TECHNICAL MEMORANDUM

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Systematic errors in surface and upper lows in the ECMWF operational spectral model (T106) during winter 1985/86, compared with corresponding errors in the T63 model

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A B S T R A C T

Systematic errors in the operational ECMWF spectral model (T106) in the 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 500 hPa over the eastern Atlantic and the Mediterranean for the 1985/86 winter season are described, and the results compared with the corresponding errors in the previous T63 model. Statistics for the cyclone tracks, filling and deepening rates, etc., and for the displacement of predicted upper lows and troughs at 500 hPa are presented.

The northward curving of cyclone tracks is better represented in the T106 model than in the T63. The speed of cyclones in the T106 is more realistic compared with the T63 model. The deepening and filling rate of cyclones are still less than those observed.

Although the frequency of occurrence of cyclones in the T106 model is more representative of the observed pattern than in the T63 model, the error pattern from both models reveals a large resemblance, e.g. the T106 model also underpredicts the cyclonic activity over the Mediterranean.

The systematic errors in the displacement, the flow pattern, etc., of cut-off lows and troughs at 500 hPa over the Mediterranean and the eastern Atlantic are significantly reduced in the T106 model compared with the T63. However, similar systematic errors to that in the T63 still exist in the T106 model. For example, most of the displacement of the Mediterranean cut-offs and troughs in T106 is towards the east, and also the T106 model has a tendency to predict cut-offs as troughs or vice versa, especially for the medium range.

1. INTRODUCTION

With the introduction of the high resolution model T106 in operations in May 1985 the horizontal resolution of the ECMWF spectral model in the free atmosphere was increased to 106 waves on any great circle or approximately 190 km for half a wavelength. The computations of physical processes are performed on an even finer surface grid with a 1.125 degree resolution. Operational experience shows that a better description of synoptic features such as deep lows, the intensity of fronts and associated weather phenomena results from the higher resolution. Synoptic flow pattern influenced by local orographic effects, such as the cyclogenesis, e.g. Skagerak cyclone or Genoa cyclogenesis, were also improved significantly (Jarraud et al, 1985).

In a previous paper, Akyildiz, 1985, presented the synoptic characteristics of cyclone developments in the T63 model for the winter season in the North Atlantic and the Mediterranean. The occurrence, the tracks and the deepening rates of cyclones for selected forecast days was analysed and compared with the corresponding surface and 500 hPa lows in the analysis. In particular, the shortcomings in the medium range prediction of cut-off lows off the Iberian Peninsula and in the Mediterranean were noted. Similar statistics on the prediction of cyclones, cut-off lows and troughs in the Atlantic-European region have been compiled for the new T106 model for the winter 1985/86. The results are compared with those for the T63 model.

Following the introduction of the T106 model, the objective error scores of the predicted height fields were significantly reduced. The results from this synoptic evaluation indicate that the new model also provides better forecast guidance by improved predictions of synoptic features.

2. METHOD

The methods and procedures used in this study are the same as those applied in previous investigations for the T63 model presented in Technical Memorandum No.100 (Akyildiz, 1985).

The following points should be noted:

(i) The area under investigation stretches from Newfoundland to Europe.

(ii) For each observed surface low three consecutive forecasts, one from the day (D) on which the cyclone was generated, the other two from one day earlier (D-1) and two days earlier (D-2) have been verified.

(iii) The statistics for the frequency of occurrence of surface lows, and for the upper lows for the T63 model were based on two winters (1983/84 and 1984/85). Therefore, the sample sizes of the T63 statistics is larger.

(iv) During the 1983/84 winter season, in which the T63 model was in operational use, the cyclones were less intense and had a shorter life cycle than those in the 1985/86 winter.

3. THE RESULTS

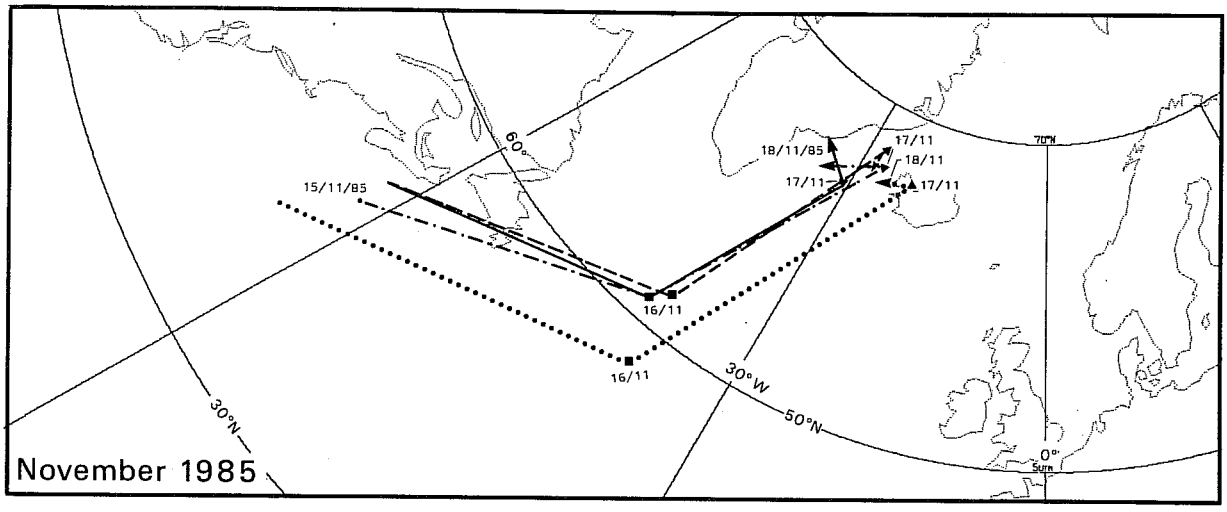
3.1 The surface lows

(a) Cyclone tracks

Fig. 1 shows four typical examples of observed and predicted cyclone tracks, one from each month from November 1985 to February 1986. The dates given along the tracks indicate the position of the lows every 24 hours at 12 GMT during the life cycle of the observed lows. For example, in the November results, the figures 16/11 indicate the position of a low which verifies at 1200 GMT on 16 November 1985.

The 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. The percentage of the forecasts predicting the cyclone tracks along the observed track (a forecast track which is positioned within 200 km either side - north or south - of the observed track, is considered to be correct) has increased substantially from T63 to T106. For example, the weighted mean of the percentage of the cases with correct tracks, for the forecasts (D+1 to D+6) from day D is 78%, and for the forecasts (D+2 to D+8) from D-1 and D-2 is 53%, whereas these numbers are 47% and 34% for T63 respectively.

The tendency of the forecast track to be to the south of the observed track is also found in T106, especially in the forecasts from D-1 and D-2, and mainly for the second half of the forecast period.



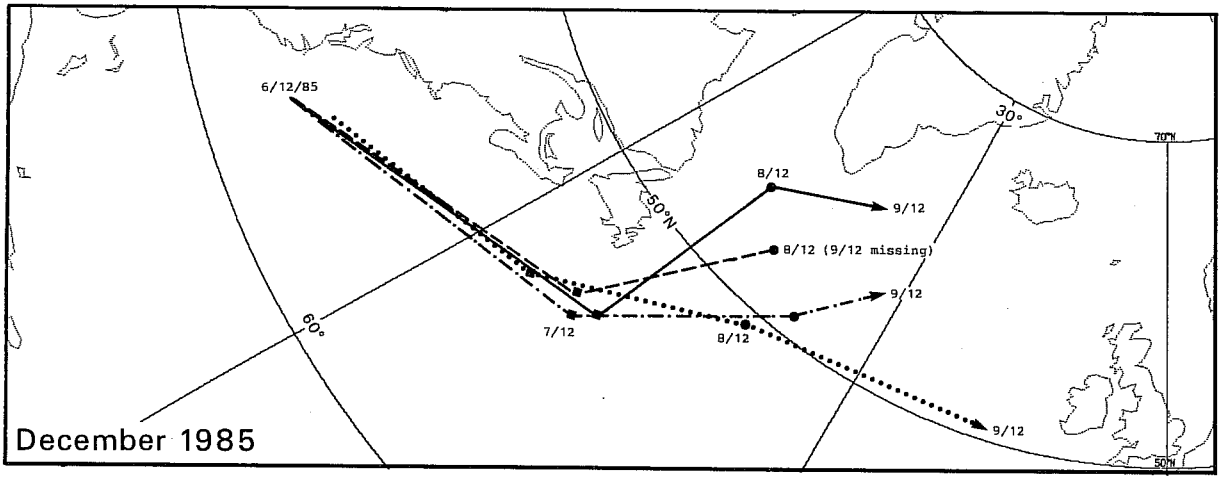
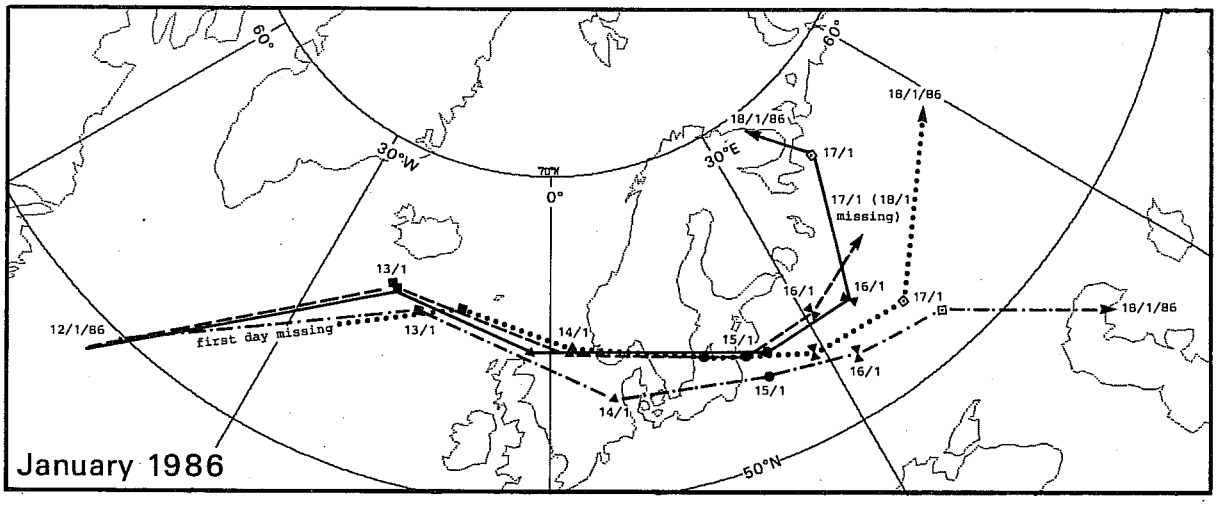


