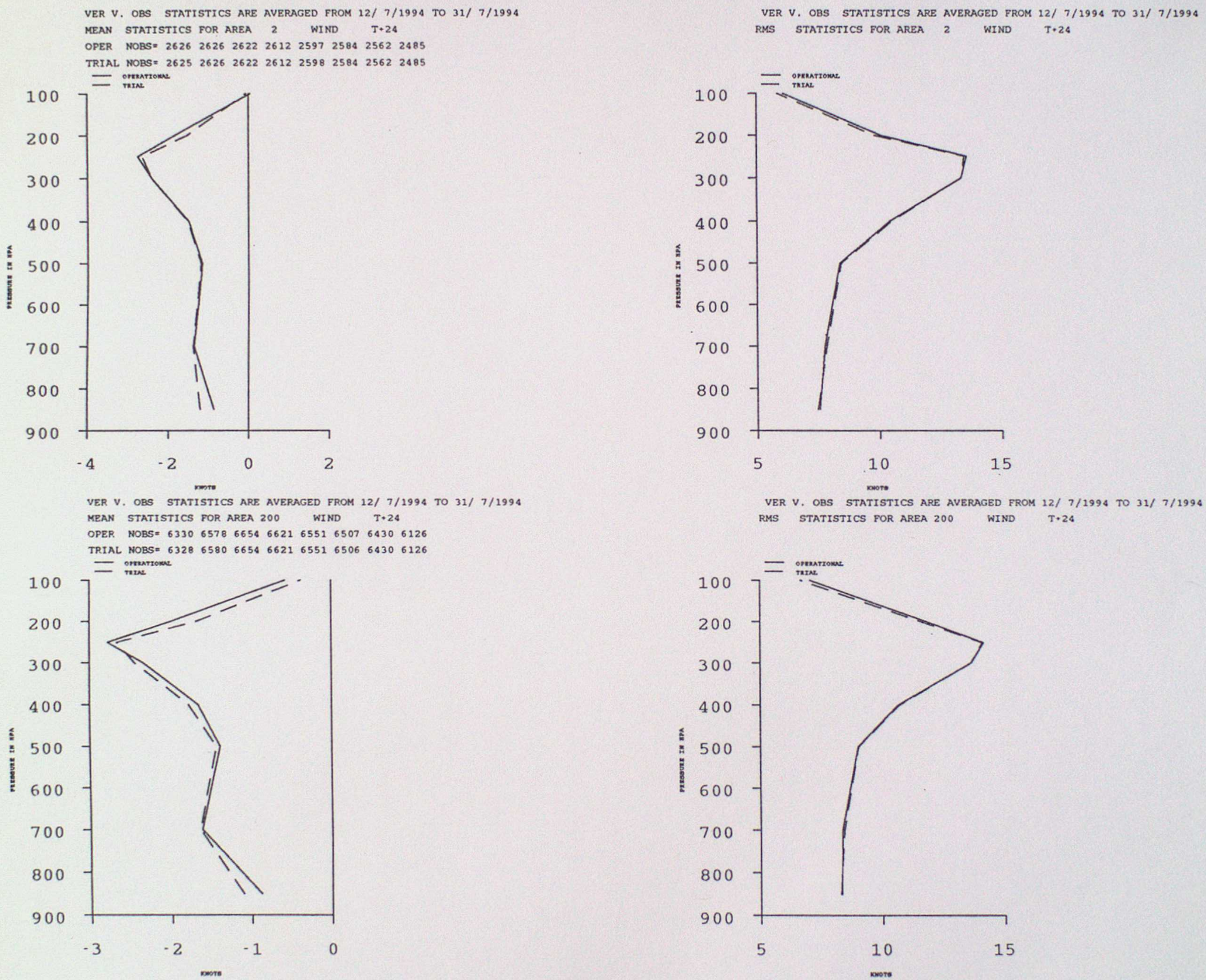
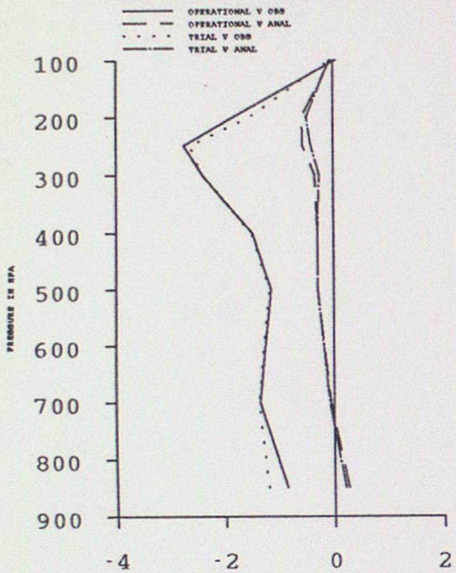
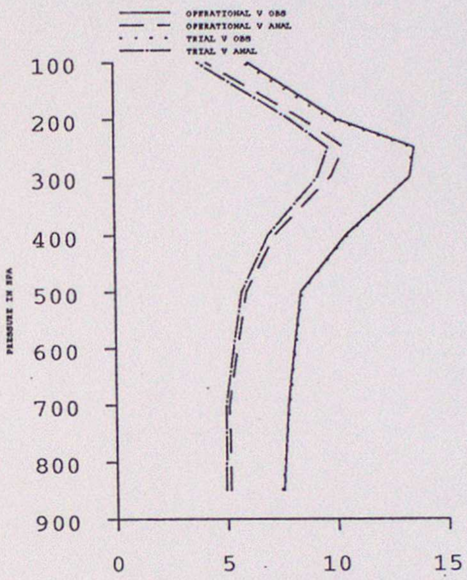

VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
MEAN STATISTICS FOR AREA 2 WIND T+24
OPER NOBS= 2626 2626 2622 2612 2597 2584 2562 2485
TRIAL NOBS= 2625 2626 2622 2612 2598 2584 2562 2485
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
-4
-2
0
2
KNOTS
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
RMS STATISTICS FOR AREA 2 WIND T+24
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
5
10
15
KNOTS
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
MEAN STATISTICS FOR AREA 200 WIND T+24
OPER NOBS= 6330 6578 6654 6621 6551 6507 6430 6126
TRIAL NOBS= 6328 6580 6654 6621 6551 6506 6430 6126
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
-3
-2
-1
0
KNOTS
VER V. OBS STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
RMS STATISTICS FOR AREA 200 WIND T+24
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
5
10
15
KNOTS

**FIGURE 2.8**

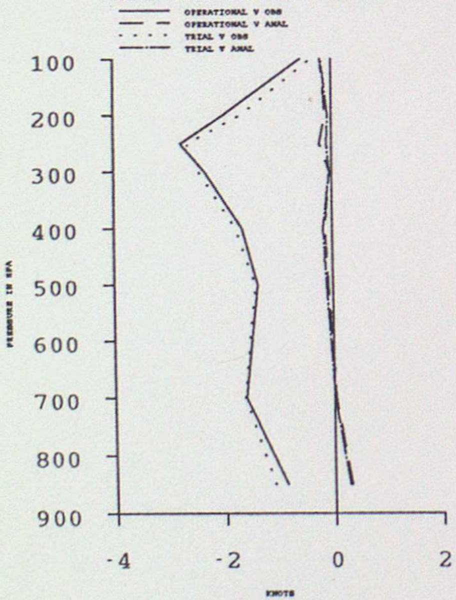
VER V.OBS,ANAL STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
MEAN STATISTICS FOR AREA 2 WIND T+24
OPER NOBS= 2626 2626 2622 2612 2597 2584 2562 2485
TRIAL NOBS= 2625 2626 2622 2612 2598 2584 2562 2485




VER V.OBS,ANAL STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
RMS STATISTICS FOR AREA 2 WIND T+24




VER V.OBS,ANAL STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
MEAN STATISTICS FOR AREA 200 WIND T+24
OPER NOBS= 6330 6578 6654 6621 6551 6507 6430 6126
TRIAL NOBS= 6328 6580 6654 6621 6551 6506 6430 6126




VER V.OBS,ANAL STATISTICS ARE AVERAGED FROM 12/ 7/1994 TO 31/ 7/1994
RMS STATISTICS FOR AREA 200 WIND T+24

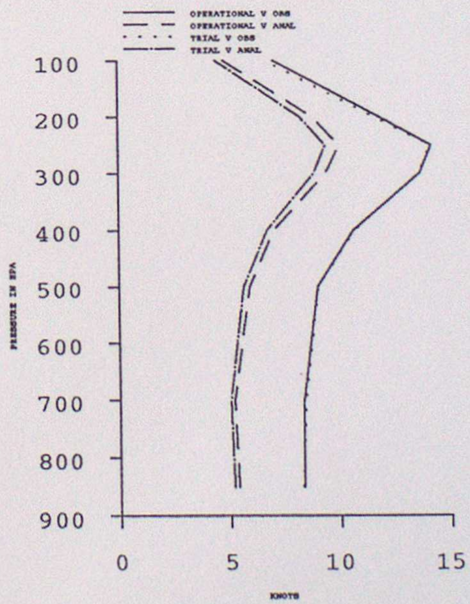
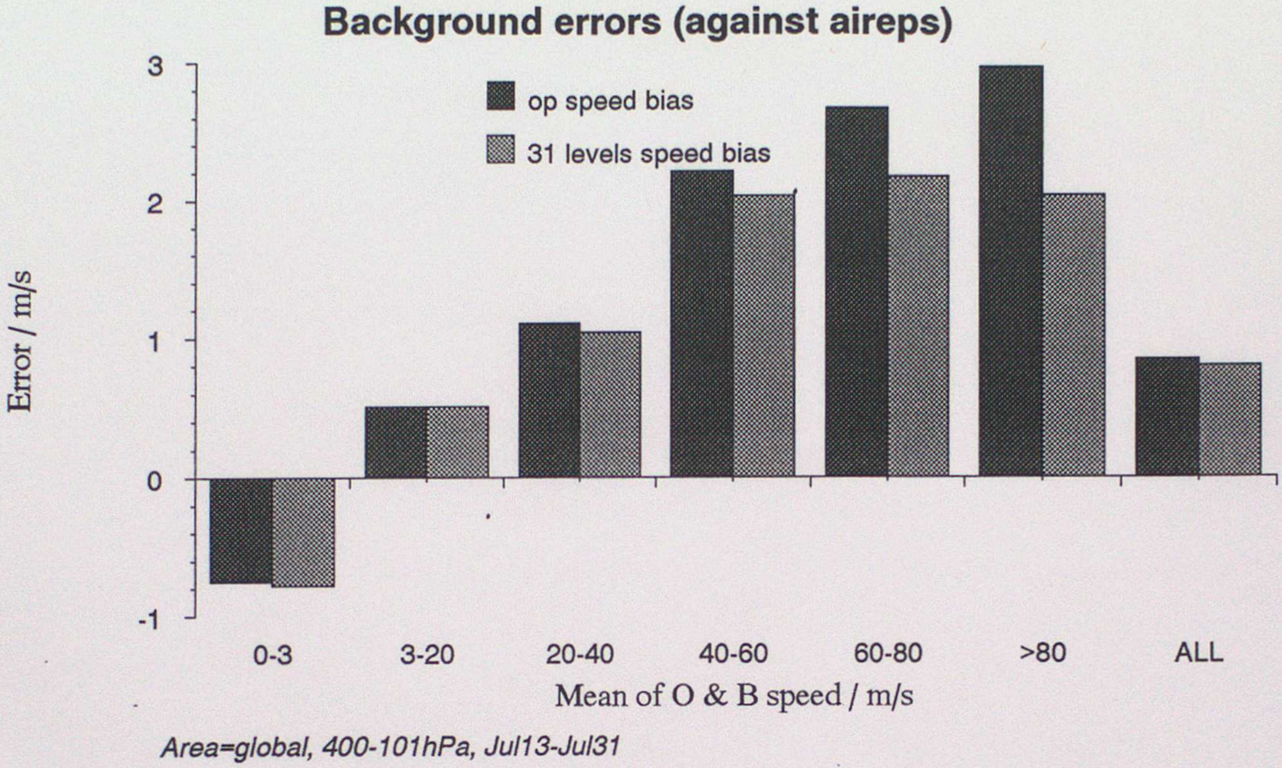



**FIGURE 2.9**

## 31 levels + long physics timestep (20 min) trial




## 31 levels +long physics timestep (20 min) trial

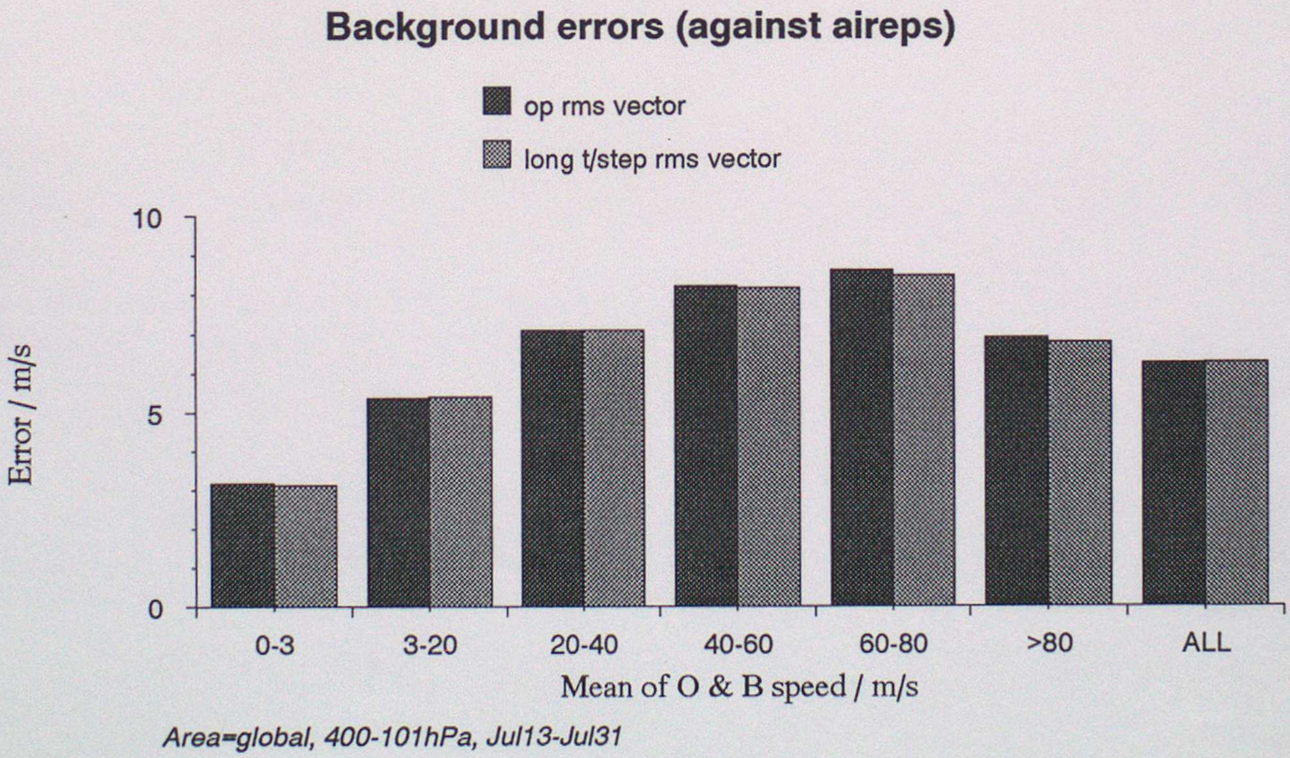
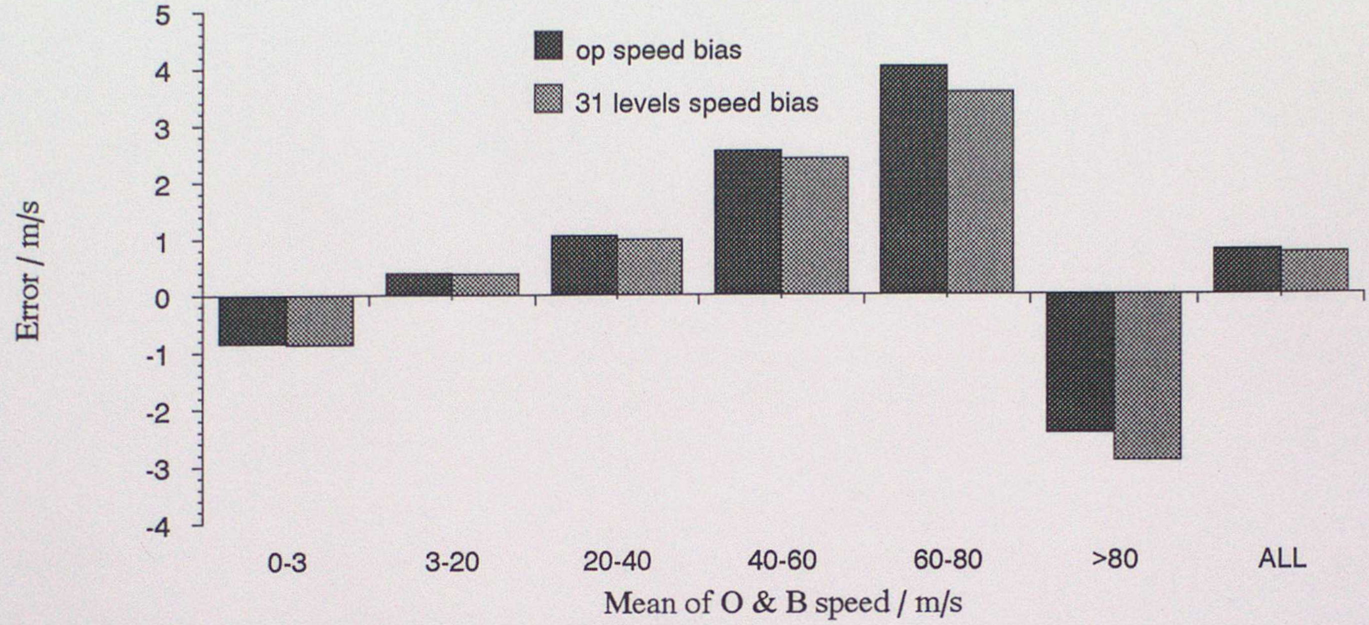



