Forecasting Research

Forecasting Research Division
Technical Report No. 165

TRIAL OF A LOCAL CORRECTION OF NEGATIVE HUMIDITY AND MODIFIED HORIZONTAL DIFFUSION NEAR STEEP OROGRAPHY IN THE GLOBAL AND LIMITED AREA MODEL

by

C.A. Wilson, O.M. Hammon and S.F. Milton

May 1995

Meteorological Office
London Road
Bracknell
Berkshire
RG12 2SZ
United Kingdom

FORECASTING RESEARCH TECHNICAL REPORT NO 165

TRIAL OF A LOCAL CORRECTION OF NEGATIVE HUMIDITY AND MODIFIED HORIZONTAL DIFFUSION NEAR STEEP OROGRAPHY IN THE GLOBAL AND LIMITED AREA MODEL

by

C. A. Wilson , O. M. Hammon and S.F. Milton

MAY 1995

Forecasting Research Division
Meteorological Office
London Road
Bracknell
Berks
RG12 2SZ

TRIAL OF A LOCAL CORRECTION OF NEGATIVE HUMIDITY AND MODIFIED HORIZONTAL DIFFUSION NEAR STEEP OROGRAPHY IN THE GLOBAL AND LIMITED AREA MODEL

CONTENTS

1. INTRODUCTION

The standard Unified Model 2nd order advection scheme produces some points with negative specific humidity (or more correctly total water). This is most likely in regions where there are large gradients of total water, q_T. Such unphysical values have to be corrected in some way, or an alternative advection scheme which is constructed to be positive definite, such as the tracer advection option, should be used. The current operational correction is a global correction whereby the total negative and positive q_T are summed for each model level; points with negative values are reset to zero and the positive values are rescaled by a constant fraction so as to maintain the global total for each level. Studies with both the climate (Hall, 1994) and global forecast versions (Lorrimer,1995) have shown that negative q_T values occur predominantly in mid-latitudes and that the global correction results in a spurious transport of moisture from the tropics to mid-latitudes. Using a local correction whereby the negative values are reset from the surrounding points (Hall, 1994; Lorrimer,1995) is a more reasonable procedure since the problem arises from *local* inaccuracies in the advection scheme. Preliminary tests (Lorrimer,1995) have shown the spurious transport of moisture can be eliminated and there is a slight beneficial impact on model cooling at upper tropospheric levels due mainly to reduced cloud.

Near steep orography the "horizontal diffusion" of moisture, potential temperature and winds is inappropriate since the model level surfaces are no longer horizontal. Applying diffusion along the model coordinate surfaces in these regions results in a cooling and moistening over model mountains, and consequently large spurious precipitation totals. This is particularly evident in the tropics eg over the Andes and New Guinea. At high latitudes it has also been found that the noise problems which occasionally occur may be excited by the horizontal diffusion. Schemes which apply a quasi-horizontal correction can be used but there are difficulties in specifying the fictitious atmosphere beneath the mountains. A pragmatic modification has been developed whereby the horizontal diffusion is switched off when the orography is too steep such that pressure at the neighbouring point lies outside the pressure range of the adjacent levels at a point.[1] The effect of this in both climate and global forecast versions has been to reduce markedly the spurious excessive rainfall in the tropics over steep orography. The high latitude noise has also been eliminated in some cases.

This technical report contains the results of subjective and objective assessments of a parallel suite test of the two modifications. The trial was performed from 07-30 April 1995 for both the global and limited area models. A fully independent assimilation cycle was maintained for the parallel global model and forecasts to T+120 were made once per day from the 12 UTC main analysis time. The limited area model 4-cycle assimilation (15,18,21,00 UTC) was intermittently started from the 12 UTC analysis and forecasts to T+36 were made once per day from its own 00 UTC analysis. The operational verification packages were included to give comparable statistics from the parallel and operational suites. The impact was expected to be largely neutral in respect of standard verification scores with the main benefits those outlined above. The trial revealed that winds were also improved, especially for the Northern Hemisphere and upper levels in the tropics. Locally, in regions where large rms error are frequently found the error was reduced and systematic errors were improved (see section 4).

2. OBJECTIVE VERIFICATION

GLOBAL MODEL

The analyses and forecasts were verified against observations (sondes and synops) for the period 07/04/95 to 30/04/95. 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+48, 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. A quicker and clearer overall assessment is gained from the vertical profiles of the changes for all verification periods which are plotted in **FIGS 2.1,2.2,2.3** for height, temperature and vector wind errors respectively. A 1% threshold is shown dotted on these figures, beneath which the changes are regarded as not significant.

For area 2 the expectation of neutral impact is clearly borne out, with relatively few changes in excess of 1%. The clearest benefits are for the temperatures and winds, particularly upper level winds, in the Northern hemisphere and tropics (see **FIGS 2.2,2.3**). In the Southern

[1] An alternative scheme which limits the pressure at the neighbouring points to lie within the range of the model layer boundaries has also been devised. This is more stringent and has not been tested here.

%RMS CHANGE (TRIAL-OPERATIONAL) PERIOD 07/04/95-30/04/95
VERIFICA AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72	T+120
AREA	2				
HEIGHTS					
850	-0.7	0.1	-1.1	-0.8	-0.9
700	0	-1	-0.4	-1.2	-0.6
500	0	-0.6	-0.4	-1.3	-0.6
300	0	-0.7	0.2	-0.6	0
250	0	-0.8	-0.2	0	0
200	-0.3	-1.8	-0.2	-0.5	-0.1
100	-0.2	-0.9	-0.6	0.8	1.4
50	0.1	0.4	0.7	1.6	4
MEAN	-0.1	-0.7	-0.2	-0.2	0.4
TEMPERATURES					
850	-0.9	-2	-0.3	0.2	0.2
700	-0.5	-0.9	-0.3	0.4	0.4
500	0	-1.8	-0.8	-0.1	0
300	-0.6	0.3	0.6	0.7	-0.9
250	1.5	0.6	-0.2	0.4	0.1
200	0	0.1	1	0.5	-1.4
100	0.4	0.5	-1.2	-0.3	0.7
50	0	-0.4	-0.1	0.7	-0.5
MEAN	0	-0.4	-0.2	0.3	-0.2
WINDS					
850	-0.1	-0.7	0.4	0.3	0.1
700	-0.6	-0.3	0.4	-0.6	0.8
500	0.1	-0.1	0.1	-0.3	0.8
400	0.3	0	0.2	0.3	0.1
300	0.2	-0.1	0.7	0.1	-0.3
250	0.4	0.2	1.3	0.2	-0.7
200	0.2	0.1	0.7	-0.3	-0.5
100	0	-0.3	-0.6	-0.4	-1.4
MEAN	0.1	-0.1	0.4	-0.1	-0.1
RH					
850	-0.3	0.3	1	0.7	1.9
700	-0.3	-0.9	0.3	0.3	1.2
500	-0.1	-0.3	0.4	0.4	-0.2
MEAN	-0.2	-0.3	0.6	0.5	1
SURF					
-pmsl	-0.3	-1.3	-1.3	0.6	-0.4
-temp	2.2	4	4.8	3.9	1.6
-wind	-0.2	-0.4	-0.6	-0.3	0.5
MEAN	0.6	0.8	1	1.4	0.6
MEANALI	0	-0.3	0.2	0.2	0.2

	T+0	T+24	T+48	T+72	T+120
AREA	N Hem to 30N				
HEIGHTS					
850	-0.4	0.1	-1.8	-1.4	-1.6
700	0.7	1.7	-0.2	-0.9	-0.6
500	1.1	0.5	-0.5	-0.9	-0.8
300	1	-1.4	-1.8	0.3	-0.7
250	1.1	-1.6	-2.4	0.7	-0.6
200	0.8	-1.5	-2.1	1.6	-0.3
100	0.7	-0.5	-0.7	1.8	1.6
50	0.2	0.5	0.3	1.7	2.8
MEAN	0.6	-0.3	-1.1	0.4	0
TEMPERATURES					
850	-1.3	-1.4	-1	-0.5	-0.4
700	0.1	-3.6	-4	-2.5	-1.9
500	-0.8	-1.2	-2.2	-1	-1.6
300	0.1	-1.8	-2.6	0.2	-0.4
250	0.6	-1.2	-0.7	0.8	0.2
200	-0.2	-0.4	-0.7	-1.1	-1.8
100	-0.3	-1.5	-3	-2.6	-3.4
50	0.2	-0.3	0.7	1.1	-1.5
MEAN	-0.2	-1.4	-1.7	-0.7	-1.3
WINDS					
850	0	-0.4	-0.6	-0.4	-0.4
700	-0.2	-0.2	-0.3	-0.6	-0.5
500	0.4	-1	-0.4	-1.4	-0.3
400	0.2	-1.2	-0.8	-0.9	-0.8
300	0.1	-2.3	-1.6	-1	-1.4
250	-0.1	-3.9	-3.2	-1.9	-2.4
200	-0.2	-6.5	-5.6	-3.1	-3.2
100	0.2	-2.2	-2.2	-2.8	-2.5
MEAN	0	-2.2	-1.8	-1.5	-1.4
RH					
850	0.5	1.5	1.7	1.4	2.3
700	0.2	-0.2	0.5	0.6	1.7
500	0.1	-0.5	0	0	-0.3
MEAN	0.3	0.3	0.7	0.7	1.2
SURF					
-pmsl	-2.8	-0.5	-1.9	-0.5	-1.3
-temp	1.2	3.6	4.7	4.4	2.9
-wind	-0.2	-0.7	-0.9	-0.7	-0.5
MEAN	-0.6	0.8	0.6	1.1	0.4
MEANALI	0.1	-0.9	-1.1	-0.3	-0.6

TABLE 2.1

%RMS CHANGE (TRIAL-OPERATIONAL) PERIOD 07/04/95-30/04/95
VERIFIC/ AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72	T+120
AREA	Tropics 30N to 30S				
HEIGHTS					
850	0.5	-0.7	0.5	-0.2	-0.8
700	0.8	4.9	7.5	6.8	5.2
500	0.7	3.3	5.7	6.5	5.2
300	0.6	0.9	2.9	3.3	2.7
250	0.3	0.5	2.3	2.6	2.6
200	0.7	0.8	1.2	2.2	1.5
100	0	-1	-1.4	-0.3	-1.2
50	0.1	-0.4	-0.6	-0.2	0.4
MEAN	0.5	1	2.3	2.6	1.9
TEMPERATURES					
850	-1.5	-1.9	-3.2	-3	-2
700	-1.4	-2.8	-2.9	-1.6	-1.2
500	-1.2	0	-0.4	0.1	0
300	0.2	-1.1	-1.6	-1.2	0.7
250	1.4	-0.8	-1.1	-1.2	-1.8
200	-1.1	-3	-5.4	-4.7	-2.2
100	0	-1.2	-1.6	-1.2	-1.1
50	-0.3	-0.2	-0.1	-0.1	-0.4
MEAN	-0.5	-1.4	-2	-1.6	-1
WINDS					
850	-0.2	-1.8	-2.8	-1.3	-0.4
700	-0.4	-1.9	-2.5	-0.9	-0.9
500	-0.5	-1.5	-2.6	-2.4	-0.9
400	-0.6	-2.5	-3	-2.4	-1.1
300	-0.3	-3.7	-6.1	-4.1	-2.3
250	-0.3	-4.7	-7.5	-5.7	-3.5
200	0.3	-3.9	-6.9	-5.3	-4.8
100	0.3	0	-2	-2.9	-4.1
MEAN	-0.2	-2.5	-4.2	-3.1	-2.3
RH					
850	-0.2	-0.5	-0.4	0.6	0.4
700	-0.9	-0.8	-0.6	-0.5	-1.3
500	-0.4	-1.2	-2	-0.4	-0.8
MEAN	-0.5	-0.8	-1	-0.1	-0.6
SURF					
-pmsl	-0.2	-0.3	-2.1	-3.7	-2.9
-temp	0.3	1.5	-0.2	-0.3	-2.2
-wind	-2.1	-1.5	-1.9	-2.1	-1.1
MEAN	-0.7	-0.1	-1.4	-2	-2.1
MEANALI	-0.2	-0.8	-1.3	-0.8	-0.6

	T+0	T+24	T+48	T+72	T+120
AREA	S Hem from 30S				
HEIGHTS					
850	-0.9	-1.8	0.5	0.7	0.3
700	0	-0.1	-1	-2.1	-0.6
500	1.1	0.7	0.8	-1.6	0.6
300	-0.1	-0.3	-0.1	-1.4	-0.1
250	0.9	-0.4	-0.6	-1.2	-1.1
200	-0.4	-0.6	-1.2	-1	-0.9
100	0.6	-0.7	-2.1	-0.8	0.2
50	1.8	1.1	-0.4	-0.3	-0.6
MEAN	0.4	-0.3	-0.5	-1	-0.3
TEMPERATURES					
850	-1.5	0.4	1.6	1.9	-0.5
700	-5.3	-0.9	2.2	-0.4	0.7
500	-1	-0.8	0.6	-1.8	-2
300	1.1	-0.4	0.8	-0.5	-4.7
250	1.9	0.8	0.6	-1.8	-0.2
200	0.5	1	0.3	-0.7	-1.4
100	1.5	1.2	1.3	0.5	-1.3
50	-0.5	-0.1	0.4	0.1	-1.1
MEAN	-0.4	0.1	1	-0.3	-1.3
WINDS					
850	-0.9	-0.8	-0.7	0.3	-1.1
700	-0.2	-0.3	-0.8	0.1	-0.6
500	0.4	-0.8	-0.8	-0.3	-0.8
400	1.9	0.3	0.2	1.4	-0.1
300	-0.8	-1.7	-0.5	0.4	-0.8
250	-1.2	-2.1	-0.3	-0.6	-2.8
200	-1.1	-1.4	0.3	-1.3	-3.1
100	0.3	0.8	1	0.2	0.8
MEAN	-0.2	-0.7	-0.2	0	-1.1
RH					
850	-1.5	-0.9	-1	-0.8	0.3
700	-2.8	0.7	1.6	1.2	-0.2
500	2	0.9	-0.4	-1.2	-2.1
MEAN	-0.8	0.2	0.1	-0.3	-0.7
SURF					
-pmsl	0.6	-0.9	-1.1	0	-1.2
-temp	1	1.6	-0.6	-1.1	-0.9
-wind	0.4	-0.1	-0.6	-1	-2.3
MEAN	0.7	0.2	-0.8	-0.7	-1.5
MEANALI	-0.1	-0.2	0	-0.4	-0.9

TABLE 2.2

hemisphere the beneficial impact for winds is less marked and there are fewer improved temperature errors . The largest degradations are found in the tropical height errors (**FIG 2.1**). The absolute height errors are smaller in the tropics which tends to emphasise any adverse change however, and the worsening contrasts with the surface pressure changes which show a general improvement in the tropics (**TABLE 2.2**). The only other adverse effect appears to be on surface temperatures in area 2 and the northern hemisphere, where rms errors are up to 5% worse (**TABLE 2.1**).

Overall, the trial version appears better; there are some reasonably large improvements in rms errors and which are counterbalanced by only a few 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 area 2. For the Southern Hemisphere the trial is slightly better, whilst the trial is clearly better in the Northern hemisphere and tropics, for the reasons discussed above.

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")	9	130	11
N Hemisphere	47	85	18
Tropics	67	64	19
S Hemisphere	32	101	17

TOTAL SCORE FOR EACH AREA=150

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. Vertical profiles of the changes for all verification periods are plotted in **FIGS 2.4,2.5,2.6** for height, temperature and vector wind errors respectively.

The beneficial impact on winds and temperatures for the northern hemisphere and tropics noticed from verification against sondes is confirmed, as are the degraded height forecasts at lower levels in the tropics. The improved winds in area2 and the southern hemisphere are rather more pronounced than for the verification against observations. In the tropics, the reductions in surface pressure rms errors are again found despite the worsening of the height errors.

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%

RMSE %CHANGE(TRIAL-OPERATIONAL)

VERIFICATION AGAINST ANALYSES PERIOD=07/04/95-30/04/95

	T+24	T+72	T+120		T+24	T+72	T+120
AREA	2			N.HEM			
HEIGHT				HEIGHT			
850	-0.9	-2.7	-0.6	850	-3.1	-3.0	-2.0
700	-0.9	-2.5	-0.9	700	-0.8	-2.2	-1.5
500	-0.7	-2.3	-0.6	500	-1.4	-2.4	-1.1
300	-0.9	-2.2	0.0	300	-2.8	-2.7	-0.5
250	-0.9	-2.7	0.2	250	-3.5	-3.2	-0.4
200	-1.0	-2.6	0.6	200	-4.3	-3.5	0.2
100	1.4	-1.2	0.7	100	-1.1	-2.2	-0.7
50	1.3	1.7	2.3	50	1.0	1.0	-0.5
mean	-0.3	-1.8	0.2	mean	-2.0	-2.3	-0.8
TEMP				TEMP			
850	2.8	-0.9	0.0	850	-2.6	-2.6	-0.6
700	0.0	-0.9	1.7	700	-2.9	-1.8	0.3
500	0.0	-0.4	1.4	500	-2.0	-2.2	0.0
300	0.0	-0.9	-1.0	300	-1.6	-2.2	-0.3
250	-2.1	-0.4	-1.1	250	-2.3	-1.2	-1.2
200	0.8	-1.7	-1.8	200	-1.6	-3.3	-2.5
100	-1.4	-0.7	0.0	100	-4.1	-2.7	0.0
50	1.6	-1.6	0.0	50	-1.4	-2.7	-1.9
mean	0.2	-0.9	-0.1	mean	-2.3	-2.3	-0.8
WIND				WIND			
850	-0.8	-1.9	0.6	850	-1.1	-2.5	-1.3
700	-0.7	-1.1	0.1	700	-1.1	-2.1	-1.9
500	-0.4	-0.5	-0.2	500	-1.3	-1.9	-2.0
400	0.0	-0.5	-0.7	400	-1.5	-2.0	-1.8
300	0.5	-1.3	-0.9	300	-2.4	-2.8	-1.7
250	0.9	-2.0	-0.9	250	-3.1	-3.7	-1.9
200	0.9	-1.7	0.0	200	-4.5	-4.3	-1.6
100	-1.0	-1.9	-1.3	100	-2.8	-4.6	-1.2
mean	-0.1	-1.4	-0.4	mean	-2.2	-3.0	-1.7
RELHUM				RELHUM			
950	1.3	1.5	0.6	950	2.6	1.6	2.7
850	1.3	0.2	0.4	850	1.9	-0.3	1.4
700	-1.0	-0.2	0.5	700	-0.4	-1.1	0.1
500	0.8	0.2	0.7	500	-0.1	-0.2	0.1
mean	0.6	0.4	0.6	mean	1.0	-0.0	1.1
PMSL	-0.6	-2.5	-0.3	PMSL	-4.2	-3.1	-1.9

TABLE 2.4

RMSE %CHANGE(TRIAL-OPERATIONAL)

VERIFICATION AGAINST ANALYSES PERIOD=07/04/95-30/04/95

		T+24	T+72	T+120			T+24	T+72	T+120
TROPICS					S.HEM				
HEIGHT					HEIGHT				
	850	-2.3	-0.8	1.8		850	0.5	-0.9	-0.3
	700	2.5	3.3	3.7		700	0.0	-0.9	-0.2
	500	3.6	7.2	4.1		500	0.9	-1.5	0.3
	300	-1.0	1.5	-1.8		300	-0.3	-1.5	0.3
	250	-0.9	0.8	-2.1		250	-0.7	-1.6	0.0
	200	-2.2	-0.3	-1.8		200	-1.5	-1.7	-0.2
	100	-3.7	-3.6	-2.0		100	-1.0	-2.6	-0.3
	50	-2.7	-2.7	-1.6		50	-1.9	-2.6	0.2
mean		-0.8	0.7	0.0	mean		-0.5	-1.7	-0.0
TEMP					TEMP				
	850	-5.3	-3.2	-3.3		850	0.0	0.7	1.2
	700	0.0	1.4	1.7		700	0.0	-0.9	1.1
	500	1.8	10.0	9.0		500	0.7	-0.7	0.5
	300	1.5	-1.5	-1.3		300	0.0	-0.4	0.0
	250	0.0	-2.1	-1.8		250	0.0	-2.4	-0.5
	200	-2.4	-3.7	-4.1		200	0.7	-1.7	-1.4
	100	-1.6	0.0	-2.8		100	1.3	-0.6	-1.1
	50	-1.6	0.0	-2.3		50	0.0	0.7	0.5
mean		-1.0	0.1	-0.6	mean		0.3	-0.7	0.0
WIND					WIND				
	850	-0.7	-2.6	-1.4		850	-0.9	-1.4	-0.5
	700	0.7	0.4	0.6		700	-0.3	-1.4	-0.6
	500	-0.2	1.1	-1.0		500	0.2	-1.2	-0.6
	400	-1.2	0.5	-2.4		400	0.1	-1.3	-0.5
	300	-1.0	-0.9	-1.5		300	-0.3	-1.6	-1.1
	250	-1.0	-1.1	-1.2		250	-0.4	-1.4	-1.4
	200	-1.1	-1.4	-1.9		200	-0.1	-1.2	-1.7
	100	-0.4	-2.3	-2.3		100	0.0	-0.6	-0.1
mean		-0.6	-0.8	-1.4	mean		-0.2	-1.3	-0.8
RELHUM					RELHUM				
	950	-0.4	-3.5	-3.9		950	0.1	0.7	1.0
	850	-0.8	-1.0	-0.4		850	-0.6	0.3	-0.7
	700	-0.9	-0.9	-0.8		700	1.4	1.6	0.1
	500	0.4	0.9	3.3		500	0.4	0.1	0.8
mean		-0.4	-1.1	-0.5	mean		0.3	0.7	0.3
PMSL		-4.4	-5.4	-1.8	PMSL		0.4	-1.0	-0.3

TABLE 2.5

deemed equal. The trial version is clearly favoured in both the northern hemispheric and tropical regions. There is slightly more weight for the trial in areas 2 and the southern hemisphere in comparison with the verification against observations, but the large number of scores deemed equal shows the impact to be largely neutral in these areas.

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")	20	57	10
N Hemisphere	63	20	4
Tropics	42	30	15
S Hemisphere	22	60	5

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 2.7 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 area are slightly greater whilst in the tropics there are generally larger negative biases. The former changes are probably not significant, but the increase tropical bias is probably contributing to the worse rms height errors .

HEIGHT

FIGURE 2.8 shows the bias (left) and rms (right) height error profiles for T+120 for area 2 (top) and N Hemisphere (bottom). **FIGURE 2.9** shows the same for the tropics and S Hemisphere. For area 2 and N Hemisphere there has been a small decrease in heights but the trial is closer to zero bias for 500hPa and levels below. The small worsening of the negative height bias in the tropics has a larger effect on the rms errors which are smaller here than in the extratropics.

TEMPERATURE

FIGURE 2.10 shows the bias temperature error profiles for T+120 for area 2 , N Hemisphere (left) and Tropics and S. Hemisphere (right). There is a slight cooling evident at all levels up to 300hPa for all regions. The cold bias is generally worse at the lowest level (850hPa) by ~0.2-0.2K. However for area 2 and N Hemisphere the trial bias is closer to zero at 700hPa.

At 250 and 200 hPa there is a slight beneficial warming as found in the earlier tests (Lorrimer,1995).

The cold bias for surface temperatures has been worsened (**FIGURE 2.11** , left) by ~0.2-0.3K in all regions, and there are generally worse rms errors. Partly this is due to the removal of erroneous diffusion of higher potential temperature from the peaks in orography to surrounding grid points, and partly due to some increases in low cloud (see section 3).

WINDS

FIGURE 2.12 shows the speed bias (left) and rms vector (right) wind error profiles for T+24 for area 2 (top) and N Hemisphere (bottom), whilst **FIGURE 2.13** shows the same for the tropics and S Hemisphere . There is a small reduction in the low speed bias in the extratropics, especially the Northern hemisphere, although not over the North Atlantic (area 2). In the tropics the mean bias has been improved by larger speeds for the trial. The rms errors are smaller for most regions and especially at upper tropospheric levels.

2.3 GEOGRAPHICAL DISTRIBUTION OF CHANGES IN ERROR

FIGURE 2.14 shows the mean error at T+72 of pressure at mean sea level for the operational version (top) and the change for the parallel suite (bottom). The shading is for negative bias and positive changes respectively, so that if the change acts to reduce the bias over a region it should be shaded similarly. The largest improvements are to the east of the Andes and around the Himalayas, where the negative biases have been reduced, although there are similar but smaller benefits over the Rockies and east of Greenland. The small increases over eastern North America, Europe and Russia are detrimental as are the decreases through much of the tropical belt.

The area mean verification showed the biggest improvements to the rms vector wind in the tropics and Northern hemisphere. To see which regions are contributing most to the improvements the rms errors (against analyses) at each location have been obtained. **FIGURE 2.15** of the errors at T+72 (top) shows that the largest improvements (bottom) are located to the north of the Himalayas, over south-east Asia and north-east Pacific and over the south Atlantic. All these regions have substantial errors operationally which are persistent during the year; the trial version is acting to correct long-standing errors. Similar benefits can be seen in these regions by comparing the mean vector wind errors for the operational and parallel suites (**FIGURE 2.16**, top and bottom). The impact over the Rockies is much smaller, and over the North Atlantic there is little change as has already been noted from the area mean summary tables (see section 2.1).

LIMITED AREA MODEL VERIFICATION

The analyses and forecasts were verified against observations (Sondes and synops) for the period 15/04/95 to 26/04/95. (There were system problems in both the operational and parallel suites which prevented comparison of verification results over a longer period.) Verification was also performed against analyses, each suite was verified against its own

%RMS CHANGE (TRIAL-OPERATIONAL) Period 15/04/95-26/04/95
VERIFICATION AGAINST OBSERVATIONS

		T+0	T+24			T+0	T+24
AREA		5		AREA		88	
HEIGHTS				HEIGHTS			
	850	2.9	0.0		850	0.0	-1.6
	500	4.4	-0.6		500	0.0	0.1
	300	1.6	1.3		300	0.0	-0.1
	250	0.0	2.9		250	0.9	-0.6
	200	2.2	0.0		200	0.0	-1.2
	100	2.6	0.9		100	0.0	-0.5
MEAN		2.3	0.7	MEAN		0.1	-0.6
TEMPERATURES				TEMPERATURES			
	850	0.0	-2.5		850	0.0	-0.1
	500	0.0	-3.4		500	0.0	-1.3
	300	0.0	-2.7		300	0.0	1.4
	250	0.0	-0.2		250	0.0	-2.3
	200	0.0	0.4		200	-1.4	2.7
	100	0.0	0.0		100	1.3	0.0
MEAN		0.0	-1.4	MEAN		0.0	0.1
WINDS				WINDS			
	850	-2.0	-1.5		850	-0.8	-0.3
	500	1.7	0.1		500	0.7	1.0
	300	-0.9	-2.4		300	-1.0	-1.1
	250	-0.2	-0.4		250	-0.2	-0.3
	200	-0.6	-1.1		200	-0.3	0.0
	100	0.0	-0.4		100	2.2	1.3
MEAN		-0.3	-0.9	MEAN		0.1	0.1
RH				RH			
	850	2.4	-0.8		850	0.1	-1.5
	700	-3.1	-1.8		700	-1.5	-2.5
	500	0.1	-0.3		500	-0.4	-0.6
MEAN		-0.2	-1.0	MEAN		-0.6	-1.5
SURF				SURF			
PMSL		1.7	-2.3	PMSL		0.0	-2.9
TEMP		-1.3	-3.3	TEMP		1.6	1.8
WIND		-0.5	-1.3	WIND		-0.3	-0.9
MEAN		0.0	-2.3	MEAN		0.4	-0.7
MEANALL		0.5	-0.8	MEANALL		0.0	-0.4

TABLE 2.7

analyses for the same period 07/04/95 to 30/04/95 as for the global model. Time-mean results will mostly be discussed here . Results for forecast times T+0, T+24 and for areas "5", "88" and for analyses "888" will be given. Area "5" is the near UK from Iceland to mid Spain, area "88" is 80W-40E, 30-80N and "888" is the full LAM area.

2.5 RMS ERRORS -OVERALL SUMMARY FOR LAM

Only a brief summary of the main results will be given since most of the major impacts have already been described for the global model in section 2.1

TABLE 2.7 summarises the objective scores for verification against observations. It shows the percentage changes in rms errors for heights, temperatures and winds (6 levels each) and 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. From vertical profiles of the changes (FIGURE 2.17) it is apparent that the changes for the larger domain, area88 are mostly small and neutral as might be anticipated from the short period global results for the north Atlantic. Over the smaller region the heights are worse but forecast temperature and winds are better for the trial. However this is a very small area and the restricted number of cases makes the reliability of such conclusions rather dubious.

TABLE 2.8 summarises the overall performance of the trial based on the scores in TABLE 2.7. 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. For changes less than 1% operational and trial were deemed equal. With 24 fields and 2 verification times there are 48 possible scores in total for each area.

The overall impression is there is little to choose between the trial and operational versions.

TABLE 2.8 : Summary of objective verification scores from TABLE 2.7

Area	Trial better	equal	operational better
5	13	25	10
88	10	31	7

TOTAL SCORE FOR EACH AREA=48

TABLE 2.9 summarises the objective scores for verification against analyses at T+24, with vertical profiles of the changes shown in FIGURE 2.18. The results for area 5 disagree with those from verification against observations, particularly for heights, but are over a longer period and so likely to be more representative.

The overall summary is shown in TABLE 2.10. which again indicates little difference between trial and operational versions.

RMSE %CHANGE (TRIAL-OPE PERIOD 09/04/95-26/04/95

	T+24		T+24		T+24
VERIFICATION AGAINST ANALYSES					
AREA	5	AREA	88	AREA	888
HEIGHT		HEIGHT		HEIGHT	
850	-0.8	850	-0.8	850	0
500	-0.7	500	0	500	0
300	-0.5	300	-0.5	300	0
250	-1	250	0	250	0
200	-1.6	200	0	200	0
100	-2.1	100	-0.5	100	-0.5
TEMP		TEMP		TEMP	
850	0.9	850	0.9	850	0.8
500	0	500	0.9	500	1
300	-0.8	300	-0.7	300	0
250	-0.7	250	-0.7	250	-0.7
200	-1.4	200	0	200	0
100	1.4	100	0	100	0
WIND		WIND		WIND	
850	-0.6	850	-0.2	850	-0.5
500	-0.7	500	0	500	0
300	-0.3	300	0.6	300	0.4
250	0.7	250	0.4	250	0.4
200	0.2	200	1.3	200	1
100	-0.6	100	0	100	-0.4
REL HUM		REL HUM		REL HUM	
950	3.8	950	3.7	950	3.4
850	1.3	850	1.2	850	1.4
700	-0.2	700	1.1	700	0.9
500	0.7	500	1.3	500	1.2
PMSL	-1.1	PMSL	-1.1	PMSL	0

TABLE 2.9

TABLE 2.10 : Summary of objective verification scores from **TABLE 2.9**

Area	Trial better	equal	operational better
5	4	16	3
88	0	18	5
888	0	20	3

TOTAL SCORE FOR EACH AREA=23

2.6 OBJECTIVE VERIFICATION - SUMMARY

The verification scores show many benefits from the changed formulation. Winds and temperatures in the northern hemisphere and tropics are particularly improved. There is a slight worsening of temperature biases in the lower atmosphere and at the surface. Tropical rms height errors are also degraded.