Fig. 1: Tracks of cyclones in the verifying analyses (——), in the forecasts from the day (D) on which the low was generated (----). in the forecasts from the previous day D-1(-·-·), in the forecasts from 2 days earlier D-2 (·····).



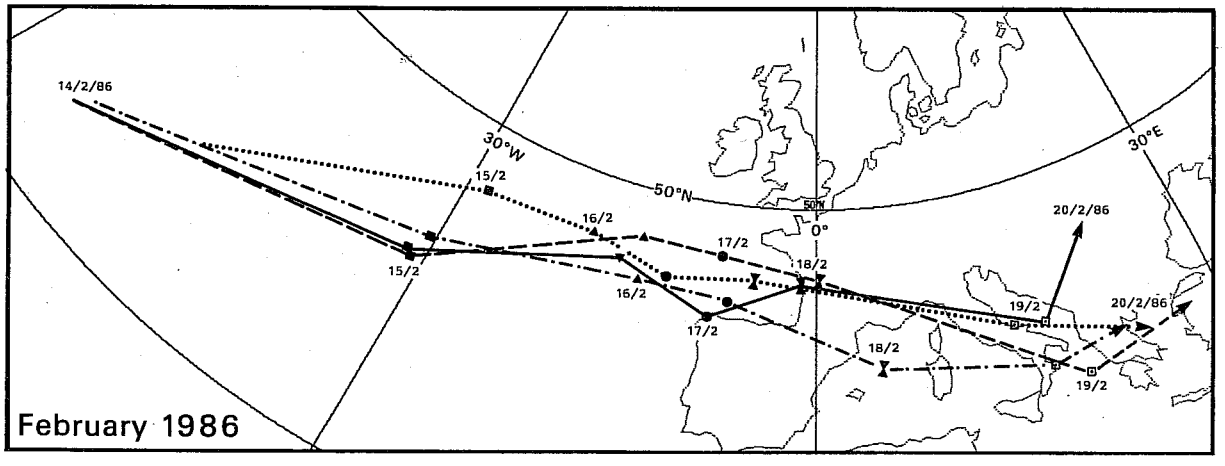


Fig. 1 Continued

(b) Speed of cyclones

The speed (East-West component) of the model cyclones is calculated for each 24 hr time interval and is compared with the analysed value to give the East-West phase error. The scatter diagrams for the 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 (a and b). The improvement in the speed of the model cyclones for T106 is evident.

Similar diagrams for days 4 and 5 of the life cycle of the observed lows are shown in Fig. 2 (c and d). Although the sample size is small, it appears that the speed of the model cyclones is less than the observed speed.

(c) Deepening and filling rates of cyclones

The contingency table of the forecast and observed deepening rates of cyclones (Table 1) indicates that the forecast deepening rate for T106 does not show any improvement compared to T63 (see Table 1, Technical Memorandum No. 100). On the contrary, the number of cases for which the T106 model underestimates the deepening rate of cyclones is greater than that for T63. This could partly be due to sampling problems. It should be noted that the cyclones in the 1983/84 winter season were less intense than those in the 1985/86 winter.

The forecast filling rate is still underestimated with the T106 model, as it had been the case for T63 (see Table 2).

(d) Magnitude of cyclones

The systematic errors in the magnitude of cyclones (as measured by the geographical area enclosed by the largest closed contour) for T63 and T106 are shown in Fig. 3. The tendency of the model cyclones to be too small in the early stages of the cyclone life, and to be too large in later stages is seen to be true for both models.

(e) The life span of cyclones

The life span of the cyclones in the forecasts (from day D and D-1) and in the verifying analyses is compared. Out of 56 cases, in 12 of the cases (21%) the forecast cyclones (including very early missing ones) had shorter life span than

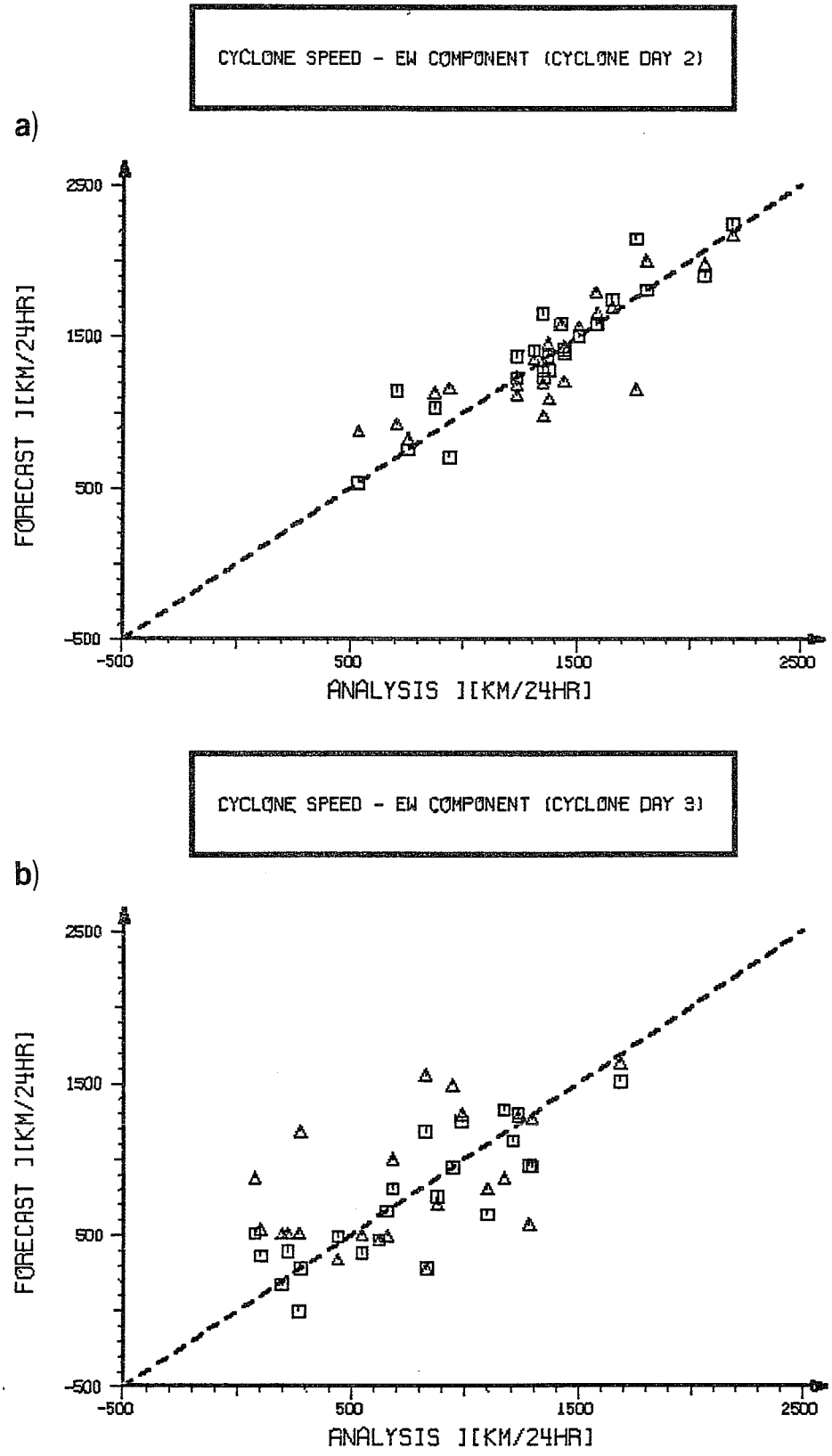
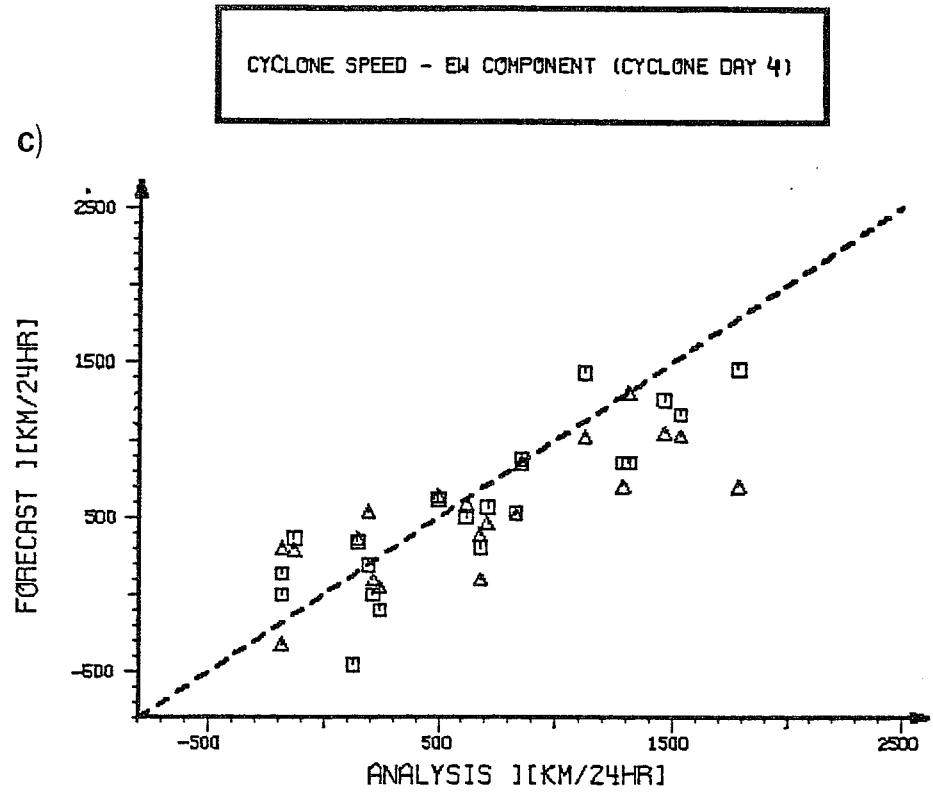


