Forecasting Research

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TRIALS OF A LONGER TIMESTEP FOR PHYSICS IN THE LIMITED AREA MODEL

by

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September 1994

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1. Introduction

The timestep chosen for the unified model is based on numerical stability considerations for the solution of the dynamics equations on a finite grid (see Cullen et al, UMDP 10) . The timestep conventionally refers to that for the advection step (with the adjustment step repeated a number of times, normally 3, for each advection timestep). Until now, the physical parametrizations have been called with the same timestep as the advection, except for the full radiation calculations which are performed less frequently (currently every 3h for both global and LAM). For the limited area version this has meant physics calculations every 5 min, at a cost of ~30% of the run time. Given the highly parametrised nature of the physics schemes and the relatively slow scale of many of the processes it is questionable whether such a high frequency of physics calls is necessary; (although the ice-fallout process of the precipitation scheme is much faster and already known to be rather sensitive to the timestep) . There is no stability restriction on using a longer physics timestep since the boundary layer calculations are implicit as are some of the precipitation scheme's. It was decided to test the impact of using a 15 minute timestep for the physics, i.e called 3 times less frequently than the dynamics scheme. The saving would be around 20% of total run time. This may well be a more appropriate way to introduce the physics increments, which tend to be more noisy from grid-point to grid point, and allow the dynamics more iterations to adjust to produce "smoother" meteorological fields. This note describes the results of a long parallel test and assessment of the impact on forecasts. Some tests were performed with the current operational 19 levels and some further tests were performed with 31 levels based upon those used at ECMWF which gives extra vertical resolution in the free atmosphere and around jet levels.

The layout of this note is as follows. In section 2 there is a subjective assessment of the long period of parallel running from mid-March to end May with the current operational 19 levels. The results of verification of these forecasts against operational analyses is given in section 3. The sensitivity of including the assimilation increments at the longer timestep is investigated in section 4. Finally the conclusions are given in section 5.

2. Subjective Assessment

Period of trial 16th March - 26th May 1994

The limited area model was rerun daily during the trial from DT00Z using a 15 minute timestep for all the physics but still keeping a 5 minute timestep for the dynamics. The trial forecasts were assessed by comparison with the operational forecasts. The trial forecasts had a 12 hour assimilation cycle but used the operational acobs files.

Comparing the trial and operational forecasts subjectively, it was apparent that running with the 15 minute timestep for the physics had little impact upon the forecasts. Most differences in mean sea level pressure and 500hPa forecasts were insignificant,even at T+48, with no evolution changes.

Nearly all the impact upon the precipitation forecasts resulted from minor variations in the distribution of showers over land and differences in light precipitation over the sea. Differences in heavier dynamic rainfall associated with fronts were small and difficult to spot subjectively. The overall impression was that running with the longer timestep tended to produce more showers over land at 12Z.

The main differences seen in precipitation can be classified as follows:

(i) small differences in light precipitation over sea	55.5%
(ii) distribution of showers over land	32.9%
(iii)switch from dynamic rain to convective rain	5.8%
(iv) shower distribution around depressions over the sea	5.8%

Five examples of typical differences are described below.

2.1 Light precipitation over the sea

Differences in the forecast distribution of light snow showers over the sea north of 60N were fairly common during March and April but the accumulations were very small. One such example is shown between the operational (**Figure 1a/b**) and trial (**Figure 1c/d**) T+06/12 forecasts verifying at 06Z/12Z 20th April. Small differences can be seen in the distribution of light snow showers between 65N and 70N, 10W to 10E.

Differences also occurred with light showers forecast in cold air outbreaks further south over the warmer sea. **Figure 2** compares the T+18 forecasts of precipitation and cloud verifying at 18Z 22nd March. The operational forecast, (**Figure 2 a/b**) predicted more light snow but less low cloud over the Atlantic between 55N and 60N, 30W t0 40W.

These differences were due to small changes in low level humidity and ice fallout around the freezing level. The accumulations involved were very small (0.1-0.5 mm/6hrs).

2.2 The distribution of showers overland.

In some cases, there was a small increase in the development of light showers over land by 12Z, mainly over Eastern Europe. Changes in the distribution of showers over the

U.K. were assessed as even, with half in favour of the trial and half in favour of the operational forecasts. Three examples are described below.

At 18Z on the 19th April, the radar image in **Figure 3c** shows showers mainly confined to northern and western Scotland, with a more organised band of rain over Ireland, North Wales and Northwest England. A few light showers also developed over East Anglia. The trial T+18 forecast,(**Figure 3b**),predicted too many showers over the East Midlands and the operational forecast,(**Figure 3a**) was slightly better on this occasion.

During the afternoon of the 24th April, showers were frequent in the west but East Anglia and Southeast England remained dry and mainly sunny. The radar image, **Figure 4c**, shows the distribution of showers at 18Z. The operational T+18 forecast,(**Figure 4a**), predicted showers to be too widespread and the dry areas in the southeast were better forecast by the trial.

At 06Z on the 14th May, the radar image,(**Figure 5c**), shows Southern England to be dry with only isolated showers near the Isle of Wight. A thundery trough over Northwest France and the Channel Isles was moving slowly northwards. The operational T+30 forecast for this time predicted showers from medium level instability already over Southern England by 06Z. This was too soon and the trial forecast was better in this case.

2.3 Difference in output on 6-up charts

There was a slight switch from dynamic symbols to convective in unstable cold airstreams over the sea.

2.4 Impact on cloud

Very little impact was seen in areas of medium cloud predicted by the model. In some cases, there was a small increase in the low cloud predicted by the trial forecasts.

2.5 Subjective assessment conclusions

(i) Differences in mean sea level pressure and 500hPa forecasts were insignificant,even at T+48, with no evolution changes.

(ii) Small differences in shower distribution over land were assessed evenly. The overall impression was that running with the longer timestep tended to produce more showers overland at 12Z.

(iii)Differences in light precipitation over the sea resulted from small changes in low level humidity and ice fallout around the freezing level.

The overall conclusion was that running with a 15 minute timestep for the physics had little significant impact upon the forecasts.

3. VERIFICATION

A limited verification was performed for some key parameters using the operational analyses. The parameters were pressure at mean sea level, 500hPa height, 250hPa winds and temperatures and 850hPa temperatures. Forecasts for T+24 were verified for the whole limited area domain, and for "area 5"[1], the region from Iceland to Northern Spain, (**Fig 6**). Daily forecasts verifying from 14/04/94 to 24/05/94 were used for area 5, and forecasts verifying from 06/04/94 to 24/05/94 were used for the whole domain (except for PMSL when the shorter period was used).

The mean changes in bias and rms for the parameters verified over the periods were very small (**Table 1**). The bias in PMSL changed by only a little more than 1/10th hPa and the rms worsened by only 0.07% over the whole LAM domain. The worst degradation was for 500hPa height with rms 1.3% and 1.1% worse over the whole LAM domain and area 5 respectively. The longer timestep had a beneficial impact on 250hPa temperatures for which the bias improved significantly and the rms were ~1% better over both domains.

Time series of the results are shown in **Figures 7 to 11**. Although individual cases are sometimes slightly better or worse than the operational forecasts there are no large excursions during the 40+ day periods. This is typically illustrated by the behaviour of the surface pressure (**Fig 7**). The 500hPa height (**Fig 8**) is slightly worse generally, with larger negative bias by up to 0.8m, but this is still very small and the geographical changes (not shown) are barely perceptible. 850hPa temperature (**Fig 9**) bias and rms are marginally worse over the whole LAM domain and marginally better over the smaller area 5. 250hPa temperature (**Fig 10**) bias is generally improved. Winds at jet levels (250 hPa, **Fig 11**) are little altered by using the longer timestep.

These verification figures suggest that use of the longer timestep is not detrimental to the forecast skill.

4. SENSITIVITY OF ANALYSIS TO LONG TIMESTEP FOR ASSIMILATION

All the tests described above used a longer ,15 minute, timestep for the physics *and* the assimilation. Since this effectively means fewer iterations in the analysis correction scheme it was possible that the analyses were worse and perhaps detrimental to the forecasts. To test this 8 cases were rerun from 27/04/94 to 04/05/94 with the assimilation scheme called on the

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[1] This area is not exactly that used by the operational verification system

shorter ,5 minute, timestep with the dynamical model. For technical reasons[2], the assimilation scheme must be called after the physics, so for the first call it was still after 15 minutes into the assimilation cycle. The reruns here were all performed with a continuous run of the model so this only affected the T-12 start. Operationally, when the assimilation is performed in separate 3h cycles the 15 minute timestep would occur periodically. (To avoid this, the order of routines within a timestep could be revised to perform the physics calculations first rather than the dynamics as at present.)

The quality of the analyses and forecasts were assessed by verification against the observations used in the operational assimilation cycles (ie the ACOBS files). By running the model for one timestep the observation - model differences are obtained for each model layer, and may be meaned over the LAM domain to give bias and rms figures. Temperatures and winds were verified against sonde and airep observations, and relative humidity against sondes for both T+0 and T+24.

The largest differences at T+0 using the long timestep for both physics and assimilation are for winds when verified against aireps (**Fig 13b**). The largest changes of vector wind rms from the operational runs are for levels 8,9,10 (~505, 422, 355hPa) where the rms errors are ~0.2ms^{-1} worse (4-6%). However, against sondes (**Fig 12b**), the longer timestep for both is closer to the operational, whereas the run with long timestep for the physics alone is the worst at levels 10,11,12 (~355,300,250 hPa) where the rms errors are ~0.1ms^{-1} worse (2-3%) than the other two runs. For the T+24 forecast, there is virtually no difference between all three runs, the operational, long physics alone and long physics with assimilation, when compared to sondes (**Fig 14b**). Against aireps the longer timestep for both verifies the best for levels 8 to 11 at T+24 (**Fig 15b**) in contrast to the T+0 verification; the rms are better by ~0.2-0.4ms^{-1} (2-4%). The westerly wind biases are very similar for all three runs when measured against sondes (**Figs 12b,14b**), but are generally slightly worse for the longer timestep for both when measured against aireps (**Figs 13b,15b**). Although the results are somewhat contradictory there is no strong evidence that calling the assimilation scheme with the longer timestep is greatly degrading the forecast skill for winds.

The temperature analyses (**Figs 12a**) have a greater bias and rms at level 1 of ~0.15K. (Note the biases are plotted as Observation-model values, so the model has a cold bias.) Above level 1 the run with long timestep for physics alone is slightly colder than operational generally and the run with long timestep for both is slightly warmer, but the differences in most cases is ~0.01-0.02K. The rms errors are very similar with differences at most ~0.02K. For the T+24 forecasts, the boundary layer levels 1 to 4 are colder by ~0.2K for level 1 and ~0.05K for levels 2 to 4 (**Figs 14a**) for both runs with long timesteps. Above, from levels 8 to 12 the longer timestep for both verifies the best with an improvement over the other two of ~0.02K warming. The rms differences are very small generally and are ~0.02K. Again

[2]Assimilation of synops,MOPS by the mesoscale version which require background values calculated by the physics

from this verification against sondes there is little reason to prefer the assimilation to be performed with the shorter timestep, and the long timestep does not degrade the model performance in any significant way. The verification against aireps (**Figs 13a,15a**),generally supports this conclusion. The run with long timestep for both physics and assimilation again has a slightly better temperature bias at mid-levels at T+0, and the rms errors are generally very close for all three runs. At T+24 (**Fig 15a**) the long timestep run for both has a worse cold bias at low levels (~0.2K) ,improved bias (~0.2K) at mid-levels (6-9) and then worse again for levels 11-13 (~0.1K), with a similar pattern of differences in rms, and maximum differences ~0.2K.

The verification of relative humidity against sondes (**Fig 16**) shows the long timestep for both produces slightly worse rms errors at T+0, but by T+24 there is very little to chose between all three runs in terms of rms, and the longer timestep runs have generally slightly worse moist biases.

Overall the conclusion from these tests is that it is not necessary to include the assimilation at the shorter timestep. Also, the verification against observations confirms the results of section 3 for verification against analyses, that the use of a longer timestep for physics has very little detrimental effect.

5. CONCLUSIONS

The conclusion from the subjective assessment, verification against analyses and observations is that running with a 15 minute timestep in the limited area model does not significantly affect the forecasts. It is also unnecessary to perform the assimilation at the shorter timestep that is used for the dynamics. Implementing this change would save approximately 20% of the run time, which could be used for other model enhancements, such as increased vertical resolution.