3. SUBJECTIVE ASSESSMENT

Daily comparison of trial and operational charts during the parallel suite trial showed few big differences in the Northern Hemisphere, and the main impact was seen in tropical rainfall forecasts (especially over the northwest corner of South America and New Guinea) and also in the differences developing in mean sea level pressure and 500hPa in the Southern Hemisphere at T+72 onwards. Most differences were small and due to positional and depth differences rather than due to evolution changes. The overall subjective assessment of the global mean sea level pressure differences at T+120 favoured the trial forecasts and the results are summarised in Table 3.1 below.

TABLE 3.1: Subjective assessment of global mean sea level pressure differences at T+120. Overall, trial better 43%, equal 28%, operational better 29%

differences %		**Trial better**	**equal**	**operational better**
Pattern	**17**	**7**	**5**	**5**
Depth (depressions, troughs,ridges)	**31**	**17**	**4**	**10**
Positional	**41**	**17**	**10**	**14**
Evolution	**11**	**2**	**9**	**0**

Some examples of the biggest differences seen in the Northern Hemisphere, Tropics and Southern Hemisphere are described in the following subsections.

a) Northern Hemisphere (north of 30N)

Most differences in mean sea level pressure in the Northern Hemisphere were seen in the North Pacific and Sea of Japan, as shown in **FIGURE 3.1**, with just isolated differences in the North Atlantic.

A typical example of positional differences in the North Pacific is shown in **FIGURE 3.2**, which compares the trial (a) and operational (b) forecasts verifying at 12Z 2nd May. Both forecasts are good, but the trial depression is slightly further southeast and closer to the analysis (c).

The maximum difference in the North Atlantic during the trial is shown in **FIGURE 3.3** by comparing the trial (a) and operational (b) T+120 forecasts verifying at 12Z 29th April. Again, the main difference in the Atlantic is positional. Both forecasts predicted the depression to be too far north, with a small wave feature to the south. The trough over Western Ireland and Southwest England was not predicted well by either forecast.

The 250hPa wind difference chart, **FIGURE 3.4a**, indicates that the main impact of the trial was in the jet over Asia and the North Pacific. The subtropical jet at 30-40N in the North Pacific verified slightly better against the analysis on most occasions. In contrast, the impact over the North Atlantic, **FIGURE 3.4b**, was small.

Table 3.2 below shows that there was a small increase in the mean low cloud fraction of 0.1, (6.4%), in the Northern Hemisphere. The cloud difference chart, **FIGURE 3.5a**, shows that the location of this increased low cloud in the Northern Hemisphere was in the vicinity of high ground, notably the Rockies, Alps and Himalayas .

TABLE 3.2: Mean differences in low,medium,high cloud fractions

Area	N.Hem (30-90N)	Tropics (30N-30S)	S. Hem (30-90S)
cloud fractions	**trial / oper**	**trial / oper**	**trial / oper**
low cloud	**0.311 / 0.292**	**0.092 / 0.082**	**0.367 / 0.364**
medium cloud	**0.295 / 0.289**	**0.075 / 0.064**	**0.358 / 0.355**
high cloud	**0.337 / 0.337**	**0.269 / 0.268**	**0.323 / 0.322**

The differences in the total precipitation at T+24 and T+72 are shown in **FIGURE 3.6 a/b** respectively. These show that rainfall differences in the Northern Hemisphere were mainly concentrated over the high ground in Asia 30-45N and differences over the North Atlantic were small.

Overall, the main impact on the Northern Hemisphere was mainly confined to Asia and the

North Pacific.

b) Tropics (30N - 30S)

The differences in the total precipitation at T+72, **FIGURE 3.6**, show that the diffusion change has reduced the peak amounts over all significant orography, eg the Rockies, Alps, Himalayas, Andes, East African Highlands etc. The largest impact is upon tropical rainfall. The areas of greatest impact were South America and New Guinea. In **FIGURE 3.7a/b**, we compare the 24-hour accumulations forecast over the northwest corner of South America. These totals are the average 24-hour accumulation forecast during the period of the trial . The highlights of the operational forecast, (b), are the huge accumulations (>100mm) predicted at a few grid points over the mountains. In contrast, the trial accumulations are smaller and more evenly spread out. The huge individual gridpoint values predicted by the operational forecast can be seen more clearly in the boxes drawn on **FIGURE 3.8a**. At one gridpoint in particular, the operational forecast predicted an average daily total of 185mm. Verification is difficult, with the main source of information being satellite imagery plus a few observations. The operational forecast predicts high vertical velocities and huge rainfall totals over the mountains in the west but tends to have a deficit of rain further east over South America due to subsidence. The operational 'waterfalls' must be greatly overdone, and the smaller more spread out trial totals are probably better. The mean 72-hour accumulation totals are compared in **FIGURE 3.9 a/b**. The operational maximum gridpoint value of 671mm, **FIGURE 3.9a**, has much smaller totals of 21mm and 16mm on either side. The corresponding trial values, see **FIGURE 3.9b**, are 23mm,21mm and 22mm.

The second high impact area was over New Guinea, where the operational model, **FIGURE 3.10a**, predicted individual T+72 gridpoint totals as high as 364mm and 574mm. In contrast, the trial total accumulations, **FIGURE 3.10b**, were much lower, with maximum gridpoint total 53mm. Again, the only sources of information were a few coastal observations and satellite imagery. The available satellite imagery indicated storms peaking at 09Z centred over the central mountainous regions of New Guinea. Whilst operational totals look much too high, trial values may be too smoothed out.

Table 3.2 indicates an average increase in the low cloud fraction in the Tropics of 0.01 (12.3%) and an increase of 0.01 (17.3%) in the average medium cloud fraction. The cloud difference charts, **FIGURE3.5a/b**, show that the maximum increases of low and medium cloud were centred over South America. **FIGURE 3.11a** highlights the large area of increased medium cloud in the northwest corner of South America to the east of the mountains. The operational forecast has large systematic errors in the long wave radiation in this region due to insufficient cloud and also in the hydrology due to the surface drying out too quickly. Hence this increase in the medium cloud is very beneficial to the model's climatology.

FIGURE 3.11b shows the increase in low cloud mainly along the coast of South America. The operational model has a systematic deficit of stratocumulus along the coast, especially 15-30S, hence the increase of low cloud in the trial forecasts is also beneficial.

c) Southern Hemisphere (30S - 90S)

Differences of 10-20hPa between trial and operational mean sea level forecasts were often seen at T+120. However, even in the Southern Hemisphere, most differences in mean sea level pressure were due to small changes in the depth and position of depressions, troughs and ridges rather than to changes in evolution.

A few differences occurred in the vicinity of South America in the South Atlantic. A typical example of a positional difference in the this area is shown in **FIGURE 3.12**, which compares the trial (a) and operational (b) forecasts verifying at 12Z 23rd April. Both forecasts are good, but the trial depression compares slightly better in depth and position with the analysis (c).

FIGURE 3.13 compares the trial (a) and operational (b) T+120 forecast of a depression over the Falkland Islands. Both forecasts exaggerated the trough to the north of the depression but the trial errors were worse on this occasion.

Several large differences in mean sea level pressure occurred south of 60S, on the edge of Antarctica. In the example shown in **FIGURE 3.14**, there was a large difference of 21hPa between the trial and operational forecasts at 63S 01E at T+120, verifying at 12Z 2nd May. The difference was due to the operational depression being 8hPa deeper and further south. The depth of the operational depression was closer to the analysis but the trial depression had the better position and pattern.

The main impact on the 250hPa winds in the Southern Hemisphere, due to the diffusion change, was over South America. These differences at analysis time and T+72 are shown in **FIGURES 3.16 a/b**.

d) Subjective conclusions

i) Improvement in mean sea level pressure and subtropical jet forecasts over the North Pacific.

ii) Beneficial reduction in enormous precipitation forecasts on single gridpoints over Andes.

iii) Beneficial increase in medium cloud in the north of South America.

iv) Some gain from increase of low cloud along the coast of South America.

e) SUBJECTIVE ASSESSMENT - LIMITED AREA MODEL

There is very little to say about the impact on limited area forecasts since no significant differences were seen during the trial. Small differences in mean sea level pressure of 2-5hPa at T+36 were due to minor positional differences which were difficult to spot by looking at the charts. Some differences in the 250hPa jets were seen south of 40N but, again, these were small positional or directional changes which were not significant at T+24/36.

4. Impact on Global Model Systematic Errors

This section details the impact of the model changes upon known systematic errors in the global Unified Model. A full discussion of the systematic errors in the operational model can be found in Milton et al. (1995).

4.1 Zonally Averaged Winds and temperatures.

(i) Zonal wind

The operational systematic errors in the zonally averaged zonal wind over the period of the trial show large westerly biases in the southern hemisphere, easterly bias in the tropics and smaller biases in the northern hemisphere (Fig. 4.1(b)). The impacts of the trial are generally small (Fig. 4.1(c)) but in the correct sense to reduce the westerly bias at 20S and over Antarctica at 70S (Fig. 4.1(d)). In the northern hemisphere the trial tends to increase westerlies at 30N and reduce westerly flow at 40-50N. This response is geographically located over the Himalayas in the vicinity of the Pacific subtropical jet and is discussed in section 4.2.

(ii) Meridional wind

The Hadley circulation in the operational model is too intense (Fig 4.2(b)). The trial acts to reduce the erroneous Hadley circulation (Fig 4.2(c)).

(iii) Temperatures.

The T+72 temperature biases in the operational model (Fig 4.3(b)) show the familiar cooling at the tropopause. The warming north of 50N is stronger than that found in systematic errors defined from longer term averages (Milton et al. 1995) and may be a function of the synoptic flow over the period of the trial. The impact of the trial is to cool in the lower troposphere in the subtropics of both hemispheres and warm in the upper troposphere (Fig 4.3(c)). The cooling appears to be a local response to the changes in horizontal diffusion over steep orography. This can be seen from the 850hPa temperature difference (trial-operational) at T+120 (Fig 4.4(a)),with the main cooling located over the East pacific adjacent to the Andes and over the Himalayas/Tibetan Plateau. Both of these cooling maxima act to reduce known warm biases in the 850hPa temperature (Figure 4.4(b)). A similar but smaller impact can also be seen over the Alps. Despite the local reductions in systematic errors the zonally averaged cold bias is increased in the trial (Fig 4.3(d)). This is simply due to the reduction of the warm biases near orography which were acting as compensating errors for the cooling present at other longitudes. The upper tropospheric warming is beneficial and comes from the local resetting of negative humidities (Lorrimer, 1994).

4.2 Divergent and Rotational Wind

A useful way to look at changes in the large scale circulation is to split the wind vector into its divergent ($v(\chi)$) and rotational ($v(\psi)$) components. These can be further expressed in terms of the scalar functions, velocity potential (X) and streamfunction (Ψ)

$$\mathbf{V} = \mathbf{V}(\chi) + \mathbf{V}(\psi) = \nabla\mathbf{X} + \mathbf{k} \times \nabla\mathbf{\Psi}$$

The velocity potential shows the planetary scale divergent circulation and is related to the divergence (D) by $D=\nabla^2\mathbf{X}$. The divergent wind is proportional to the gradient in **X** and flows perpendicular to the gradient from negative (areas of divergence) to positive (areas of convergence) values. The streamfunction is related to the relative vorticity (ξ) by $\xi=\nabla^2\mathbf{\Psi}$, and the rotational wind follows the streamlines and is proportional to the gradient in Ψ.

Figure 4.5(a) shows the velocity potential at 850hPa for the operational analysis. Areas of convergence occur over the main tropical convective regions of the west Pacific, central America, and central Africa with areas of compensating divergence over the east Pacific and east Atlantic. The T+72 error in velocity potential from the operational forecasts (fig 4.5(b)) shows an area of increased convergence off Peru with increased divergence to the east. This dipole pattern indicates an erroneous local circulation with excessive ascent over the Peruvian Andes and excessive/compensating descent over Brazil. The other main error is an increase in the Walker circulation over the Indian Ocean with excessive convergence/ascent over the west Pacific/China and excessive divergence/descent over the central Pacific. These systematic errors are persistent features of the climatology of the Unified Model and have largely been attributed to excessive diabatic heating (Milton et. al. ,1995). The impact of the model changes are shown by the difference in 850hPa velocity potential, Trial - Operational (Fig 4.5(c)). The largest impact is over South America where the changes induce a divergence over Peru and convergence over Brazil. This pattern is in the opposite sense to the systematic error and implies a reduction of the erroneous ascent being forced by the Andes. This is consistent with the following beneficial changes in other aspects of the circulation/hydrology;

- Reductions in precipitation over the Andes
- Reductions in the Hadley circulation.
- Reduction of the warm bias over the East Pacific - This warming was caused by excessive subsidence acting to compensate the erroneous ascent over the Andes.
- Increase in low cloud over the East Pacific (see previous point)
- Increases in medium cloud over South America. - The excessive subsidence over the continent (Fig 4.5(c)) which caused warming and drying has been removed.

The trial also acts to reduce erroneous convergence over the Himalayas (Fig. 4.5 (c)). Similar beneficial impacts can be seen at 250hPa.

Finally we consider what impact the model changes have upon the rotational wind. The 850hPa streamfunction difference (Trial-Oper) at T+72 (Fig. 4.6(c)) shows large rotational circulations over South America and the Himalayas. These are presumably forced by differences in the divergent circulation (Sardesmukh and Hoskins, 1988). They also act to reduce the cyclonic error over South America and the anticyclonic error over the Himalayas in the operational model (Fig. 4.6(b)). At 250hPa we have a similar response but of the opposite sign as shown by the streamfunction difference (Fig. 4.7(c)). At this level wavetrains of positive and negative differences, which originate over the orography, propagate downstream into the Pacific and Southern Oceans. Again we note that these changes in the 250hpa streamfunction act to reduce the rotational systematic errors in the operational model (Fig. 4.7 (b)). A good example of this is the anticyclonic-cyclonic dipole error located over Northern India and east of China which is reduced, improving the definition of the Pacific subtropical jet.

To summarize, errors in the divergent circulation have been substantially reduced largely through the change to prevent horizontal diffusion operating in regions of steep orography.

In essence this change prevents spurious vertical motions from being generated over orography. The rotational flow responds to these changes on a planetary scale with wavetrains of differences (Trial-Oper) which propagate downstream and act to correct known errors.

5. Conclusions

Both the local correction for negative humidity and the modification to remove diffusion near steep orography may be justified on the grounds of being more physically reasonable than the current operational formulations. From both the objective and subjective assessments it is clear that they generally either improve the performance of the model or are neutral. The changes give the following benefits:

- reduced noise at high latitudes
- improved upper level winds, particularly in the tropics and north-east Pacific
- better tropical rainfall over Andes and New Guinea
- small reduction in cold bias near and immediately below the tropopause
- reduced systematic errors-improved divergent circulation, reduced strength Hadley cell, rotational flow changes act to correct known errors
- beneficial increased low cloud over East Pacific and medium cloud over south America

It is therefore recommended that the modifications are introduced to the operational suite at the earliest opportunity. The diffusion change has already been implemented in the mesoscale model in the spring 1995 upgrade and both changes are included in the specification of the 3rd climate physics package.

REFERENCES

Hall, C.D., 1994:*Hadley Centre Internal note No.61*

Lorrimer, S.L., 1994: A comparison of local and global schemes for correcting negative specific humidities in forecast mode. *Forecasting Research Technical Report No. 148.*

Milton, S.F., C.A.Wilson and A.D. Van Der Wal, 1995: A Review of Systematic Errors in the Global Unified Model used for NWP 1994-95. *Forecasting Research Technical Report No. 162.*

Sardesmukh, P.D. and B.J. Hoskins, 1988: The generation of global rotational flow by steady idealized tropical divergence. *JAS,45,1228-1251.*

FIGURE CAPTIONS

Figure 3.1 - Mean sea level pressure differences (trial - operational) over the North Pacific at T+120, time-meaned over the period 13/04/95 - 02/05/95.

Figure 3.2 - Mean sea level pressure for 12Z 02/05/95 over the North Pacific, comparing (a) trial T+120 forecast, (b) operational T+120 forecast, (c) verifying operational analysis, (d) trial - operational differences.

Figure 3.3 - Mean sea level pressure for 12Z 29/04/95 over the North Atlantic, comparing (a) trial T+120 forecast, (b) operational T+120 forecast, (c) verifying operational analysis, (d) trial - operational differences.

Figure 3.4 - Mean 250hPa wind differences (trial - operational) at T+72, time-meaned over the period 11/04/95 - 30/04/95, showing (a) differences over Asia and the North Pacific,
(b) differences over the North Atlantic.

Figure 3.5 - Mean cloud differences (trial - operational) at T+120, time-meaned over the period 13/04/95 - 02/05/95, showing (a) trial - operational low cloud differences,
(b) trial - operational medium cloud differences. Shaded areas indicate an increase in cloud in the trial forecasts.

Figure 3.6 - Total precipitation differences (trial - operational) at T+72, time-meaned over the period 12Z 11/04/95 to 12Z 30/04/95.

Figure 3.7 - T+24 total precipitation forecast, in Kg/m^2/day, over the northwest corner of South America, time-meaned over the period 12Z 09/04/95 to 12Z 28/04/95, showing (a) trial forecast, (b) operational forecast.

Figure 3.8 - as Figure 3.7, but showing grid-point values.

Figure 3.9 - similar to Figure 3.8, but showing grid-point values at T+72.

Figure 3.10 - T+72 total precipitation forecast, in Kg/m2/day, over New Guinea , time-meaned over the period 12Z 11/04/95 to 12Z 30/04/95, showing grid-point values from (a) trial forecast, (b) operational forecast.

Figure 3.11 - Mean cloud differences (trial - operational) over South America at T+120, time-meaned over the period 13/04/95 - 02/05/95, showing (a) trial - operational medium cloud differences, (b) trial - operational low cloud differences. Shaded areas indicate an increase in cloud in the trial forecasts.

Figure 3.12 - Mean sea level pressure for 12Z 23/04/95 over the South Atlantic,

comparing (a) trial T+120 forecast, (b) operational T+120 forecast, (c) verifying operational analysis, (d) trial - operational differences.

Figure 3.13 - Mean sea level pressure for 12Z 01/05/95 over the South Atlantic, comparing (a) trial T+120 forecast, (b) operational T+120 forecast, (c) verifying operational analysis, (d) trial - operational differences.

Figure 3.14 - Mean sea level pressure for 12Z 02/05/95 over the South Atlantic near Antartica, comparing (a) trial T+120 forecast, (b) operational T+120 forecast, (c) verifying operational analysis, (d) trial - operational differences.

Figure 3.15 - Mean 250hPa wind differences (trial - operational), (a) analysis, time-meaned over the period 08/04/95 - 27/04/95, (b) T+72 forecast, time-meaned over the period 11/04/95 - 30/04/95

Figure 4.1 - Zonally averaged zonal wind, time-meaned over the period of the parallel trial showing (a) Operational analysis, (b) Operational T+72 mean error (against operational analysis), (c) T+72 difference Trial-Operational, (d) Trial T+72 mean error (against trial analysis).

Figure 4.2 - As figure 4.1 but for time-mean and zonally averaged meridional wind.

Figure 4.3 - As figure 4.1 but for time-mean and zonally averaged temperature.

Figure 4.4 - 850hPa temperatures (a) Trial -Operational at T+72, (b) T+72 monthly mean error from operational forecasts during January 1995.

Figure 4.5 - 850hPa velocity potential from the parallel trial period showing a) Operational Analysis , b) Operational T+72 forecast - Operational Analysis , and c) Trial - Operational T+72 forecasts.

Figure 4.6 - 850hPa streamfunction from the parallel trial period showing a) Operational Analysis, b) Operational T+72 forecast - Operational Analysis , and c) Trial - Operational T+72 forecasts .

Figure 4.7 - 250hPa streamfunction from the parallel trial period showing a) Operational Analysis , b) Operational T+72 forecast - Operational Analysis , and c) Trial - Operational T+72 forecasts .

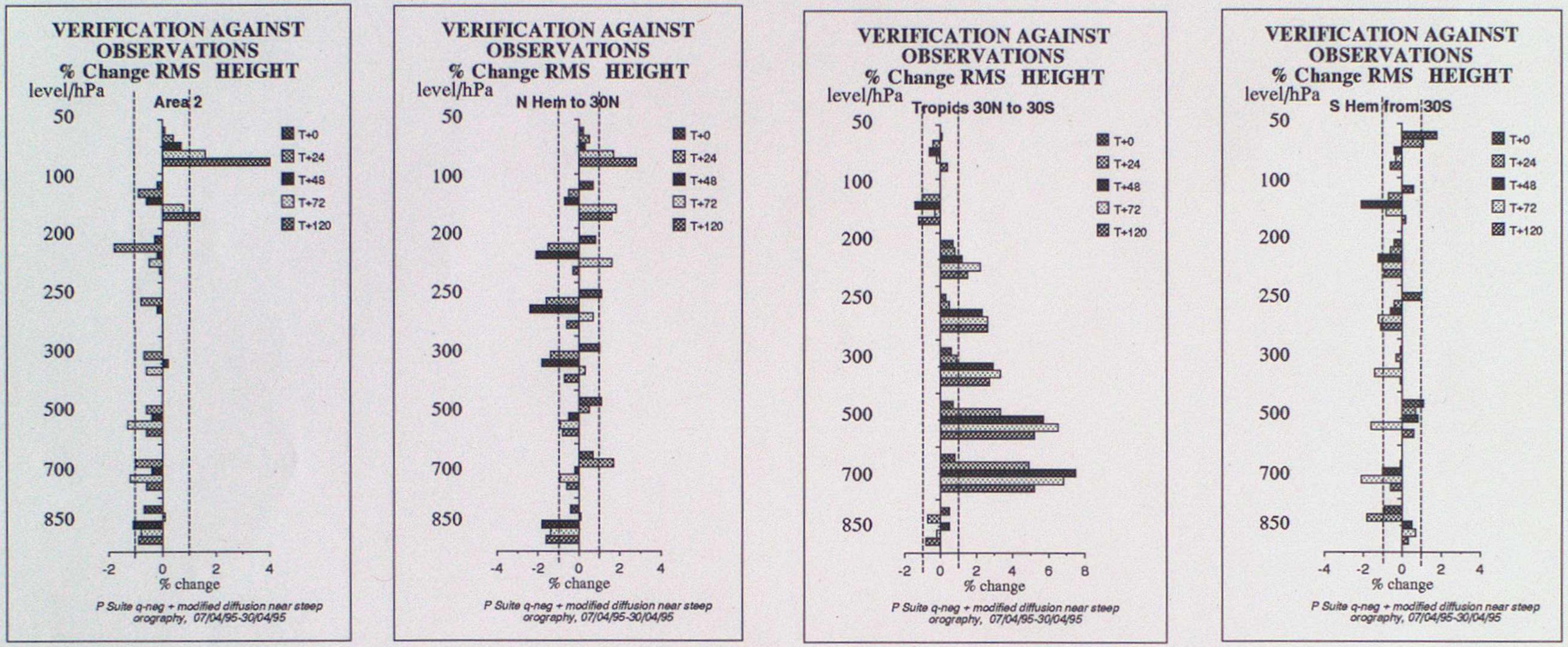

VERIFICATION AGAINST OBSERVATIONS
% Change RMS HEIGHT
level/hPa
Area 2
50
100
200
250
300
500
700
850
-2
0
2
4
% change
T+0
T+24
T+48
T+72
T+120
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST OBSERVATIONS
% Change RMS HEIGHT
level/hPa
N Hem to 30N
-4
-2
0
2
4
% change
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST OBSERVATIONS
% Change RMS HEIGHT
level/hPa
Tropics 30N to 30S
-2
0
2
4
6
8
% change
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST OBSERVATIONS
% Change RMS HEIGHT
level/hPa
S Hem from 30S
-4
-2
0
2
4
% change
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95

FIGURE 2.1

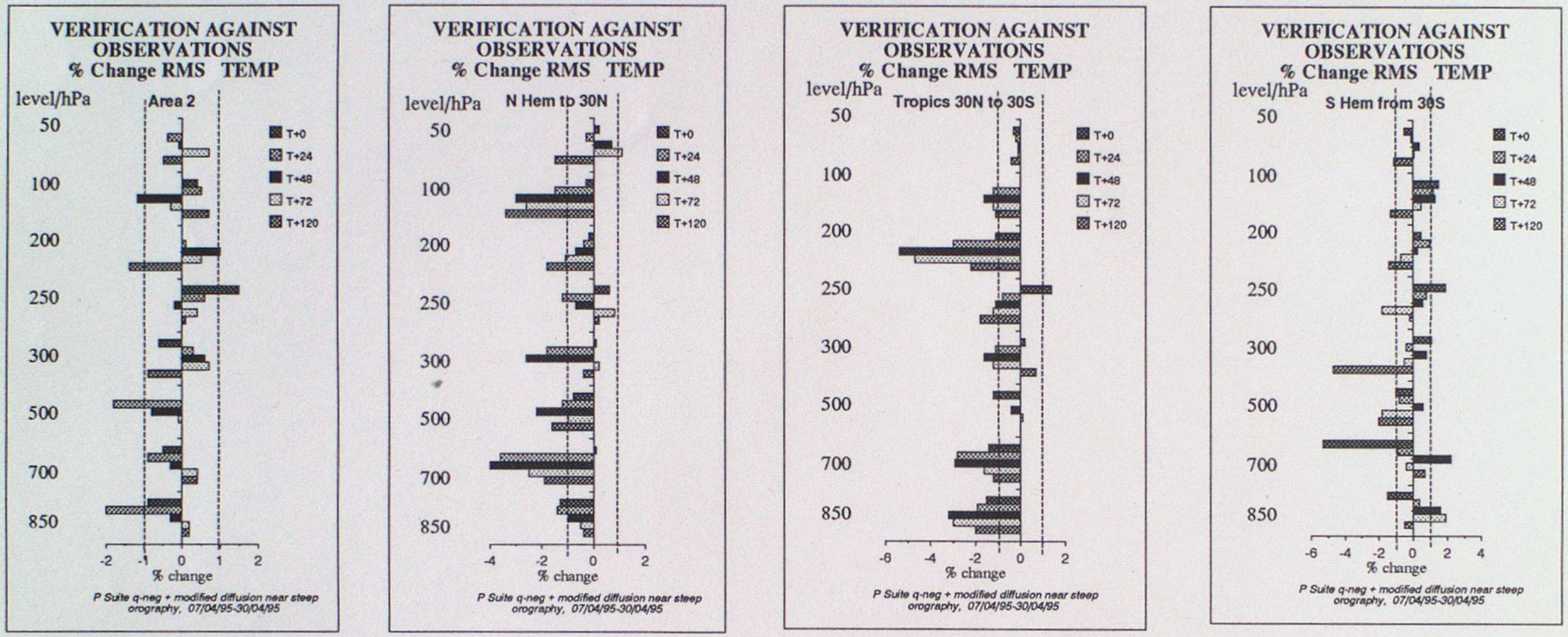

VERIFICATION AGAINST OBSERVATIONS
% Change RMS TEMP
level/hPa
Area 2
50
100
200
250
300
500
700
850
-2
-1
0
1
2
% change
T+0
T+24
T+48
T+72
T+120
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST OBSERVATIONS
% Change RMS TEMP
level/hPa
N Hem to 30N
50
100
200
250
300
500
700
850
-4
-2
0
2
% change
T+0
T+24
T+48
T+72
T+120
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST OBSERVATIONS
% Change RMS TEMP
level/hPa
Tropics 30N to 30S
50
100
200
250
300
500
700
850
-6
-4
-2
0
2
% change
T+0
T+24
T+48
T+72
T+120
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST OBSERVATIONS
% Change RMS TEMP
level/hPa
S Hem from 30S
50
100
200
250
300
500
700
850
-6
-4
-2
0
2
4
% change
T+0
T+24
T+48
T+72
T+120
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95

FIGURE 2.2

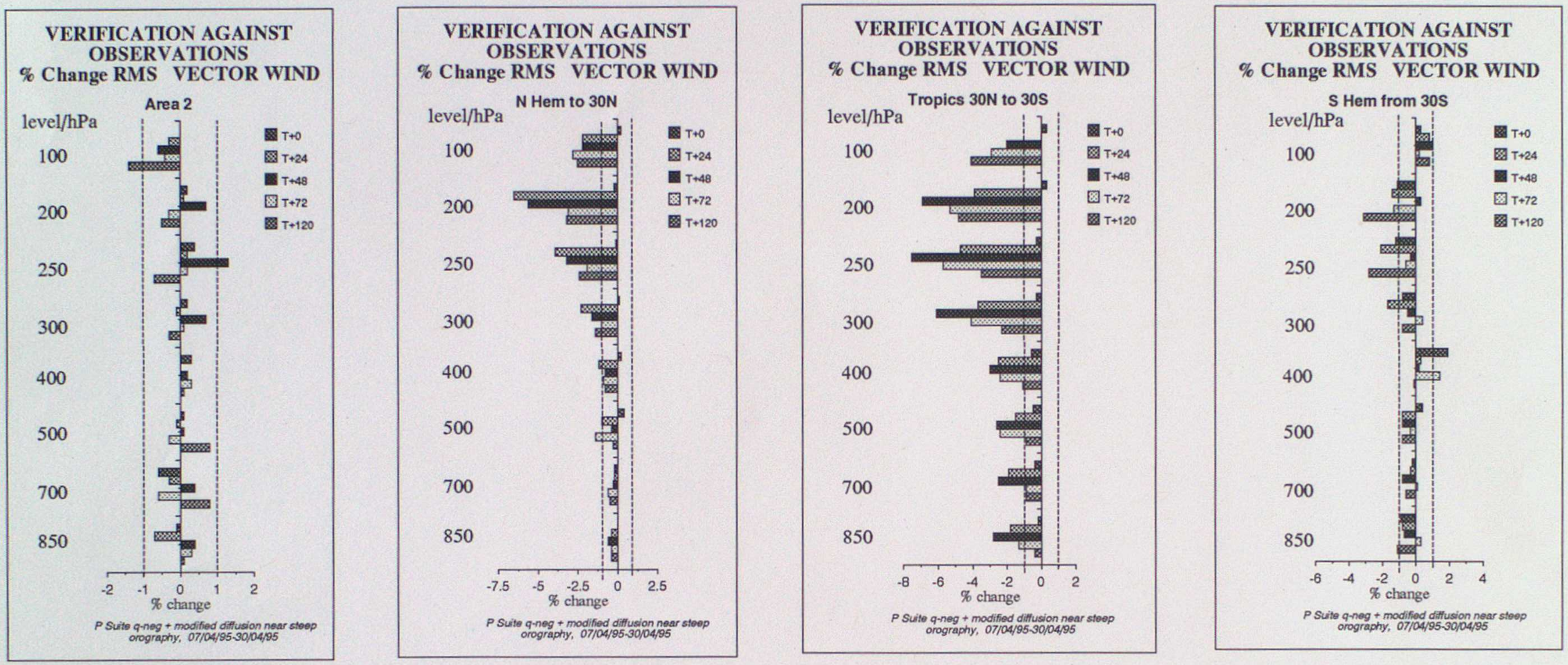
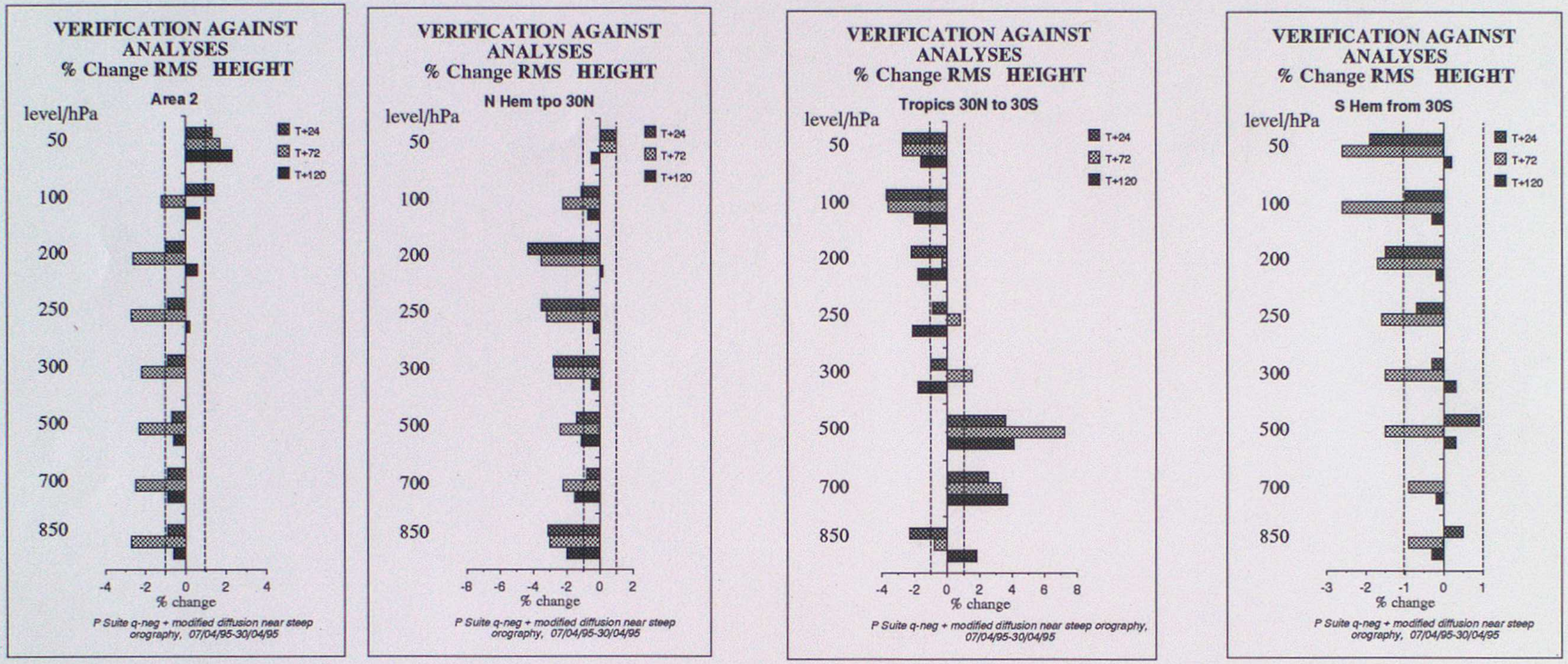