Fig. 2: Cyclone speed (E-W component) in the forecasts and in the verifying analyses, a) second day of the life cycle of the observed lows (above), b) third day of the life cycle of the observed lows (below).

□ F/C from the day on which cyclone was generated

△ F/C from one day earlier than the day on which cyclone was generated



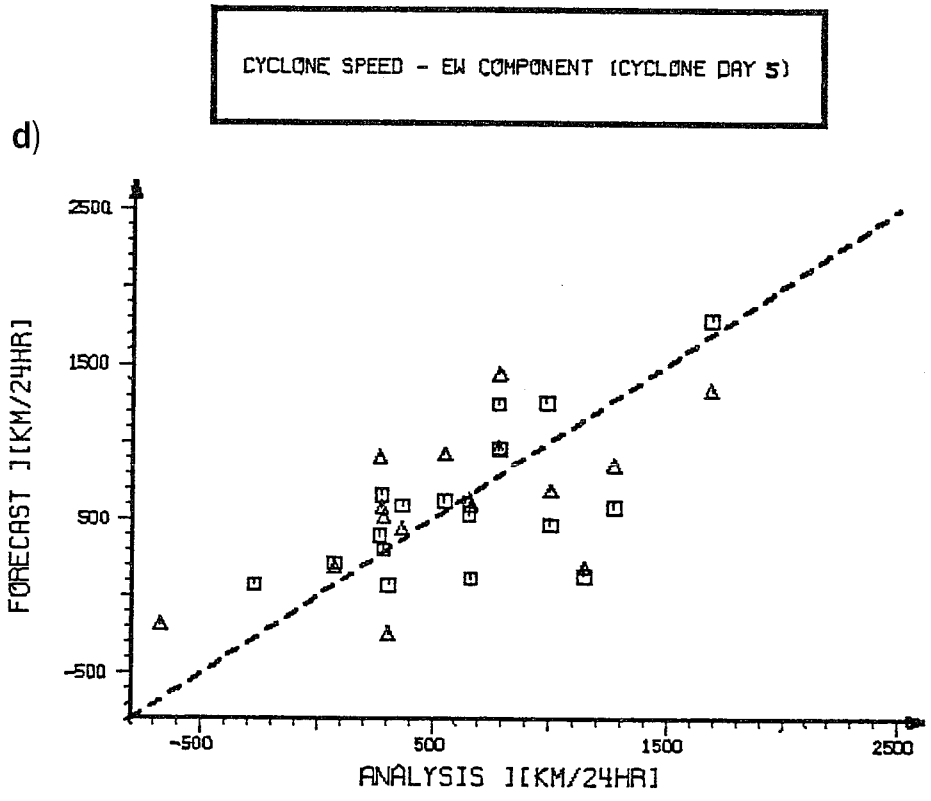


Fig. 2 (cont.):
c) fourth day of the life cycle of the observed lows (above), d) fifth day of the life cycle of the observed lows (below).

□ F/C from the day on which cyclone was generated

△ F/C from one day earlier than the day on which cyclone was generated

the observed lows, in 20 of the cases (36%) the forecast cyclones had a longer life span, for the rest (43%) the forecast cyclones filled in agreement with the observations. The T106 model still shows a tendency to be too slow in filling the cyclones. The main lows are often maintained without generating a secondary cyclone in time. Consequently, the life cycle of cyclone families is not predicted properly.

Table 1: Cyclones sorted by forecast deepening rate and observed deepening rate of cyclones (both in hPa/24 hr), 87 cases

Observed Deepening Rate	Forecast deepening rate					
	0<7	+8<15	+16<23	+24<31	+32<39	+40<
0 < 7	16	2				
+8 < 15	11	16	2	1		
+16 < 23	3	10	8			
+24 < 31		1	5	2	1	
+32 < 39			3	3		
+40 <					2	1

Table 2: Cyclones sorted by observed filling rate and forecast filling rate (both in hPa/24 hr), 58 cases

Observed Deepening Rate	Forecast filling rate					
	0<	+5<	+10<	+15<	+20<	+25<
0 <	3	3				
+5 <	14	8	3			
+10 <		2	5	2		
+15 <	2		2	2		
+20 <	5	2	1	1		
+25 <			2	1		

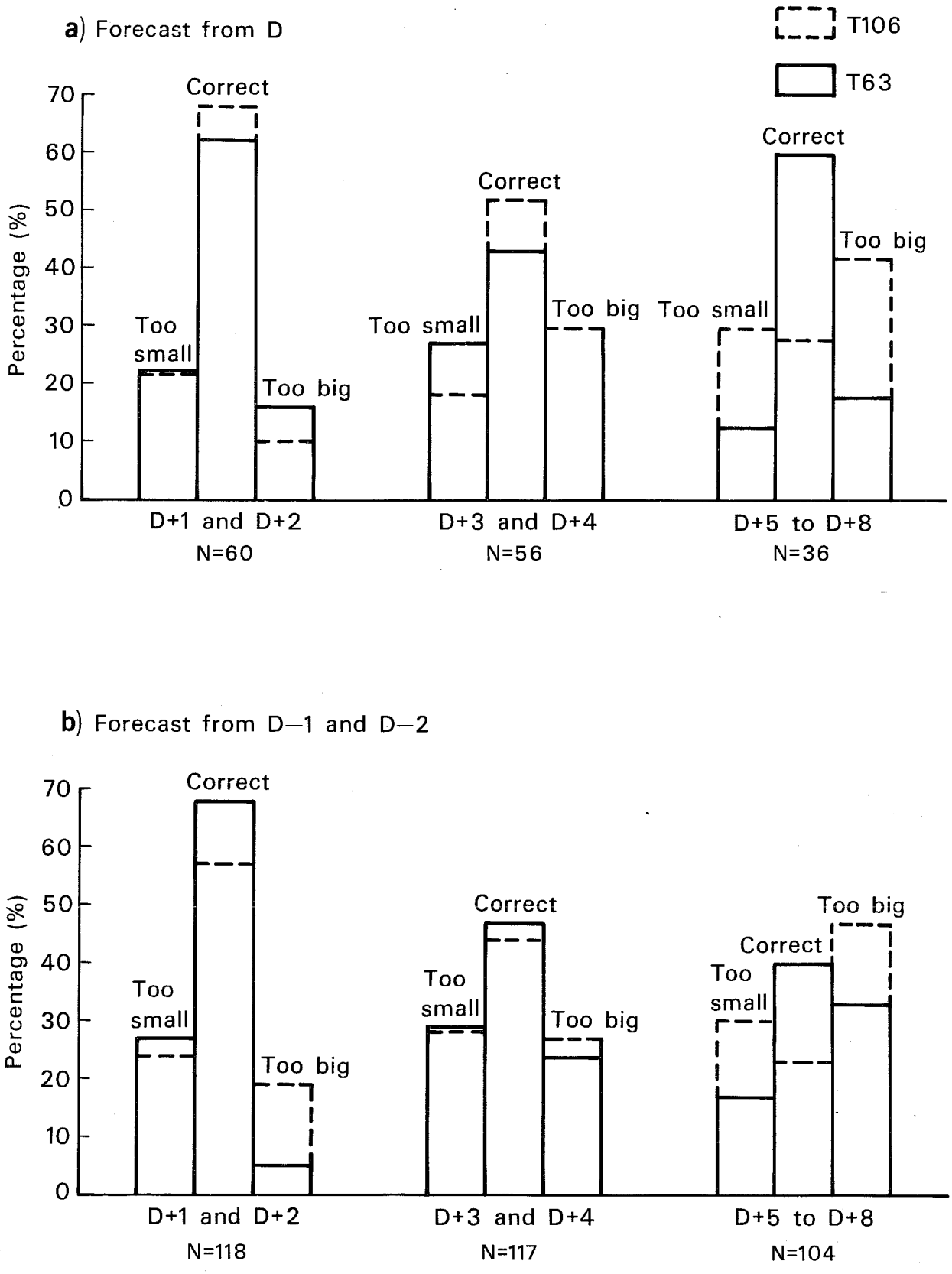


Fig. 3: Comparison of horizontal scale (magnitude) of cyclones in the forecasts (T63 and T106) and in the verifying analyses, a) forecast from the D, b) forecast from the D-1 and D-2.
N = sample size for T106, similar numbers for T63

