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Systematic errors in surface and upper lows in ECMWF's operational spectral model for the1983 1984 winter season and comparing these to the relevant errors in grid point mod

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ABSTRACT

Systematic errors in forecasts (up to ten days) of cyclones over the North Atlantic and Europe, and systematic errors in the D+3, D+5 and D+7 forecasts of upper lows and troughs at 500mb over the eastern Atlantic and the Mediterranean, by the ECMWF spectral model (T63) for the 1983-84 winter season are described, and the results compared to those from the grid point model (N48). Statistics for the cyclone tracks, filling and deepening rates, etc., and for the displacement of forecast cut-off lows and troughs are presented.

The spectral model predicts cyclone tracks with a sufficient northward curvature, whereas the grid point model revealed a tendency to displace the cyclone tracks towards the south. Especially for fast moving cyclones, the phase error for the spectral model resembles that for the grid point model; that is, for the fast moving systems both models are too slow. The forecast deepening rate in the T63 model is more realistic than that in the grid point model; however, the filling rate is still less than that observed. For both the N48 and T63 models, the horizontal scale of model cyclones is, in general, too small during the first two or three days of the life cycle and too large during the later stages.

The frequency of occurrence of cyclones is overpredicted over Europe and underpredicted over the Mediterranean in both models.

The forecast cut-off lows and troughs at 500mb over the Mediterranean are mostly displaced too far to the east. The T63 model shows a tendency to displace the cut-off lows over the eastern Atlantic (the cut-off lows off the Iberian Peninsula) too far to the west and north for days 3 and 5, but for day 7 they are too far to the east. The frequency and distance of the eastward displacement of the forecast cut-off lows and troughs increase with forecast time. Some of the cut-off lows and troughs over the eastern Atlantic and the Mediterranean do not have a correct flow pattern (i.e. lows as troughs, or vice versa) and some missed. 56% of the cut-off lows off the Iberian Peninsula, 38% of the Mediterranean cut-off lows, and 58% of the Mediterranean troughs are correctly predicted by the day 7 forecast, the rest are missed or inaccurately predicted.

1. INTRODUCTION

A study, similar to a previous evaluation of the systematic errors in forecasting cyclones in the operational grid point model during winter months 1980/81 and 1981/82 (Technical Memorandum No. 74), has now been carried out for the ECMWF operational spectral model (T63, i.e. triangular truncation with maximum wave number 63, Simmons and Jarraud, 1984) for the 1983/84 winter season. The investigation also considered the errors in predicting 500mb lows and troughs over the eastern Atlantic and the Mediterranean for the period from November 1983 to February 1984.

It should be pointed out that during the 1983/84 winter season, in which the spectral model was in operational use, the cyclones were less intense and had a shorter life cycle than those in the 1981/82 winter. Also the geographical distribution of the cyclones for the spectral model was based on four months' statistics, from November 1983 to February 1984, whereas for the grid point model it was six months (2 winters). These facts should be kept in mind when the results from the two models are compared.

Besides studying the cyclones at mean sea level pressure (MSL), the systematic errors in the displacement and flow pattern of the lows and troughs at 500mb for the D+3, D+5 and D+7 forecasts, over the eastern Atlantic, southern Europe and the Mediterranean were also investigated.

2. DESCRIPTION OF THE STUDY

The method and procedure used for this study of cyclones, are the same as those followed by Akyildiz, 1983, in his study of the behaviour of the grid point model.

When studying the upperflow, a cut-off low is defined to be a low pressure centre, surrounded by one or more closed contours plotted at 4 dam intervals in the ECMWF analysis and forecast charts for 500mb; a similar definition is used for the cyclones at 1000mb. The 500mb forecasts for days 3, 5 and 7 were verified during November 1983 to February 1984. The displacement of the 500mb forecast troughs and cut-off lows (i.e. the distance between the forecast low and that in the verifying analysis) in degrees and kilometres has been computed. The displacement for a trough is defined as the distance between the mid-points of the trough arcs (subjectively assessed) for the forecast and for the verifying analysis.

The cut-off lows and troughs were also classified according to whether the model forecast the correct flow pattern - for example whether a cut-off low was predicted as a cut-off low, a trough or entirely missed.

3. THE RESULTS

3.1. The surface lows

(a) Cyclone tracks

Fig. 1 shows four examples of observed and predicted cyclone tracks, one from each month from November 1983 to February 1984. The dates on the tracks indicate the centre of the lows every 24 hours during the life cycle of the observed lows. For example, in the December results, the figures 25/12 indicate the position of a low which verifies at 1200 GMT on 25 December 1983.

Tracks which are oriented in the east-west direction, have been grouped into cases when the forecast track was to the left (north) of, to the right (south) of, or along the observed track. For the spectral model it was found that there was sufficient northward curving of the tracks in the forecasts from the same day and from one day earlier than the day on which cyclones were generated, whereas the general tendency of the grid point model is to keep the cyclone tracks towards the south (see Table 1 in Tech. Memo. No. 74). However, examining the forecasts from D-2 (the forecasts from two days earlier than the day on which the cyclone was generated) the percentage of southward displacement of the tracks for second generation cyclones is greater than that for northward displacement. This tendency of the forecast track from D-2 to be south of the observed track can also be seen in Fig. 1.

(b) Speed of cyclones

The mean speed (EW-component) of the model cyclones is calculated for every 24 hour time interval and is compared with the analysed value to give the EW phase error. The lows found in this study range from those which are slow eastward moving (or even retrogressing) to fast eastward moving lows. The sample size of cyclones which have a 4 day life span or more is very small, therefore the calculations are only performed up to the third day of the life cycle of the observed low, while for the forecasts they only go up to day 3 or 4, depending upon whether the forecasts from day D or D-1. Therefore the phase error might apply to short range forecasts only. The scatter diagrams for the mean speed of cyclones in the forecasts from D and D-1, and in the verifying analyses for the second and third day of the life cycle of the observed lows are shown in Fig. 2.

It is clear from Fig. 2 that for the slow moving lows the T63 model is realistic, while for the fast moving lows it is too slow (for D+2 and D+3). However, when comparing these results to the N48 model, some improvements with the T63 model are evident (see Fig. 2 in Tech. Memo. No. 74).

