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The global impact of the recent developments of the physical parameterisation schemes

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1. Introduction

Several changes to the physical parameterisation processes have been introduced into the fine-mesh model over the past two years. The three major changes were, firstly, the replacement of the climatological radiation scheme by an interactive scheme where the radiative fluxes depend on the model's temperature and humidity profiles and on the model's diagnosed cloud layers. Secondly, a modelling of the heat flux between the surface and deeper soil layers was introduced, with the deepest of four soil layers assigned a seasonally varying climatological value. Thirdly, the convection scheme was improved in three ways, by including the effects of mixing by detrainment, by imposing a critical cloud depth for the formation of precipitation and by including a surface resistance to evaporation. In addition to these changes, several other improvements are now available for testing. These include corrections to the interactive radiation code, plus further modifications to that code in order to model the effects of ozone on the solar beam and also to impose (only for the purpose of the radiation calculation) climatological values of mixing ratio in the stratosphere to overcome problems with excessive moisture in the model. The implicit scheme for solving the vertical diffusion equations in the boundary layer, which enables the overdeepening correction to be removed, was also available for testing.

All the above changes have been tested in the coarse-mesh model during a recent trial. The main purpose of introducing these changes is to improve the surface temperature forecasts from the coarse-mesh model, which are beginning to have some useful applications in the Central Forecast Office. Another benefit is the simplification achieved by having only one physics package for both fine and coarse mesh models, and by having a physics package in the coarse mesh model which contains many of the features of the Met O 20 climate model. The convection changes were introduced to the fine-mesh model in order to improve shower forecasts in mid-latitudes and there is no evidence that they are applicable globally. However, they are included in this test because it was the only convenient way of making the diagnosed cloud available to the interactive radiation scheme.

The trial consisted of twelve 5 day forecasts, six from the winter 84/85 period and six from the summer of 1985. Control forecasts using the present operational version of the model were available for comparison purposes, as were the verifying analyses. Verification against observations at selected levels and for three latitude zones was done at daily intervals using the Met O 2b verification package. For surface temperatures, the verification was obtained for each continental area separately using Met O 20 post-processing software.

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In the next section the results of the objective verification against observations will be discussed. The third section will highlight some of the main differences between the two sets of forecasts. Finally I will elaborate on the impact of the various components of the package by considering results from forecasts with all the changes except interactive radiation.

2.Verification against observations

a)Surface pressure and upper air fields

Verification results were available at 24 hour intervals, but to simplify the presentation only the T+120 results will be discussed. Because the impact of the radiation changes will be seasonally dependent, the results from the winter and summer cases will be considered separately. Considering first the winter cases, the verification results are given in full in Table 1 below.

	R.M.S. ERRORS			MEAN ERRORS		
	N.HEM c/t	TROPICS c/t	S.HEM c/t	N.HEM c/t	TROPICS c/t	S.HEM c/t
pmsl						
-land	8.8/ 8.9	3.3/ 3.4	5.1/ 5.1	-1.2/-2.5	-0.1/ 0.3	0.3/ 0.5
-sea	7.8/ 7.7	2.7/ 2.6	5.5/ 5.7	1.9/ 2.1	-1.0/-0.4	-0.6/-0.6
hts						
-850mb	6.0/ 6.1	2.3/ 2.2	4.1/ 4.2	-0.7/-1.8	-0.7/-1.0	-0.4/-0.7
-500mb	9.7/ 9.6	3.9/ 3.9	6.9/ 6.9	-3.0/-2.8	-2.1/-2.5	-1.1/-1.5
-250mb	13.2/12.6	5.5/ 6.0	10.1/10.1	-3.3/-2.3	-2.9/-3.7	-1.2/-1.2
-100mb	12.9/14.5	7.6/ 7.8	7.9/10.5	-6.3/-9.5	-4.2/-4.6	-3.4/-7.9
temps						
-850mb	5.1/ 4.7	2.7/ 3.1	3.8/ 3.8	-1.1/-0.5	0.1/-0.9	0.2/-0.4
-500mb	4.3/ 4.2	2.3/ 2.2	3.4/ 3.4	-0.9/-0.2	-1.0/-0.6	-0.8/-0.4
-250mb	4.4/ 4.6	2.5/ 2.7	3.4/ 3.2	0.3/-1.1	0.3/-0.6	1.0/-0.6
-100mb	3.8/ 4.1	4.5/ 4.3	3.1/ 2.9	-0.6/-1.2	2.9/ 2.3	0.1/-0.7
wind						
-850mb	19.1/18.9	13.3/13.2	18.2/18.0			
-500mb	28.8/29.2	16.4/16.5	24.2/24.7			
-250mb	40.0/40.4	25.1/25.8	35.2/36.3			
-100mb	21.0/21.3	21.6/21.7	21.0/22.0			
rh						
-850mb	29.3/29.1	24.0/22.8	27.5/27.6	-1.2/-1.2	-5.1/ 2.3	5.4/ 8.7
-700mb	34.1/33.0	32.7/30.4	34.5/36.1	5.4/ 1.6	12.9/ 5.0	14.5/14.1
-500mb	35.4/34.9	30.3/28.1	33.7/32.0	2.3/ 0.2	12.9/ 4.8	16.4/12.8

Results of verification against observations for ensemble of winter cases at T+120 (c/t indicates CONTROL/TRIAL)

Table 1

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The results in Table 1 can be summarised as follows:

Surface pressure:-The only area which was consistently better in the trial was the tropical oceans. Results elsewhere were generally worse, but only by a small margin. The slightly higher r.m.s. errors over land in the Northern Hemisphere resulted from a lowering of the mean surface pressure (biasses increased from -1mb to -2.5mb).

Heights:- The trial results represented an improvement in the middle and upper tropospheric levels for the Northern Hemisphere. Elsewhere, changes were small except for the 100mb heights where the increased negative biasses were wholly responsible for the increase in the r.m.s. error.

Temperatures:- Results were mixed, with half the verifying levels improved in all three areas. The increased cold bias was the major contributing factor to the deterioration of the levels which had a higher r.m.s. error in the trial.

Winds:- The 5 day forecast results in Table 1 show a very slight improvement at low levels and a correspondingly small deterioration at higher levels. A different picture emerges when one looks at earlier forecast periods. The trial gives an improvement at 250mb and 100mb in the Northern Hemisphere and at 500mb and 250mb in the Southern Hemisphere upto and including the day 4 results.

Relative Humidity:- The trial is generally better with biasses reduced. Substantial improvements were also noted for for verification against sea observations in the Northern Hemisphere, where at 850mb the dry bias in the control forecasts (-10%)was almost completely eliminated.

On balance the effect of the change is broadly neutral with one exception. There is an unacceptable cooling at the tropopause which makes the, already low, 100mb heights even lower.

The results from the verification of summer cases are detailed in Table 2 below. In summary:

Surface pressure: There is a significant improvement for all three areas, both over land and sea.

Heights:- The 850mb level is improved, but there is a substantial increase in r.m.s. errors at the other three verifying levels. Nearly all the increase in r.m.s. error can be attributed to a substantial lowering of heights in the trial forecasts.

Temperatures:- The trial and control forecasts are broadly similar in the Southern Hemisphere. There is a substantial cooling in trial forecasts at all levels in the Northern Hemisphere which is worst at 850mb and 250mb. The result is an increase r.m.s. errors at all levels except 250mb where the cooling represents and improvement on the previous warm bias.

Winds:- The changes are very small, but are more likely to be for the worse.

Relative:- Humidity More verification area/levels are improved than are made worse. There is a marked increase in relative humidity at low levels in response to the cooling, and in the Northern Hemisphere this results in a worse forecast.

	R.M.S. ERRORS			MEAN ERRORS		
	N.HEM c/t	TROPICS c/t	S.HEM c/t	N.HEM c/t	TROPICS c/t	S.HEM c/t
pmsl						
-land	6.8/ 6.1	3.7/ 3.3	10.0/ 9.4	-1.6/-0.2	-0.9/ 0.0	2.2/ 1.7
-sea	6.1/ 5.8	2.8/ 2.7	12.8/12.1	-0.2/-0.5	-0.8/-0.5	-0.8/-0.7
hts						
-850mb	5.1/ 4.9	2.8/ 2.5	7.8/ 7.7	-1.7/ -1.8	-1.5/-1.3	-0.3/ -1.1
-500mb	6.8/ 8.1	3.2/ 4.1	12.0/12.7	-2.0/ -4.5	-1.6/-2.9	-5.2/ -5.8
-250mb	9.5/11.2	4.7/ 6.3	16.8/17.3	-1.5/ -5.4	-1.4/-4.4	-6.7/ -6.6
-100mb	7.2/14.0	6.9/ 9.2	15.2/17.4	-2.7/-11.6	-2.5/-6.1	-10.0/-12.5
temps						
-850mb	4.2/ 5.1	2.8/ 3.4	6.1/ 6.2	-0.3/-2.7	0.1/-1.5	-3.2/-3.6
-500mb	3.2/ 3.4	2.0/ 2.0	4.9/ 4.8	-0.1/-1.3	0.2/-0.4	-2.4/-2.0
-250mb	4.0/ 3.9	2.1/ 2.7	4.3/ 4.2	1.1/-0.7	0.1/-1.3	0.8/-0.1
-100mb	2.7/ 3.1	4.2/ 3.8	4.2/ 4.4	0.0/-0.8	2.5/ 1.9	0.3/-0.5
wind						
-850mb	17.7/17.0	15.3/14.8	23.9/24.9			
-500mb	23.0/23.1	16.9/17.3	34.2/35.7			
-250mb	33.0/33.7	23.8/24.2	49.7/50.2			
-100mb	14.3/15.8	22.3/22.9	27.9/27.7			
rh						
-850mb	24.7/25.7	21.1/19.6	33.9/33.0	-1.8/9.1	-6.6/ 2.5	-7.1/ 8.7
-700mb	29.5/31.2	24.3/23.8	38.7/38.7	-2.2/2.9	4.1/-1.2	14.7/11.7
-500mb	32.5/32.3	27.6/28.6	44.3/38.4	1.4/4.0	4.7/-0.4	21.7/15.5

Results of verification against observations for ensemble of summer cases at T+120 (c/t indicates CONTROL/TRIAL)

Table 2

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Clearly the cooling in the trial forecasts is even more unacceptable in these summer cases. In the Northern Hemisphere, all the levels verified were colder than both the control forecasts and the verifying observations. This gives rise to lowered heights at every level and at 100mb the mean error is increased to 12dm with a doubling in the r.m.s. error.

b) Surface Temperature verification

Table 3 summarises the results of the surface temperature verification. The results for the verification of the 5 day forecasts is averaged separately for the winter and the summer cases. No attempt was made to remove unrepresentative stations from the sample, so the r.m.s.errors are slightly exaggerated as the coastal and mountain stations have high values. This does not negate the comparison between trial and control forecast results. Plots of (observed - forecast) differences at station locations were also examined to check the validity of the mean figures. The five main continents were assessed separately.

The verification is done at 12z and therefore it is early morning in the Americas and afternoon in Africa, Asia and Europe. In winter the Americas are too cold in the control forecasts at 12z, whereas the trial forecasts have a reduced bias and lower r.m.s.errors. The same is also true for the summer 12z forecasts in the Americas. The winter results for the other three continents are also better for the trial forecasts. In summer the results are not so good, with excessive cooling in the trial forecasts suppressing daytime temperatures throughout Asia, Africa and Europe and resulting in significantly higher r.m.s. errors for those regions.

	WINTER		SUMMER	
	Mean(ob-fc) c/t	R.M.S. c/t	MEAN(ob-fc) c/t	R.M.S. c/t
N.AMERICA	4.0/-0.3	7.5/6.5	2.4/1.6	4.8/4.1
S.AMERICA	3.0/1.8	5.0/3.7	3.7/1.1	5.5/3.8
EUROPE	0.9/1.4	4.8/4.1	2.6/4.1	5.2/6.0
ASIA	0.4/0.0	5.8/5.5	0.7/2.2	5.2/5.5
AFRICA	0.2/1.7	4.8/4.8	0.2/2.7	4.6/5.3

Verification of surface temperature (1.5metre)
Format is control/trial (c/t)
Results are mean of 6 T+120 f/c
Table 3

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A slightly clearer picture of the differences between trial and control forecasts of surface temperature emerges when one looks at Meteograms (timeseries of selected variables). Pairs of Meteograms for 40 cities were examined for the forecasts starting at 12z 13 June 1985. The temperature timeseries from the control forecasts show a regular diurnal cycle which is only perturbed when a change of airmass occurs. In contrast, there is much more variation in the timeseries from the trial forecast. The time of maximum or minimum temperature may be advanced or retarded and also there is most likly to be a reduction in the amplitude of the diurnal cycle with maxima slightly lowered and minima frequently significantly warmer. The pair of Meteograms for Wellington (NZ) are given in Figure 1. The diurnal surface temperature range is forecast to be 5.6degC in the control(average of 5days), but only 0.6degC in the trial.