(f) Regional distribution of the cyclones for winter months 1985/86

The number of cyclones in 5° latitude by 10° longitude squares for D+5 and D+10 forecasts and for the verifying analyses is shown in Fig. 4. From this figure the following results can be summarised for both time ranges:

(i) the model underestimates the occurrence of the Mediterranean cyclones;

(ii) the cyclonic activity around/off the Iberian Peninsula is reduced or missing;

(iii) the Newfoundland cyclones in the forecasts are either missing or shifted too far north;

(iv) the cyclonic activity over southern and eastern Scandinavia and north-eastern Europe shifted too far east;

(v) the model overestimates the occurrence of the cyclones between Iceland and southern Greenland.

The error pattern of the T106 model in regional distribution of cyclones is in general similar to T63 (see also Fig. 4 in Technical Memorandum No. 100).

3.2 Results for the upper lows (500 hPa)

The forecast cut-off lows/troughs at 500 hPa over the east Atlantic (off the Iberian Peninsula), and over the Mediterranean and southern Europe, for days 3, 5 and 7, for the period November 1985 to February 1986 have been studied for systematic errors in displacement and flow pattern. As before, the east Atlantic and Mediterranean areas are 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 according to the type of flow pattern; they were put into the following:

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

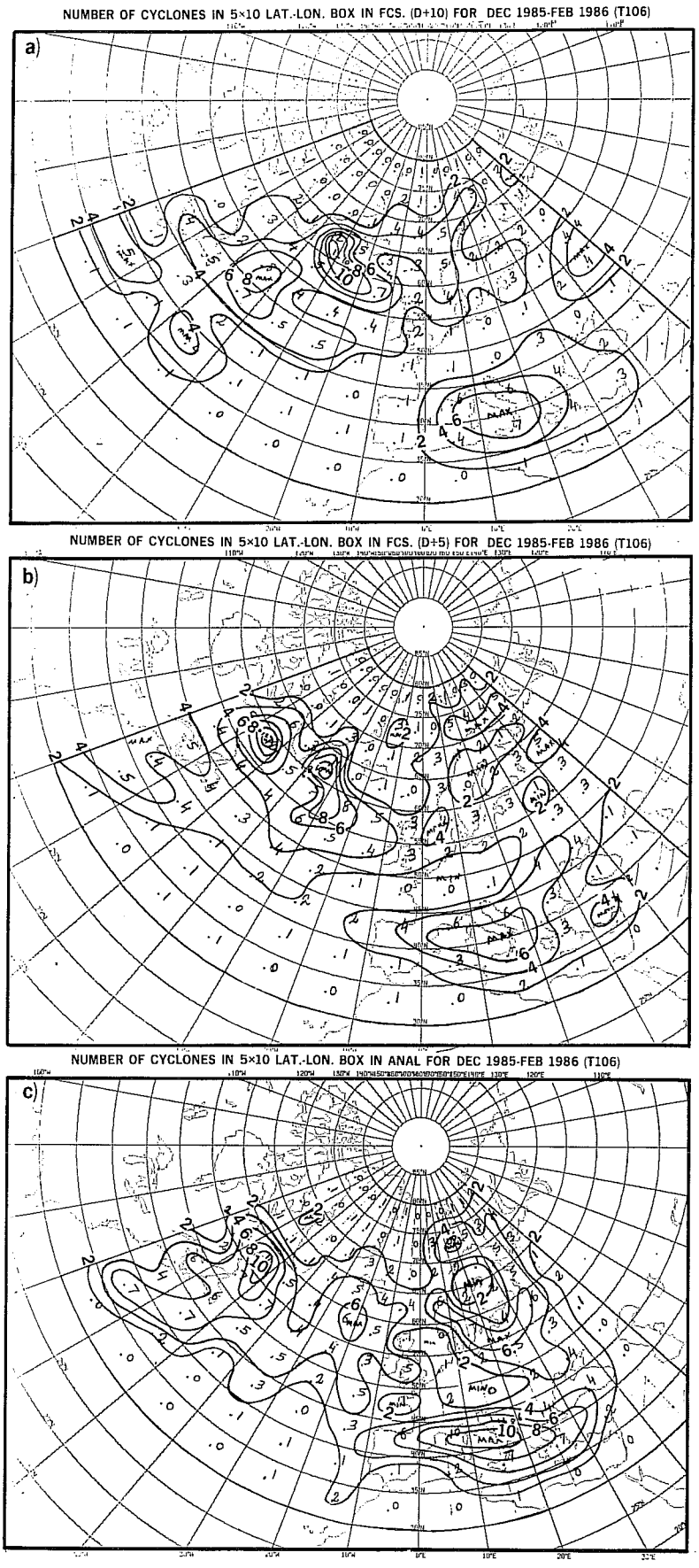


Fig. 4: Number of cyclones at the surface in 5° latitude by 10° longitude (square) for a) 10-day forecasts, b) 5-day forecasts and c) verifying analyses for the period from December 1985 to February 1986.

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

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

(a) The eastern Atlantic

Since neither the sample size of the cut-off lows, nor the sample size of the troughs over the eastern Atlantic alone are adequate for a statistical summary, both have been combined.

Fig. 5 shows the forecast skill in predicting the flow pattern over the east Atlantic (cut-off lows/troughs off the Iberian Peninsula) for 3, 5 and 7 day forecasts by T106, as well as by T63. Examining Fig. 5, one can clearly see the systematic improvement in T106.

Fig. 6 shows the percentage of the forecast lows and troughs displaced more than 200 km from the verifying position in four directions (N, S, E and W ± 45°) with the correct ones in the middle. As for T63, significant westward and northward displacements of the forecast cut-off lows/troughs are found, especially up to day 5 or 6. However, comparing Fig. 6 with Fig. 5 in Technical Memorandum No. 100 some improvements in the T106 model can be seen.

The mean displacement of cut-off lows/troughs over the eastern Atlantic for T106 is similar to that for T63.

(b) The Mediterranean

Besides the systematic errors in position and flow pattern of the 500 hPa forecast cut-off lows and troughs over the Mediterranean, the bias (F/C - AN) for the mean central geopotential height of the Mediterranean cut-off lows has been computed for T106 as well as for T63 and is shown in Fig. 7. In the mid-troposphere the cooling which was the most obvious bias for T63, is now corrected in the T106, and a small positive systematic error is evident.