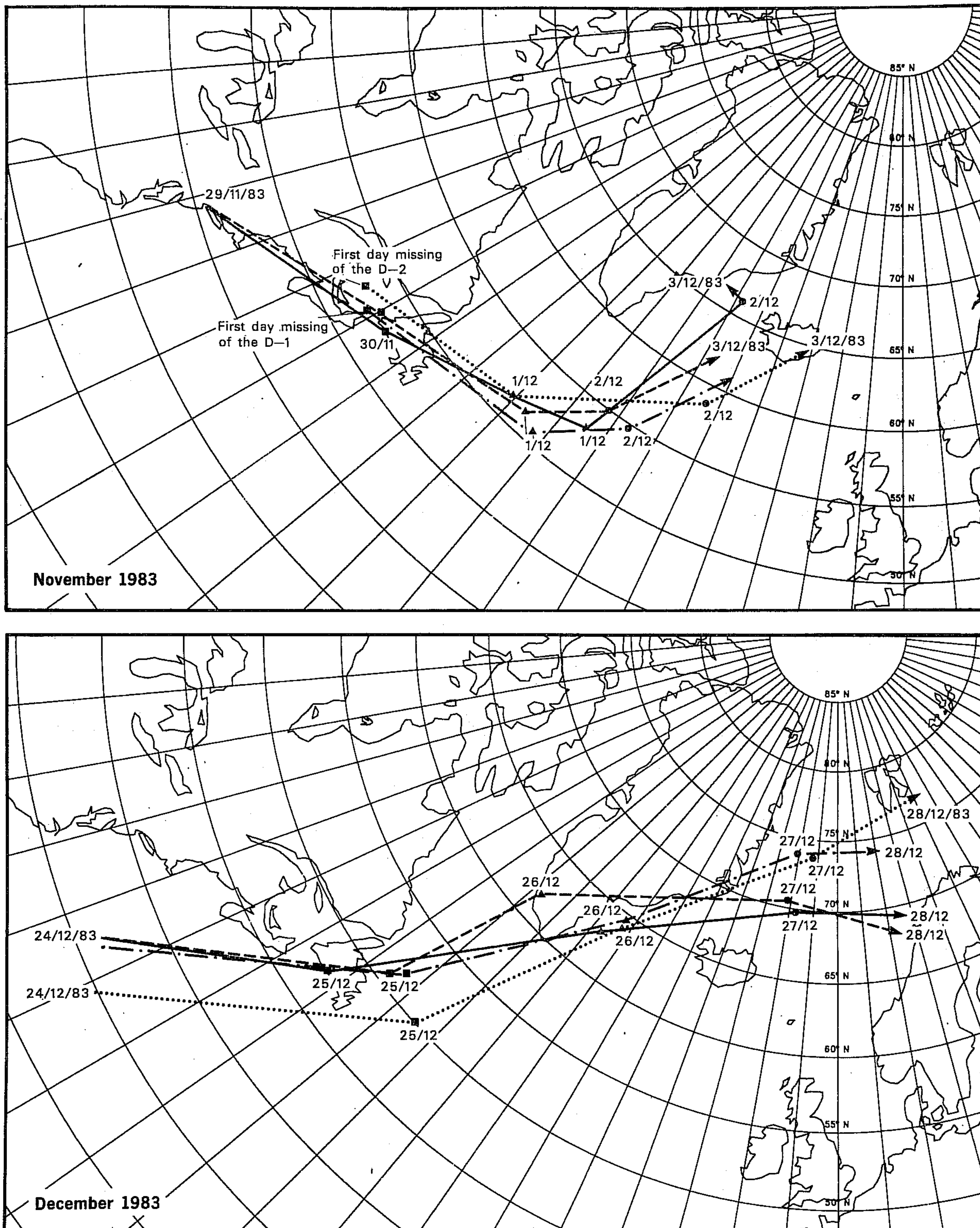
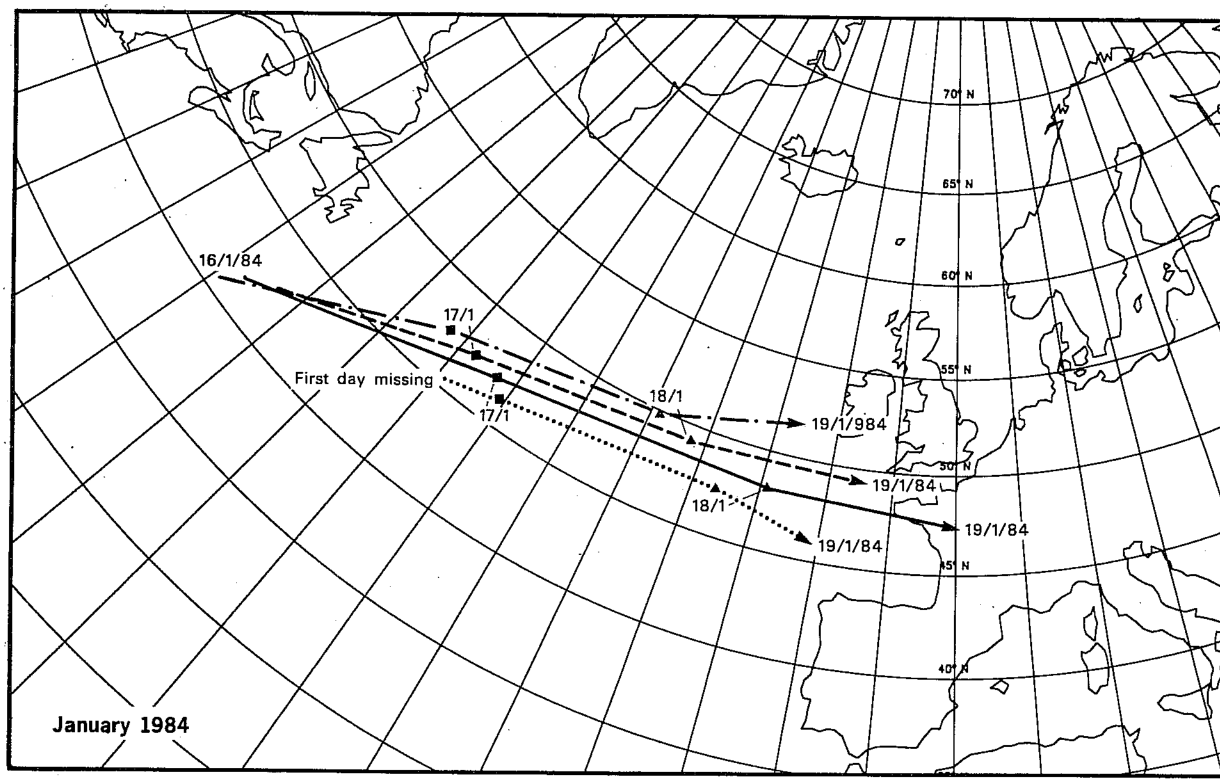


Fig. 1: Tracks of cyclones in the verifying analyses (———), in the forecasts from the day (D) on which the low was generated (– – – –), in the forecasts from the previous day D-1 (—·—·), in the forecasts from 2 days earlier D-2 (·········).