VERIFICATION AGAINST OBSERVATIONS
% Change RMS VECTOR WIND
Area 2
level/hPa
100
200
250
300
400
500
700
850
-2 -1 0 1 2
% change
T+0
T+24
T+48
T+72
T+120
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST OBSERVATIONS
% Change RMS VECTOR WIND
N Hem to 30N
level/hPa
100
200
250
300
400
500
700
850
-7.5 -5 -2.5 0 2.5
% change
T+0
T+24
T+48
T+72
T+120
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST OBSERVATIONS
% Change RMS VECTOR WIND
Tropics 30N to 30S
level/hPa
100
200
250
300
400
500
700
850
-8 -6 -4 -2 0 2
% change
T+0
T+24
T+48
T+72
T+120
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST OBSERVATIONS
% Change RMS VECTOR WIND
S Hem from 30S
level/hPa
100
200
250
300
400
500
700
850
-6 -4 -2 0 2 4
% change
T+0
T+24
T+48
T+72
T+120
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95

FIGURE 2.3



VERIFICATION AGAINST ANALYSES
% Change RMS HEIGHT
Area 2
level/hPa
50
100
200
250
300
500
700
850
T+24
T+72
T+120
-4 -2 0 2 4
% change
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST ANALYSES
% Change RMS HEIGHT
N Hem tpo 30N
level/hPa
50
100
200
250
300
500
700
850
T+24
T+72
T+120
-8 -6 -4 -2 0 2
% change
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST ANALYSES
% Change RMS HEIGHT
Tropics 30N to 30S
level/hPa
50
100
200
250
300
500
700
850
T+24
T+72
T+120
-4 -2 0 2 4 6 8
% change
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST ANALYSES
% Change RMS HEIGHT
S Hem from 30S
level/hPa
50
100
200
250
300
500
700
850
T+24
T+72
T+120
-3 -2 -1 0 1
% change
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95

FIGURE 2.4

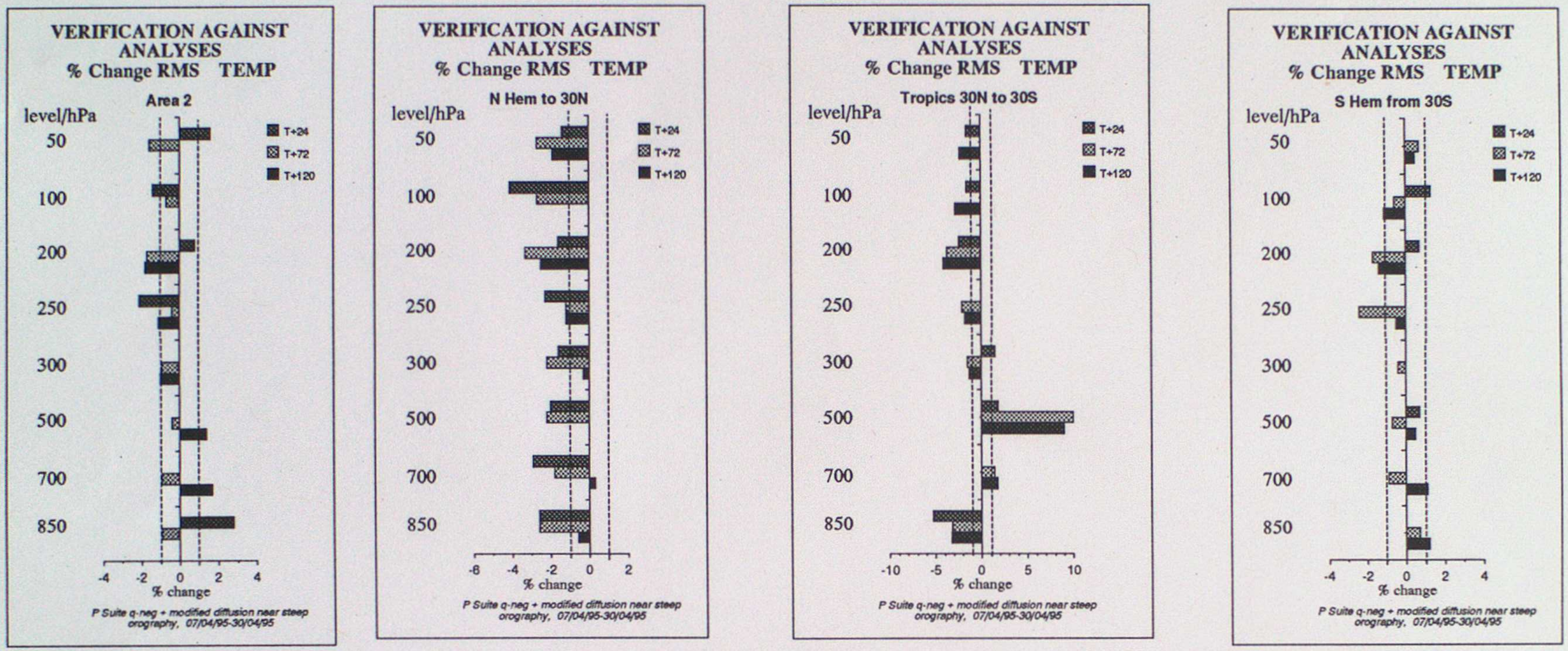

VERIFICATION AGAINST ANALYSES
% Change RMS TEMP
Area 2
level/hPa
50
100
200
250
300
500
700
850
T+24
T+72
T+120
-4 -2 0 2 4
% change
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST ANALYSES
% Change RMS TEMP
N Hem to 30N
level/hPa
50
100
200
250
300
500
700
850
T+24
T+72
T+120
-6 -4 -2 0 2
% change
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST ANALYSES
% Change RMS TEMP
Tropics 30N to 30S
level/hPa
50
100
200
250
300
500
700
850
T+24
T+72
T+120
-10 -5 0 5 10
% change
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST ANALYSES
% Change RMS TEMP
S Hem from 30S
level/hPa
50
100
200
250
300
500
700
850
T+24
T+72
T+120
-4 -2 0 2 4
% change
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95

FIGURE 2.5

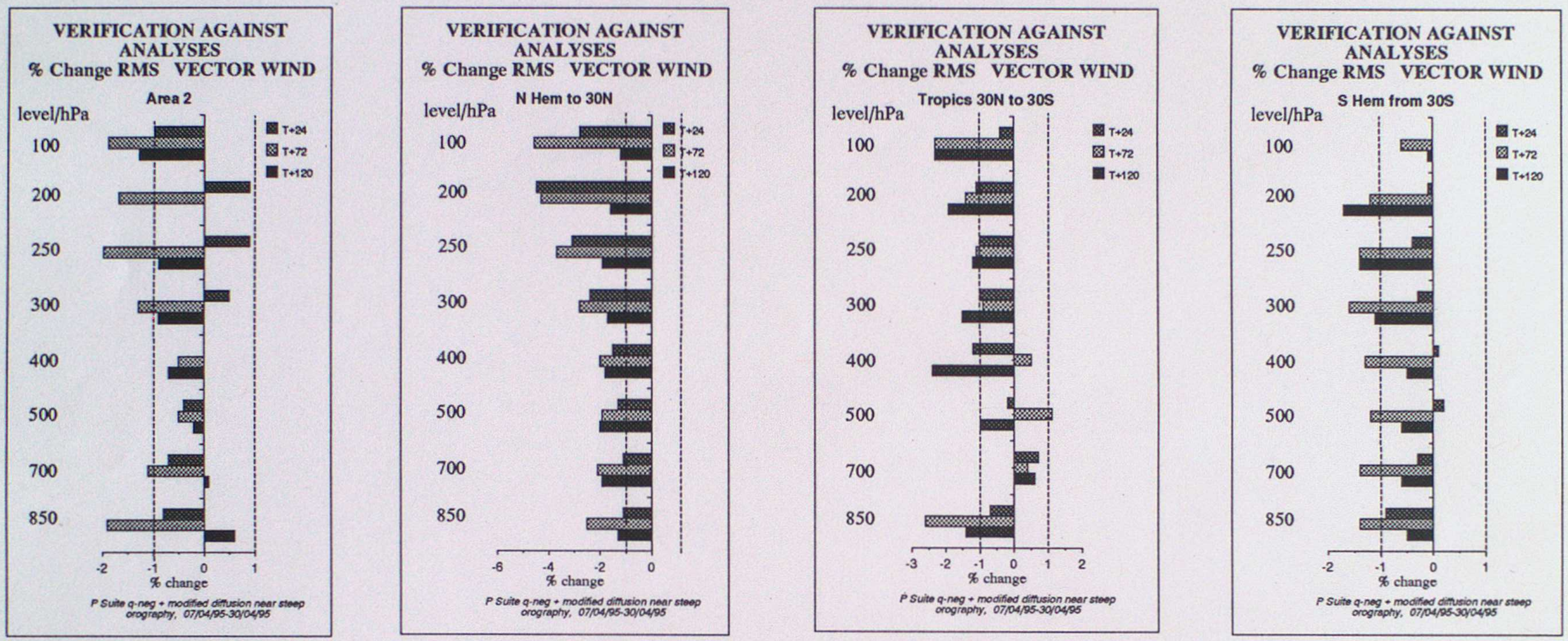

VERIFICATION AGAINST ANALYSES
% Change RMS VECTOR WIND
Area 2
level/hPa
100
200
250
300
400
500
700
850
T+24
T+72
T+120
-2
-1
0
1
% change
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST ANALYSES
% Change RMS VECTOR WIND
N Hem to 30N
level/hPa
100
200
250
300
400
500
700
850
T+24
T+72
T+120
-6
-4
-2
0
% change
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST ANALYSES
% Change RMS VECTOR WIND
Tropics 30N to 30S
level/hPa
100
200
250
300
400
500
700
850
T+24
T+72
T+120
-3
-2
-1
0
1
2
% change
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95
VERIFICATION AGAINST ANALYSES
% Change RMS VECTOR WIND
S Hem from 30S
level/hPa
100
200
250
300
400
500
700
850
T+24
T+72
T+120
-2
-1
0
1
% change
P Suite q-neg + modified diffusion near steep orography, 07/04/95-30/04/95

FIGURE 2.6

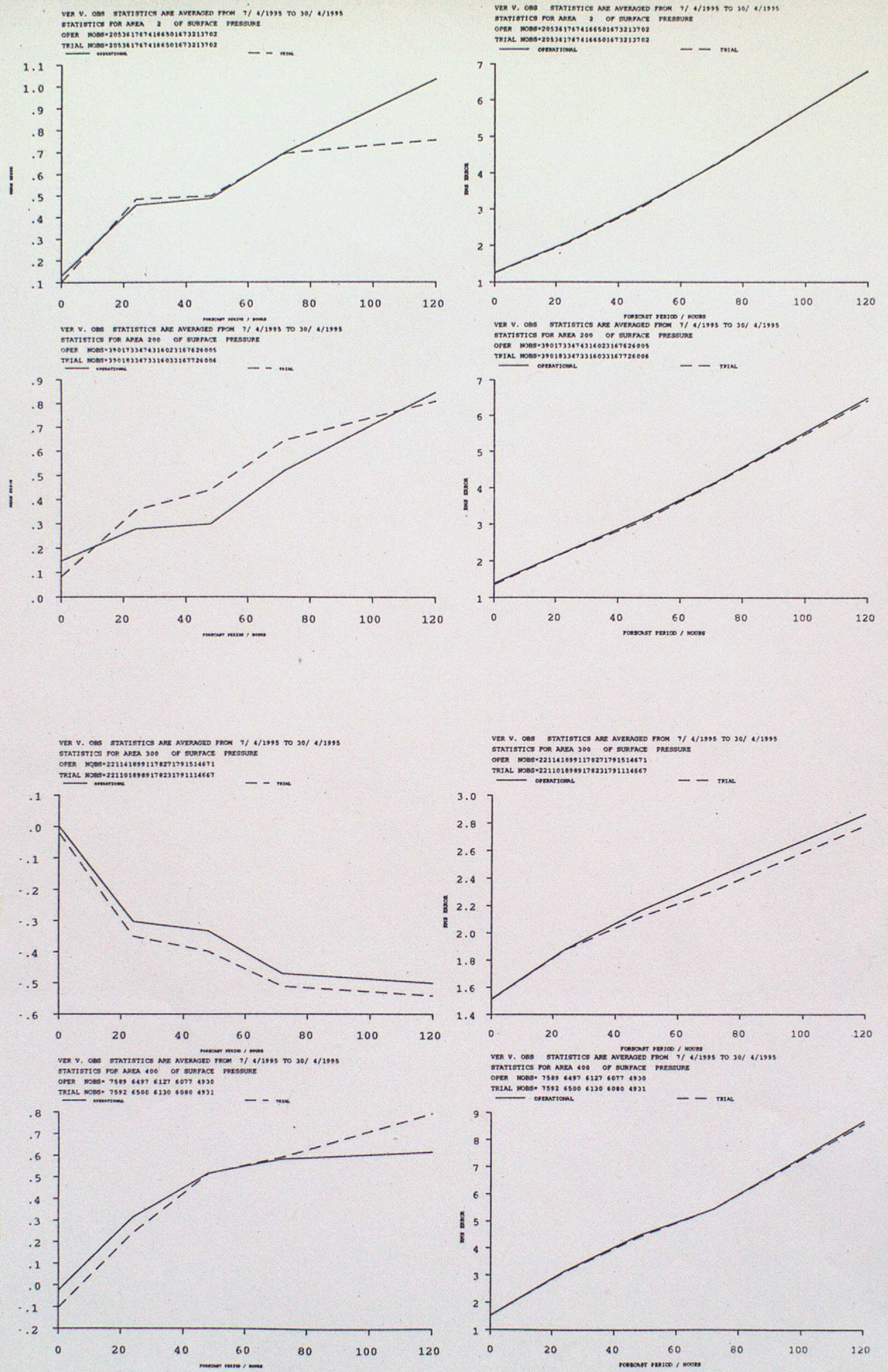

VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
STATISTICS FOR AREA 2 OF SURFACE PRESSURE
OPER NOBS=2053617674166501673213702
TRIAL NOBS=2053617674166501673213702
OPERATIONAL
TRIAL
FORECAST PERIOD / HOURS
RMS ERROR
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
STATISTICS FOR AREA 200 OF SURFACE PRESSURE
OPER NOBS=3901733474316023167626005
TRIAL NOBS=3901833473316033167726006
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
STATISTICS FOR AREA 300 OF SURFACE PRESSURE
OPER NOBS=2211418991178271791514671
TRIAL NOBS=2211018989178231791114667
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
STATISTICS FOR AREA 400 OF SURFACE PRESSURE
OPER NOBS= 7589 6497 6127 6077 4930
TRIAL NOBS= 7592 6500 6130 6080 4931

FIGURE 2.7

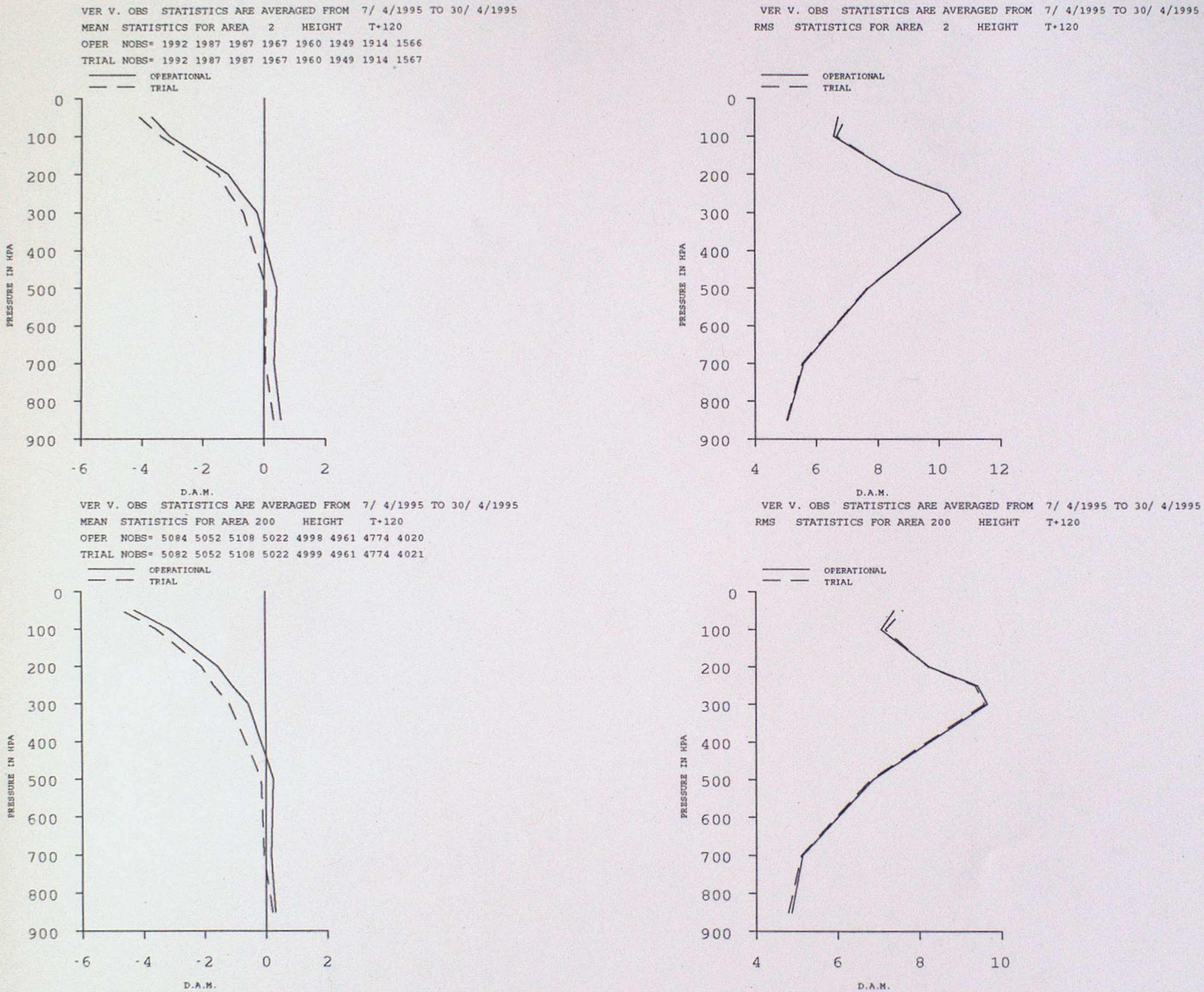

VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
MEAN STATISTICS FOR AREA 2 HEIGHT T+120
OPER NOBS= 1992 1987 1987 1967 1960 1949 1914 1566
TRIAL NOBS= 1992 1987 1987 1967 1960 1949 1914 1567
OPERATIONAL
TRIAL
PRESSURE IN HPA
D.A.M.
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
RMS STATISTICS FOR AREA 2 HEIGHT T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
D.A.M.
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
MEAN STATISTICS FOR AREA 200 HEIGHT T+120
OPER NOBS= 5084 5052 5108 5022 4998 4961 4774 4020
TRIAL NOBS= 5082 5052 5108 5022 4999 4961 4774 4021
OPERATIONAL
TRIAL
PRESSURE IN HPA
D.A.M.
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
RMS STATISTICS FOR AREA 200 HEIGHT T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
D.A.M.

FIGURE 2.8

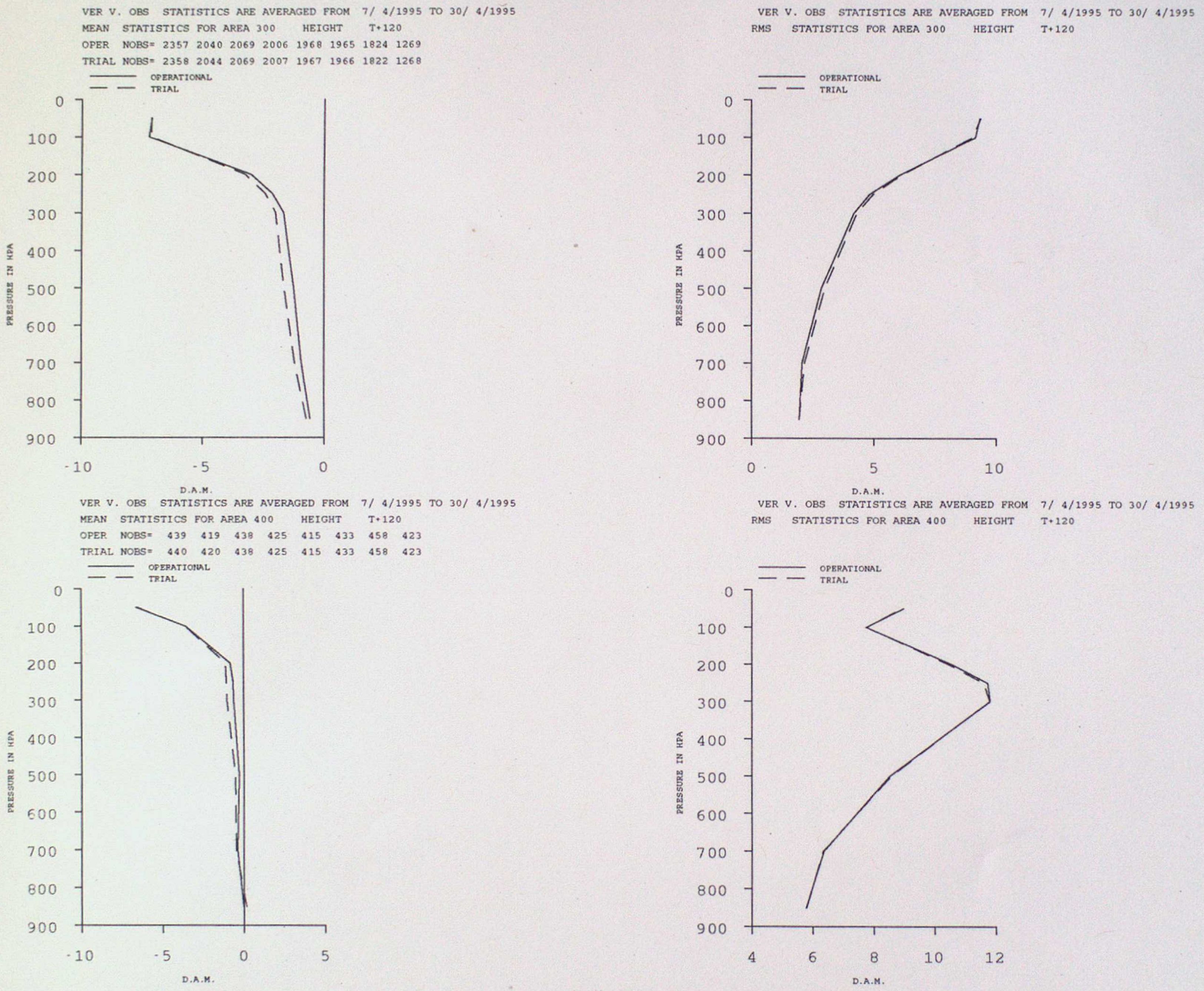

VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
MEAN STATISTICS FOR AREA 300 HEIGHT T+120
OPER NOBS= 2357 2040 2069 2006 1968 1965 1824 1269
TRIAL NOBS= 2358 2044 2069 2007 1967 1966 1822 1268
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-10
-5
0
D.A.M.
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
RMS STATISTICS FOR AREA 300 HEIGHT T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
5
10
D.A.M.
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
MEAN STATISTICS FOR AREA 400 HEIGHT T+120
OPER NOBS= 439 419 438 425 415 433 458 423
TRIAL NOBS= 440 420 438 425 415 433 458 423
OPERATIONAL
TRIAL
PRESSURE IN HPA
-10
-5
0
5
D.A.M.
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
RMS STATISTICS FOR AREA 400 HEIGHT T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
4
6
8
10
12
D.A.M.

FIGURE 2.9

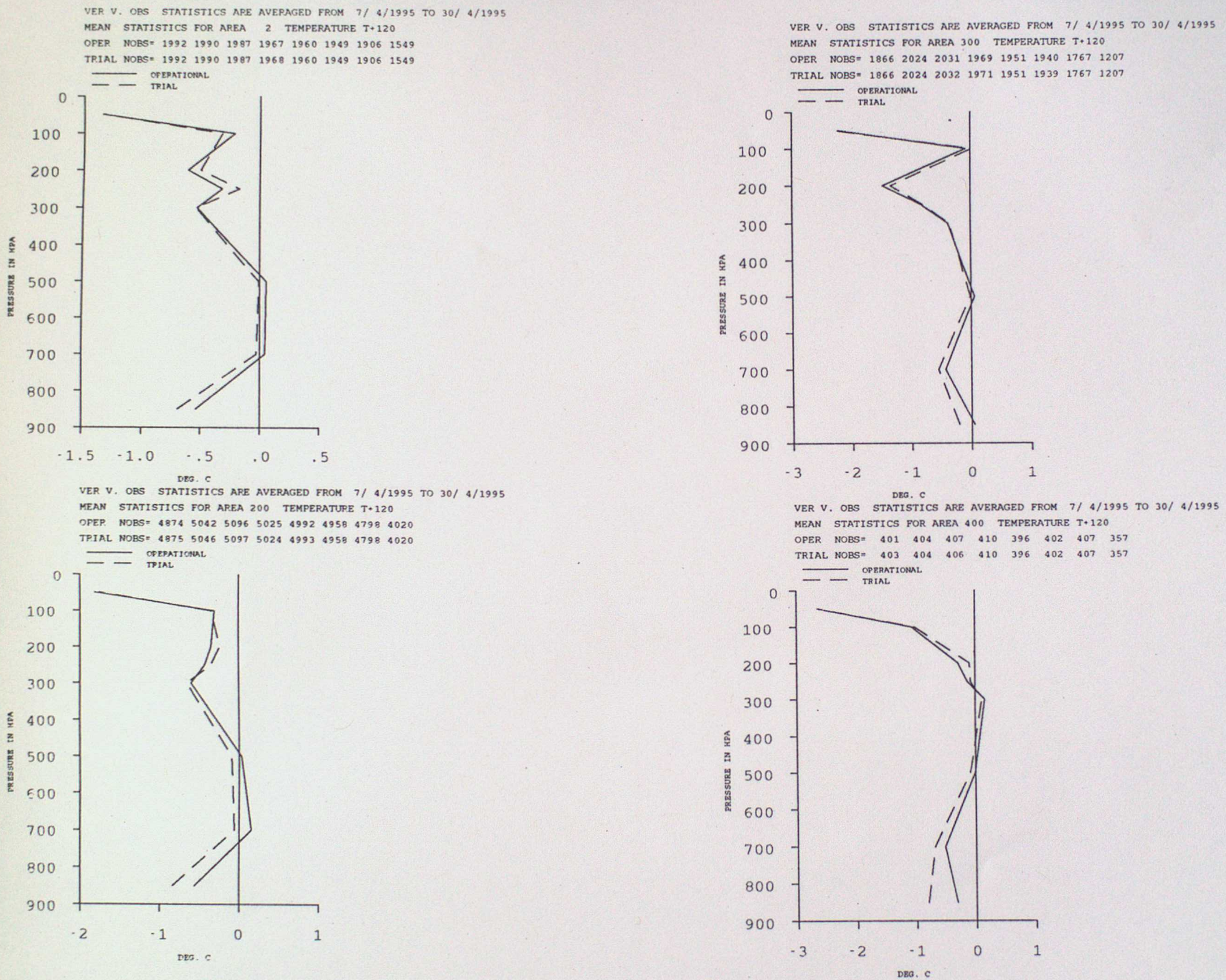

VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
MEAN STATISTICS FOR AREA 2 TEMPERATURE T+120
OPER NOBS= 1992 1990 1987 1967 1960 1949 1906 1549
TRIAL NOBS= 1992 1990 1987 1968 1960 1949 1906 1549
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-1.5 -1.0 -.5 .0 .5
DEG. C
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
MEAN STATISTICS FOR AREA 300 TEMPERATURE T+120
OPER NOBS= 1866 2024 2031 1969 1951 1940 1767 1207
TRIAL NOBS= 1866 2024 2032 1971 1951 1939 1767 1207
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-3 -2 -1 0 1
DEG. C
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
MEAN STATISTICS FOR AREA 200 TEMPERATURE T+120
OPER NOBS= 4874 5042 5096 5025 4992 4958 4798 4020
TRIAL NOBS= 4875 5046 5097 5024 4993 4958 4798 4020
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-2 -1 0 1
DEG. C
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
MEAN STATISTICS FOR AREA 400 TEMPERATURE T+120
OPER NOBS= 401 404 407 410 396 402 407 357
TRIAL NOBS= 403 404 406 410 396 402 407 357
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-3 -2 -1 0 1
DEG. C