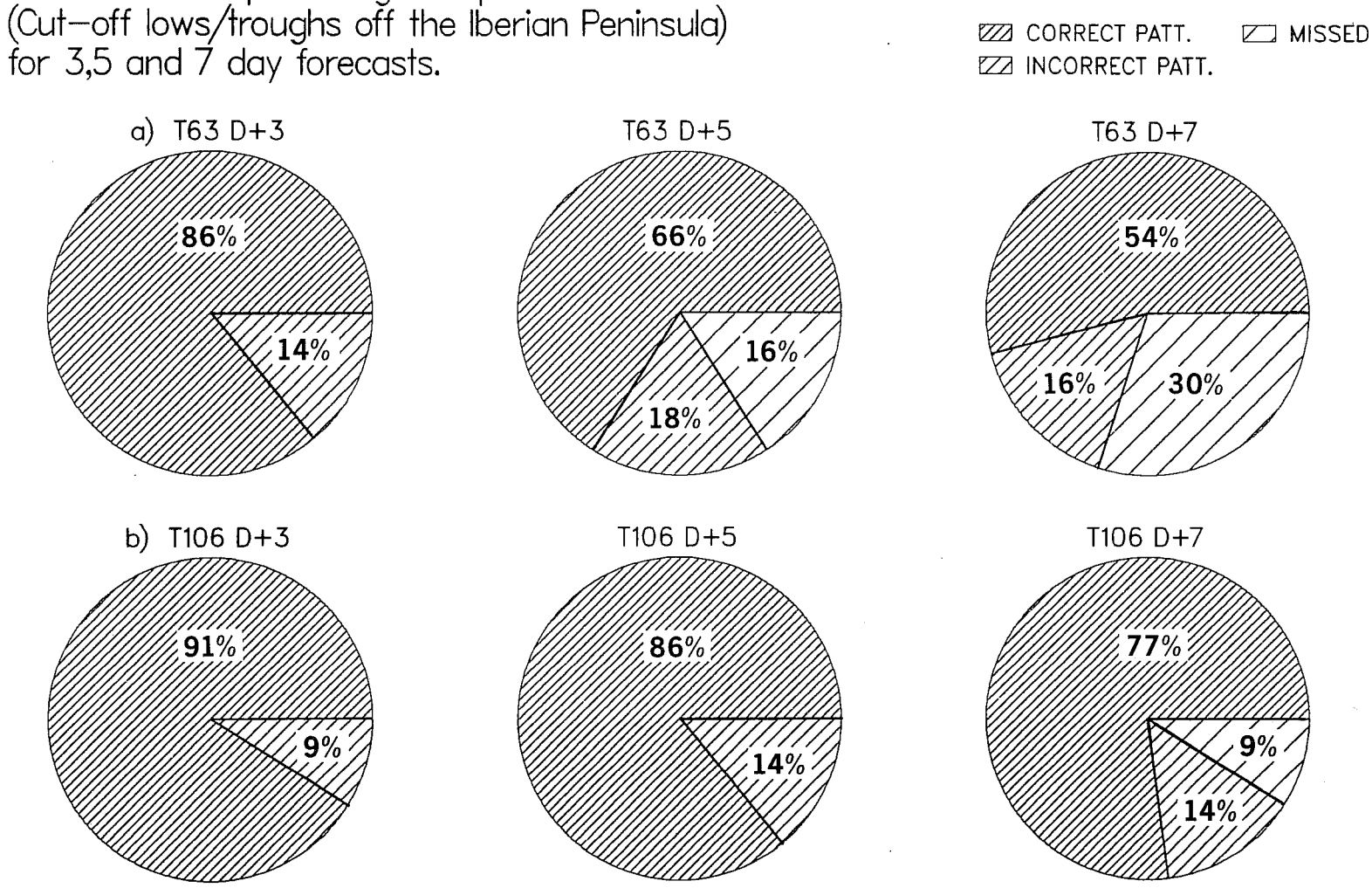
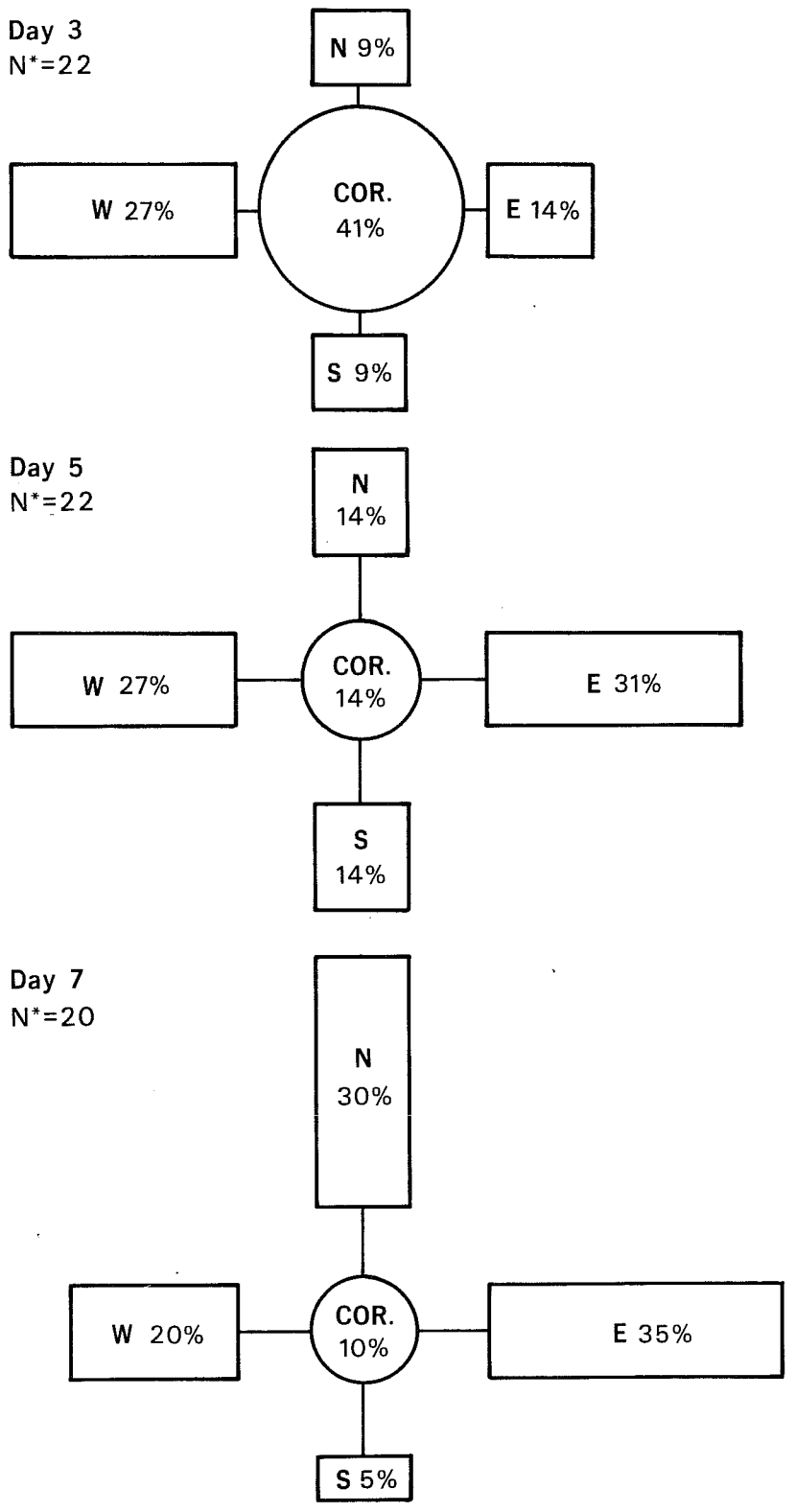
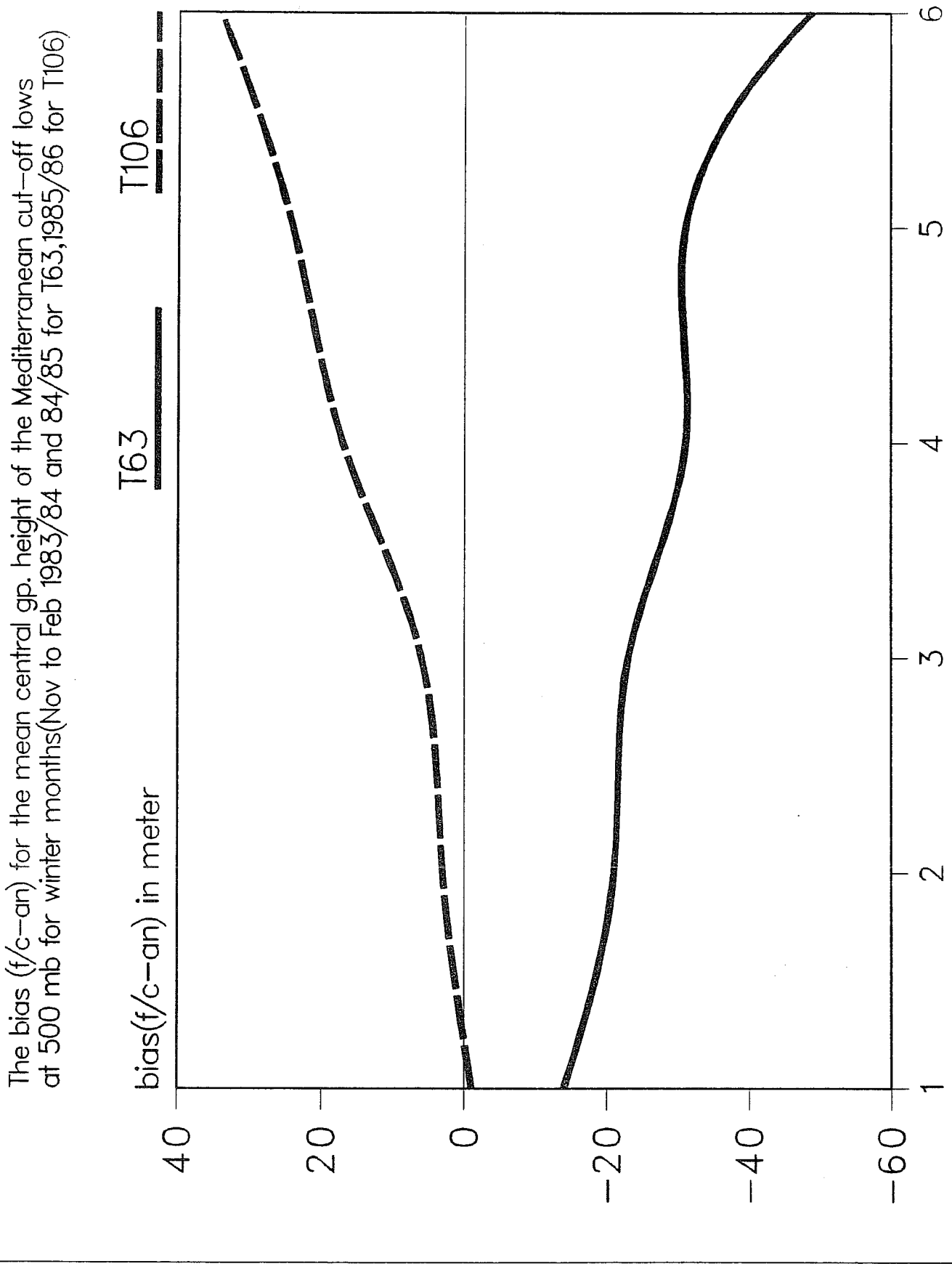


Fig. 5: Forecast skill in predicting flow pattern over the eastern Atlantic for 3, 5 and 7-day forecasts, a) for T63 during November to February 1983/84 and 1984/85, sample size = 50, b) for T106 during November 1985 to February 1986, sample size = 22.