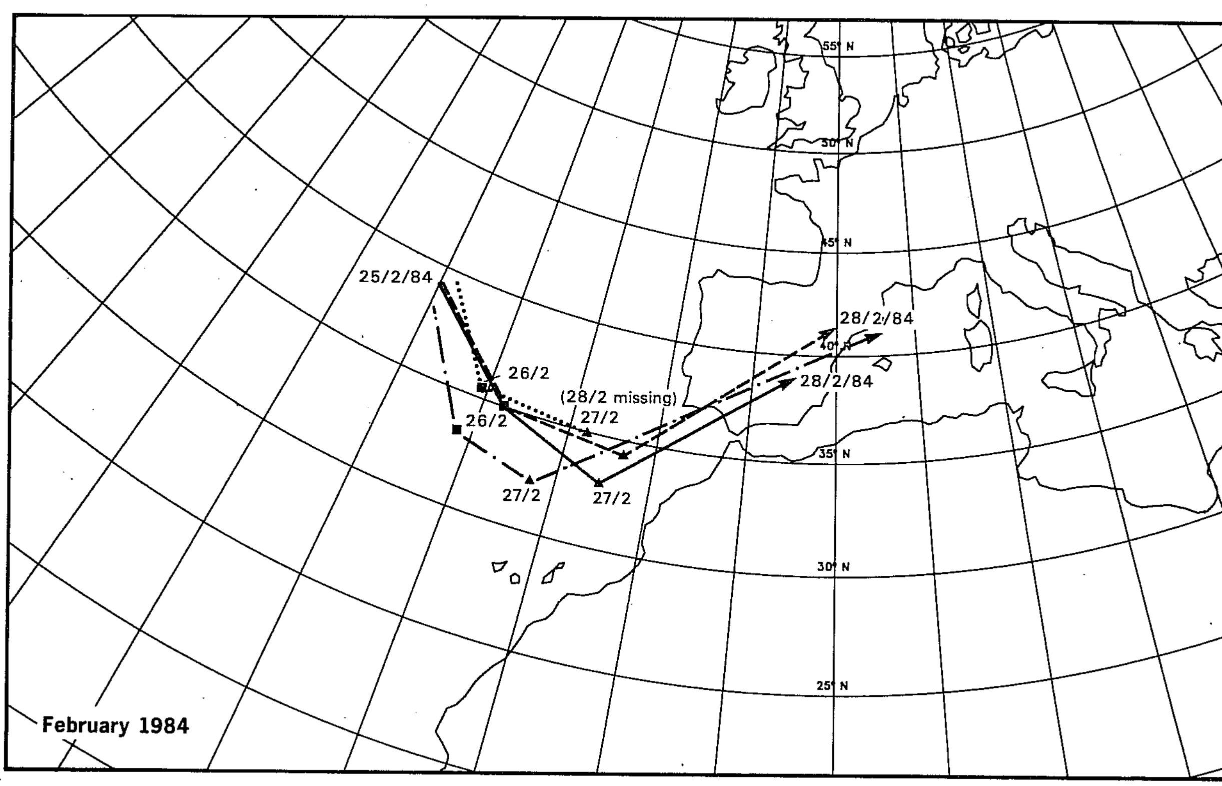


Fig. 1: continued

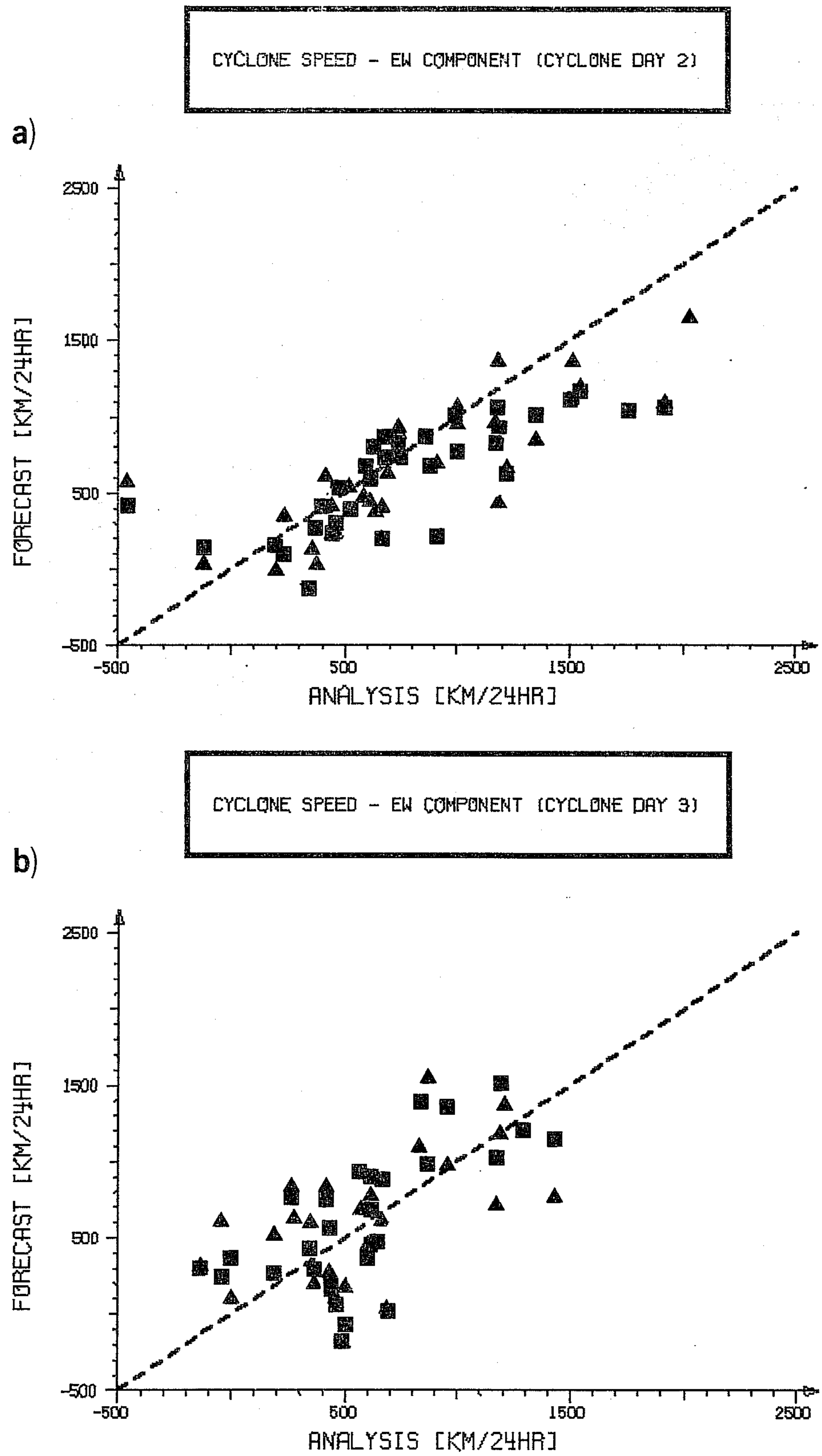


Fig. 2: Cyclone speed (E-W component) in the forecasts and in the verifying analyses, a) second day of the life cycle of the observed lows (above), b) third day of the life cycle of the observed lows (below).

■ F/c from the day on which cyclone was generated

▲ F/c from one day earlier than the day on which cyclone was generated.

(c) Deepening and filling rates of cyclones

The contingency table of 87 cases (Table 1), in which the deepening rates are divided into categories depending on the combination of forecast deepening rate and observed deepening rate, shows an improvement of the deepening rate in the spectral model compared to the grid point model (see Table 6 in Tech. Memo. No. 74); that is, there are more correct cases, and the error distribution in T63 model is more symmetric.

Table 2 also shows that the forecast filling rate is less than the observed rate, i.e., the observed lows fill faster than the model predicts. Similar errors were experienced with the grid point model (see Tables 7,8 and 9 in Tech. Memo. No. 74).

Table 1: Cyclones grouped by forecast deepening rate (initial central pressure - verified central pressure) and observed deepening rate of cyclones (both in mb/24hr). N = 87

Observed Deepening Rate	Forecast Deepening Rate				
	0 ⩽ 7	+8⩽ 15	+16⩽23	+24⩽31	+32⩽39
0 ⩽ 7	25	7	1		
+ 8 ⩽ 15	12	22	6	1	
+16 ⩽ 23		1		2	
+24 ⩽ 31				1	2
+32 ⩽ 39			2	3	2

N = sample size

Table 2: Cyclones grouped by observed filling rate (-(minimum central pressure - central pressure 24 hr later)) and forecast filling rate (both in mb/24 hr). N = 69

Observed Deepening Rate	Forecast Filling Rate					
	0 ⩽	+ 5 ⩽	+10 ⩽	+15 ⩽	+20 ⩽	+25 ⩽
0 ⩽	19	6				
+ 5 ⩽	12	4	3			
+10 ⩽	2	8	4			
+15 ⩽	1	3	2	2		
+20 ⩽		1	1			
+25 ⩽			1			

N = sample size

(d) Magnitude of cyclones

The systematic error in the magnitude of cyclones, (as measured by the geographical area enclosed by the largest closed contour) for the T63 model, as well as for the N48 model, are shown in Fig. 3. The observed cyclones, in general, are larger in their horizontal extention than the model predicts during the first two or three days of the forecast (true for both models), whereas during the later stages of the forecast both models show a tendency to overpredict the horizontal scale of the lows. However, Fig. 3a indicates that the extent of the lows in the forecasts from the day on which the cyclone was generated, is more realistic for the T63 model.

(e) The life span of cyclones

Table 3: The percentage of the cases of cyclones in forecasts (LF) which are greater than, less than or equal to the analysed (LA) life span. D is the day on which the cyclone was generated.

Forecast from	Percentage of Cases (%)				Sample Size
	LA < LF	LF < LA	LF = LA	F/C Missing	
day D	41	13	38	8	39
day D-1	38	21	33	8	39
day D-2	44	28	20	8	39

According to the comparison of the life span of the cyclones in the forecasts (from day D, D-1 and D-2) and in the verifying analyses, shown in Table 3, the percentage of correct cases (i.e. the observed and the forecast cyclones having the same life span) vary from 20 to 38 depending on the initial day of the forecasts; the earlier the forecast (e.g. from the D-2) initiates the cyclone, the fewer correct cases have been recorded. Except for the cases in which the forecast cyclones decayed in the very early stages of the observed cyclones (which are shown in the column "F/C Missing" in Table 3), the forecast cyclones have longer life spans than the observed lows. Thus, the model is generally too slow in filling the cyclones. This result resembles the systematic error in cyclone life span for the N48 model (see Table 11 in Tech. Memo. No. 74).

