TECHNICAL MEMORANDUM

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Differences between the initialised and uninitialised analyses of the upper air fields and the impact on the verification results

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1. Introduction

The objective verification of ECMWF forecasts is performed against the initialised analyses. This practice was natural in the beginning when only the initialised analyses and forecasts were archived. Later, the uninitialised analyses were added to the archives (height and wind components since July 1981, and temperature and humidity from November 1982). However, for continuity, the verification is still carried out against the initialised analyses. The initialisation which is performed by the non-linear normal mode techniques at the Centre modifies the analysed fields to some extent to prevent spurious oscillations in the forecast. These changes caused by the initialisation have a major impact on the surface pressure and divergent wind, and large changes usually indicate some data problems.

The purpose of this memorandum is to describe the differences between the initialised and uninitialised upper air analyses, and to present the impact on the verification results, when the uninitialised fields are used instead of the initialised analyses.

2. Initialisation

When using a primitive equation model the analyses need to be initialised in order to control unwanted gravity waves. This control is particularly important in an integrated data-assimilation system where short forecasts serve as the first-guess fields (in the ECMWF system these are 6 hour forecasts). Non-linear normal mode initialisation, first proposed by Machenhauer (1977), has been used at ECMWF. Initially an adiabatic formulation was implemented; this worked reasonably well in the extra tropics, but had some shortcomings when dealing with the diabatically driven processes in the tropics, for example, it weakened the Hadley circulation. A revised version of the diabatic non-linear normal mode initialisation described by Wergen (1982) was introduced operationally at the Centre in September 1982. The diabatic forcing is derived by calculating the diabatic tendencies from short time-averaged forecasts starting from the uninitialised analysis. A gravity mode filter is then used to maintain only those components which force inertia-gravity waves with a period longer than a certain cut-off value. The use of the diabatic scheme leads to stronger divergent circulations and reduces the initialisation changes.

The initialisation affects mainly the surface pressure and the divergent wind, and has only a minor influence on temperature and the rotational wind, and no direct effect on humidity. Any changes to the surface pressure are reflected in changes to the upper air height fields since the surface pressure is used as a reference level in the interpolation from sigma to pressure levels. The uninitialised analysis is obviously closer to the data. However, it is not self-evident that the uninitialised analysis is always closer to the real atmosphere, because very often large differences between the initialised and uninitialised analyses appear in the areas where the data is questionable.

3. Objective verification

Forecasts are verified at ECMWF against the initialised analyses. The results presented here have been calculated with the operational limited area verification system implemented at the Centre (Nieminen, 1983). This verification procedure uses post-processed grid point fields which are interpolated from sigma to pressure levels. For these upper air fields a large variety of objective scores are produced for each hemisphere and several smaller areas. The calculations for this paper were performed for two three month periods, December 1982-January-February 1983 and June-July-August 1983, with both the initialised and uninitialised fields being used as verifying analyses. Between these two periods a spectral model with a new envelope orography was implemented operationally on 21 April 1983. The higher orography might have an influence on some initialisation changes over mountainous regions.

4. Differences between the initialised and uninitialised analysis fields

The mean difference maps between the 12 GMT initialised and uninitialised analyses have been computed for the winter and summer periods mentioned earlier. The analyses of geopotential height, temperature and vector wind have been compared at five pressure levels: 1000, 850, 500, 200 and 50 mb. Figs. 1-5 show that the most pronounced differences can be seen in the height analyses. These changes caused by the initialisation are usually gathered around some isolated locations where the data have created "noisy" increments between the first-guess and the uninitialised analysis which are then removed by the initialisation. Similar patterns (with opposite signs) can be found in the height increment maps which also reveal the areas where erroneous or doubtful observations create big increments. At the upper levels, (see Figs. 4-5), there are large negative differences between the height analyses over the South Pole surrounded by a band of positive difference values during the Southern Hemisphere winter. These initialisation changes are probably related to problems with the high orography at the South Pole, and in the surrounding Pacific they indicate the difficulties in analysing the PAOBS data. The PAOBS are manually interpreted surface pressure values from satellite photographs which are used to fill in sparse data areas in the Southern Hemisphere. This work is done by NMAC, in Melbourne, and the PAOBS messages are disseminated on the GTS. Returning to the lower levels, Figs. 1-2 show some kind of semi-diurnal cycle in the initialisation changes of the 1000 and 850 mb height for the winter cases. This feature is not so clear for the upper levels and for the summer period.

The differences in the wind analyses (Figs. 5-10) are generally small and also restricted to isolated areas. An exception is the 50 mb wind analysis where the initialisation modifies the uninitialised wind fields in many regions during the Northern Hemisphere winter, as can be seen from Fig. 10. The summer period in the same figure also shows large differences for the 50 mb wind in the tropics, but these changes reveal a specific feature, the quasi-biennial oscillation. The observations introduce this phenomena into the analysis, but the model is not able to maintain it and so the initialisation wipes it out. The initialisation has little impact on temperature as was mentioned in section 2. This is confirmed by Figs. 11-15 where the differences between the initialised and uninitialised temperature analyses are usually very small.

5. Comparison of the verification results produced against the initialised and uninitialised analyses.

The results of the operational limited area verification, using the initialised analyses, have been compared to the results based on the uninitialised analyses. The anomaly correlations of height and RMS-errors for height, temperature and vector wind have been calculated at five pressure levels: 1000, 850, 500, 200 and 50 mb. The mean scores for the two hemispheres and the tropical zone, and for three smaller areas, Europe, China-Japan and North America, have been produced for those two periods mentioned in section 3. The scores for the operational verification and the deviations from those when the uninitialised analyses were used have been presented for the forecast days 1,3,5 and 7 in Annex 1.

The comparison of the two verification sets (initialised-uninitialised system) for the two hemispheres and the tropical zone have been summarised in Table 1 by combining the deviations for different forecast days into mean values for each parameter. It can be seen from this table that the differences are generally negligible for vector wind and temperature, but larger deviations can be found for the height scores. This, of course, is in agreement with the difference maps discussed in section 4 where the largest impact of the initialisation was seen in the height analyses. The initialisation changes are relatively large compared to the variation of height fields in the tropics. This leads to bigger deviations between the scores in the equatorial zone, as shown in Table 1. The sign of the differences is more or less expected for the summer results; RMS-errors are smaller and the correlations higher for the operational verification. In the winter period, however, some positive deviations are found for the RMS-error of height. For the vector wind the RMS-error is slightly higher for most of the operational results.

The differences between the two verification sets were also investigated for three smaller areas of the Northern Hemisphere. Only the RMS-errors of height and vector wind and the height anomaly correlations were compared because the differences for temperature are negligible almost everywhere. The deviations for the scores are presented in Table 2. They were calculated in a similar way to those in Table 1. This might not be as well justified as for the hemispheric results because the sign of the deviation is, in many cases, different for the shorter forecasts compared to the longer ones, as Tables 7-9 show. This fact indicates that in small areas few individual analyses which have large initialisation changes can alter the verification results randomly. For the same reason, the comparison between these limited area scores shows that the verification against the initialised analyses does not always give smaller RMS-errors and higher correlations. It can be seen from Table 2, for example, that for the areas of Europe and China-Japan in the winter period the RMS-errors are mostly larger and the correlations lower when verified against the initialised analyses. However, the deviations between the two verification sets when small areas are considered are generally modest, except at the 50 mb level where considerably large differences can be found in the area of North America for both the RMS-errors and the correlations of geopotential height.

6. Summary

The initialised and uninitialised analyses of the upper air fields were compared. The differences are negligible for temperature, and the diabatic version of the initialisation generally causes only minor changes to the wind fields. Larger differences between the two wind analyses are mainly seen at the 50 mb level. These differences are usually related to some data problems, but they also reveal how the quasi-biennial oscillation in the tropics is handled in the analysis-forecasting system. This feature is introduced into the

Winter 1982/83

		Rms-error difference height (m)	Rms-error difference vec. wind (m/s)	Rms-error difference temp. (°C)	Anom. correl. difference height (*100)
Northern Hemisphere	1000 mb	-0.5	+0.1	0.0	-0.2
	850 "	-0.7	0.0	0.0	0.0
	500 "	-0.4	+0.1	0.0	+0.1
	200 "	+1.4	+0.1	0.0	+0.2
	50 "	+3.7	-0.2	-0.1	+0.3
Tropics	1000 mb	-3.2	+0.1	0.0	+8.6
	850 "	-3.1	0.0	-0.1	+11.1
	500 "	+0.7	+0.1	-0.1	+3.9
	200 "	+1.4	+0.1	-0.1	+5.7
	50 "	-2.8	+0.4	+0.3	+12.1
Southern Hemisphere	1000 mb	-1.0	0.0	0.0	+1.0
	850 "	-1.0	0.0	0.0	+0.9
	500 "	-0.7	0.0	-0.1	+0.6
	200 "	-0.8	0.0	-0.1	+0.6
	50 "	-1.5	-0.1	-0.1	+2.5

Summer 1983

		Rms-error difference height (m)	Rms-error difference vec. wind (m/s)	Rms-error difference temp. (°C)	Anom. correl. difference height (*100)
Northern Hemisphere	1000 mb	-0.5	-0.1	0.0	+0.7
	850 "	-0.8	-0.1	0.0	+1.0
	500 "	-1.0	0.0	-0.1	+0.5
	200 "	-2.3	-0.2	0.0	+0.9
	50 "	-1.9	-0.2	+0.1	+2.5
Tropics	1000 mb	-2.3	+0.1	0.0	+10.0
	850 "	-2.5	-0.1	-0.1	+13.5
	500 "	-0.4	0.0	0.0	+4.7
	200 "	-2.1	-0.2	0.0	+3.8
	50 "	-4.3	-0.6	-0.1	+8.7
Southern Hemisphere	1000 mb	-0.6	0.0	0.0	+0.5
	850 "	-0.9	-0.1	0.0	+0.7
	500 "	-1.0	0.0	0.0	+0.5
	200 "	-1.0	-0.2	0.0	+0.4
	50 "	-2.8	-0.2	0.0	+2.4

Table 1 Comparison of verification results for the hemispheric areas and the tropical belt when verifying height, temperature and wind forecasts against the initialised and uninitialised analyses. The results are shown as differences between the scores, e.g. rms (initialised) - rms (uninitialised), and presented as mean values for the forecast days 1, 3, 5 and 7 from the three month averages, December 1982 - February 1983 and June - August 1983.

		Rms-error difference height (m)	Rms-error difference vec. wind (m/s)	Anom. correl. difference height (*100)
Winter 1982/83				
Europe	1000 mb	+0.1	+0.1	-0.4
	850 "	+0.5	+0.1	-0.4
	500 "	+1.5	+0.1	-0.2
	200 "	+4.1	+0.1	+0.3
	50 "	+5.0	-0.4	-0.3
China/ Japan	1000 mb	+1.1	-0.4	-2.1
	850 "	+0.6	-0.3	-2.1
	500 "	-1.5	+0.2	-0.8
	200 "	-0.2	+0.3	-1.1
	50 "	+0.9	-0.2	-0.1
North America	1000 mb	-3.1	-0.9	+0.7
	850 "	-3.5	-0.8	+2.0
	500 "	-5.0	-0.2	-0.2
	200 "	-4.9	+0.1	+0.1
	50 "	+16.2	-0.7	-3.8
Summer 1983				
Europe	1000 mb	-0.6	0.0	+0.4
	850 "	-1.5	-0.1	+0.8
	500 "	-1.0	0.0	+0.5
	200 "	-1.5	-0.1	+0.4
	50 "	+1.2	-0.3	-5.1
China/ Japan	1000 mb	+0.4	-0.5	+1.3
	850 "	+0.3	-0.6	-1.0
	500 "	-1.3	-0.2	-1.4
	200 "	-4.2	-0.9	+0.3
	50 "	-2.2	-0.5	+12.6
North America	1000 mb	-2.1	-0.6	-1.7
	850 "	-2.0	-0.5	-5.0
	500 "	-1.9	-0.2	-2.5
	200 "	-0.9	-0.6	-3.0
	50 "	-6.7	-0.8	+14.1

Table 2 Comparison of verification results for three northern hemispheric areas when verifying height and wind forecasts against the initialised and uninitialised analyses. The results are shown as differences between the scores, e.g. rms (initialised) - rms (uninitialised), and presented as mean values for the forecast days 1, 3, 5 and 7 from the three month averages, December 1982 - February 1983 and June - August 1983.

uninitialised analyses of the 50 mb wind but is removed by the initialisation. The largest changes between the initialised and uninitialised analyses are found for the height fields which are affected by the modifications of the surface pressure in the initialisation process. Most of the differences between the height analyses reflect data problems which can be recognised from the localised spot values on the difference maps.

The impact on the verification scores when the uninitialised analyses are used instead of the initialised fields was investigated both in the large hemispheric and equatorial zones and in three small areas in the Northern Hemisphere. For temperature, the verification results remain practically unchanged for all areas, and for vector wind only minor differences can be found when the hemispheric or the tropical scores are compared. The impact is more obvious on the verification results of height forecasts, particularly in the tropics where the initialisation changes are relatively large compared to the variation of height fields. The differences between the verification scores for the small areas tend to be larger than for the hemispheric zones, especially at the 50 mb level. The sign of the deviations between the two verification sets varies also more randomly when the scores for the small areas are considered. In most of the cases the initialisation smooths out the "noisy" features from the uninitialised analyses. Therefore, it seems justifiable to verify against the initialised analyses, at least, for the data-assimilation-forecasting system from which the results for this comparison were computed.

Acknowledgement

I wish to thank D. Shaw, P. Lönnberg and W. Wergen for helpful discussions and suggestions during the preparation of the paper.

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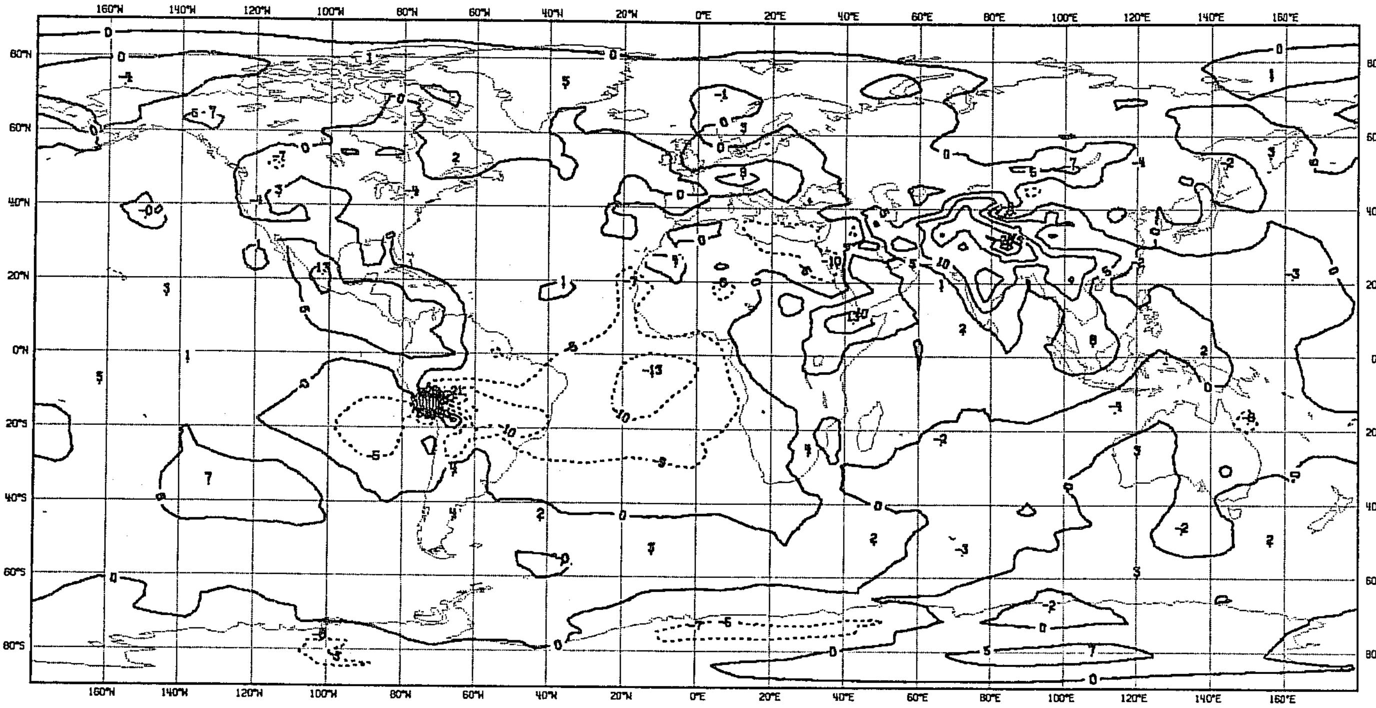
Nieminen, R., 1983: Operational verification of ECMWF forecast fields and results for 1980-1981. ECMWF Technical Report No. 36, 40pp.