The most probable reason for the reduction in amplitude of the diurnal cycle is the excessive low cloud being diagnosed in the trial forecasts. The mean global cloud amounts at T+120 are 35% cover of high cloud, 29% cover of medium cloud, 67% cover of low cloud and 12% cover of convective cloud. High cloud is predominantly in the tropics and medium cloud predominates in mid-latitudes. The low cloud is distributed evenly, with only the arid land areas being clear.

3.Comparison of the mean fields

Verification against observations is rather restrictive, in that only selected level are available for assessment and also results are biassed to the populated land areas. A comparison of the mean forecast fields, both for different versions of the forecast model and using verifying objective analyses yields information globally at every level. Some caution must be exercised when using verifying analyses, because they may be biassed towards the operational version of the model in data sparse areas.

a) Winter zonal mean differences

A summary of the winter results is given in the zonally meaned cross-section fields given in Figures 2-4. These three figures show the differences (control-trial), (trial-verification) and (control-verification) respectively of the meaned t+120 fields for both heights and temperatures. Looking first at the height fields we see from Fig.2 that the major effect is above 200 mb with lowered heights in the trial at the higher latitudes of both hemispheres.

The temperature differences, shown below the height differences in Fig 2, indicate a cooling in the tropics and Southern (summer) Hemisphere at low levels and a warming at low levels in the Northern (winter) Hemisphere. Away from the tropics there is also a warming at mid-tropospheric levels, peaking at 400mb and significant cooling above this level. The other major feature is a very large warming in the tropics and Southern (summer) Hemisphere at the top model level.

The differences of forecast from verification in figs 3 and 4 show that the biasses are substantially higher for the trial forecasts The only change in the right direction is at mid-troposheric levels around 50N, where a 1.5 degC cold bias in the control forecasts has been improved upon.

b) Summer zonal mean differences

Similar zonally-meaned difference fields for the summer cases are shown in Figures 5-7. The mean temperature difference of the trial forecast from the control in Figure 5 is almost a mirror image about the equator of the comparable figure from the winter cases. The trial is cooler in the tropics and Northern (summer) Hemisphere at low levels, but this cooling extends to higher levels in these cases. The warming at 400mb away from the equator is also present in these cases but is less strong in the Northern Hemisphere. The marked cooling in mid and high latitudes at 200mb is as stong in the Northern Hemisphere as in the previous cases, but less strong in the Southern Hemisphere. The very stong warming at the top level is still centered on the summer pole which in these cases is of course the North Pole.

With more cooling than warming, we see lowered heights at almost every level and latitude. The largest difference is at 70mb at the North Pole, where the trial is 13dm lower. Unlike the winter cases where significant height differences were only noticeable in the stratosphere, these summer cases are showing substantial lowering of heights at 500mb in Northern Hemisphere mid-latitudes.

The differences of forecast from verification for these summer cases is given in figs 6 and 7. As with the winter cases the biasses are substantially higher for the trial forecasts The only change in the right direction is at mid-troposheric levels around 60S, where a 2 degree cold bias in the control forecasts has been reduced.
Also of interest are the relative humidity differences. These are similar for winter and summer comparisons.The summer differences are shown in Fig 8. We see a substantial moistening at low levels with zonally averaged mean values for the trial exceeding the control by in excess of 10% at 850-900mb around 20-30S. This moistening is almost certainly in response to the cooling. There is a drying at higher levels in the tropics which also exceeds 10% around 10N.

c) Difference Maps

The next set of four charts (Fig 9-12) show the mean difference maps (control-trial) for the winter cases to illustrate the geographical variation. Fig 9 gives mean pmsl differences which are mostly quite small. The positive areas, particularly near Iceland and the Aleutians represent a slight deepening and shift of the meaned low pressure systems. In general, the removal of the overdeepening correction from the model code does not seem to have caused any significant problems.

The surface temperature differences in fig.10 show that all the cold land areas have been warmed, particularly the land ice areas. The warmer land areas have been cooled. This presumably indicates that the deep soil temperatures are having a restraining effect, although the suppression of the diurnal cycle because of the excess of low cloud will undoubtedly be having a significant effect too.

Figures 10 and 11 show the large impact at upper levels. The largest differences in the 200mb temperatures(Fig 11)occur over Siberia and the Canadian Arctic where the temperatures are lowest. Fig 12 shows differences in the 100mb height fields are in the same areas.

4. Further Trial forecasts

The above section has highlighted several problem areas, the most significant of which is the increased temperature biasses at upper tropospheric and lower stratospheric levels. The change to the radiation parameterisation is suspected of contributing most to this problem and to check this suspicion we repeated the entire trial with all changes except those to the radiation scheme. The impact of the changes in this second trial was very much more modest as can be seen from Fig.13 which compares directly with Fig.2. The zonal mean differences (CONTROL-TRIAL2) for the mean of the 6 winter T+120 forecasts in Fig.13 shows most impact in the tropics. There is a 3dm lowering of heights in the forecasts from the second trial at 200mb near the equator. This corresponds with a cooling in excess of 1degC at upper tropospheric levels. The only other significant change is a warming of about 1degC at low levels between 60N and 70N.

The temperature changes in the tropics are a consequence of the convection changes which have brought about a change in the rainfall. Table 4 gives the area weighted global mean rainfall between T+96 and T+120 as an average for both the summer and winter sets of cases. In both winter and summer there has been a very large reduction in the convective mean convective rain, amounting to almost a 1mm/day reduction in the global average. On examining the charts it is clear that outside the tropics there has been a compensating increase in the dynamic rain, particularly in the first trial when interactive radiation was included. However in the tropics there has been a decrease in the total rainfall.

The overall reduction in rainfall in the trial runs is probably beneficial, since the 3mm/day total for the control run is greater than generally assumed by climatologists. However, the switch from convective to dynamic rain in the trial forecasts is so dramatic that the change deserves a more detailed consideration.

	WINTER			SUMMER		
	dynamic	convec	total	dynamic	convec	total
CONTROL	.52	2.43	2.95	.53	2.55	3.08
TRIAL	1.27	1.62	2.89	1.26	1.56	2.82
TRIAL 2	.95	1.52	2.47	.92	1.52	2.44

Area weighted global mean rainfall (mm/day)
from periods T+96 to T+120

Table4

The surface temperature verification results for the second trial are given in Fig.5. Fig.5 compares directly with Fig.3 for the first trial. The surface temperature biasses from the second trial are very small and are comparable with those from the first trial in winter and better than both control and TRIAL1 in summer.

	WINTER		SUMMER	
	Mean(ob-fc) c/t2	R.M.S. c/t2	MEAN(ob-fc) c/t2	R.M.S. c/t2
N.AMERICA	4.0/-0.5	7.5/6.6	2.4/-0.1	4.8/3.6
S.AMERICA	3.0/-0.1	5.0/3.5	3.7/-0.1	5.5/3.8
EUROPE	0.9/-0.7	4.8/4.2	2.6/1.1	5.2/4.5
ASIA	0.4/-1.7	5.8/5.7	0.7/0.9	5.2/5.0
AFRICA	0.2/-0.9	4.8/4.4	0.2/-0.6	4.6/4.3

Verification of surface temperature (1.5metre)
Format is CONTROL/TRIAL2 (c/t2)
Results are mean of 6 T+120 f/c

Table5

The objective verification against verifying radiosondes and surface reports was also repeated for the second trial and the results compared with both CONTROL and TRIAL1 results. A summary of this comparison is given in Table 6 which gives the average r.m.s. errors for the trials at T+120 expressed as a percentage of the r.m.s. error from the control comparison forcasts. The columns labelled t/c are the ratio of the r.m.s. errors given in Table 2 and can be easily compared with the columns t2/c to give the relative performance of all three versions of the model. The figures marked with an asterix(*) indicate changes of r.m.s.error in excess of 10 percent in trial forecasts when compared with control. The overall impression is that TRIAL2 has had a positive impact relative to TRIAL1, but not as great as might be expected. Although the largest problems of TRIAL1 have been alleviated, TRIAL2 is still worse than control and in some cases gains made with TRIAL1 have been lost.

	RATIO OF R.M.S. ERRORS WINTER CASES						RATIO OF R.M.S. ERRORS SUMMER CASES					
	N.HEM		TROPICS		S.HEM		N.HEM		TROPICS		S.HEM	
	t/c	t2/c	t/c	t2/c	t/c	t2/c	t/c	t2/c	t/c	t2/c	t/c	t2/c
pmsl												
-land	101	103	103	106	100	105	* 90	96	* 89	100	94	101
-sea	99	101	96	112 *	104	107	95	98	96	96	95	99
hts												
-850mb	102	105	96	100	102	105	96	96	89	96	99	104
-500mb	99	106	100	108	100	104	*119	108	*128	119*	106	109
-250mb	95	104	109	122*	100	102	*118	111*	*134	134*	103	108
-100mb	*112	106	103	117*	*133	111*	*194	126*	*133	129*	*114	112*
temps												
-850mb	92	96	*115	104	100	103	*121	102	*121	100	102	102
-500mb	98	102	96	117*	100	106	106	100	100	110*	98	104
-250mb	105	102	108	108	94	100	98	98	*129	114*	98	102
-100mb	108	103	96	104	94	103	*115	100	90	100	104	102

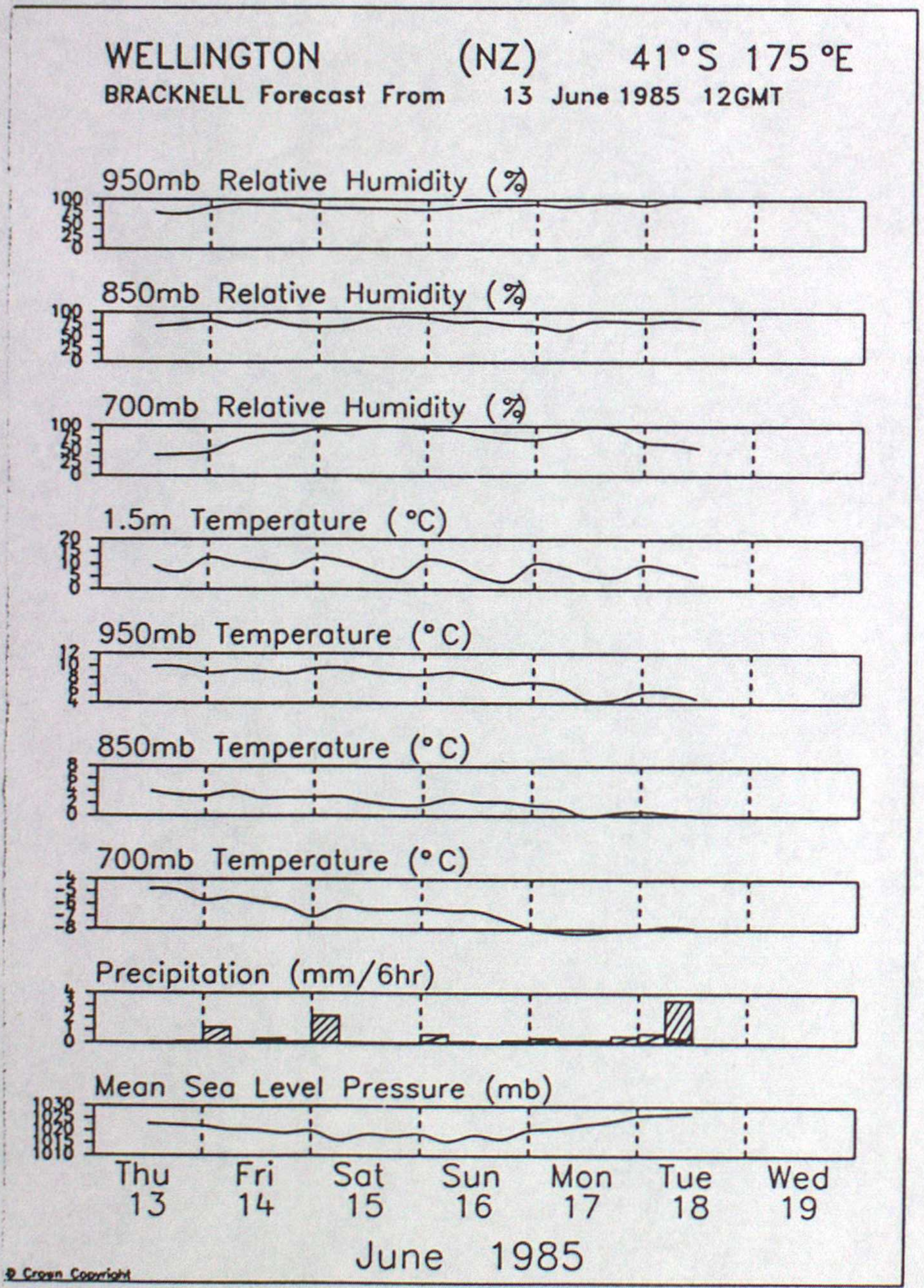
Ratio of trial r.m.s. errors to control r.m.s. errors
expressed as a percentage
Results are for means of 6 cases at t+120
t/c for first trial and t2/c for second trial

Table 6

5.Conclusions

The results of the trial have proved rather disappointing. The model's hmr fields and diagnosed cloud are at present insufficiently accurate to be used by the radiation scheme. The increase in low cloud during the forecast and the excessive cloudiness in general, allied with the poor hmr structure at stratospheric levels needs to be remedied before they can be usefully input to the radiation scheme.