FIGURE 2.10

## 31 levels +long physics timestep (20 min) trial

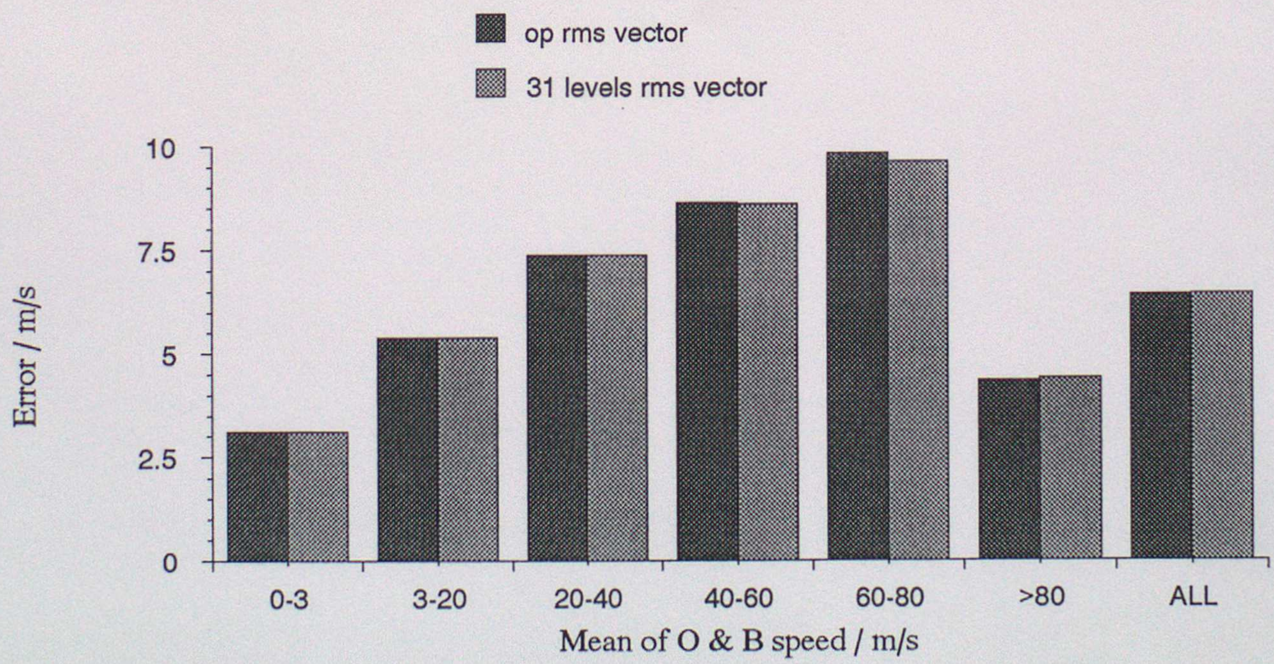
### Background errors (against aireps)




*Area=30N-90N, 400-101hPa, Jul13-Jul31*

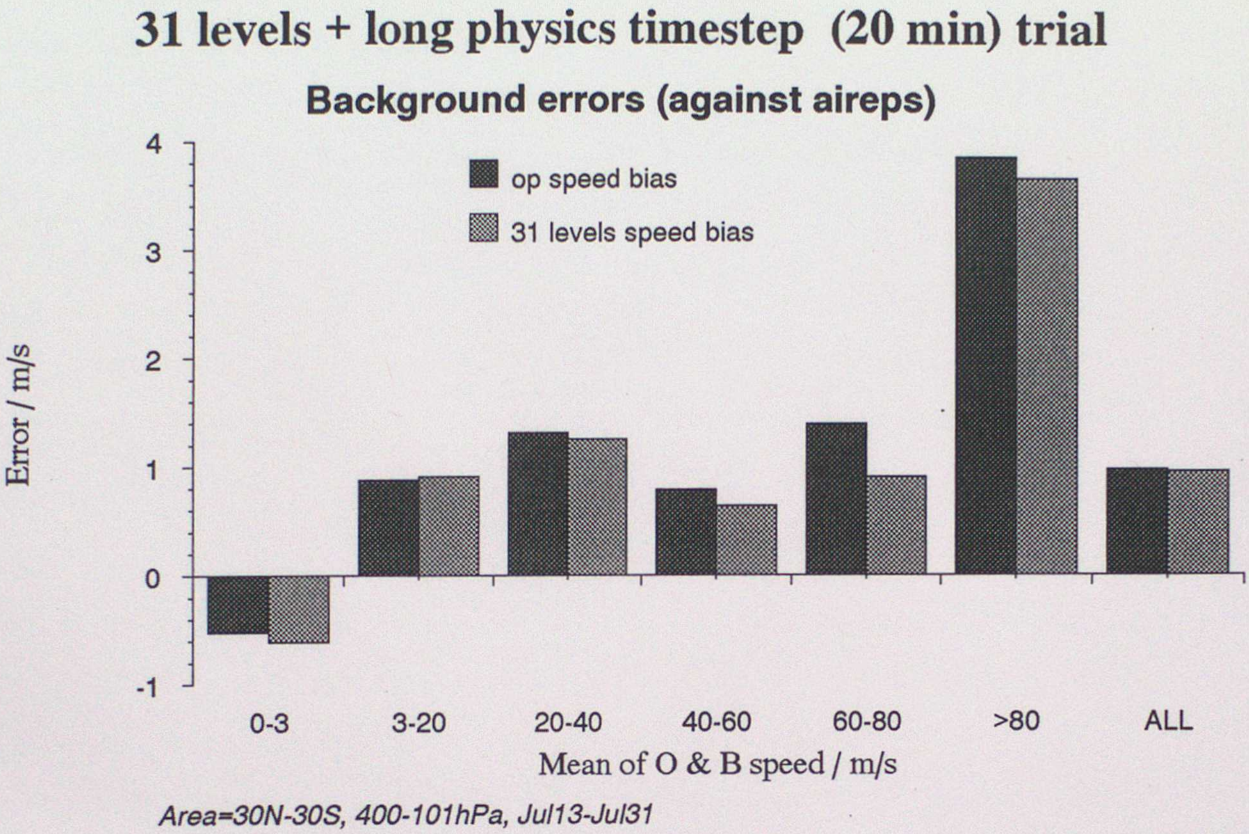
## 31 levels +long physics timestep (20 min) trial

### Background errors (against aireps)




*Area=30N-90N 400-101hPa, Jul13-Jul31*

FIGURE 2.11


31 levels + long physics timestep (20 min) trial
Background errors (against aireps)
op speed bias
31 levels speed bias
Error / m/s
4
3
2
1
0
-1
0-3
3-20
20-40
40-60
60-80
>80
ALL
Mean of O & B speed / m/s
Area=30N-30S, 400-101hPa, Jul13-Jul31

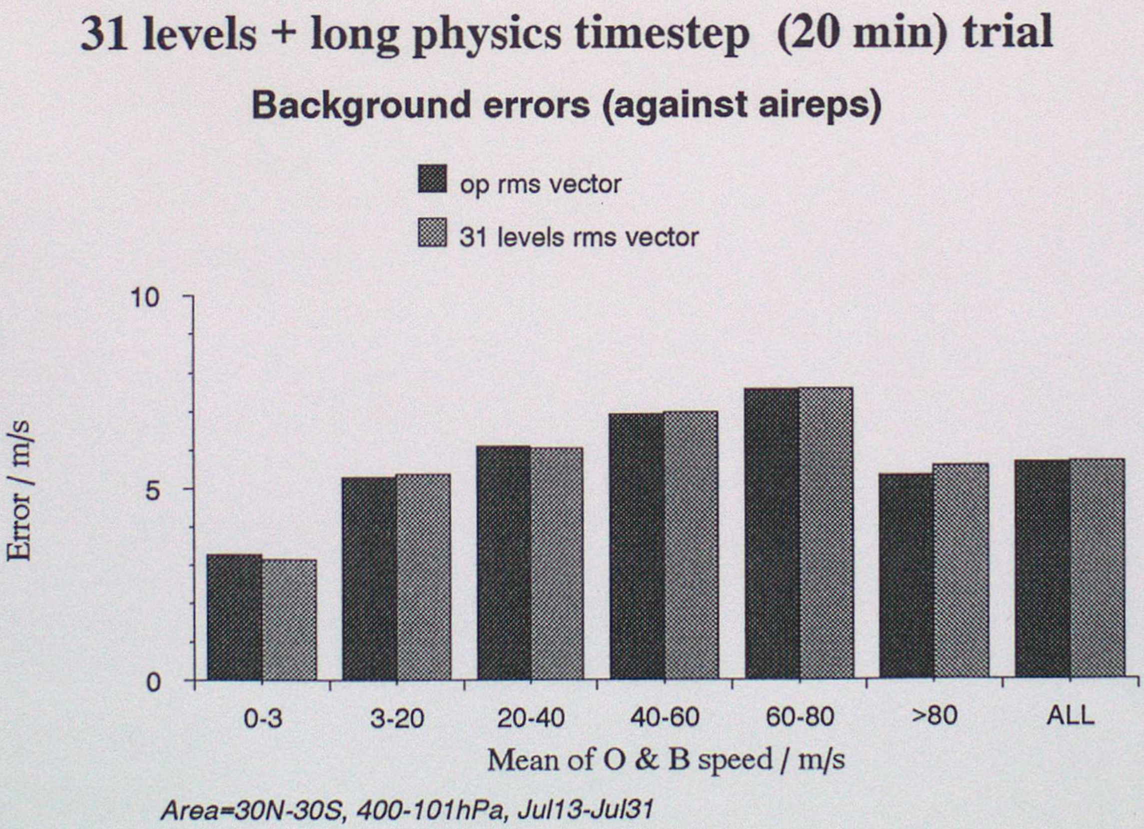
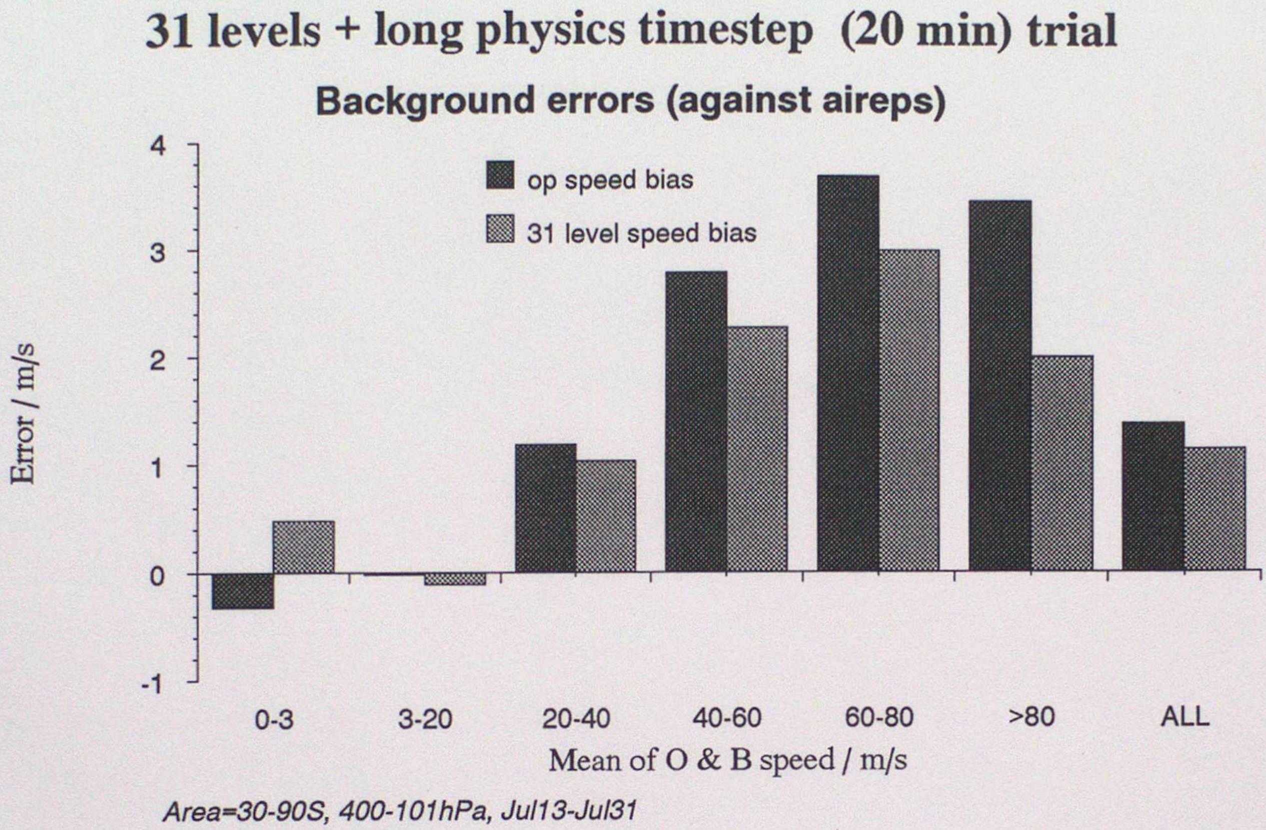
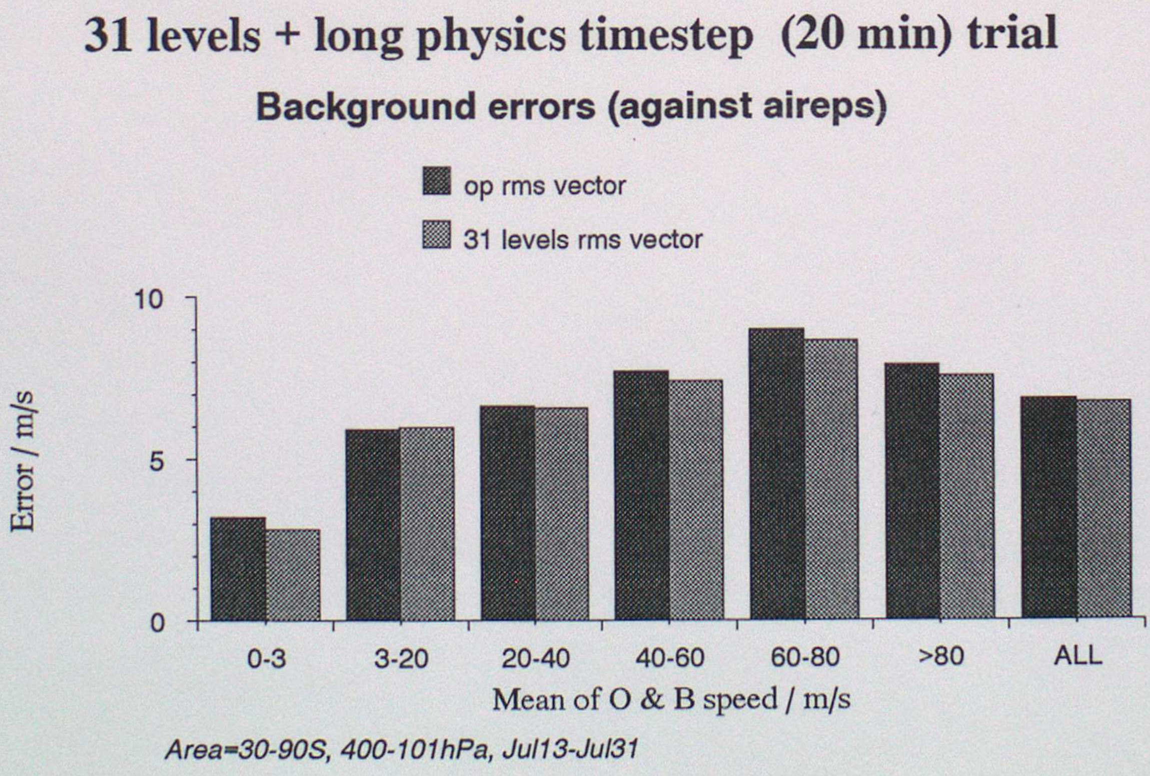