REFERENCES

Cullen, M J P, T Davies and M H Mawson, 1994
Conservative finite difference schemes for a unified forecast/climate model. *Unified Model Documentation Paper 10.*

FIGURES

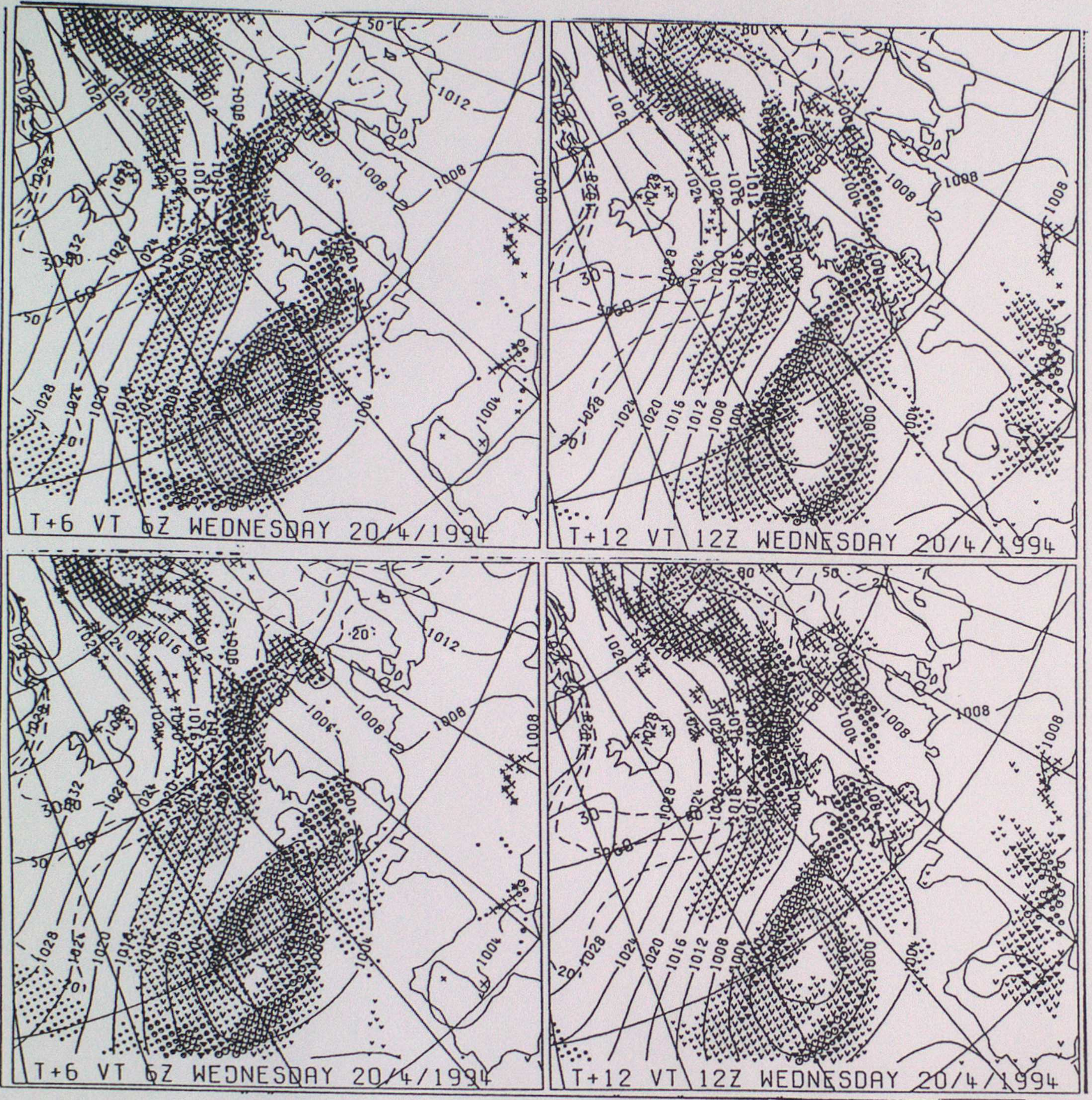
Figure 1 T+6, T+12 forecasts of surface pressure and precipiation rates for 6,12Z 20/04/94; operational (top, a,b), trial (bottom, c,d)

Figure 2 T+18 forecasts of precipiation rates and cloud for 18Z 22/03/94; operational (top, a,b), trial (bottom, c,d)

TABLE 1

Verification against operational analyses for whole LAM domain T+24						
Mean results for period 06/04/94 - 24/05/94 (PMSL 14/04/94 - 24/05/94)						
parameter	operational		trial		changes	
	mean	rms	mean	rms	mean	%rms
H500/ m	-4.12	15.89	-4.37	16.09	-0.26	1.29
PMSL/ Pa	-21.10	198.27	-19.78	198.40	1.32	0.07
T250/ K	-0.45	1.45	-0.34	1.43	0.11	-0.98
T850/K	-0.23	1.29	-0.23	1.30	-0.00	0.84
V250/ m/s	0.23	4.81	0.23	4.83	0.00	0.39
VWE250/m/s		6.65		6.68		0.45
Verification against operational analyses for area "5" T+24						
Mean results for period 14/04/94 - 24/05/94						
parameter	operational		trial		changes	
	mean	rms	mean	rms	mean	%rms
H500/ m	-5.70	16.29	-5.62	16.47	0.07	1.11
PMSL/ Pa	-38.34	179.66	-38.56	180.10	-0.21	0.24
T250/ K	-0.44	1.58	-0.29	1.56	0.14	-1.07
T850/K	-0.16	0.98	-0.12	0.98	0.04	-0.29
V250/ m/s	0.26	4.56	0.28	4.59	0.02	0.49
VWE250/m/s		6.36		6.40		0.61

a) b)



c) d)

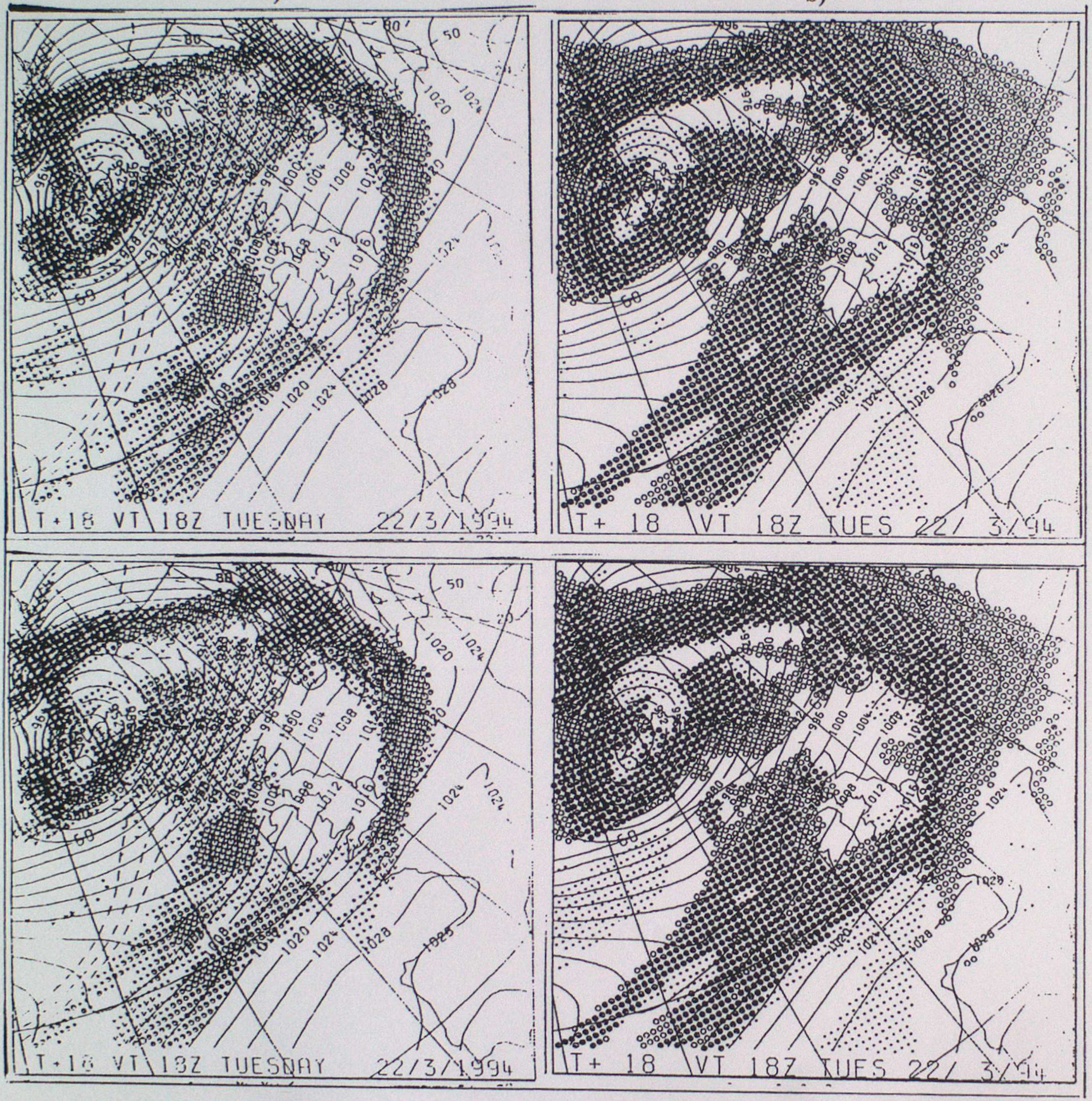
FIGURE 1

	.03	.1	.5	4.0	MM/HR AT VT
SNOW	×	×	⁎	⁎	
CONVECTIVE	˅	˅	▾	▿	
DYNAMIC	•	●	⊙	✲	

operational

trial

a) b)



c) d)

Figure 2

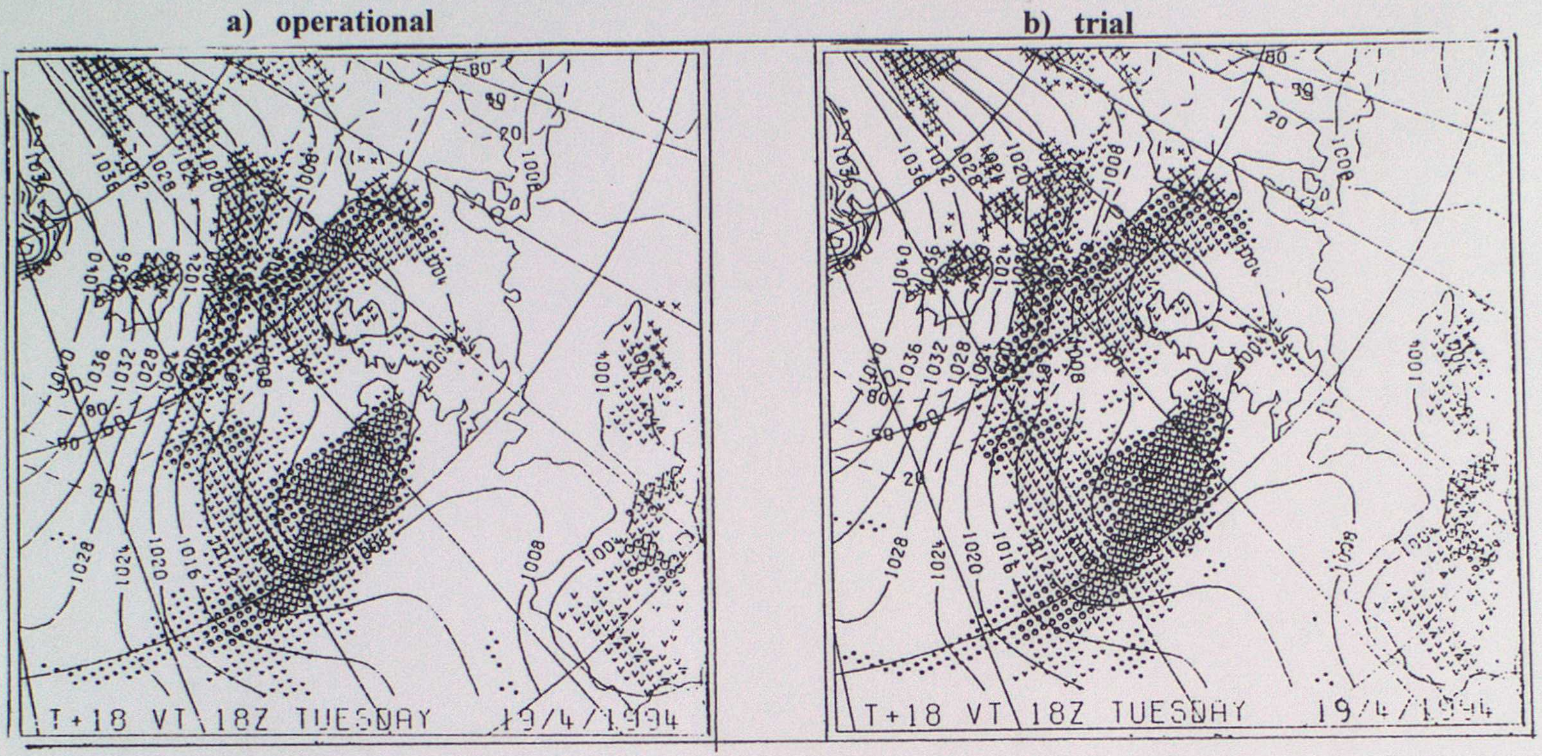
	.03	.1	.5	4.0 MM/HR AT VT
SNOW	×	×	×	✱
CONVECTIVE	▾	v	▾	▽
DYNAMIC	•	●	⊙	✡