Wergen, W., 1982: Initialisation, Proceedings of ECMWF Seminar on "Interpretation of numerical weather prediction products".

List of figures

INITIALISED-UNINITIALISED ANALYSIS /1000 MB HEIGHT
MEAN DIFFERENCE FOR JUNE-JULY-AUGUST 1983



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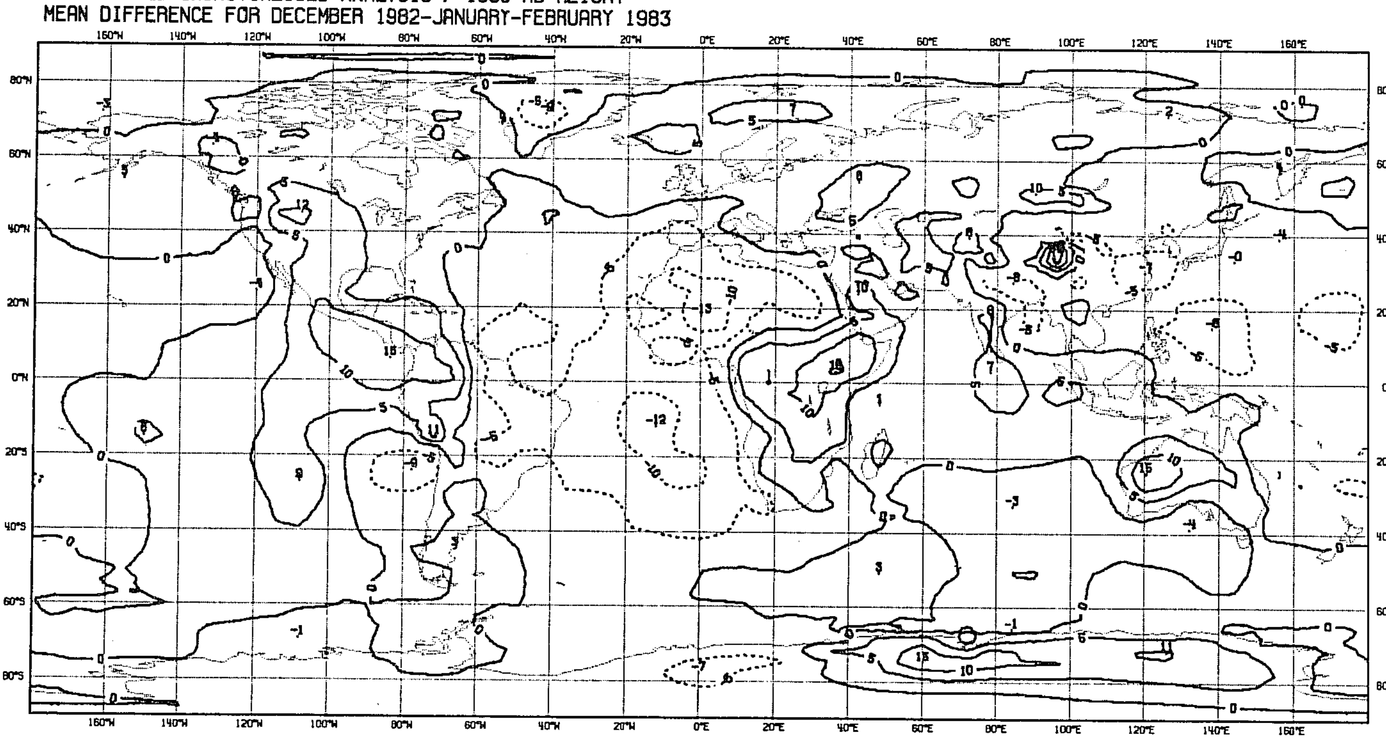

Fig. 1 Differences between the initialised and uninitialised analyses of the 1000 mb height for the winter 1982/83 and the summer 1983. Units: m.

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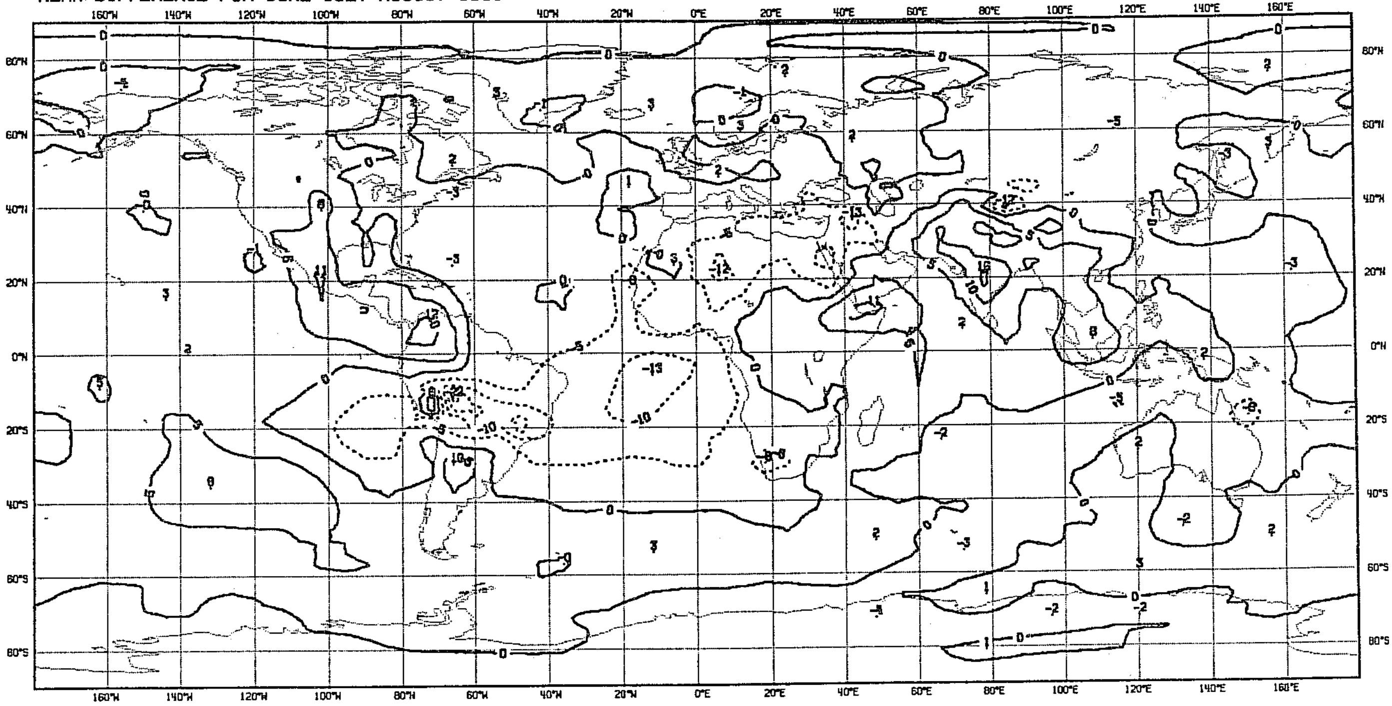

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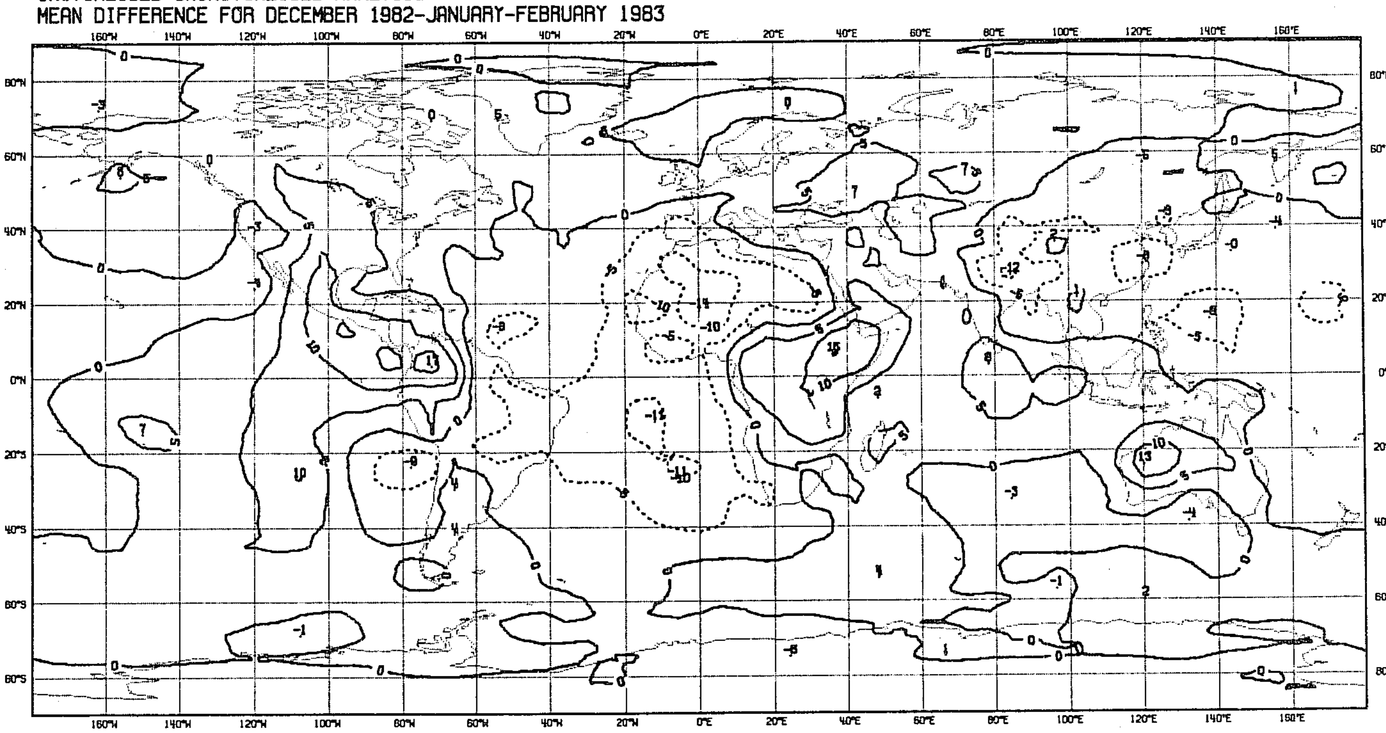

Fig. 2 Same as Fig. 1 but for the 850 mb height

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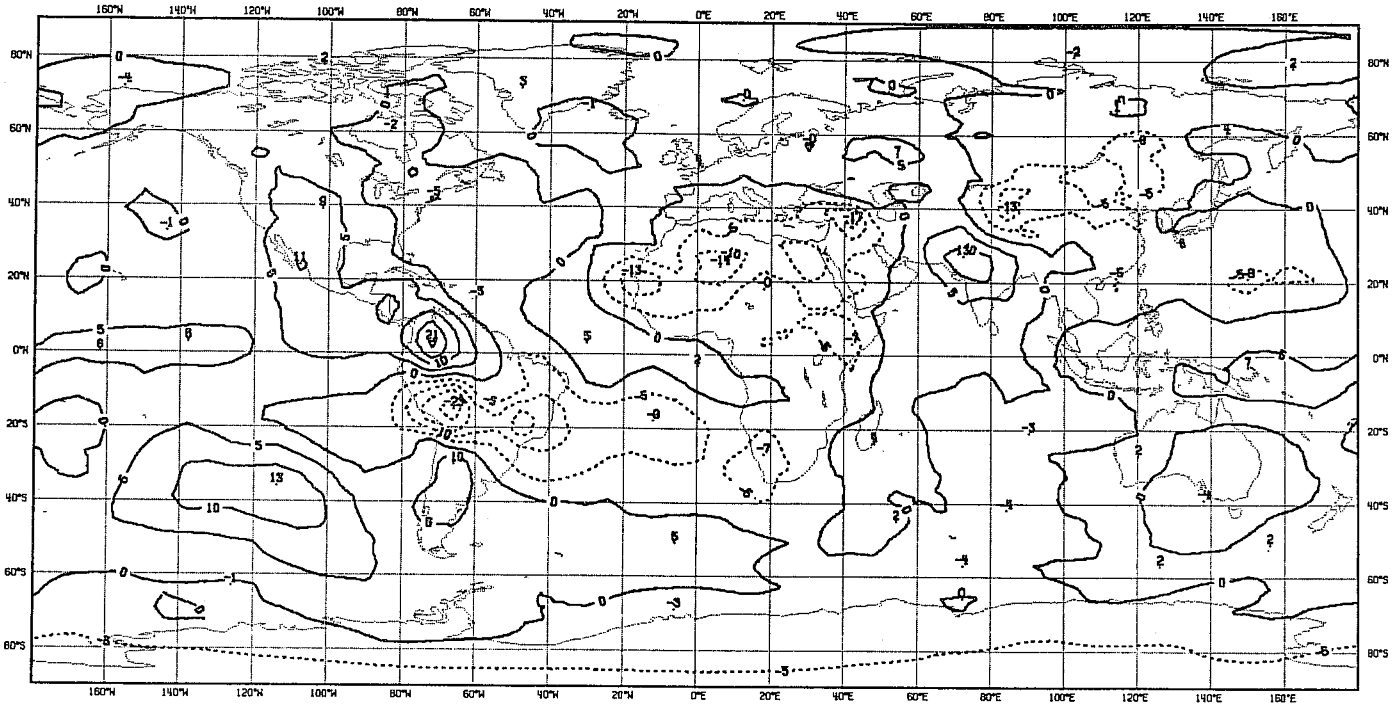

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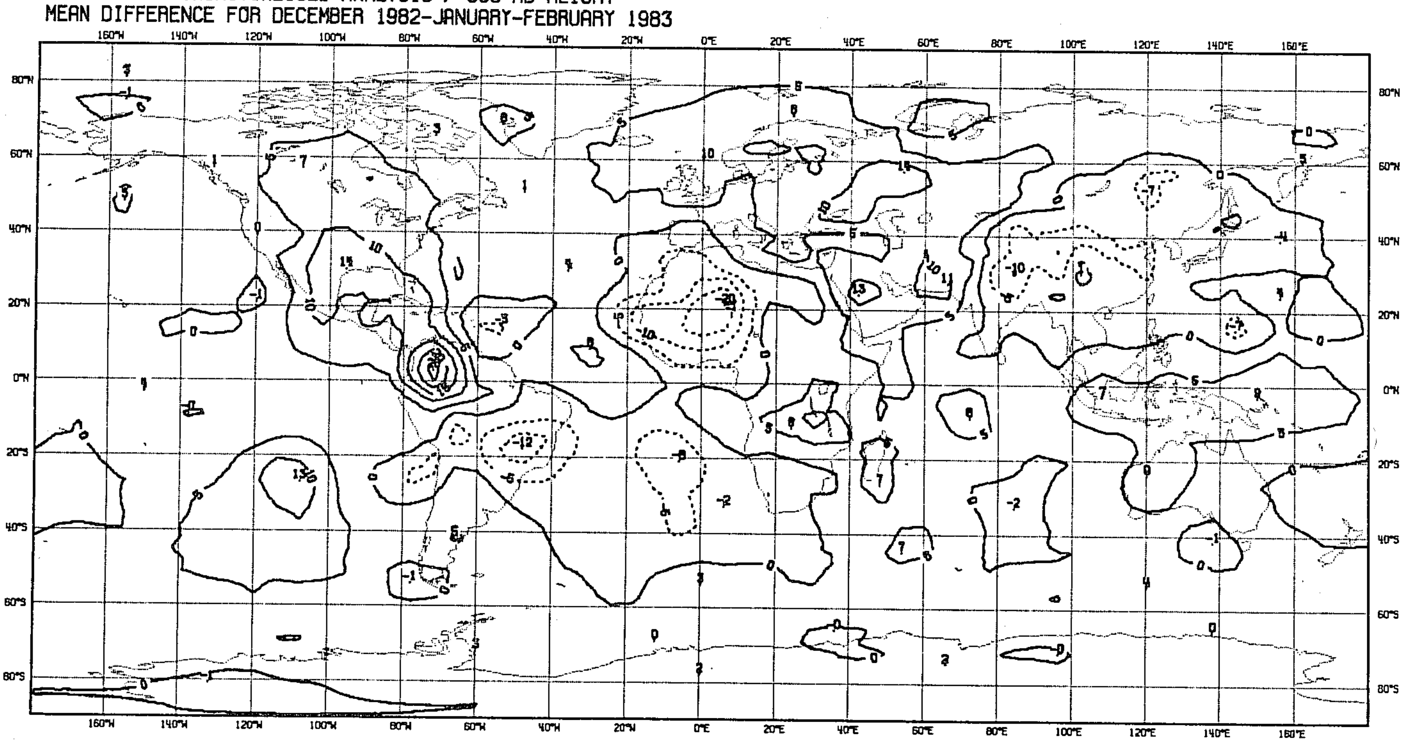