31 levels + long physics timestep (20 min) trial
Background errors (against aireps)
op rms vector
31 levels rms vector
Error / m/s
10
5
0
0-3
3-20
20-40
40-60
60-80
>80
ALL
Mean of O & B speed / m/s
Area=30N-30S, 400-101hPa, Jul13-Jul31

FIGURE 2.12



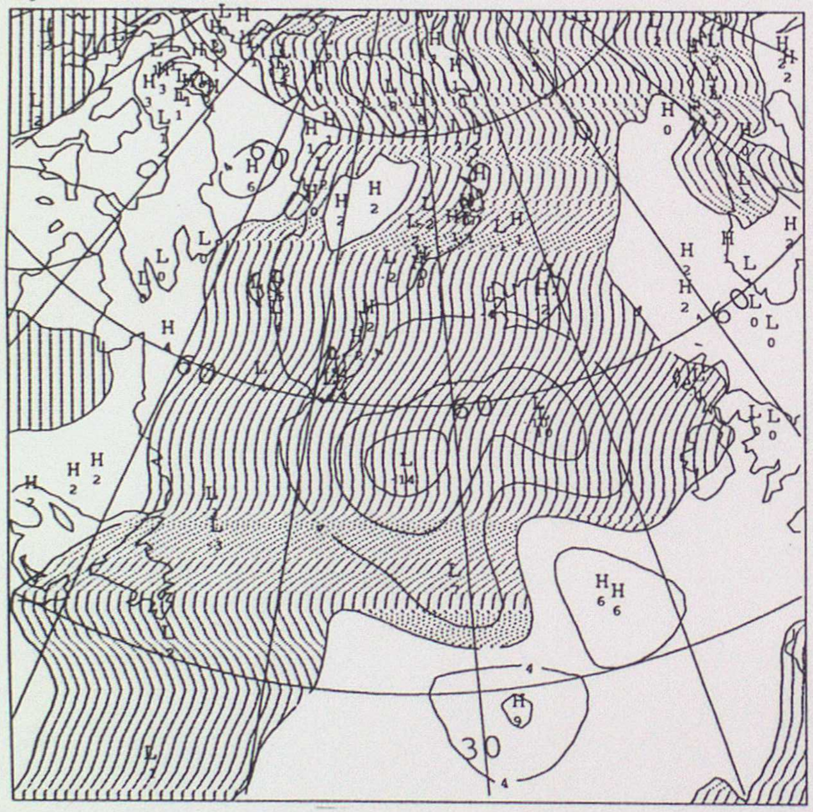
31 levels + long physics timestep (20 min) trial
Background errors (against aireps)
op speed bias
31 level speed bias
Error / m/s
4
3
2
1
0
-1
0-3
3-20
20-40
40-60
60-80
>80
ALL
Mean of O & B speed / m/s
Area=30-90S, 400-101hPa, Jul13-Jul31

31 levels + long physics timestep (20 min) trial
Background errors (against aireps)
op rms vector
31 levels rms vector
Error / m/s
10
5
0
0-3
3-20
20-40
40-60
60-80
>80
ALL
Mean of O & B speed / m/s
Area=30-90S, 400-101hPa, Jul13-Jul31

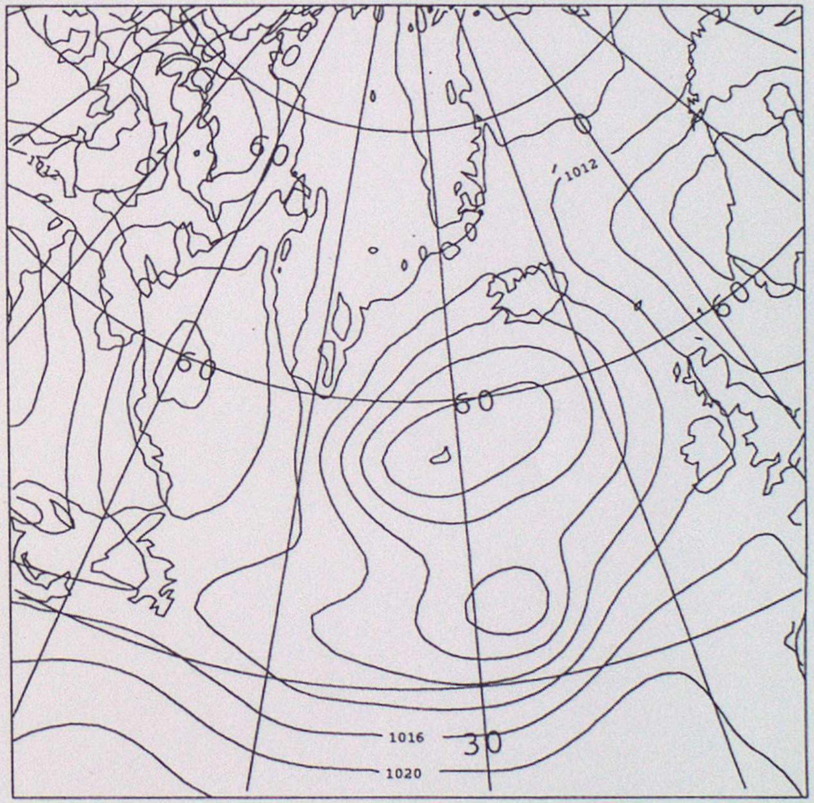

FIGURE 2.13

MEAN SEA LEVEL PRESSURE DIFFERENCES
TRIAL(31 LEVELS) - OPERATIONAL
T+120 FORECAST FROM DT 12Z 19/07/94
Negative differences shaded




a

MEAN SEA LEVEL PRESSURE
OPERATIONAL
ANALYSIS
DT12Z 24/07/94




b

**FIGURE 3.1**

MEAN SEA LEVEL PRESSURE
GLOBAL MODEL PARALLEL SUITE TRIAL
T+120 FORECAST FROM DT12Z 19/07/94
31 LEVELS + 20MIN TIMESTEP FOR PHYSICS

MEAN SEA LEVEL PRESSURE
OPERATIONAL
T+120 FORECAST FROM DT12Z 19/07/94
19 LEVELS


a

b

**FIGURE 3.2**

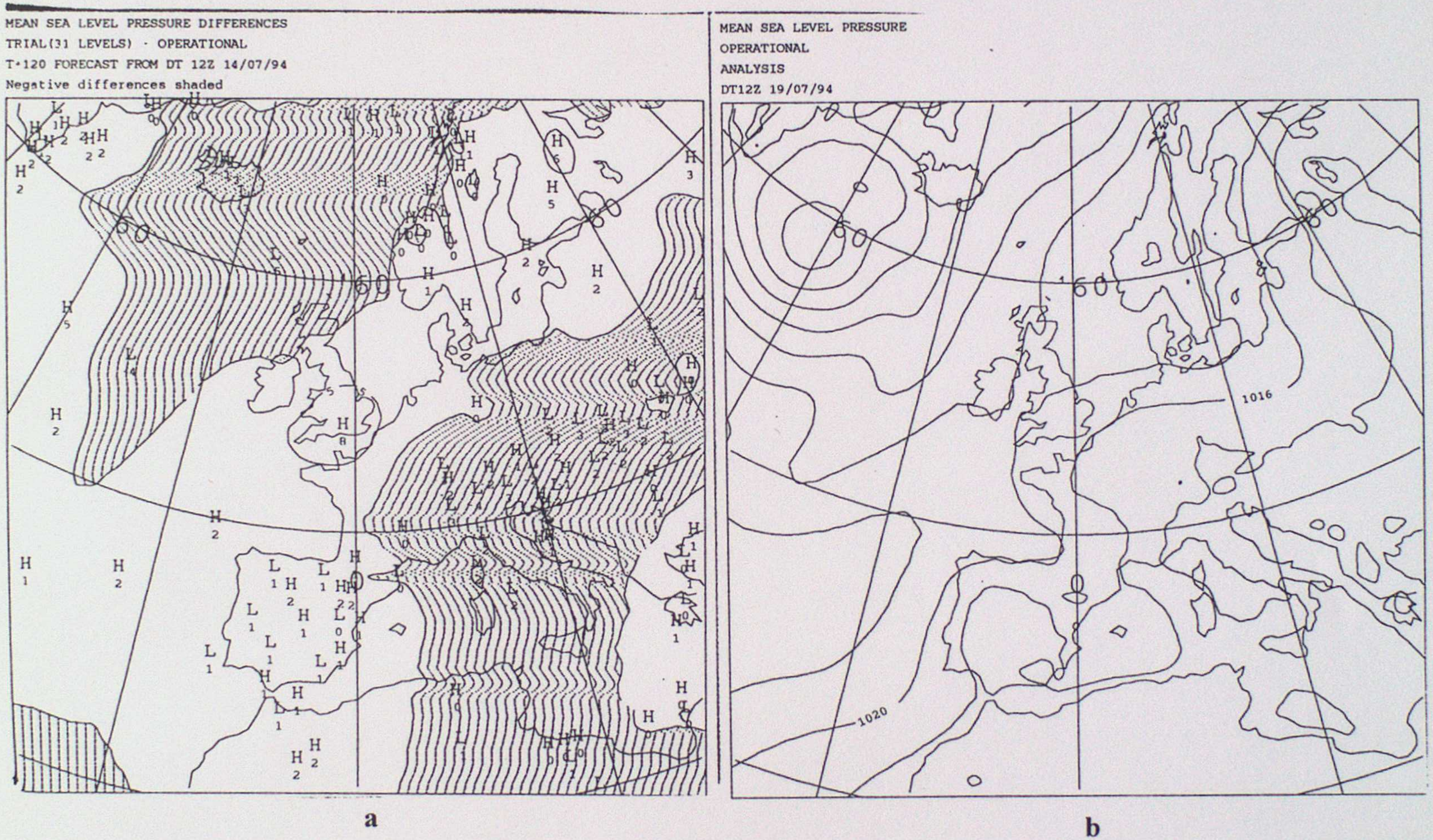
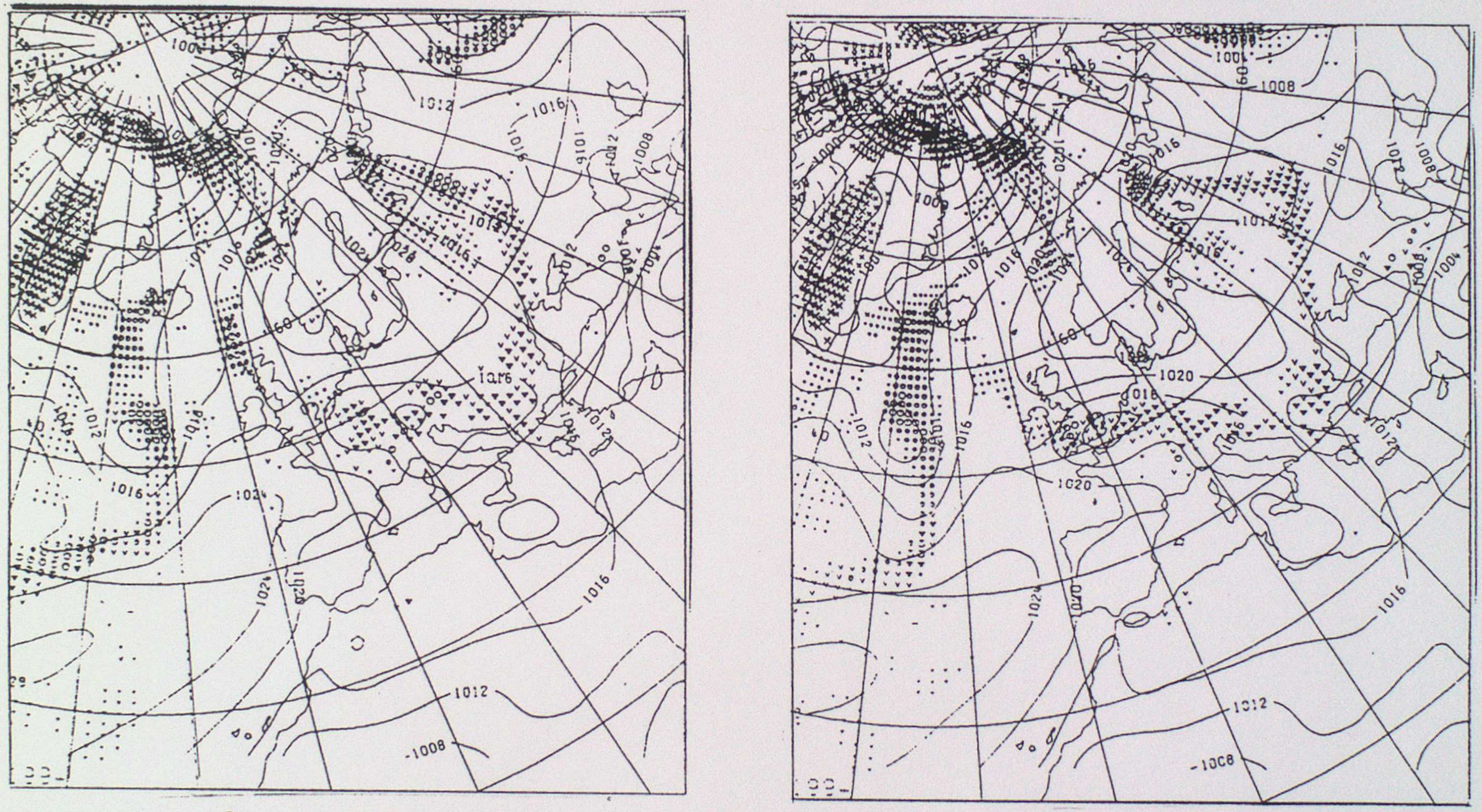

MEAN SEA LEVEL PRESSURE DIFFERENCES
TRIAL(31 LEVELS) - OPERATIONAL
T+120 FORECAST FROM DT 12Z 14/07/94
Negative differences shaded
MEAN SEA LEVEL PRESSURE
OPERATIONAL
ANALYSIS
DT12Z 19/07/94
1016
1020
a
b