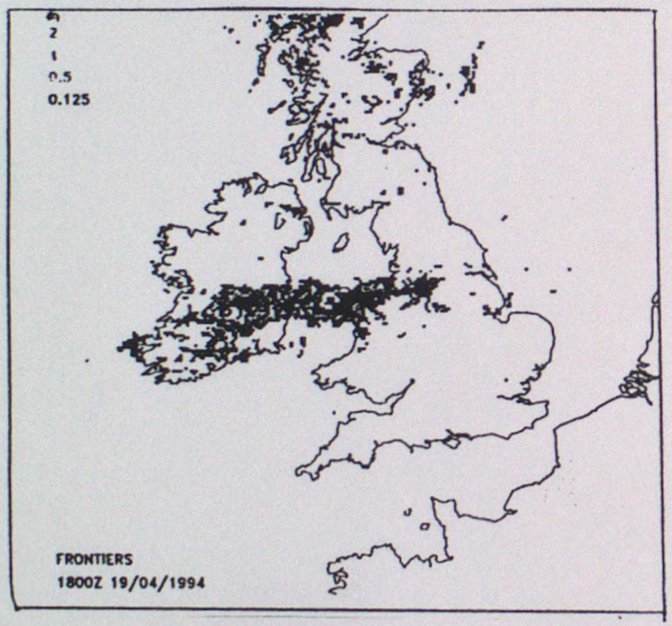
MEDIUM CLOUD > 4 OCTAS ○

LOW CLOUD > 4 OCTAS •

operational

trial



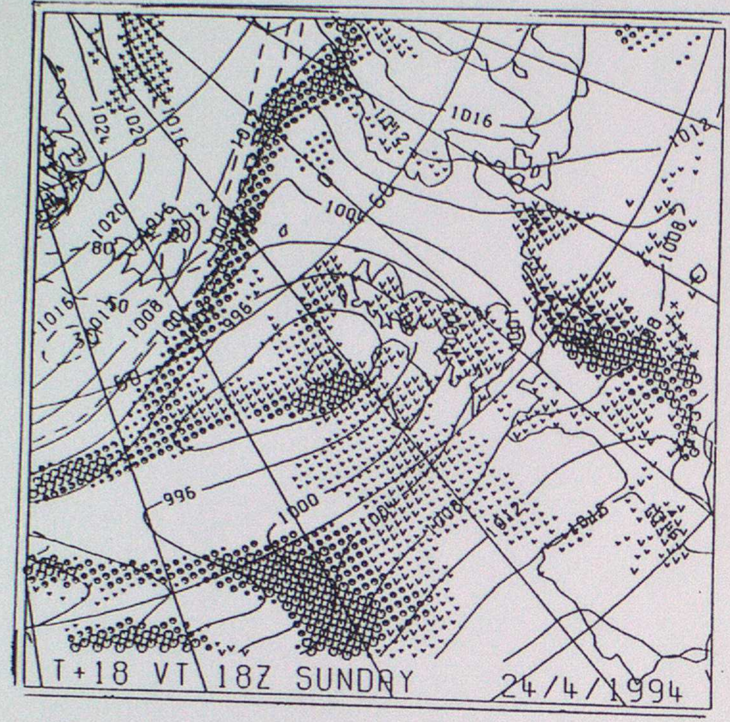


c) radar

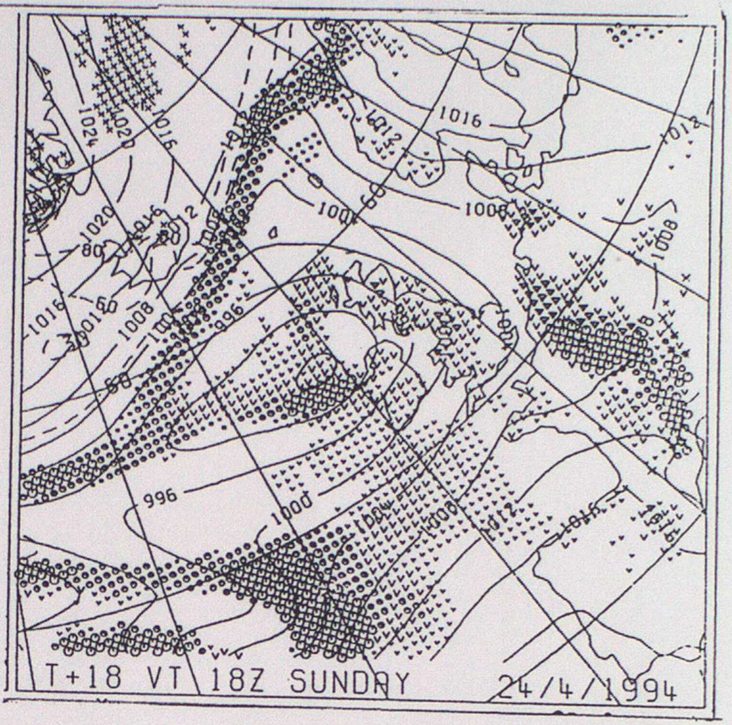
FIGURE 3

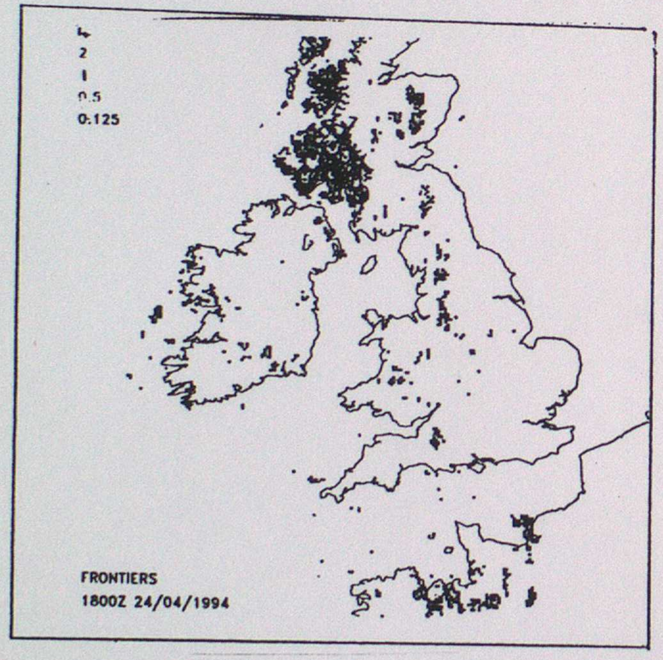
	.03	.1	.5	4.0	MM/HR AT VT
SNOW	×	×	✱	✳	
CONVECTIVE	˅	˅	▼	▽	
DYNAMIC	•	⊙	⊙	✡	

a) operational



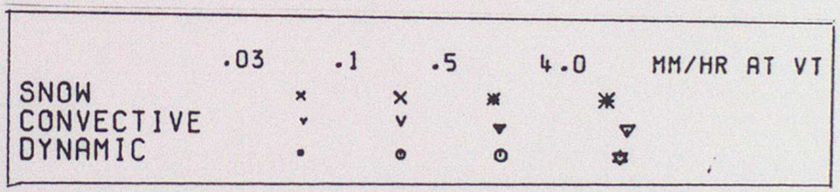
b) trial



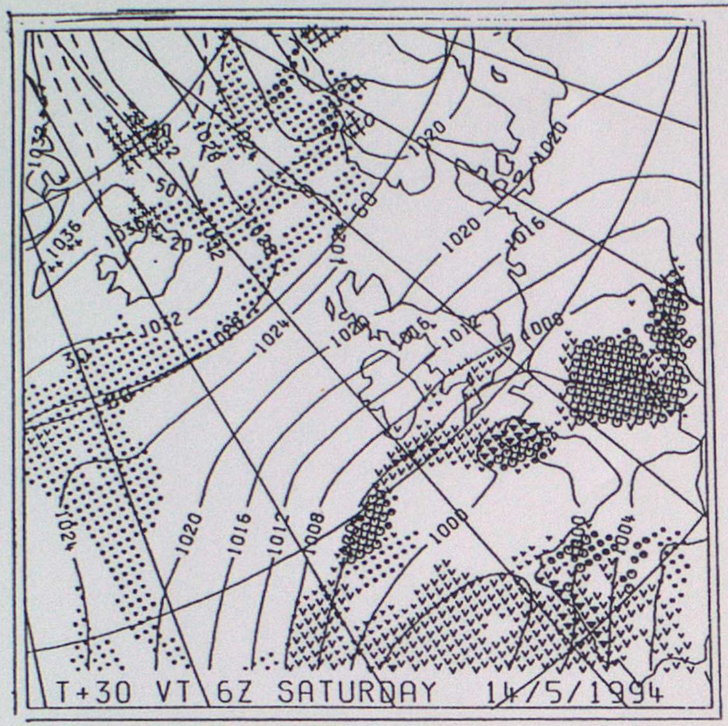


c) radar

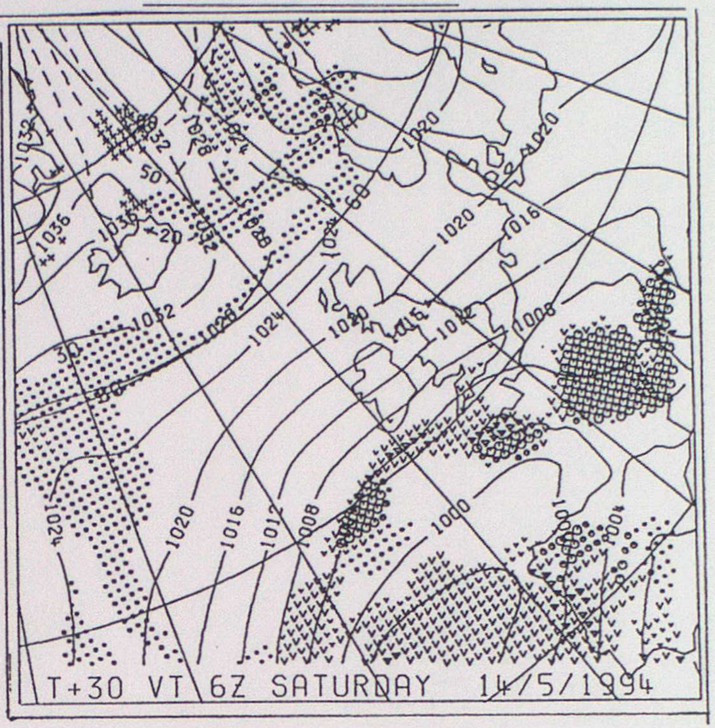
FIGURE 4

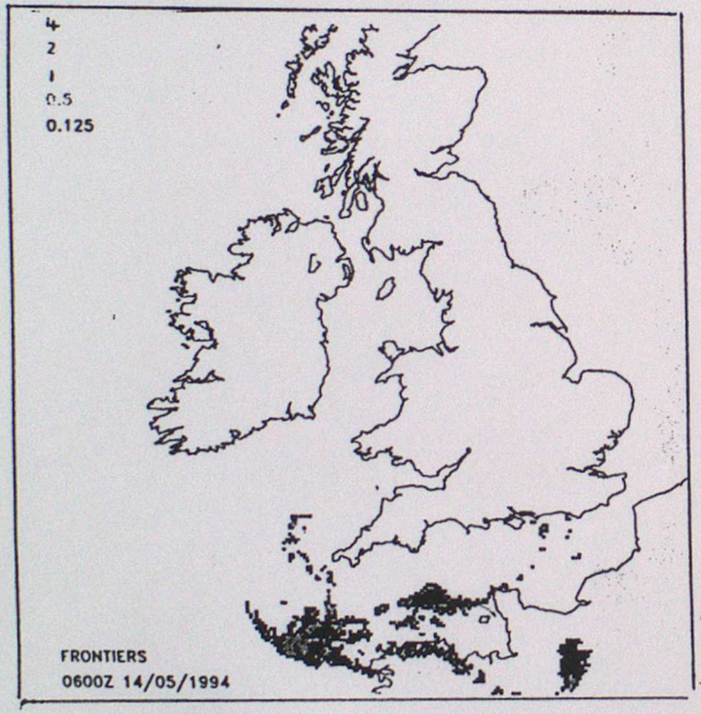


a) operational



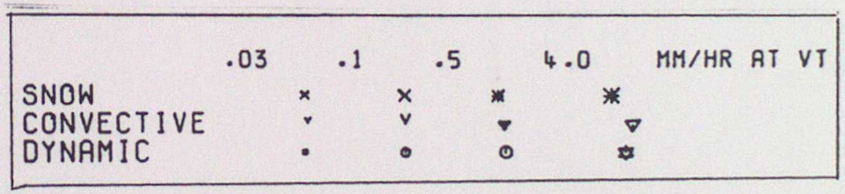
b) trial





c) radar

FIGURE 5



MEAN SEA LEVEL PRESSURE
VALID AT 0Z ON 20/ 4/1994 DAY 110 DATA TIME 0Z ON 20/ 4/1994 DAY 110
SEA LEVEL EXPERIMENT NO.: 3

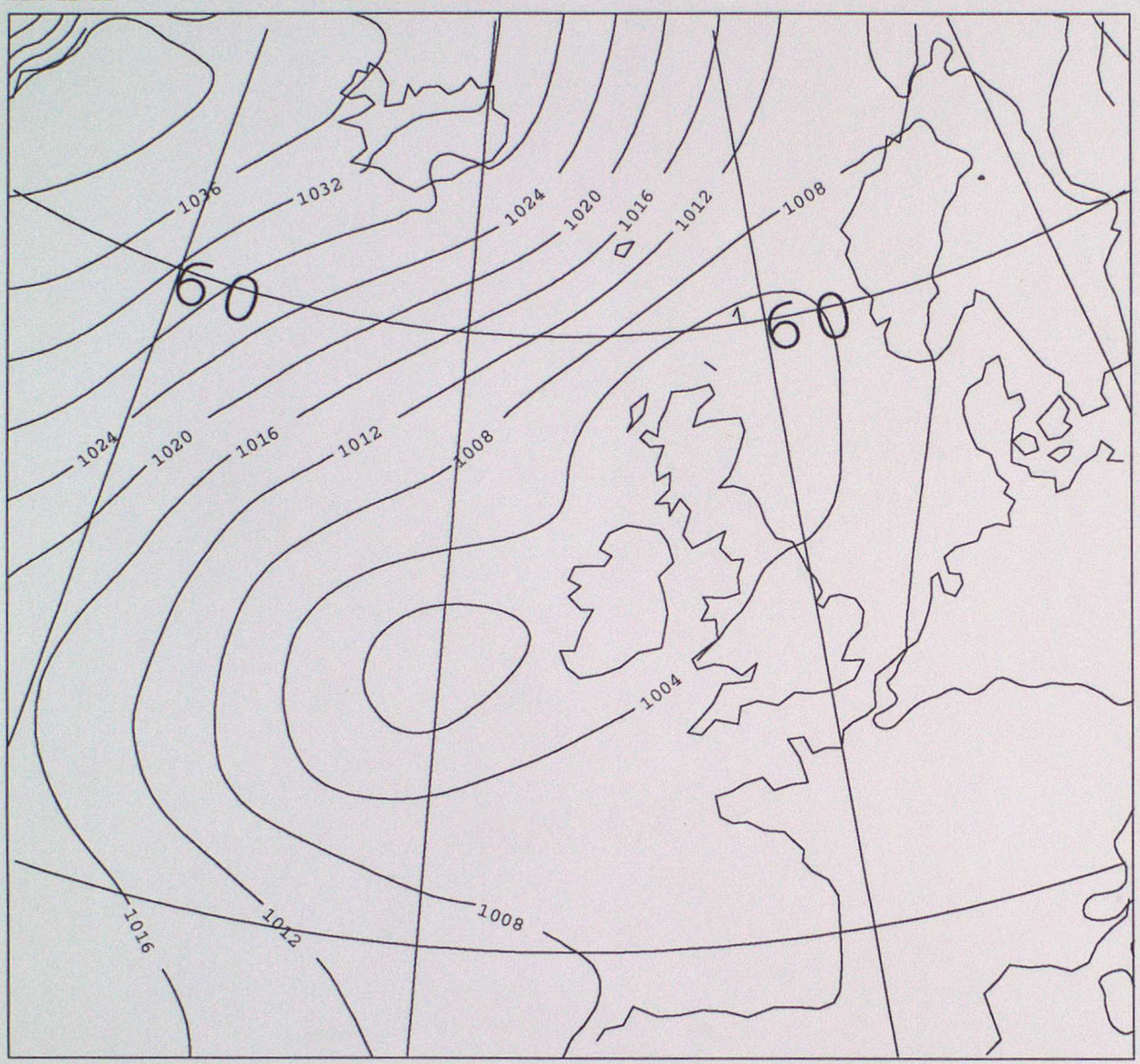
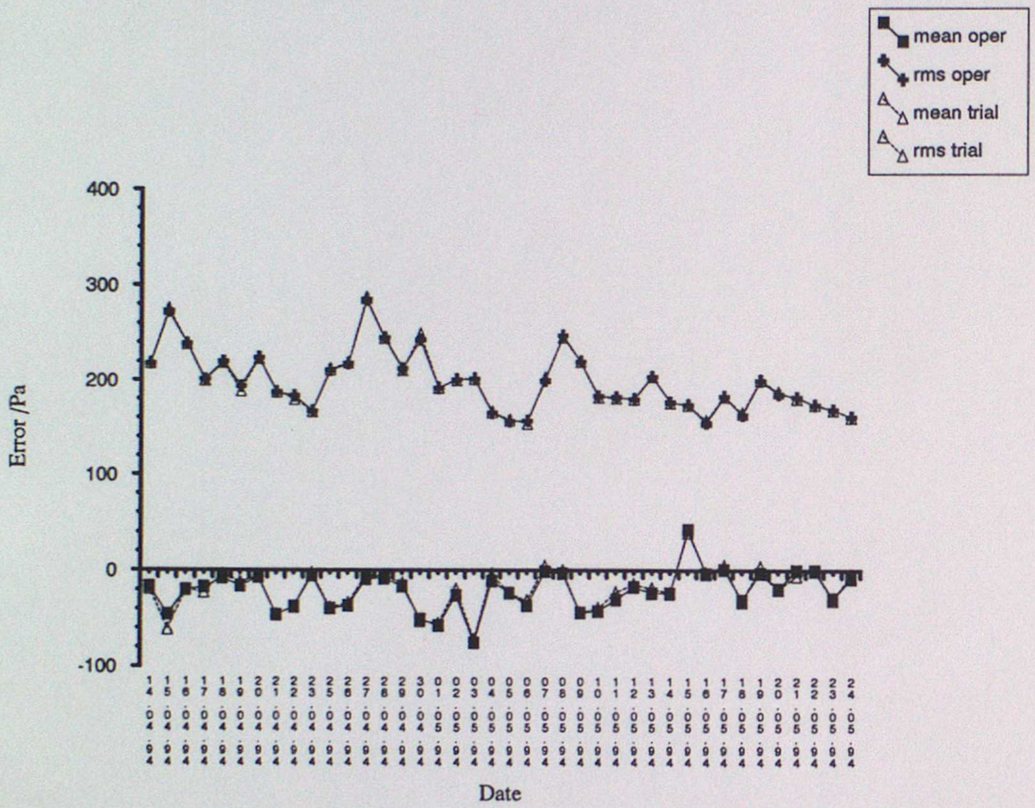