CONTROL



TRIAL

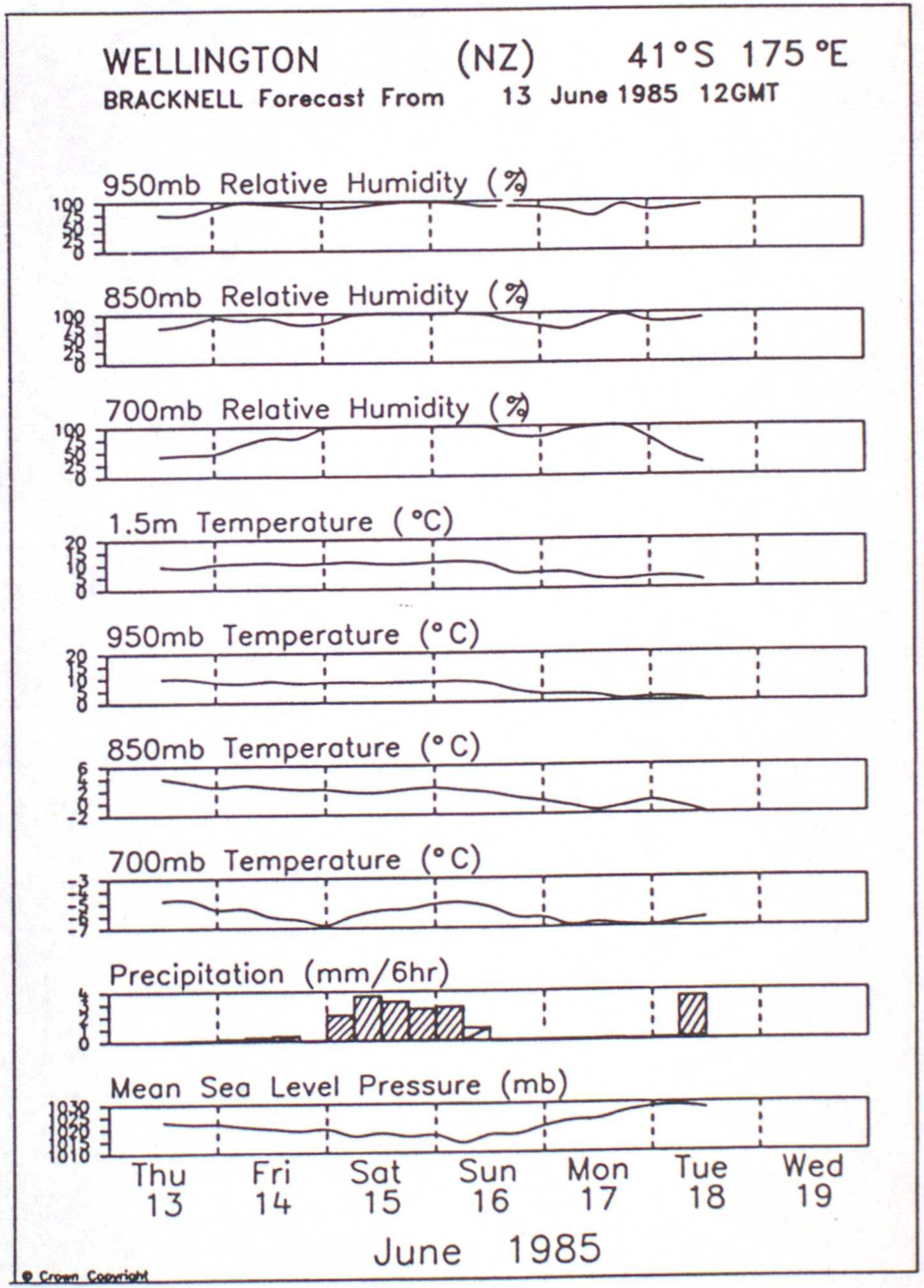
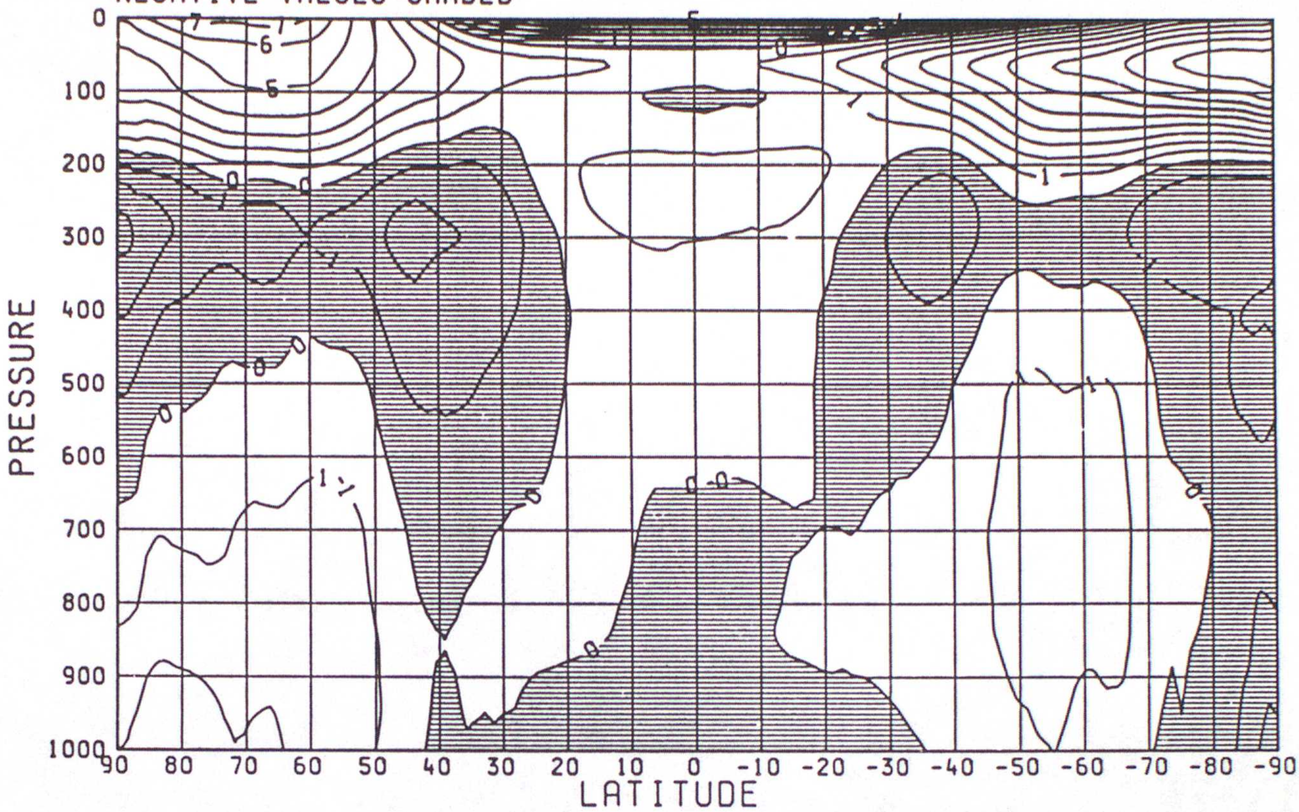


FIG 1

6 WINTER CASES...CONTROL-TRIAL
HEIGHT ZONAL MEAN DIFFERENCE
AVERAGE FROM 12Z ON 21/11/1984 DAY 326 TO 12Z ON 2/1/1985 DAY 2
NEGATIVE VALUES SHADED



6 WINTER CASES...CONTROL-TRIAL
TEMPERATURE ZONAL MEAN DIFFERENCE
AVERAGE FROM 12Z ON 21/11/1984 DAY 326 TO 12Z ON 2/1/1985 DAY 2
NEGATIVE VALUES SHADED