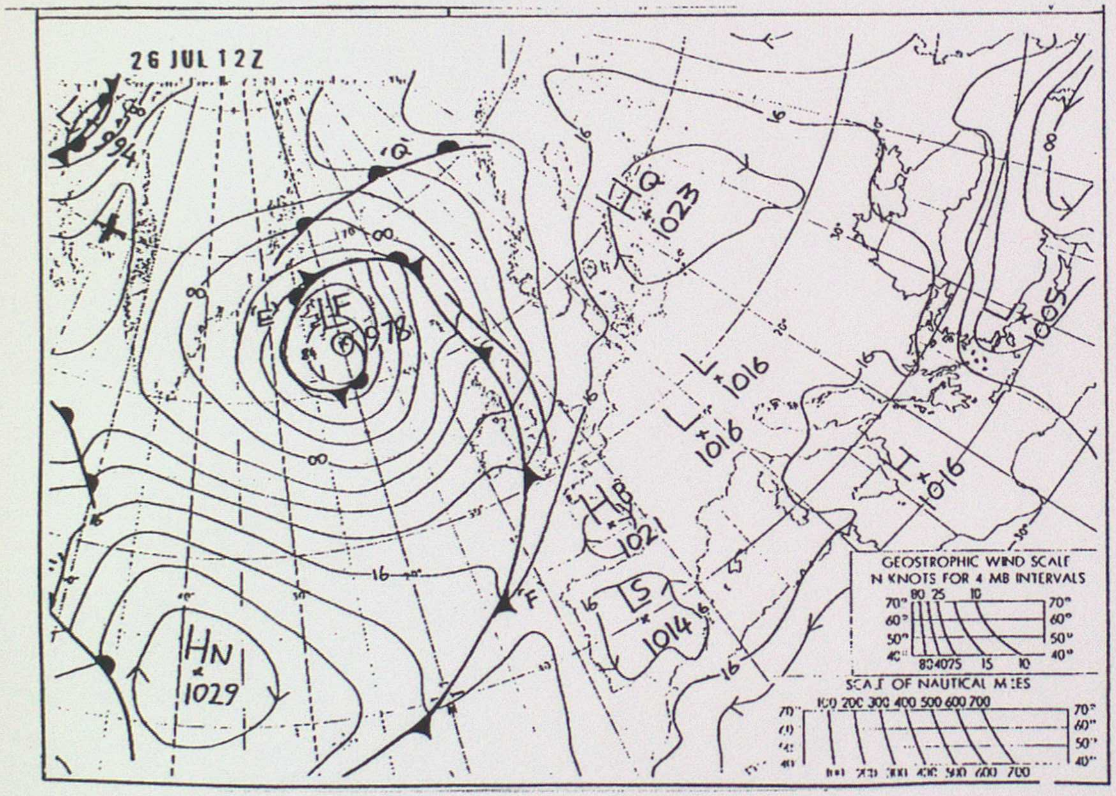
**FIGURE 3.3**



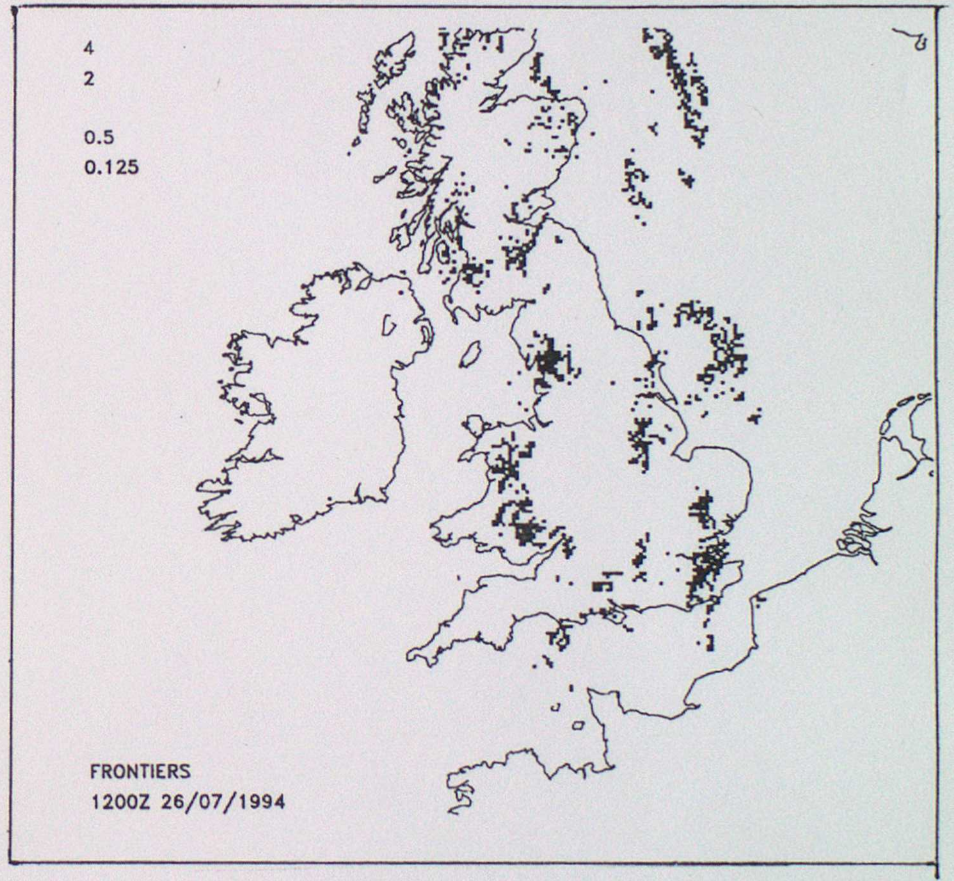
a TRIAL(31 levels)

b OPERATIONAL

**FIGURE 3.4**

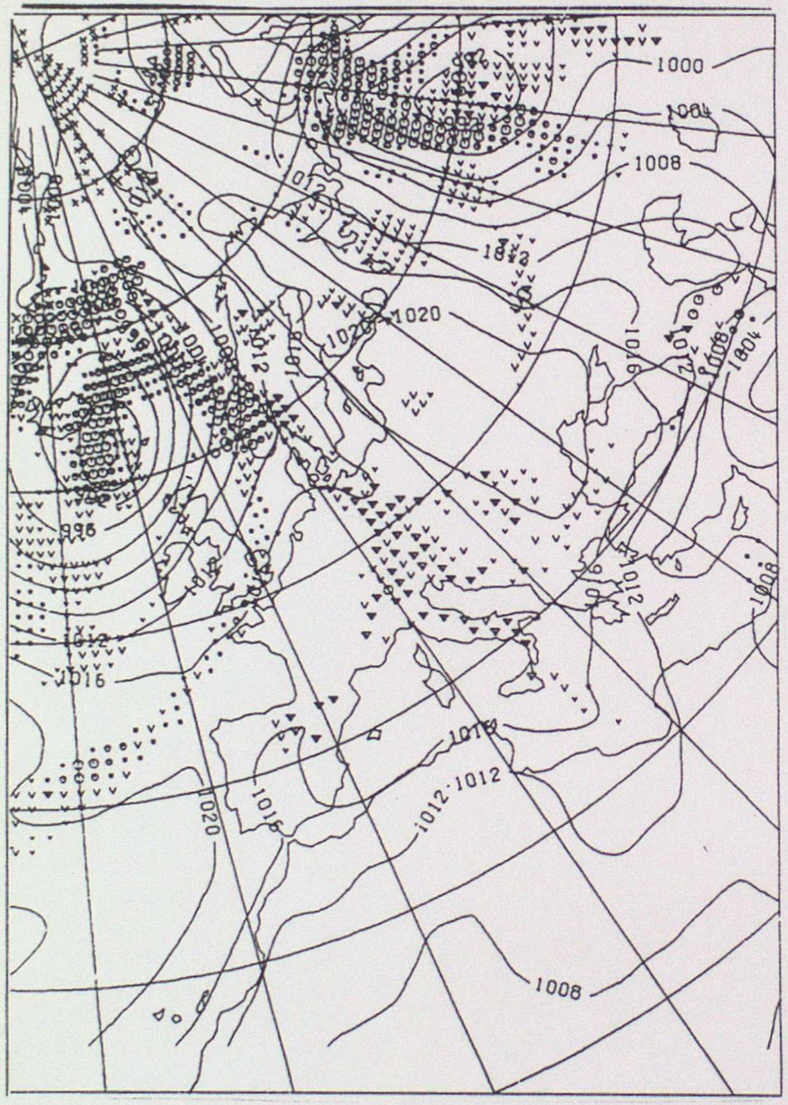



a. ANALYSIS for 12Z 26/07/94

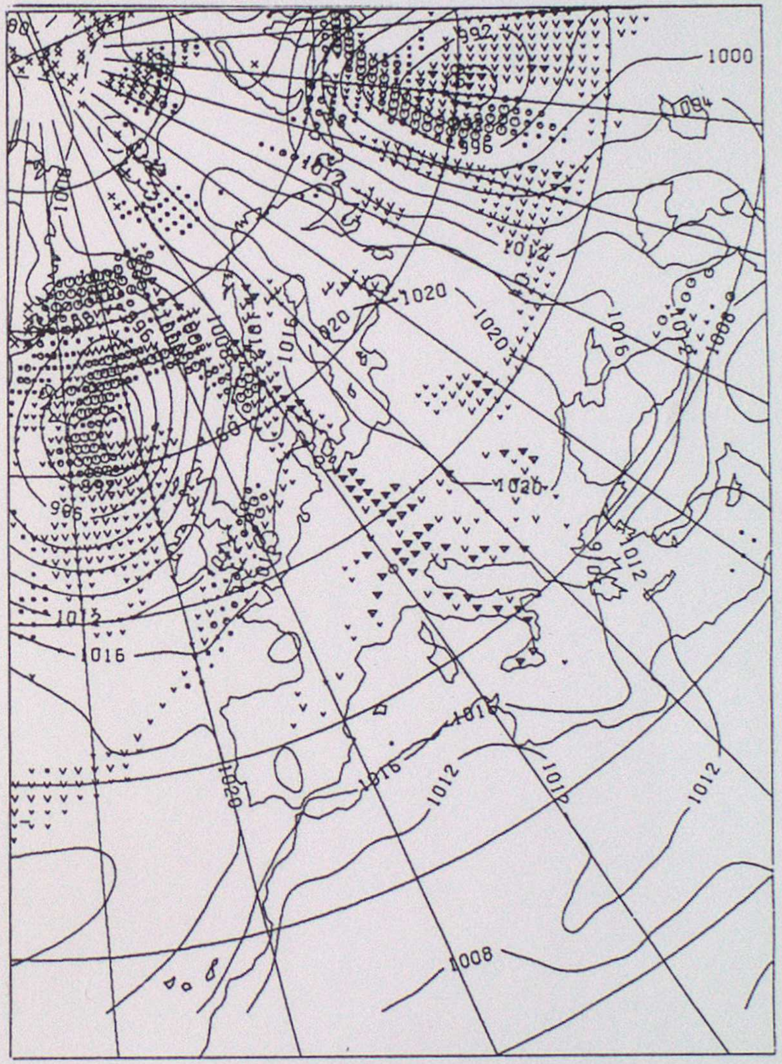



b. RADAR for 12Z 26/07/94

FIGURE 3.5

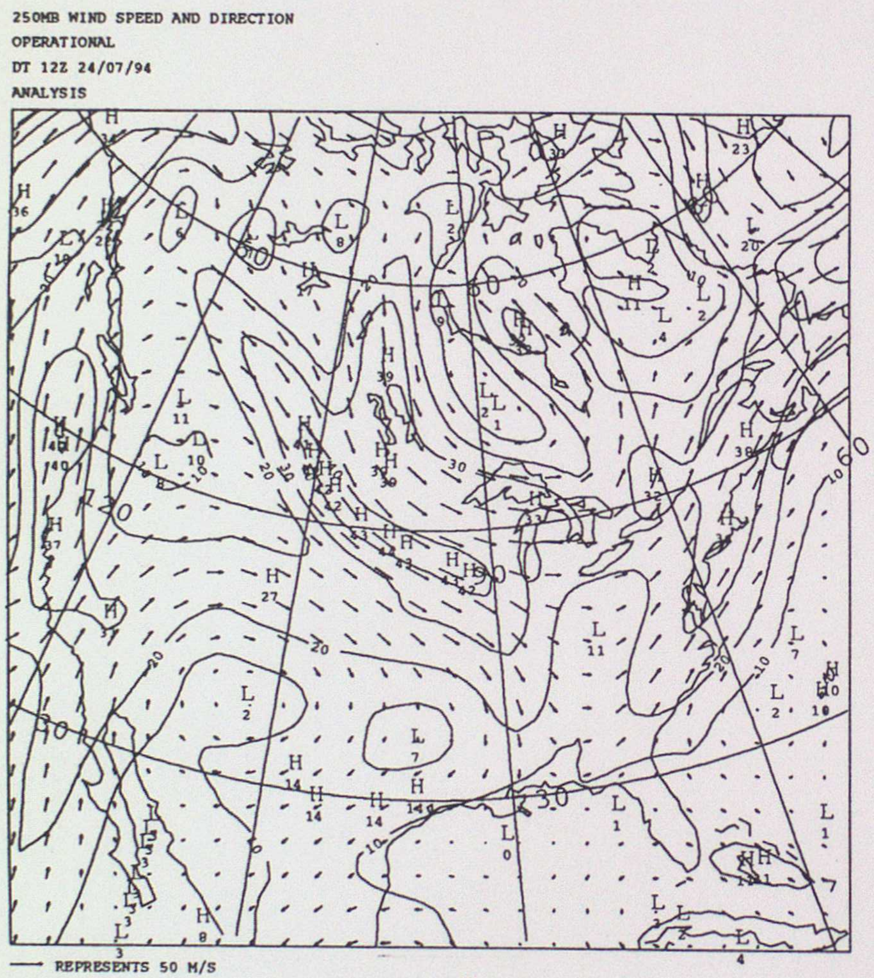


a. TOTAL PRECIPITATION RATES
T+72 FORECAST VT 12Z 26/07/94
FROM TRIAL (31 LEVELS)