FIGURE 2.10

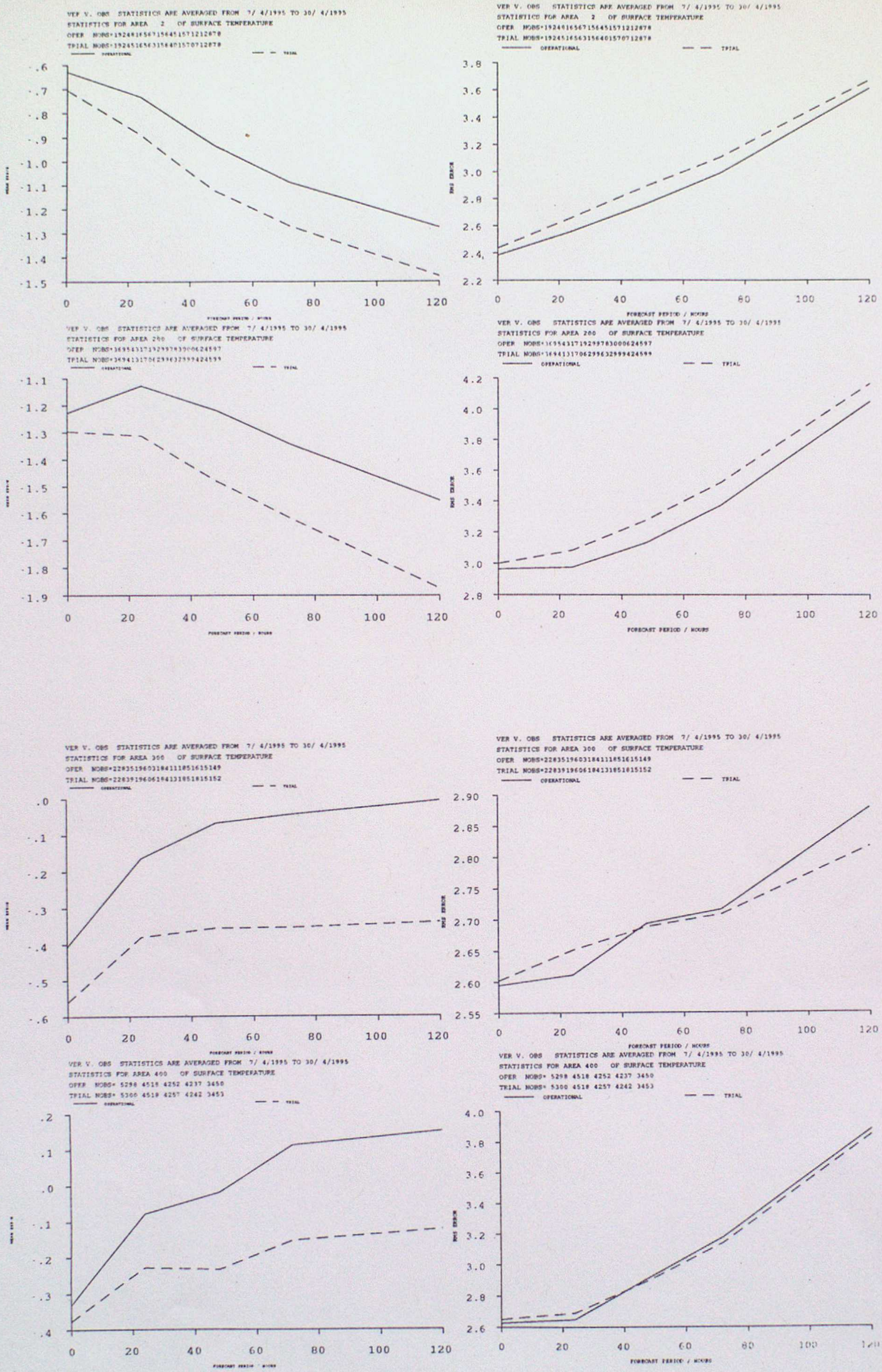

VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
STATISTICS FOR AREA 2 OF SURFACE TEMPERATURE
OPER NOBS=1924816567156451571212878
TRIAL NOBS=1924516563156401570712878
OPERATIONAL
TRIAL
RMS ERROR
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
STATISTICS FOR AREA 200 OF SURFACE TEMPERATURE
OPER NOBS=3695431719299783000624597
TRIAL NOBS=3694131706299632999424599
OPERATIONAL
TRIAL
RMS ERROR
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
STATISTICS FOR AREA 300 OF SURFACE TEMPERATURE
OPER NOBS=2283519603184111851615149
TRIAL NOBS=2283919606184131851815152
OPERATIONAL
TRIAL
RMS ERROR
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
STATISTICS FOR AREA 400 OF SURFACE TEMPERATURE
OPER NOBS= 5298 4518 4252 4237 3450
TRIAL NOBS= 5300 4518 4257 4242 3453
OPERATIONAL
TRIAL
RMS ERROR
FORECAST PERIOD / HOURS

FIGURE 2.11

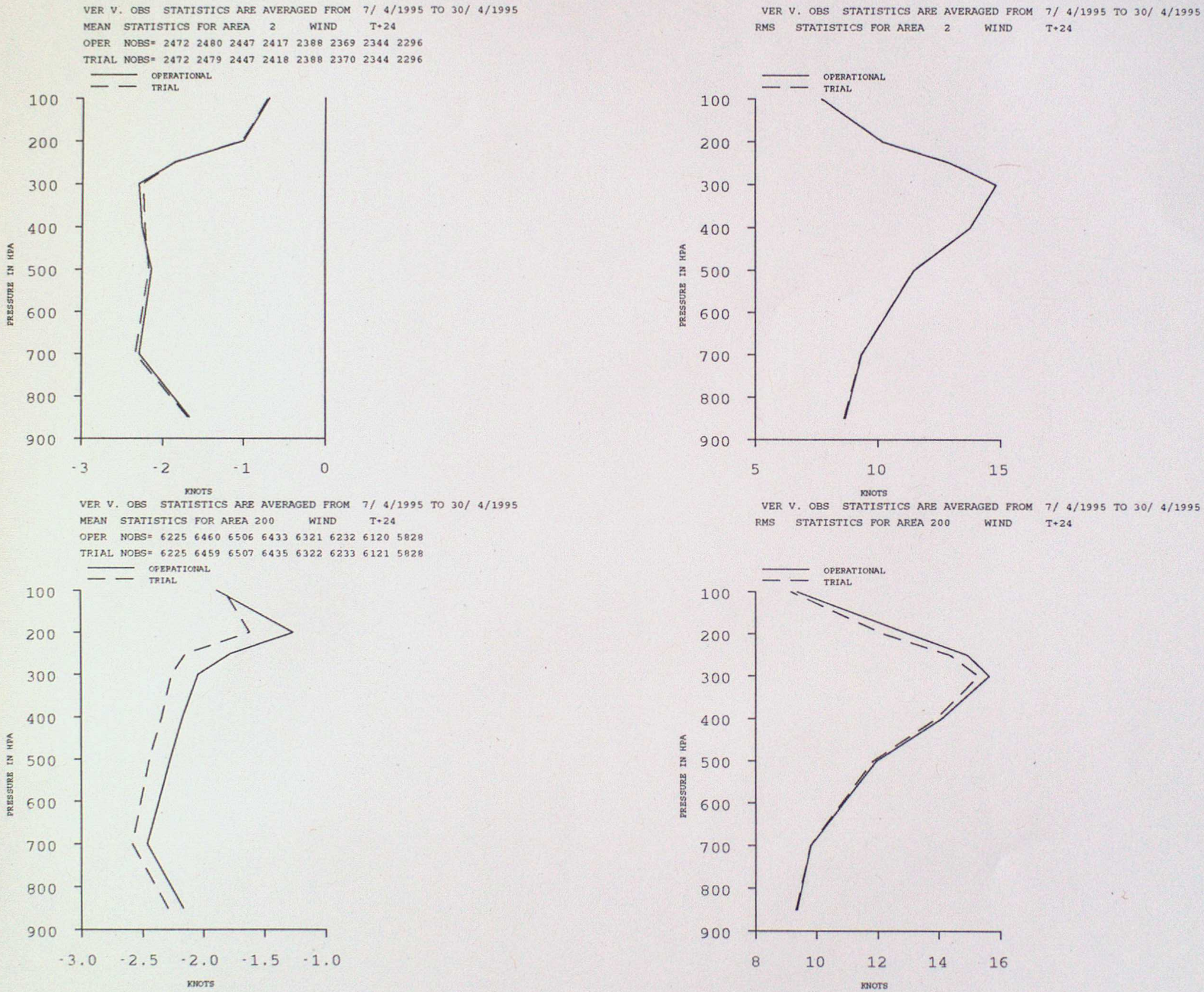

VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
MEAN STATISTICS FOR AREA 2 WIND T+24
OPER NOBS= 2472 2480 2447 2417 2388 2369 2344 2296
TRIAL NOBS= 2472 2479 2447 2418 2388 2370 2344 2296
OPERATIONAL
TRIAL
PRESSURE IN HPA
100 200 300 400 500 600 700 800 900
-3 -2 -1 0
KNOTS
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
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 7/ 4/1995 TO 30/ 4/1995
MEAN STATISTICS FOR AREA 200 WIND T+24
OPER NOBS= 6225 6460 6506 6433 6321 6232 6120 5828
TRIAL NOBS= 6225 6459 6507 6435 6322 6233 6121 5828
OPERATIONAL
TRIAL
PRESSURE IN HPA
100 200 300 400 500 600 700 800 900
-3.0 -2.5 -2.0 -1.5 -1.0
KNOTS
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
RMS STATISTICS FOR AREA 200 WIND T+24
OPERATIONAL
TRIAL
PRESSURE IN HPA
100 200 300 400 500 600 700 800 900
8 10 12 14 16
KNOTS

FIGURE 2.12

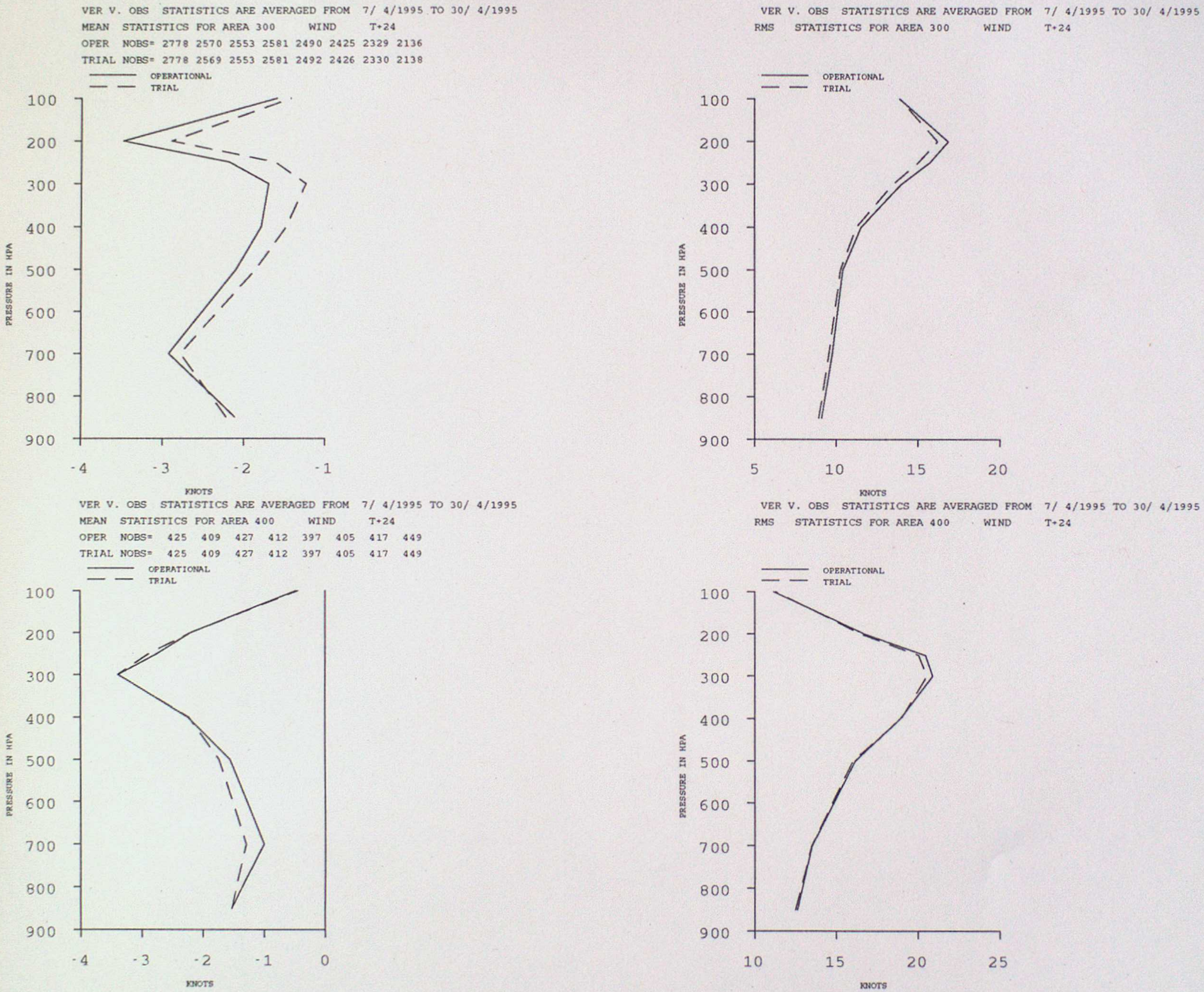
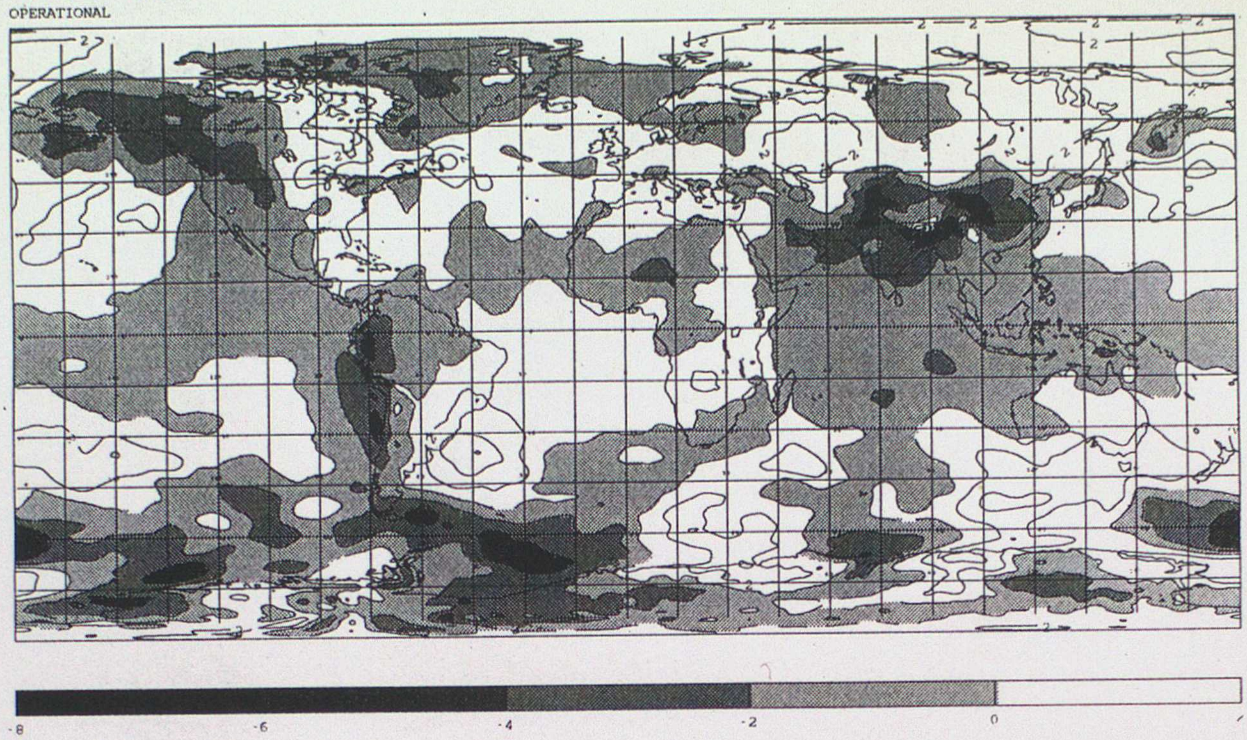

VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
MEAN STATISTICS FOR AREA 300 WIND T+24
OPER NOBS= 2778 2570 2553 2581 2490 2425 2329 2136
TRIAL NOBS= 2778 2569 2553 2581 2492 2426 2330 2138
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
-4
-3
-2
-1
KNOTS
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
RMS STATISTICS FOR AREA 300 WIND T+24
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
5
10
15
20
KNOTS
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
MEAN STATISTICS FOR AREA 400 WIND T+24
OPER NOBS= 425 409 427 412 397 405 417 449
TRIAL NOBS= 425 409 427 412 397 405 417 449
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
-4
-3
-2
-1
0
KNOTS
VER V. OBS STATISTICS ARE AVERAGED FROM 7/ 4/1995 TO 30/ 4/1995
RMS STATISTICS FOR AREA 400 WIND T+24
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
10
15
20
25
KNOTS

FIGURE 2.13

MSLP MEAN ERRORS
T+72 F/C MEANED FROM 12Z 11/04/95 TO 12Z 30/04/95
OPERATIONAL SUITE
OPERATIONAL



MSLP MEAN ERROR DIFFERENCES
T+72 F/C MEANED FROM 12Z 11/04/95 TO 12Z 30/04/95
PARALLEL SUITE TRIAL - OPERATIONAL
TRIAL(RESET NEG Q/MODIFIED DIFFUSION NEAR STEEP OROGRAPHY)

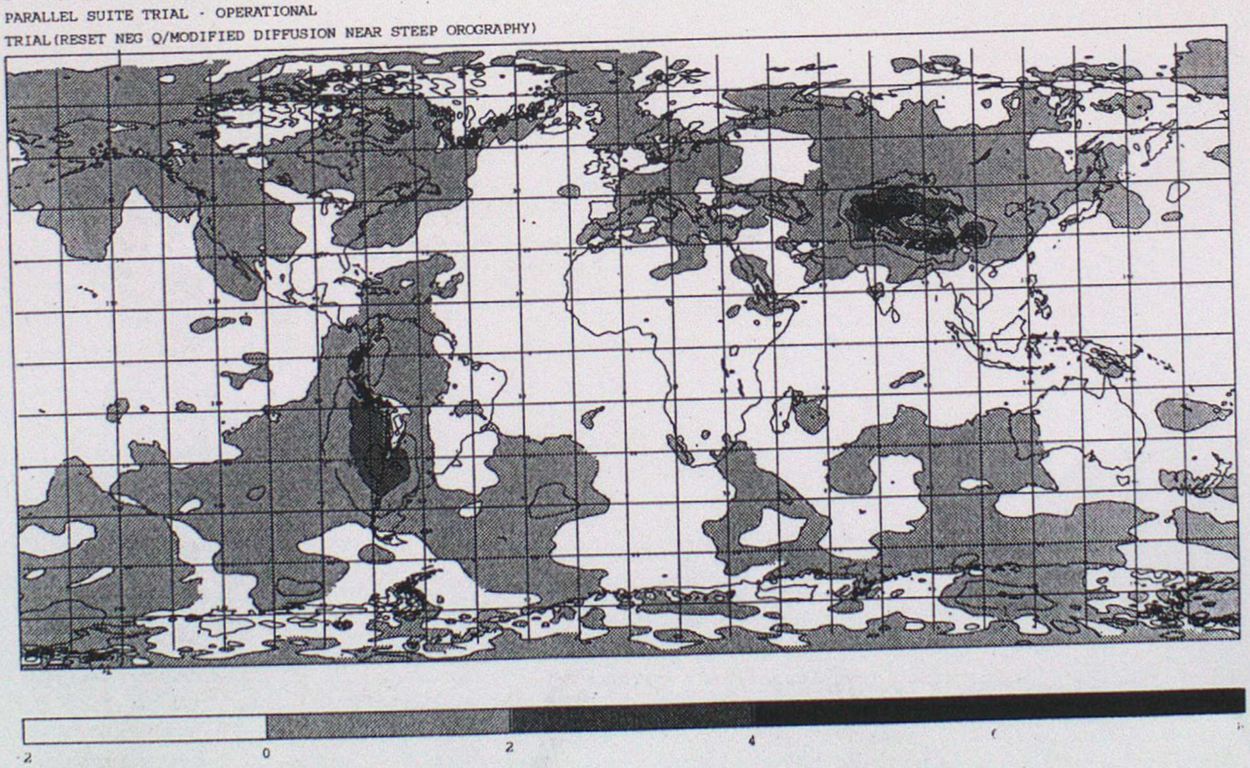
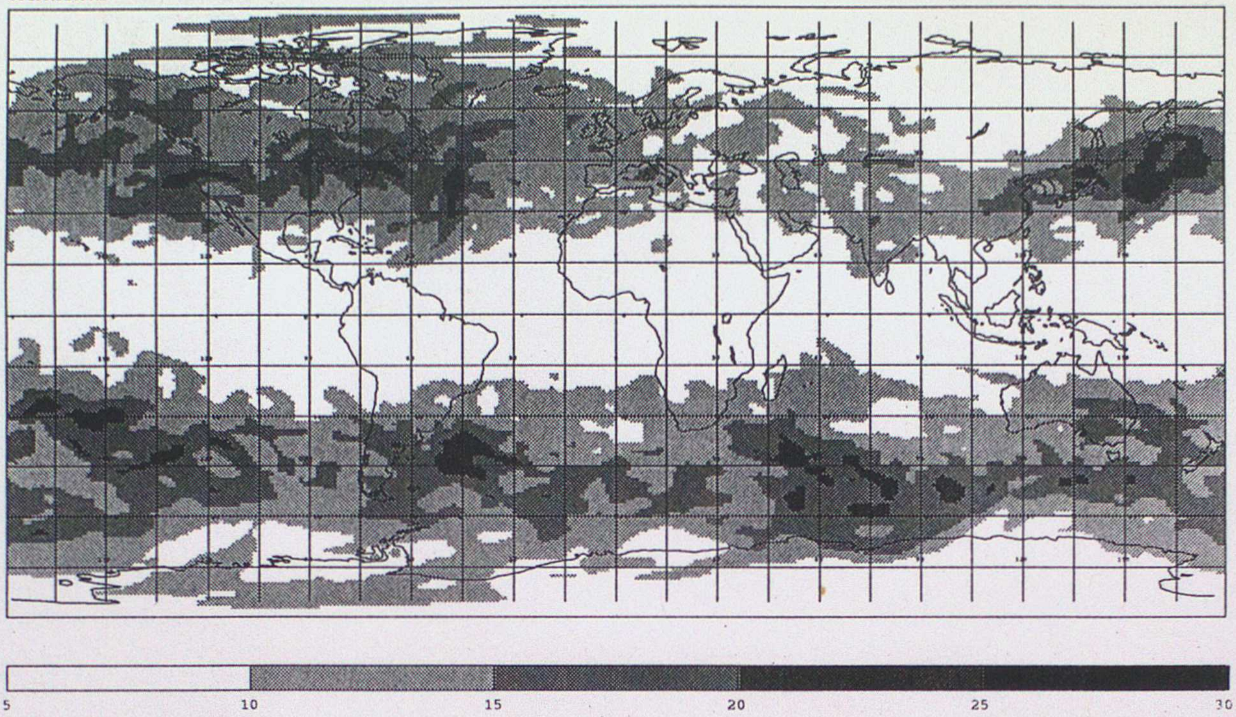


FIGURE 2.14

250hPa WIND RMS ERRORS
T+72 F/C MEANED FROM 12Z 11/04/95 TO 12Z 30/04/95
OPERATIONAL SUITE
OPERATIONAL



250hPa WIND RMS ERROR DIFFERENCES
T+72 F/C MEANED FROM 12Z 11/04/95 TO 12Z 30/04/95
TRIAL - OPERATIONAL
PARALLEL SUITE (RESET NEG Q/MODIFIED DIFFUSION NEAR STEEP OROGRAPHY)

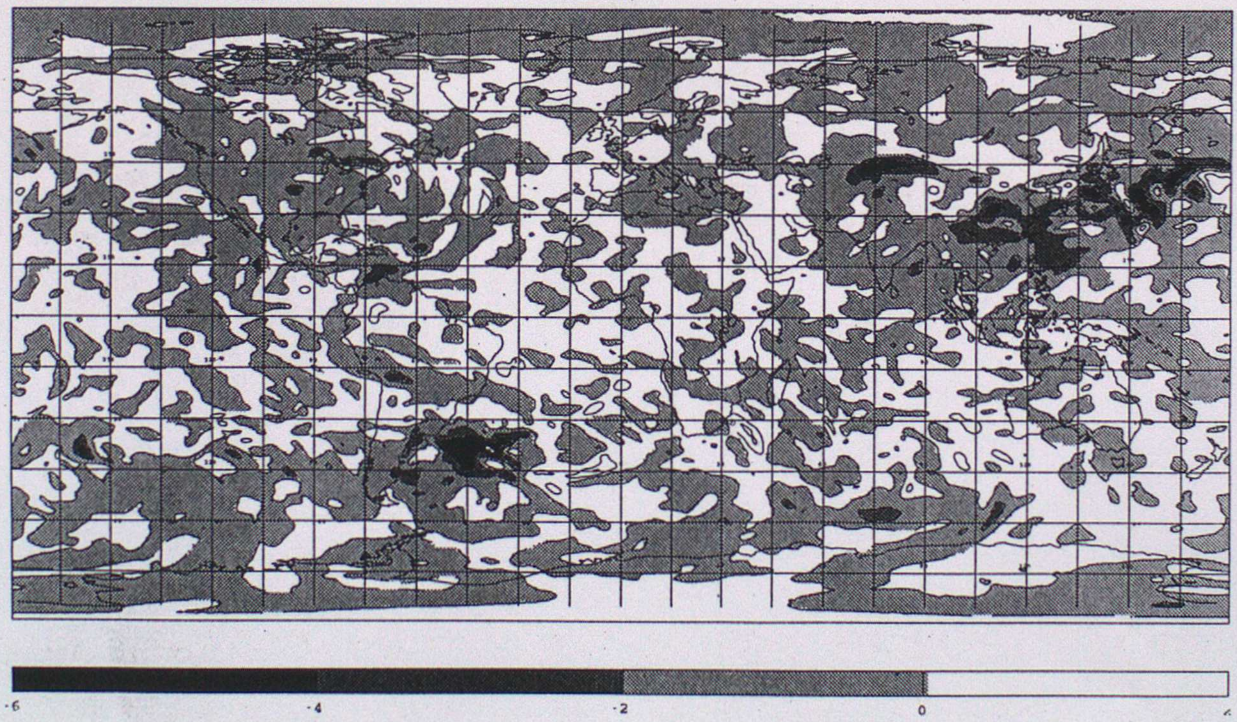
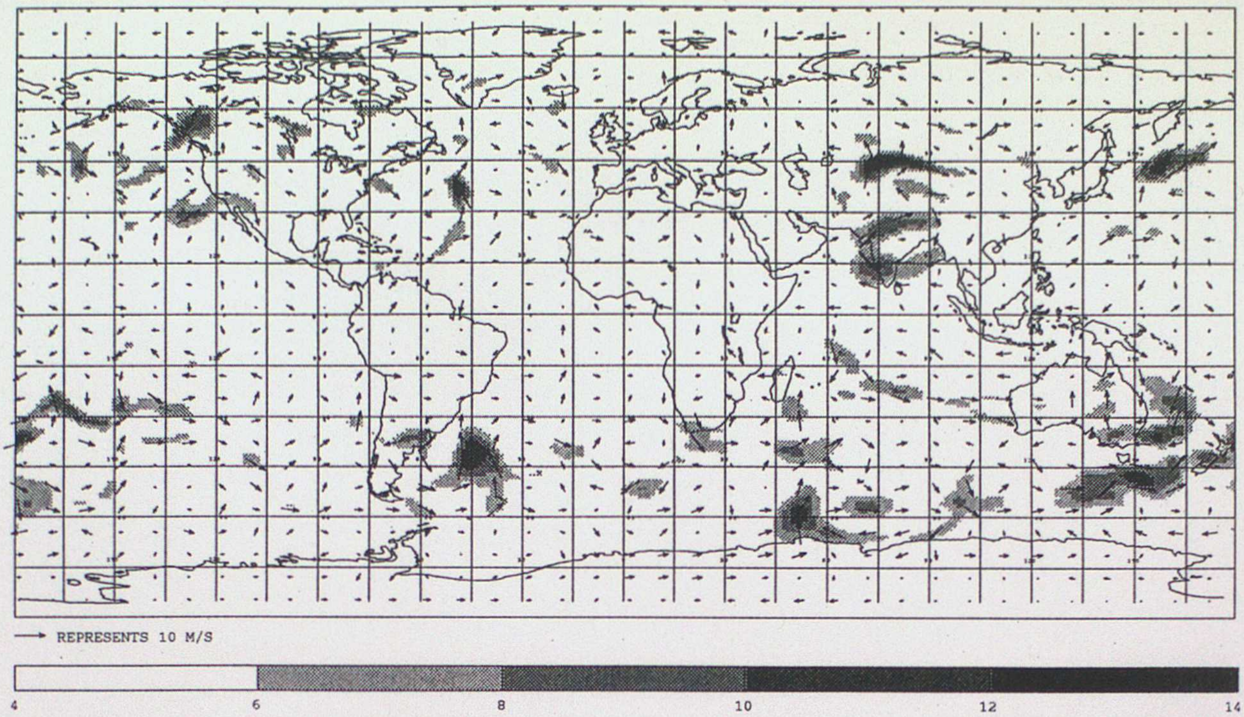


FIGURE 2.15

250hPa WIND MEAN ERRORS
T+72 F/C MEANED FROM DT 12Z 08/04/95 TO 12Z 27/04/95
PARALLEL SUITE TRIAL
OPERATIONAL



250hPa WIND MEAN ERRORS
T+72 F/C MEANED FROM DT 12Z 08/04/95 TO 12Z 27/04/95
PARALLEL SUITE TRIAL
RESET NEG Q/MODIFIED DIFFUSION NEAR STEEP OROGRAPHY