Fig. 3 Same as Fig. 1 but for the 500 mb height

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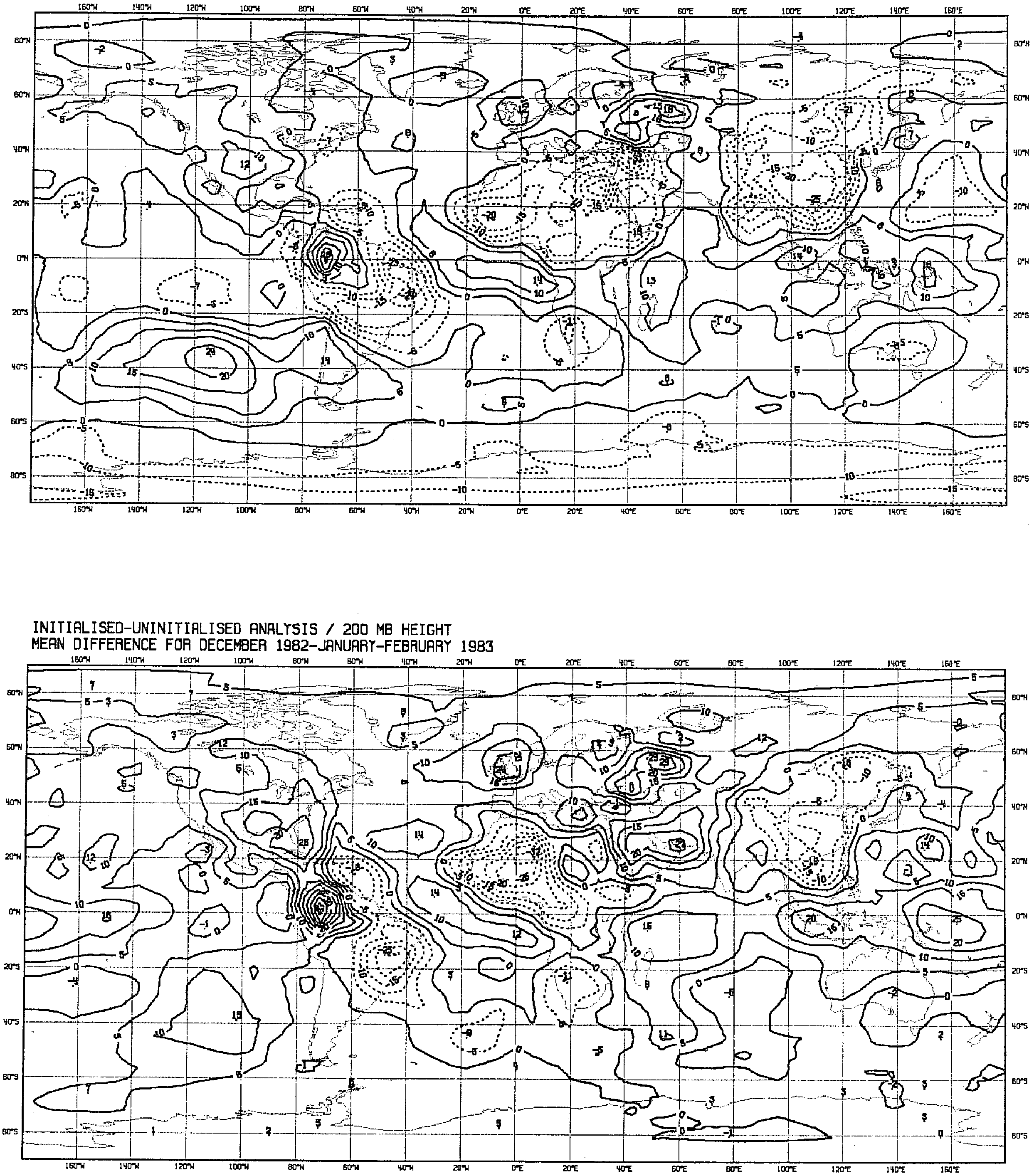

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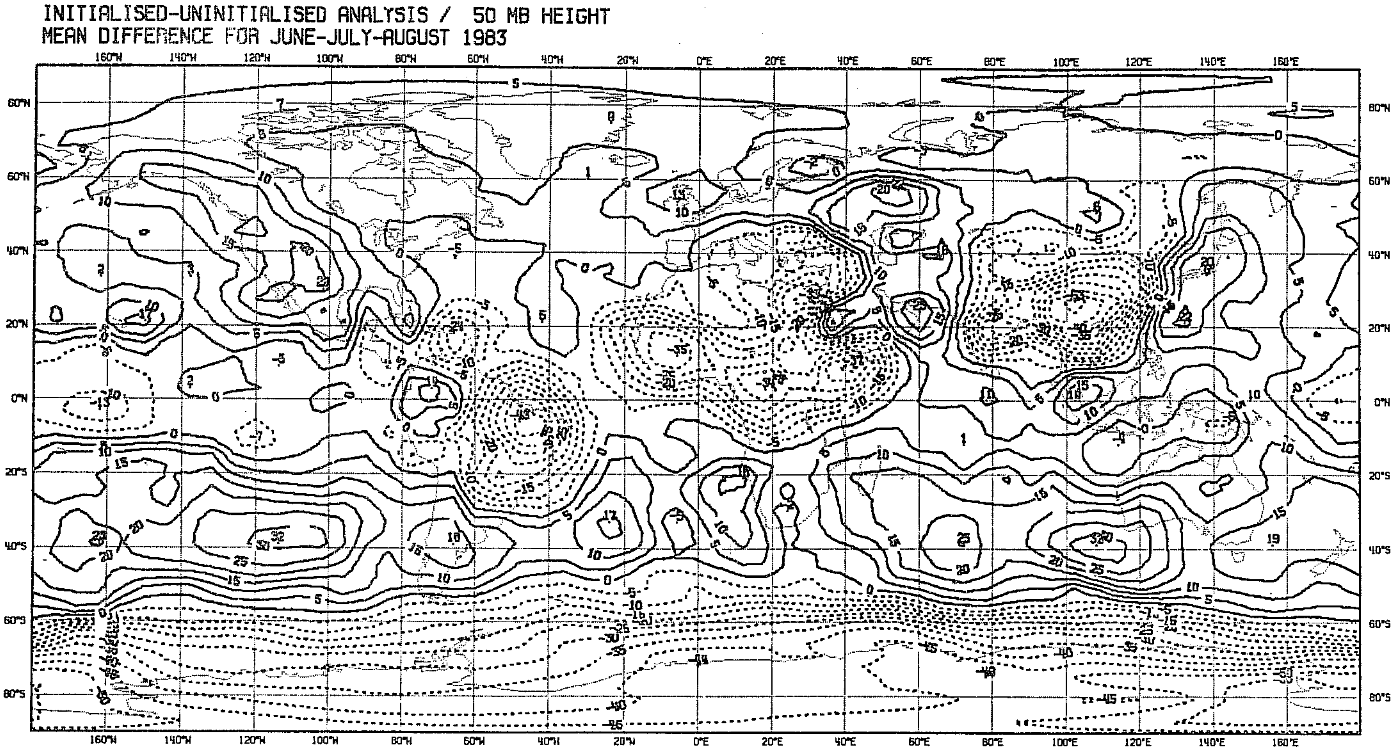
Fig. 4 Same as Fig. 1 but for the 200 mb height



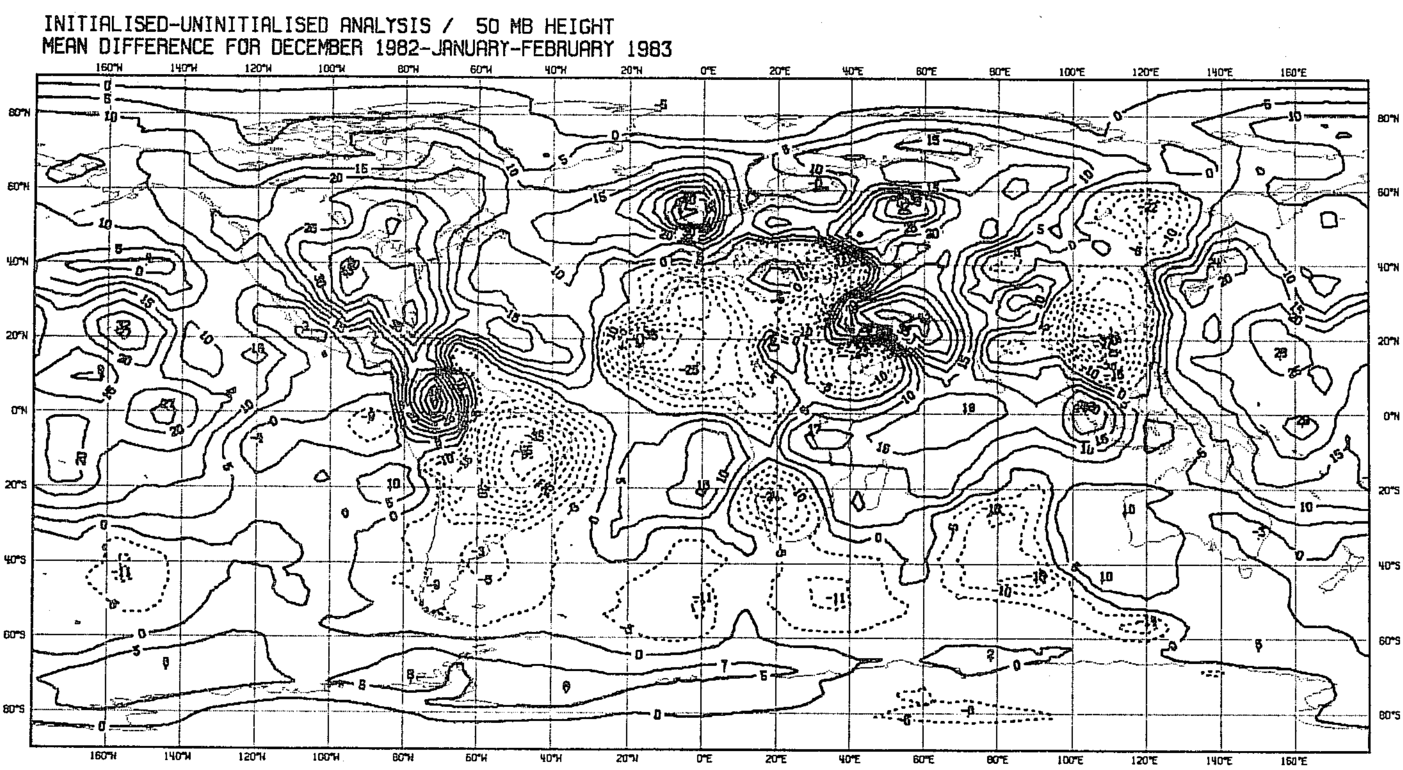


Fig. 5 Same as Fig. 1 but for the 50 mb height

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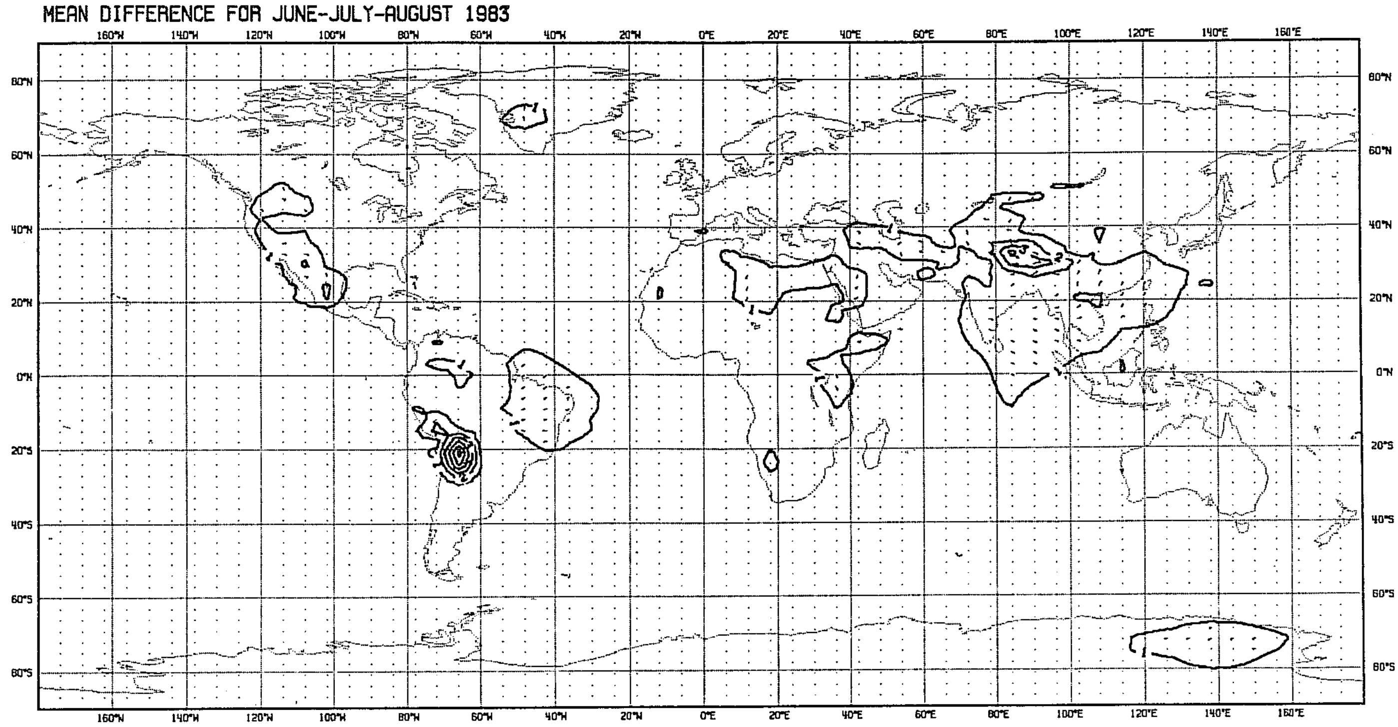