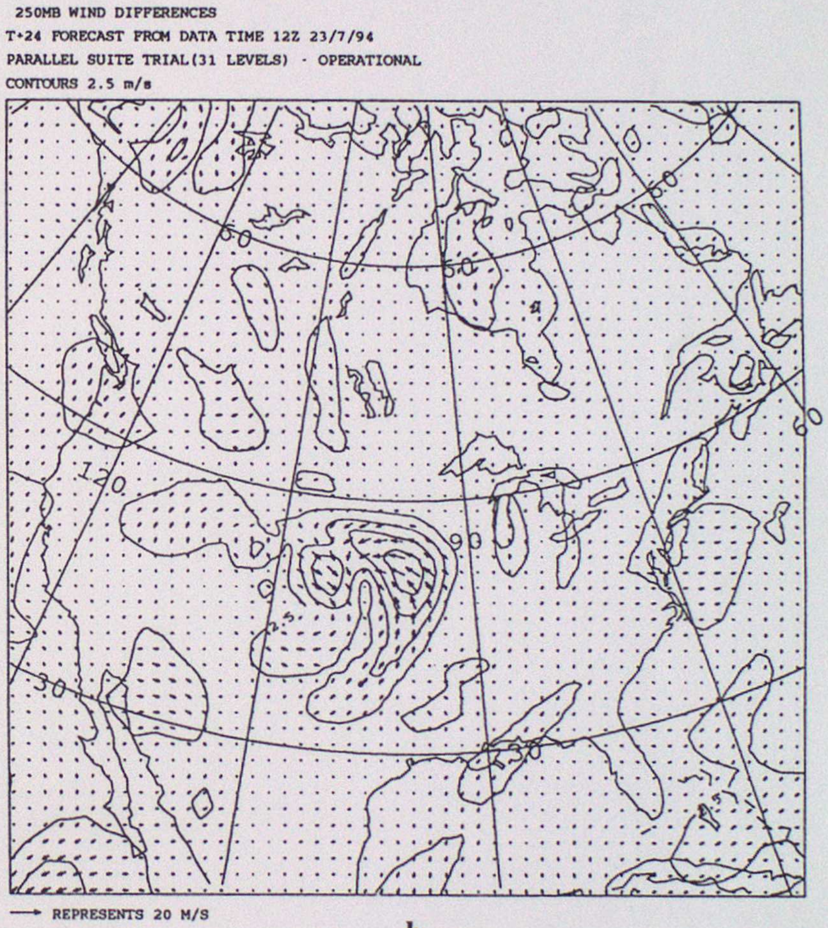


b. TOTAL PRECIPITATION RATES
T+72 FORECAST VT 12Z 26/07/94
FROM OPERATIONAL

**FIGURE 3.6**


250MB WIND SPEED AND DIRECTION
OPERATIONAL
DT 12Z 24/07/94
ANALYSIS
REPRESENTS 50 M/S

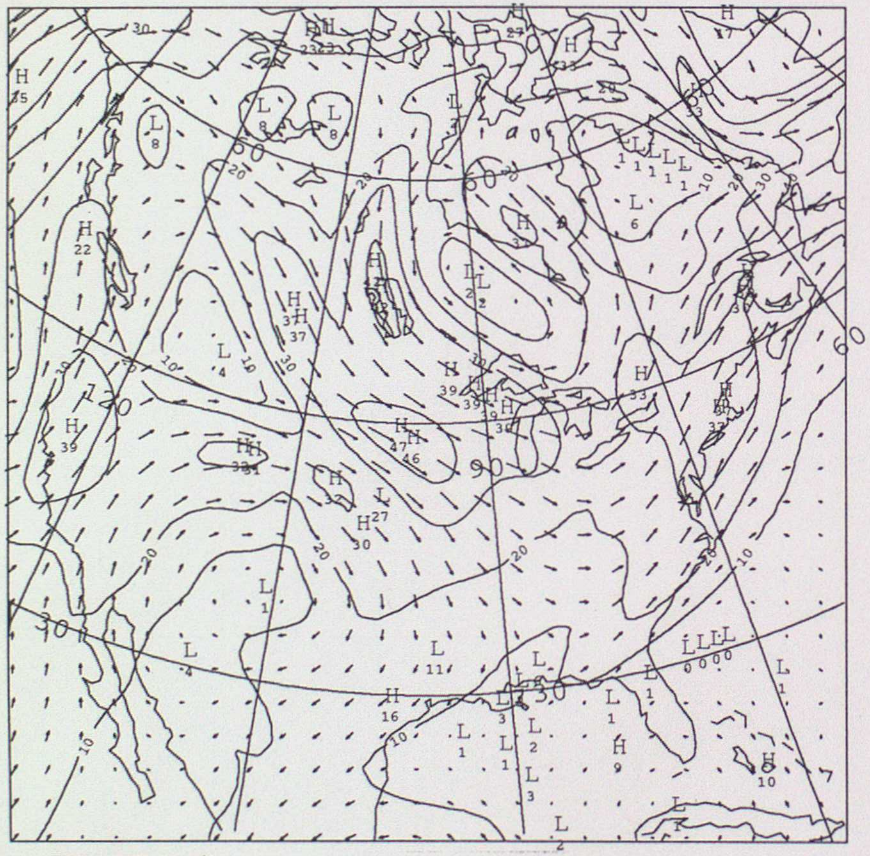
a


250MB WIND DIFFERENCES
T+24 FORECAST FROM DATA TIME 12Z 23/7/94
PARALLEL SUITE TRIAL(31 LEVELS) - OPERATIONAL
CONTOURS 2.5 m/s
REPRESENTS 20 M/S

b

FIGURE 3.7

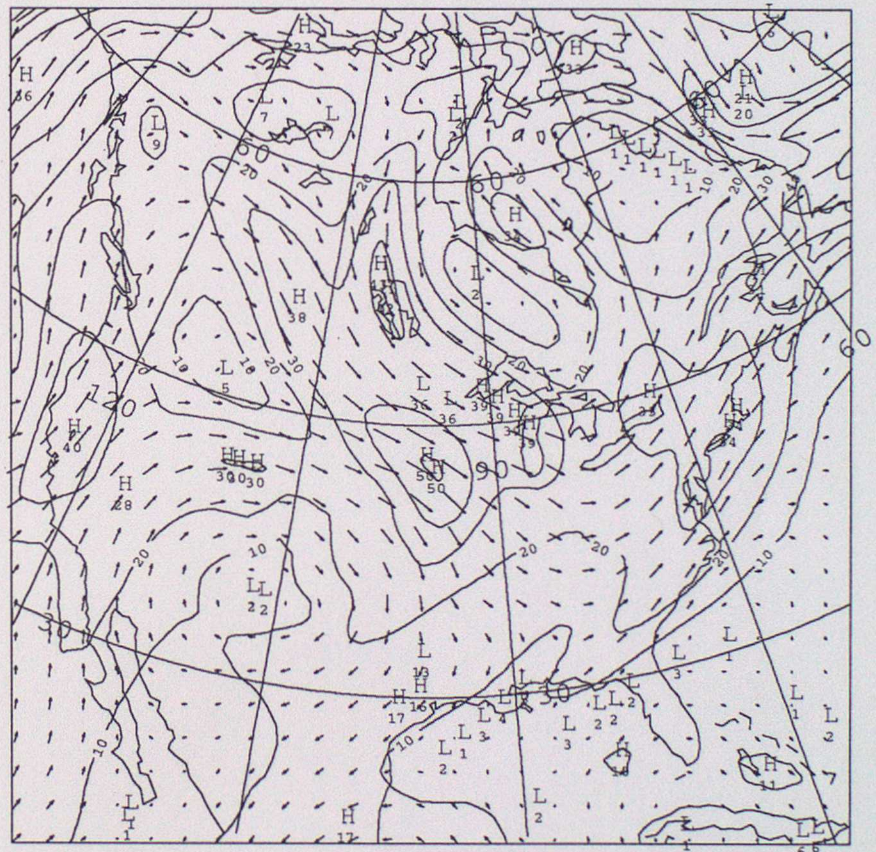
250MB WIND SPEED AND DIRECTION
PARALLEL SUITE TRIAL (31 LEVELS)
DT 00Z 23/07/94
T+24 FORECAST



REPRESENTS 50 M/S

a

250MB WIND SPEED AND DIRECTION
OPERATIONAL
DT 00Z 23/07/94
T+24 FORECAST



REPRESENTS 50 M/S

b

**FIGURE 3.8**

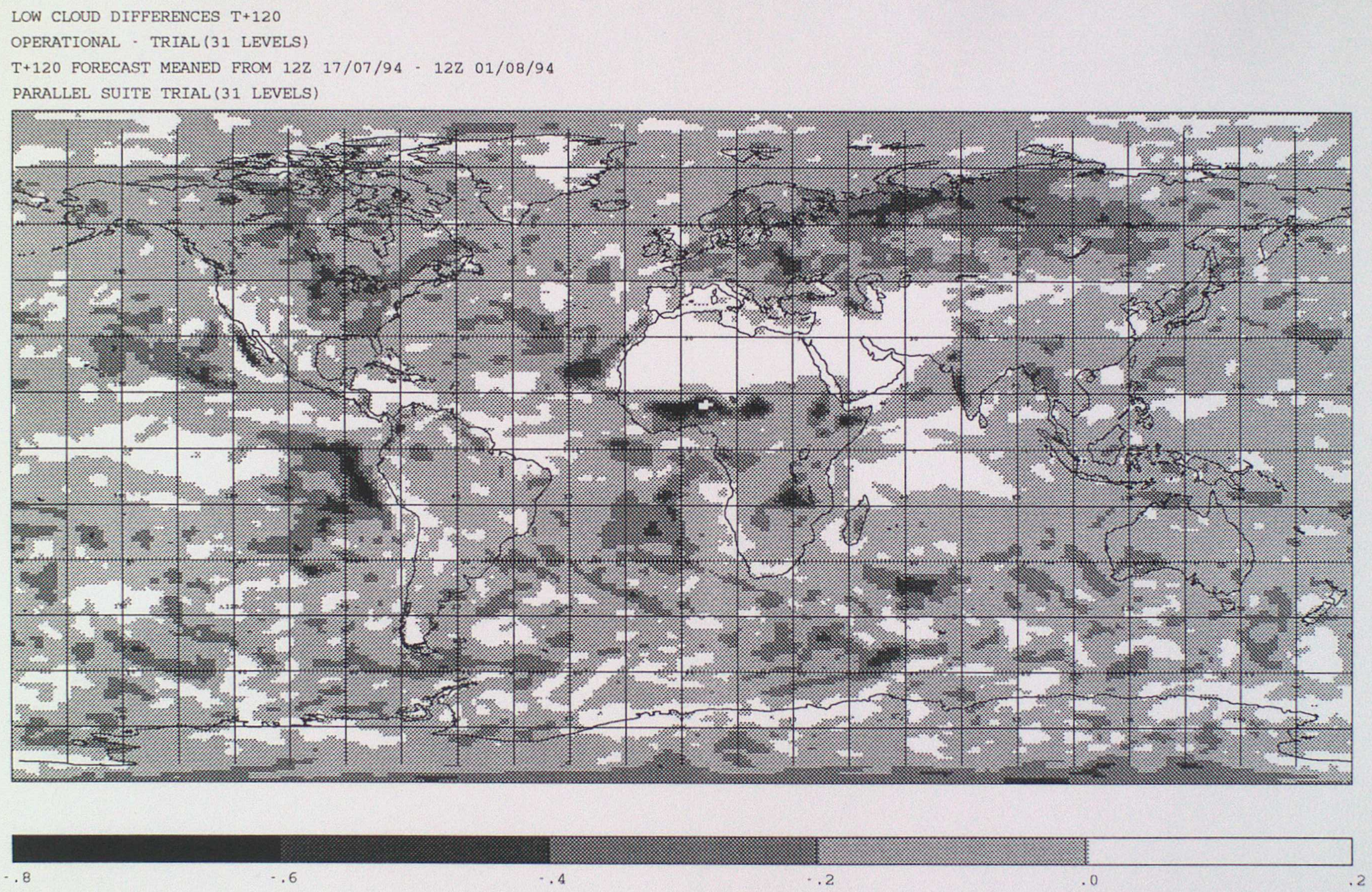

LOW CLOUD DIFFERENCES T+120
OPERATIONAL - TRIAL(31 LEVELS)
T+120 FORECAST MEANED FROM 12Z 17/07/94 - 12Z 01/08/94
PARALLEL SUITE TRIAL(31 LEVELS)
-.8
-.6
-.4
-.2
.0
.2

**FIGURE 3.9a**

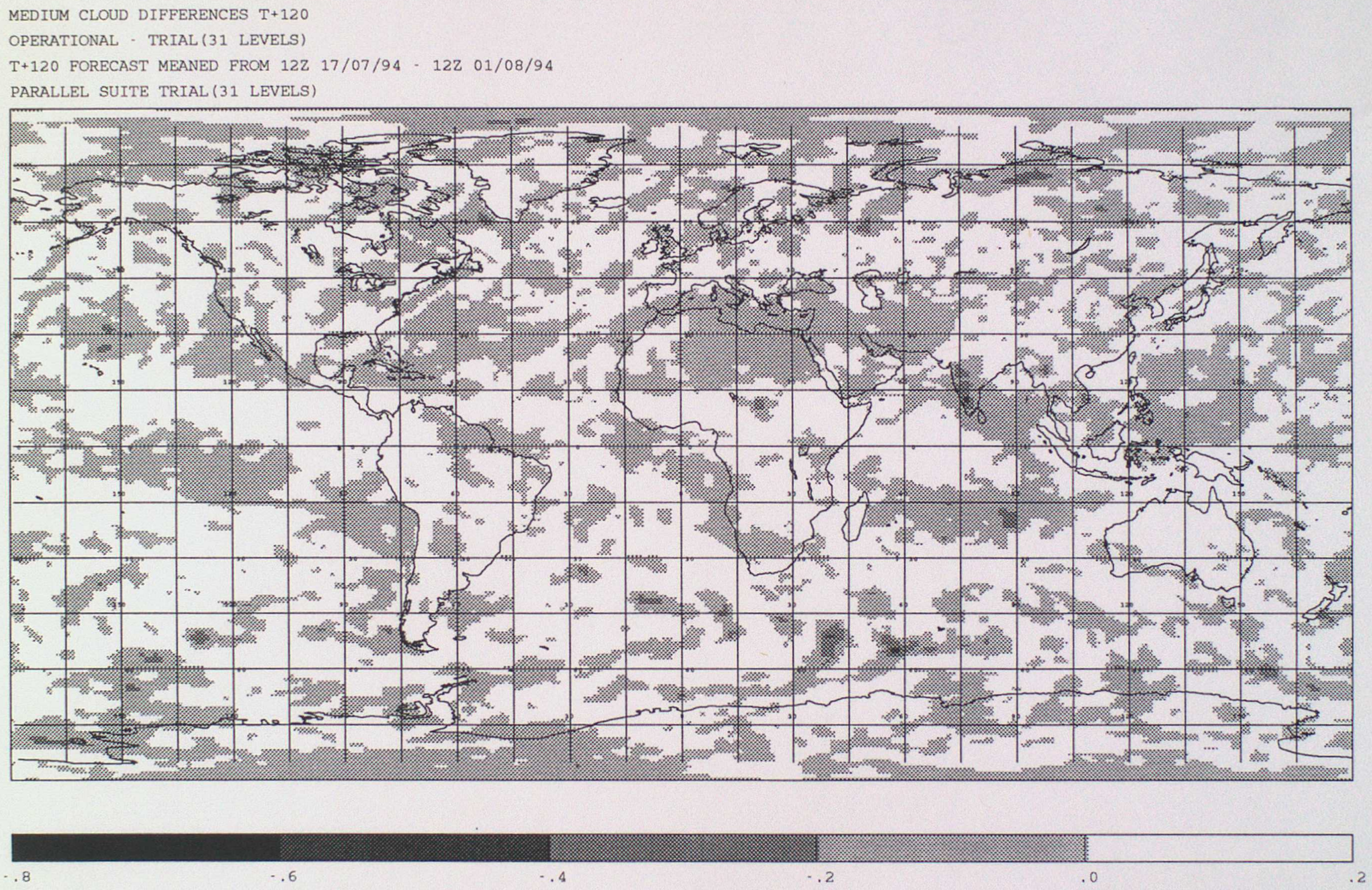

MEDIUM CLOUD DIFFERENCES T+120
OPERATIONAL - TRIAL(31 LEVELS)
T+120 FORECAST MEANED FROM 12Z 17/07/94 - 12Z 01/08/94
PARALLEL SUITE TRIAL(31 LEVELS)
-.8
-.6
-.4
-.2
.0
.2