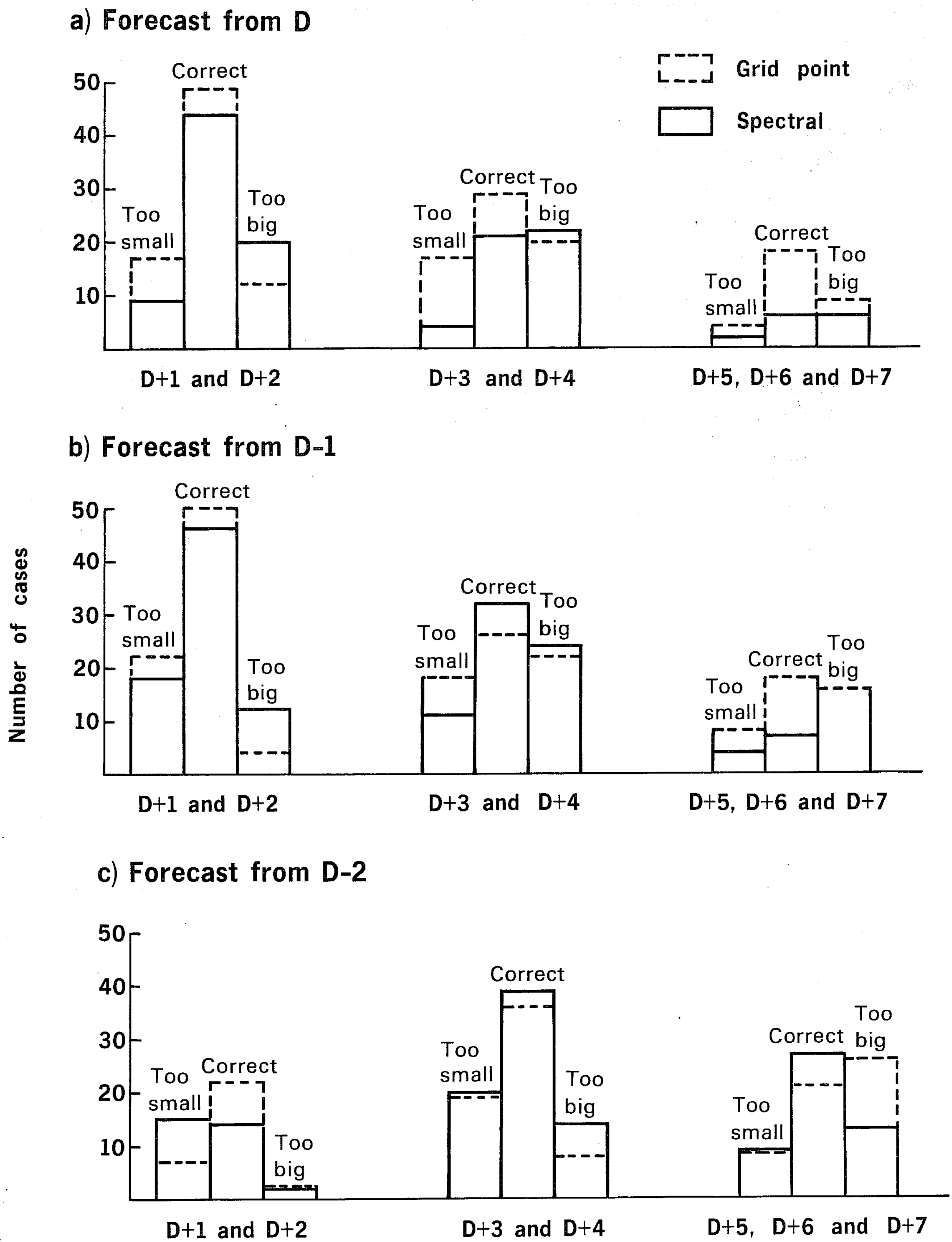


Fig. 3: Comparison of horizontal scale (magnitude) of cyclones in the forecasts (from the grid point and the spectral model) and in the verifying analyses, a) forecast from the D, b) forecast from the D-1, c) forecast from the D-2.

(f) Regional distribution of the cyclones for winter months, 1983/84

The number of cyclones in 5° latitude by 10° longitude squares for the D+5 and D+10 forecasts, and the verifying analyses are shown in Fig. 4. These results indicate that for both time ranges:

- there is an underestimate of the occurrence of Mediterranean cyclones; they are shifted northeast towards the Balkans and the Black Sea;
- the cyclones between 45°N and 55°N over the North Atlantic are missing to a large extent, or shifted too far north;
- the cyclonic activity near Madeira, southwest of the Iberian Peninsula and to the southwest of the Azores are missing;
- the number of lee cyclones near southern Greenland are underestimated;
- the occurrence of cyclones east of Greenland, the southern part of the Norwegian Sea, and the continent of Europe are overestimated.

The error pattern in the regional distribution of cyclones over the North Atlantic and Europe, which emerge in the T63 and N48 models, are similar (see Figs. 9 to 13 in Tech. Memo. No. 74).

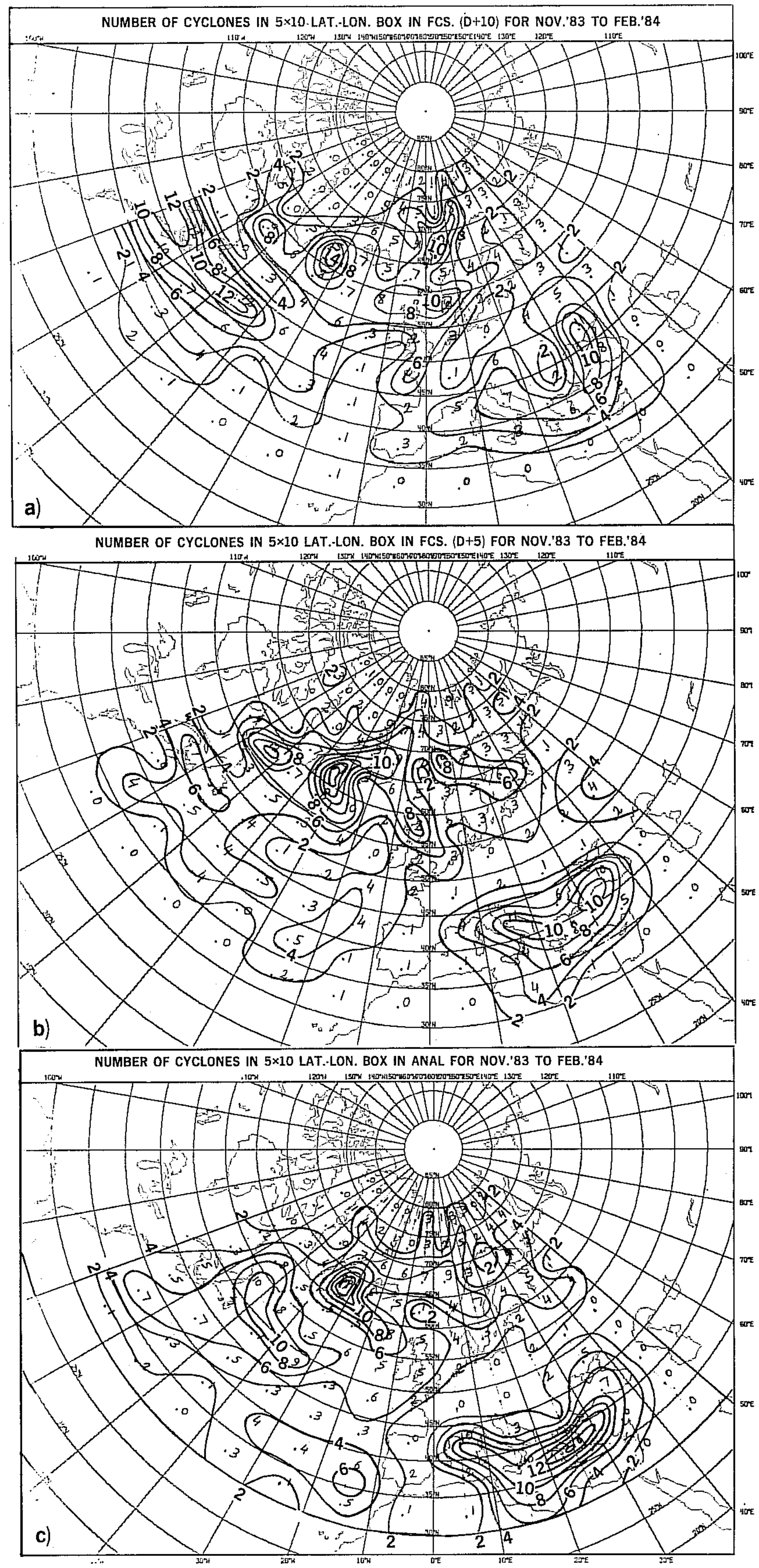


Fig. 4: Number of cyclones at the surface in 5° latitude by 10° longitude (square) for a) 10-day forecasts, b) 5-day forecasts and c) verifying analyses for the period from November 1983 to February 1984.