FIGURE 6

FIGURE 7

PMSL VERIFICATION AGAINST ANALYSES T+24

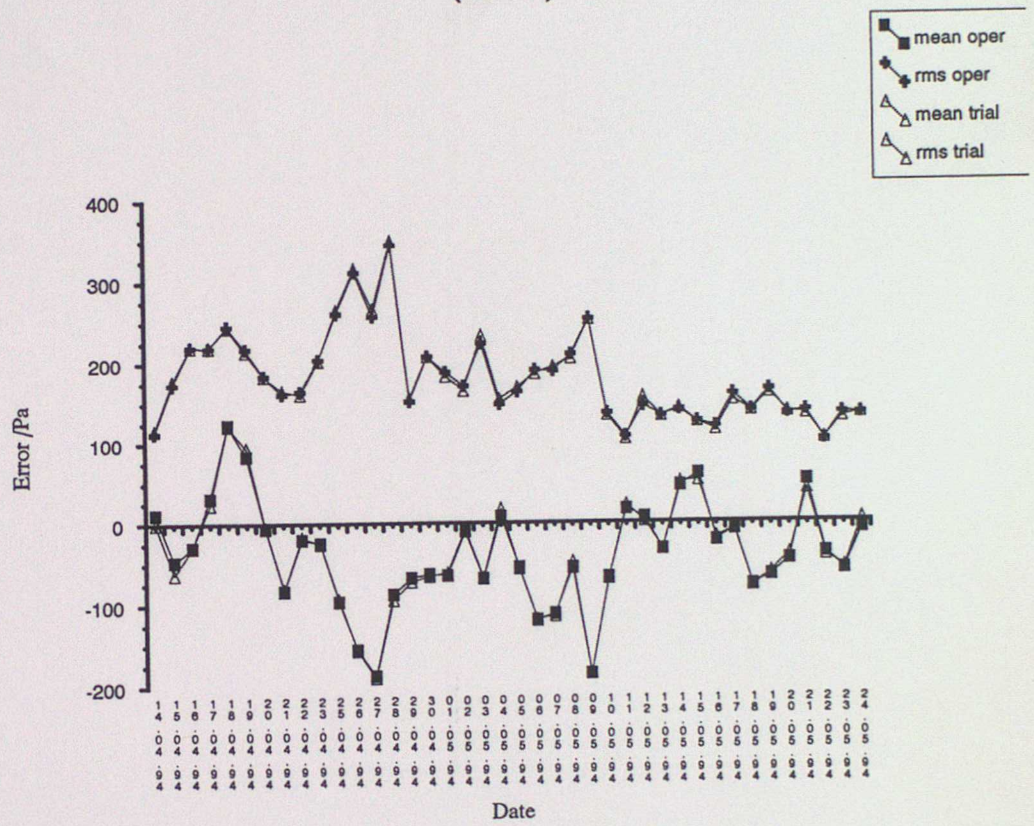
LONG PHYSICS+ASSIMILATION TIMESTEP
(15 min)



a)

PMSL VERIFICATION AGAINST ANALYSES T+24
for area "5"

LONG PHYSICS+ASSIMILATION TIMESTEP
(15 min)

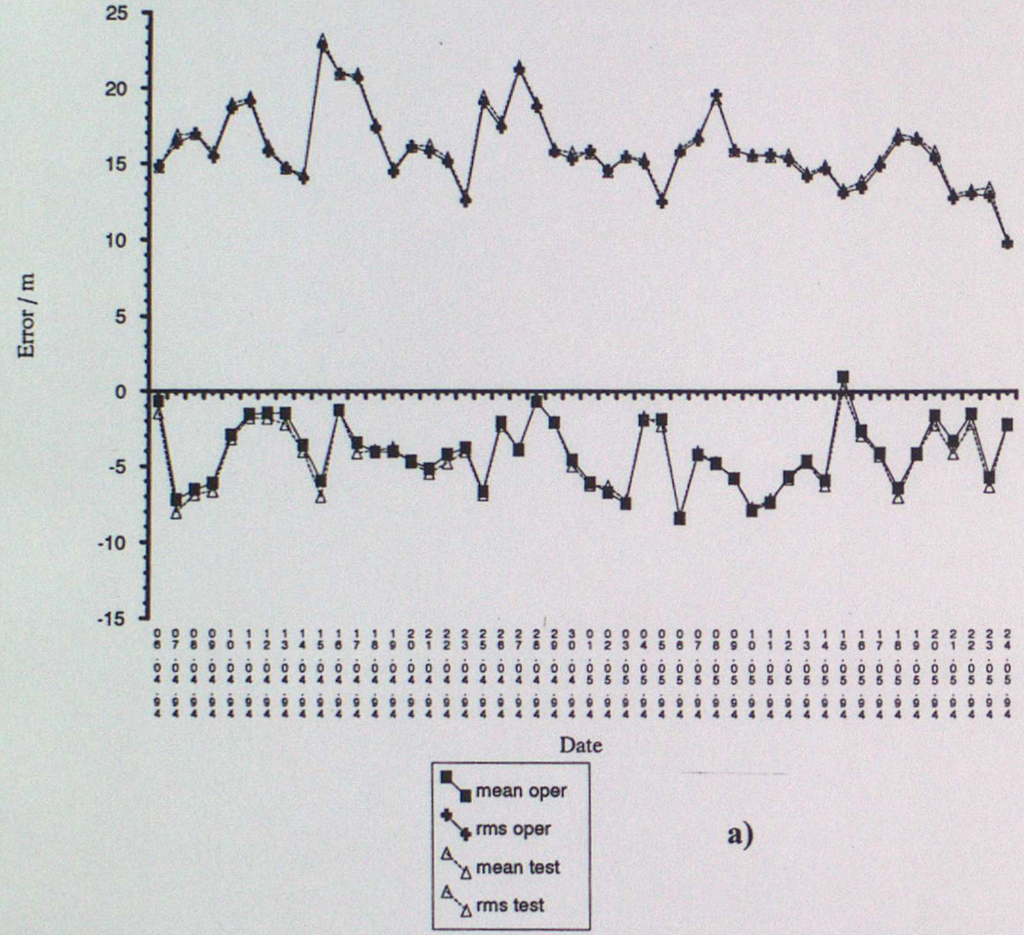


b)

FIGURE 8

H500 VERIFICATION AGAINST ANALYSES T+24

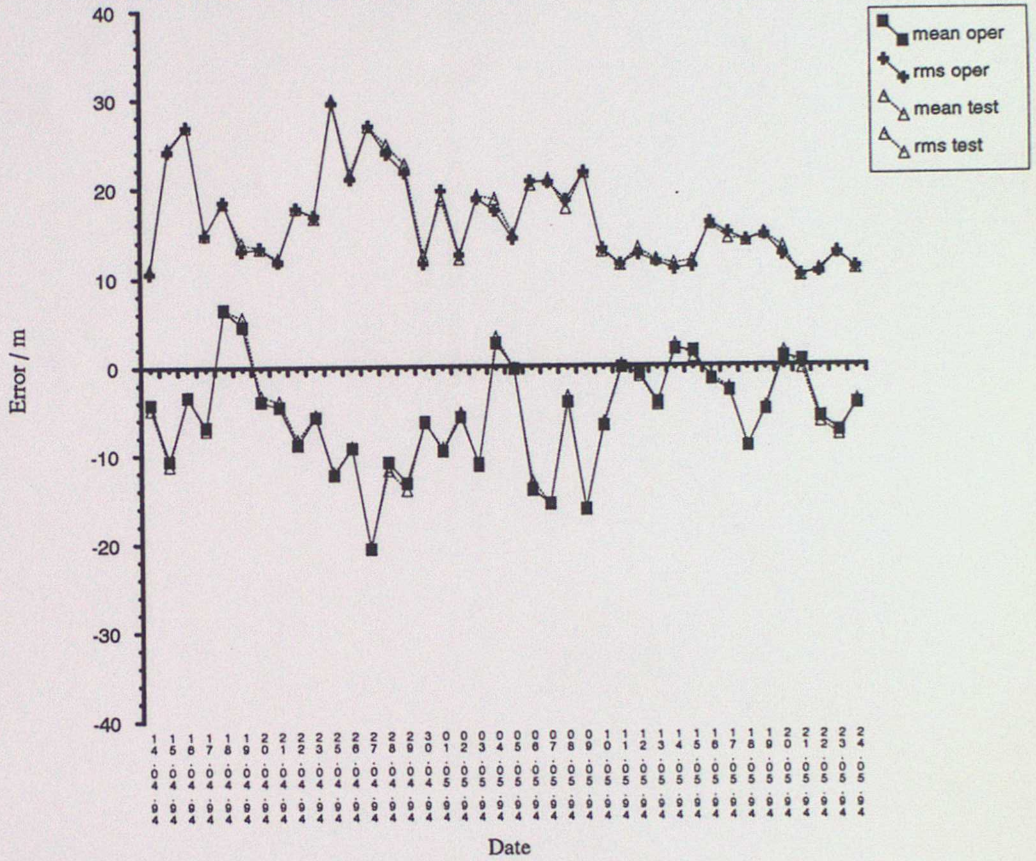
TEST OF LONG PHYSICS + ASSIMILATION TIMESTEP (15 min)



a)

H500 VERIFICATION AGAINST ANALYSES T+24
for area "5"

TEST OF LONG PHYSICS + ASSIMILATION TIMESTEP (15 min)

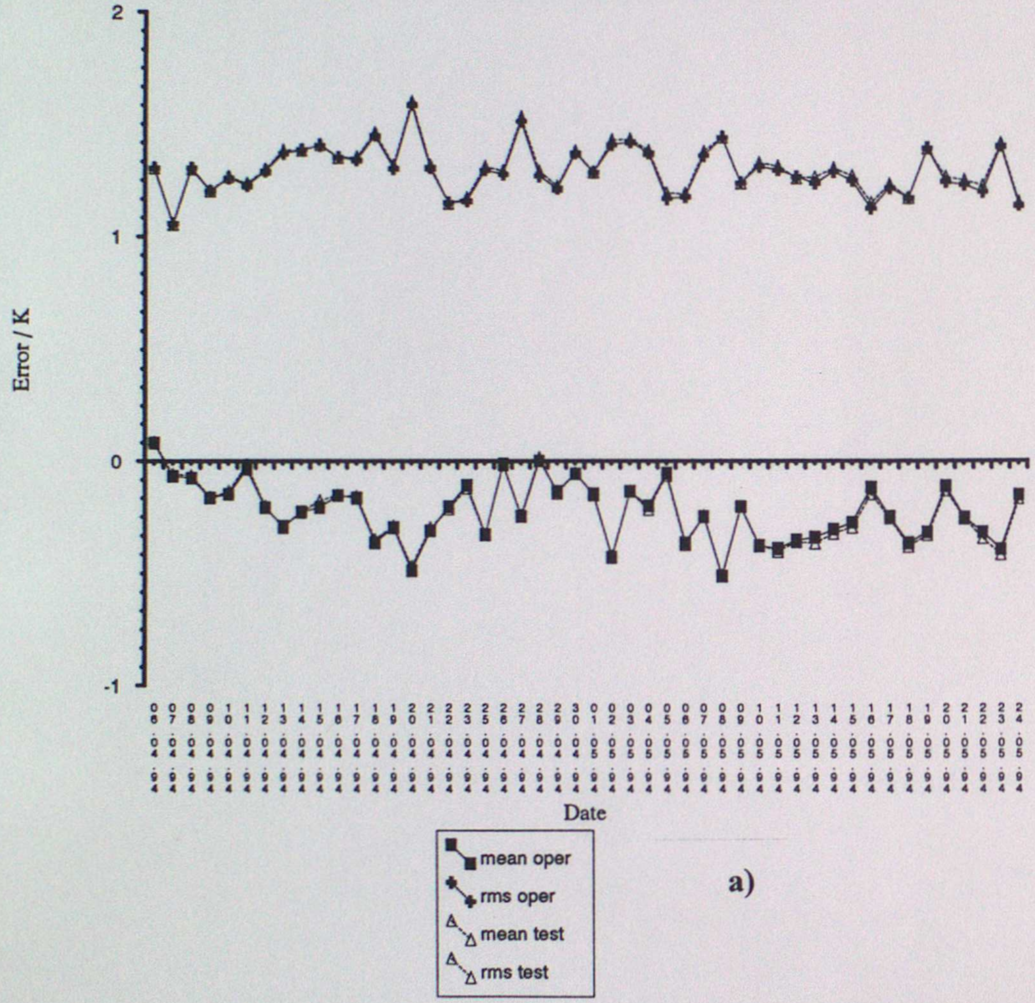


b)