**FIGURE 3.9b**

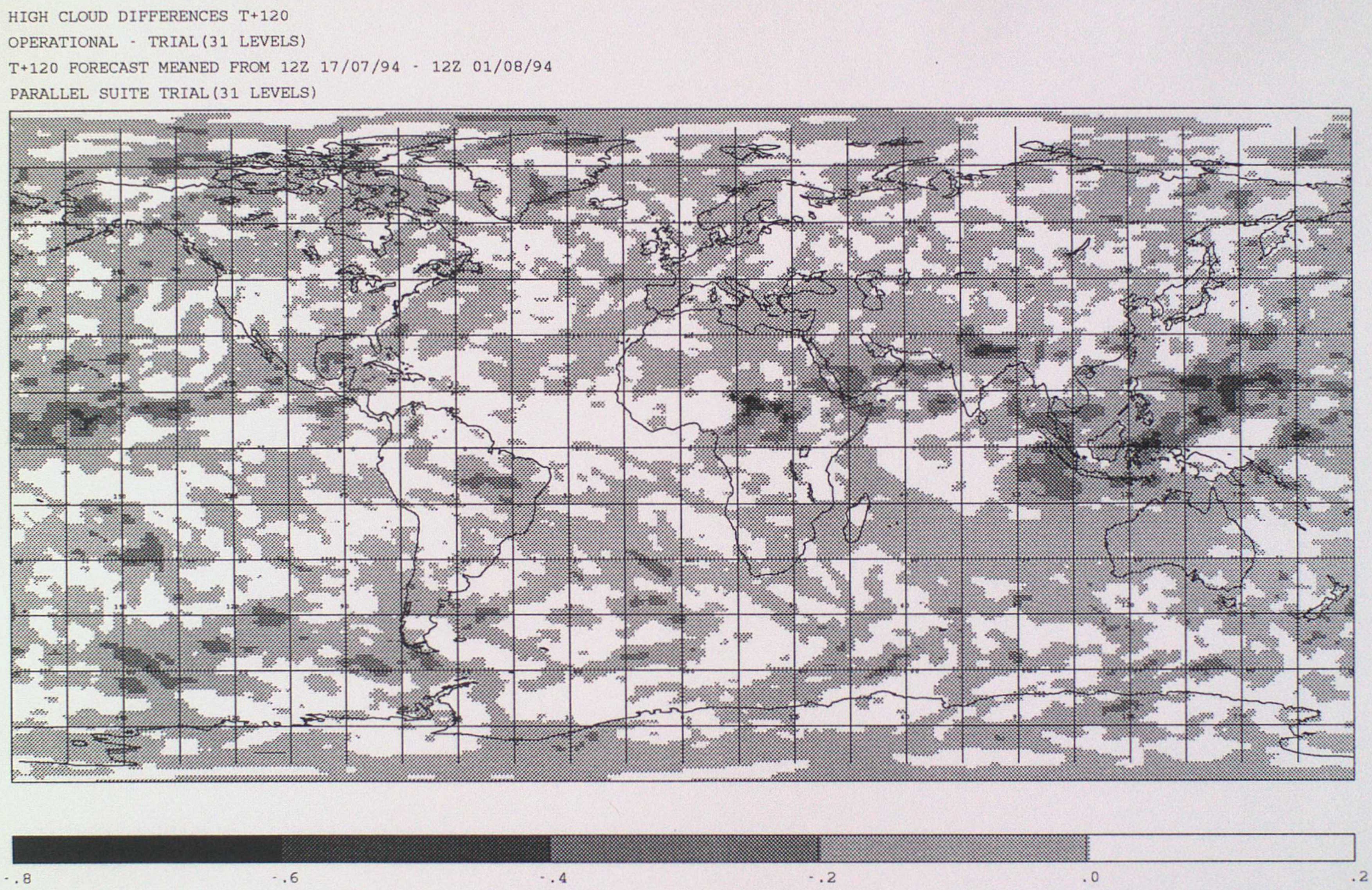

HIGH CLOUD DIFFERENCES T+120
OPERATIONAL - TRIAL(31 LEVELS)
T+120 FORECAST MEANED FROM 12Z 17/07/94 - 12Z 01/08/94
PARALLEL SUITE TRIAL(31 LEVELS)
-.8
-.6
-.4
-.2
.0
.2

**FIGURE 3.9c**

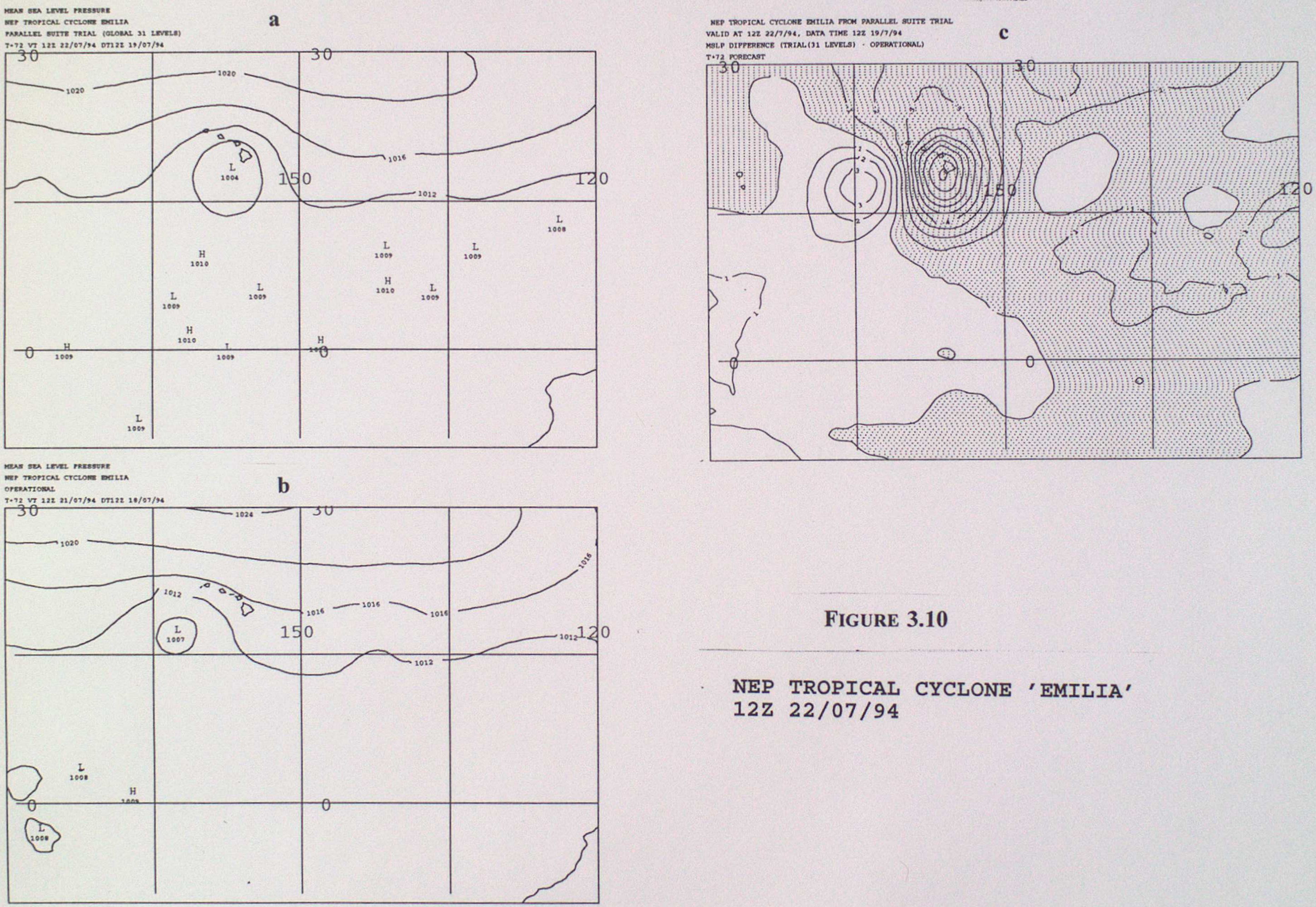
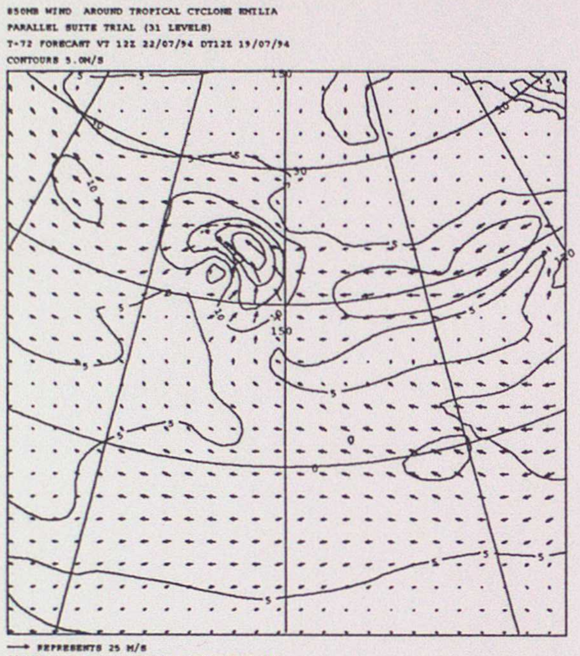
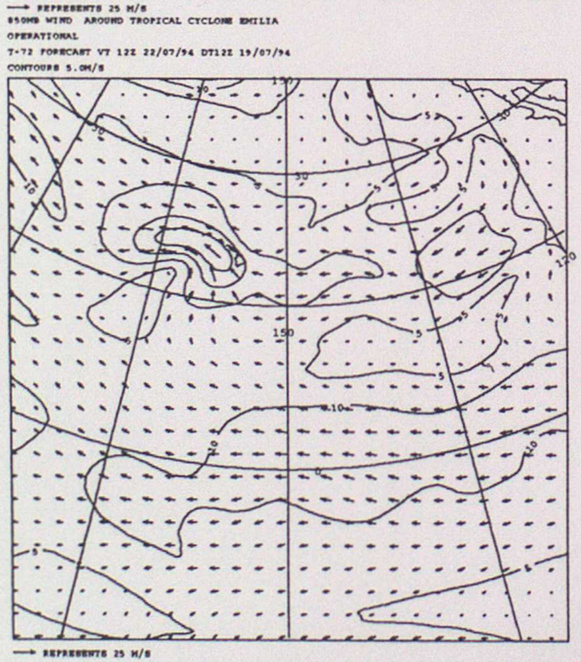



**FIGURE 3.10**

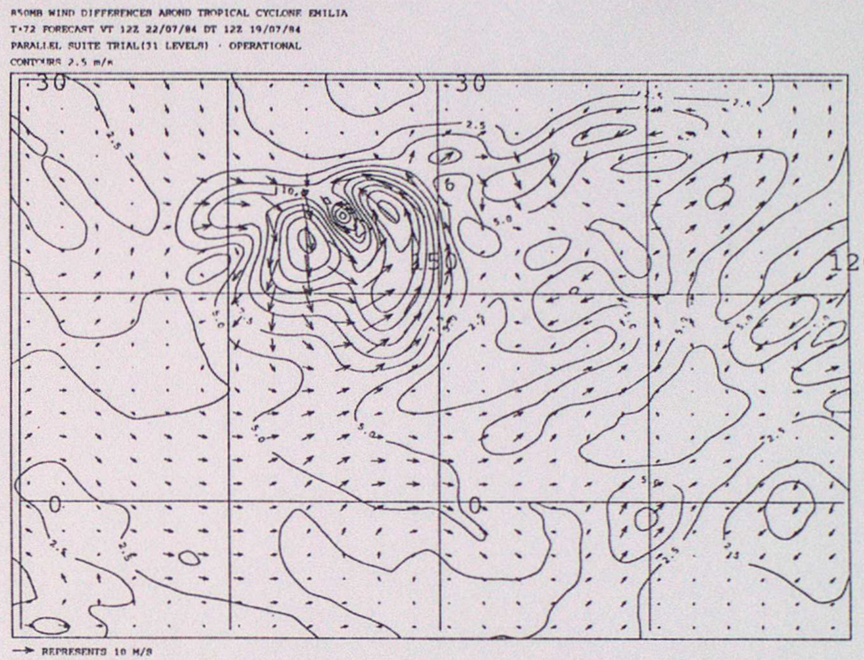
NEP TROPICAL CYCLONE 'EMILIA'
12Z 22/07/94




a




b




c

**FIGURE 3.11**

NEP TROPICAL CYCLONE 'EMILIA'
12Z 22/07/94

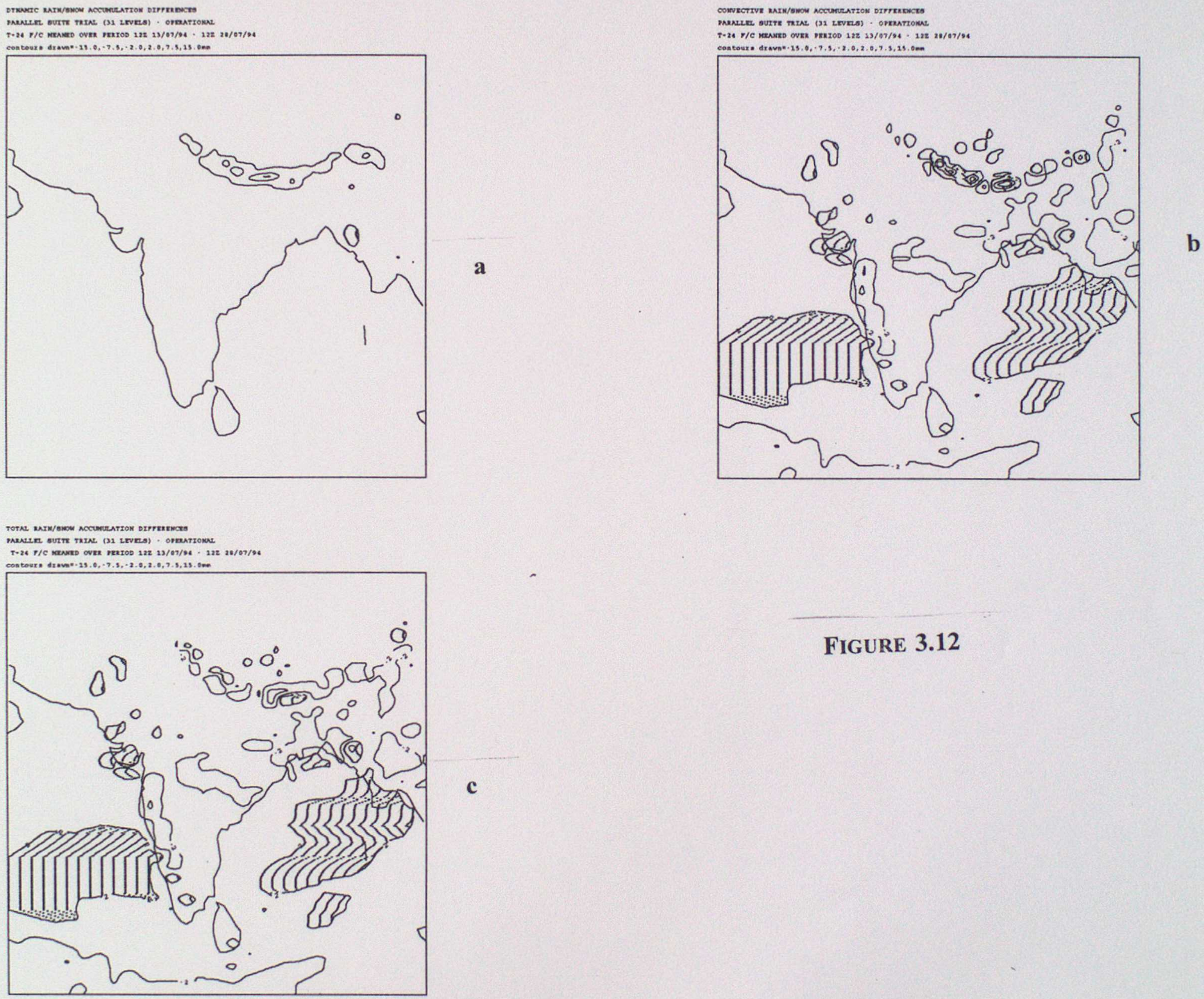
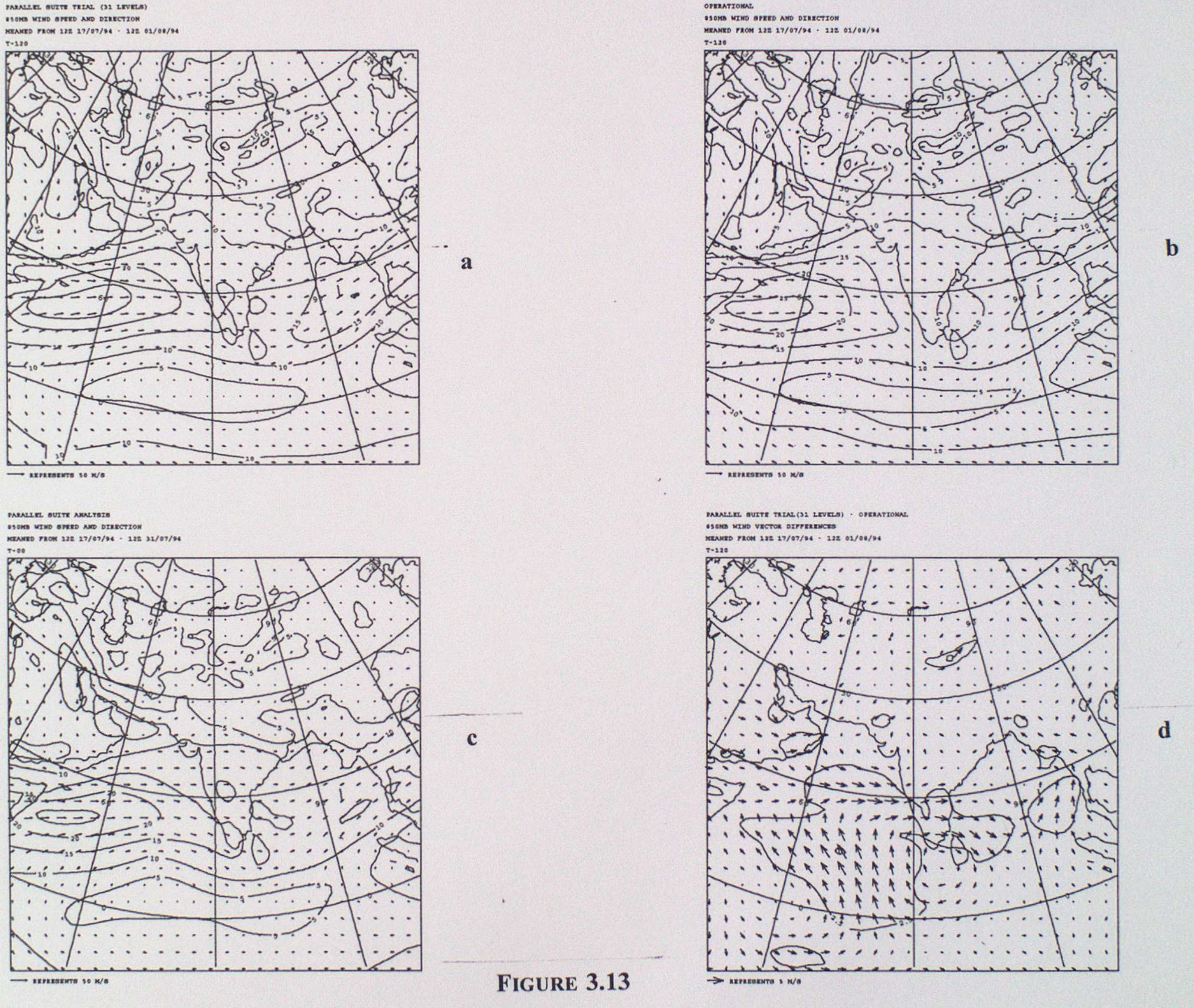