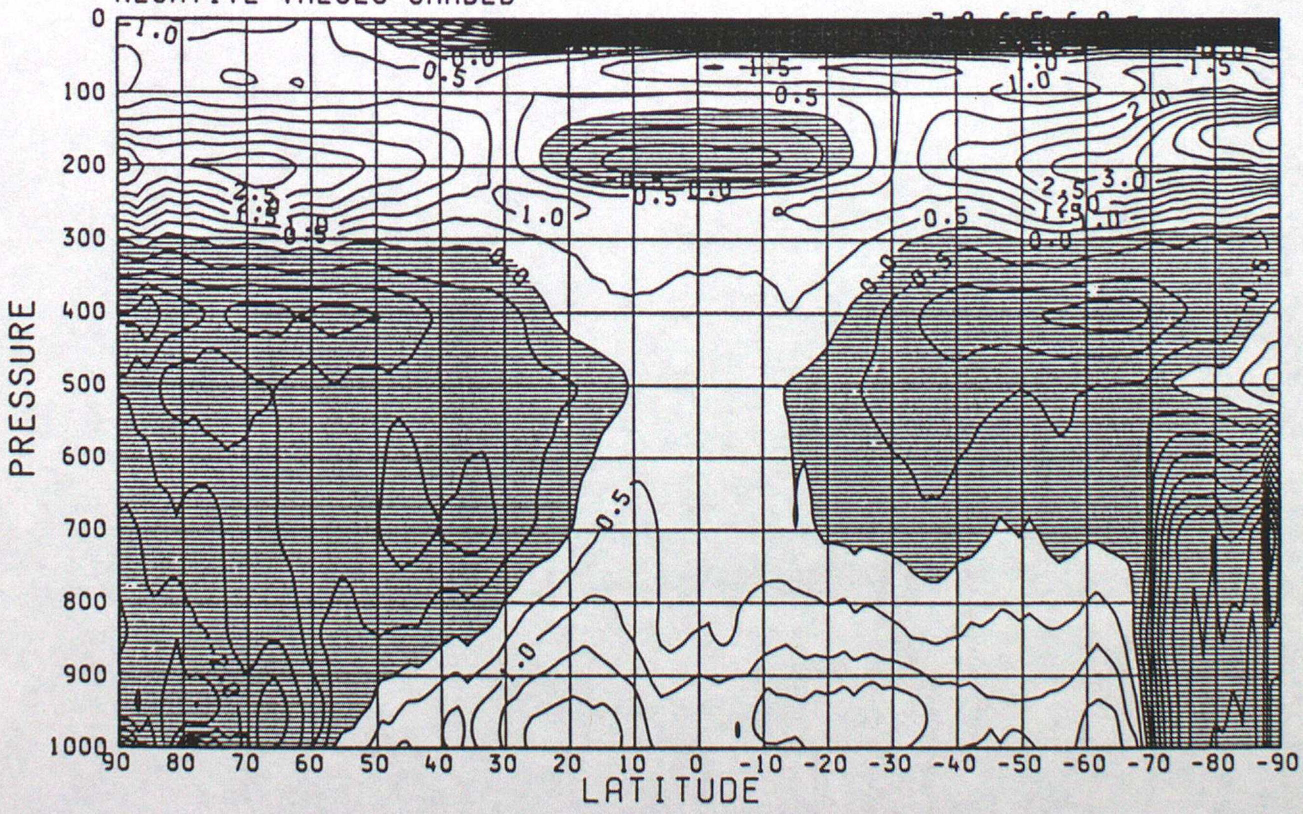
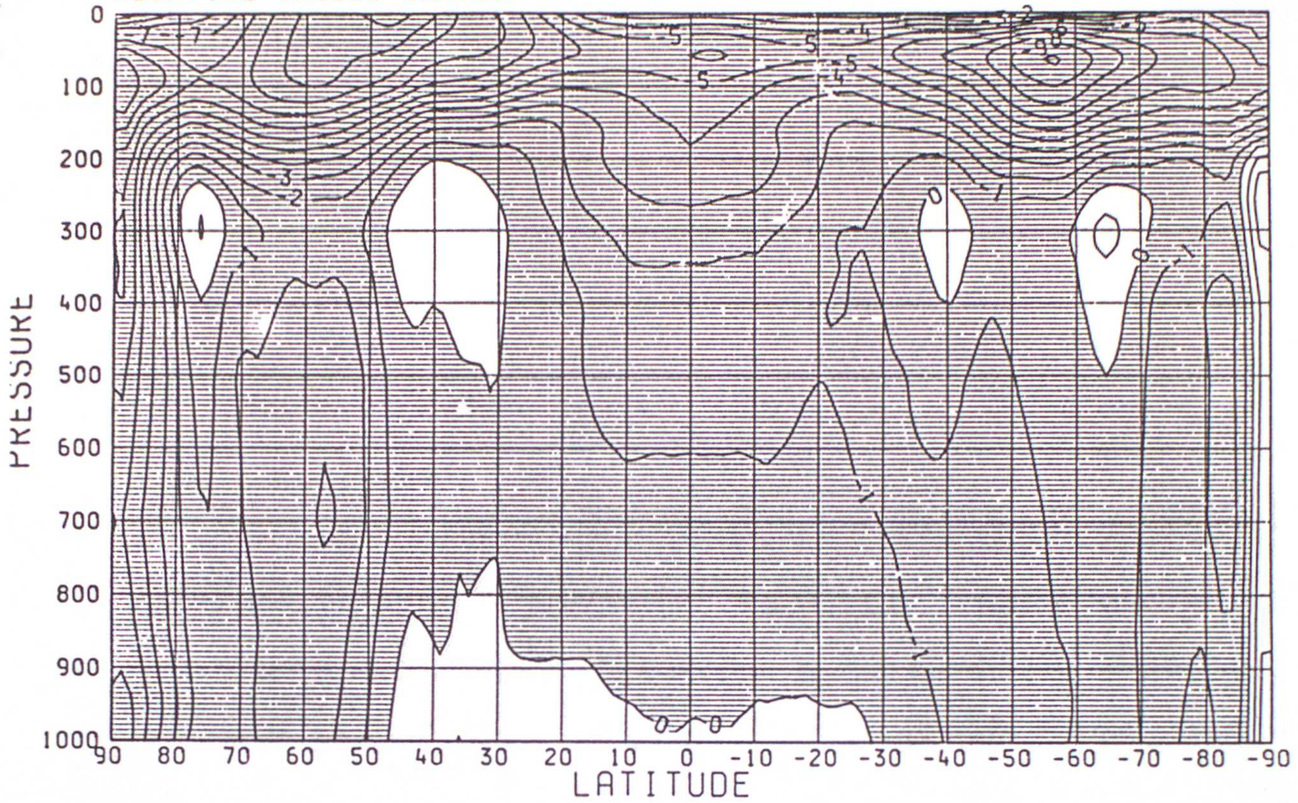


FIG 2

6 WINTER CASES...TRIAL - VERIF
HEIGHT ZONAL MEAN DIFFERENCE
AVERAGE FROM 12Z ON 21/11/1984 DAY 326 TO 12Z ON 2/1/1985 DAY 2
NEGATIVE VALUES SHADED



6 WINTER CASES...TRIAL - VERIF
TEMPERATURE ZONAL MEAN DIFFERENCE
AVERAGE FROM 12Z ON 21/11/1984 DAY 326 TO 12Z ON 2/1/1985 DAY 2
NEGATIVE VALUES SHADED

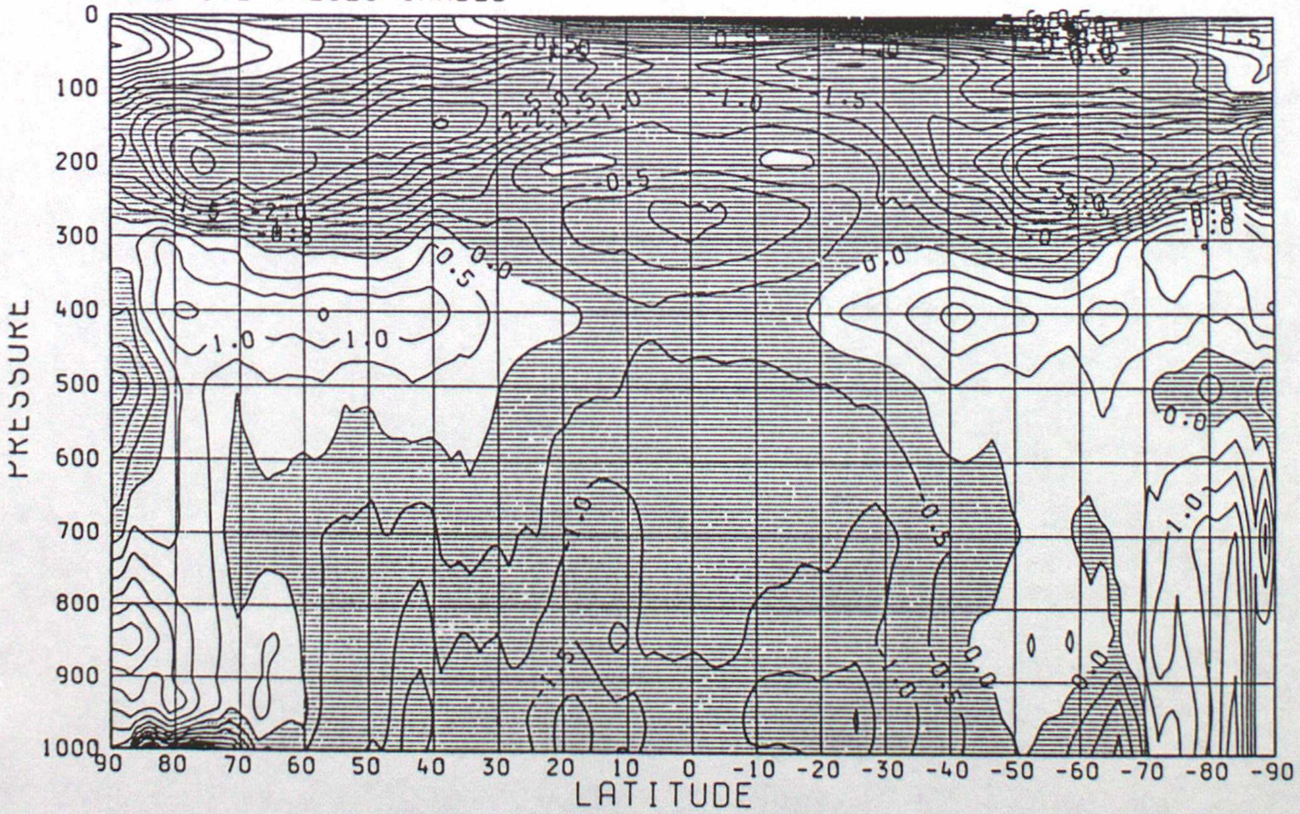
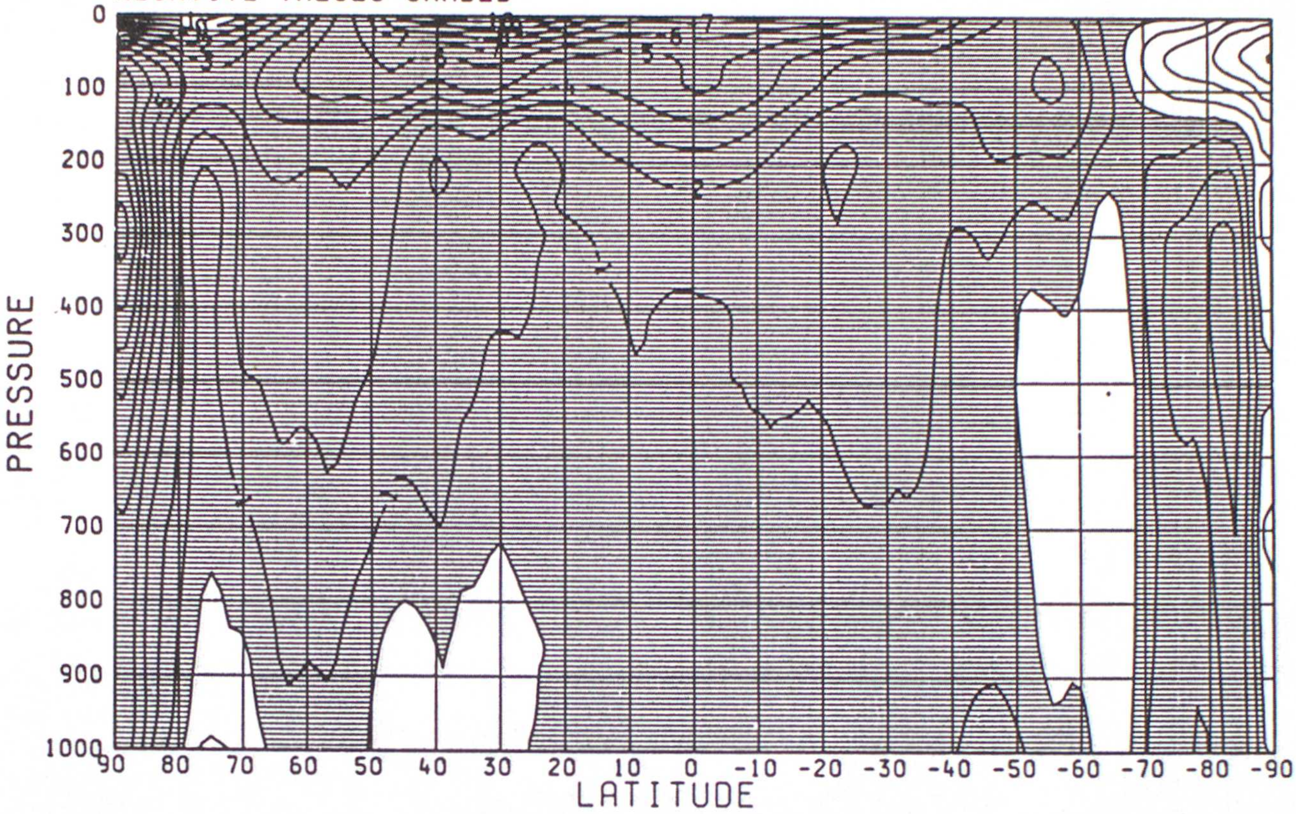