FIGURE 9

850 hPa Temperature verification against analyses T+24

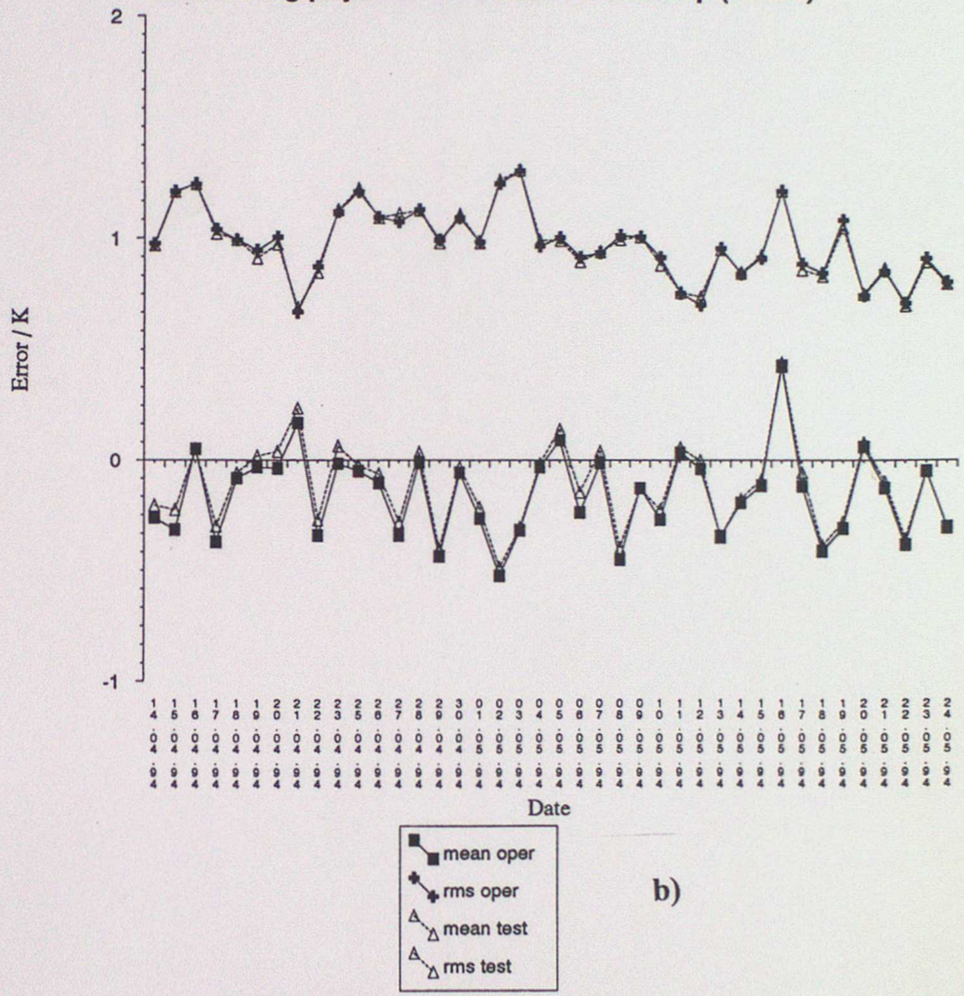
Test of long physics + assimilation timestep (15min)



a)

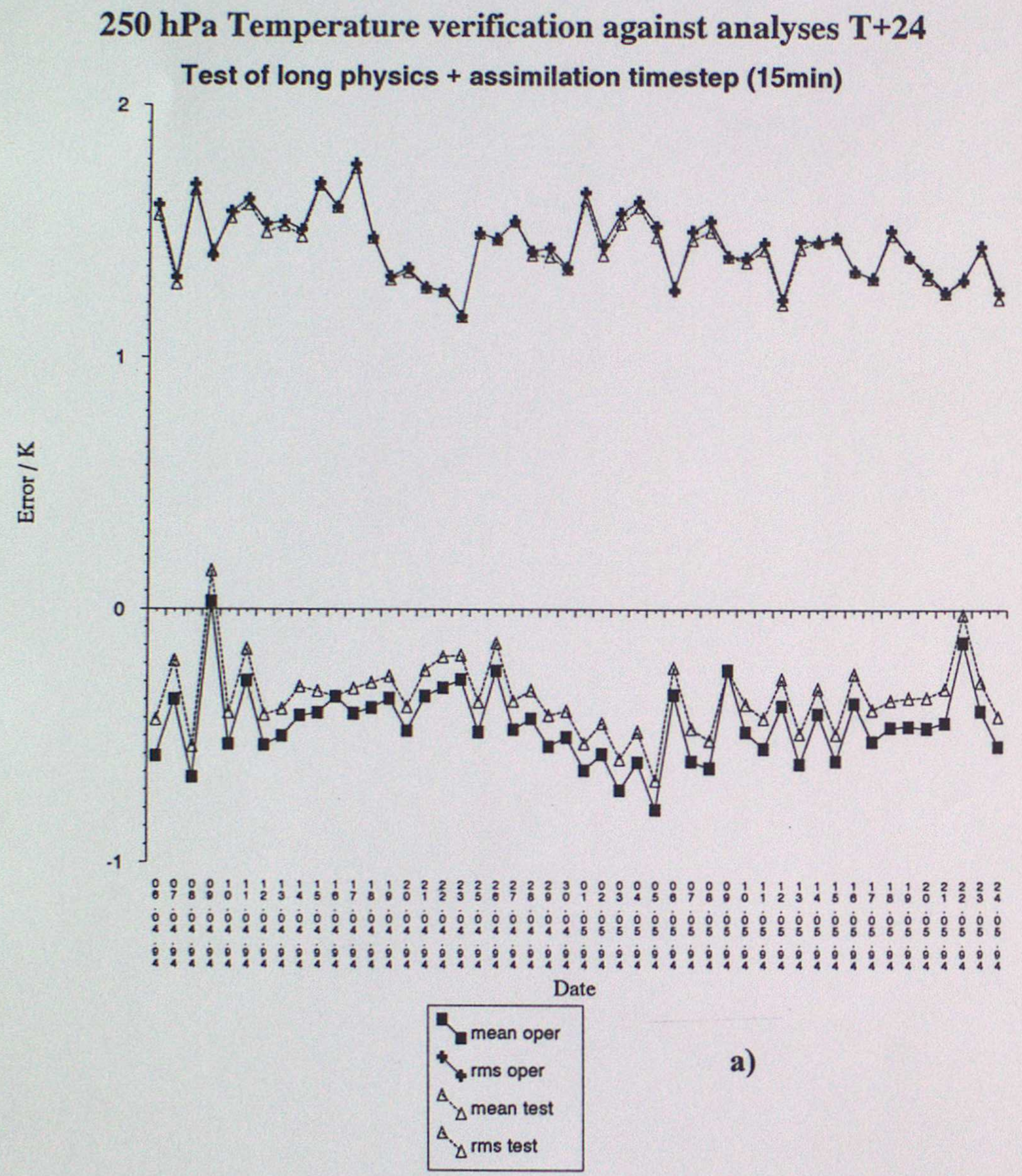
850 hPa Temperature verification against analyses T+24 for area "5"

Test of long physics + assimilation timestep (15min)



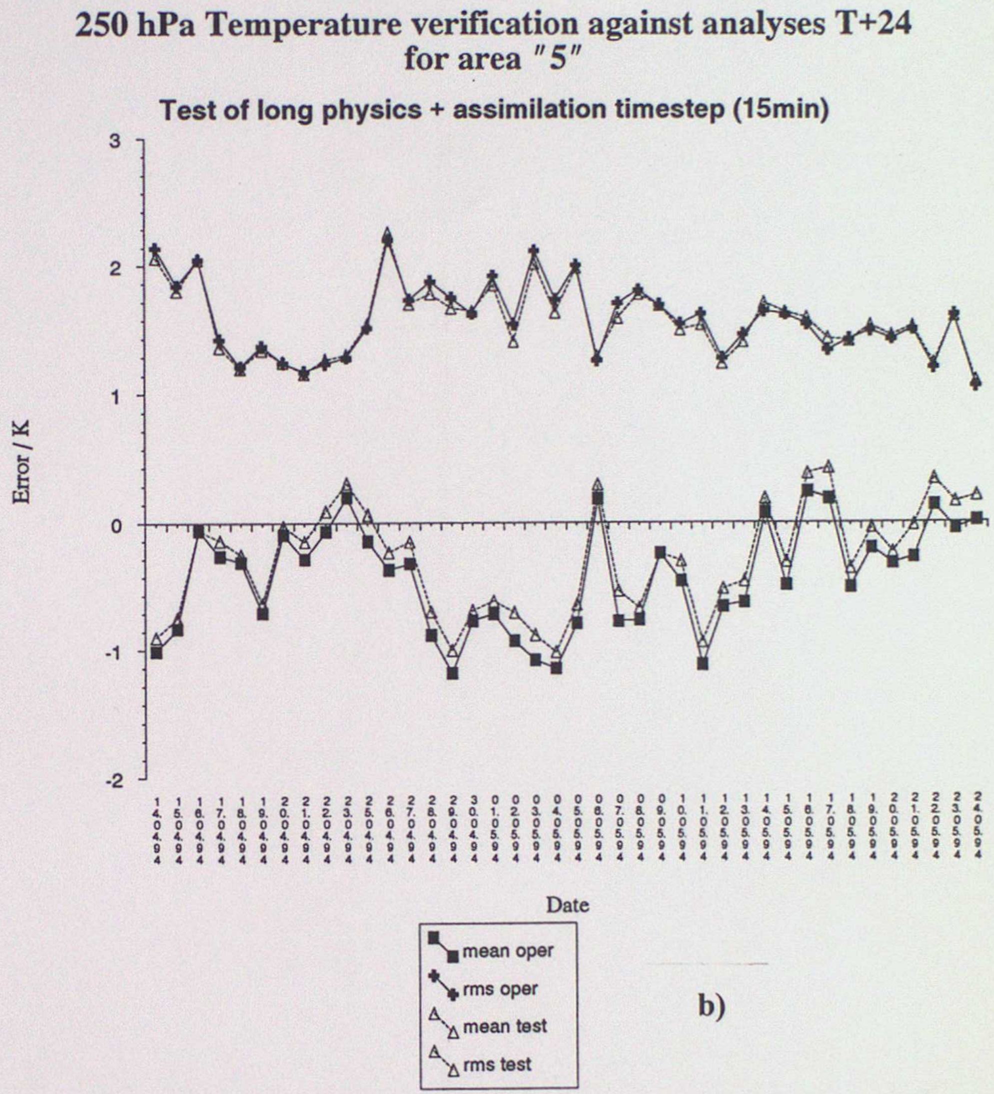
b)

FIGURE 10



250 hPa Temperature verification against analyses T+24
Test of long physics + assimilation timestep (15min)
Error / K
2
1
0
-1
Date
mean oper
rms oper
mean test
rms test

a)



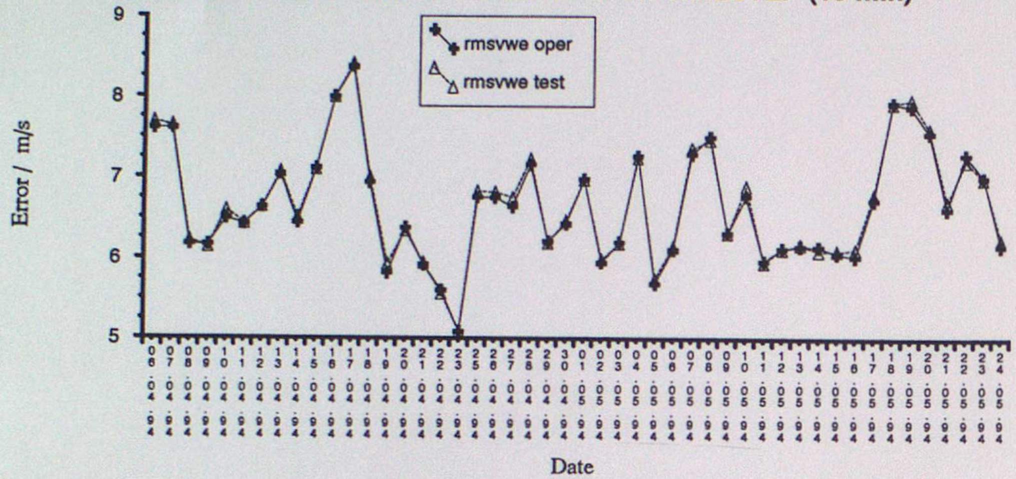
250 hPa Temperature verification against analyses T+24
for area "5"
Test of long physics + assimilation timestep (15min)
Error / K
3
2
1
0
-1
-2
Date
mean oper
rms oper
mean test
rms test

b)

FIGURE 11

250hPa WIND VERIFICATION AGAINST ANALYSES T+24

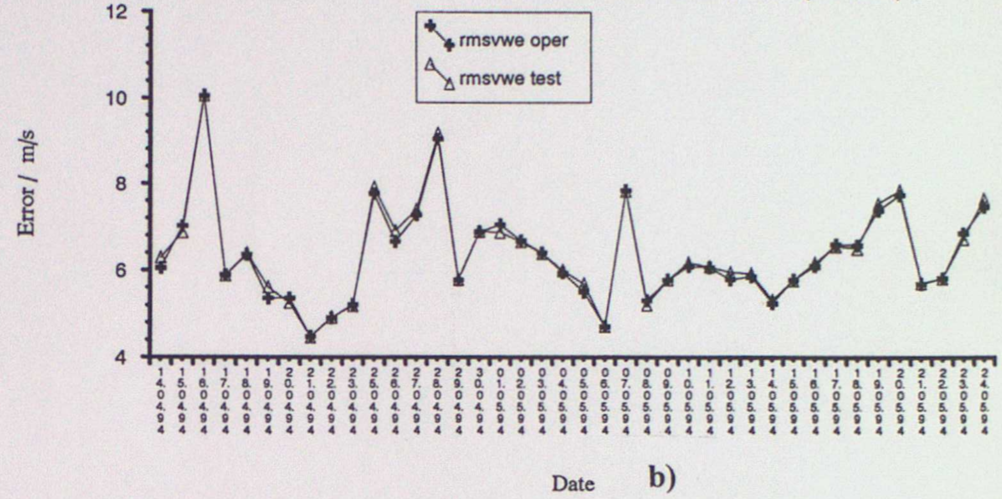
TEST OF LONG PHYSICS + ASSIMILATION TIMESTEP (15 min)



a)

250hPa WIND VERIFICATION AGAINST ANALYSES T+24
for area "5"