3.2. Results for the upper lows (500mb)

The systematic displacement of the cut-off lows and troughs in the eastern Atlantic and the Mediterranean tend to behave differently, therefore these two areas have been examined separately.

The displacement of the forecast lows and troughs from the verifying position has been grouped into four directions (N, E, S and W) with plus and minus 45 degrees. Cut-off lows predicted within a radius of 200 km of the analysed position are considered correct. The forecast cut-off lows (troughs) were also sorted in type of flow pattern; they were put into the following categories:

(a) CORRECT PATTERN - cut-off lows (troughs) predicted in a correct flow pattern;

(b) INCORRECT PATTERN - the cut-off lows (troughs) are predicted as troughs (cut-off lows) in the flow pattern;

(c) MISSED - the cut-off lows (troughs) are missed by the forecasts.

(a) The eastern Atlantic

The eastern Atlantic troughs have been ignored because the sample size is too small, thus here we consider the cut-off lows near the Iberian Peninsula. Fig. 5 shows the percentage of the occurrence of the displacement of the cut-off lows according to directions (N, E, S, W ± 45°); the percentage of correct forecasts is given inside the circles. The area of the bars is proportional to the percentage of cases for which the cut-off lows were displaced towards either of the four directions. The D+3 and D+5 forecasts shifted the cut-off lows over the eastern Atlantic too far west or too far north (only day 5). However, the D+7 forecast shows a tendency for eastward displacement, probably due to the fact that the sample size for day 7 is very small, and the displacements in some of these cases are very large.

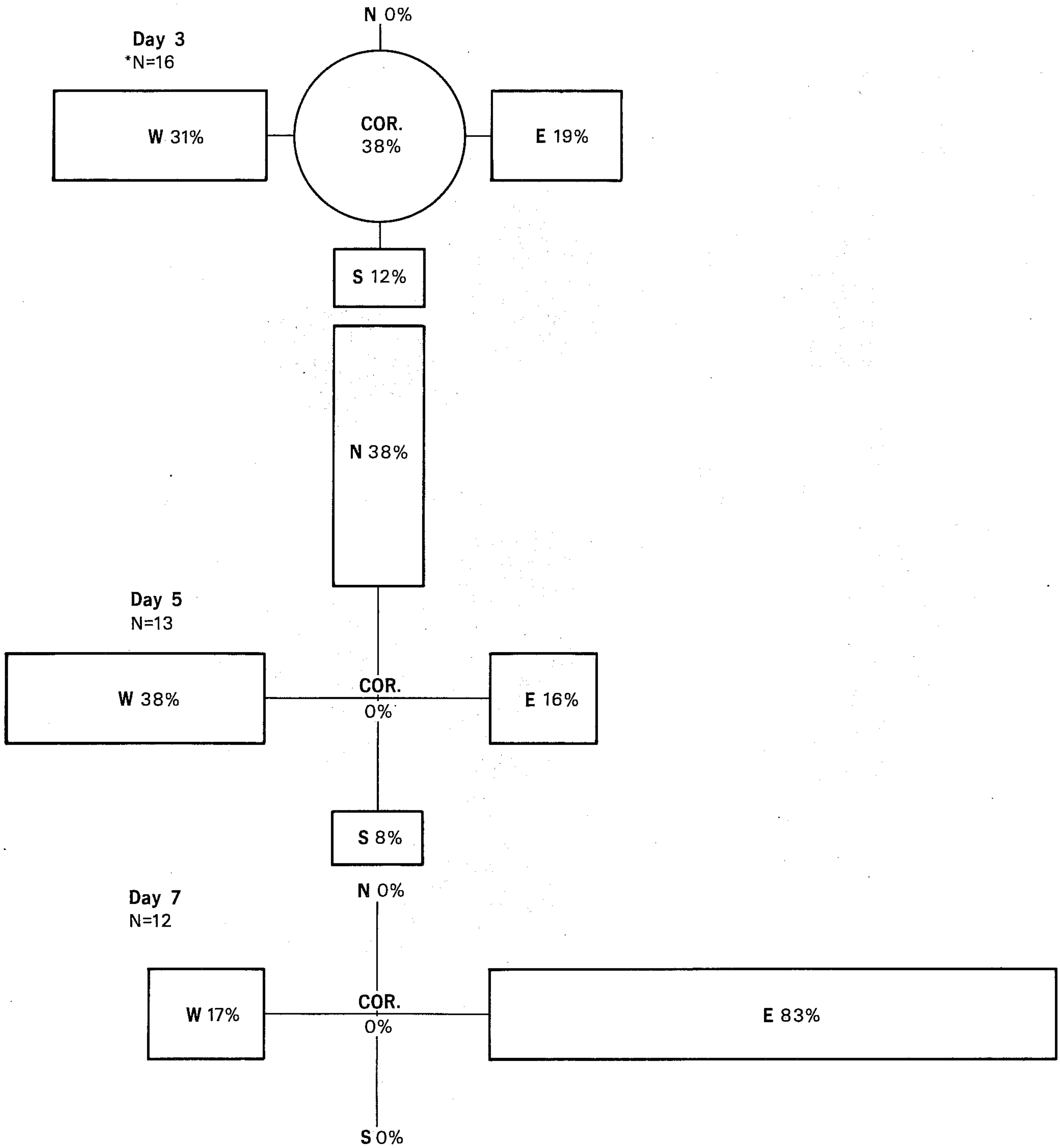
Table 4 shows the average displacement of the 500mb cut-off lows near Iberia in the D+3, D+5 and D+7 forecasts (November 1983-February 1984) for cases where the sample size is 5 or more and the displacement is more than 200 km.

Table 4: Mean displacement of cut-off lows at 500mb over the eastern Atlantic (near the Iberian Peninsula). Only the quadrants with sample size equal to/or greater than 5, in which the displacement of the cases is more than 200km, are shown.

F/C Day	Direction	Mean Displacement				Sample Size
		Degree	S.D.	km	S.D.	
3	W	4.3	1.7	369	154	5
5	W	4.5	3.1	385	258	5
	N	4.5	1.2	393	123	5
7	E	9.0	4.9	795	411	10

S.D. = Standard deviation

EAST ATLANTIC CUT-OFF LOWS
Percentage of directional displacement



*N=Sample size. COR.=Correct within 200km.

Fig. 5: The percentage of occurrences of directional displacement of the cut-off lows at 500mb off the Iberian Peninsula during the period from November 1983 to February 1984.