FIG 3

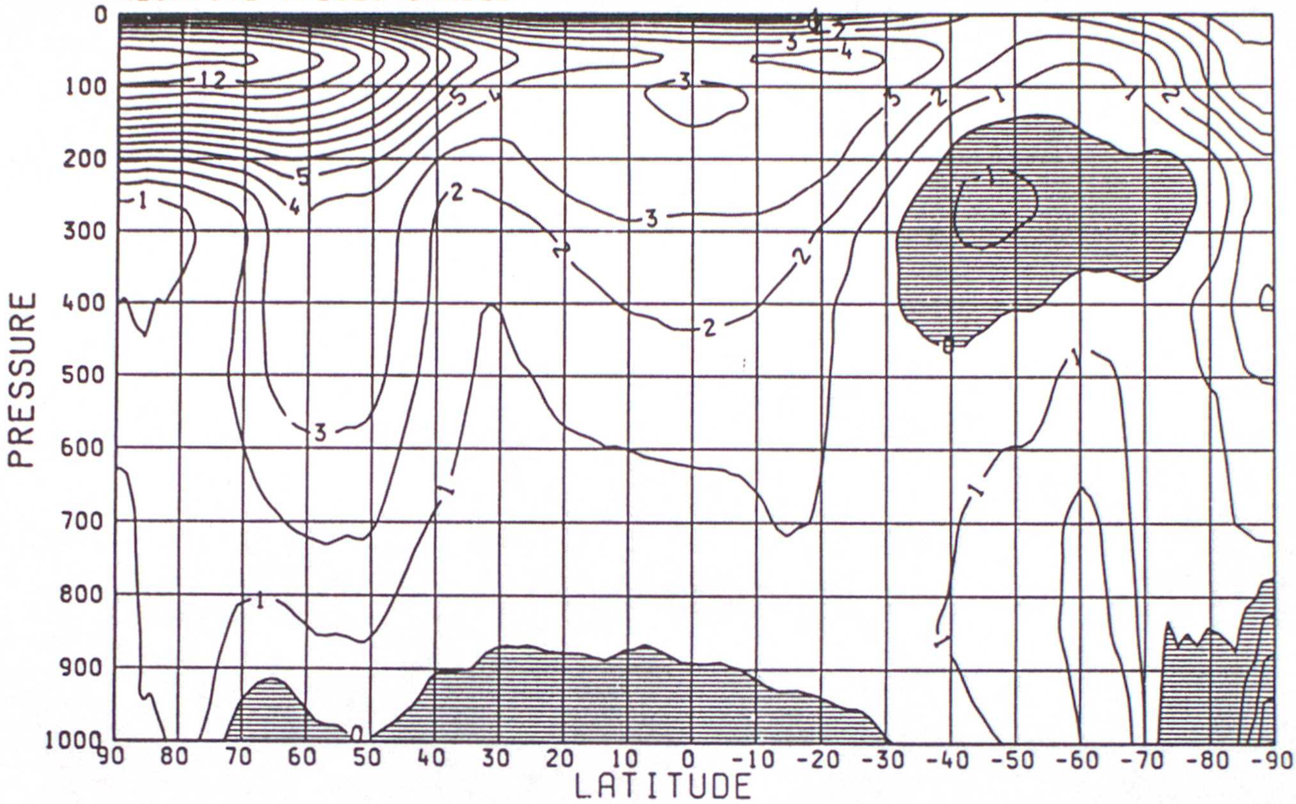
6 WINTER CASES...CONTROL-VERIF
HEIGHT ZONAL MEAN DIFFERENCE
AVERAGE FROM 12Z ON 21/11/1984 DAY 326 TO 12Z ON 2/1/1985 DAY 2
NEGATIVE VALUES SHADED



6 WINTER CASES...CONTROL-VERIF
TEMPERATURE ZONAL MEAN DIFFERENCE
AVERAGE FROM 12Z ON 21/11/1984 DAY 326 TO 12Z ON 2/1/1985 DAY 2
NEGATIVE VALUES SHADED

FIG 4

6 SUMMER CASES...CONTROL-TRIAL
HEIGHT ZONAL MEAN DIFFERENCE
AVERAGE FROM 12Z ON 28/5/1985 DAY 148 TO 12Z ON 2/7/1985 DAY 183
NEGATIVE VALUES SHADED



6 SUMMER CASES...CONTROL-TRIAL
TEMPERATURE ZONAL MEAN DIFFERENCE
AVERAGE FROM 12Z ON 28/5/1985 DAY 148 TO 12Z ON 2/7/1985 DAY 183
NEGATIVE VALUES SHADED

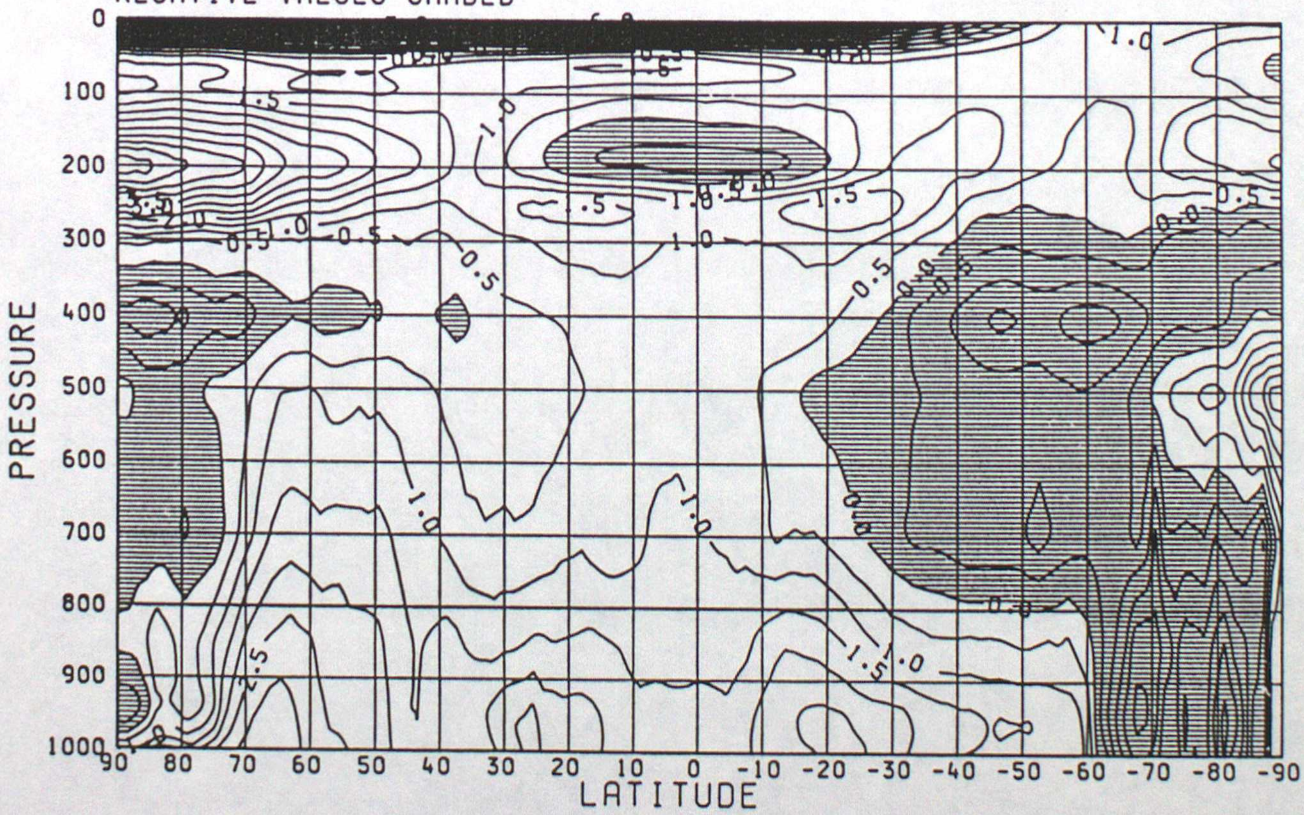
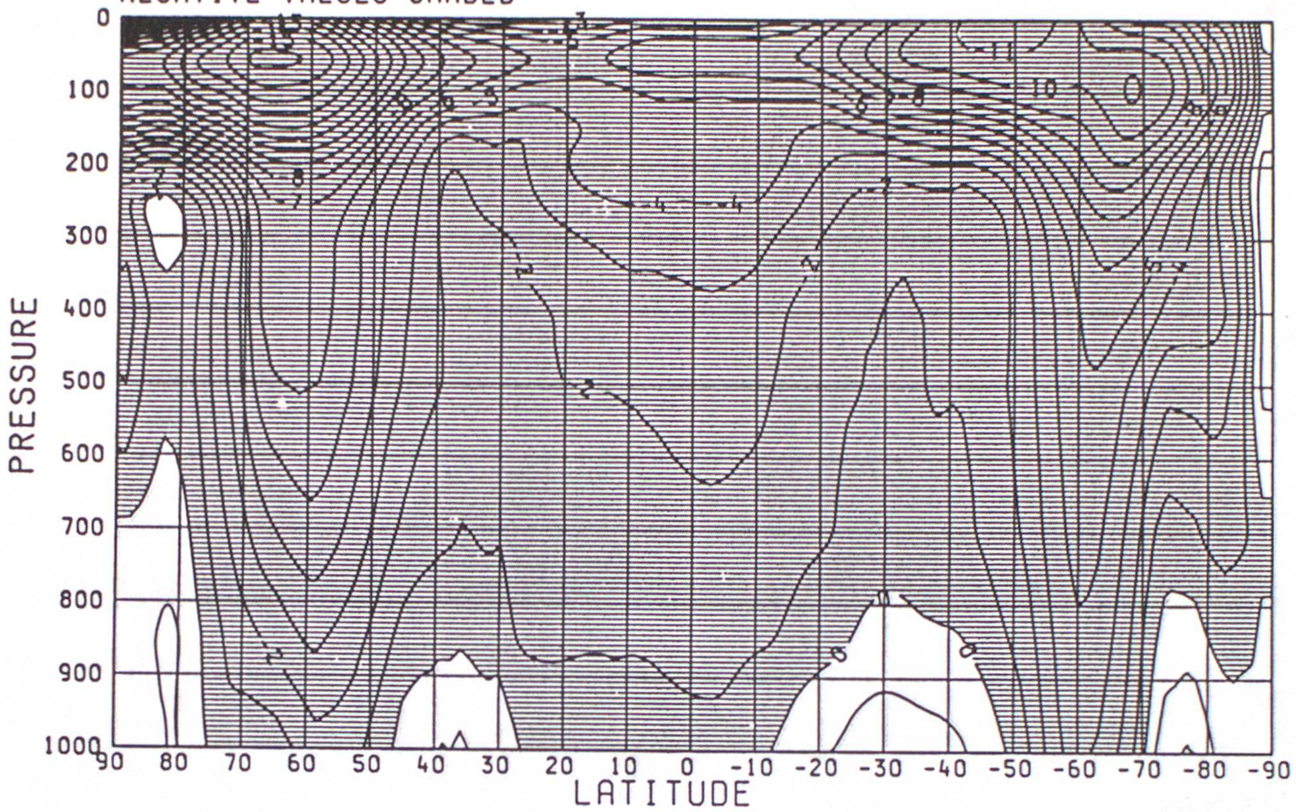


FIG 5

6 SUMMER CASES...TRIAL-VERIF
HEIGHT ZONAL MEAN DIFFERENCE
AVERAGE FROM 12Z ON 28/5/1985 DAY 148 TO 12Z ON 2/7/1985 DAY 183
NEGATIVE VALUES SHADED



6 SUMMER CASES...TRIAL-VERIF
TEMPERATURE ZONAL MEAN DIFFERENCE
AVERAGE FROM 12Z ON 28/5/1985 DAY 148 TO 12Z ON 2/7/1985 DAY 183
NEGATIVE VALUES SHADED

