OVERVIEW OF VALIDATION OF DIRECT MODEL OUTPUT

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1. INTRODUCTION

As part of its operational numerical weather prediction activity, ECMWF performs an extensive range of verifications of upper level and surface fields produced by the forecast model. In particular, specific verifications are made of the direct model output of weather parameters: cloud cover, 2 metre temperature and 10 metre wind, for which verifying observations are available on the GTS.

The question addressed by this paper is the following: given an accurate forecast of a synoptic situation, what is the skill of the corresponding forecast of the weather elements? In that formulation, the word "accurate" has no precise definition; the criterion is that the agreement between the forecast and analysed situations should be good from a synoptic point of view, so that the statistics of weather elements are not contaminated by errors in the synoptics. In practice, over Europe the range 60 to 72 hours is adequate and will be considered here.

2. CLOUD COVER

Figure 1 shows the monthly bias and standard deviation of the cloud forecast over Europe at T+60 hours (night time) and T+72 hours (daytime) since 1988. The main feature is a negative bias of around 0.8 octa during daytime, while the standard deviation is rather large. The correlation between predicted and observed total cloud cover is shown in figure 2. Overall the skill of the forecast at day 3 is similar to the skill of a persistence forecast. In fact, daily monitoring of the forecast has shown that the direct model output for cloud cover is only useful in frontal situations, where the quality can be quite good.

Figure 3 shows the evolution of the error from T+6 to T+120 (note that the cloud cover is not analysed). The high value of the standard deviation from the start and its small increase with forecast lead time confirm that there is only limited skill.

A particular problem with low level clouds was addressed by a model change introduced on 17 August 1992. Before that change, the model had an excessive tendency to produce low level inversion clouds in high pressure conditions. This was particularly noticeable in the Mediterranean area during the night. The effect of the model change was to suppress inversion clouds in the lowest three model levels, which gives now a much more realistic forecast.

3. TEMPERATURE AT 2 METRES

The skill of the T2m forecast depends very much on the season and on the distance from the sea. Overall, the tendency for the model is to be slightly too cold in the boundary layer, by around 1.5 degree on average, while in summer a warm bias develops over the continent during the day, up to 5 or 6 degrees in places (fig. 4). The error pattern is there from the early range of the forecast (fig. 5; again, T2m is not analysed). There is at the same time an excessive amplitude of the diurnal cycle and a general warming, which has not yet reached saturation at day 5. However, the forecast is not affected by increasing random errors in summer; the standard deviation remains at around 3 degrees at day 3 (figure 4), and therefore this bias can be efficiently dealt with, for example by a Kalman filter.