DYNAMIC RAIN/SNOW ACCUMULATION DIFFERENCES
PARALLEL SUITE TRIAL (31 LEVELS) - OPERATIONAL
T+24 F/C MEANED OVER PERIOD 12Z 13/07/94 - 12Z 28/07/94
contours drawn=-15.0,-7.5,-2.0,2.0,7.5,15.0mm
a
CONVECTIVE RAIN/SNOW ACCUMULATION DIFFERENCES
PARALLEL SUITE TRIAL (31 LEVELS) - OPERATIONAL
T+24 F/C MEANED OVER PERIOD 12Z 13/07/94 - 12Z 28/07/94
contours drawn=-15.0,-7.5,-2.0,2.0,7.5,15.0mm
b
TOTAL RAIN/SNOW ACCUMULATION DIFFERENCES
PARALLEL SUITE TRIAL (31 LEVELS) - OPERATIONAL
T+24 F/C MEANED OVER PERIOD 12Z 13/07/94 - 12Z 28/07/94
contours drawn=-15.0,-7.5,-2.0,2.0,7.5,15.0mm
c

FIGURE 3.12



PARALLEL SUITE TRIAL (31 LEVELS)
850MB WIND SPEED AND DIRECTION
MEANED FROM 12Z 17/07/94 - 12Z 01/08/94
T-120
REPRESENTS 50 M/S
a
OPERATIONAL
850MB WIND SPEED AND DIRECTION
MEANED FROM 12Z 17/07/94 - 12Z 01/08/94
T-120
REPRESENTS 50 M/S
b
PARALLEL SUITE ANALYSIS
850MB WIND SPEED AND DIRECTION
MEANED FROM 12Z 17/07/94 - 12Z 31/07/94
T-00
REPRESENTS 50 M/S
c
PARALLEL SUITE TRIAL(31 LEVELS) - OPERATIONAL
850MB WIND VECTOR DIFFERENCES
MEANED FROM 12Z 17/07/94 - 12Z 01/08/94
T-120
REPRESENTS 5 M/S
d


FIGURE 3.13

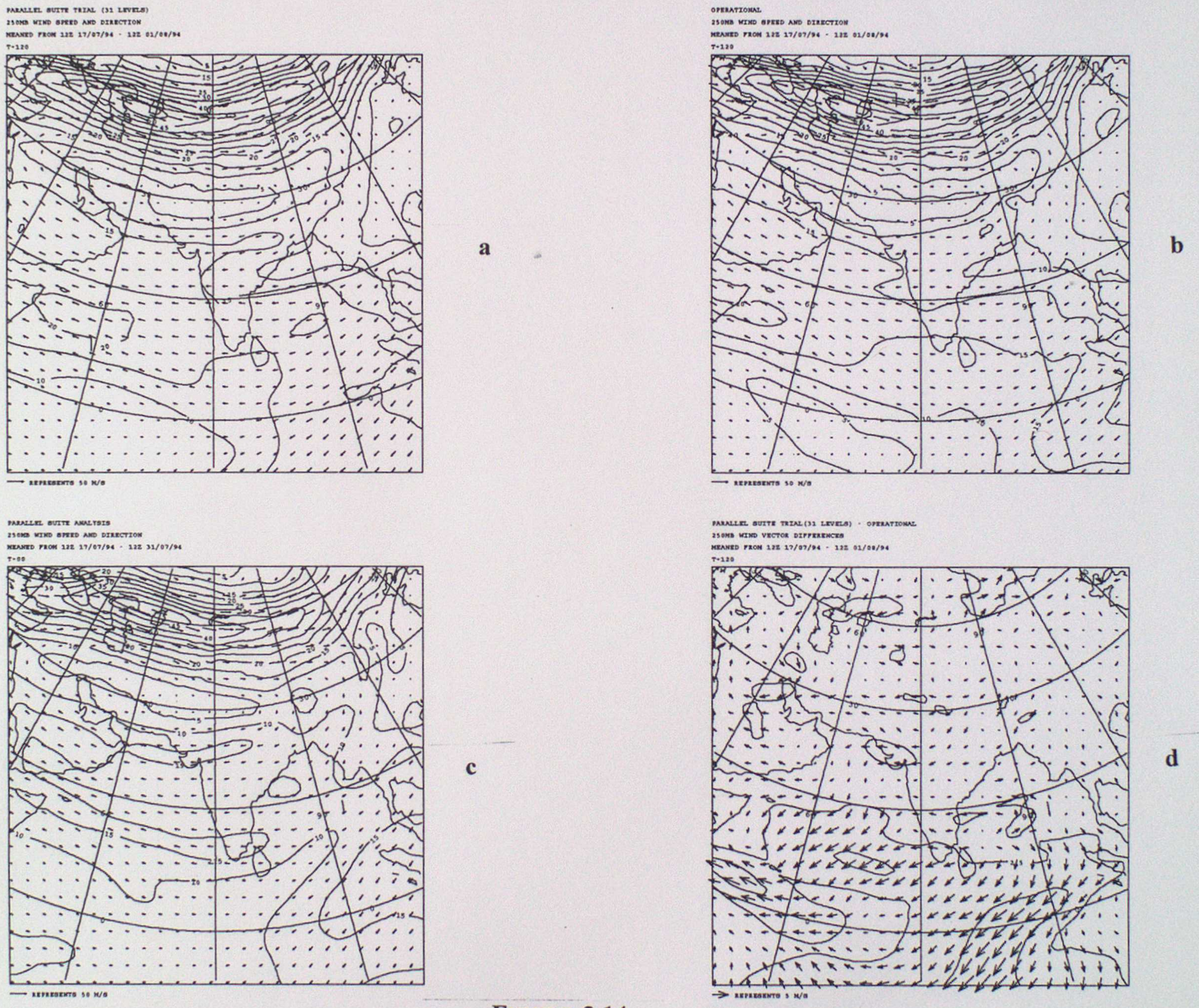

PARALLEL SUITE TRIAL (31 LEVELS)
250MB WIND SPEED AND DIRECTION
MEANED FROM 12Z 17/07/94 - 12Z 01/08/94
T+120
REPRESENTS 50 M/S
a
OPERATIONAL
250MB WIND SPEED AND DIRECTION
MEANED FROM 12Z 17/07/94 - 12Z 01/08/94
T+120
REPRESENTS 50 M/S
b
PARALLEL SUITE ANALYSIS
250MB WIND SPEED AND DIRECTION
MEANED FROM 12Z 17/07/94 - 12Z 31/07/94
REPRESENTS 50 M/S
c
PARALLEL SUITE TRIAL(31 LEVELS) - OPERATIONAL
250MB WIND VECTOR DIFFERENCES
MEANED FROM 12Z 17/07/94 - 12Z 01/08/94
T+120
REPRESENTS 5 M/S
d

FIGURE 3.14

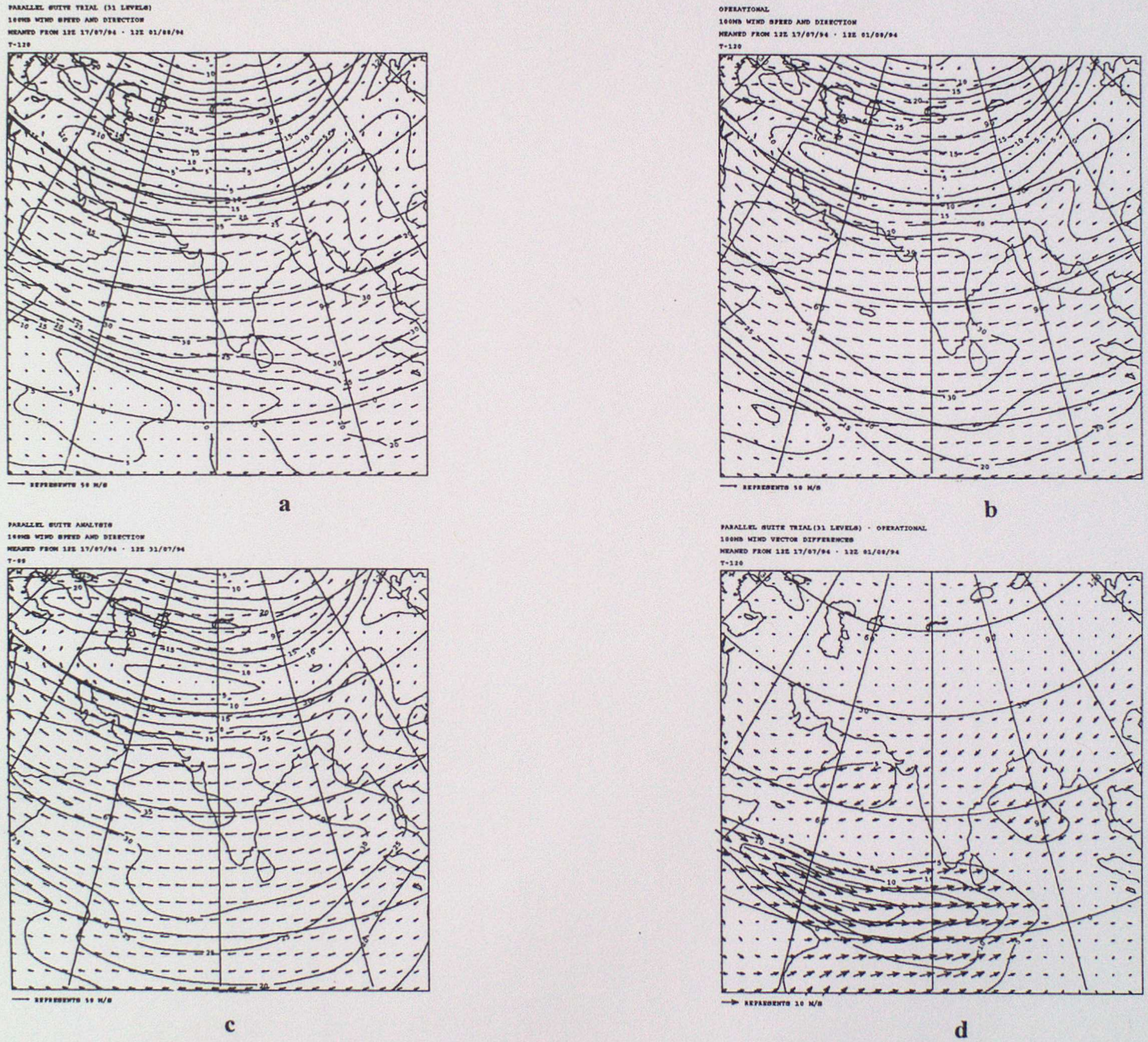
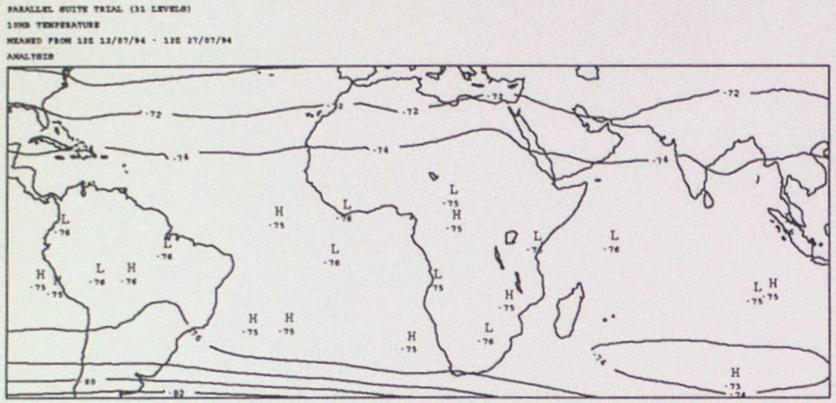
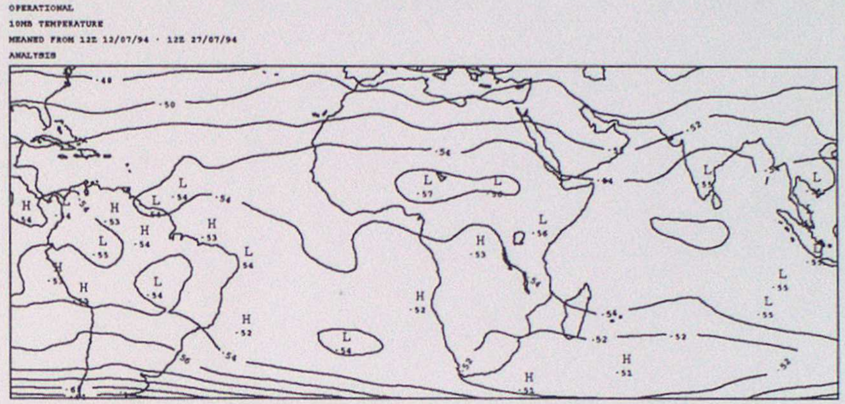

PARALLEL SUITE TRIAL (31 LEVELS)
100MB WIND SPEED AND DIRECTION
MEANED FROM 12Z 17/07/94 - 12Z 01/08/94
T-120
REPRESENTS 50 M/S
a
OPERATIONAL
100MB WIND SPEED AND DIRECTION
MEANED FROM 12Z 17/07/94 - 12Z 01/08/94
T-120
REPRESENTS 50 M/S
b
PARALLEL SUITE ANALYSIS
100MB WIND SPEED AND DIRECTION
MEANED FROM 12Z 17/07/94 - 12Z 31/07/94
REPRESENTS 50 M/S
c
PARALLEL SUITE TRIAL(31 LEVELS) - OPERATIONAL
100MB WIND VECTOR DIFFERENCES
MEANED FROM 12Z 17/07/94 - 12Z 01/08/94
T-120
REPRESENTS 10 M/S
d