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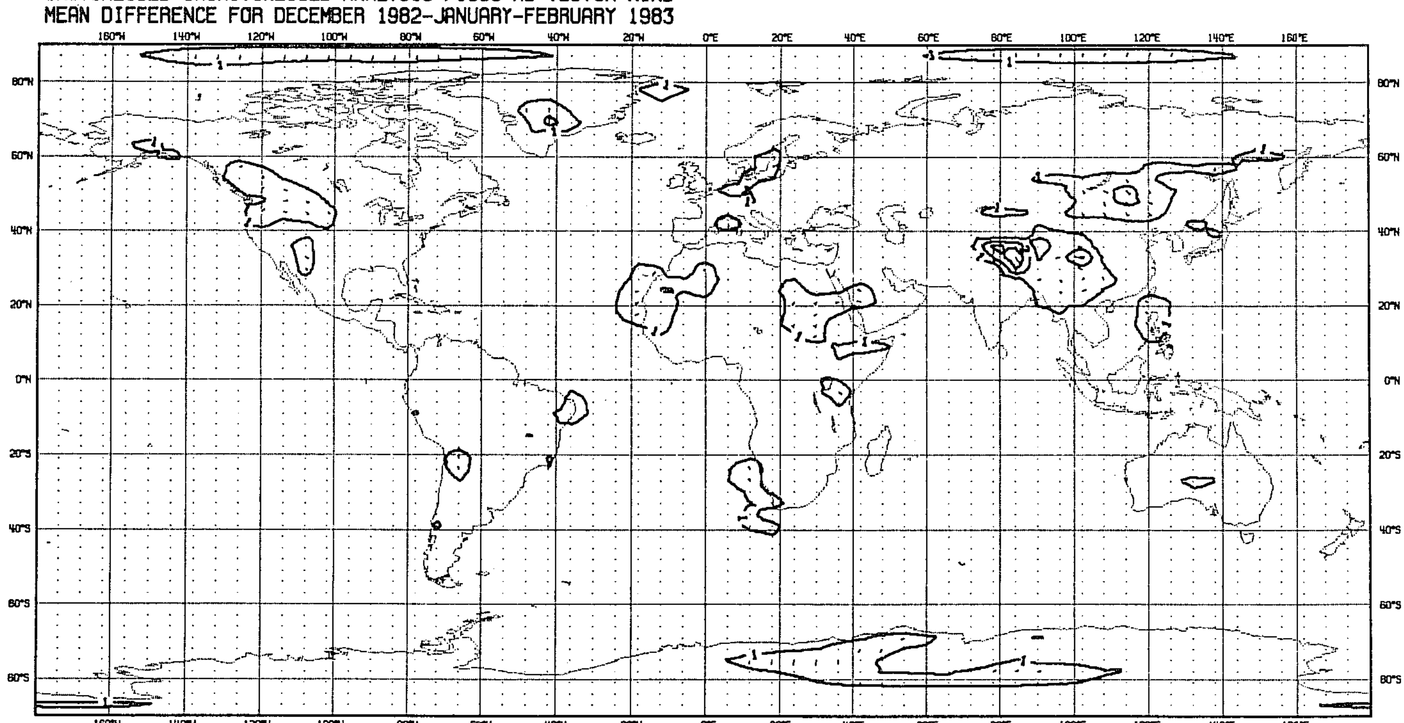
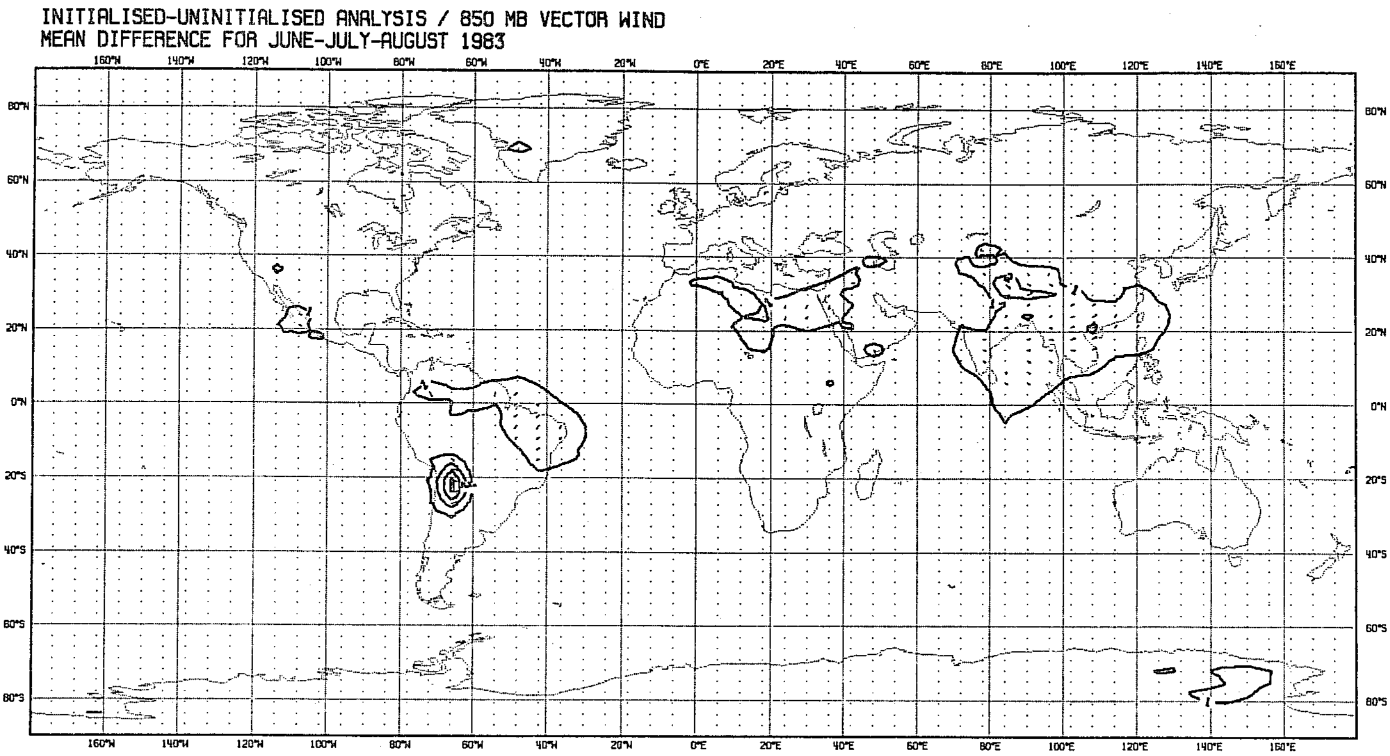


Fig. 6 Differences between the initialised and uninitialised analyses of the 1000 mb vector wind for the winter 1982/83 and the summer 1983. Units: m/s.



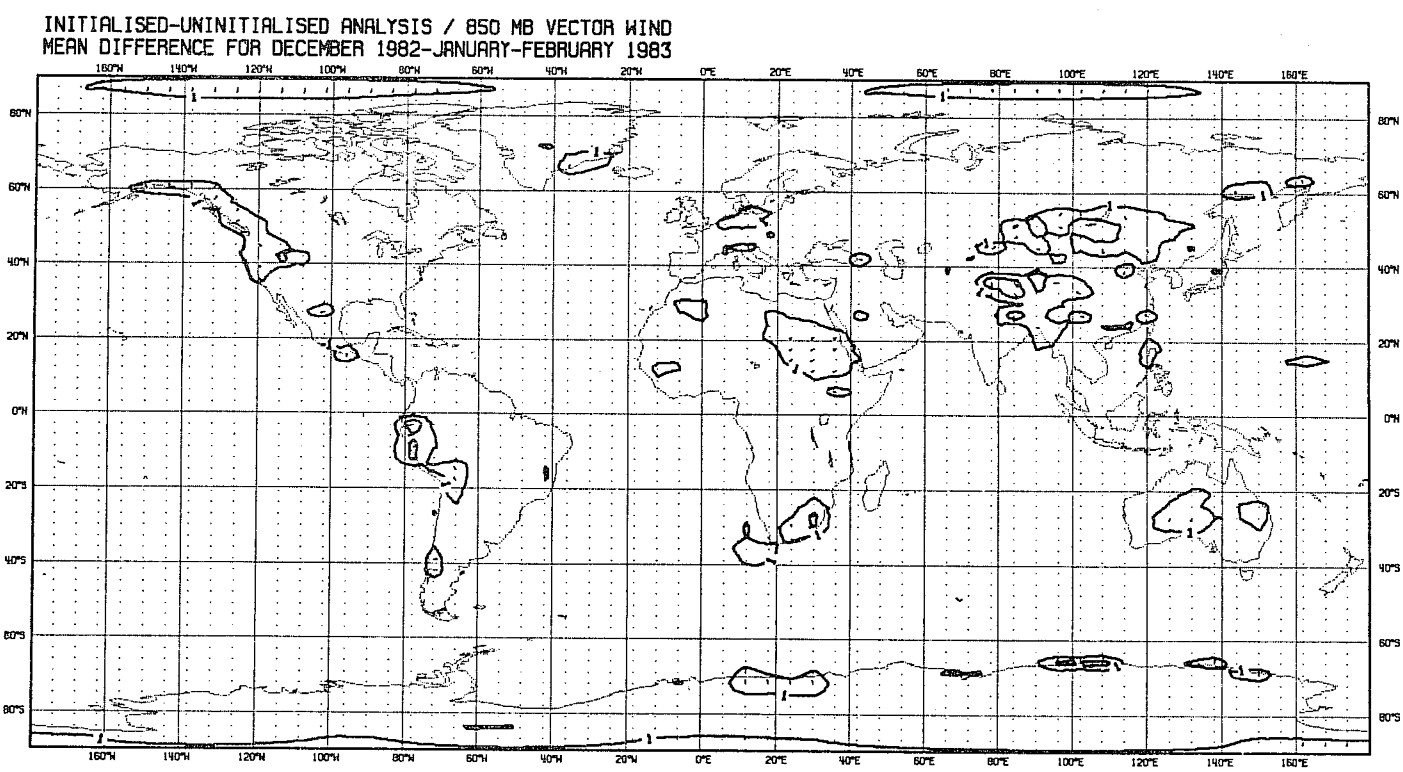
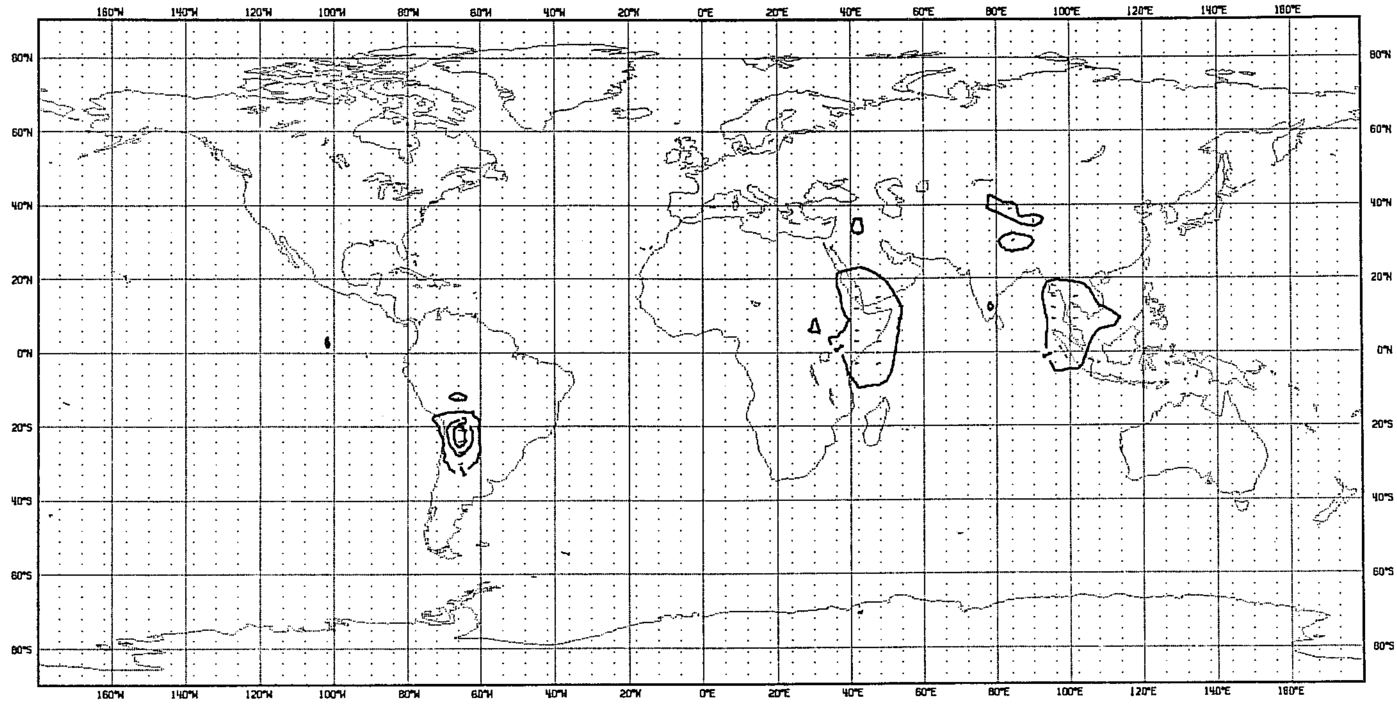


Fig. 7 Same as Fig. 6 but for the 850 mb vector wind



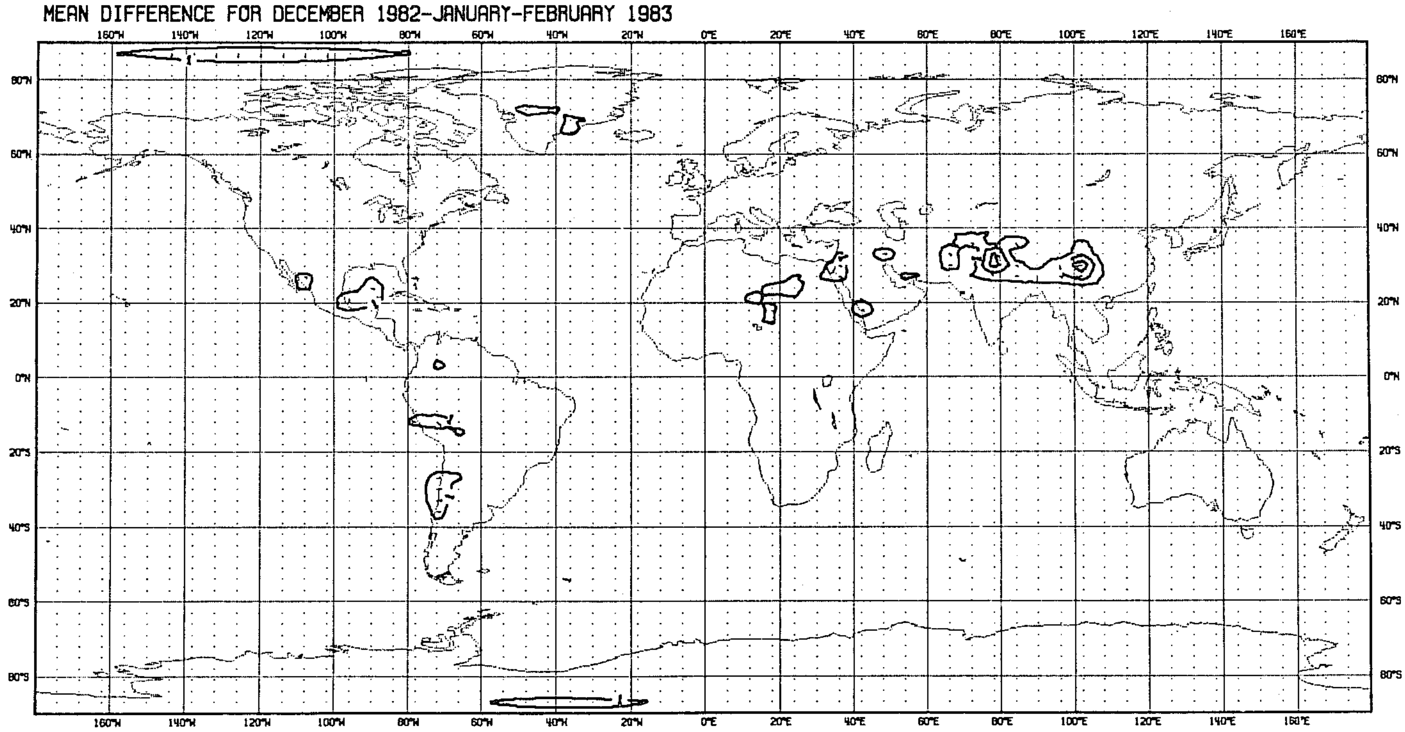
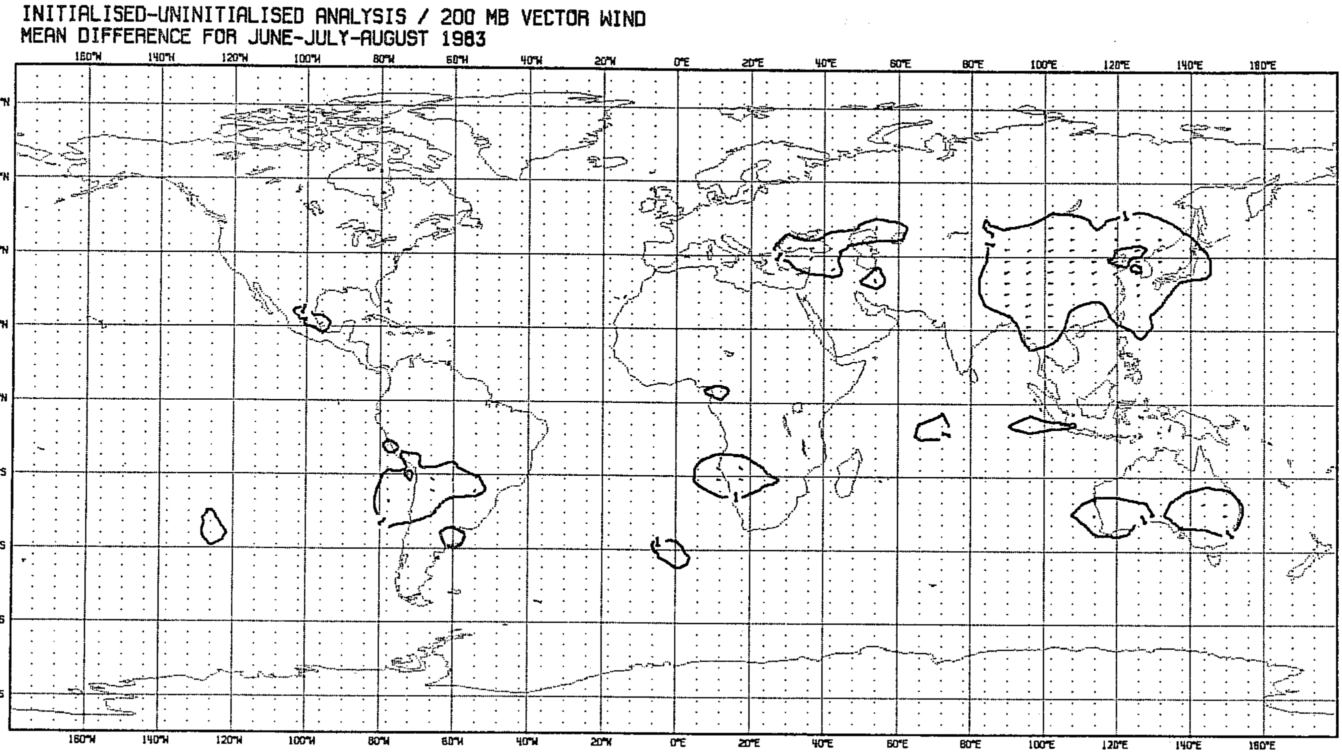