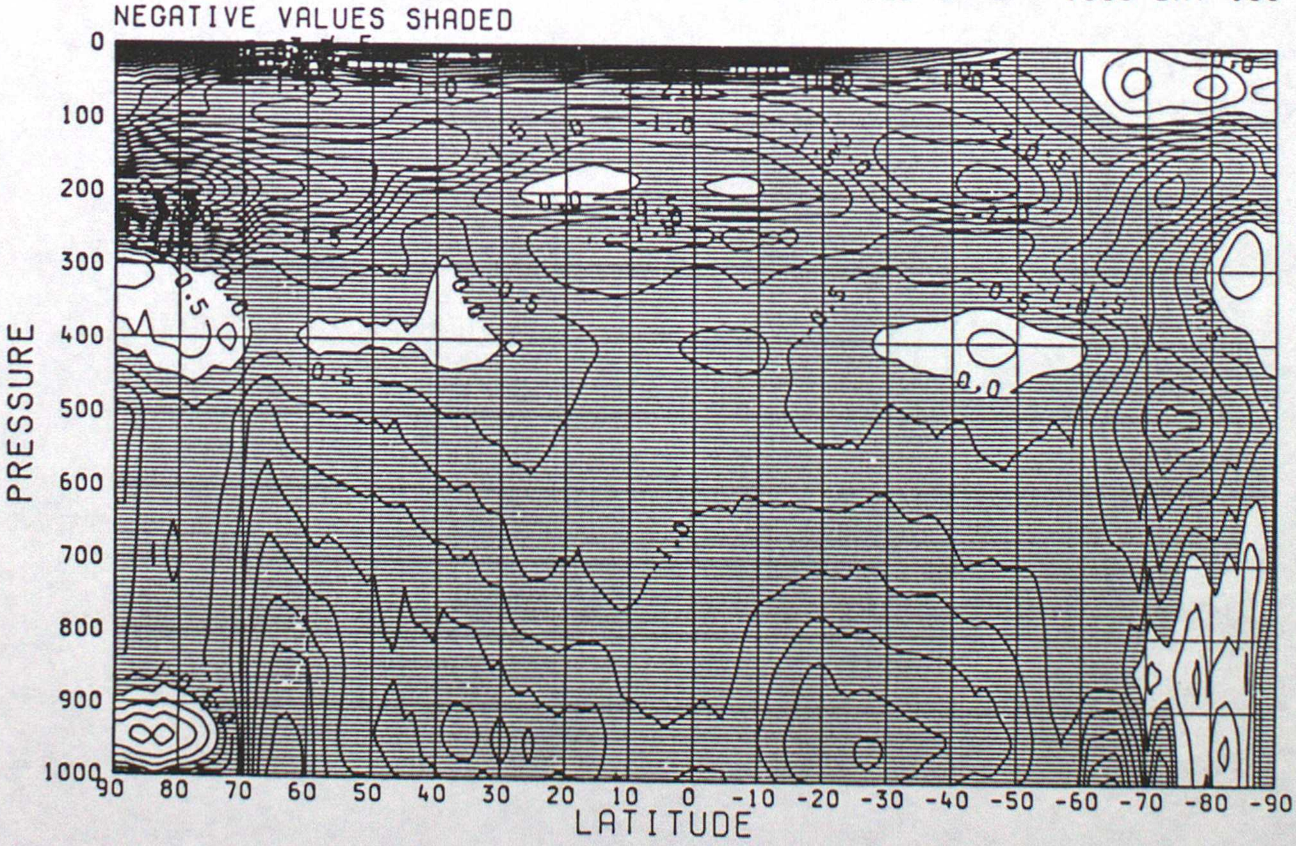
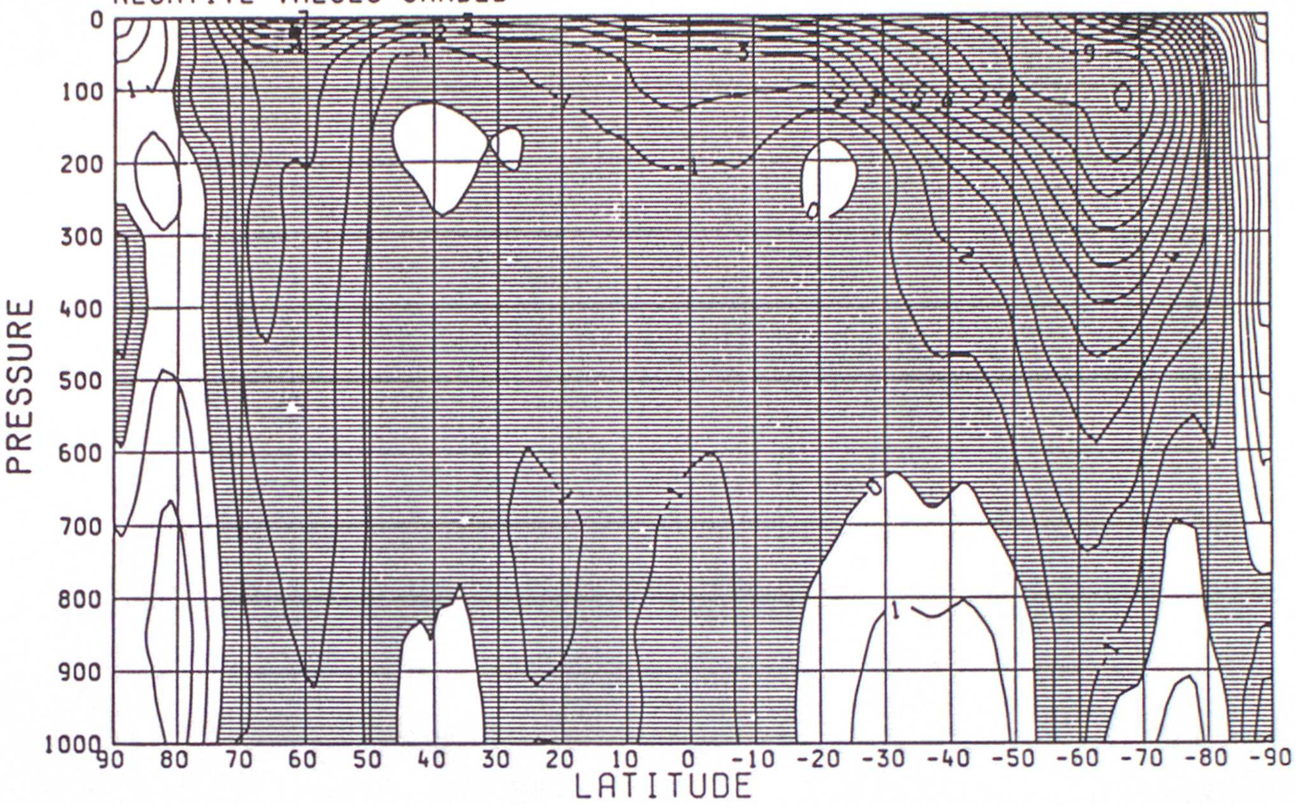


FIG 6

6 SUMMER CASES...CONTROL-VERIF
HEIGHT ZONAL MEAN DIFFERENCE
AVERAGE FROM 12Z ON 28/5/1985 DAY 148 TO 12Z ON 2/7/1985 DAY 183
NEGATIVE VALUES SHADED



6 SUMMER CASES...CONTROL-VERIF
TEMPERATURE ZONAL MEAN DIFFERENCE
AVERAGE FROM 12Z ON 28/5/1985 DAY 148 TO 12Z ON 2/7/1985 DAY 183
NEGATIVE VALUES SHADED

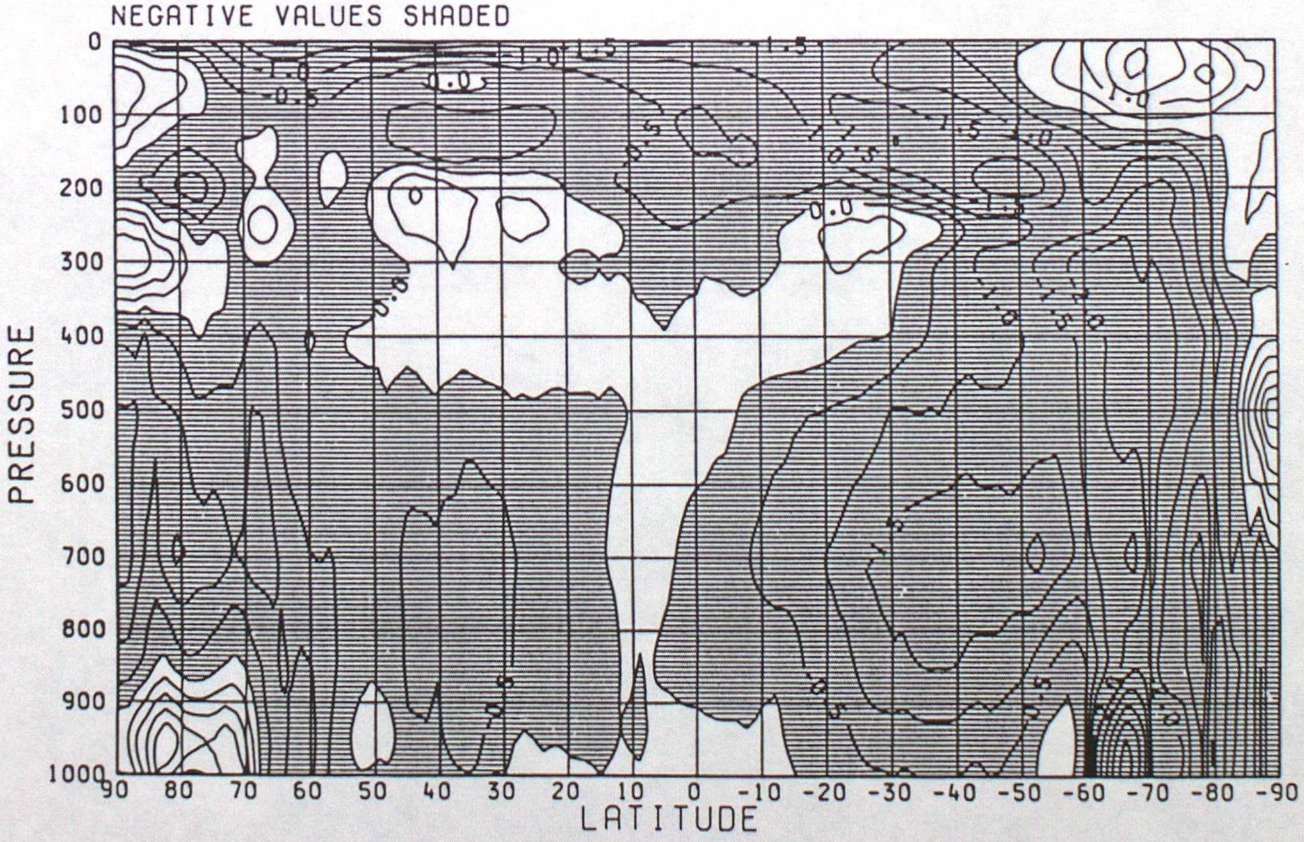


FIG 7

6 SUMMER CASES...CONTROL-TRIAL
RELATIVE HUMIDITY ZONAL MEAN DIFFERENCE
AVERAGE FROM 12Z ON 28/5/1985 DAY 148 TO 12Z ON 2/7/1985 DAY 183
NEGATIVE VALUES SHADED

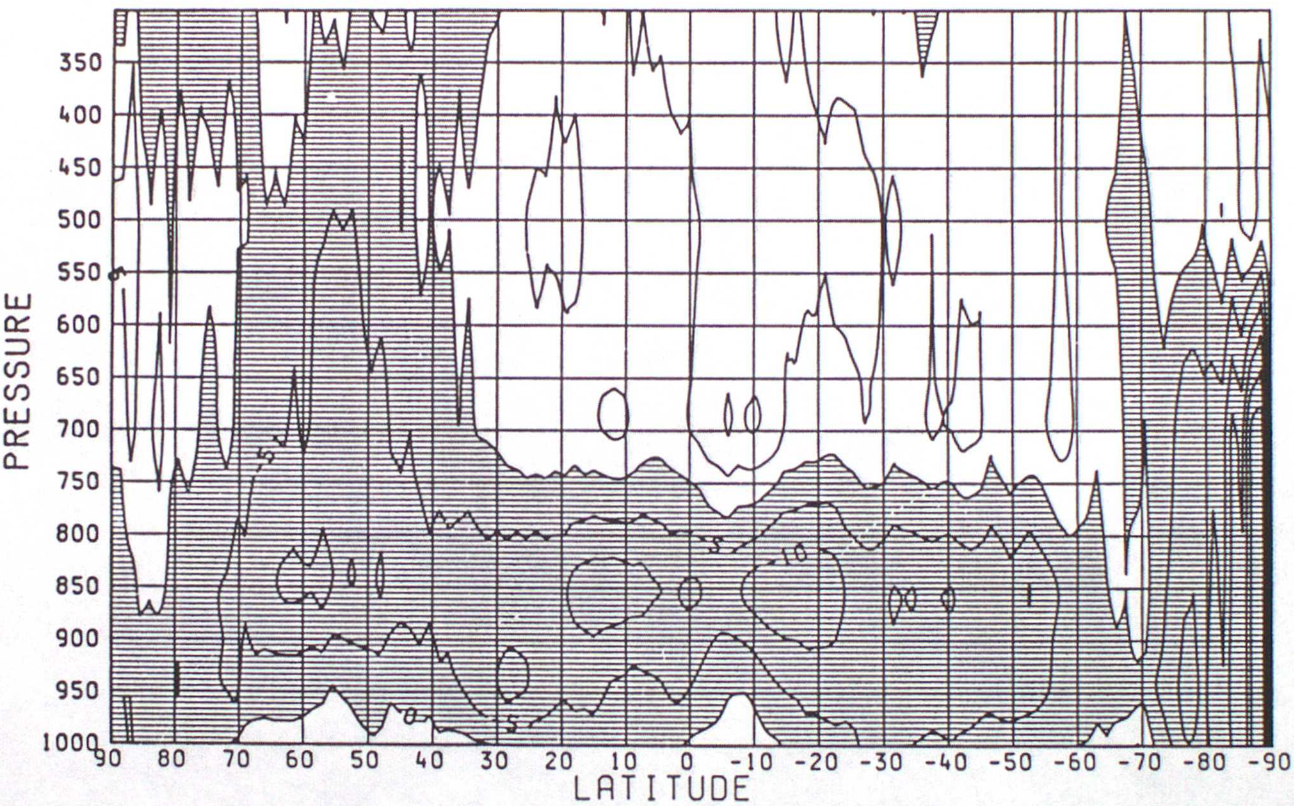


FIG 8

MEAN T+120 CONTROL-TRIAL
MEAN SEA LEVEL PRESSURE
AVERAGE FROM 12Z ON 21/11/1984 DAY 326 TO 12Z ON 2/1/1985 DAY 2
LEVEL: SEA LEVEL