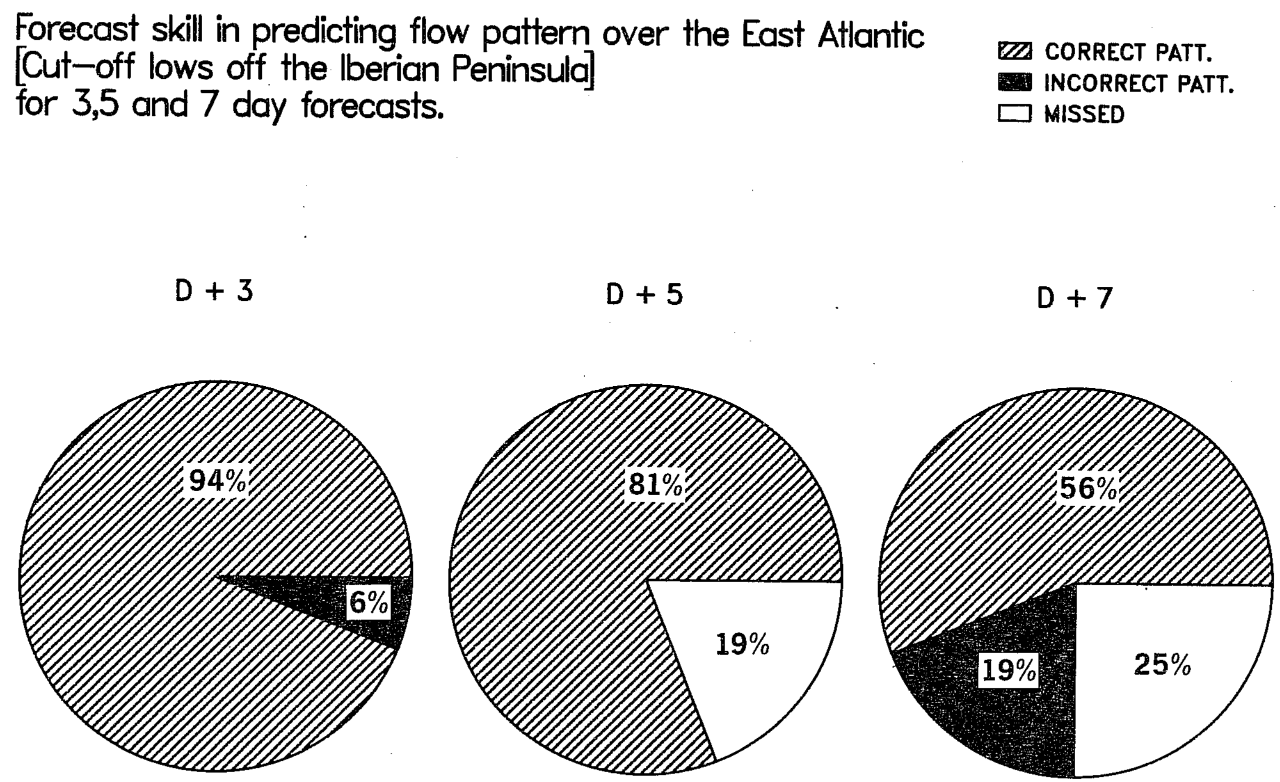


Fig. 6: Forecast skill in predicting flow pattern over the eastern Atlantic (cut-off lows off the Iberian Peninsula) for 3, 5 and 7-day forecasts for the period from November 1983 to February 1984. Sample size = 16

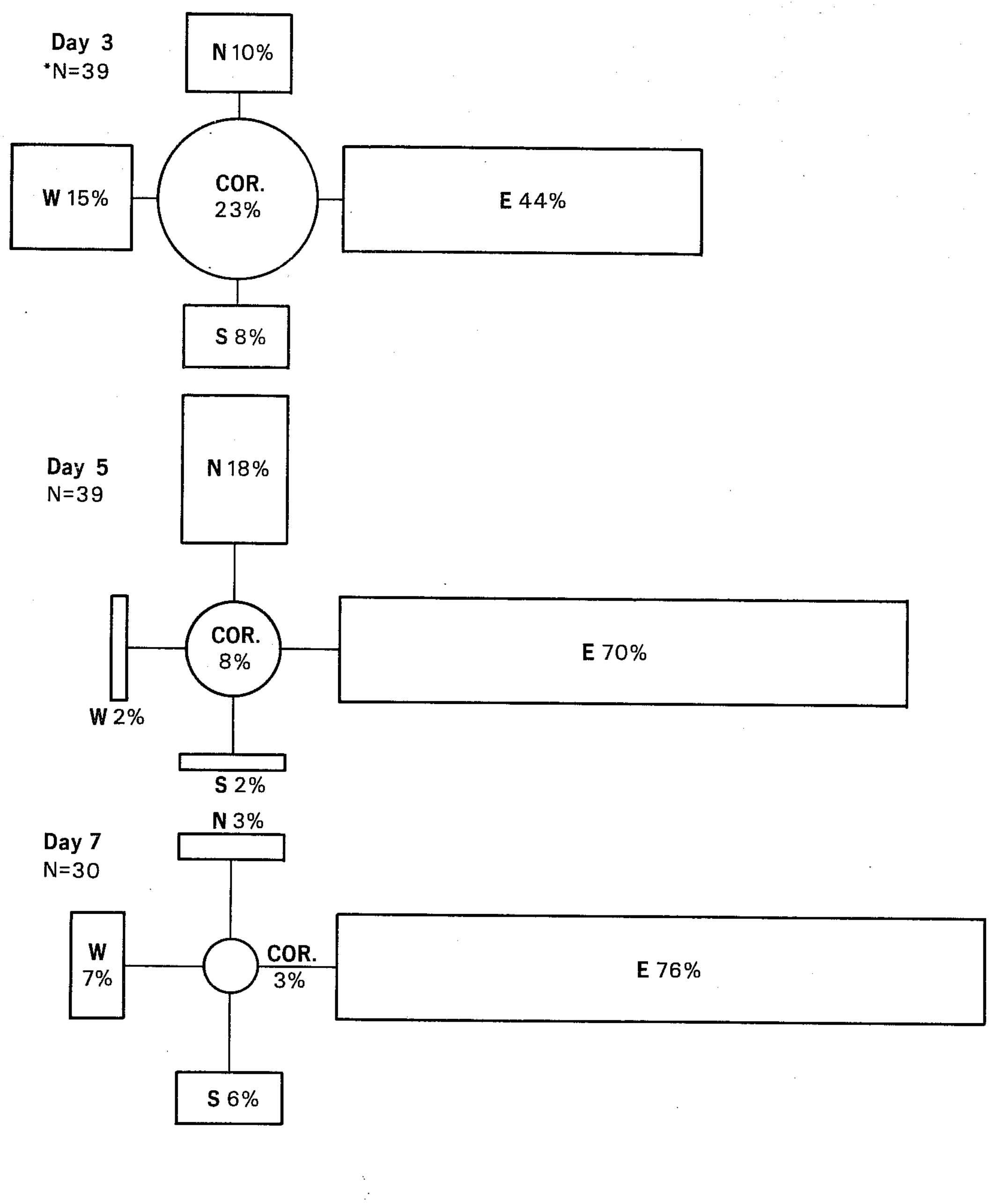
The average displacement for these cut-off lows is 4.3, 4.5 and 9.0 degrees-longitude for the days 3, 5 and 7 respectively.

Fig. 6 shows that 19% and 25% of the cut-off lows off the Iberian Peninsula were missed in the 5-day and 7-day forecasts, and 19% of the day-7 forecast cut-off lows were predicted as troughs.

(b) The Mediterranean

The percentage of occurrences of the displacement of the cut-off lows and troughs over the Mediterranean and southern Europe have also been computed and are shown in Figs. 7 and 8. Most of the shifts of the cut-off lows and troughs over this region are towards the east. These forecast errors (more than 200km) increase with forecast time, e.g. the percentages of the eastward displacement (E ± 45 degrees) of the Mediterranean lows are 44%, 70%, 76% for days 3, 5 and 7. The troughs for the Mediterranean show a similar behaviour, but they are less frequent (see Fig. 8). Besides the eastward displacement, 27% of the troughs in the day-7 forecasts were shifted too far north, that is the southward extension of troughs is not sufficient.