Fig. 8 Same as Fig. 6 but for the 500 mb vector wind



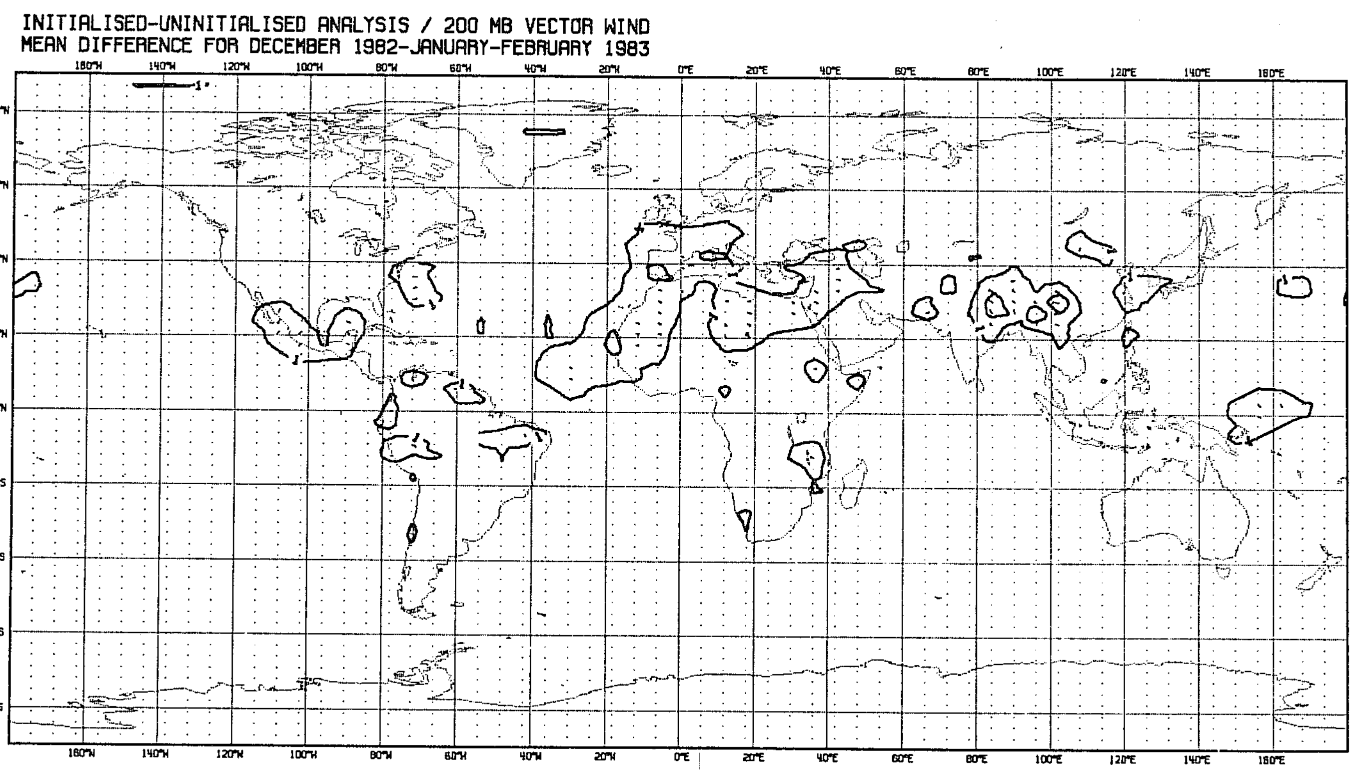


Fig. 9 Same as Fig. 6 but for the 200 mb vector wind

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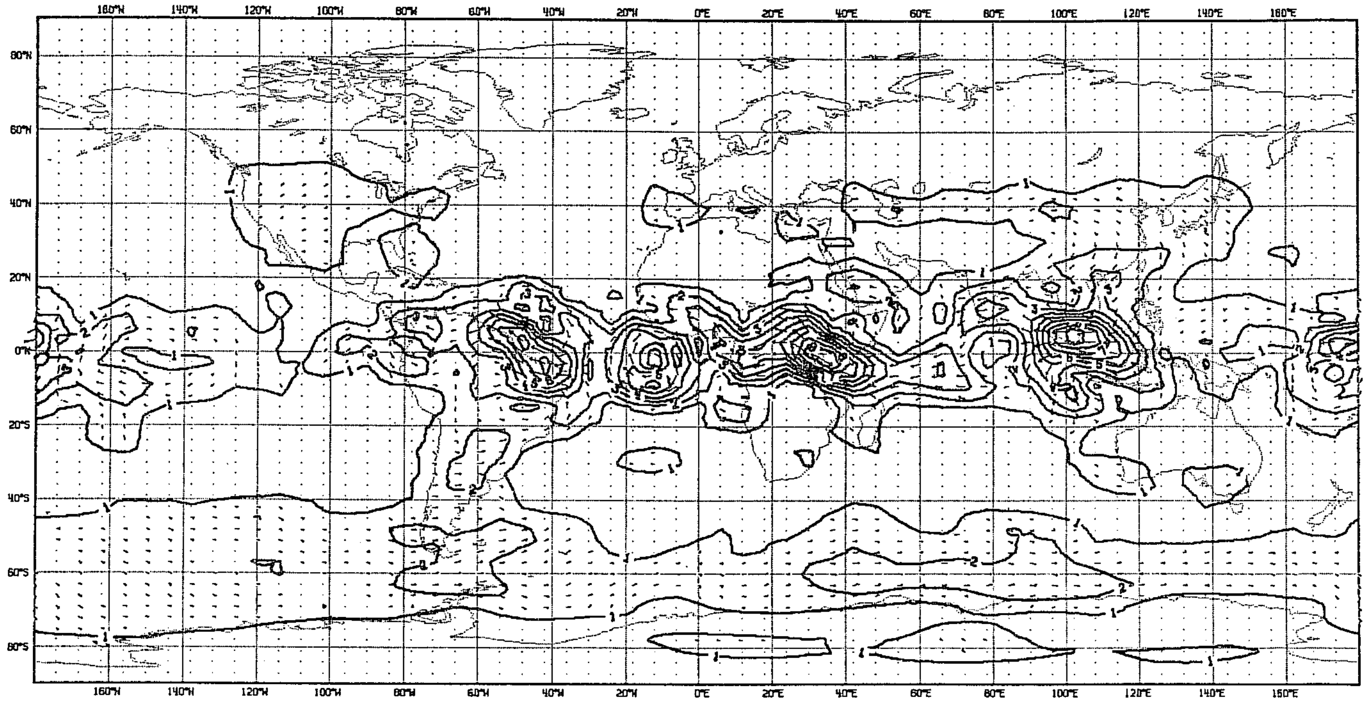

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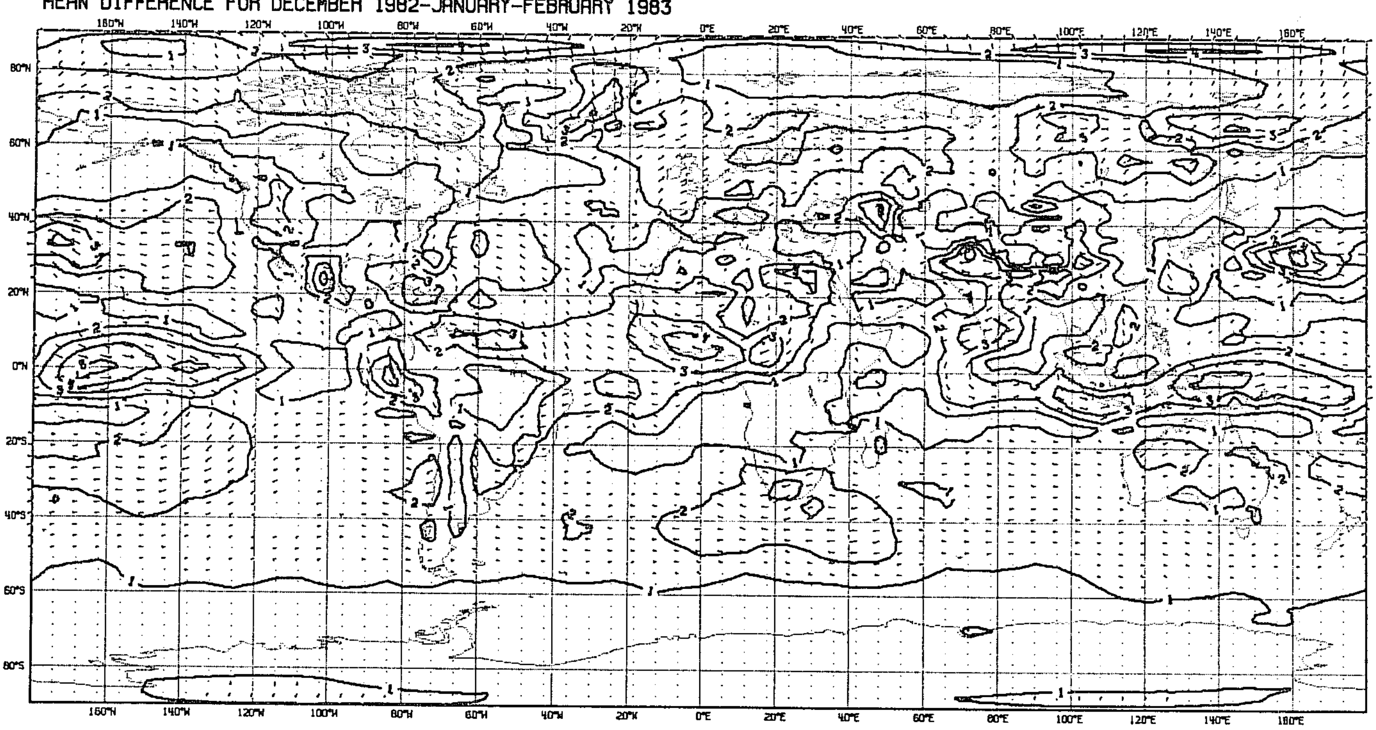

Fig. 10 Same as Fig. 6 but for the 50 mb vector wind

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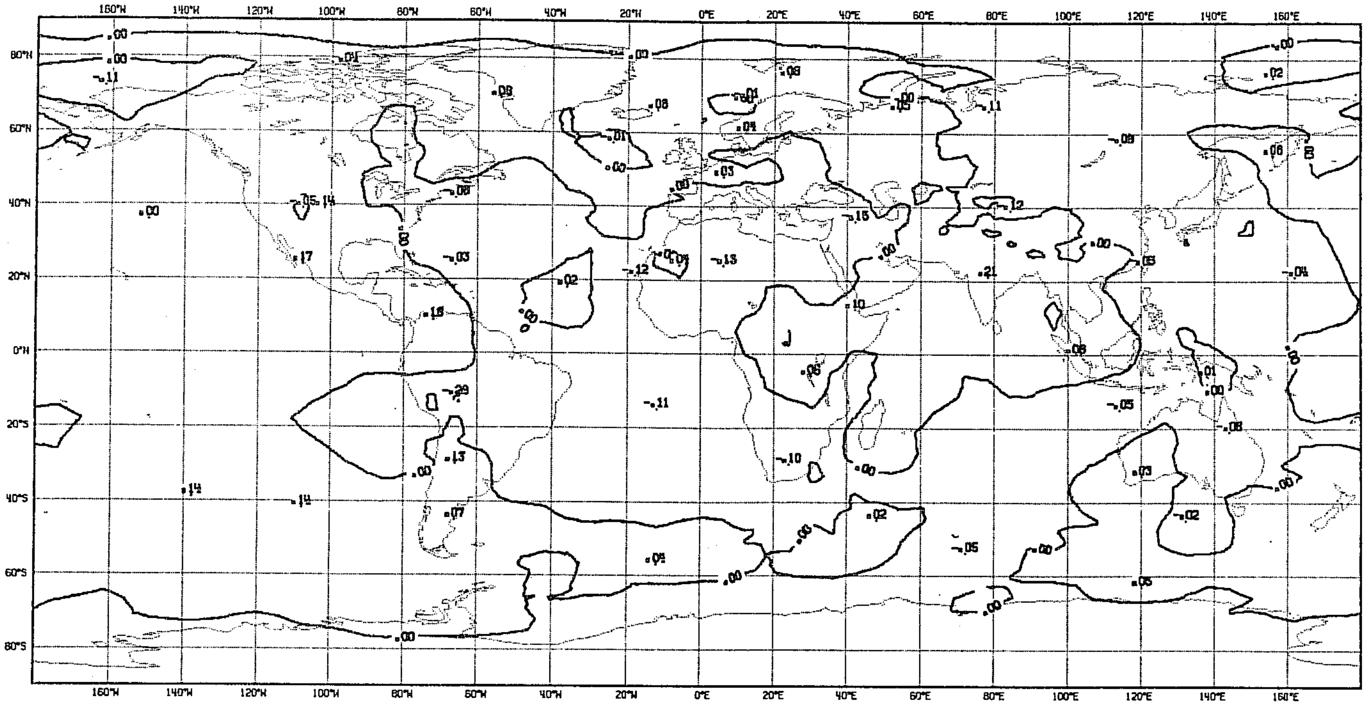
MEAN DIFFERENCE FOR JUNE-JULY-AUGUST 1983



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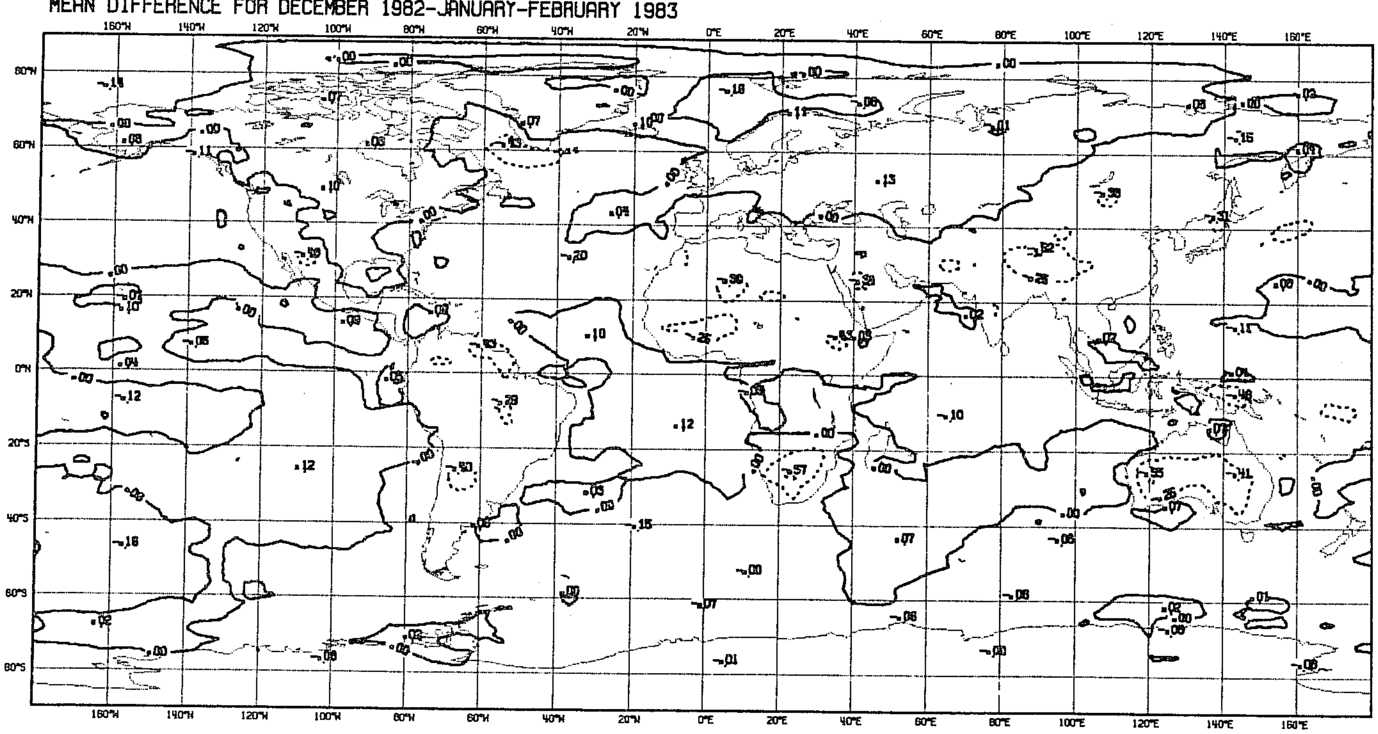

Fig. 11 Differences between the initialised and uninitialised analyses of the 1000 mb temperature for the winter 1982/83 and the summer 1983. Units: °C.