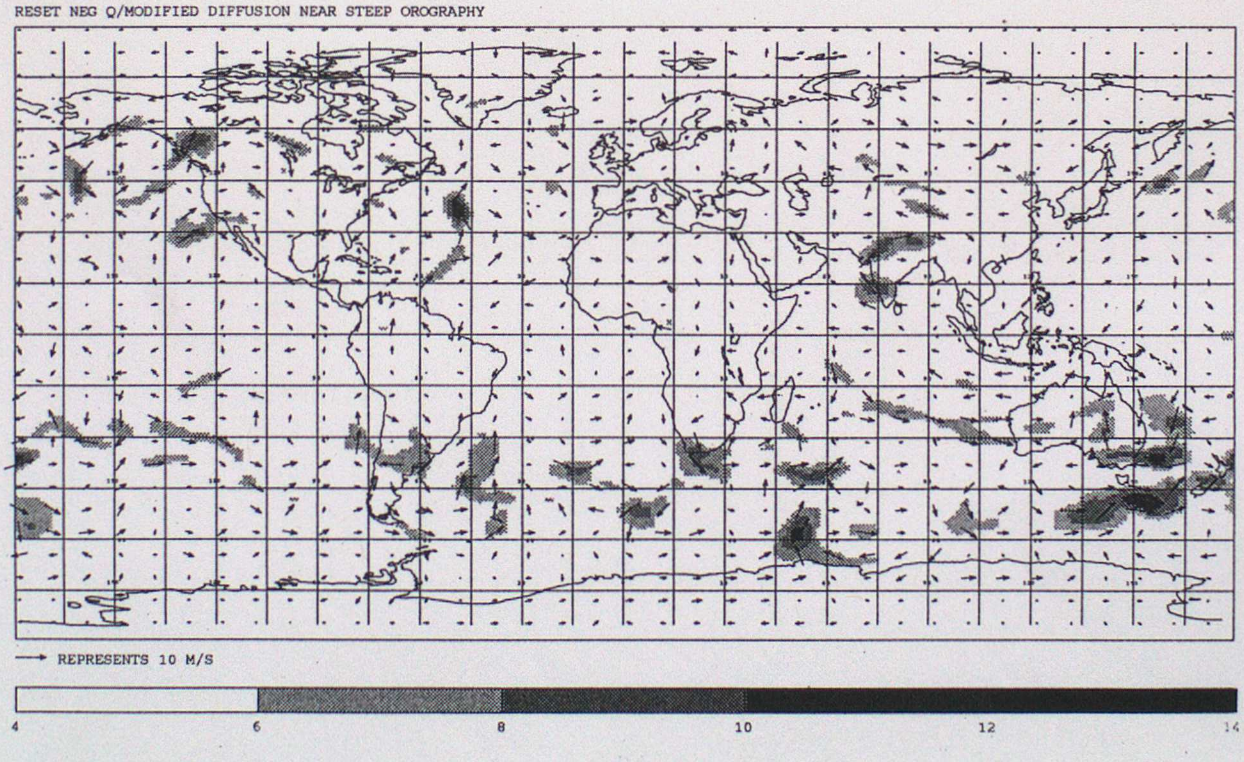


FIGURE 2.16

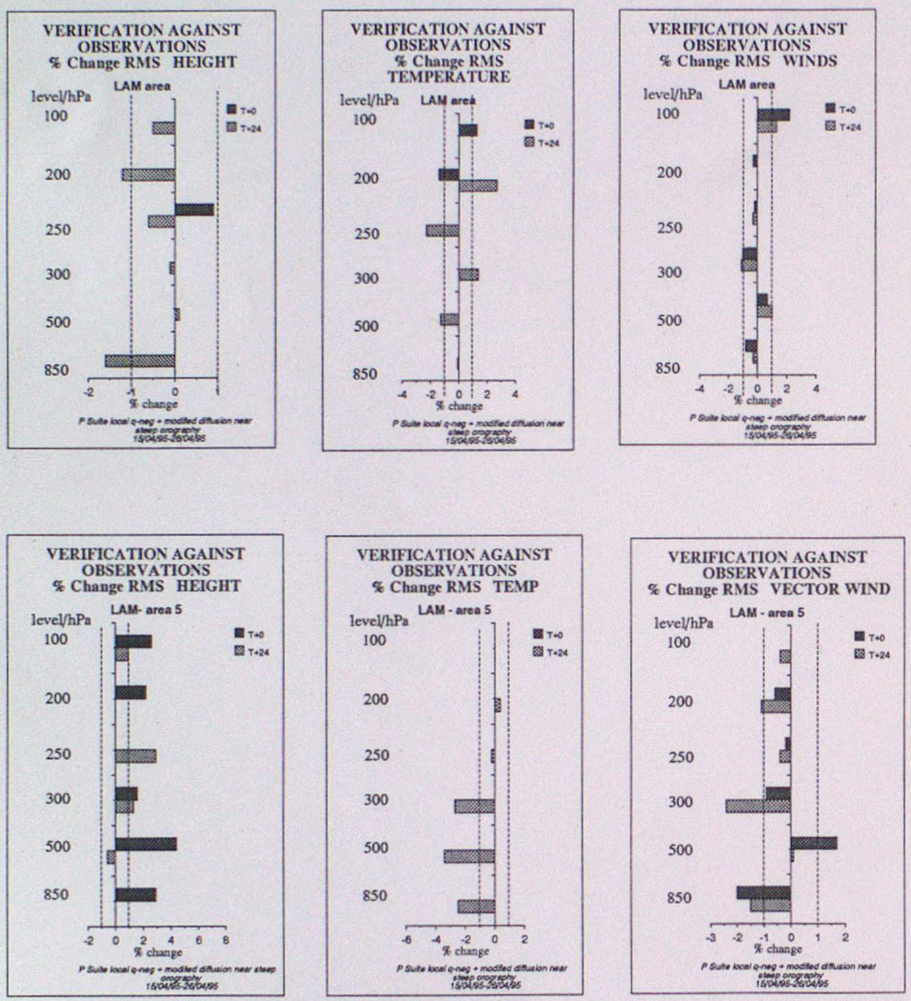


FIGURE 2.17

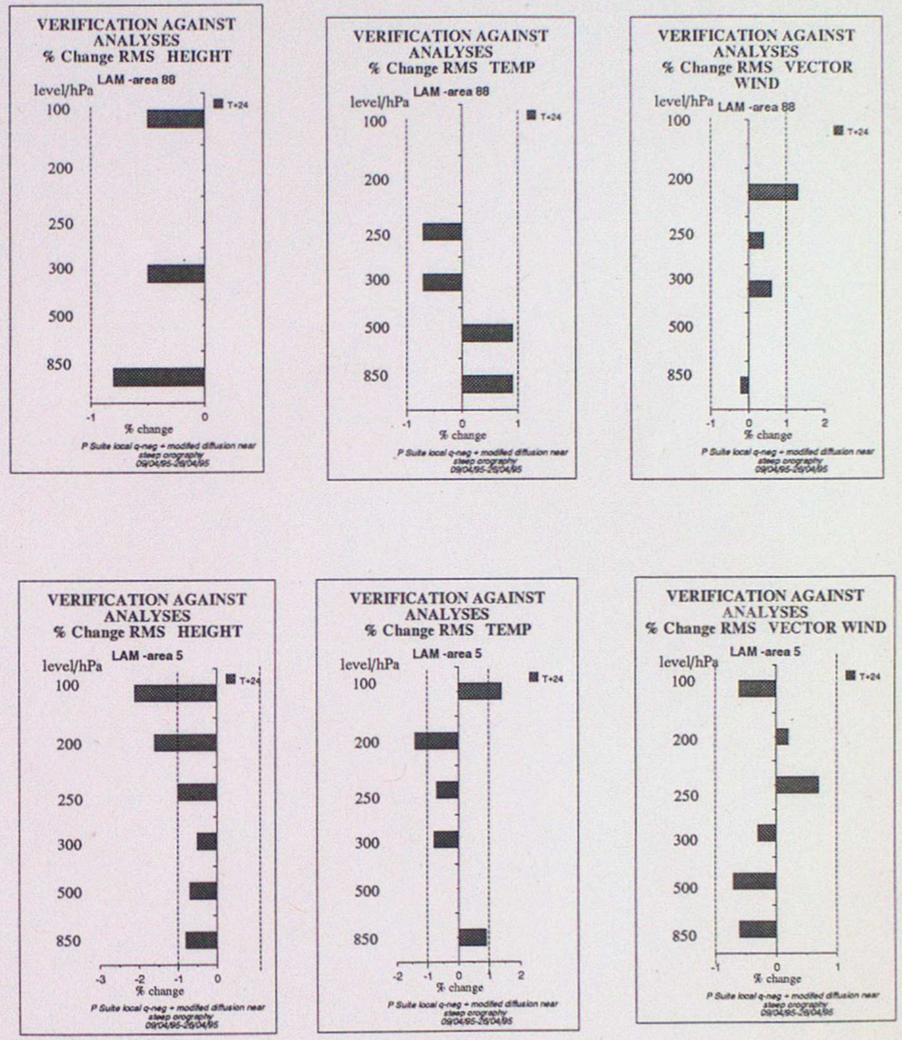


FIGURE 2.18

MEAN SEA LEVEL PRESSURE DIFFERENCES T+120

PARALLEL SUITE TRIAL - OPERATIONAL

FORECAST MEANED FROM 12Z 13/04/95 TO 12Z 02/05/95

RESET NEG Q,SWITCH OFF HORIZONTAL DIFFUSION NEAR STEEP OROGRAPHY

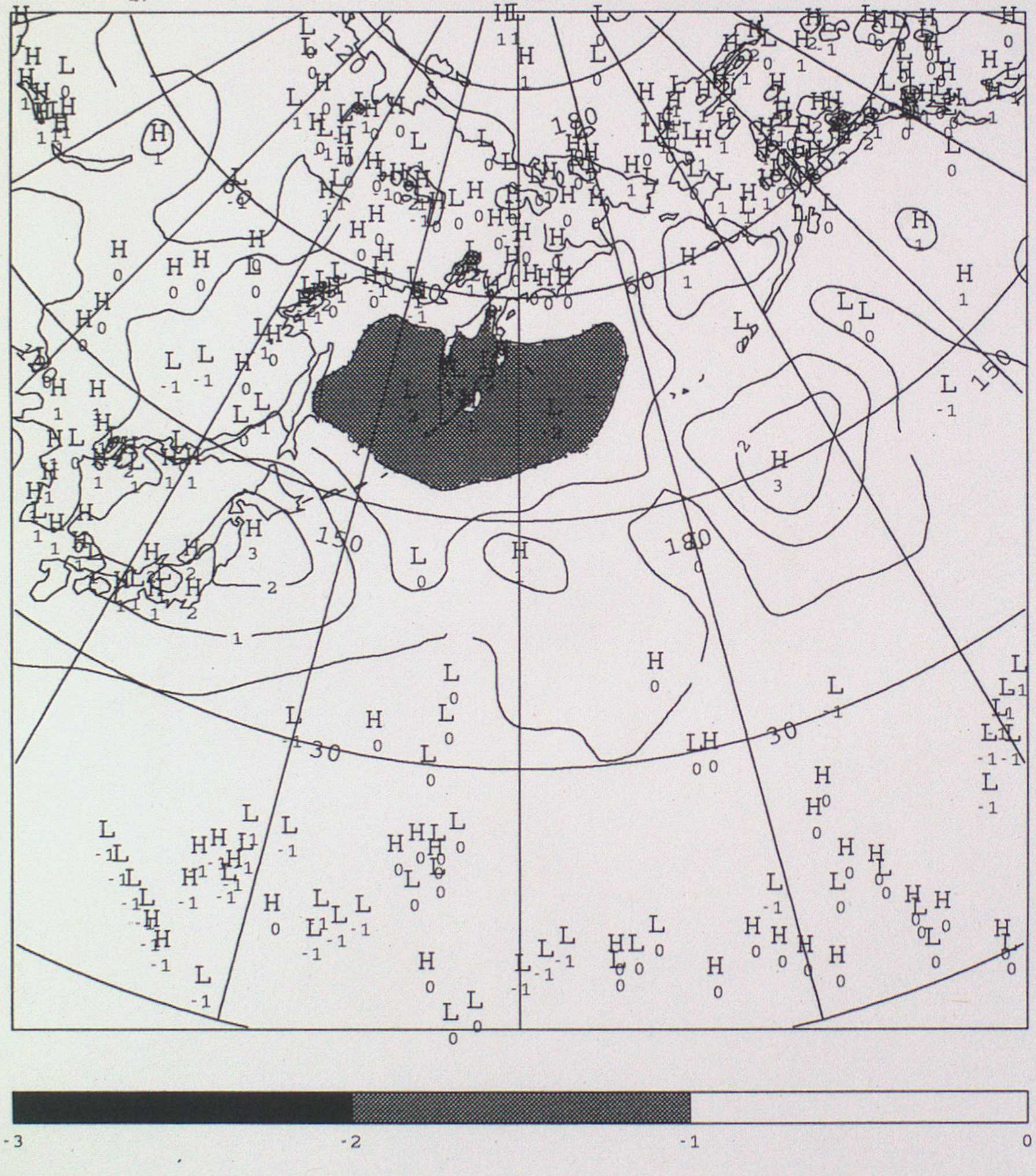


FIGURE 3.1

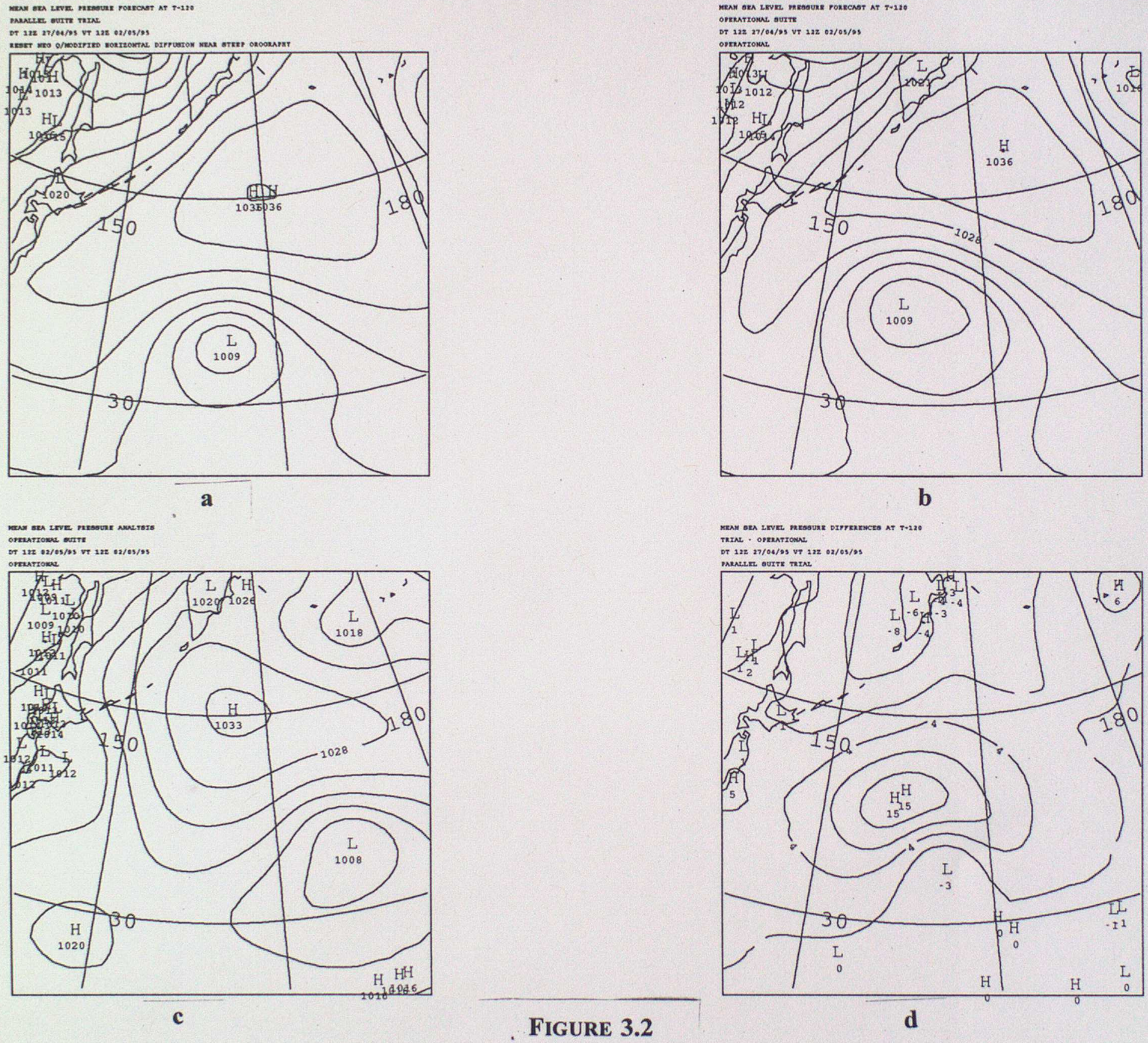

MEAN SEA LEVEL PRESSURE FORECAST AT T+120
PARALLEL SUITE TRIAL
DT 12Z 27/04/95 VT 12Z 02/05/95
RESET NEG Q/MODIFIED HORIZONTAL DIFFUSION NEAR STEEP OROGRAPHY
a
MEAN SEA LEVEL PRESSURE FORECAST AT T+120
OPERATIONAL SUITE
DT 12Z 27/04/95 VT 12Z 02/05/95
OPERATIONAL
b
MEAN SEA LEVEL PRESSURE ANALYSIS
OPERATIONAL SUITE
DT 12Z 02/05/95 VT 12Z 02/05/95
OPERATIONAL
c
MEAN SEA LEVEL PRESSURE DIFFERENCES AT T+120
TRIAL - OPERATIONAL
DT 12Z 27/04/95 VT 12Z 02/05/95
PARALLEL SUITE TRIAL
d

FIGURE 3.2

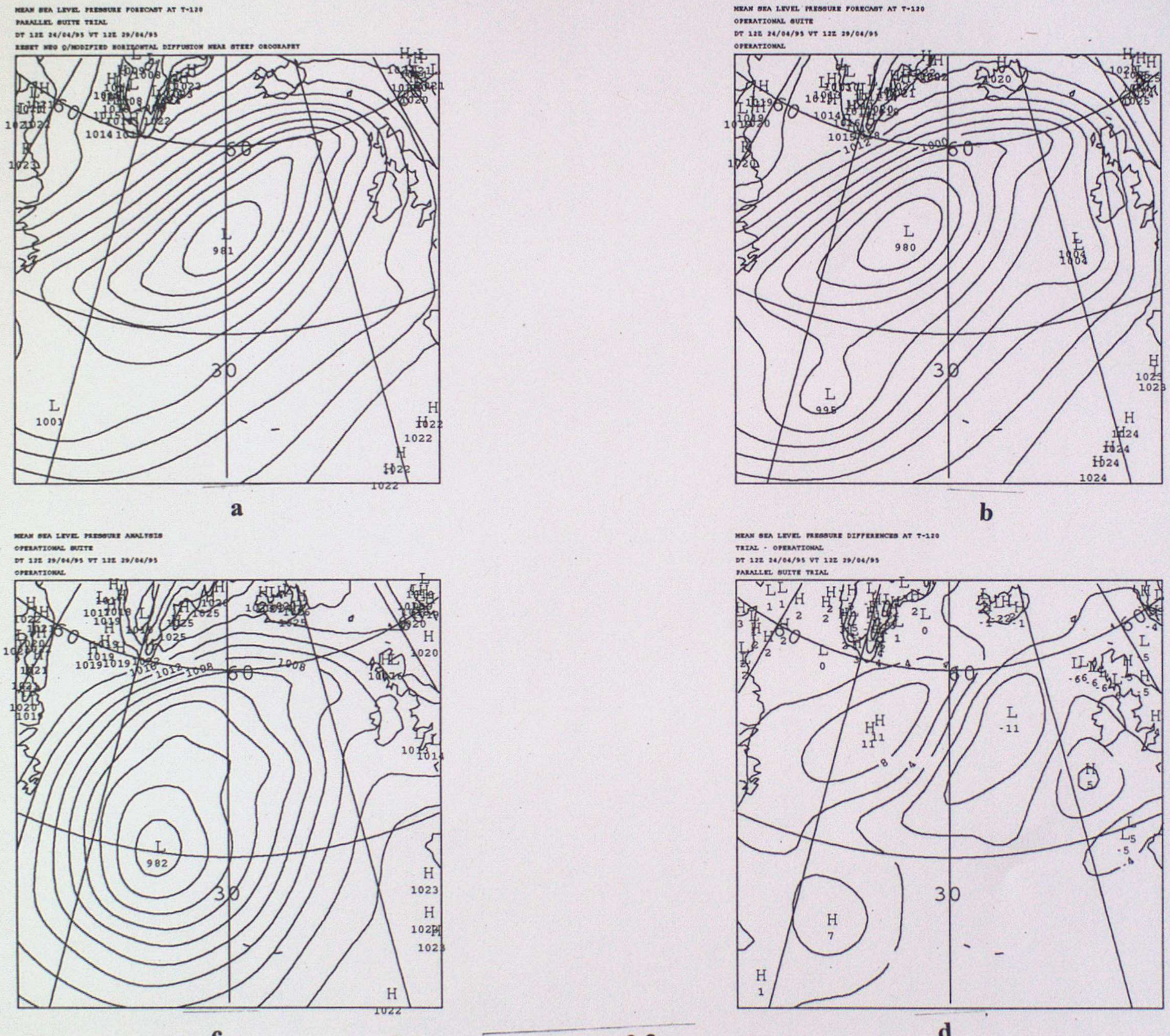
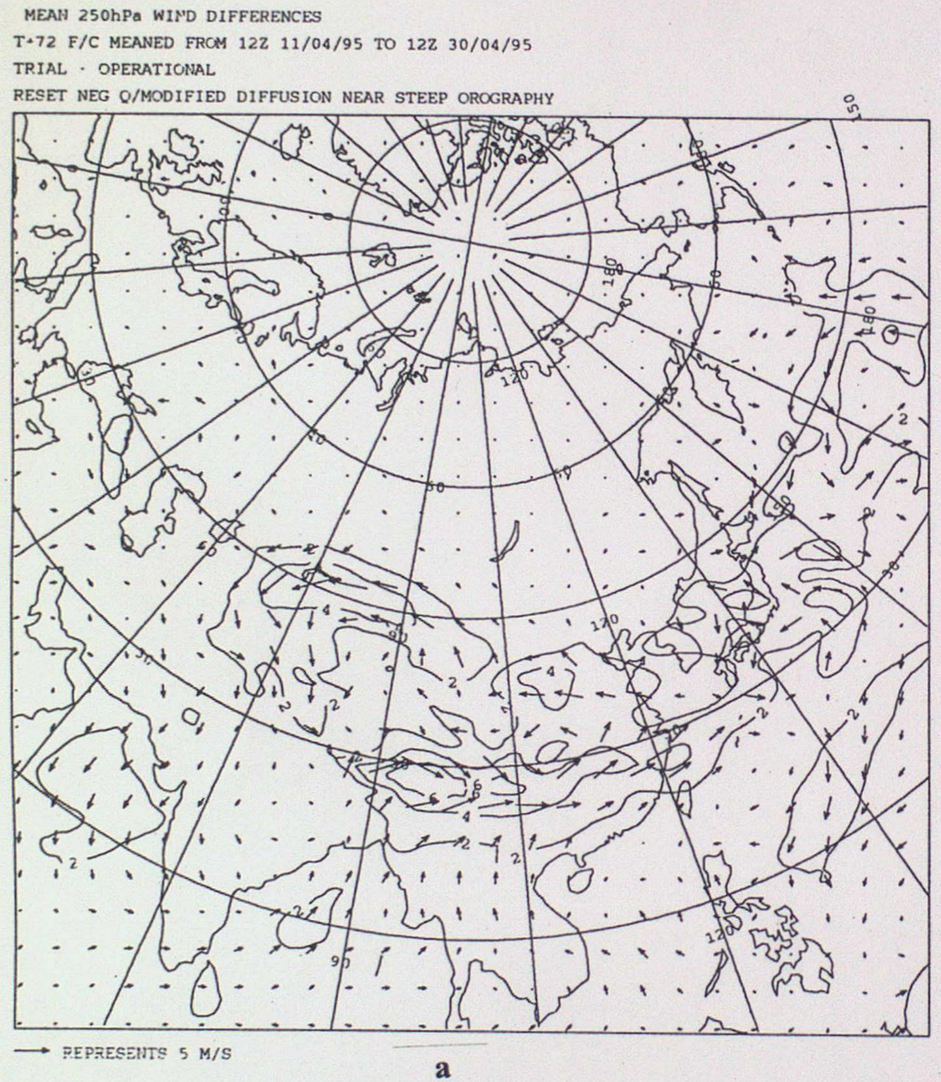
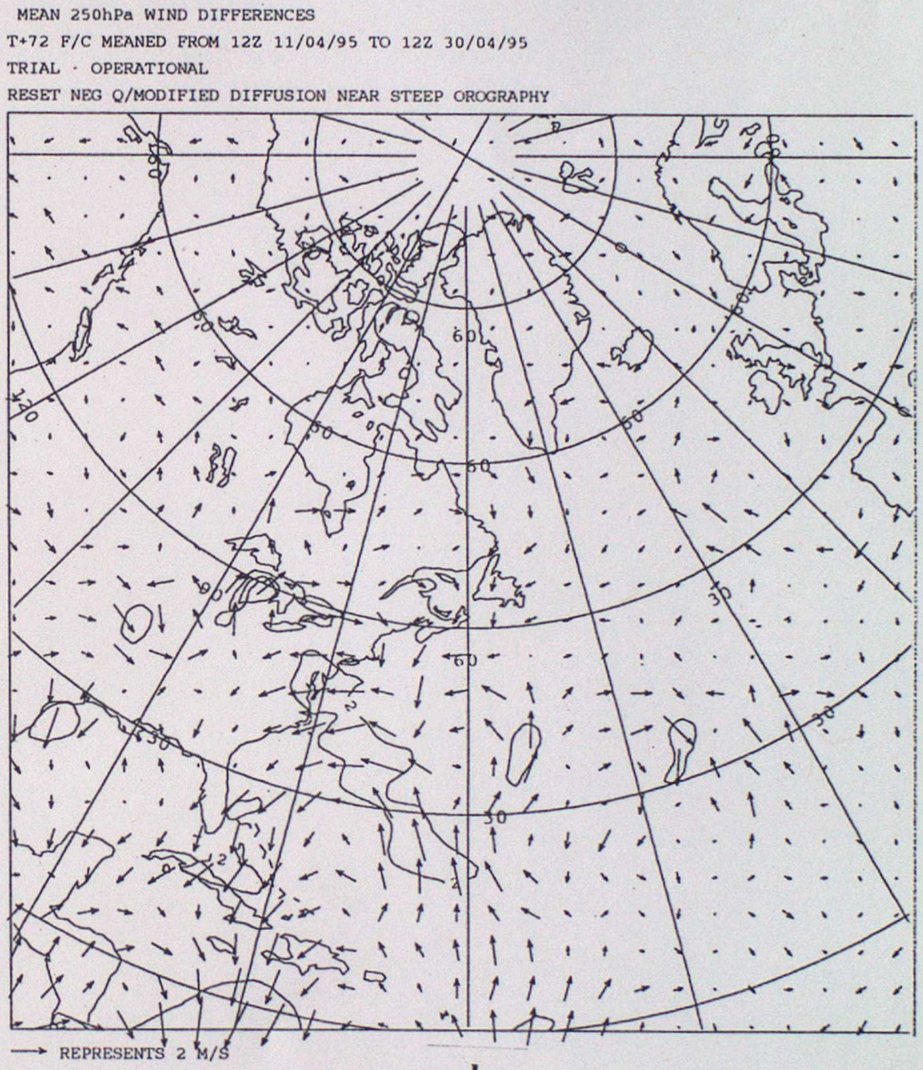

MEAN SEA LEVEL PRESSURE FORECAST AT T+120
PARALLEL SUITE TRIAL
DT 12Z 24/04/95 VT 12Z 29/04/95
RESET NEG Q/MODIFIED HORIZONTAL DIFFUSION NEAR STEEP OROGRAPHY
a
MEAN SEA LEVEL PRESSURE FORECAST AT T+120
OPERATIONAL SUITE
DT 12Z 24/04/95 VT 12Z 29/04/95
OPERATIONAL
b
MEAN SEA LEVEL PRESSURE ANALYSIS
OPERATIONAL SUITE
DT 12Z 29/04/95 VT 12Z 29/04/95
OPERATIONAL
c
MEAN SEA LEVEL PRESSURE DIFFERENCES AT T+120
TRIAL - OPERATIONAL
DT 12Z 24/04/95 VT 12Z 29/04/95
PARALLEL SUITE TRIAL
d

FIGURE 3.3


MEAN 250hPa WIND DIFFERENCES
T+72 F/C MEANED FROM 12Z 11/04/95 TO 12Z 30/04/95
TRIAL - OPERATIONAL
RESET NEG Q/MODIFIED DIFFUSION NEAR STEEP OROGRAPHY
REPRESENTS 5 M/S