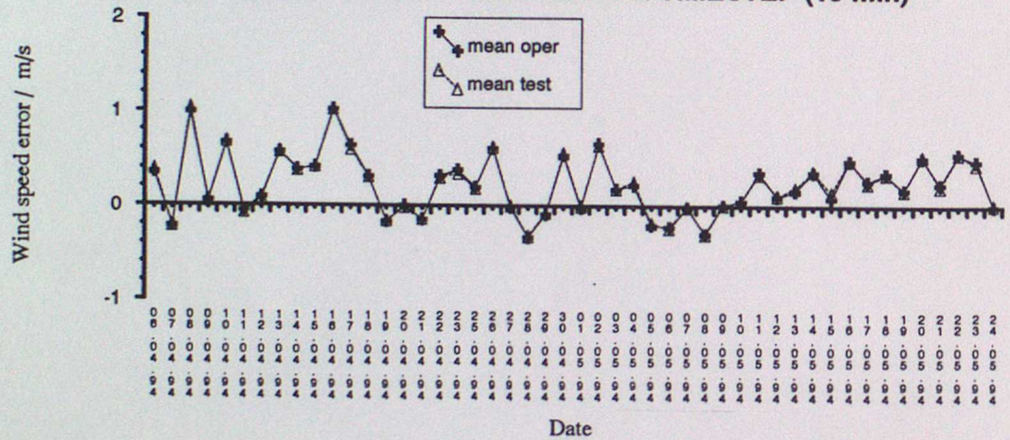
TEST OF LONG PHYSICS + ASSIMILATION TIMESTEP (15 min)



b)

250hPa WIND VERIFICATION AGAINST ANALYSES T+24

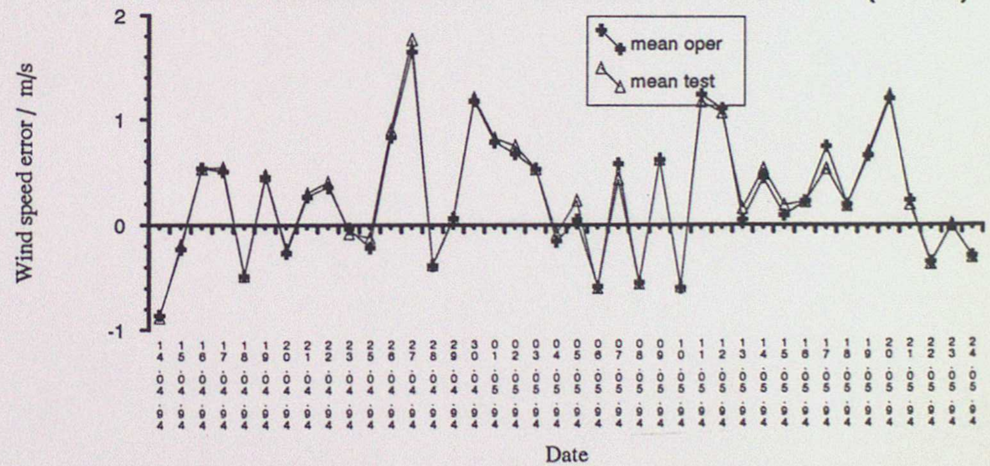
TEST OF LONG PHYSICS + ASSIMILATION TIMESTEP (15 min)



c)

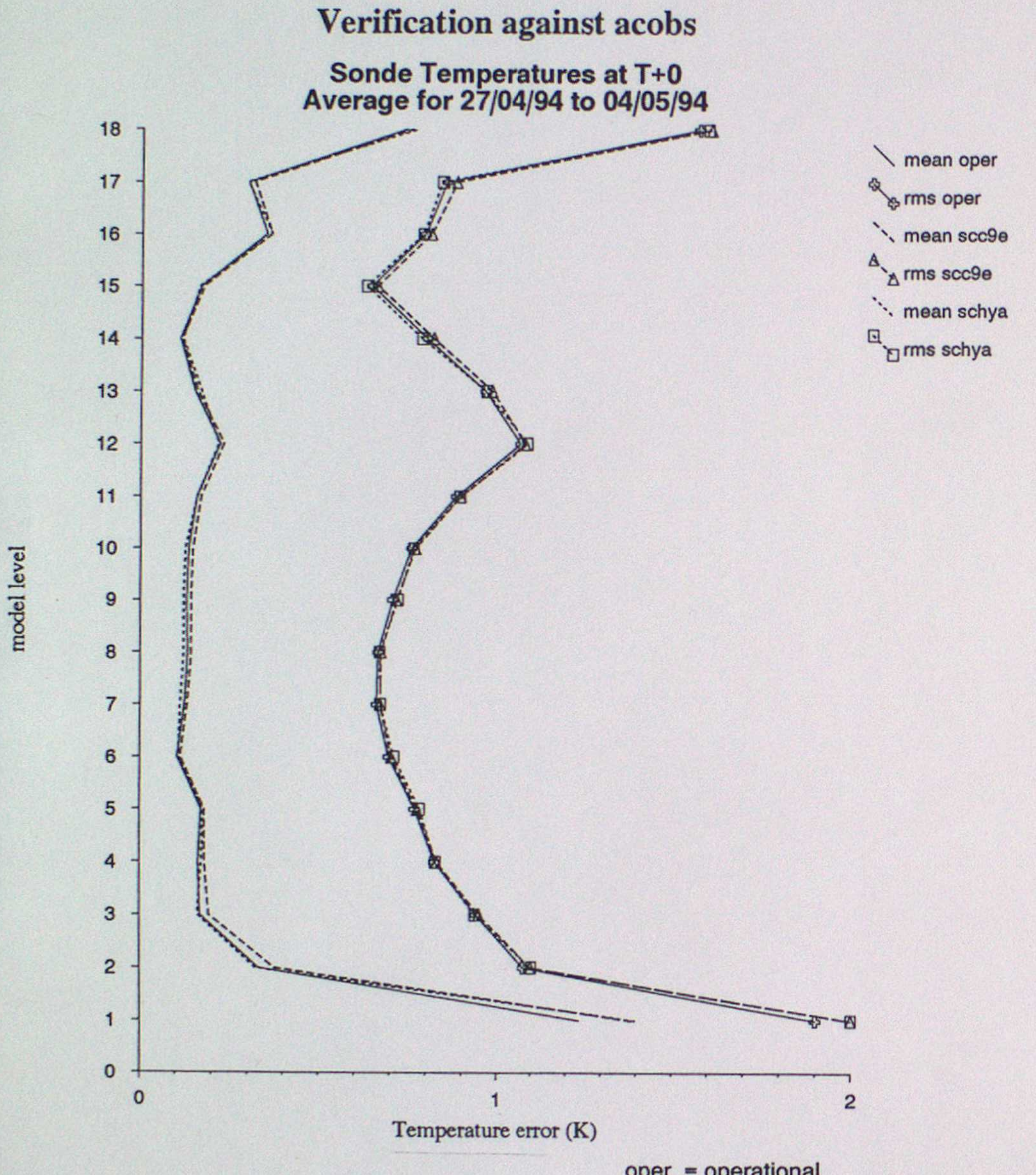
250hPa WIND VERIFICATION AGAINST ANALYSES T+24
for area "5"

TEST OF LONG PHYSICS + ASSIMILATION TIMESTEP (15 min)



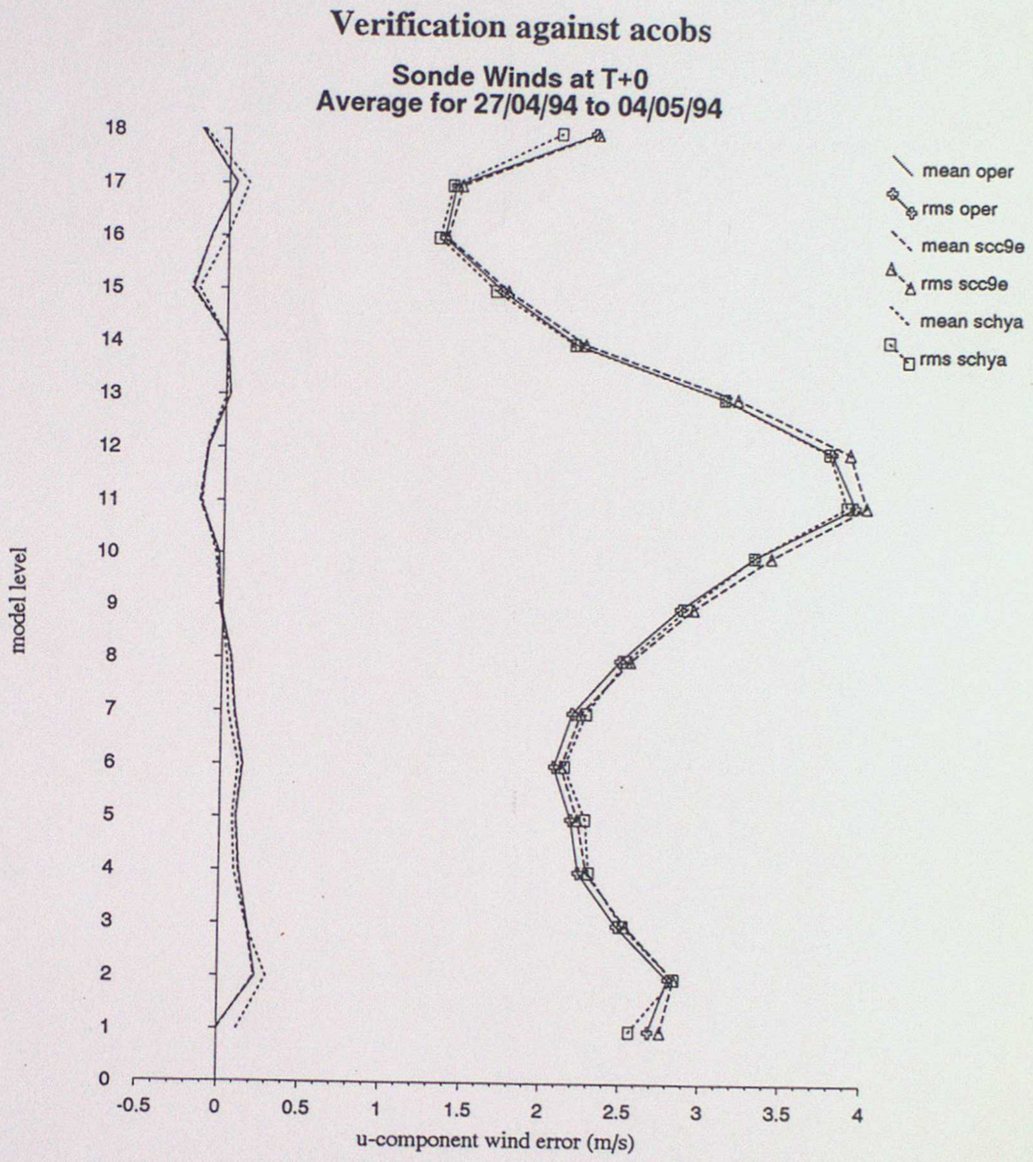
d)

FIGURE 12



Verification against acobs
Sonde Temperatures at T+0
Average for 27/04/94 to 04/05/94
mean oper
rms oper
mean scc9e
rms scc9e
mean schya
rms schya
model level
Temperature error (K)
0
1
2
oper = operational
scc9e = long physics timestep
schya = long physics & assm. timestep

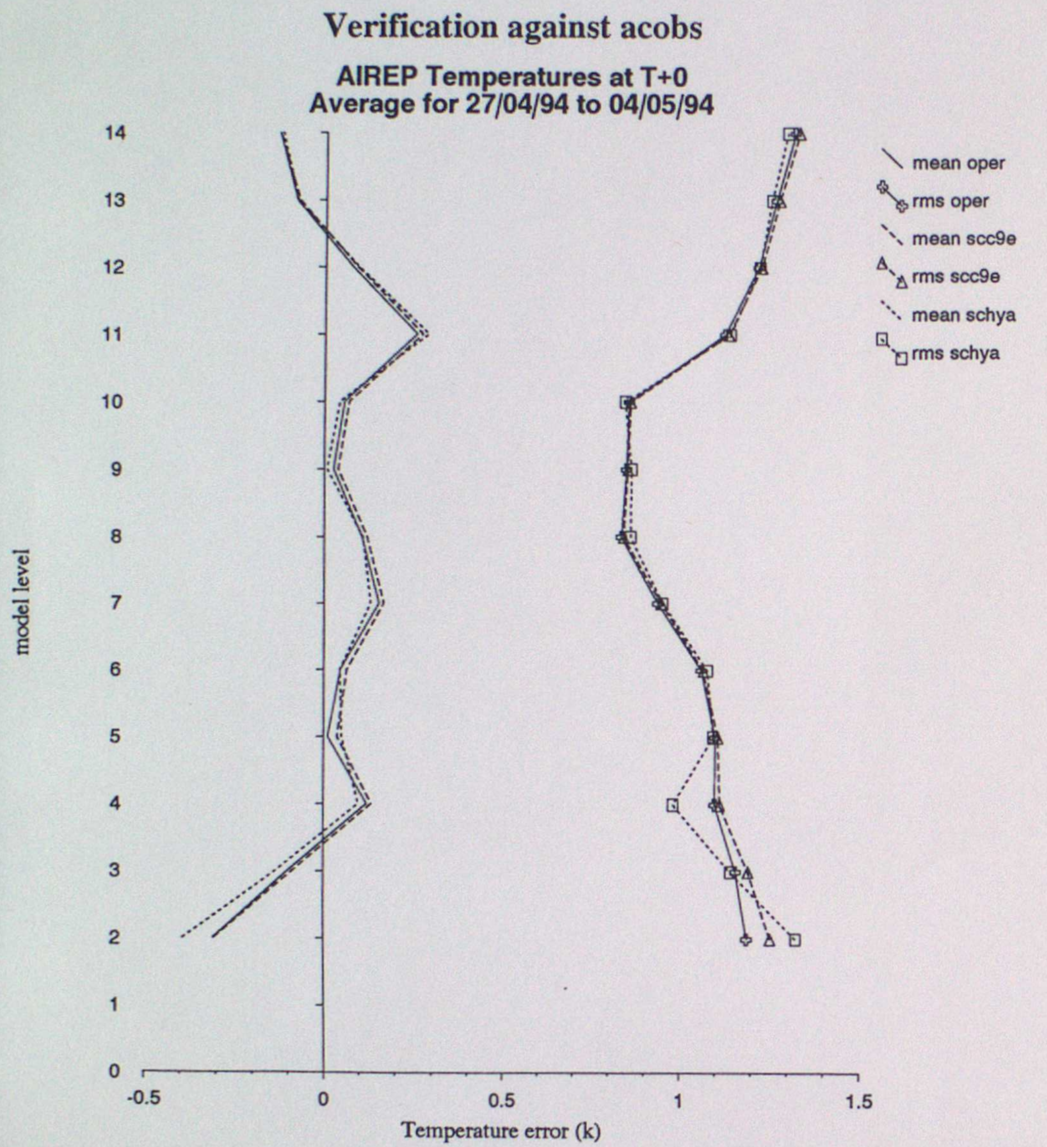
a)