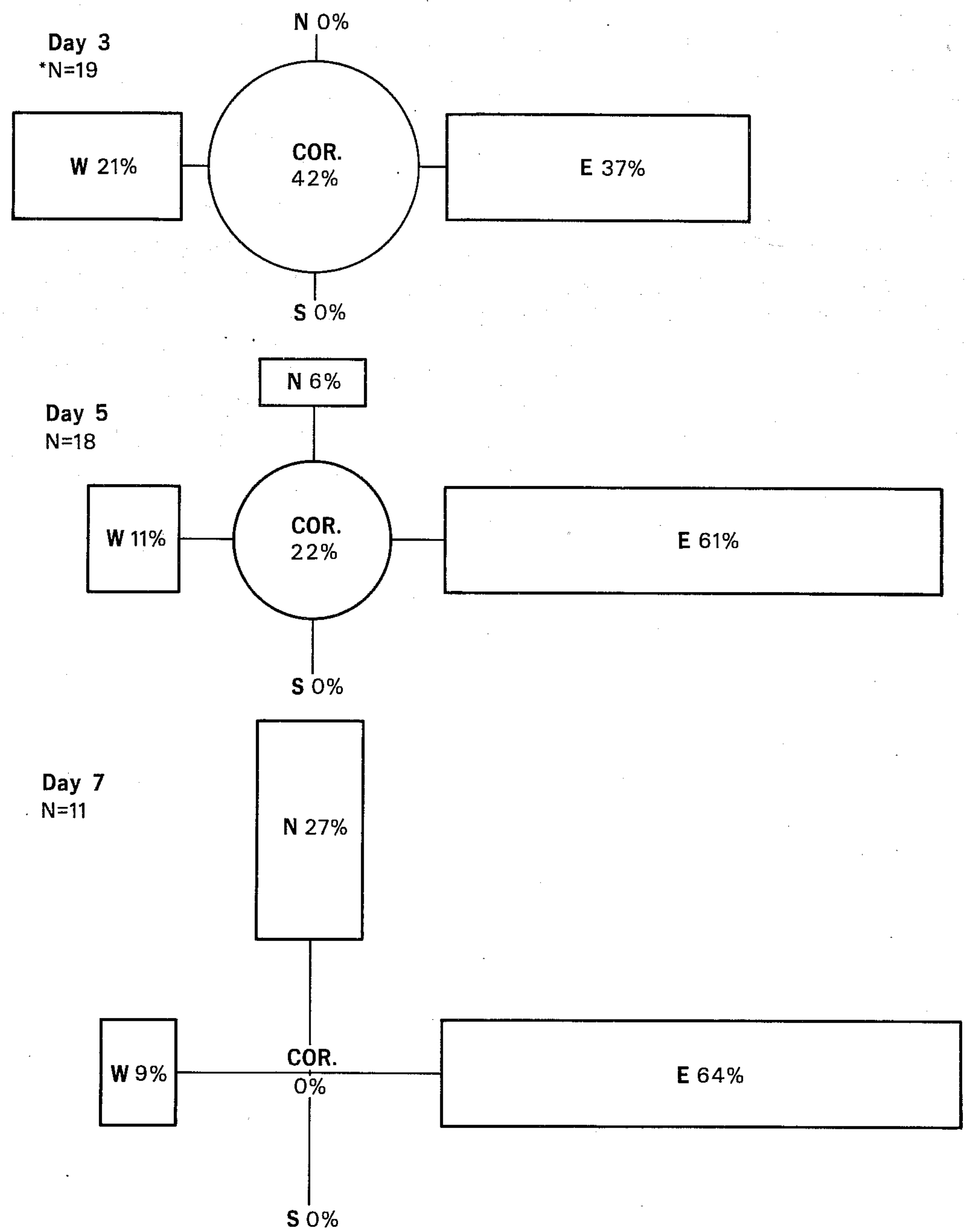
MEDITERRANEAN CUT-OFF LOWS
Percentage of directional displacement



*N=Sample size. COR.=Correct within 200km.

Fig. 7: As Fig. 5, but for the Mediterranean cut-off lows.

MEDITERRANEAN TROUGHS
Percentage of directional displacement



*N=Sample size. COR.=Correct within 200km.

Fig. 8: As Fig. 5, but for the Mediterranean troughs.

The average eastward displacement of the 500mb cut-off lows over southern Europe and the Mediterranean in the D+3, D+5 and D+7 forecasts (November 1983-February 1984) for cases where the sample size is 5 or more and the displacement is more than 200 km, shown in Fig. 9, is significant; for example the displacement of the cut-off lows (troughs) is 9.2 (7.8) degrees longitude for 5-day forecast, and 13.2 (8.7) degrees longitude for 7-day forecast. Fig. 9 also shows that the displacement of the cut-off lows is greater than that for the troughs. This difference is probably partly due to two facts. Firstly, the sample size for the troughs is smaller than that for the cut-off lows (e.g. the sample size is 7 for the troughs, 27 for the cut-off lows for day 7). Secondly, the measurement of the displacement of a trough is mostly dependent upon human skill; this might produce a tendency for the error in the displacement of the trough to be reduced more than that for a cut-off low.

Fig. 10 shows the forecast skill in predicting the flow pattern over southern Europe and the Mediterranean (cut-off lows and troughs) for 3, 5 and 7 day forecasts (November 1983-February 1984). It is evident from Fig. 10 that, even as early as day 3, 20% of the cases for the cut-off lows and the troughs over the Mediterranean had an incorrect flow pattern (i.e. cut off lows are predicted as troughs or vice versa). This number of incorrect patterns increases to 40% by day 7. Almost half of the observed troughs, and one quarter of the observed cut-off lows were missed by the 7-day forecasts. It is also clear from Fig. 10 b that the 500mb troughs in the 7-day forecasts do not show any incorrect patterns, that is the model tends to smooth the flow pattern so that cut-off lows fill out earlier than the observed.

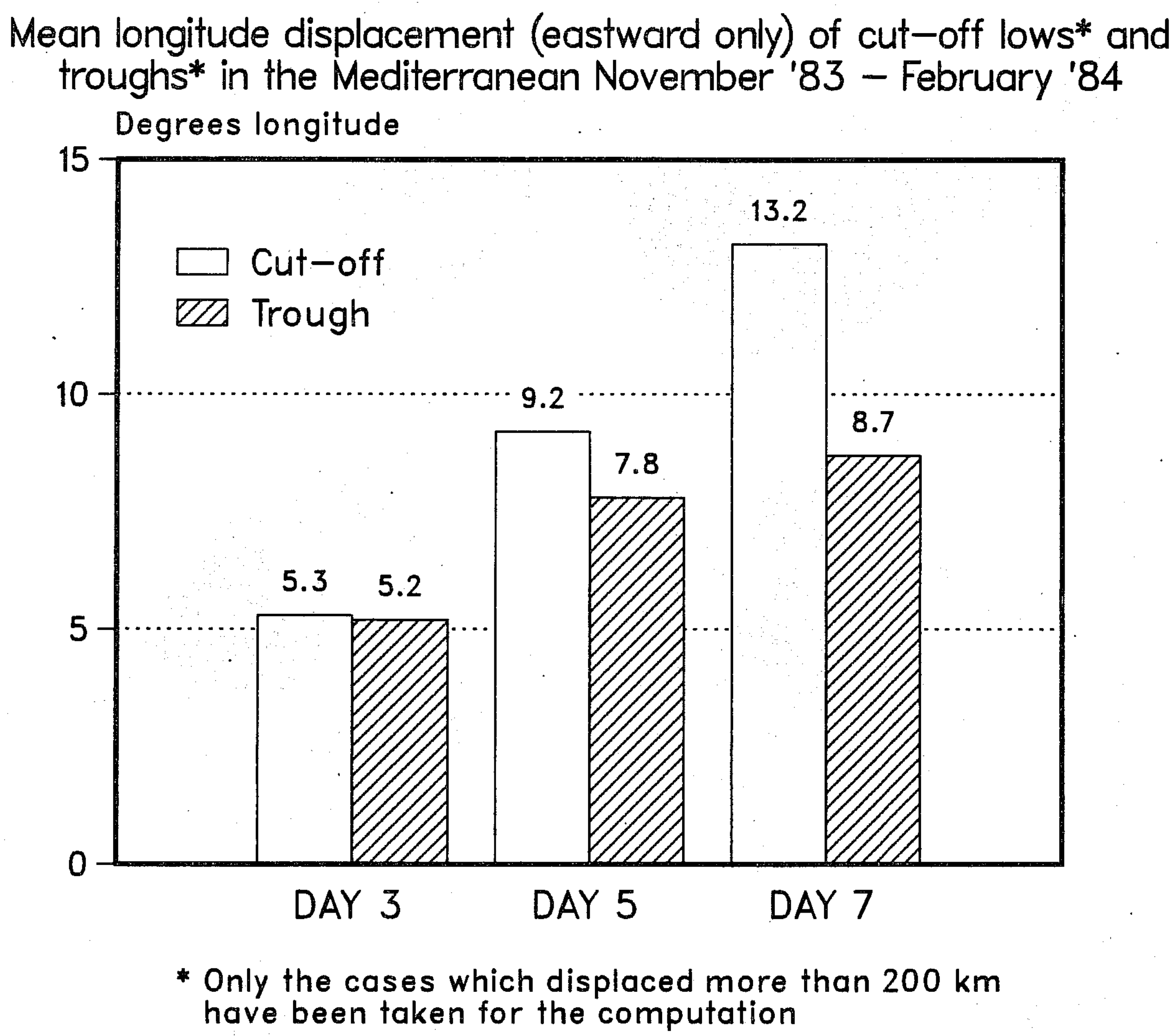


Fig. 9: Average displacement of cut-off lows and troughs (eastward only) in 500mb forecasts for the Mediterranean for November 1983 to February 1984 (only the cases which displaced more than 200km have been taken for the computation).