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

Fig. 6: The percentage of occurrences of directional displacement of the cut-off lows/troughs at 500 hPa off the Iberian Peninsula during the period from November 1985 to February 1986.


The bias (f/c−an) for the mean central gp. height of the Mediterranean cut−off lows
at 500 mb for winter months(Nov to Feb 1983/84 and 84/85 for T63,1985/86 for T106)
T63
T106
bias(f/c−an) in meter
40
20
0
−20
−40
−60
1
2
3
4
5
6
Forecast Days
MOV
10 Oct 1986

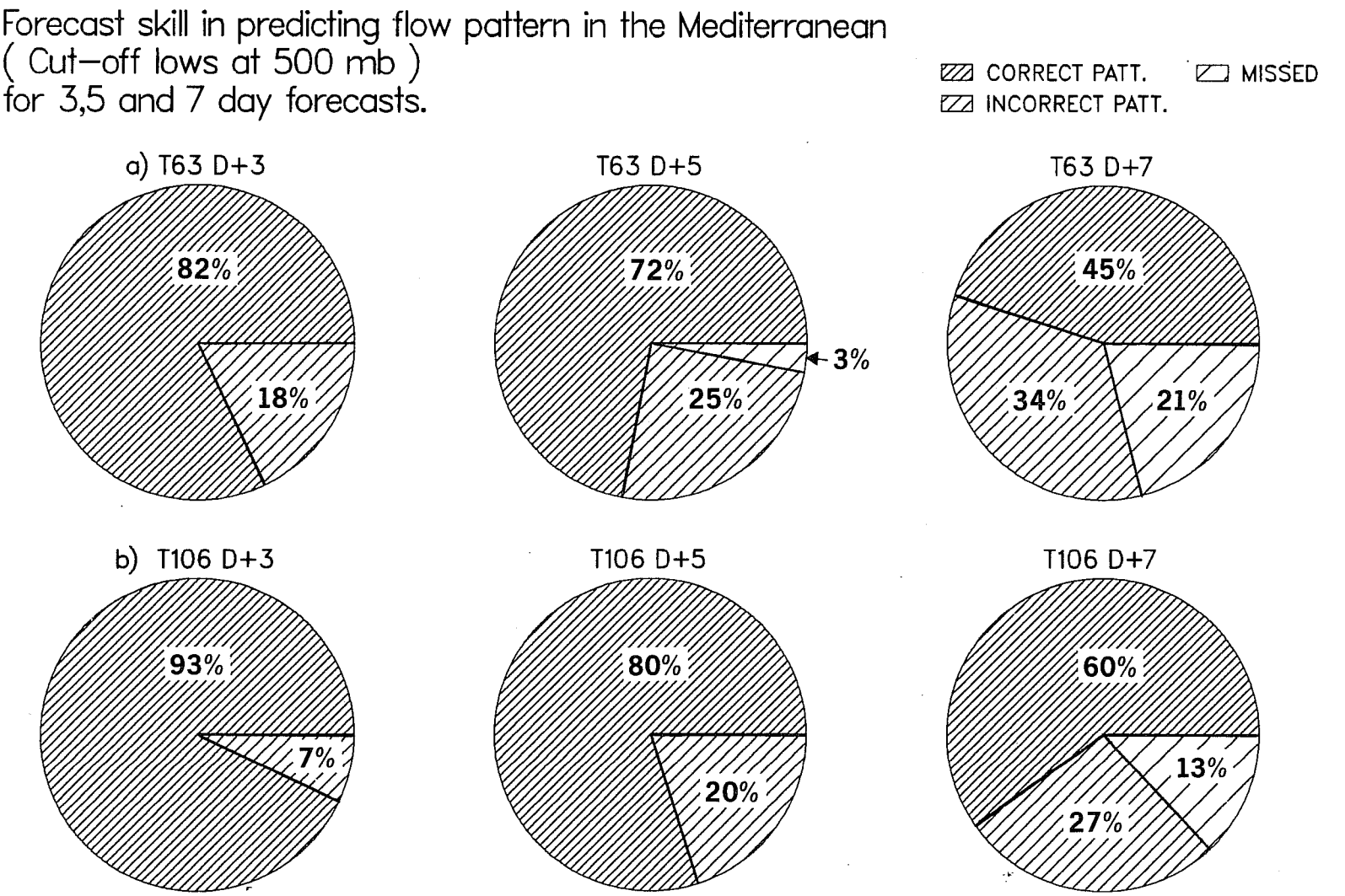


Fig. 8: As Fig. 5, but for the Mediterranean cut-off lows. Sample sizes: 68 for T63, 30 for T106

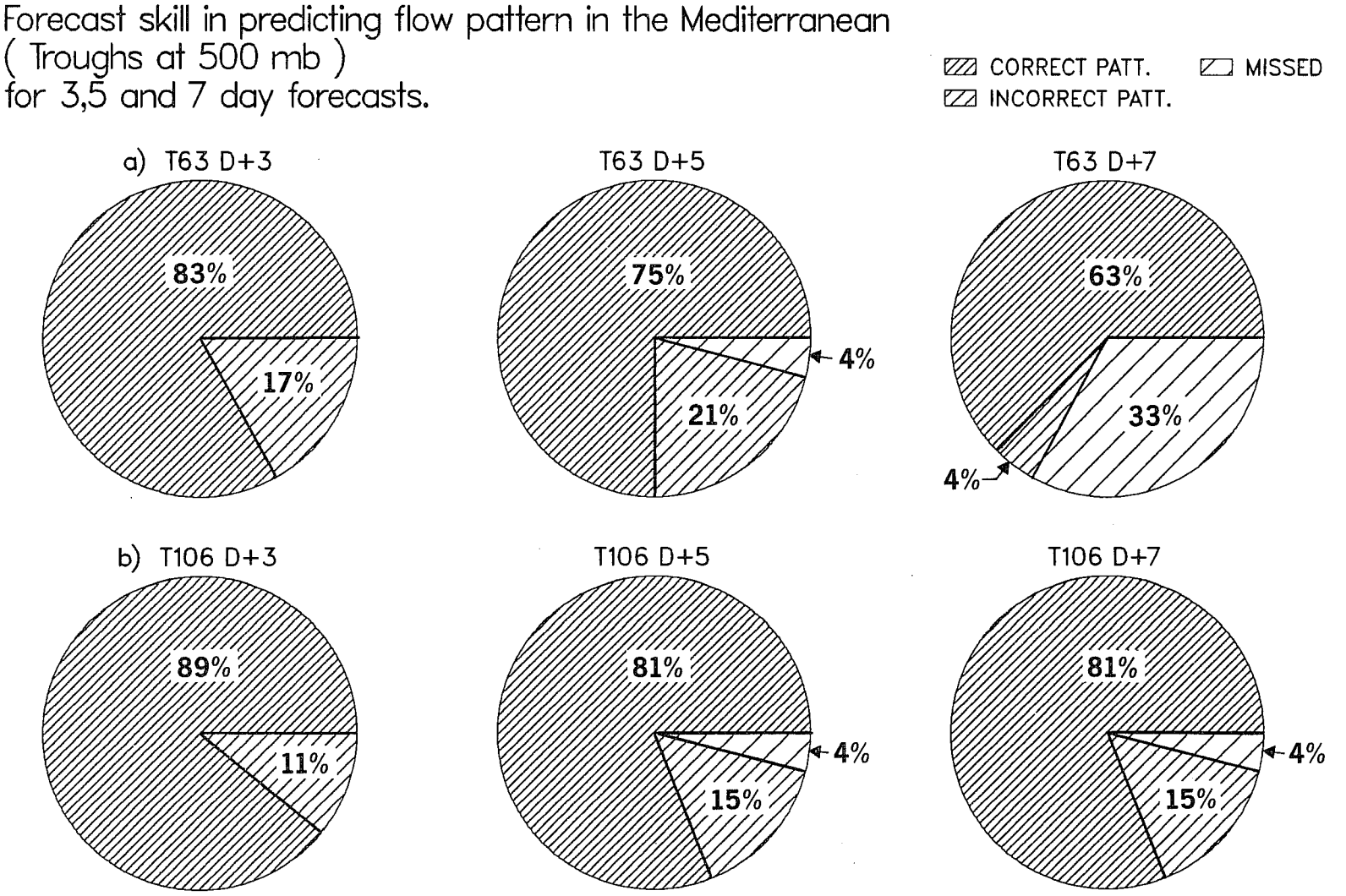


Fig.9: As Fig. 5, but for the Mediterranean troughs. Sample sizes: 24 for T63, 27 for T106

Examining the flow pattern over the Mediterranean (now treating cut-off lows and troughs separately), again a significant improvement has been found from T63 to T106 (see Figs. 8 and 9). The error sizes for the D+5 and D+7 forecasts from the T106 model, in predicting the flow pattern for the troughs (Fig. 9), are the same.