Verification against acobs
Sonde Winds at T+0
Average for 27/04/94 to 04/05/94
mean oper
rms oper
mean scc9e
rms scc9e
mean schya
rms schya
model level
u-component wind error (m/s)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
oper = operational
scc9e = long physics timestep
schya = long physics & assm. timestep

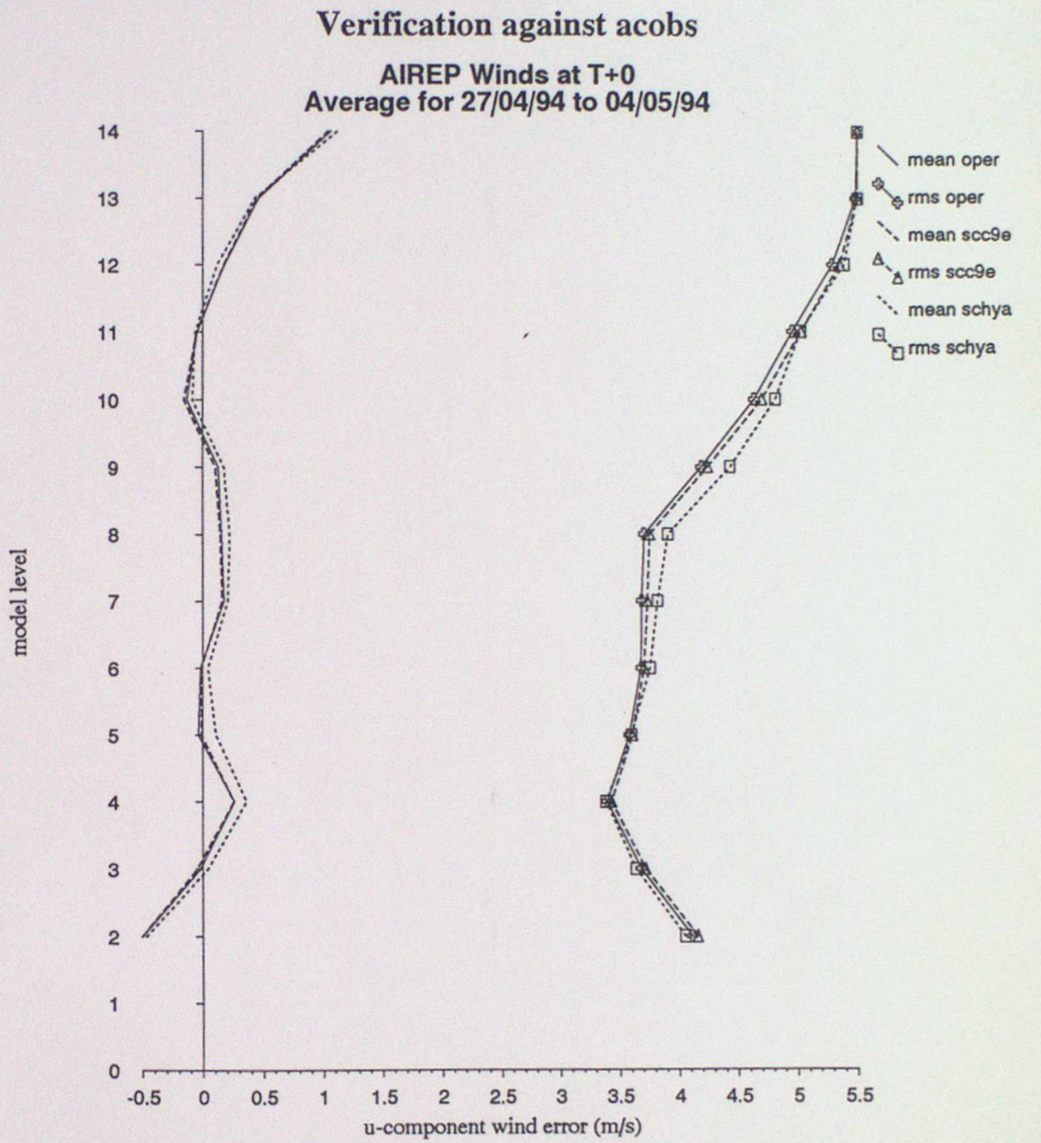
b)

FIGURE 13



oper = operational
scc9e = long physics timestep
schya = long physics & assm. timestep

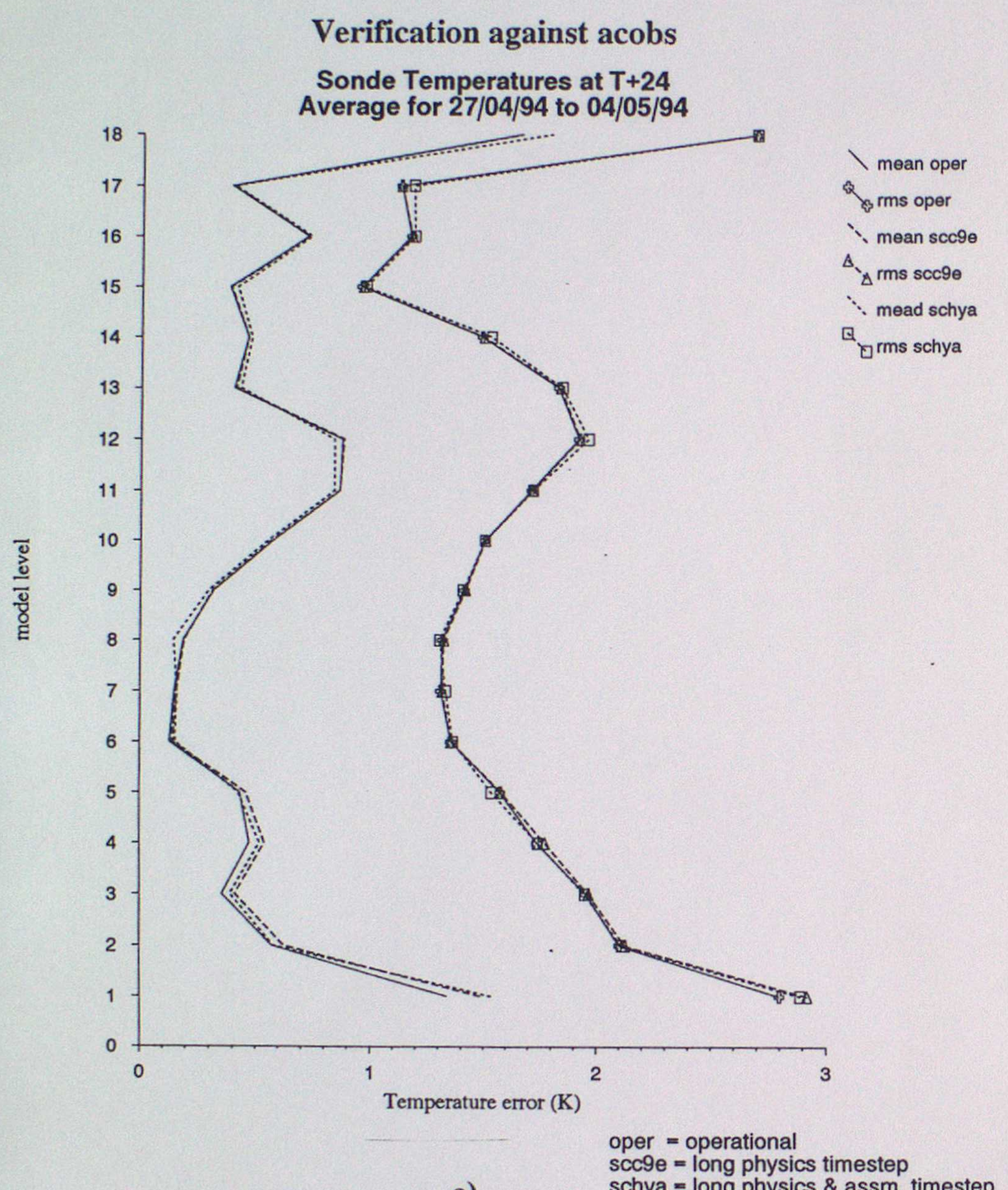
a)



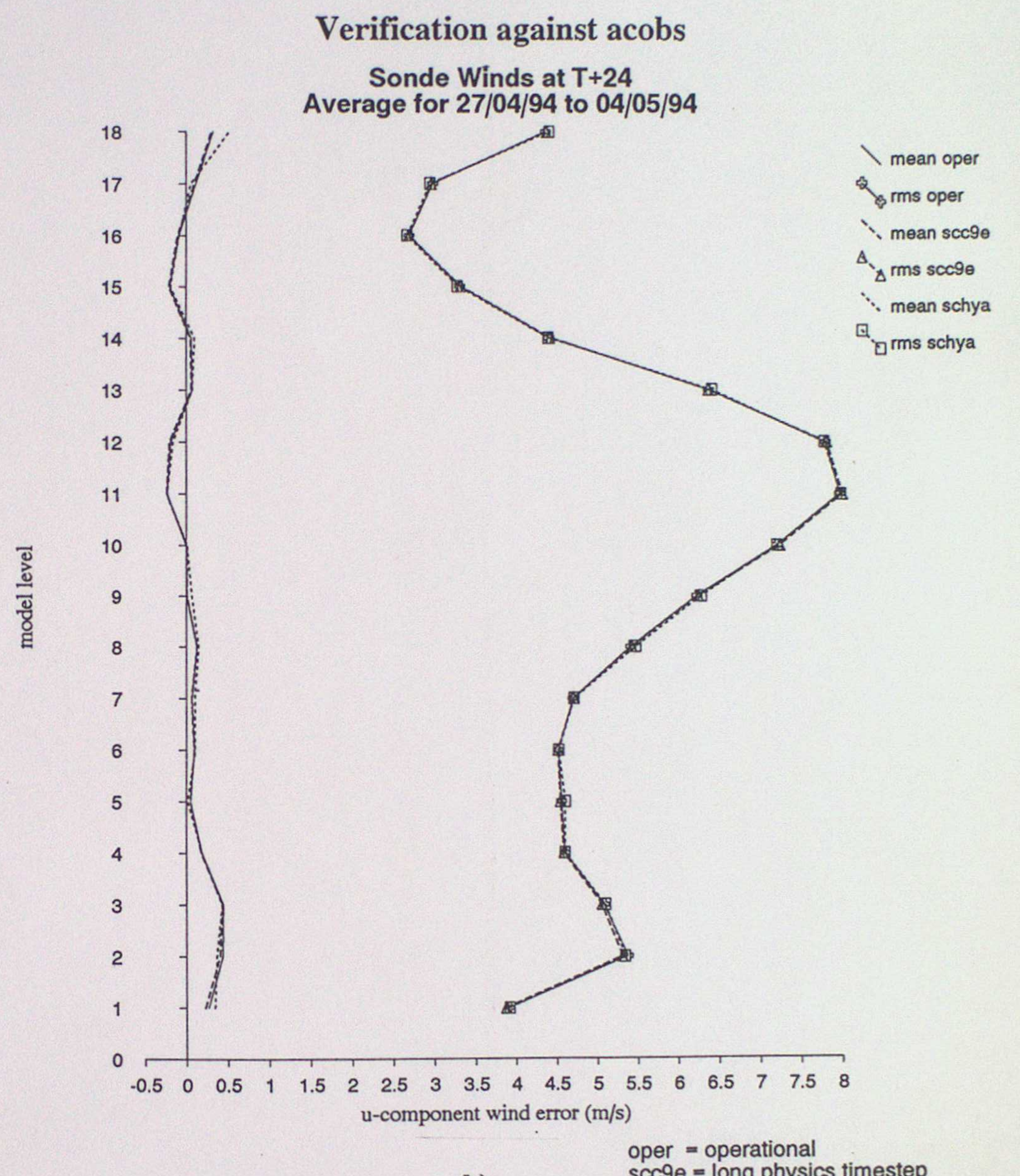
oper = operational
scc9e = long physics timestep
schya = long physics & assm. timestep

b)