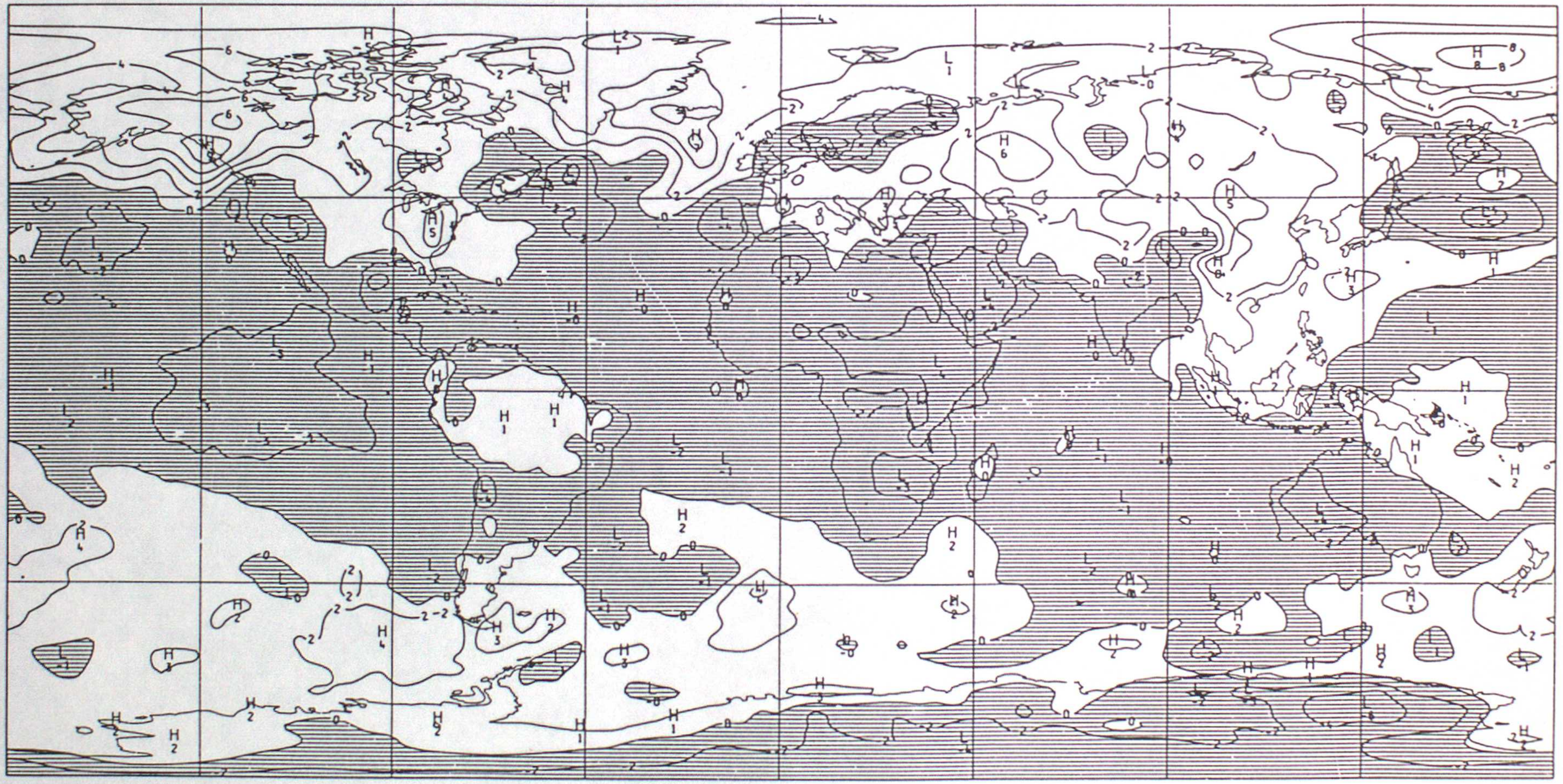


FIG 9

MEAN T+120 CONTROL-TRIAL
TEMPERATURE (1·5 METRE)
AVERAGE FROM 12Z ON 21/11/1984 DAY 326 TO 12Z ON 2/1/1985 DAY 2

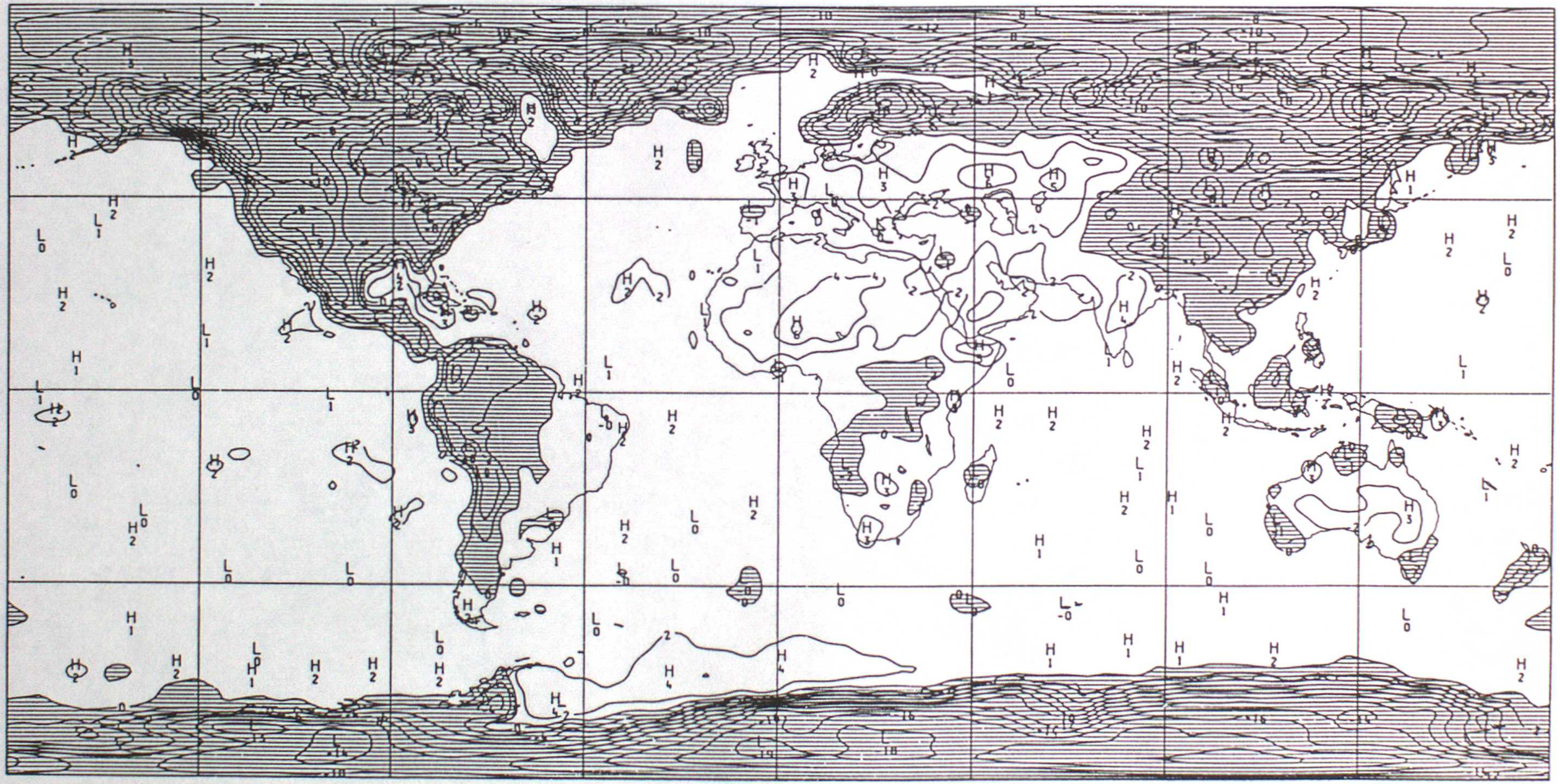


FIG 10

MEAN T+120 CONTROL-TRIAL
TEMPERATURE
AVERAGE FROM 12Z ON 21/11/1984 DAY 326 TO 12Z ON 2/1/1985 DAY 2
LEVEL: 200 MB

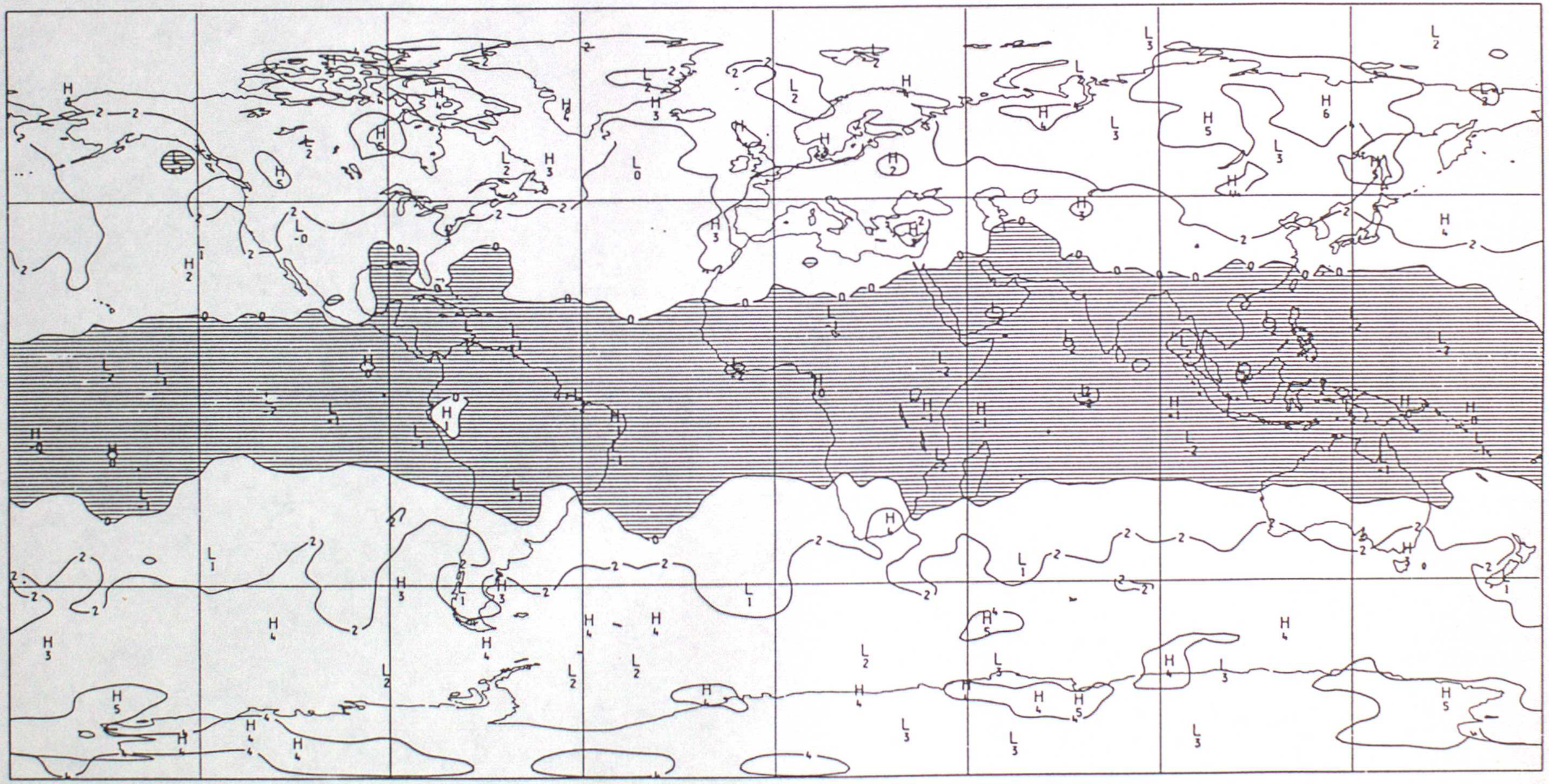


FIG 11

MEAN T+120 CONTROL-TRIAL
GEOPOTENTIAL HEIGHT
AVERAGE FROM 12Z ON 21/11/1984 DAY 326 TO 12Z ON 2/1/1985 DAY 2
LEVEL: 100 MB