Similar to the behaviour of the T63, most of the displacement of the Mediterranean cut-off lows and troughs in the T106 is towards the east (see Figs. 10 and 11). However, the number of correct cases in positioning the cut-off lows and troughs for T106 is greater than that for T63.

The mean eastward longitude displacement for the cut-off lows and troughs over the Mediterranean is reduced for T106 relative to T63 (see Figs. 12 and 13).

3. SUMMARY

After the introduction of the high resolution spectral model (T106) in May 1985, the systematic errors in the predicted tracks, central pressure and positions of surface lows, and the displacement and the flow pattern of upper lows (500 hPa), showed some improvements in several respects compared with the T63 model. These improvements and persisting errors are summarised below:

3.1 Surface lows

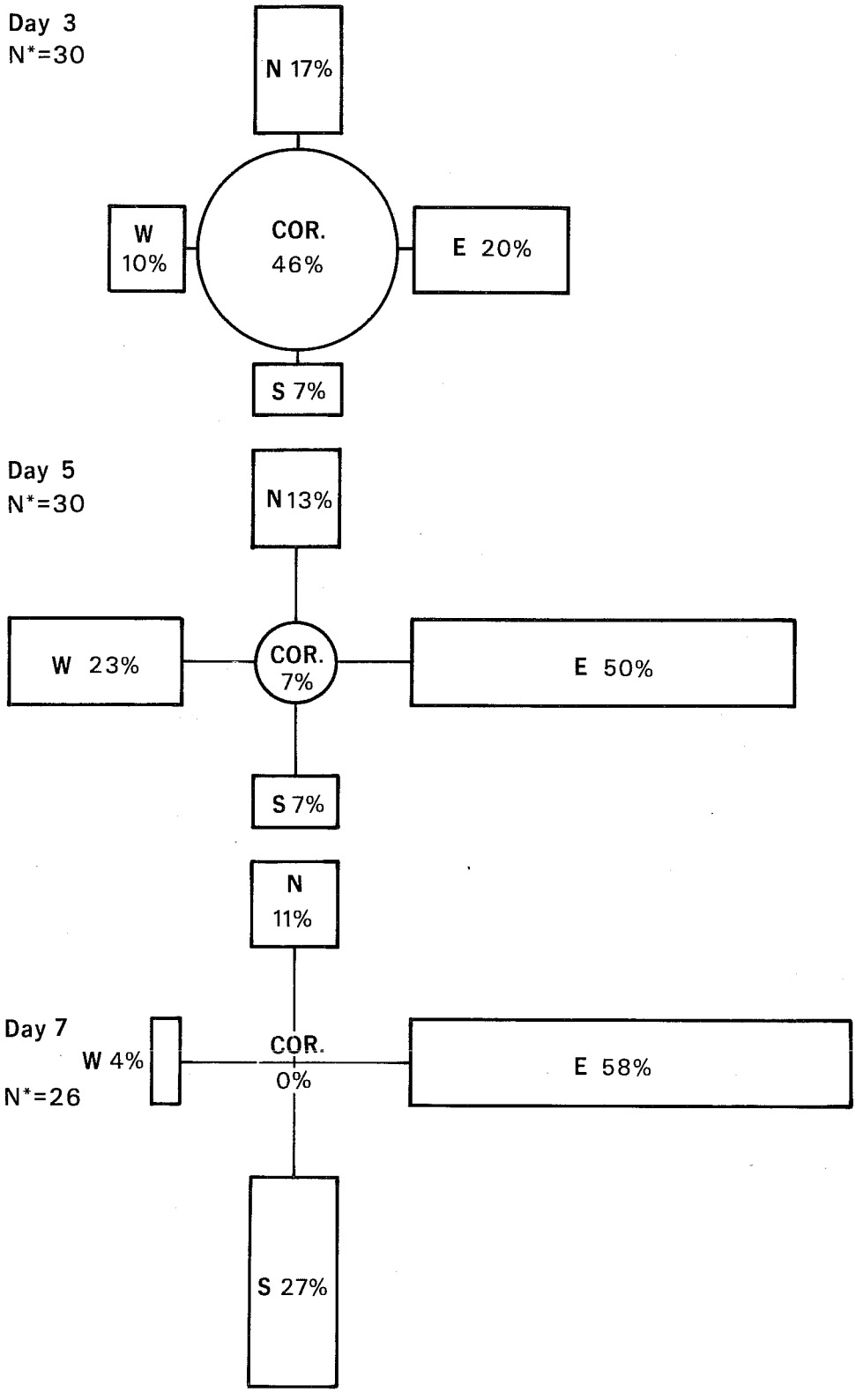
(i) The northward curving of cyclone tracks is better represented in T106 than in the T63;

(ii) the speed of cyclones in the T106 has improved relative to T63 (see Fig. 2);

(iii) deepening and filling rate of cyclones are still insufficient (see Tables 1 and 2);

(iv) there still exists a tendency for the forecasts to produce lows which cover too small an area at the beginning of their life cycle, and are too widespread towards the end;

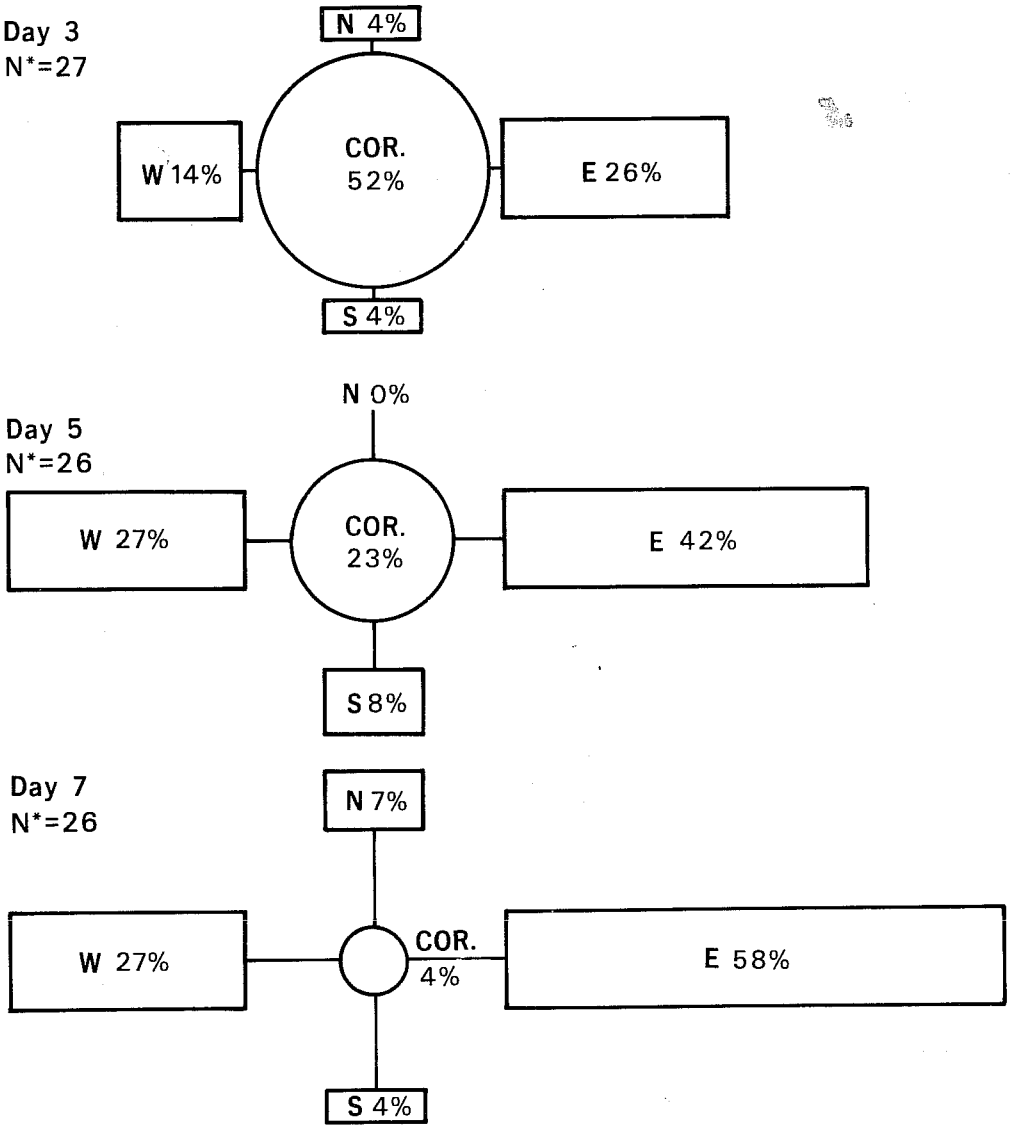
MEDITERRANEAN CUT-OFF LOWS T106
Percentage of directional displacement