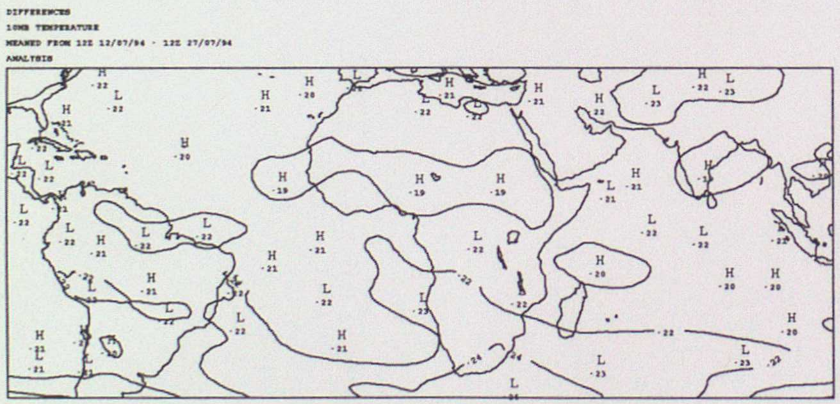
FIGURE 3.15




a



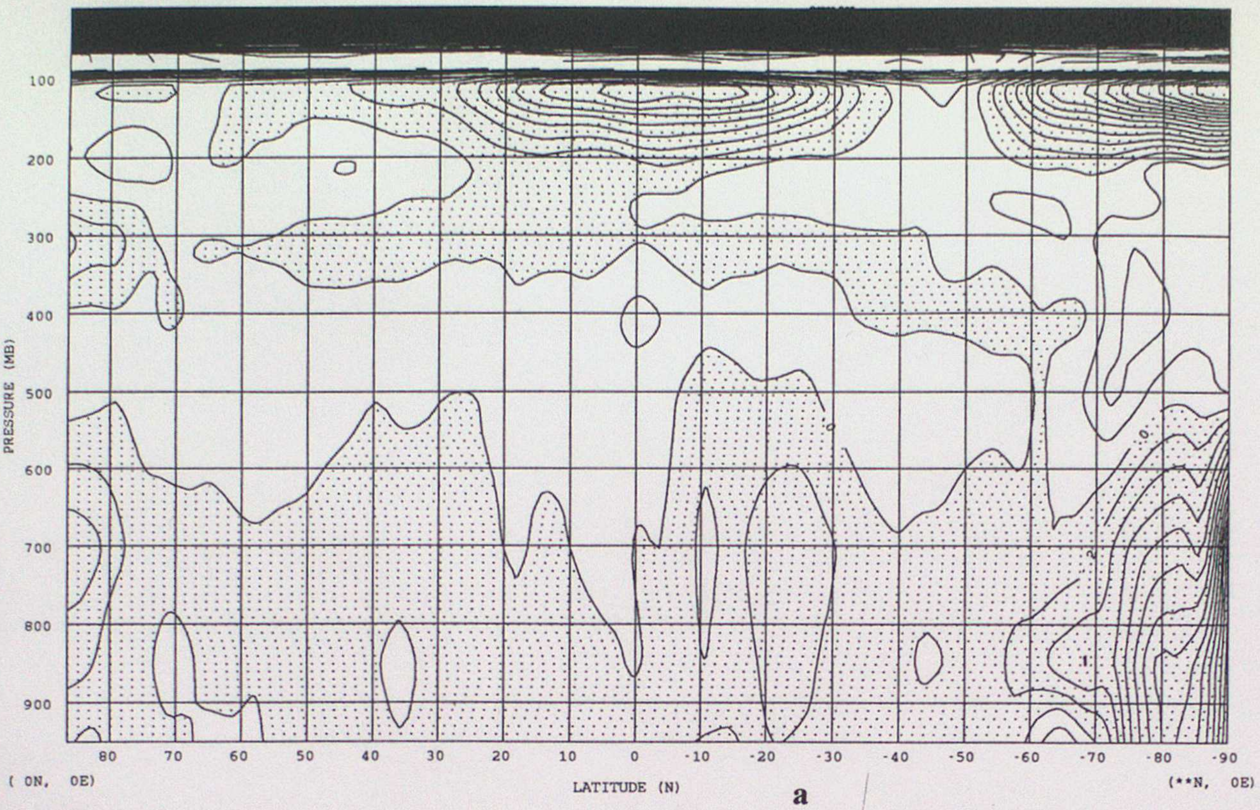

b




c

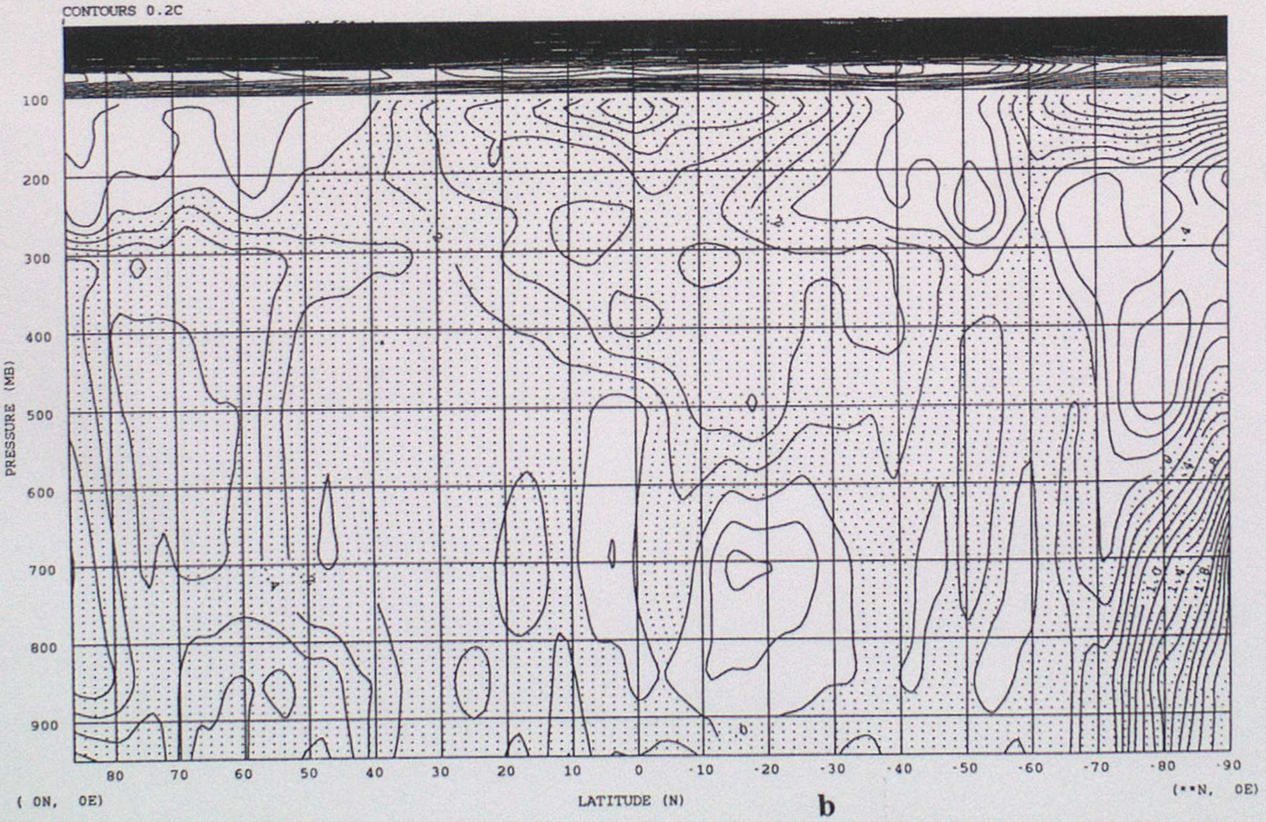
FIGURE 3.16

ZONAL MEAN CROSS-SECTION SHOWING TEMPERATURE DIFFERENCES
ANALYSIS (AVERAGE FROM 12Z 12/7/94 TO 12Z 27/7/94)
PARALLEL SUITE TRIAL (31 LEVELS) - OPERATIONAL
CONTOURS 0.2C



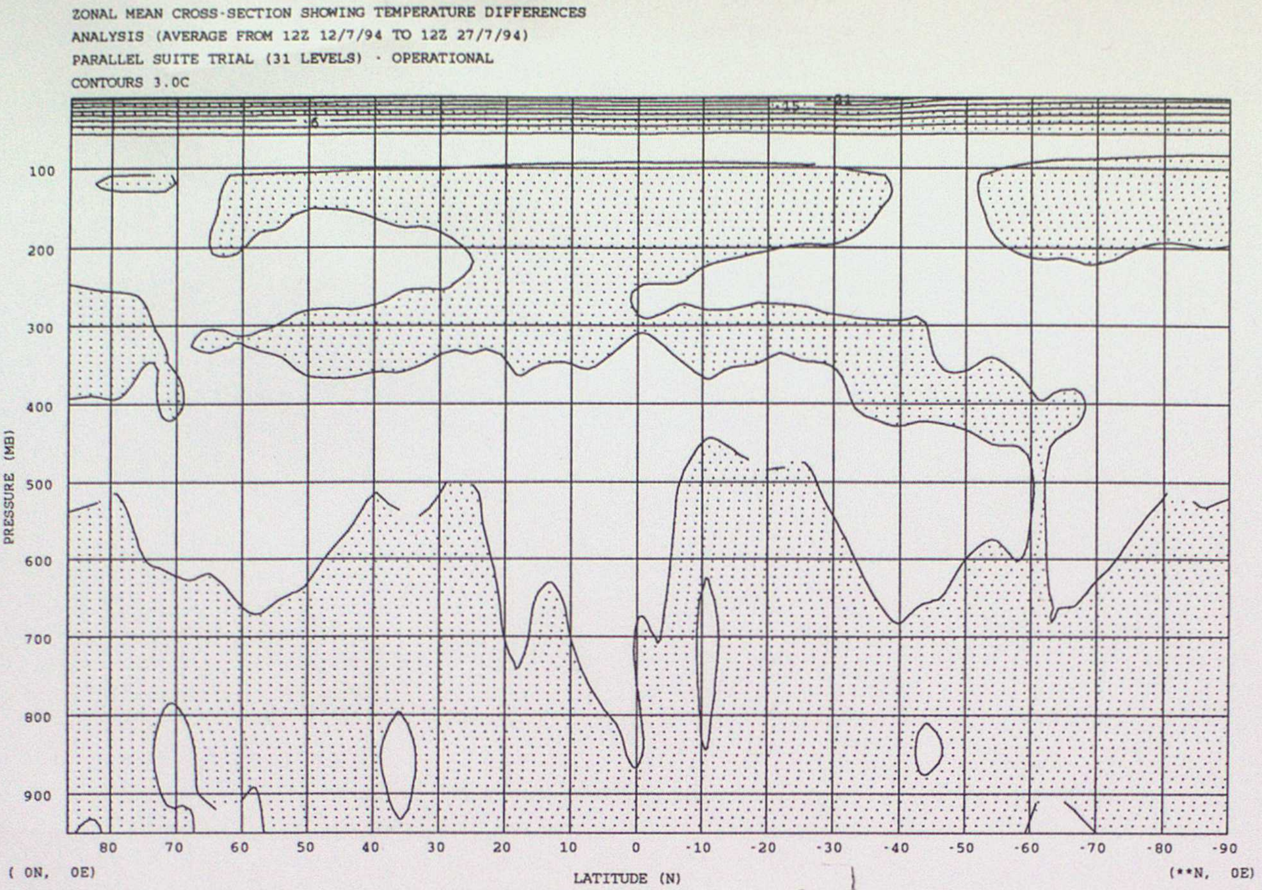

a

ZONAL MEAN CROSS-SECTION SHOWING TEMPERATURE DIFFERENCES
T+120 (AVERAGE FROM 12Z 17/7/94 TO 12Z 1/8/94)
PARALLEL SUITE TRIAL (31 LEVELS) - OPERATIONAL
CONTOURS 0.2C

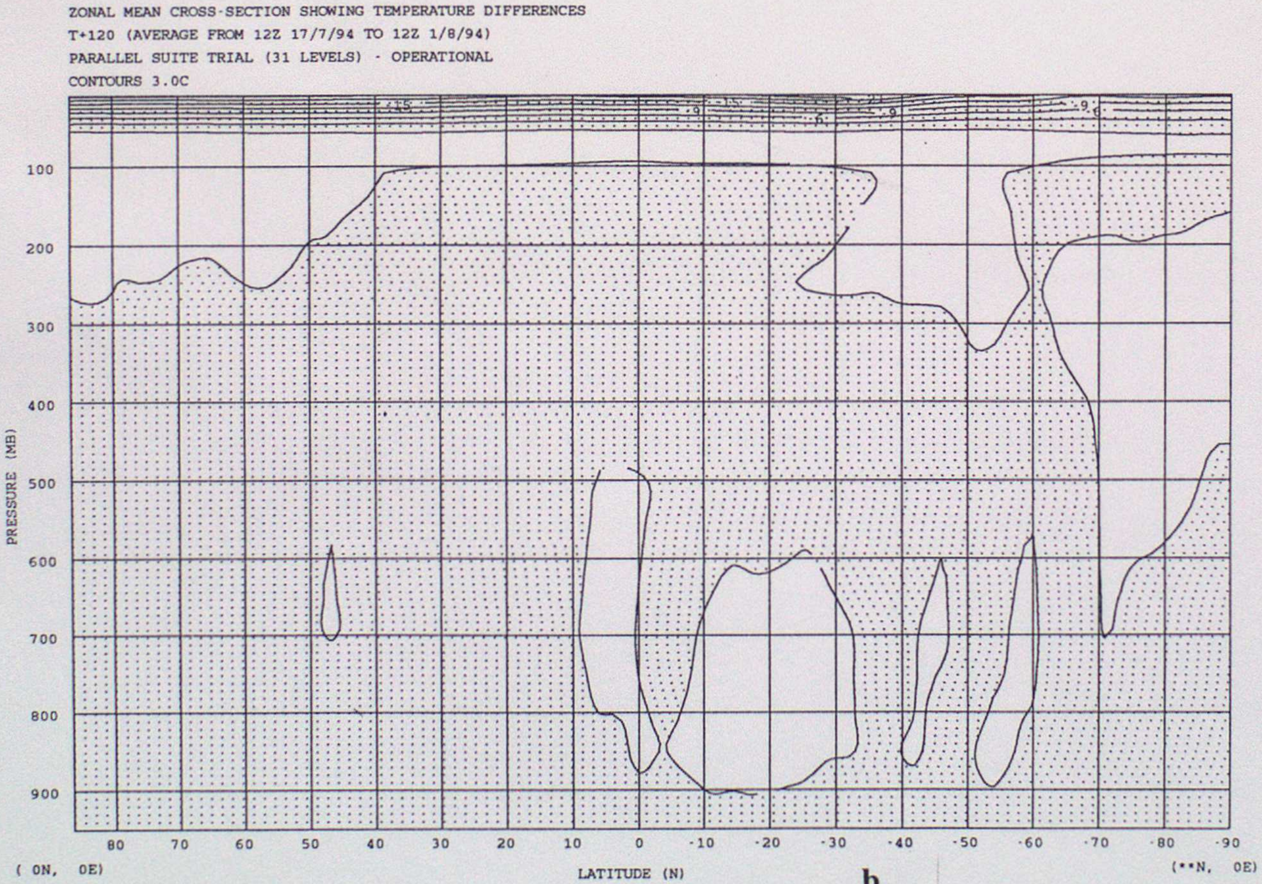



b

**FIGURE 3.17**




a




b

**FIGURE 3.18**