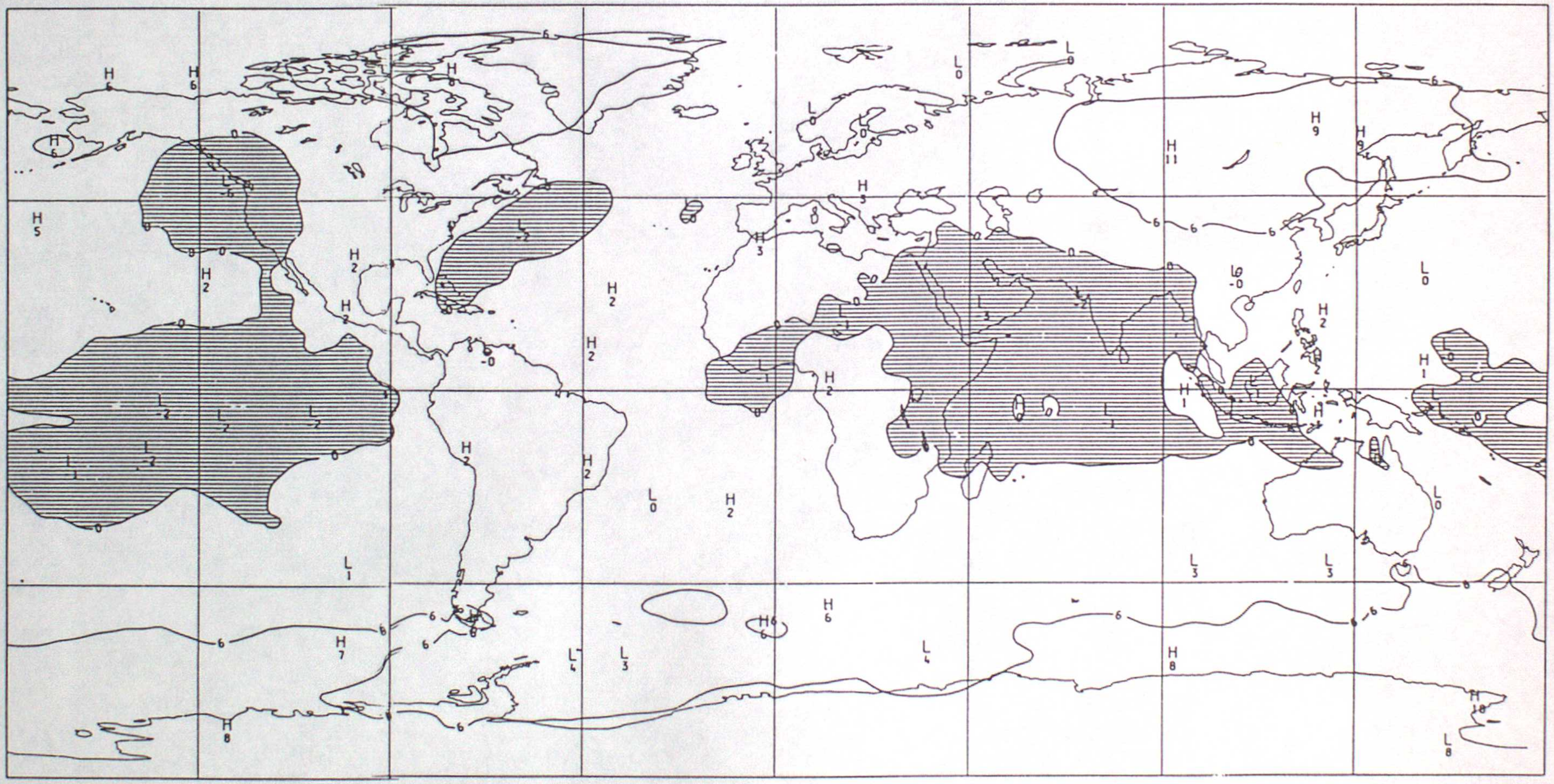
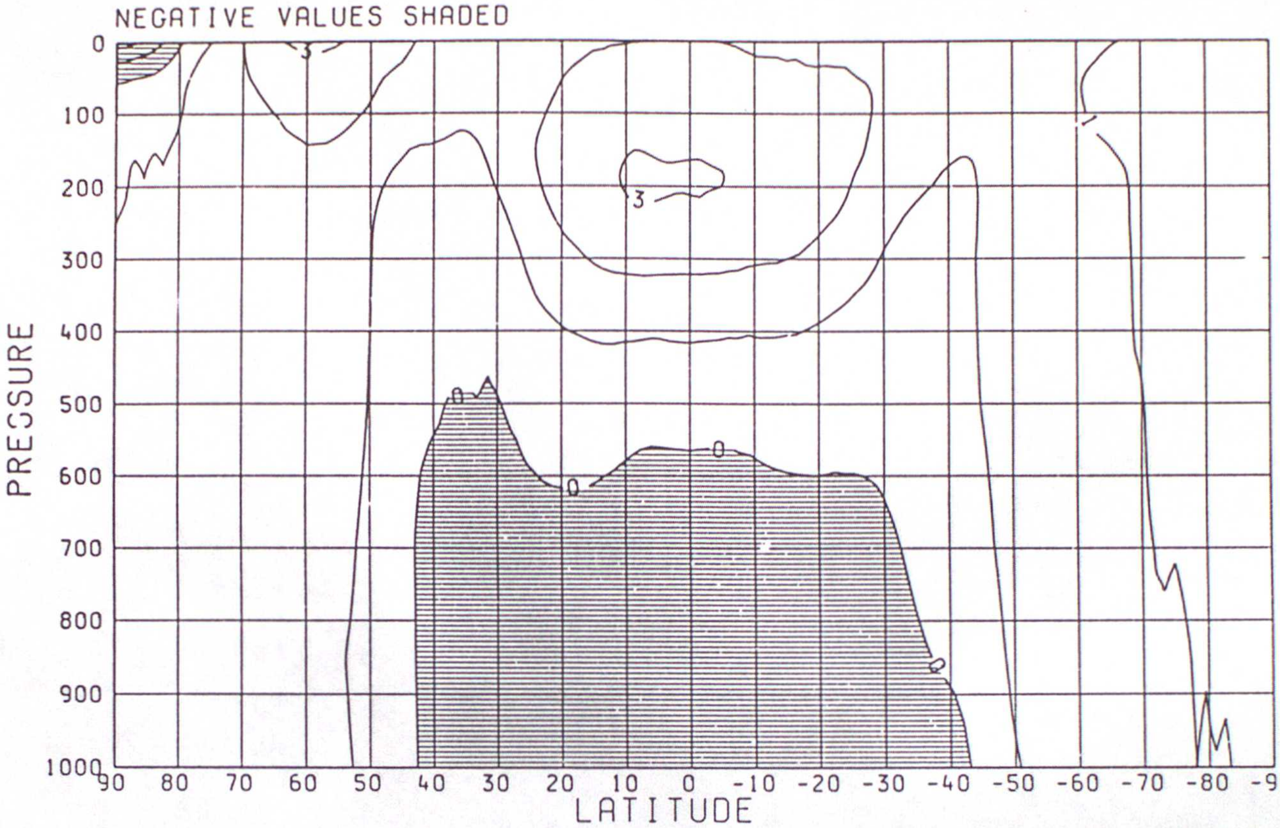


FIG 12

6 WINTER CASES...CONTROL-TRIAL2
HEIGHT ZONAL MEAN DIFFERENCE
AVERAGE FROM 12Z ON 21/11/1984 DAY 326 TO 12Z ON 2/1/1985 DAY 2
NEGATIVE VALUES SHADED



6 WINTER CASES...CONTROL-TRIAL2
TEMPERATURE ZONAL MEAN DIFFERENCE
AVERAGE FROM 12Z ON 21/11/1984 DAY 326 TO 12Z ON 2/1/1985 DAY 2
NEGATIVE VALUES SHADED

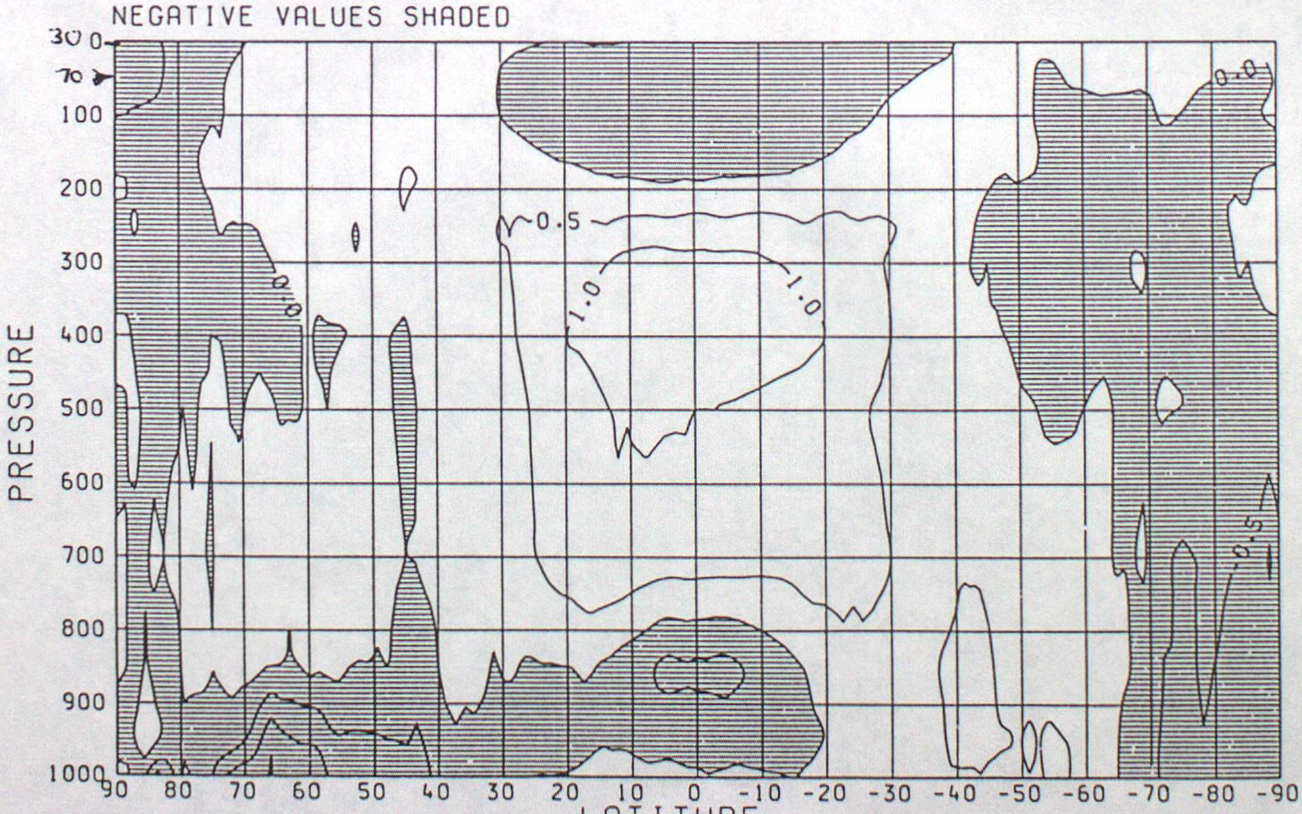


FIG 13