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

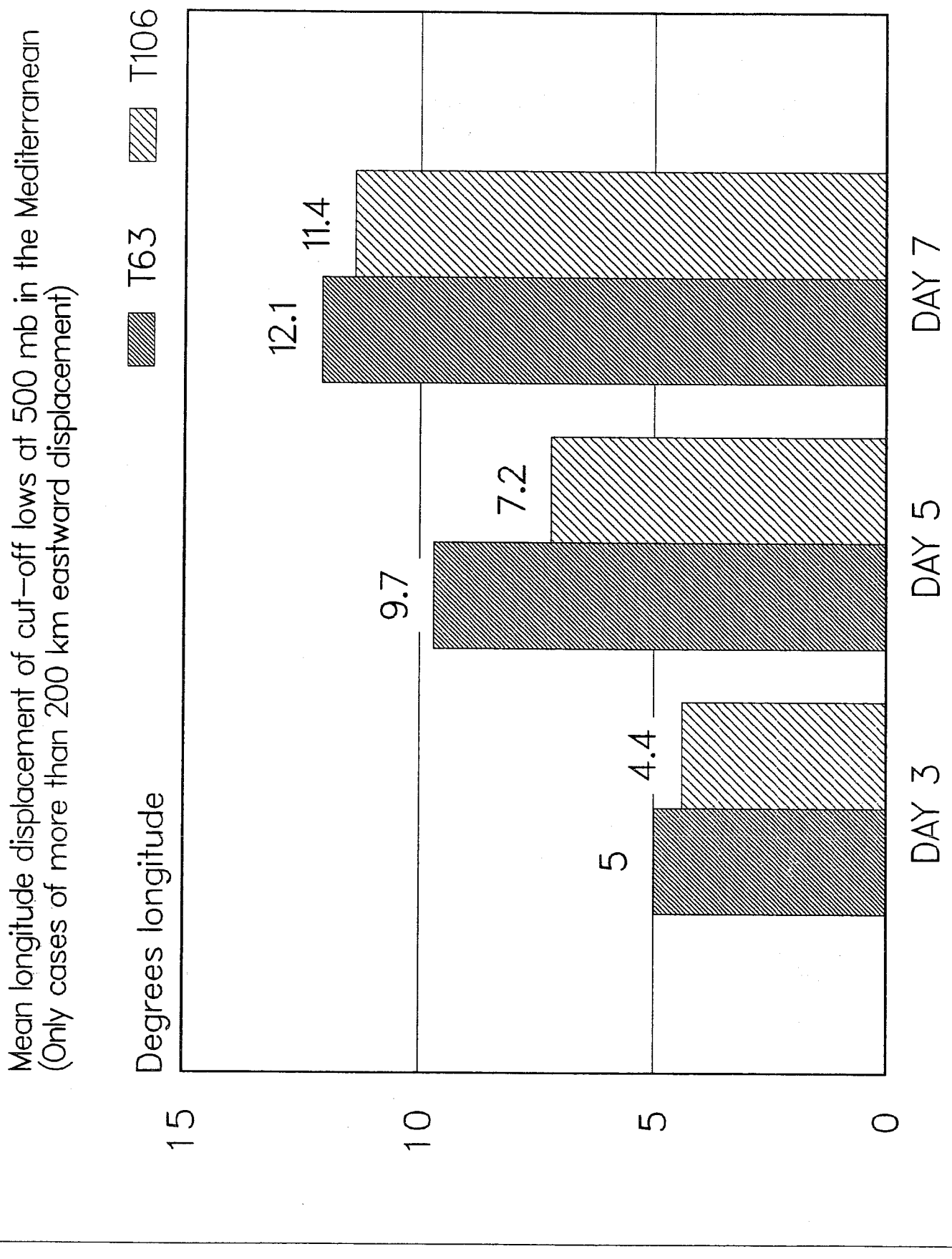
Fig. 10: As Fig. 6, but for the Mediterranean cut-off lows.

MEDITERRANEAN TROUGHS T106
Percentage of directional displacement



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

Fig. 11: As Fig. 6, but for the Mediterranean troughs.


Mean longitude displacement of cut-off lows at 500 mb in the Mediterranean
(Only cases of more than 200 km eastward displacement)
T63
T106
Degrees longitude
15
10
5
0
12.1
11.4
9.7
7.2
5
4.4
DAY 3
DAY 5
DAY 7
MOV
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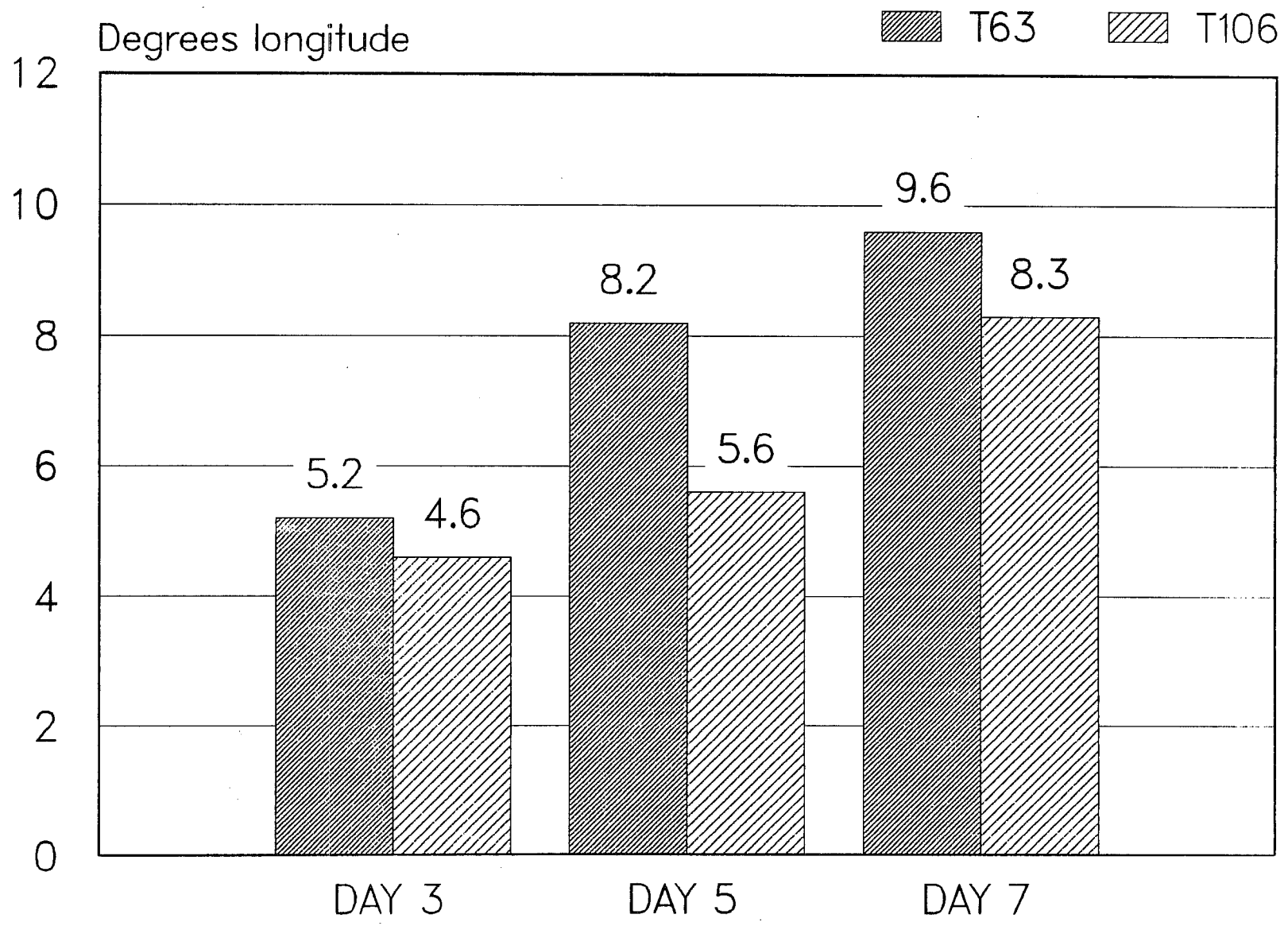
Mean longitude displacement of troughs at 500 mb in the Mediterranean
(Only cases of more than 200 km eastward displacement)



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(v) around 36% of forecast lows in the T106 model (around 40% for T63) have a longer life span than the observed cyclones; that is, the T106 model is still too slow in filling the lows in the forecast;

(vi) the error pattern of the T106 model in the regional distribution of cyclones resembles that of the T63 model, especially over the Mediterranean, where both models underestimate cyclonic activity (see Fig. 4).

3.2 Upper lows (500 hPa)

(i) The T106 model does not exhibit the mid-tropospheric cooling which was a major defect in the T63 model (see Fig. 7);

(ii) a systematic improvement in T106 for the flow pattern (cut-off lows and troughs over the eastern Atlantic and the Mediterranean) is evident (see Figs. 5, 8 and 9);

(iii) the westward and northward displacement of the east Atlantic cut-off lows/troughs is still apparent in the T106 model, especially up to day 5 or 6, however, an improvement in the prediction of the positions can be detected;

(iv) similar to the T63, most of the displacement of the Mediterranean cut-offs and troughs in T106 is towards the east (see Figs. 10 and 11), but with a reduced bias, e.g. for day 5, the mean eastward displacement of cut-off lows (troughs) are 9.7 (8.2) degrees longitude for T63, 7.2 (5.6) degrees longitude for T106 (see Figs. 12 and 13).

REFERENCES:

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Jarraud, M., Simmons, A.J., and Kanamitsu, M., 1985, Development of the high resolution model, ECMWF Technical Memorandum No. 107, 61 pp.