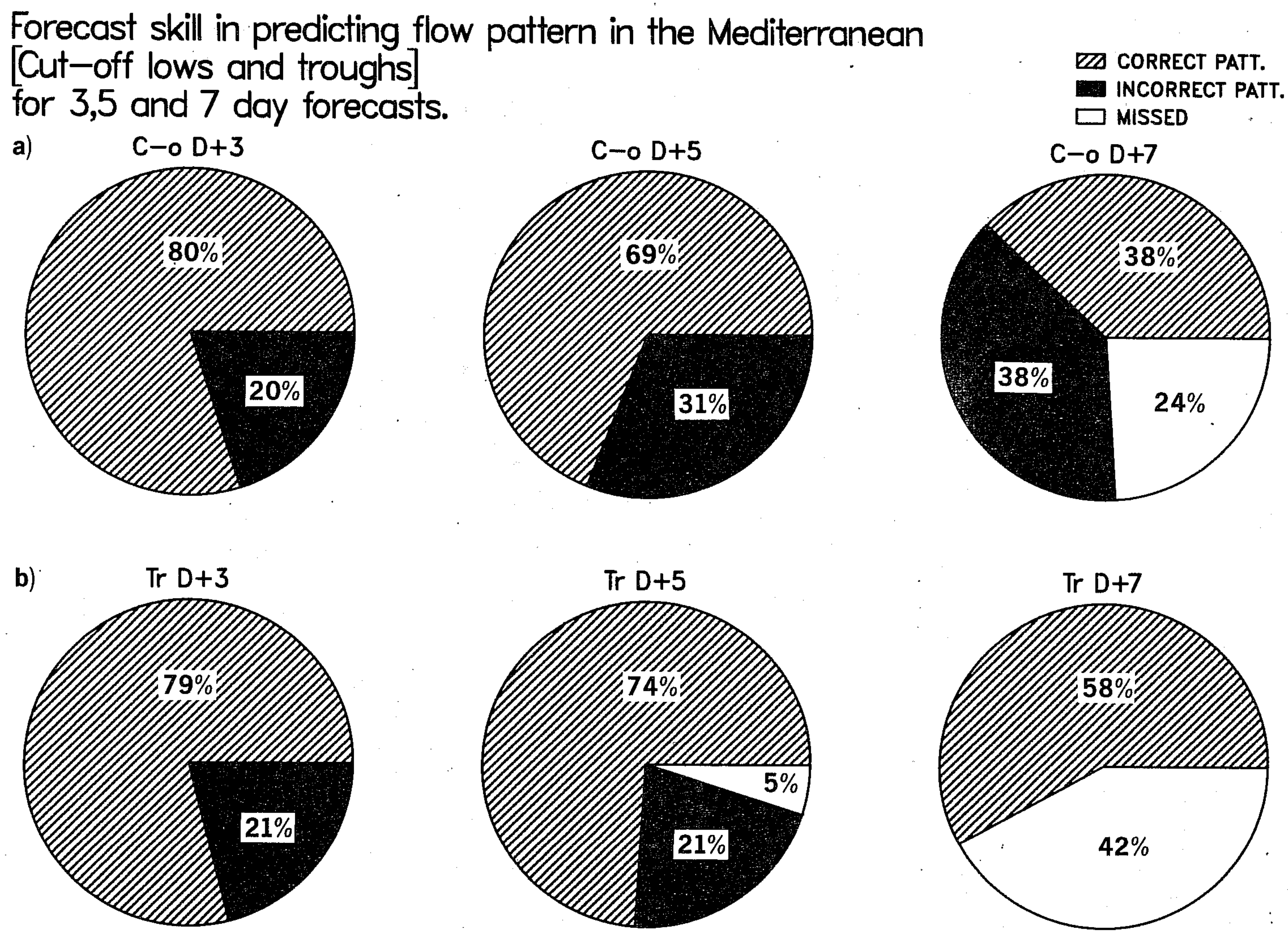


Fig. 10: As Fig. 6, but for the Mediterranean cut-off lows (a), and troughs (b).

5. SUMMARY

After the introduction of the sixteen layer spectral model (T63) in April 1983, the systematic errors in the predicted tracks, central pressure, and positions of surface cyclones, showed some improvements in several respects compared with the grid point model. The northward curving of cyclone tracks in the forecasts made with the spectral model is more realistic than that for the grid point model, except for the second generation cyclones, which still do not move northward fast enough. Both models are too slow for the fast moving cyclones, but again T63 is better than N48 in this respect. The model, on average, underestimates the filling rate of lows, but the deepening rate for the spectral model is much more improved compared to the grid point model. Though there are some improvements in the horizontal scale of the lows in the T63 model, there still exists a tendency for the forecasts to produce lows which are too small at the beginning of their life cycle, and too large towards the end. Around 40% of forecast lows in the T63 model (around 50% for N48) have a longer life span than the observed cyclones; that is, both models are too slow in decaying the forecast lows.

The error pattern of the geographical distribution of cyclones for the spectral model resembles the pattern for the grid point model. As in the grid point model, the T63 forecasts (D+5 and D+10) missed most of the cyclonic activity over the Mediterranean, especially over the central and eastern part, or shifted the cyclones too far northeast, towards the Balkan and the Black Sea. The cyclonic activity over the European continent was overestimated by the forecasts (D+5 and D+10). Most of the cyclones over the North Atlantic, especially the cyclones off the Iberian Peninsula and the lee cyclones in the southern part of Greenland were missed by the forecasts (D+5 and D+10).

The upper lows at 500mb over the eastern Atlantic (the cut-off lows off the Iberian Peninsula) are displaced too far north or west in the forecasts for days 3 and 5, but the shift for day 7 is too far east. The average displacement of these cut-off lows is around 400km for days 3 and 5, and around 800km for day 7. 19% and 25% of the eastern Atlantic cut-off lows are missed by the 5-day and 7-day forecasts respectively. 19% of the day-7 forecast cut-off lows off the Iberian Peninsula do not have an accurate flow pattern, i.e. the cut-offs are predicted as troughs (see Fig. 6).

The displacement of the cut-off lows and troughs over the Mediterranean are mostly towards the east. These displacements (more than 200km) increase with forecast interval, e.g. the percentages of the eastward displacement (E± 45 degrees) of the Mediterranean upper lows are 44%, 70% and 76% for day 3, 5 and 7 respectively. The troughs for the Mediterranean show a similar behaviour, but they are less frequent. Besides the eastward displacement, 27% of the troughs in the day-7 forecasts are shifted too far north; that is, the southward extension of troughs is not sufficient. The average eastward displacement of cut-off lows (troughs) over the Mediterranean is 5.3 (5.2), 9.2 (7.8) and 13.2 (8.7) degrees longitude for days 3, 5 and 7 respectively (see Fig. 9).

According to Fig. 10a, 20%, 31% and 38% of the forecast flow pattern for days 3, 5 and 7 are incorrect (i.e. the cut-off lows were predicted as troughs), and 24% of the lows are missed by the D+7 forecast. On the other hand, 42% of the troughs are missed by the D+7 forecast, and 21% of the troughs for each forecast day 3 and 5 do not have a correct flow pattern (i.e. the troughs were predicted as cut-off lows, see Fig. 10b); that is, the filling of upper lows are delayed in the forecasts, as is the case for the surface lows.

REFERENCES

Akyildiz, V., 1983. A synoptic analysis of cyclones in ECMWF analyses and forecasts for the winter seasons of 1980-81, 1981-82. ECMWF Technical Memorandum No. 74, 34pp.

Simmons, A.J., and Jarraud, M., 1984. The design and performance of the new ECMWF operational model. The ECMWF Seminar on "Numerical Methods for Weather Prediction", September 1983, pp. 113-164, Volume 2. Available from ECMWF.