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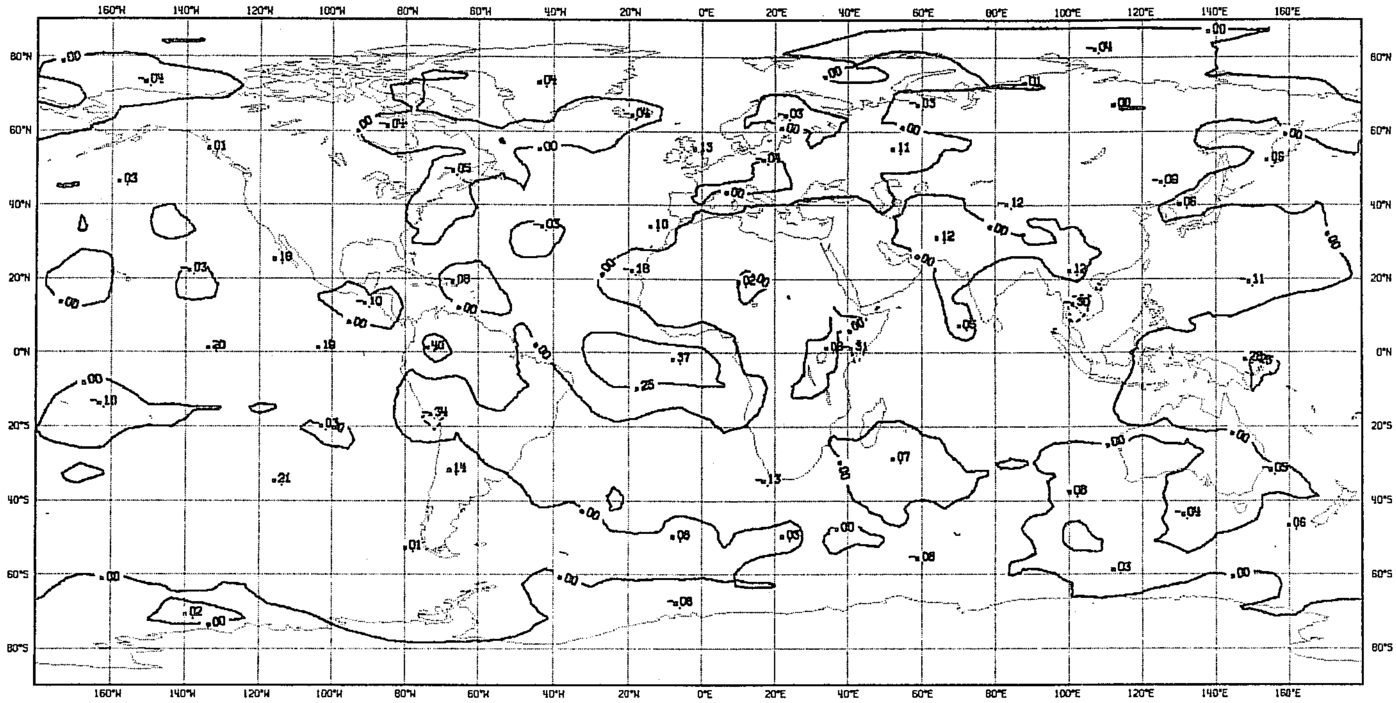
MEAN DIFFERENCE FOR JUNE-JULY-AUGUST 1983



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MEAN DIFFERENCE FOR DECEMBER 1982-JANUARY-FEBRUARY 1983

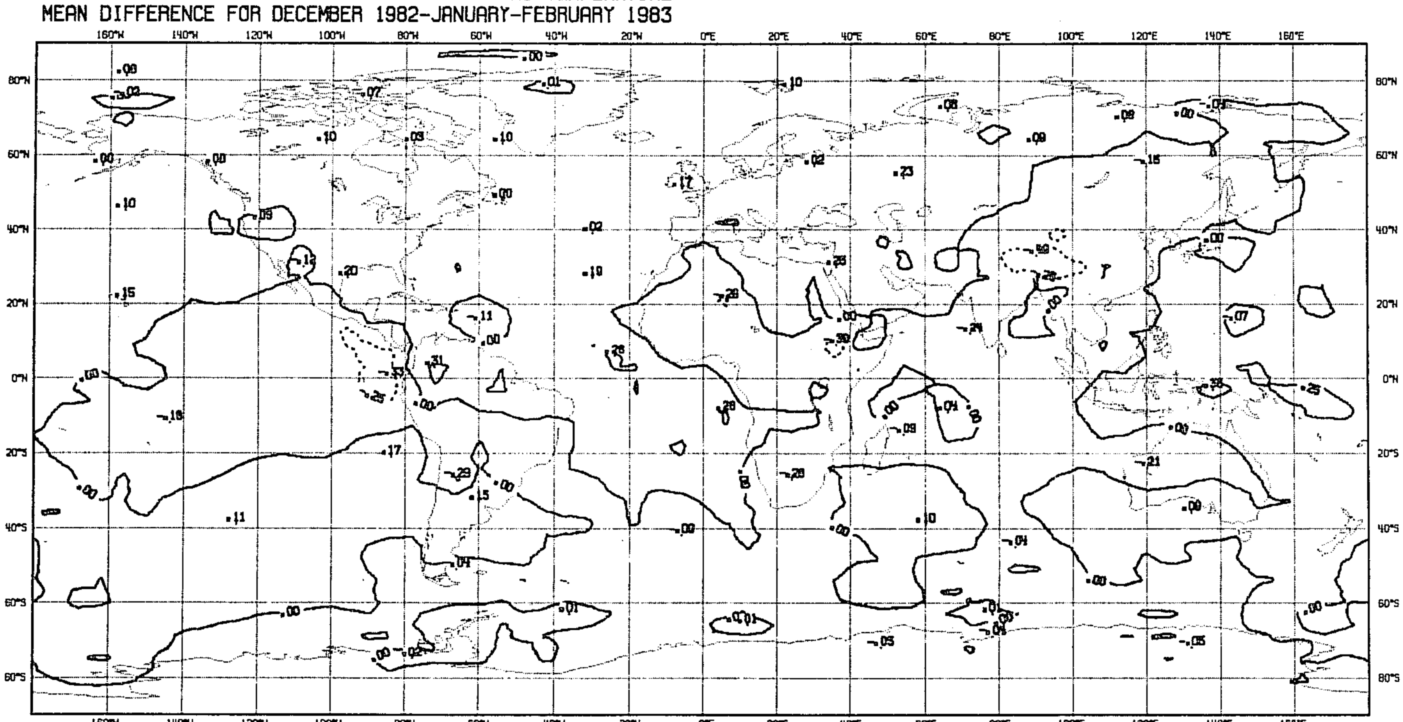

Fig. 12 Same as Fig. 11 but for the 850 mb temperature

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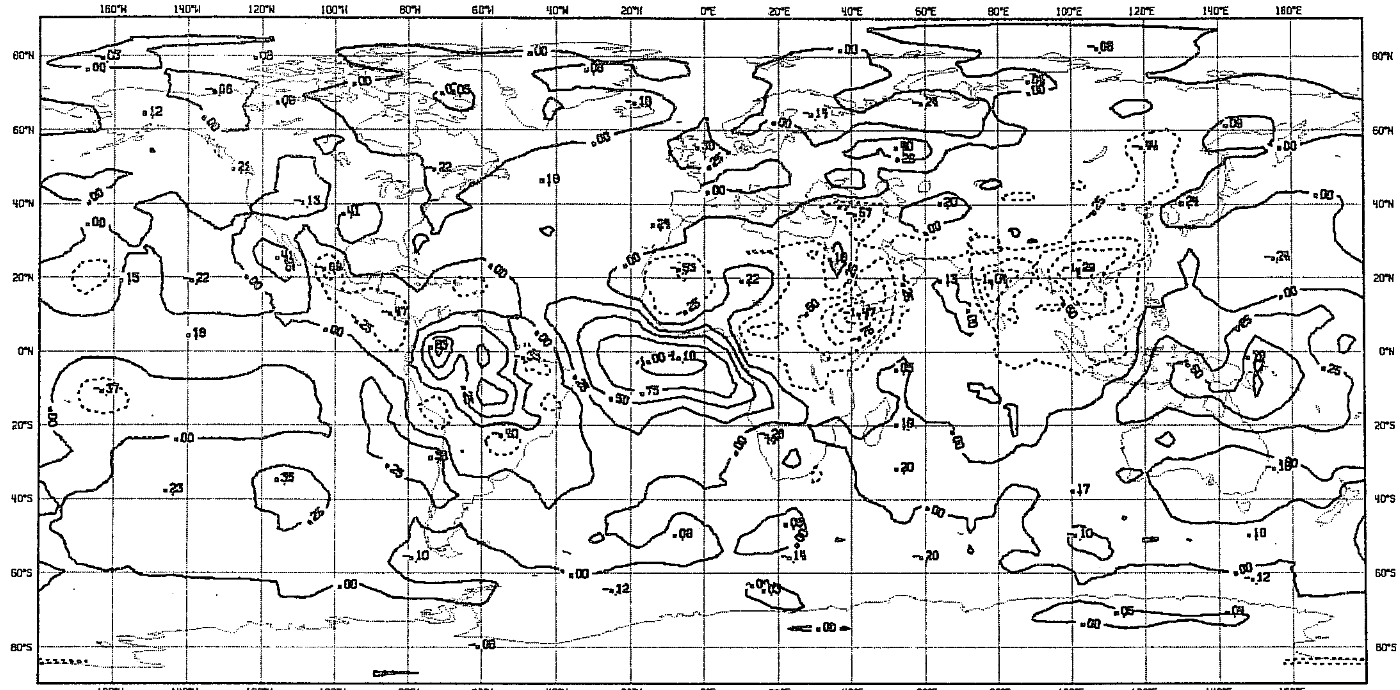
MEAN DIFFERENCE FOR JUNE-JULY-AUGUST 1983



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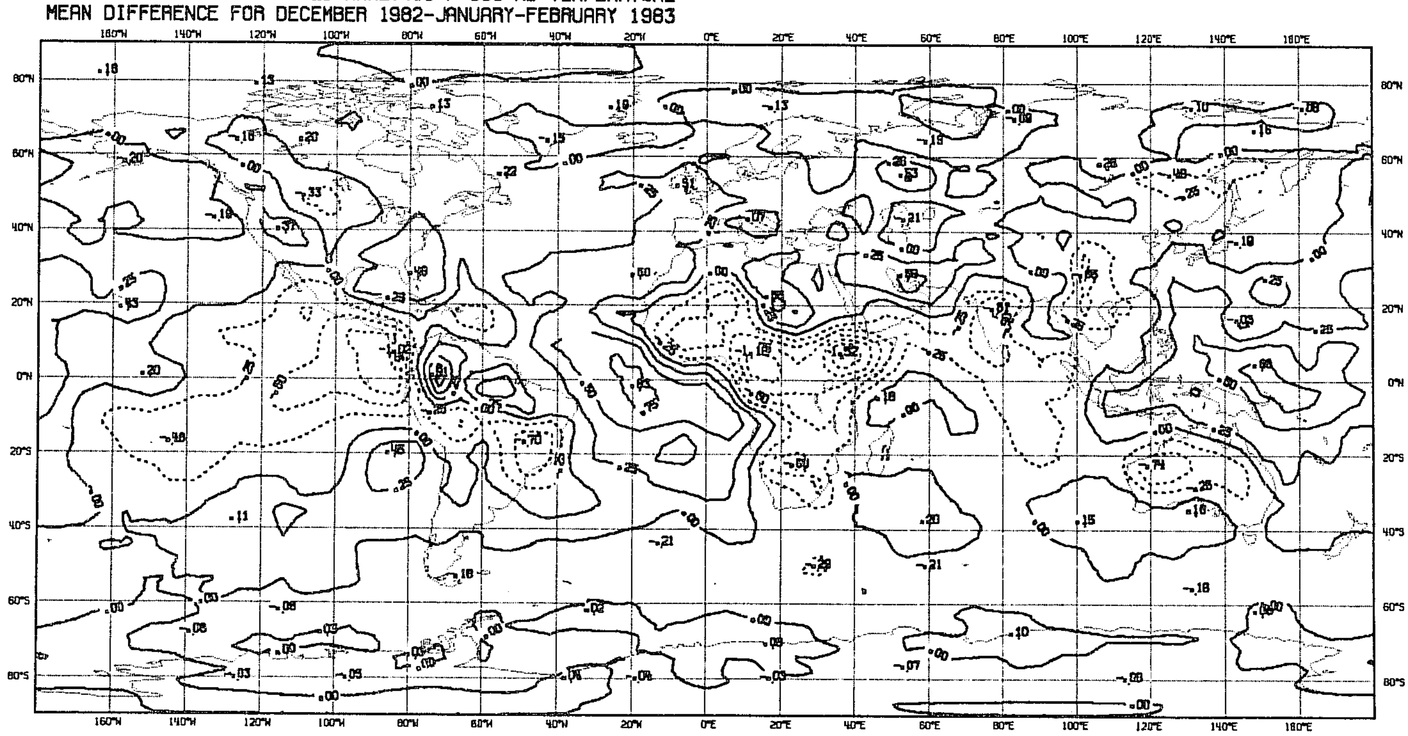

Fig. 13 Same as Fig. 11 but for the 500 mb temperature

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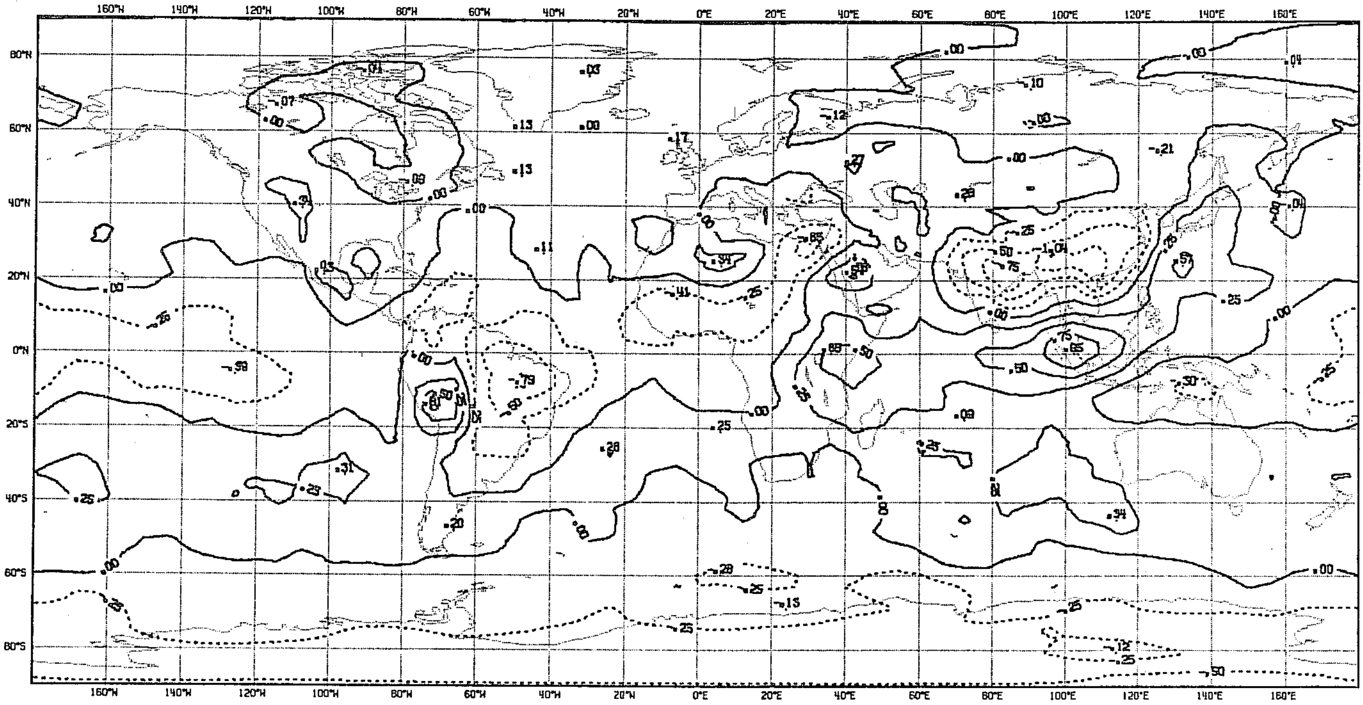