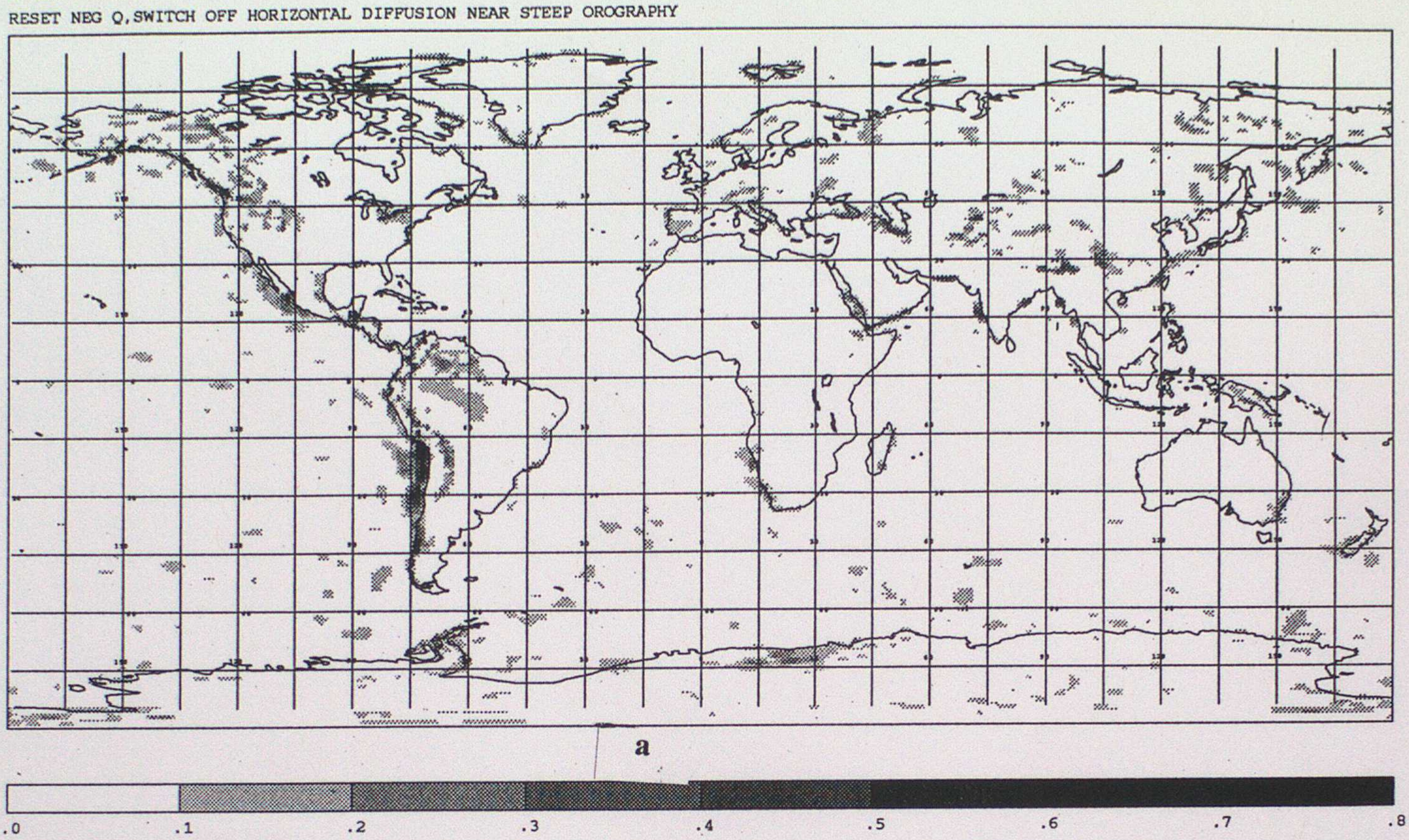
a


MEAN 250hPa WIND DIFFERENCES
T+72 F/C MEANED FROM 12Z 11/04/95 TO 12Z 30/04/95
TRIAL - OPERATIONAL
RESET NEG Q/MODIFIED DIFFUSION NEAR STEEP OROGRAPHY
REPRESENTS 2 M/S

b

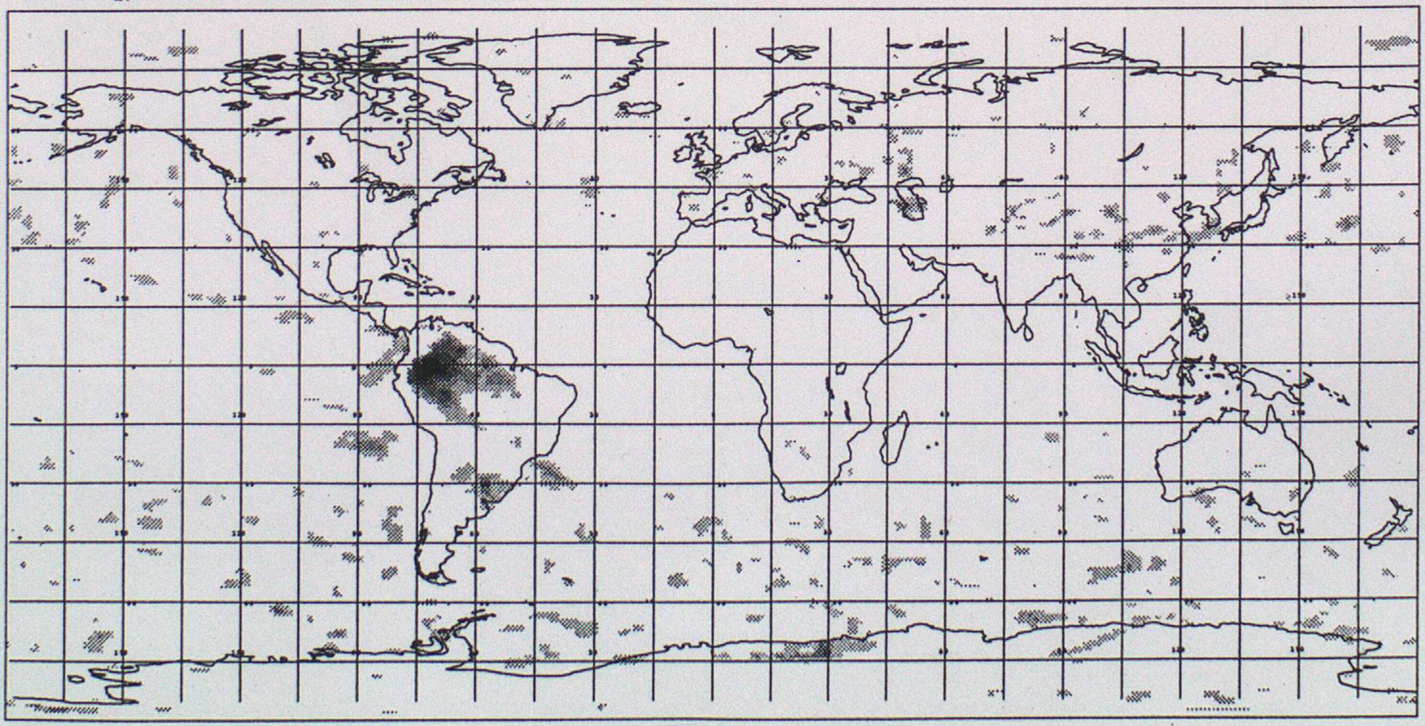
FIGURE 3.4

LOW CLOUD DIFFERENCES T+120 GLOBAL
PARALLEL SUITE TRIAL - OPERATIONAL
T+120 FORECAST MEANED FROM 12Z 13/04/95 TO 12Z 02/05/95
RESET NEG Q,SWITCH OFF HORIZONTAL DIFFUSION NEAR STEEP OROGRAPHY



a

MEDIUM CLOUD DIFFERENCES T+120 GLOBAL
PARALLEL SUITE TRIAL - OPERATIONAL
T+120 FORECAST MEANED FROM 12Z 13/04/95 TO 12Z 02/05/95
RESET NEG Q,SWITCH OFF HORIZONTAL DIFFUSION NEAR STEEP OROGRAPHY



b

FIGURE 3.5

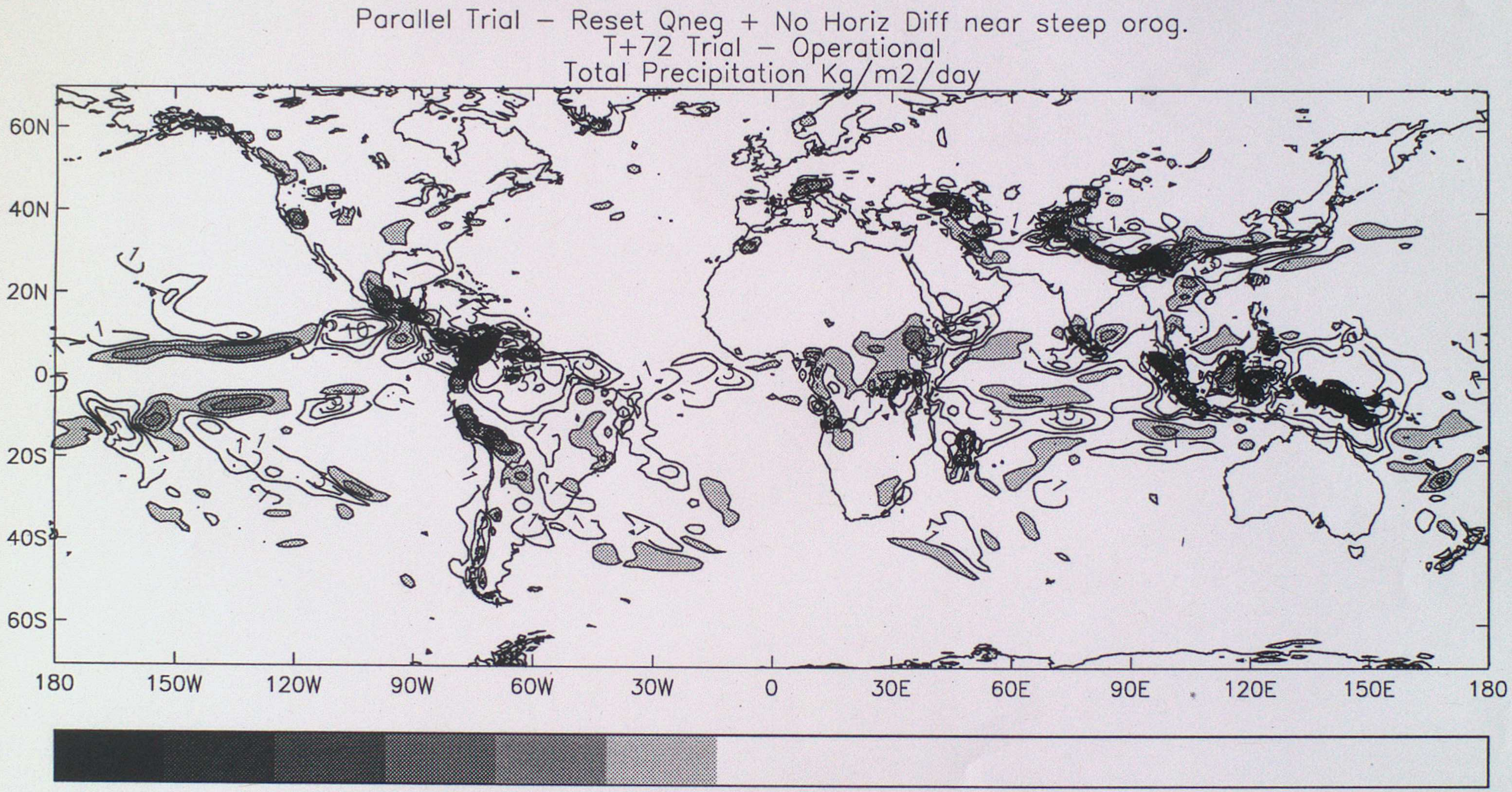
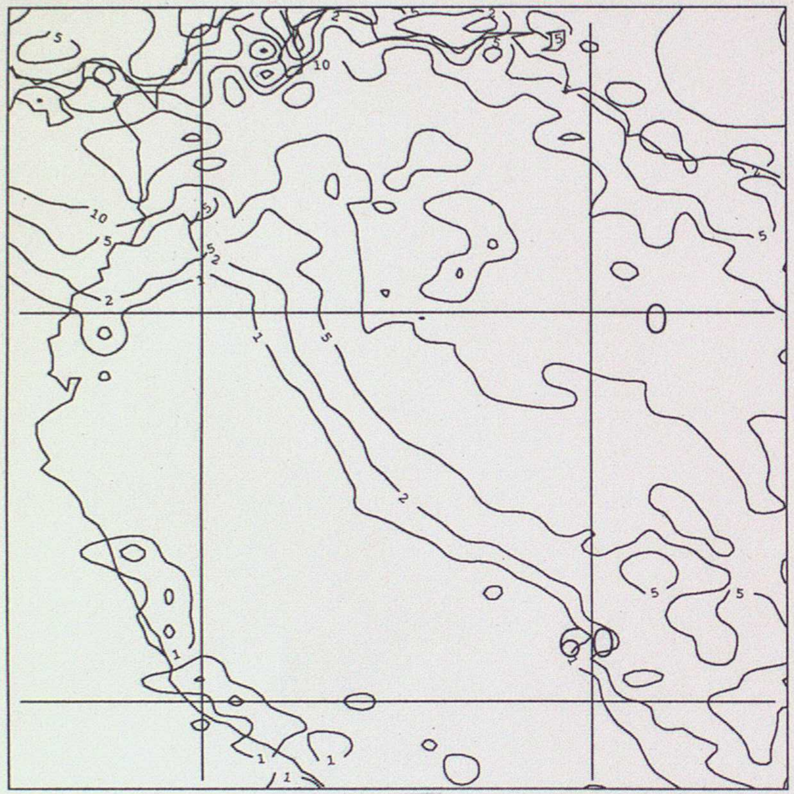

Parallel Trial – Reset Qneg + No Horiz Diff near steep orog.
T+72 Trial – Operational
Total Precipitation Kg/m2/day
60N
40N
20N
0
20S
40S
60S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180
−20
−10
−3
1
5
15

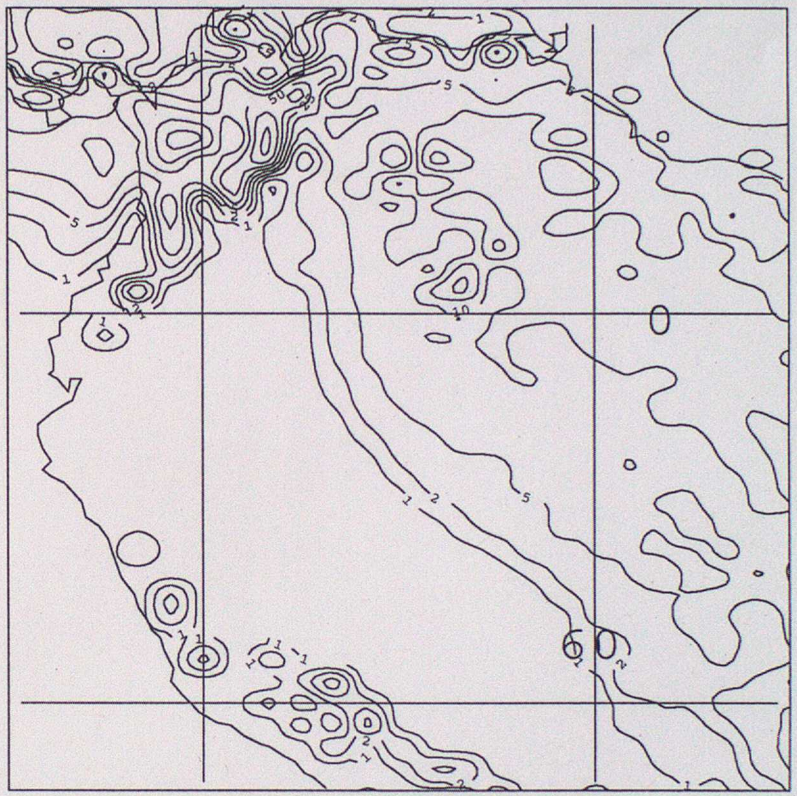
FIGURE 3.6

ACCUMULATED PRECIPITATION T+24 F/C FROM PARALLEL SUITE TRIAL
T+24 FORECAST MEANED FROM 12Z 09/04/95 TO 12Z 28/04/95
RESET NEG Q,SWITCH OFF HORIZONTAL DIFFUSION NEAR STEEP OROGRAPHY
Contours drawn at 1.0,2.0,5.0,10.0,25.0,50.0,100.0,200.0,300.0



a

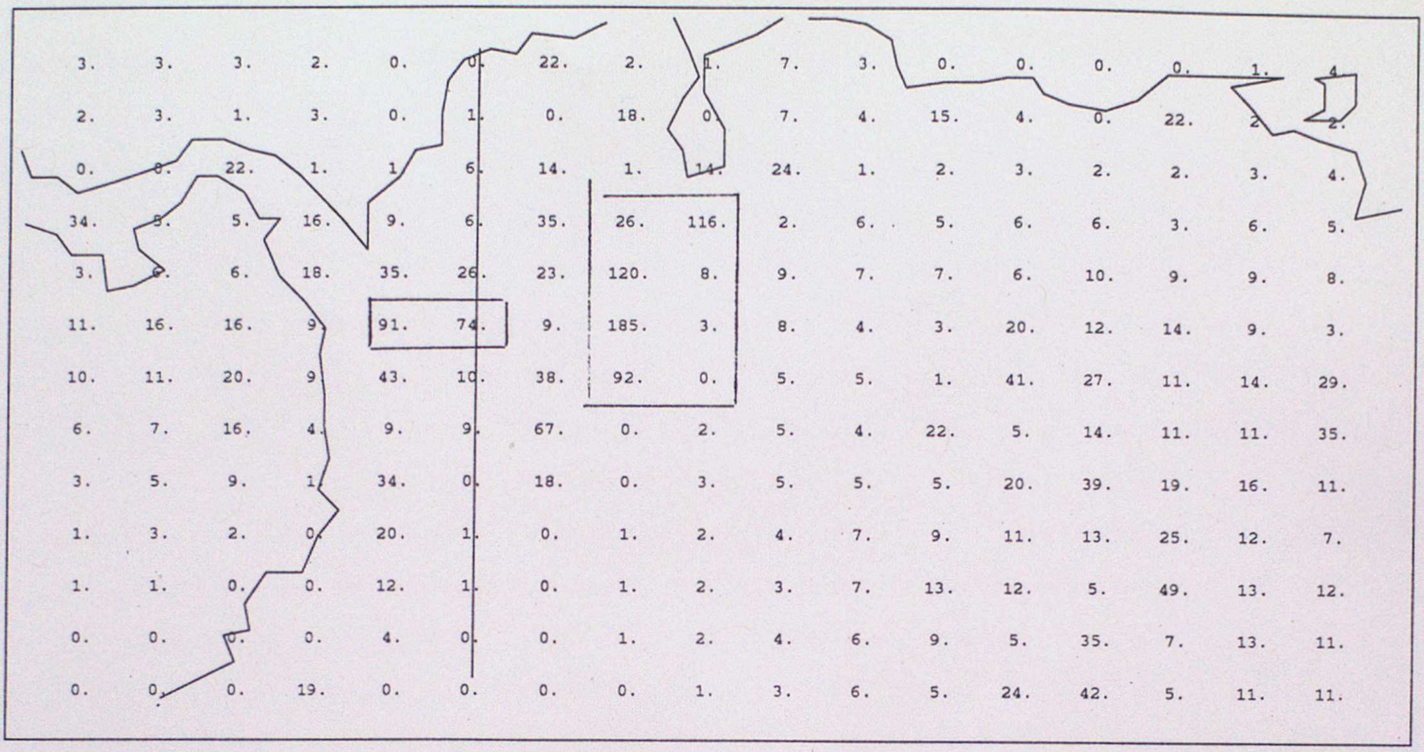
ACCUMULATED PRECIPITATION T+24 F/C from OPERATIONAL SUITE
T+24 FORECAST MEANED FROM 12Z 09/04/95 TO 12Z 28/04/95
OPERATIONAL
Contours drawn at 1.0,2.0,5.0,10.0,25.0,50.0,100.0,200.0,300.0



b

FIGURE 3.7

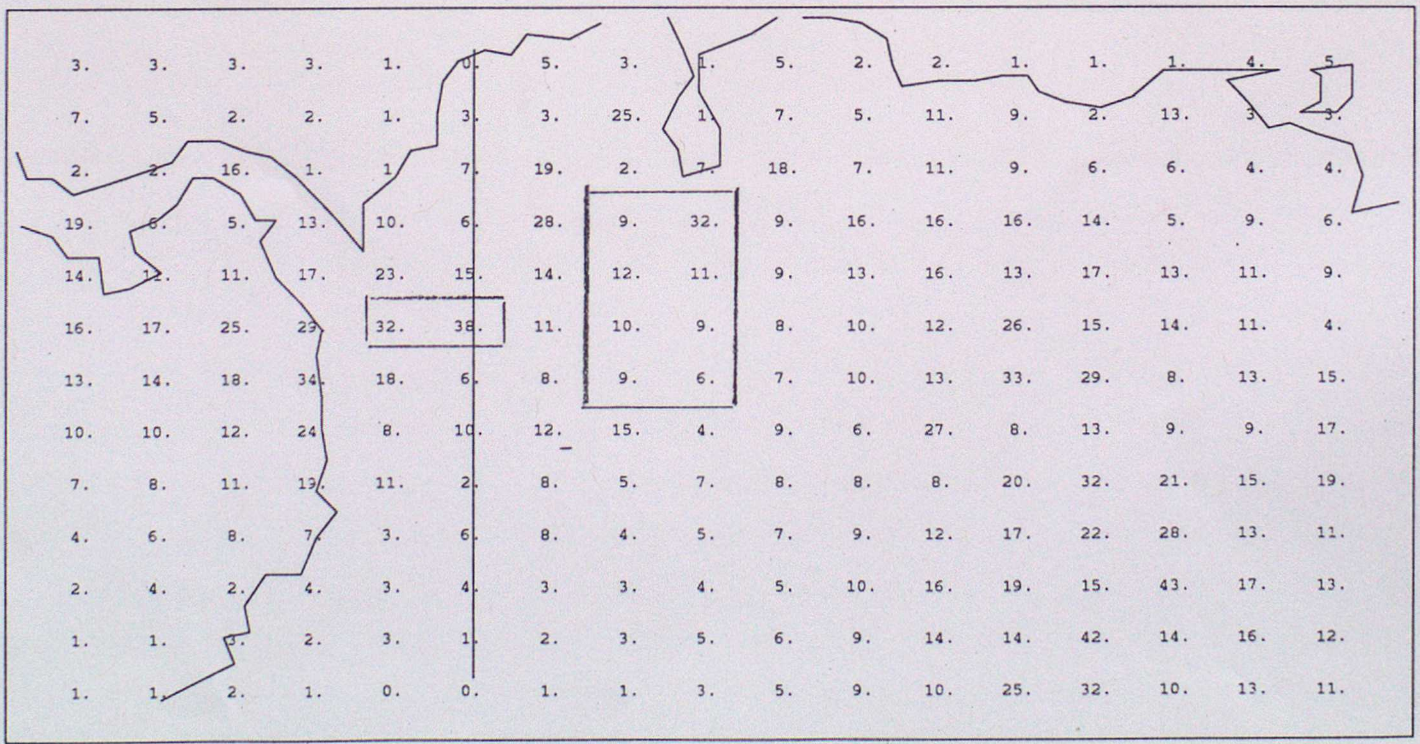
ACCUMULATED PRECIPITATION T+24 F/C from OPERATIONAL SUITE
T+24 FORECAST MEANED FROM 12Z 09/04/95 TO 12Z 28/04/95
OPERATIONAL
ACCUMULATION IN MM/24HRS



3.	3.	3.	2.	0.	0.	22.	2.	1.	7.	3.	0.	0.	0.	0.	1.	4.
2.	3.	1.	3.	0.	1.	0.	18.	0.	7.	4.	15.	4.	0.	22.	2.	2.
0.	8.	22.	1.	1.	6.	14.	1.	14.	24.	1.	2.	3.	2.	2.	3.	4.
34.	5.	5.	16.	9.	6.	35.	26.	116.	2.	6.	5.	6.	6.	3.	6.	5.
3.	6.	6.	18.	35.	26.	23.	120.	8.	9.	7.	7.	6.	10.	9.	9.	8.
11.	16.	16.	9.	91.	74.	9.	185.	3.	8.	4.	3.	20.	12.	14.	9.	3.
10.	11.	20.	9.	43.	10.	38.	92.	0.	5.	5.	1.	41.	27.	11.	14.	29.
6.	7.	16.	4.	9.	9.	67.	0.	2.	5.	4.	22.	5.	14.	11.	11.	35.
3.	5.	9.	1.	34.	0.	18.	0.	3.	5.	5.	5.	20.	39.	19.	16.	11.
1.	3.	2.	0.	20.	1.	0.	1.	2.	4.	7.	9.	11.	13.	25.	12.	7.
1.	1.	0.	0.	12.	1.	0.	1.	2.	3.	7.	13.	12.	5.	49.	13.	12.
0.	0.	0.	0.	4.	0.	0.	1.	2.	4.	6.	9.	5.	35.	7.	13.	11.
0.	0.	0.	19.	0.	0.	0.	0.	1.	3.	6.	5.	24.	42.	5.	11.	11.

a

ACCUMULATED PRECIPITATION T+24 F/C FROM PARALLEL SUITE TRIAL
T+24 FORECAST MEANED FROM 12Z 09/04/95 TO 12Z 28/04/95
RESET NEG Q,SWITCH OFF HORIZONTAL DIFFUSION NEAR STEEP OROGRAPHY
ACCUMULATION IN MM/24HRS



3.	3.	3.	3.	1.	0.	5.	3.	1.	5.	2.	2.	1.	1.	1.	4.	5.
7.	5.	2.	2.	1.	3.	3.	25.	1.	7.	5.	11.	9.	2.	13.	3.	3.
2.	2.	16.	1.	1.	7.	19.	2.	7.	18.	7.	11.	9.	6.	6.	4.	4.
19.	6.	5.	13.	10.	6.	28.	9.	32.	9.	16.	16.	16.	14.	5.	9.	6.
14.	12.	11.	17.	23.	15.	14.	12.	11.	9.	13.	16.	13.	17.	13.	11.	9.
16.	17.	25.	29.	32.	38.	11.	10.	9.	8.	10.	12.	26.	15.	14.	11.	4.
13.	14.	18.	34.	18.	6.	8.	9.	6.	7.	10.	13.	33.	29.	8.	13.	15.
10.	10.	12.	24	8.	10.	12.	15.	4.	9.	6.	27.	8.	13.	9.	9.	17.
7.	8.	11.	19.	11.	2.	8.	5.	7.	8.	8.	8.	20.	32.	21.	15.	19.
4.	6.	8.	7.	3.	6.	8.	4.	5.	7.	9.	12.	17.	22.	28.	13.	11.
2.	4.	2.	4.	3.	4.	3.	3.	4.	5.	10.	16.	19.	15.	43.	17.	13.
1.	1.	3.	2.	3.	1.	2.	3.	5.	6.	9.	14.	14.	42.	14.	16.	12.
1.	1.	2.	1.	0.	0.	1.	1.	3.	5.	9.	10.	25.	32.	10.	13.	11.

b

FIGURE 3.8

ACCUMULATED PRECIPITATION T+72 F/C from OPERATIONAL SUITE
T+72 FORECAST MEANED FROM 12Z 11/04/95 TO 12Z 30/04/95
OPERATIONAL
ACCUMULATION IN MM/72HRS

12.	13.	13.	9.	0.	0.	75.	6.	1.	20.	6.	1.	0.	0.	0.	3.	10.	9.	7.	5.	4.	4.	3.
7.	14.	2.	12.	2.	5.	1.	63.	0.	22.	10.	38.	8.	0.	52.	3.	2.	9.	8.	5.	4.	4.	3.
0.	0.	77.	1.	3.	19.	38.	2.	41.	72.	3.	6.	7.	6.	4.	4.	8.	3.	8.	7.	4.	4.	3.
100.	13.	16.	47.	21.	13.	100.	83.	376.	5.	15.	15.	14.	13.	5.	12.	9.	7.	2.	8.	5.	4.	4.
3.	8.	7.	38.	83.	49.	55.	415.	24.	28.	24.	19.	12.	24.	20.	19.	16.	12.	12.	8.	8.	6.	6.
24.	33.	24.	9.	200.	191.	21.	671.	16.	37.	16.	7.	65.	29.	31.	22.	5.	9.	15.	4.	10.	11.	11.
27.	27.	37.	10.	89.	16.	146.	385.	8.	27.	18.	4.	116.	75.	21.	29.	64.	14.	11.	11.	8.	10.	3.
19.	19.	35.	5.	20.	25.	262.	8.	15.	21.	15.	75.	13.	37.	22.	20.	83.	55.	11.	9.	8.	10.	22.
10.	14.	23.	1.	107.	1.	90.	1.	14.	20.	19.	15.	59.	110.	50.	37.	23.	21.	14.	15.	20.	7.	8.
4.	12.	9.	0.	75.	7.	4.	5.	9.	15.	24.	30.	32.	29.	65.	23.	16.	20.	37.	14.	37.	8.	11.
2.	5.	0.	1.	76.	22.	3.	6.	9.	14.	22.	42.	35.	14.	142.	29.	29.	42.	28.	18.	28.	38.	12.
1.	1.	[illegible]	12.	47.	0.	4.	8.	12.	15.	22.	30.	14.	105.	18.	33.	31.	36.	65.	39.	32.	22.	12.
0.	0.	0.	151.	1.	2.	4.	5.	9.	15.	20.	17.	69.	133.	14.	30.	32.	27.	44.	45.	25.	34.	23.

a

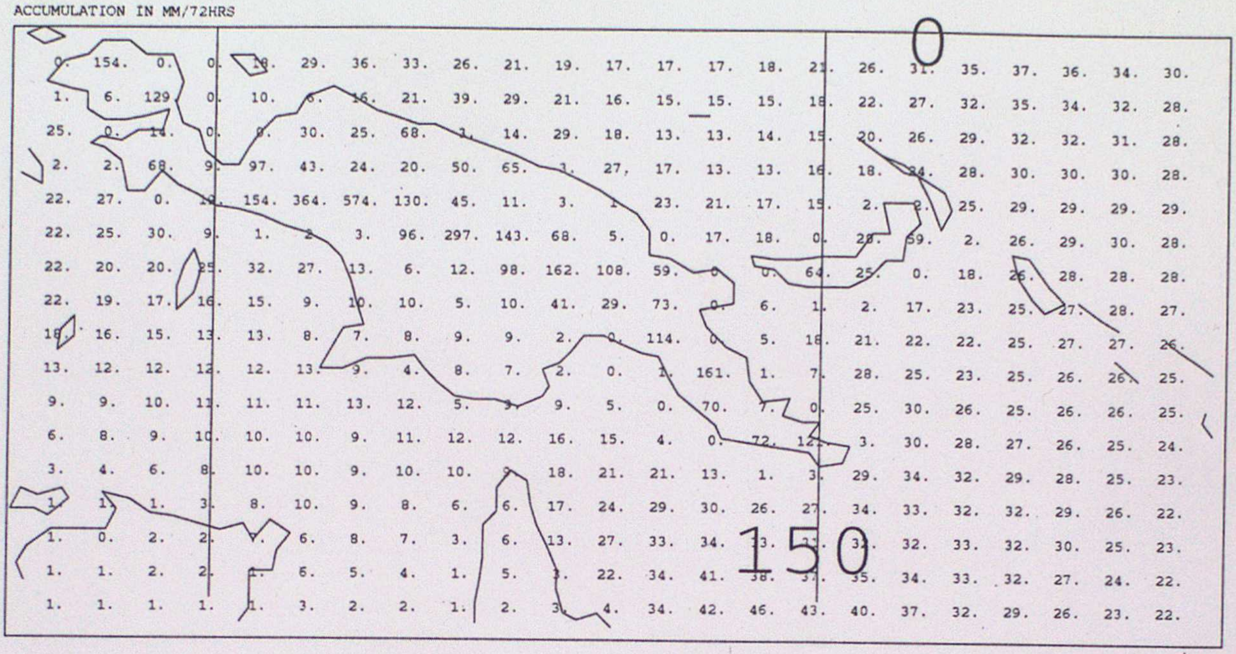
ACCUMULATED PRECIPITATION T+72 F/C FROM PARALLEL SUITE TRIAL
T+72 FORECAST MEANED FROM 12Z 11/04/95 TO 12Z 30/04/95
RESET NEG Q,SWITCH OFF HORIZONTAL DIFFUSION NEAR STEEP OROGRAPHY
ACCUMULATION IN MM/72HRS

13.	13.	12.	13.	6.	0.	15.	7.	3.	13.	5.	4.	2.	2.	2.	9.	13.	11.	8.	6.	5.	4.	3.
24.	17.	7.	8.	3.	14.	9.	83.	1.	14.	9.	21.	15.	2.	28.	6.	6.	13.	10.	7.	5.	4.	3.
5.	5.	51.	3.	2.	22.	55.	4.	16.	32.	17.	22.	17.	12.	10.	8.	10.	5.	10.	7.	4.	4.	3.
51.	17.	14.	37.	28.	18.	80.	22.	71.	19.	37.	30.	29.	26.	11.	19.	13.	9.	3.	8.	6.	4.	4.
38.	28.	22.	44.	57.	38.	32.	29.	22.	22.	30.	34.	26.	39.	30.	27.	22.	15.	10.	7.	8.	7.	6.
47.	40.	46.	50.	58.	80.	21.	23.	22.	21.	23.	27.	59.	36.	36.	31.	8.	10.	13.	3.	9.	10.	11.
39.	32.	33.	69.	36.	10.	21.	22.	18.	18.	25.	28.	72.	69.	23.	33.	40.	18.	12.	11.	8.	10.	3.
29.	25.	25.	53.	17.	23.	26.	37.	12.	22.	16.	72.	21.	37.	26.	21.	42.	37.	12.	11.	10.	11.	26.
19.	20.	24.	41.	31.	5.	22.	14.	20.	22.	21.	19.	52.	86.	53.	42.	47.	21.	15.	17.	24.	9.	12.
11.	16.	21.	15.	10.	19.	28.	11.	16.	20.	26.	30.	37.	51.	68.	32.	26.	23.	44.	16.	43.	10.	14.
6.	13.	6.	7.	11.	13.	15.	11.	16.	19.	27.	39.	41.	31.	104.	41.	34.	48.	34.	22.	31.	47.	17.
3.	3.	[illegible]	6.	11.	12.	10.	14.	22.	20.	24.	36.	28.	110.	32.	44.	37.	40.	67.	45.	39.	27.	17.
1.	1.	5.	6.	9.	3.	7.	11.	14.	20.	25.	23.	64.	75.	23.	33.	33.	30.	46.	49.	34.	44.	30.