FIGURE 14

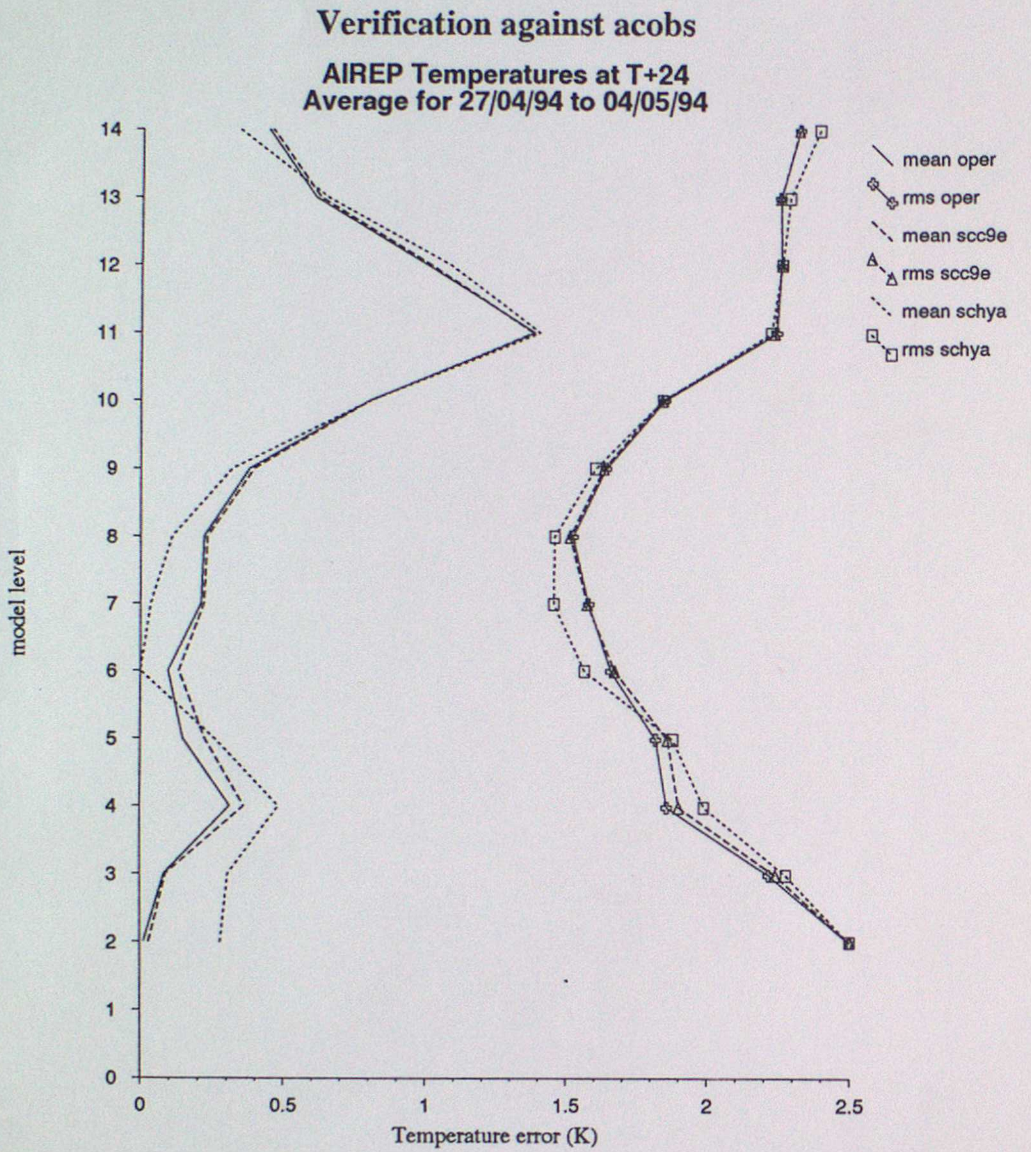

Verification against acobs
Sonde Temperatures at T+24
Average for 27/04/94 to 04/05/94
model level
Temperature error (K)
mean oper
rms oper
mean scc9e
rms scc9e
mead schya
rms schya
oper = operational
scc9e = long physics timestep
schya = long physics & assm. timestep

a)


Verification against acobs
Sonde Winds at T+24
Average for 27/04/94 to 04/05/94
model level
u-component wind error (m/s)
mean oper
rms oper
mean scc9e
rms scc9e
mean schya
rms schya
oper = operational
scc9e = long physics timestep
schya = long physics & assm. timestep

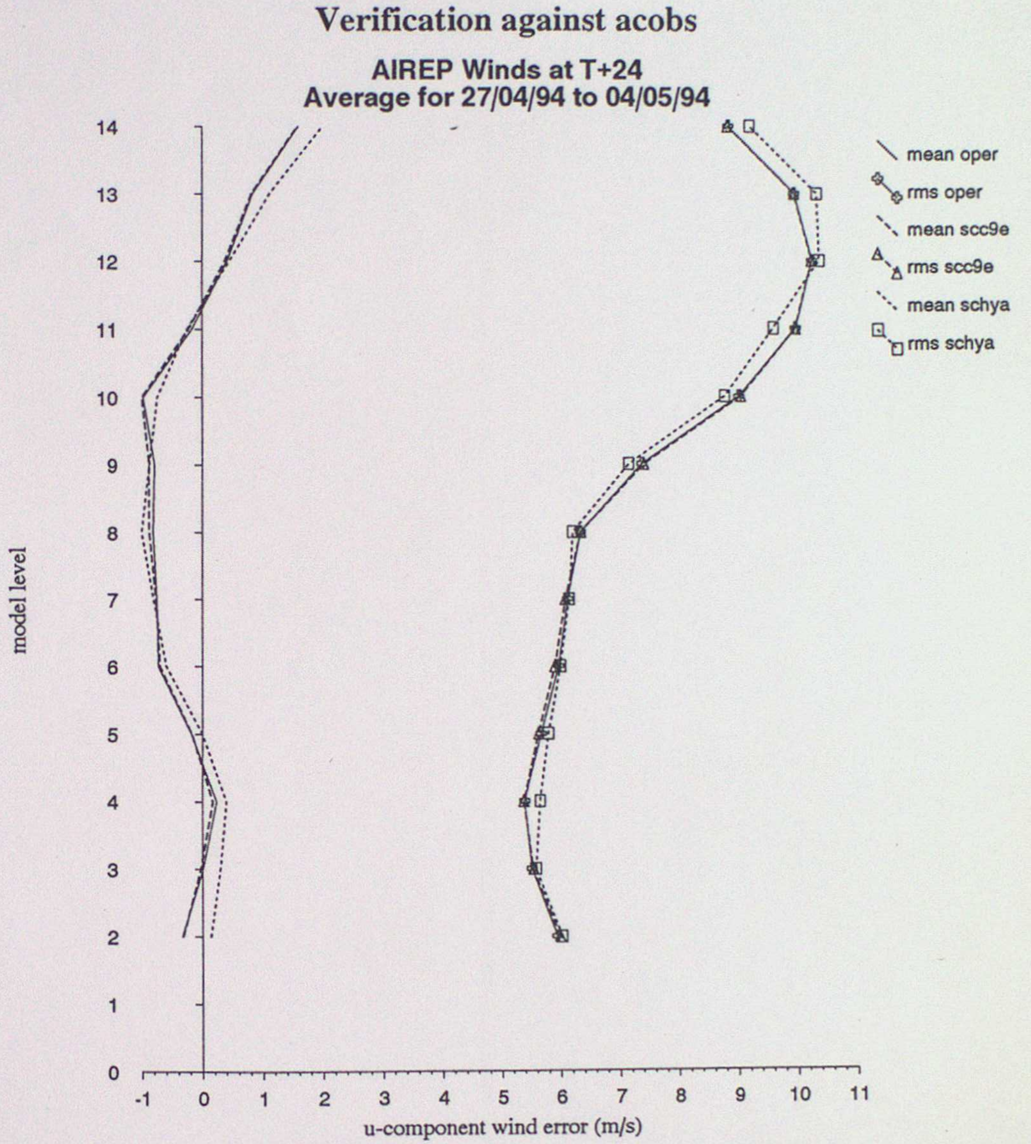
b)

FIGURE 15



oper = operational
scc9e = long physics timestep
schya = long physics & assm. timestep

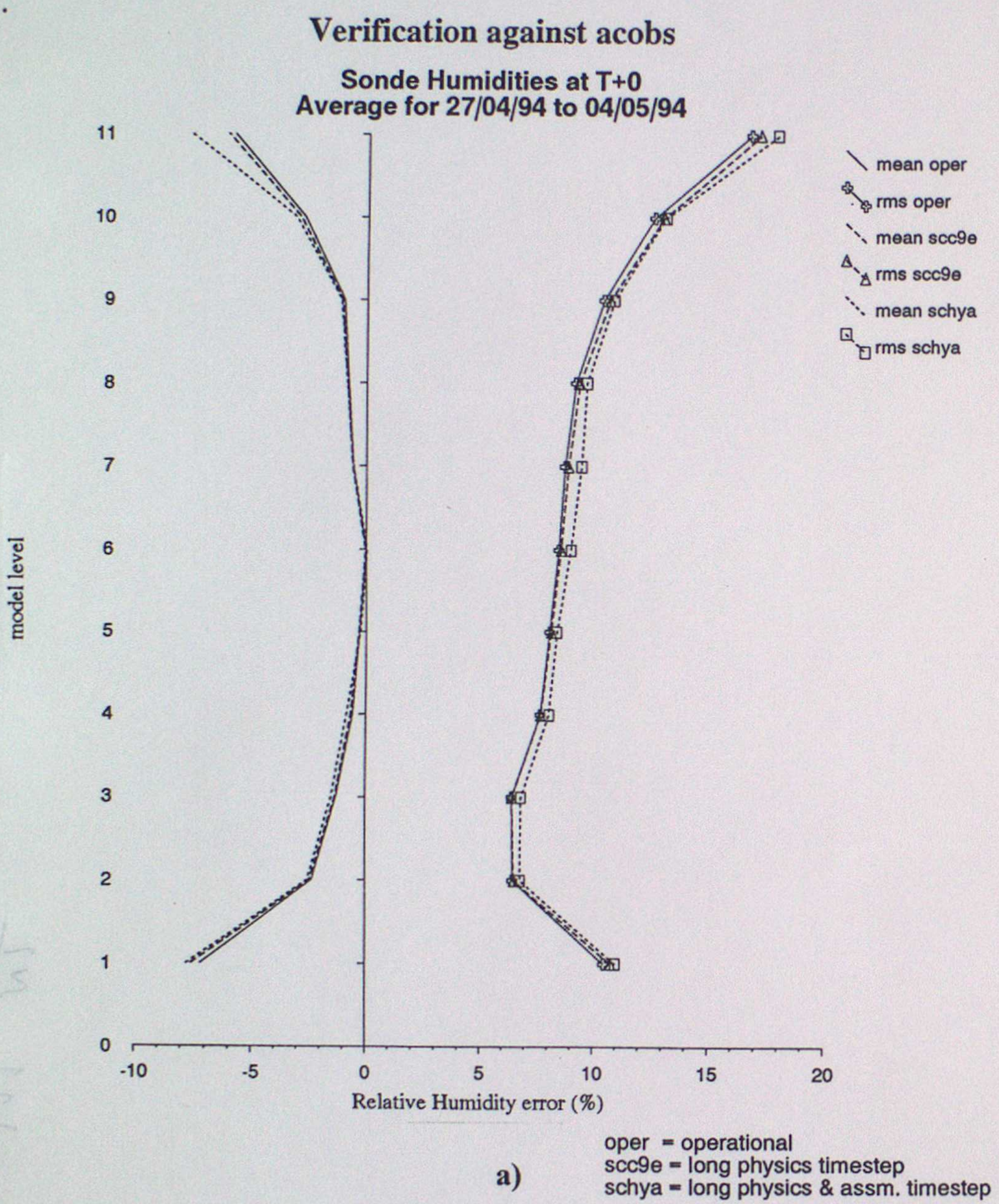
a)



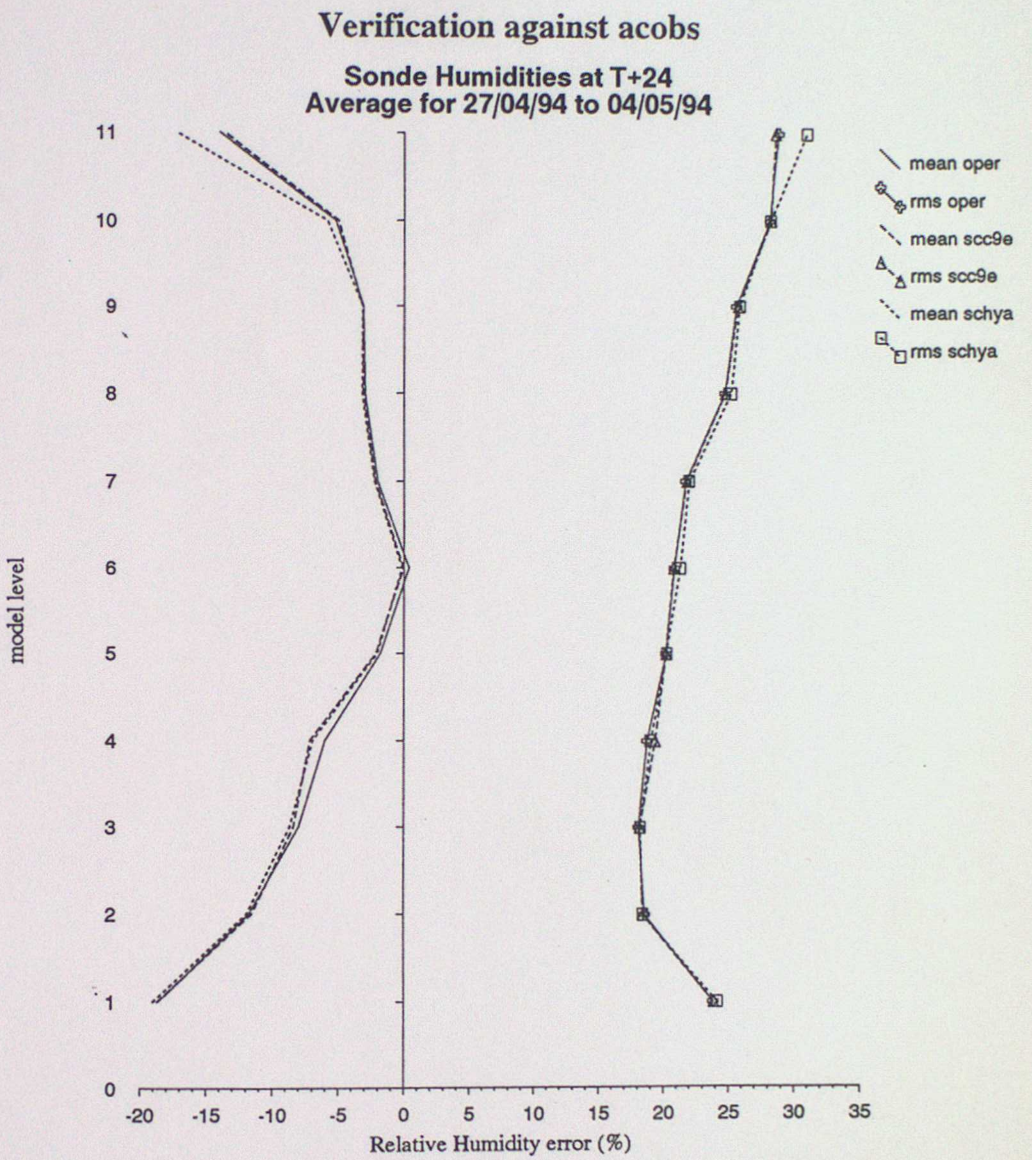
oper = operational
scc9e = long physics timestep
schya = long physics & assm. timestep

b)

FIGURE 16


Verification against acobs
Sonde Humidities at T+0
Average for 27/04/94 to 04/05/94
model level
Relative Humidity error (%)
mean oper
rms oper
mean scc9e
rms scc9e
mean schya
rms schya
oper = operational
scc9e = long physics timestep
schya = long physics & assm. timestep

a)


Verification against acobs
Sonde Humidities at T+24
Average for 27/04/94 to 04/05/94
model level
Relative Humidity error (%)
mean oper
rms oper
mean scc9e
rms scc9e
mean schya
rms schya
oper = operational
scc9e = long physics timestep
schya = long physics & assm. timestep

b)