INITIALISED-UNINITIALISED ANALYSIS / 200 MB TEMPERATURE
MEAN DIFFERENCE FOR DECEMBER 1982-JANUARY-FEBRUARY 1983

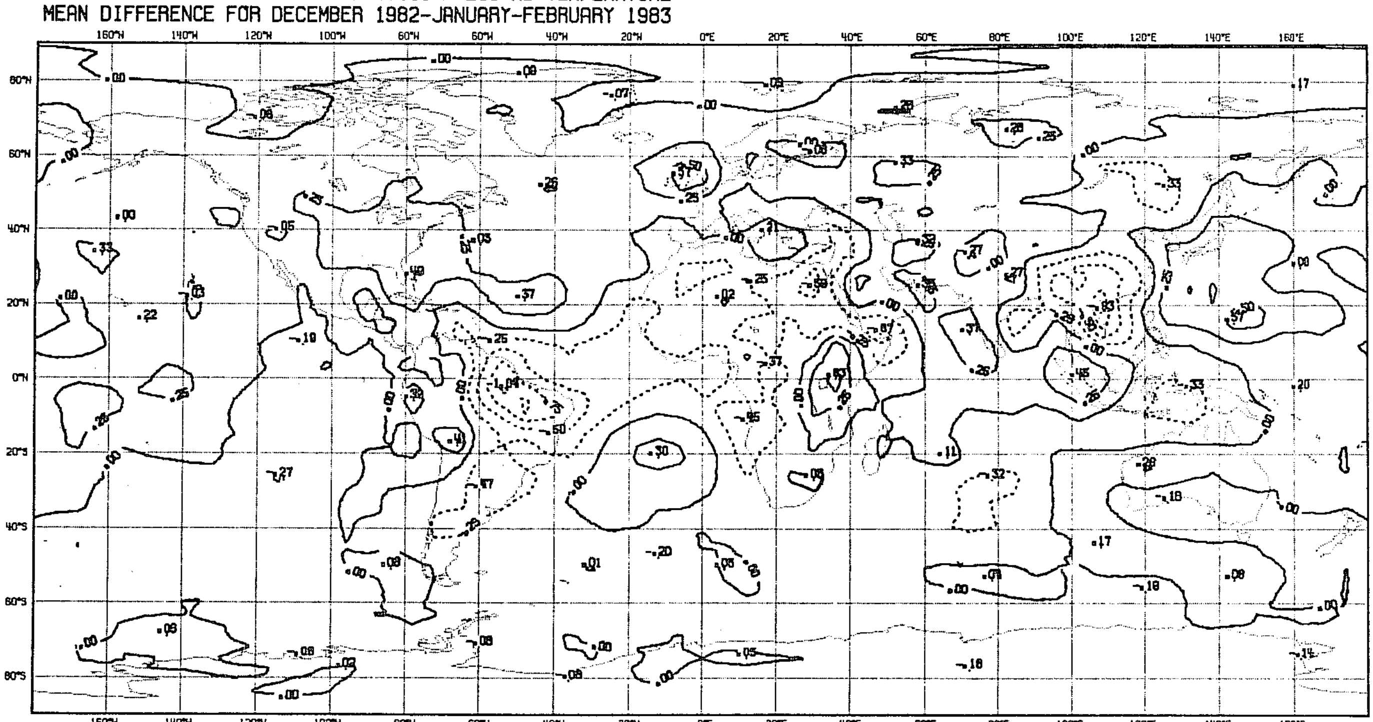
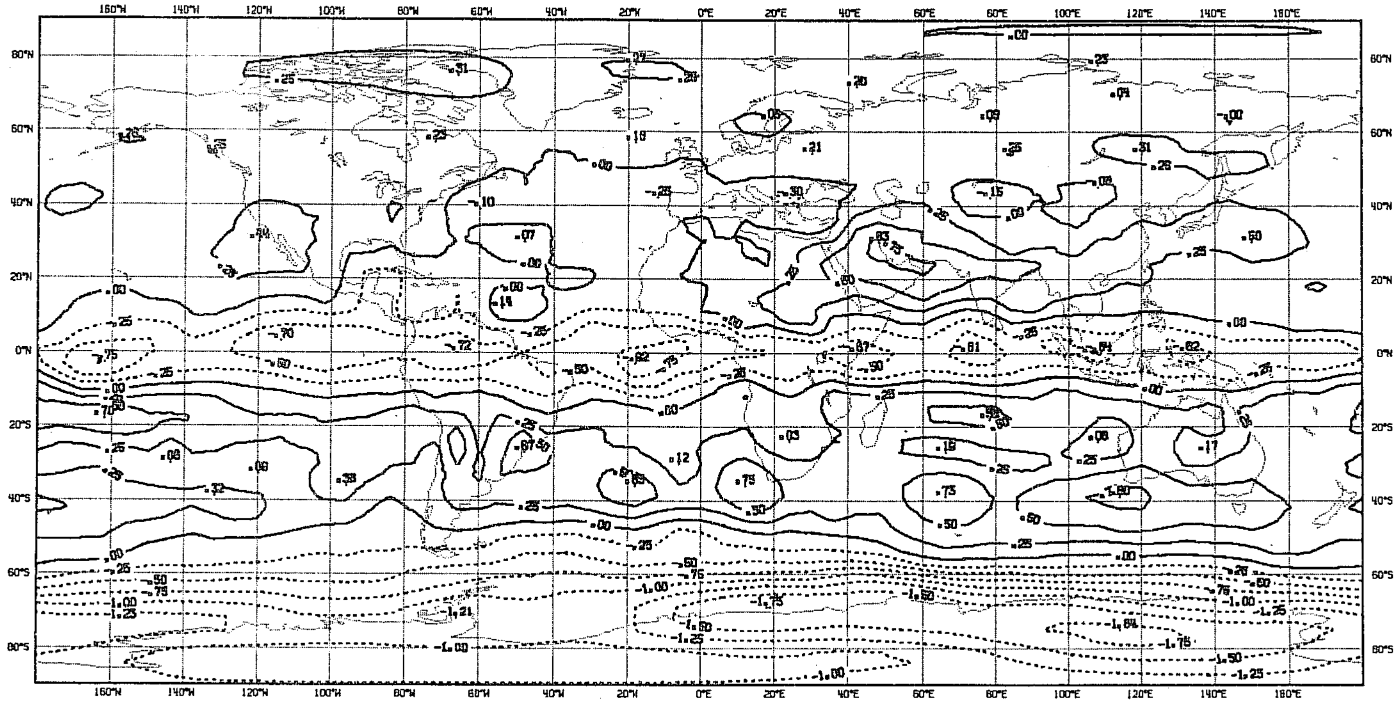


Fig. 14 Same as Fig. 11 but for the 200 mb temperature

INITIALISED-UNINITIALISED ANALYSIS / 50 MB TEMPERATURE
MEAN DIFFERENCE FOR JUNE-JULY-AUGUST 1983



INITIALISED-UNINITIALISED ANALYSIS / 50 MB TEMPERATURE
MEAN DIFFERENCE FOR DECEMBER 1982-JANUARY-FEBRUARY 1983

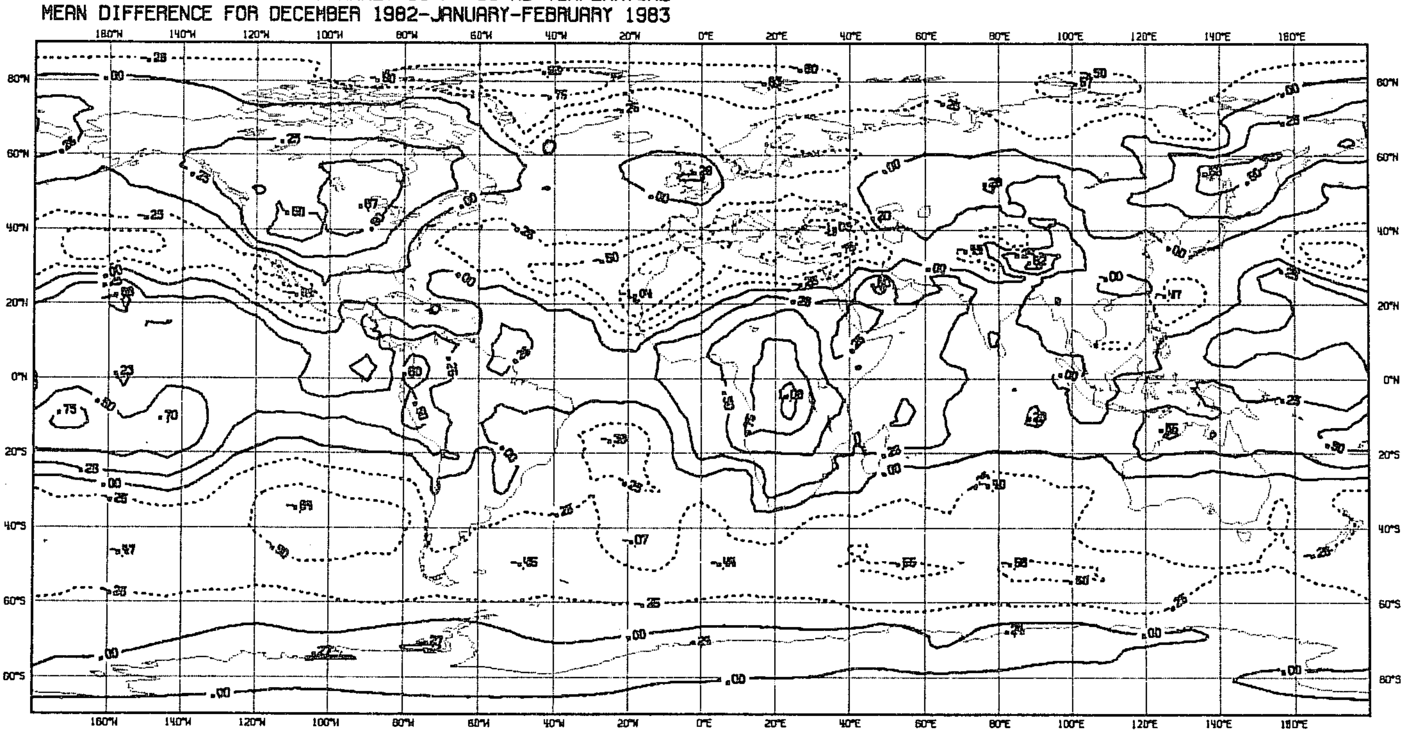


Fig. 15 Same as Fig. 11 but for the 50 mb temperature

Tables 3 - 9:

Table 3 RMS-error of height forecasts verified against the initialised analyses and the differences for the RMSE when compared to the uninitialised analyses. The results are three month averages; from December to February for the winter 1982/83 and from June to August for the summer 1983.

Table 4 Same as Table 3 but for the RMS-error of vector wind.

Table 5 Same as Table 3 but for the RMS-error of temperature.

Table 6 Same as Table 3 but for the anomaly correlation of height.

Table 7 RMS-error of height forecasts for three northern hemispheric areas verified against the initialised analyses and the differences for the RMSE when compared to the uninitialised analyses. The results are three month averages; from December to February for the winter 1982/83 and from June to August for the summer 1983.

Table 8 Same as Table 7 but for the RMS-error of vector wind.

Table 9 Same as Table 7 but for the anomaly correlation of height.

			Northern Hemisphere				Tropical Belt				Southern Hemisphere			
			+24	+72	+120	+168	+24	+72	+120	+168	+24	+72	+120	+168
Winter 1982/83	RMS - error of height (operational verification)	1000 mb	20.5	41.2	60.5	77.0	9.9	15.3	17.1	18.6	29.0	48.6	59.6	69.0
		850	18.5	38.8	57.1	74.2	7.8	12.5	14.1	16.1	27.4	47.2	58.8	68.4
		500	21.7	50.7	79.3	104.8	10.3	23.2	34.1	42.7	32.6	63.8	84.0	98.7
		200	32.1	69.6	107.7	140.9	23.2	49.2	72.8	93.3	45.0	84.2	114.0	135.2
		50	45.7	100.6	154.0	205.8	27.2	53.6	81.0	106.1	46.8	92.2	134.3	173.7
	Difference for the RMSE (initialised-uninitialised verification)	1000 mb	0.0	-0.3	-0.7	-0.9	-3.6	-3.2	-3.2	-2.8	-1.3	-0.9	-0.8	-0.9
		850	-0.5	-0.5	-0.8	-1.0	-4.0	-3.3	-2.8	-2.2	-1.4	-1.0	-0.8	-0.8
		500	-0.5	-0.2	-0.1	-0.3	-1.0	+0.8	+1.4	+1.6	-1.4	-0.7	-0.3	-0.5
		200	+0.3	+1.4	+1.8	+1.9	-1.8	+1.5	+2.8	+3.2	-1.7	-0.7	-0.3	-0.4
		50	+0.3	+5.7	+6.6	+7.2	-6.4	-0.4	+2.3	+3.4	-2.9	-1.4	-0.8	-0.8
Summer 1983	RMS - error of height (operational verification)	1000 mb	15.5	31.0	42.6	52.0	10.0	15.7	17.1	19.4	37.6	61.6	78.4	89.0
		850	14.6	30.2	42.5	52.9	8.3	13.9	15.5	18.4	35.3	58.6	75.7	87.1
		500	17.1	39.8	61.4	78.6	13.8	30.6	44.1	51.6	41.4	76.6	103.9	121.4
		200	22.9	48.8	80.0	105.0	19.0	28.6	38.9	44.8	52.8	95.3	132.9	156.3
		50	23.2	49.1	74.0	97.2	20.4	34.3	38.3	41.8	69.2	105.1	141.4	166.0
	Difference for the RMSE (initialised-uninitialised verification)	1000 mb	-0.4	-0.4	-0.6	-0.6	-2.1	-2.4	-2.4	-2.4	-0.6	-0.6	-0.5	-0.5
		850	-0.7	-0.8	-0.9	-0.9	-2.5	-2.7	-2.4	-2.2	-1.2	-0.9	-0.7	-0.7
		500	-1.4	-1.0	-0.8	-0.8	-1.2	-0.5	+0.1	+0.1	-1.8	-1.0	-0.5	-0.6
		200	-4.4	-2.3	-1.3	-1.0	-3.7	-2.6	-1.2	-0.7	-2.2	-1.0	-0.4	-0.5
		50	-4.8	-2.0	-0.3	-0.4	-8.0	-3.1	-3.0	-3.1	-4.1	-3.1	-2.2	-1.8

Table 3 RMS-error of height forecasts verified against the initialised analyses and the differences for the RMSE when compared to the uninitialised analyses. The results are three month averages; from December to February for the winter 1982/83 and from June to August for the summer 1983. Units: m.

			Northern Hemisphere				Tropical Belt				Southern Hemisphere			
			+24	+72	+120	+168	+24	+72	+120	+168	+24	+72	+120	+168
Winter 1982/83	RMS - error of vector wind (operational verification)	1000 mb	3.8	6.2	8.0	9.1	2.9	4.0	4.5	4.9	4.2	7.0	8.1	9.0
		850	4.2	7.3	9.5	11.1	3.4	5.3	6.0	6.6	4.4	7.6	9.1	10.2
		500	5.2	9.8	13.3	15.9	3.4	5.8	7.0	7.8	5.2	10.1	12.8	14.5
		200	7.3	11.6	15.5	18.8	7.3	11.3	13.6	15.2	7.9	13.6	17.6	20.1
		50	8.0	9.9	11.6	13.5	6.6	9.3	9.8	10.4	6.0	7.7	8.5	9.2
	Difference for the RMSE (initialised-uninitialised verification)	1000 mb	0.0	0.0	+0.1	+0.1	+0.1	+0.1	+0.1	+0.1	0.0	0.0	0.0	0.0
		850	-0.1	0.0	+0.1	+0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		500	-0.1	+0.1	+0.1	+0.1	0.0	+0.1	0.0	+0.1	0.0	0.0	-0.1	0.0
		200	-0.1	+0.1	+0.2	+0.3	-0.1	+0.1	+0.2	+0.2	-0.1	0.0	+0.1	+0.1
		50	-0.5	-0.2	0.0	+0.1	-0.6	+0.2	+0.3	+0.2	-0.3	-0.1	0.0	0.0
Summer 1983	RMS - error of vector wind (operational verification)	1000 mb	3.1	5.1	6.2	7.0	2.9	4.0	4.6	4.9	5.2	8.3	9.9	10.7
		850	3.3	5.8	7.3	8.4	3.3	5.3	6.2	6.6	5.4	9.2	11.2	12.2
		500	3.8	7.4	10.0	11.8	3.4	5.8	7.0	7.7	6.6	12.0	15.2	17.1
		200	6.1	10.7	14.4	17.2	6.8	10.3	12.0	13.0	8.7	14.5	18.6	21.1
		50	4.2	5.1	5.8	6.5	7.4	8.4	8.8	9.0	9.8	11.6	13.3	14.4
	Difference for the RMSE (initialised-uninitialised verification)	1000 mb	-0.2	0.0	-0.1	0.0	+0.1	0.0	+0.1	+0.2	0.0	-0.1	0.0	0.0
		850	-0.2	-0.1	-0.1	-0.1	-0.2	0.0	-0.1	0.0	-0.1	-0.1	0.0	-0.1
		500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		200	-0.3	-0.2	-0.2	-0.2	-0.3	-0.2	-0.1	-0.2	-0.3	-0.1	-0.1	-0.1
		50	-0.2	-0.2	-0.3	-0.2	-0.7	-0.7	-0.6	-0.5	-0.4	-0.3	-0.3	-0.3

Table 4 Same as Table 3 but for the RMS-error of vector wind. Units: m/s.