b

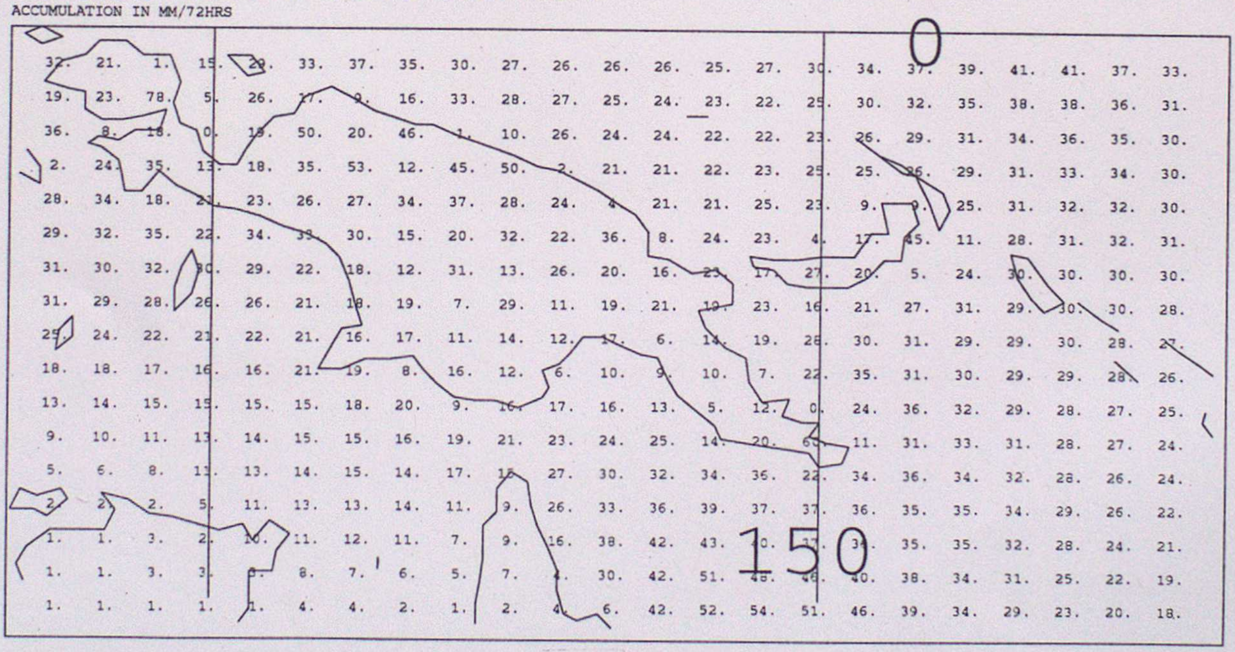
FIGURE 3.9

ACCUMULATED PRECIPITATION T+72 F/C from OPERATIONAL SUITE
T+72 FORECAST MEANED FROM 12Z 11/04/95 TO 12Z 30/04/95
OPERATIONAL
ACCUMULATION IN MM/72HRS



a

ACCUMULATED PRECIPITATION T+72 F/C FROM PARALLEL SUITE TRIAL
T+72 FORECAST MEANED FROM 12Z 11/04/95 TO 12Z 30/04/95
RESET NEG Q,SWITCH OFF HORIZONTAL DIFFUSION NEAR STEEP OROGRAPHY
ACCUMULATION IN MM/72HRS



b

FIGURE 3.10

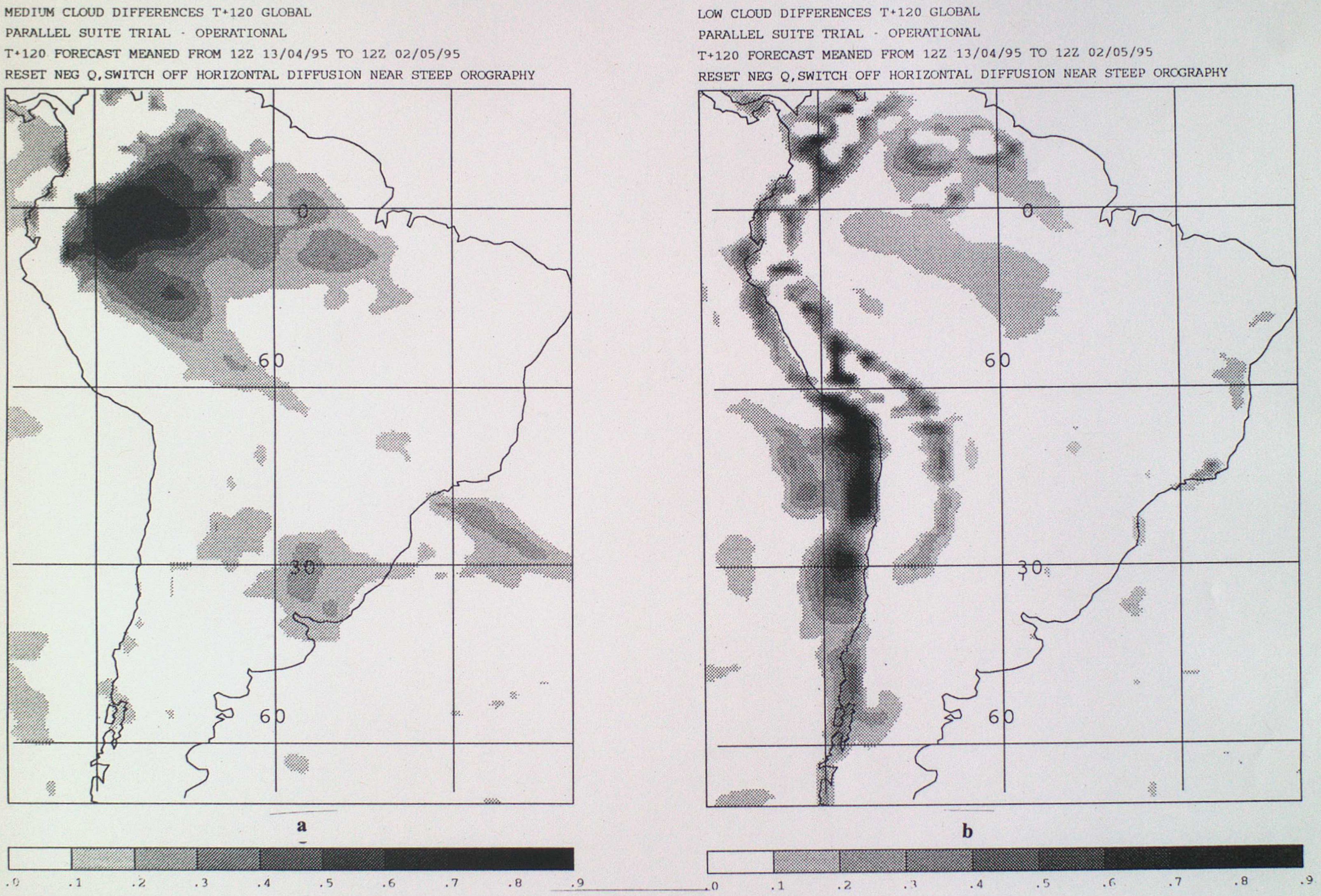

MEDIUM CLOUD DIFFERENCES T+120 GLOBAL
PARALLEL SUITE TRIAL - OPERATIONAL
T+120 FORECAST MEANED FROM 12Z 13/04/95 TO 12Z 02/05/95
RESET NEG Q,SWITCH OFF HORIZONTAL DIFFUSION NEAR STEEP OROGRAPHY
0
60
30
60
a
.0
.1
.2
.3
.4
.5
.6
.7
.8
.9
LOW CLOUD DIFFERENCES T+120 GLOBAL
PARALLEL SUITE TRIAL - OPERATIONAL
T+120 FORECAST MEANED FROM 12Z 13/04/95 TO 12Z 02/05/95
RESET NEG Q,SWITCH OFF HORIZONTAL DIFFUSION NEAR STEEP OROGRAPHY
0
60
30
60
b
.0
.1
.2
.3
.4
.5
.6
.7
.8
.9

FIGURE 3.11

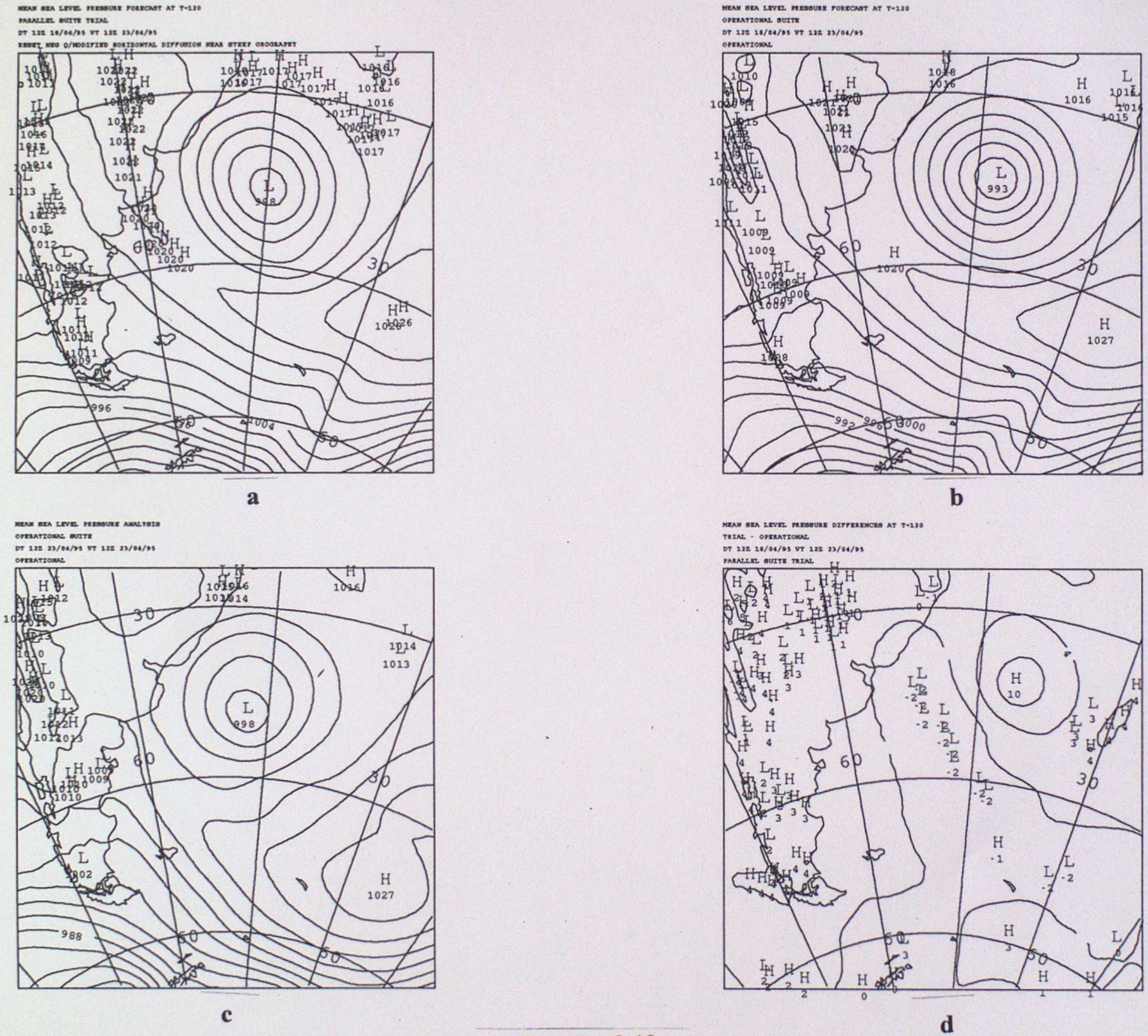

MEAN SEA LEVEL PRESSURE FORECAST AT T+120
PARALLEL SUITE TRIAL
DT 12Z 18/04/95 VT 12Z 23/04/95
RESET NEG Q/MODIFIED HORIZONTAL DIFFUSION NEAR STEEP OROGRAPHY
a
MEAN SEA LEVEL PRESSURE FORECAST AT T+120
OPERATIONAL SUITE
DT 12Z 18/04/95 VT 12Z 23/04/95
OPERATIONAL
b
MEAN SEA LEVEL PRESSURE ANALYSIS
OPERATIONAL SUITE
DT 12Z 23/04/95 VT 12Z 23/04/95
OPERATIONAL
c
MEAN SEA LEVEL PRESSURE DIFFERENCES AT T+120
TRIAL - OPERATIONAL
DT 12Z 18/04/95 VT 12Z 23/04/95
PARALLEL SUITE TRIAL
d

FIGURE 3.12

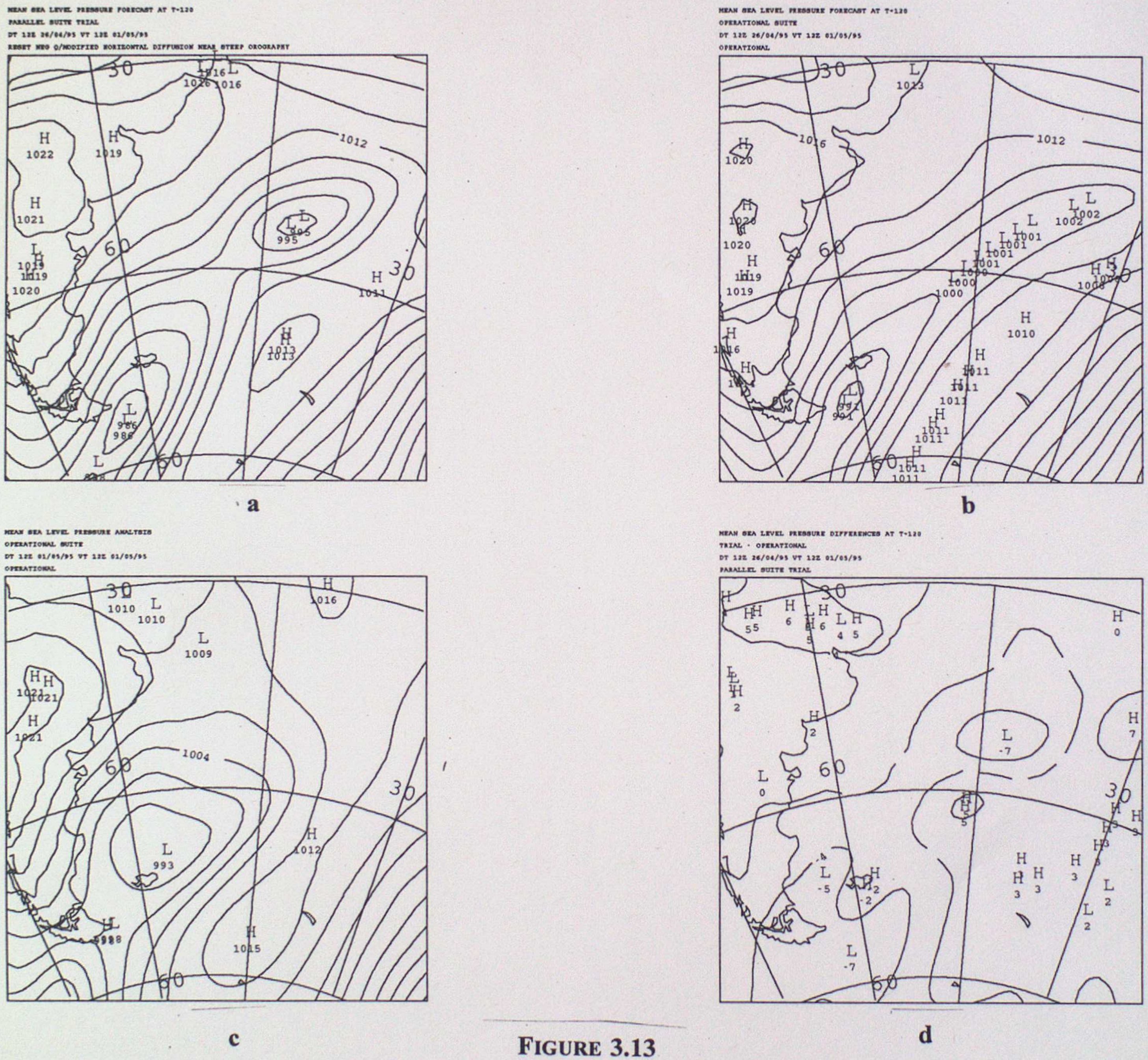

MEAN SEA LEVEL PRESSURE FORECAST AT T+120
PARALLEL SUITE TRIAL
DT 12Z 26/04/95 VT 12Z 01/05/95
RESET NEG Q/MODIFIED HORIZONTAL DIFFUSION NEAR STEEP OROGRAPHY
a
MEAN SEA LEVEL PRESSURE FORECAST AT T+120
OPERATIONAL SUITE
DT 12Z 26/04/95 VT 12Z 01/05/95
OPERATIONAL
b
MEAN SEA LEVEL PRESSURE ANALYSIS
OPERATIONAL SUITE
DT 12Z 01/05/95 VT 12Z 01/05/95
OPERATIONAL
c
MEAN SEA LEVEL PRESSURE DIFFERENCES AT T+120
TRIAL - OPERATIONAL
DT 12Z 26/04/95 VT 12Z 01/05/95
PARALLEL SUITE TRIAL
d

FIGURE 3.13

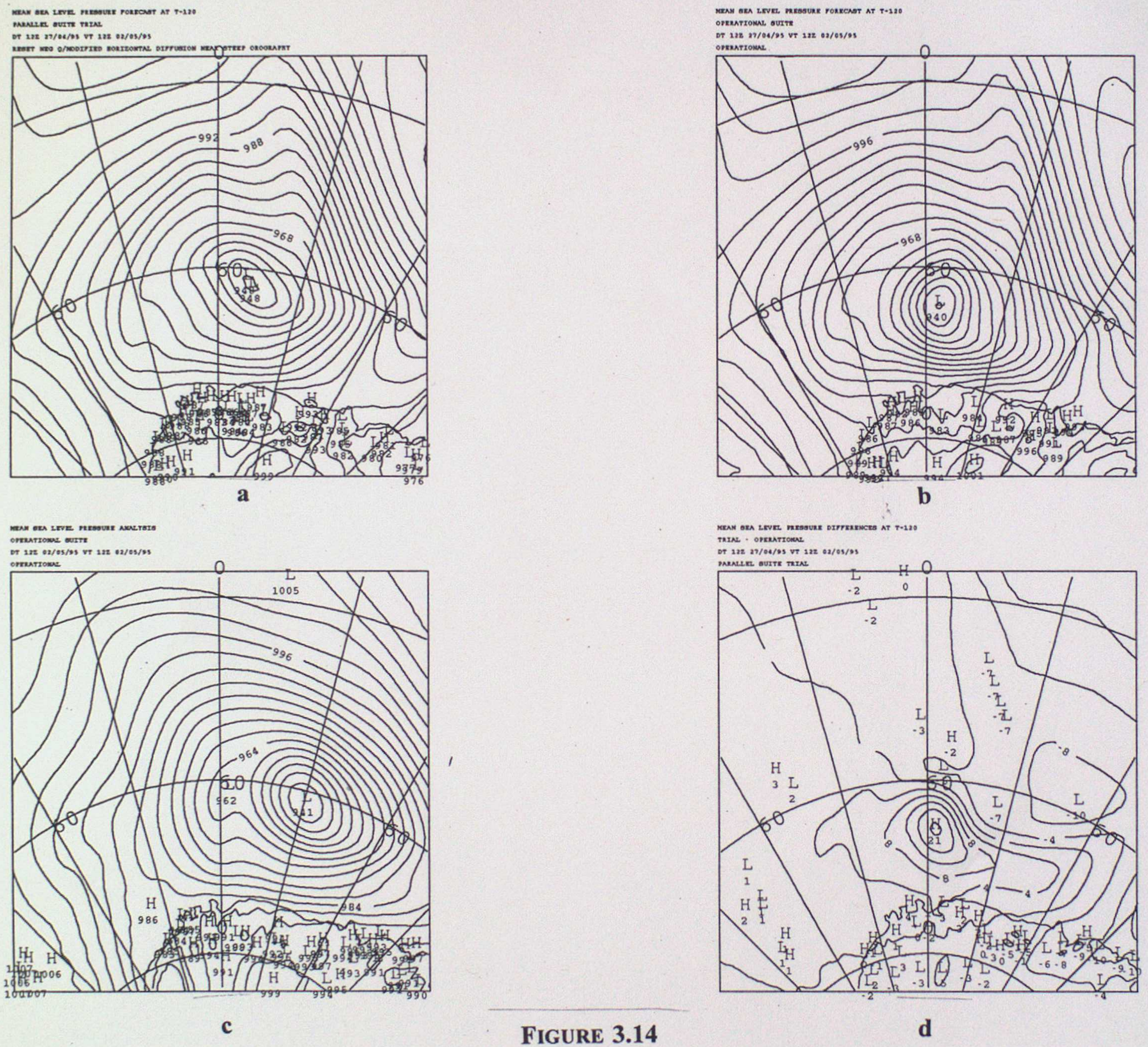
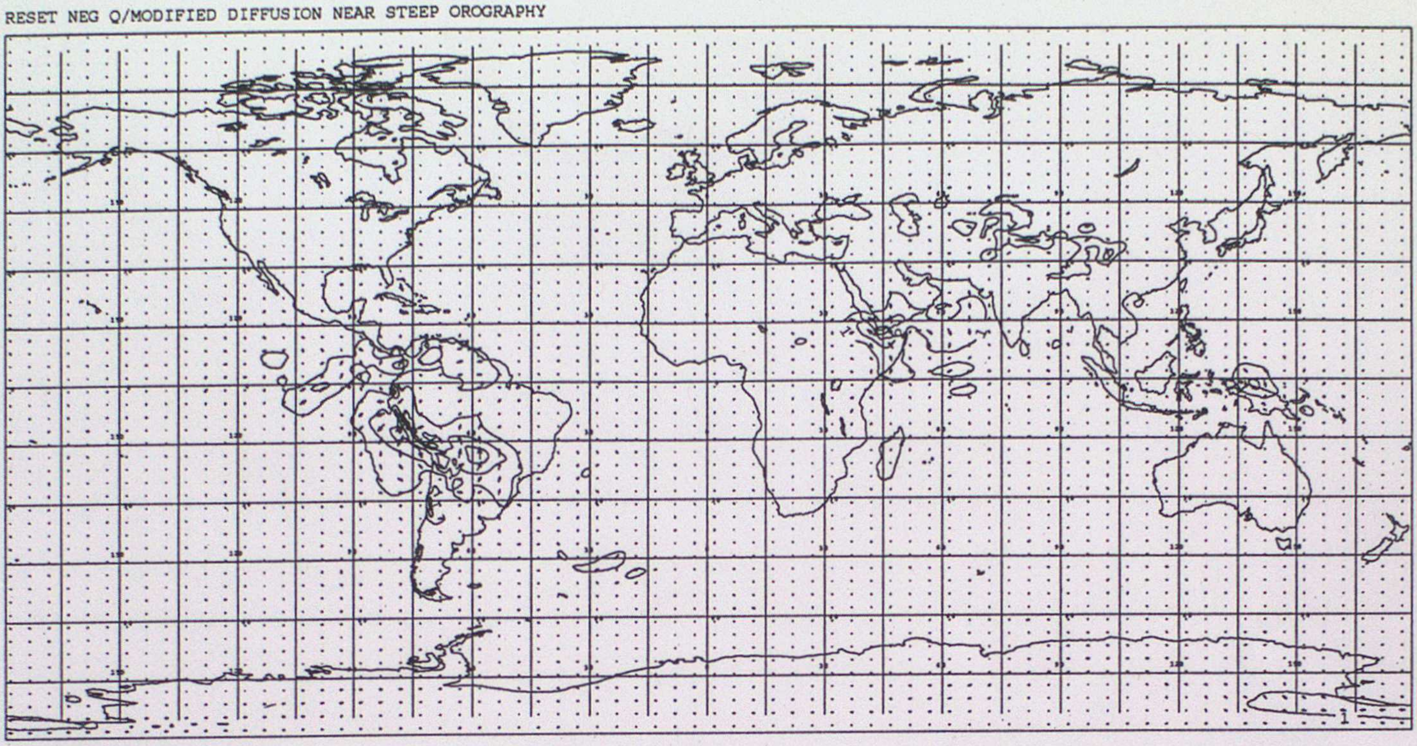

MEAN SEA LEVEL PRESSURE FORECAST AT T+120
PARALLEL SUITE TRIAL
DT 12Z 27/04/95 VT 12Z 02/05/95
RESET NEG Q/MODIFIED HORIZONTAL DIFFUSION NEAR STEEP OROGRAPHY
a
MEAN SEA LEVEL PRESSURE FORECAST AT T+120
OPERATIONAL SUITE
DT 12Z 27/04/95 VT 12Z 02/05/95
OPERATIONAL
b
MEAN SEA LEVEL PRESSURE ANALYSIS
OPERATIONAL SUITE
DT 12Z 02/05/95 VT 12Z 02/05/95
OPERATIONAL
c
MEAN SEA LEVEL PRESSURE DIFFERENCES AT T+120
TRIAL - OPERATIONAL
DT 12Z 27/04/95 VT 12Z 02/05/95
PARALLEL SUITE TRIAL
d

FIGURE 3.14

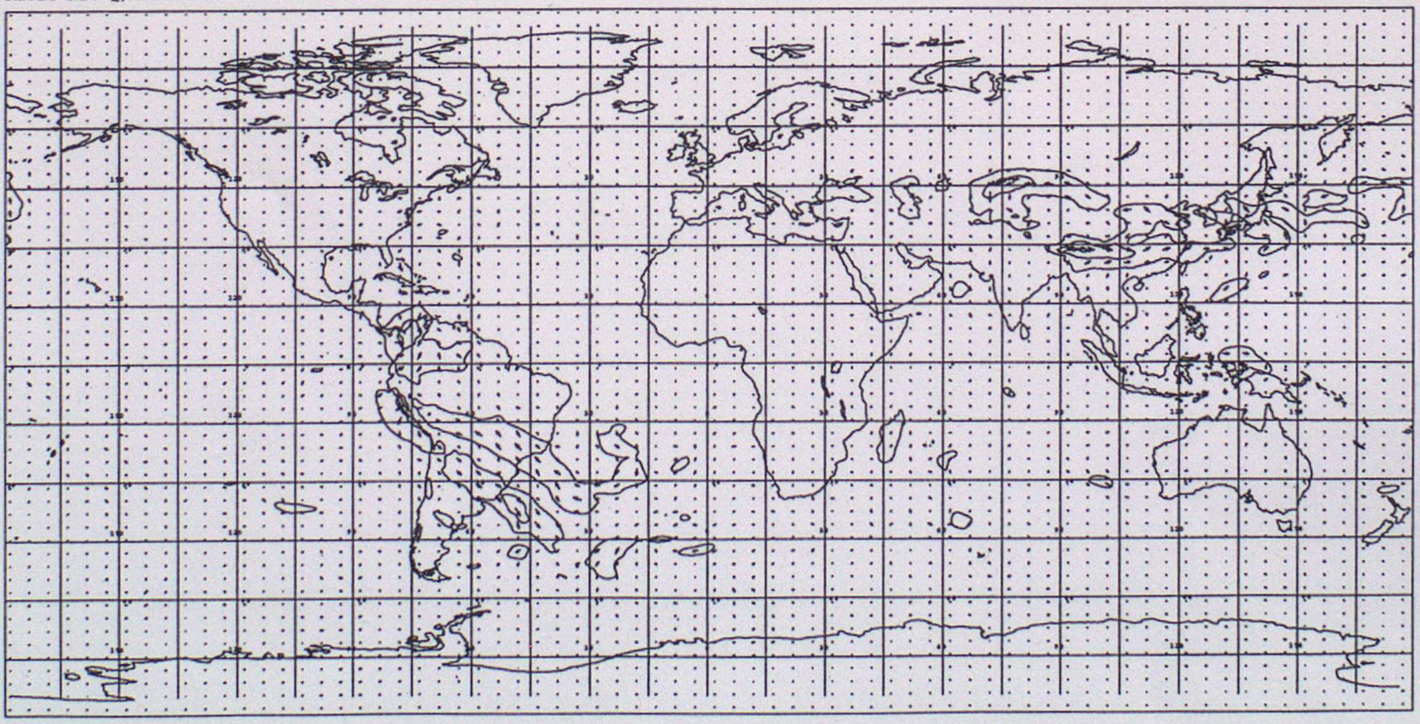
MEAN 250hPa WIND DIFFERENCES
T+00 F/C MEANED FROM 12Z 08/04/95 TO 12Z 27/04/95
TRIAL - OPERATIONAL
RESET NEG Q/MODIFIED DIFFUSION NEAR STEEP OROGRAPHY



⟶ REPRESENTS 10 M/S

a

MEAN 250hPa WIND DIFFERENCES
T+72 F/C MEANED FROM 12Z 11/04/95 TO 12Z 30/04/95
TRIAL - OPERATIONAL
RESET NEG Q/MODIFIED DIFFUSION NEAR STEEP OROGRAPHY



⟶ REPRESENTS 20 M/S

b

FIGURE 3.15

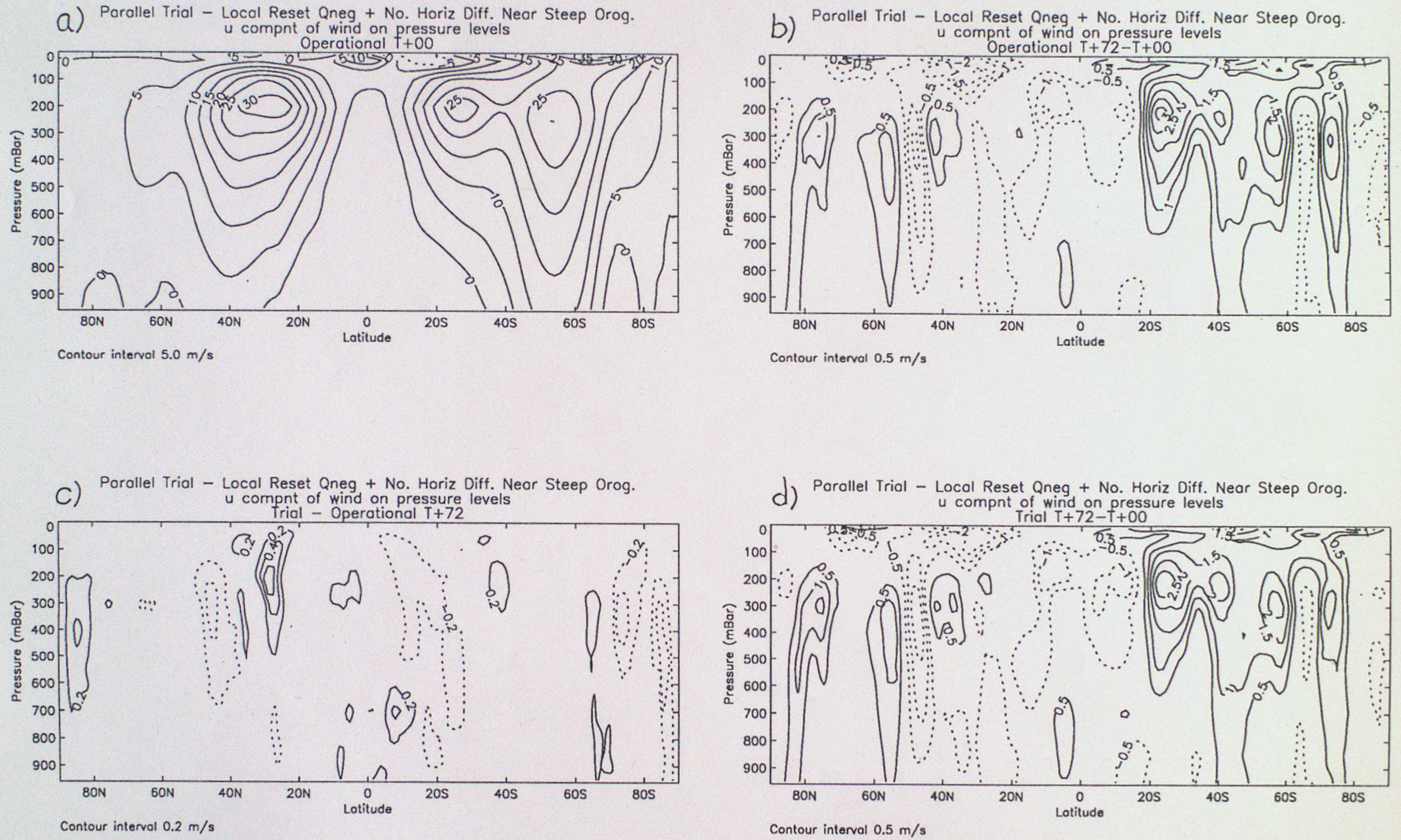

a)
Parallel Trial – Local Reset Qneg + No. Horiz Diff. Near Steep Orog.
u compnt of wind on pressure levels
Operational T+00
Pressure (mBar)
Latitude
Contour interval 5.0 m/s
b)
Parallel Trial – Local Reset Qneg + No. Horiz Diff. Near Steep Orog.
u compnt of wind on pressure levels
Operational T+72–T+00
Pressure (mBar)
Latitude
Contour interval 0.5 m/s
c)
Parallel Trial – Local Reset Qneg + No. Horiz Diff. Near Steep Orog.
u compnt of wind on pressure levels
Trial – Operational T+72
Pressure (mBar)
Latitude
Contour interval 0.2 m/s
d)
Parallel Trial – Local Reset Qneg + No. Horiz Diff. Near Steep Orog.
u compnt of wind on pressure levels
Trial T+72–T+00
Pressure (mBar)
Latitude
Contour interval 0.5 m/s