			Northern Hemisphere				Tropical Belt				Southern Hemisphere			
			+24	+72	+120	+168	+24	+72	+120	+168	+24	+72	+120	+168
Winter 1982/83	RMS - error of temperature (operational verification)	1000 mb	1.8	2.7	3.4	4.0	1.3	1.7	1.9	2.1	1.7	2.2	2.5	2.7
		850	1.5	3.0	4.1	5.1	1.1	1.8	2.3	2.7	1.6	2.9	3.6	4.1
		500	1.3	2.6	3.7	4.5	1.0	1.8	2.4	2.6	1.6	2.8	3.6	4.1
		200	1.6	2.9	3.9	4.8	0.9	1.5	1.7	1.7	1.7	2.9	3.5	4.1
		50	1.7	3.0	4.2	5.2	1.4	3.0	4.3	5.4	1.7	3.0	4.2	5.4
	Difference for the RMSE (initialised-uninitialised verification)	1000 mb	+0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		850	0.0	0.0	-0.1	0.0	-0.1	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0
		500	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	0.0	-0.1	-0.1	-0.1
		200	-0.1	+0.1	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	-0.1	0.0
		50	-0.1	-0.1	0.0	0.0	+0.2	+0.3	+0.3	+0.2	0.0	-0.1	-0.1	-0.1
Summer 1983	RMS - error of temperature (operational verification	1000 mb	1.7	2.6	3.2	3.6	1.4	1.9	2.2	2.5	2.1	2.8	3.2	3.4
		850	1.4	2.5	3.4	4.0	1.2	2.0	2.7	3.3	2.1	3.6	4.4	4.9
		500	1.0	2.0	2.8	3.4	1.1	2.1	2.6	2.7	1.8	3.1	4.0	4.5
		200	1.5	3.2	4.4	5.2	1.5	3.6	4.7	5.1	2.2	3.4	4.3	4.9
		50	0.8	1.8	2.6	3.2	1.0	2.0	3.2	3.9	1.6	3.0	3.9	4.6
	Difference for the RMSE (initialised-uninitialised verification)	1000 mb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		850	0.0	0.0	0.0	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
		500	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
		50	+0.1	+0.1	+0.1	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	+0.1

Table 5 Same as Table 3 but for the RMS-error of temperature. Units: ^{o}C.

			Northern Hemisphere				Tropical Belt				Southern Hemisphere			
			+24	+72	+120	+168	+24	+72	+120	+168	+24	+72	+120	+168
Winter 1982/83	Anomaly correl. of height (operational verification)	1000 mb	96.3	84.9	68.9	49.2	84.3	65.7	56.6	43.8	87.6	66.6	51.3	36.1
		850	96.9	86.5	71.6	52.1	87.0	69.0	58.7	43.5	89.0	68.6	53.5	38.3
		500	98.1	89.4	74.6	55.2	93.4	81.7	71.0	59.2	92.9	73.5	56.0	40.1
		200	97.9	90.6	77.9	61.5	93.8	82.4	67.1	54.4	93.1	76.3	57.6	41.9
		50	97.3	90.1	81.9	71.0	92.0	86.2	82.0	80.1	87.2	71.5	58.6	45.4
	Difference for the anom. correlation (initialised-uninitialised verification)	1000 mb	-0.1	-0.1	-0.1	-0.3	+8.7	+9.7	+9.2	+6.6	+1.0	+1.1	+0.9	+1.0
		850	+0.1	0.0	-0.1	-0.1	+13.4	+13.2	+11.0	+6.8	+1.0	+0.9	+0.7	+0.6
		500	+0.2	+0.1	0.0	0.0	+6.4	+5.0	+2.4	+1.8	+0.7	+0.6	+0.4	+0.6
		200	+0.2	+0.3	+0.1	+0.1	+7.9	+6.7	+4.7	+3.6	+0.6	+0.6	+0.4	+0.6
		50	+0.7	+0.3	+0.2	0.0	+14.2	+12.3	+11.1	+10.9	+2.7	+2.6	+2.1	+2.5
Summer 1983	Anomaly correl. of height (operational verification)	1000 mb	93.9	76.2	54.8	32.9	82.8	64.3	53.1	41.2	88.8	71.6	53.9	40.6
		850	94.8	78.4	56.4	33.6	83.8	65.1	51.8	39.2	89.3	72.0	53.1	38.0
		500	97.4	85.8	64.9	41.5	89.3	74.2	63.0	55.6	92.3	74.9	53.5	35.8
		200	97.4	87.7	67.1	43.2	92.2	81.6	68.0	59.4	92.8	77.0	56.1	39.9
		50	92.9	76.1	59.0	46.3	91.2	83.2	81.6	79.9	89.3	76.8	65.3	57.2
	Difference for the anom. correlation (initialised-uninitialised verification)	1000 mb	+0.4	+0.6	+0.9	+1.0	+7.3	+10.7	+10.6	+11.2	+0.4	+0.5	+0.5	+0.6
		850	+0.5	+1.0	+1.1	+1.3	+10.7	+15.3	+14.0	+14.1	+0.7	+0.7	+0.6	+0.7
		500	+0.5	+0.5	+0.5	+0.6	+6.6	+6.6	+2.0	+3.4	+0.6	+0.5	+0.3	+0.5
		200	+1.1	+1.0	+0.9	+0.7	+6.6	+5.9	+2.3	+0.2	+0.6	+0.5	+0.2	+0.3
		50	+4.1	+2.8	+1.3	+1.8	+9.4	+8.1	+8.6	+8.7	+1.7	+2.3	+2.6	+2.8

Table 6 Same as Table 3 but for the anomaly correlation of height.

			Europe				China/Japan				North America			
			+24	+72	+120	+168	+24	+72	+120	+168	+24	+72	+120	+168
Winter 1982/83	RMS-error of height (operational verification)	1000 mb	22.4	49.0	75.6	103.6	17.4	34.3	45.3	60.6	18.0	40.8	56.6	66.3
		850	20.3	45.8	72.5	100.1	15.2	29.9	40.2	54.9	16.5	37.4	51.5	60.3
		500	24.8	61.6	101.2	143.0	18.2	42.2	59.6	82.2	20.3	52.8	79.8	91.9
		200	34.2	89.4	143.0	203.7	28.2	57.8	79.2	105.6	28.1	65.6	102.0	122.6
		50	50.6	149.2	234.0	317.1	45.0	86.9	118.7	173.9	36.4	96.2	135.6	177.3
	Difference for the RMSE (initialised - uninitialised verification)	1000 mb	+1.6	+0.2	-0.5	-1.0	+1.5	+1.0	+1.1	+0.8	+1.4	-1.8	-6.6	-5.5
		850	+1.3	+1.1	-0.4	-1.0	+1.1	+0.5	+0.7	-0.1	-0.6	-2.6	-6.6	-4.3
		500	+2.0	+2.2	+1.1	+0.6	-0.2	-1.3	-1.5	-2.8	-1.9	-3.0	-8.2	-7.0
		200	+3.0	+5.1	+4.4	+4.0	+0.5	+0.2	+0.1	-1.5	-0.6	-3.3	-8.1	-7.4
		50	+0.2	+6.4	+6.8	+6.5	+1.7	+1.8	-0.7	+0.9	+5.4	+18.2	+19.4	+21.7
Summer 1983	RMS-error of height (operational verification)	1000 mb	14.6	34.2	50.7	62.3	16.9	31.2	40.5	45.7	14.6	29.3	39.7	47.1
		850	14.2	33.9	51.0	64.0	15.2	29.2	39.2	44.1	12.4	26.2	35.8	42.9
		500	17.1	44.8	74.0	98.9	16.2	34.5	51.3	59.4	13.2	33.4	53.4	65.7
		200	23.8	56.0	94.5	127.9	23.0	50.8	79.1	97.8	20.5	51.2	82.2	106.1
		50	19.7	45.1	74.6	106.7	22.9	49.2	71.7	87.7	15.1	33.7	52.1	72.9
	Difference for the RMSE (initialised - uninitialised verification)	1000 mb	-0.3	-0.5	-0.7	-0.8	+1.6	+0.8	-0.4	-0.6	-0.1	-1.3	-2.9	-4.3
		850	-1.5	-1.5	-1.5	-1.4	+2.0	+0.8	-0.6	-0.9	0.0	-0.9	-2.7	-4.3
		500	-1.8	-1.0	-0.7	-0.6	-0.1	-0.5	-2.2	-2.5	-0.6	-0.8	-2.2	-4.1
		200	-4.2	-1.4	-0.3	-0.1	-6.2	-3.2	-3.7	-3.6	-0.8	-1.5	-0.8	-0.7
		50	-2.8	+1.2	+2.9	+3.5	-6.2	-1.3	-0.8	-0.6	-4.8	-5.6	-7.7	-8.8

Table 7 RMS-error of height forecasts for three northern hemispheric areas verified against the initialised analyses and the differences for the RMSE when compared to the uninitialised analyses. The results are three month averages; from December to February for the winter 1982/83 and from June to August for the summer 1983. Units: m.

			Europe				China/Japan				North America			
			+24	+72	+120	+168	+24	+72	+120	+168	+24	+72	+120	+168
Winter 1982/83	RMSE-error of vector wind (operational verification)	1000 mb	3.8	6.3	8.4	10.1	3.4	5.2	6.3	7.2	3.1	5.4	6.8	7.5
		850	4.4	7.9	10.7	13.1	3.6	5.9	7.4	8.7	3.6	7.4	9.4	10.4
		500	5.2	10.4	15.0	19.0	5.0	8.8	11.4	13.8	5.1	10.9	14.3	16.0
		200	5.8	11.1	16.9	22.2	6.1	10.2	12.9	15.5	6.9	12.2	16.2	19.0
		50	6.8	8.8	12.1	15.3	6.0	8.7	10.7	12.5	5.6	8.7	10.2	11.7
	Difference for the RMSE (initialised-uninitialised verification)	1000 mb	-0.1	0.0	+0.1	+0.2	-0.3	-0.4	-0.5	-0.5	0.0	-0.5	-1.5	-1.6
		850	-0.1	+0.1	+0.1	+0.2	-0.1	-0.3	-0.3	-0.3	-0.1	-0.3	-1.4	-1.4
		500	+0.0	+0.1	+0.1	+0.1	+0.5	+0.2	+0.1	0.0	+0.3	0.0	-0.5	-0.7
		200	-0.2	0.0	+0.2	+0.3	+0.2	+0.2	+0.3	+0.4	+0.0	0.0	0.0	+0.2
		50	-0.6	-0.5	-0.3	-0.2	-0.2	-0.2	-0.1	-0.1	-1.4	-0.5	-0.4	-0.3
Summer 1983	RMS-error of vector wind (operational verification)	1000 mb	2.9	5.0	6.4	7.2	3.3	5.3	6.3	6.9	2.6	4.4	5.4	5.9
		850	3.0	5.5	7.5	8.7	3.5	6.4	7.9	8.6	2.9	5.4	7.0	7.8
		500	3.7	7.6	11.3	13.9	3.9	7.7	9.7	10.7	3.3	7.0	9.5	11.2
		200	5.5	10.2	14.8	18.6	6.0	11.7	15.7	17.9	5.4	11.2	15.2	18.4
		50	3.0	4.1	5.2	6.5	3.0	4.2	5.0	5.5	2.6	3.8	5.0	6.2
	Difference for the RMSE (initialised-uninitialised verification)	1000 mb	-0.1	0.0	0.0	0.0	-0.4	-0.5	-0.5	-0.5	-0.2	-0.4	-0.7	-0.9
		850	-0.2	0.0	0.0	0.0	-0.4	-0.6	-0.7	-0.8	-0.1	-0.4	-0.6	-0.8
		500	0.0	0.0	0.0	-0.1	0.0	0.0	-0.3	-0.3	0.0	-0.1	-0.4	-0.4
		200	-0.2	-0.1	-0.1	-0.1	-0.5	-0.7	-1.1	-1.2	-0.4	-0.5	-0.7	-0.7
		50	-0.4	-0.3	-0.3	-0.3	-0.6	-0.5	-0.5	-0.4	-1.0	-0.9	-0.8	-0.5

Table 8 Same as Table 7 but for the RMS-error of vector wind. Units: m/s.

Season	Quantity	Level	Europe +24	Europe +72	Europe +120	Europe +168	China/Japan +24	China/Japan +72	China/Japan +120	China/Japan +168	North America +24	North America +72	North America +120	North America +168
Winter 1982/83	Anomaly correl. of height (operational verification)	1000 mb	97.5	88.7	72.8	50.0	92.0	76.5	58.1	37.5	95.1	74.0	49.1	31.2
		850	97.9	89.9	74.0	51.1	92.5	77.0	57.2	37.7	95.7	75.1	51.9	36.2
		500	98.8	91.9	76.4	52.8	96.7	83.7	67.1	46.9	97.3	81.3	60.6	46.2
		200	98.7	92.2	78.7	55.6	96.0	82.4	69.0	53.1	96.8	85.1	65.5	49.0
		50	96.8	89.8	82.0	71.4	94.2	81.6	71.8	50.8	96.7	83.9	71.2	56.4
	Difference for the anom. correlation (initialised-uninitialised verification)	1000 mb	-0.1	-0.3	-0.3	-0.5	-1.4	-1.6	-3.7	-1.8	-1.5	-0.8	+3.0	+2.1
		850	-0.1	-0.3	-0.3	-0.6	-1.4	-2.3	-4.1	-0.7	-0.5	+1.0	+5.0	+2.0
		500	0.0	0.0	-0.2	-0.4	-0.4	-0.6	-1.0	-1.2	-0.5	-1.5	+1.7	-0.7
		200	+0.2	+0.3	+0.3	+0.2	-0.6	-1.1	-1.0	-1.5	-0.7	-0.3	+1.2	+0.1
		50	+0.8	+0.1	-0.7	-1.2	+2.0	+0.2	0.0	-2.5	-0.1	-3.7	-3.0	-8.3
Summer 1983	Anomaly correl. of height (operational verification)	1000 mb	95.6	79.9	53.3	28.6	91.1	70.7	49.4	36.4	91.4	65.8	38.1	15.1
		850	96.6	83.4	59.0	32.7	91.3	71.0	46.4	33.6	92.7	67.7	42.3	21.1
		500	98.3	88.3	66.0	35.6	94.5	76.4	52.7	37.7	97.6	84.1	60.2	39.4
		200	98.0	87.8	65.1	33.5	96.6	82.2	56.7	35.6	97.7	85.9	63.9	39.5
		50	90.2	56.2	22.4	3.5	90.8	74.7	58.6	46.4	86.4	59.4	30.2	15.0
	Difference for the anom. correlation (initialised-uninitialised verification)	1000 mb	+0.2	+0.3	+0.4	+0.2	-1.5	-0.5	+2.7	+4.3	-0.8	-2.8	-1.8	-1.4
		850	+0.7	+1.0	+0.9	+0.6	-2.5	-3.5	+0.4	+1.8	-2.2	-5.9	-5.6	-6.2
		500	+0.5	+0.5	+0.5	+0.3	-0.9	-2.9	-1.1	-0.7	-0.1	-1.7	-4.0	-4.3
		200	+0.9	+0.6	+0.2	-0.1	+1.4	+0.4	-0.1	+0.4	-0.1	-1.6	-4.9	-5.3
		50	+3.4	-4.3	-10.0	-9.5	+16.8	+13.5	+9.8	+10.1	+10.2	+14.8	+16.6	+14.6

Table 9 Same as Table 7 but for the anomaly correlation of height.