Figure 4.1

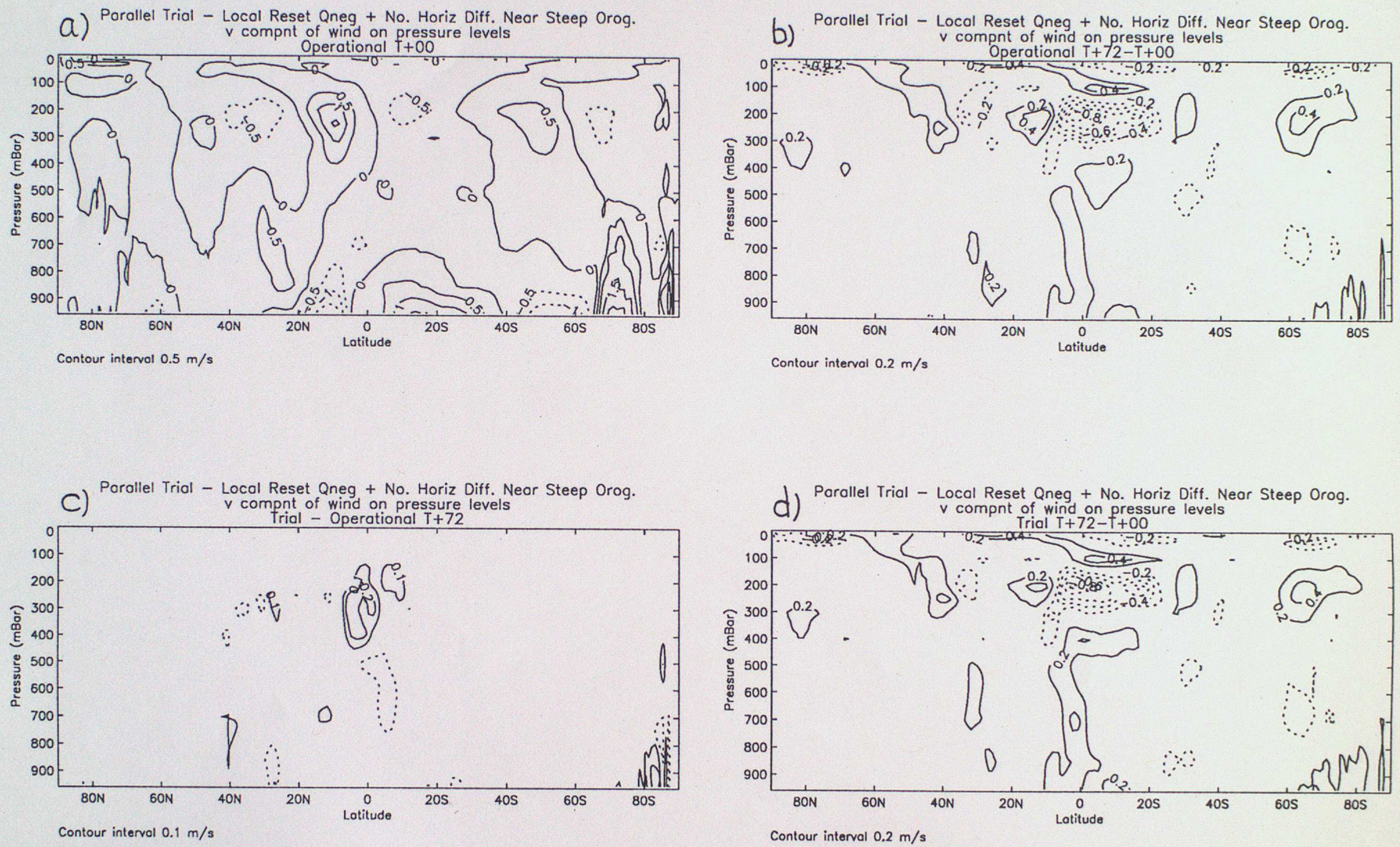

a)
Parallel Trial – Local Reset Qneg + No. Horiz Diff. Near Steep Orog.
v compnt of wind on pressure levels
Operational T+00
Pressure (mBar)
Latitude
Contour interval 0.5 m/s
b)
Parallel Trial – Local Reset Qneg + No. Horiz Diff. Near Steep Orog.
v compnt of wind on pressure levels
Operational T+72–T+00
Pressure (mBar)
Latitude
Contour interval 0.2 m/s
c)
Parallel Trial – Local Reset Qneg + No. Horiz Diff. Near Steep Orog.
v compnt of wind on pressure levels
Trial – Operational T+72
Pressure (mBar)
Latitude
Contour interval 0.1 m/s
d)
Parallel Trial – Local Reset Qneg + No. Horiz Diff. Near Steep Orog.
v compnt of wind on pressure levels
Trial T+72–T+00
Pressure (mBar)
Latitude
Contour interval 0.2 m/s

Figure 4.2

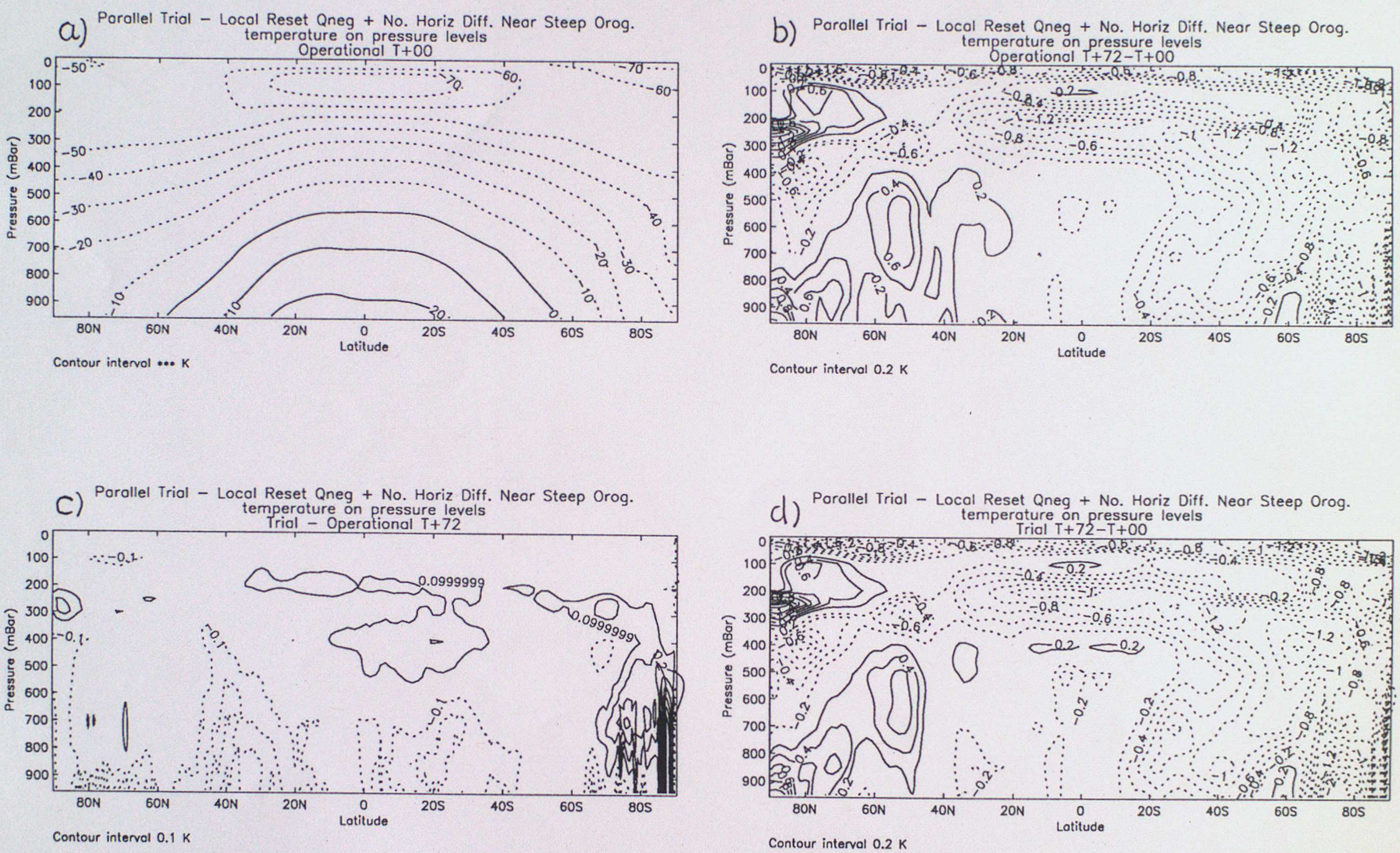
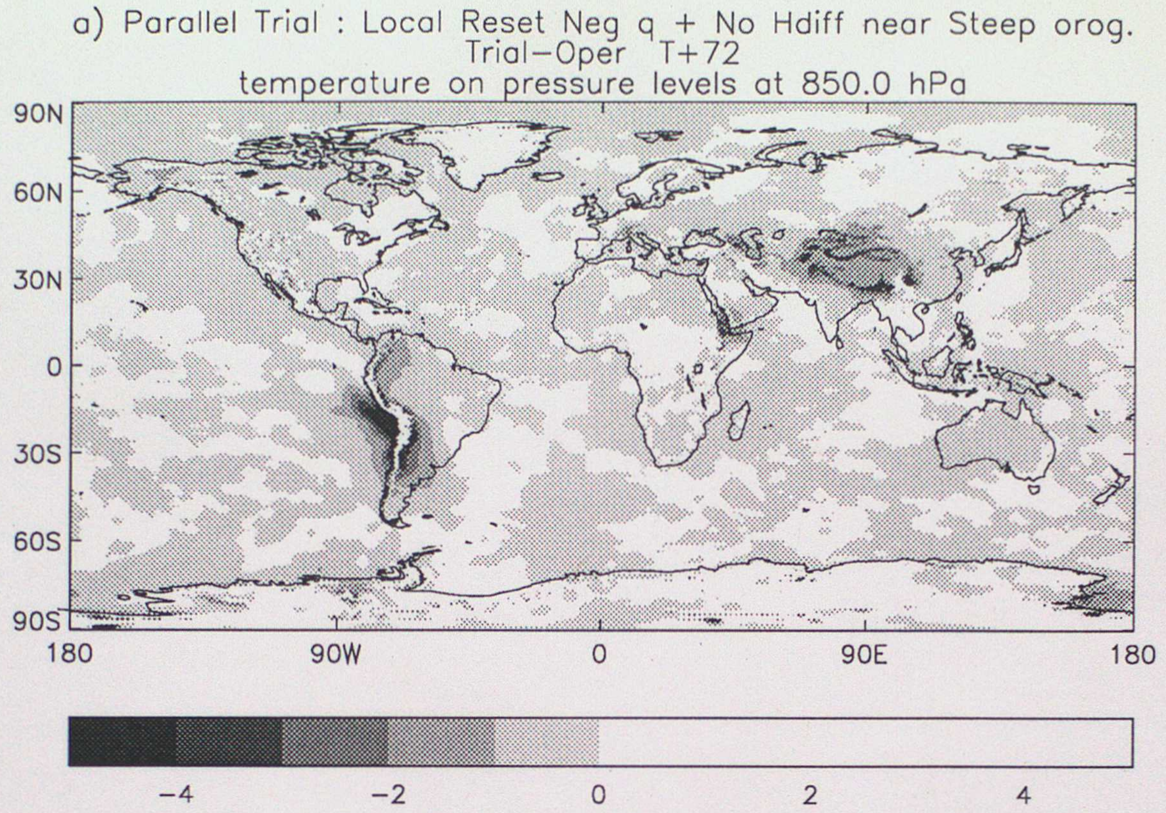

a)
Parallel Trial – Local Reset Qneg + No. Horiz Diff. Near Steep Orog.
temperature on pressure levels
Operational T+00
Pressure (mBar)
Latitude
Contour interval ••• K
b)
Parallel Trial – Local Reset Qneg + No. Horiz Diff. Near Steep Orog.
temperature on pressure levels
Operational T+72–T+00
Pressure (mBar)
Latitude
Contour interval 0.2 K
c)
Parallel Trial – Local Reset Qneg + No. Horiz Diff. Near Steep Orog.
temperature on pressure levels
Trial – Operational T+72
Pressure (mBar)
Latitude
Contour interval 0.1 K
d)
Parallel Trial – Local Reset Qneg + No. Horiz Diff. Near Steep Orog.
temperature on pressure levels
Trial T+72–T+00
Pressure (mBar)
Latitude
Contour interval 0.2 K

Figure 4.3


a) Parallel Trial : Local Reset Neg q + No Hdiff near Steep orog.
Trial–Oper T+72
temperature on pressure levels at 850.0 hPa
90N
60N
30N
0
30S
60S
90S
180
90W
0
90E
180
−4
−2
0
2
4

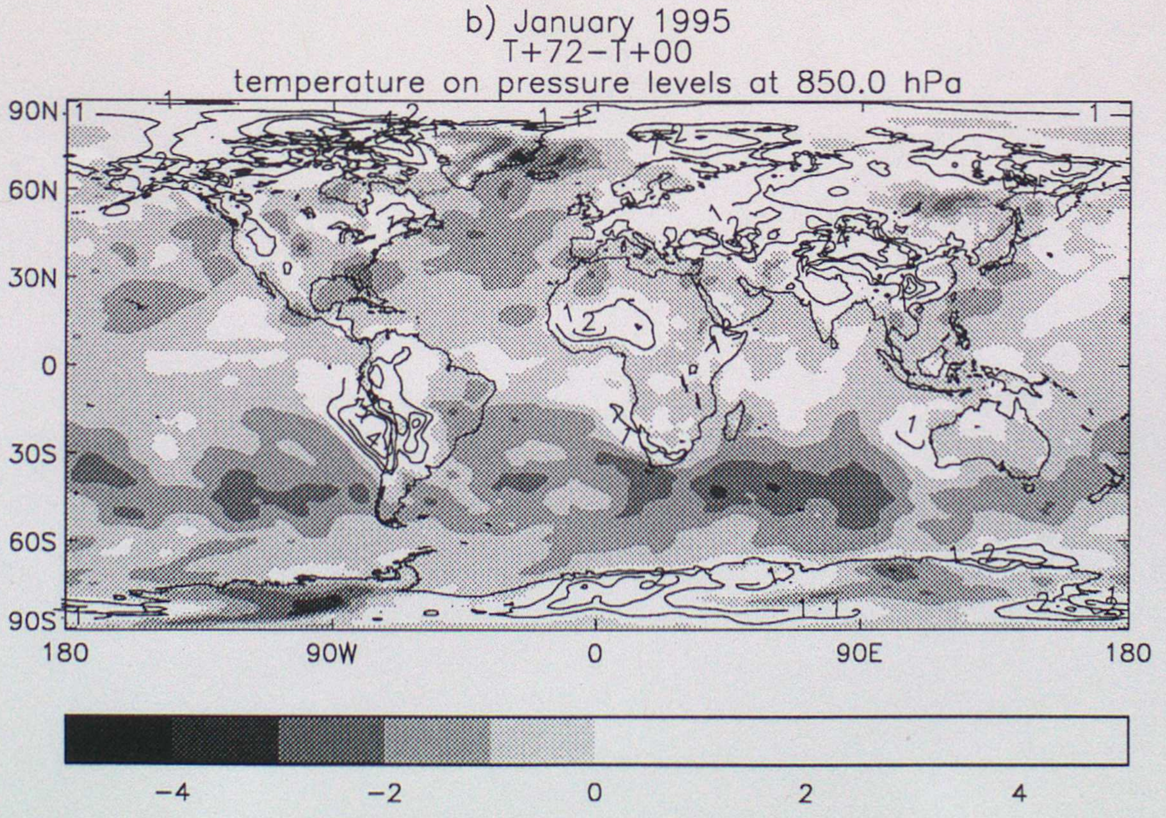
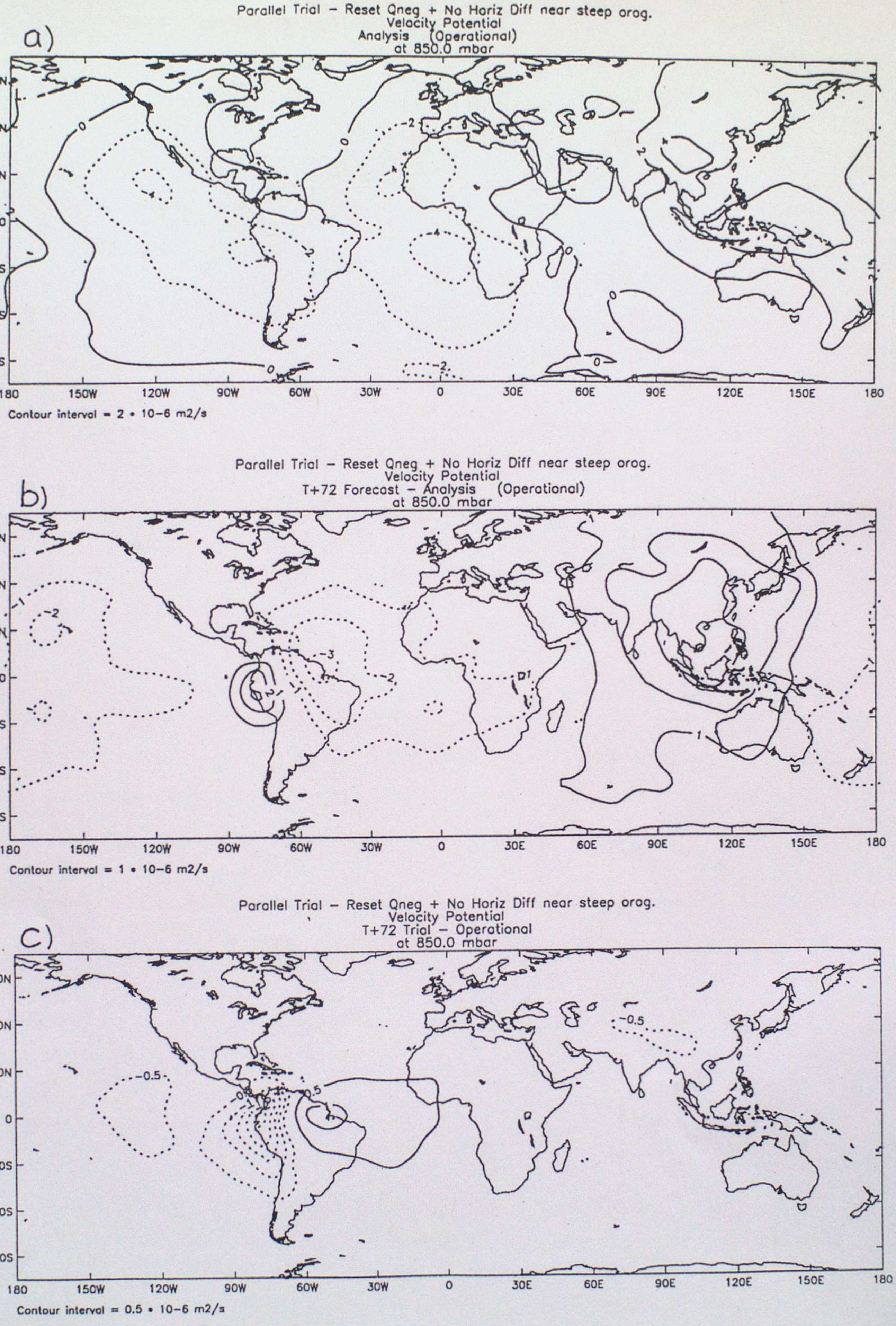
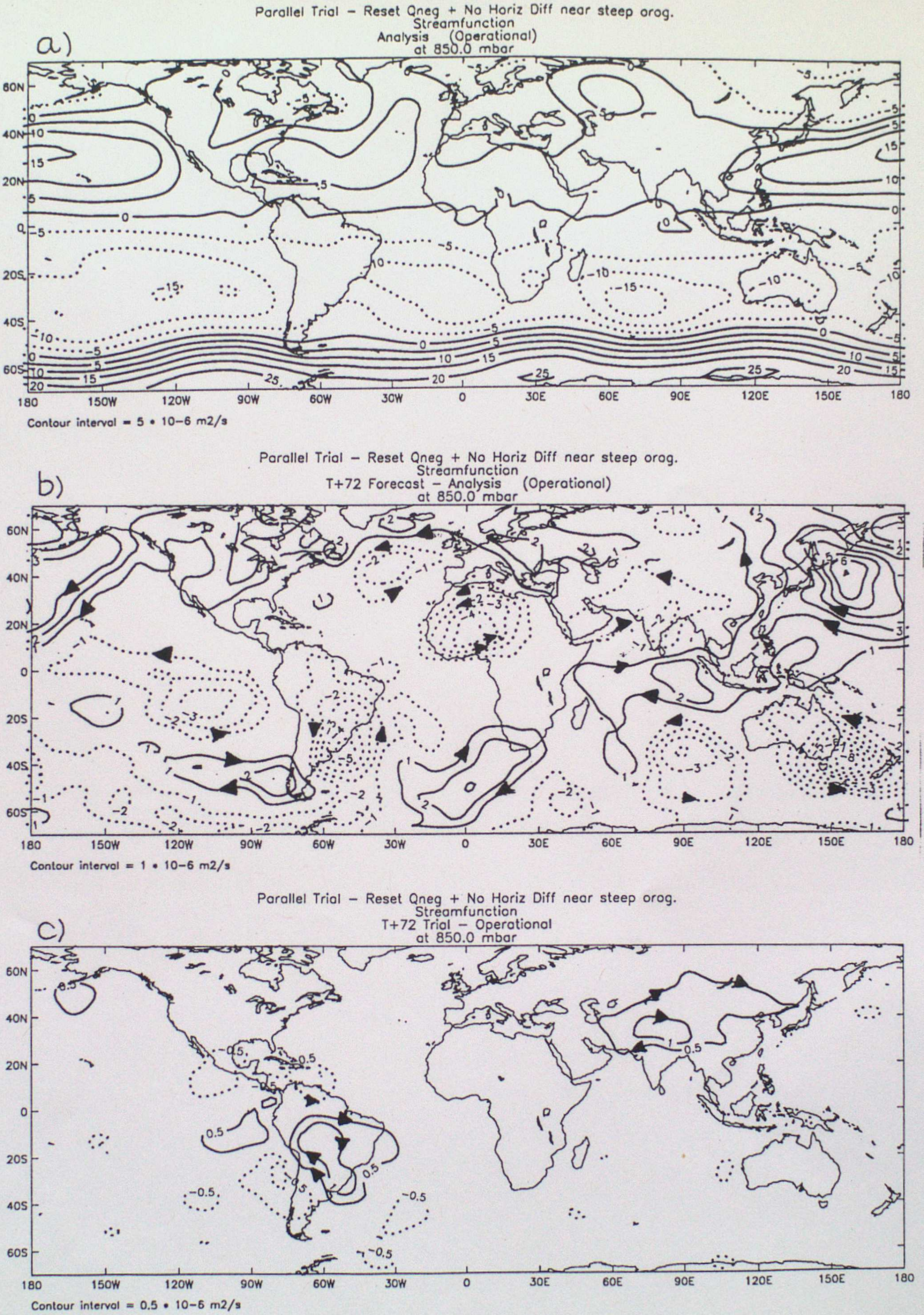

b) January 1995
T+72–T+00
temperature on pressure levels at 850.0 hPa
90N
60N
30N
0
30S
60S
90S
180
90W
0
90E
180
−4
−2
0
2
4

Figure 4.4



Parallel Trial - Reset Qneg + No Horiz Diff near steep orog.
Velocity Potential
Analysis (Operational)
at 850.0 mbar
a)
Contour interval = 2 • 10-6 m2/s
Parallel Trial - Reset Qneg + No Horiz Diff near steep orog.
Velocity Potential
T+72 Forecast - Analysis (Operational)
at 850.0 mbar
b)
Contour interval = 1 • 10-6 m2/s
Parallel Trial - Reset Qneg + No Horiz Diff near steep orog.
Velocity Potential
T+72 Trial - Operational
at 850.0 mbar
c)
Contour interval = 0.5 • 10-6 m2/s
60N
40N
20N
0
20S
40S
60S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180

Figure 4.5



Parallel Trial - Reset Qneg + No Horiz Diff near steep orog.
Streamfunction
Analysis (Operational)
at 850.0 mbar
a)
60N
40N
20N
0
20S
40S
60S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180
Contour interval = 5 • 10-6 m2/s
Parallel Trial - Reset Qneg + No Horiz Diff near steep orog.
Streamfunction
T+72 Forecast - Analysis (Operational)
at 850.0 mbar
b)
Contour interval = 1 • 10-6 m2/s
Parallel Trial - Reset Qneg + No Horiz Diff near steep orog.
Streamfunction
T+72 Trial - Operational
at 850.0 mbar
c)
Contour interval = 0.5 • 10-6 m2/s

Figure 4.6

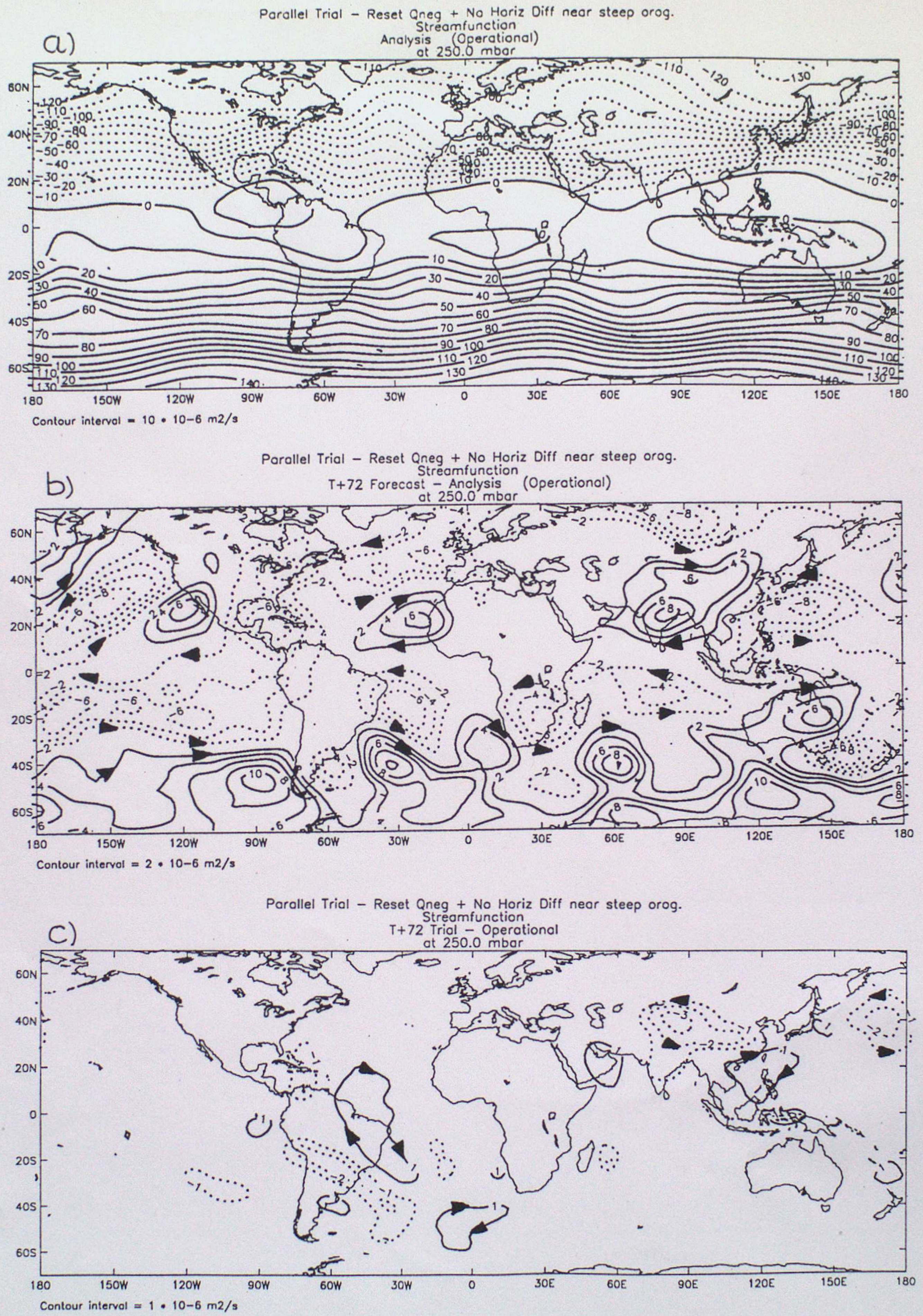

Parallel Trial - Reset Qneg + No Horiz Diff near steep orog.
Streamfunction
Analysis (Operational)
at 250.0 mbar
a)
Contour interval = 10 • 10-6 m2/s
Parallel Trial - Reset Qneg + No Horiz Diff near steep orog.
Streamfunction
T+72 Forecast - Analysis (Operational)
at 250.0 mbar
b)
Contour interval = 2 • 10-6 m2/s
Parallel Trial - Reset Qneg + No Horiz Diff near steep orog.
Streamfunction
T+72 Trial - Operational
at 250.0 mbar
c)
Contour interval = 1 • 10-6 m2/s
60N
40N
20N
0
20S
40S
60S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180

Figure 4.7