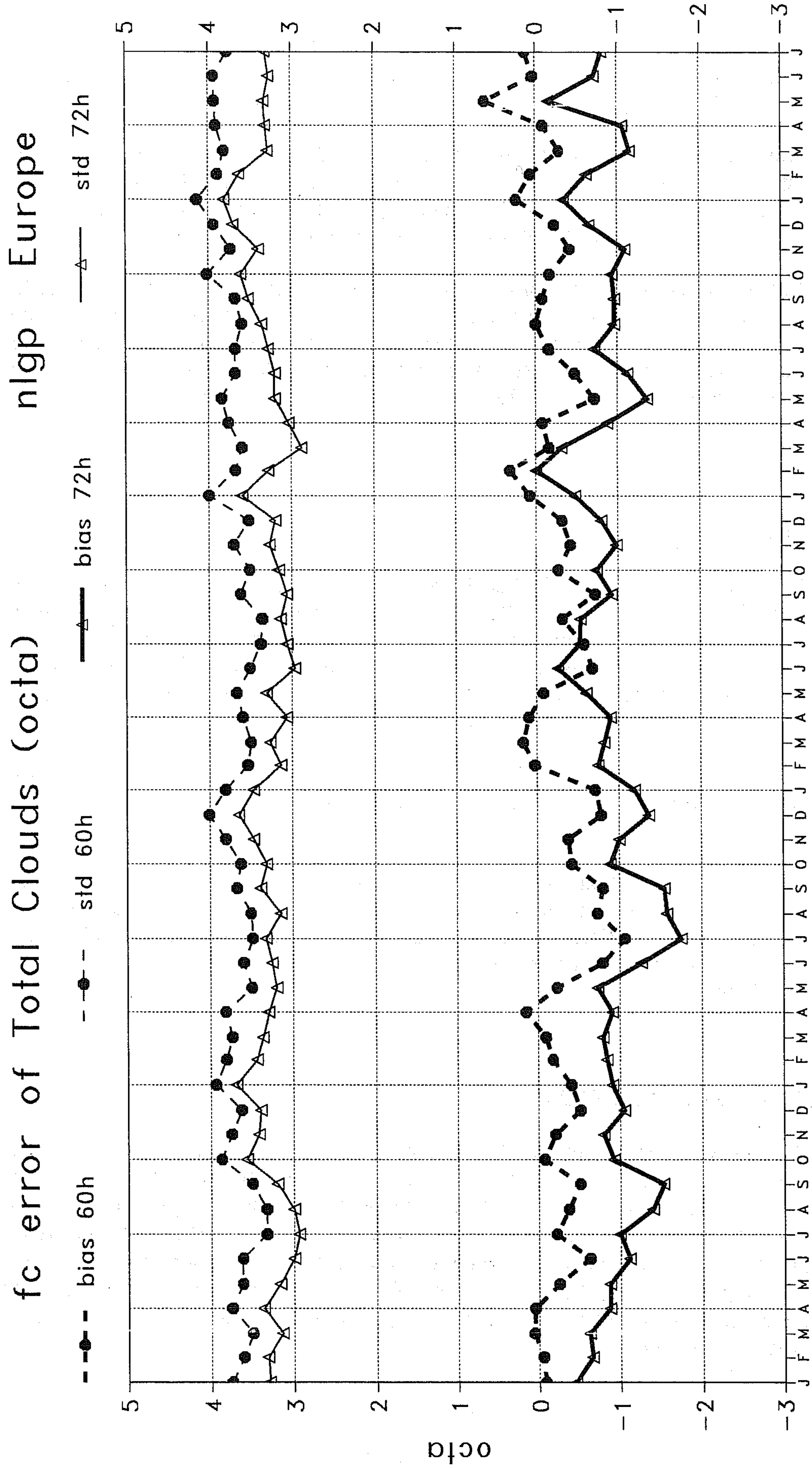


Fig. 1: Monthly mean (bold curves) and standard deviation (thin curves) of total cloud cover forecast error for Europe from January 1988 to July 1992. Dashed: t+60h forecast, night time; solid: t+72h, day time.

Contingency Table for Cloud Cover (percent)

Europe - July 1992 - T + 60

a)

Forecasted Cloud Cover \ Observed Cloud Cover	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
8.0	4.8	1.4	1.8	1.5	1.1	1.1	1.8	4.2	7.1
7.0	1.7	0.4	0.5	0.5	0.3	0.3	0.5	1.1	1.4
6.0	1.4	0.3	0.3	0.4	0.2	0.2	0.3	0.6	0.9
5.0	1.3	0.3	0.3	0.3	0.2	0.3	0.4	0.6	0.7
4.0	1.3	0.3	0.4	0.3	0.2	0.2	0.3	0.6	0.7
3.0	1.5	0.4	0.5	0.4	0.3	0.3	0.3	0.6	0.9
2.0	2.1	0.5	0.6	0.5	0.3	0.3	0.5	0.9	0.8
1.0	3.2	0.9	0.8	0.7	0.5	0.4	0.7	1.0	1.0
0.0	17.8	3.2	2.6	2.0	1.3	1.3	1.6	2.3	2.5

Contingency Table for Cloud Cover (percent)

Europe - July 1992 - T + 72

b)

Forecasted Cloud Cover \ Observed Cloud Cover	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
8.0	0.8	1.1	1.3	1.5	1.3	1.8	2.8	5.1	5.8
7.0	0.3	0.5	0.6	0.6	0.6	0.9	1.2	2.0	1.5
6.0	0.3	0.4	0.4	0.6	0.5	0.6	0.9	1.5	1.1
5.0	0.3	0.3	0.4	0.4	0.4	0.5	0.8	1.1	0.8
4.0	0.3	0.4	0.5	0.5	0.5	0.6	0.7	1.2	0.9
3.0	0.3	0.5	0.6	0.6	0.6	0.6	0.8	1.2	0.8
2.0	0.6	0.7	0.8	0.9	0.9	1.2	1.5	2.1	1.5
1.0	1.2	1.5	1.6	1.9	1.4	1.7	1.9	2.2	1.4
0.0	5.5	3.6	3.0	2.6	1.9	1.8	2.1	1.6	0.9

Fig. 2: Relative frequency (in percent) in classes of forecasted vs. observed total cloud cover for Europe in July 1992. a) t+60h; b) t+72h.

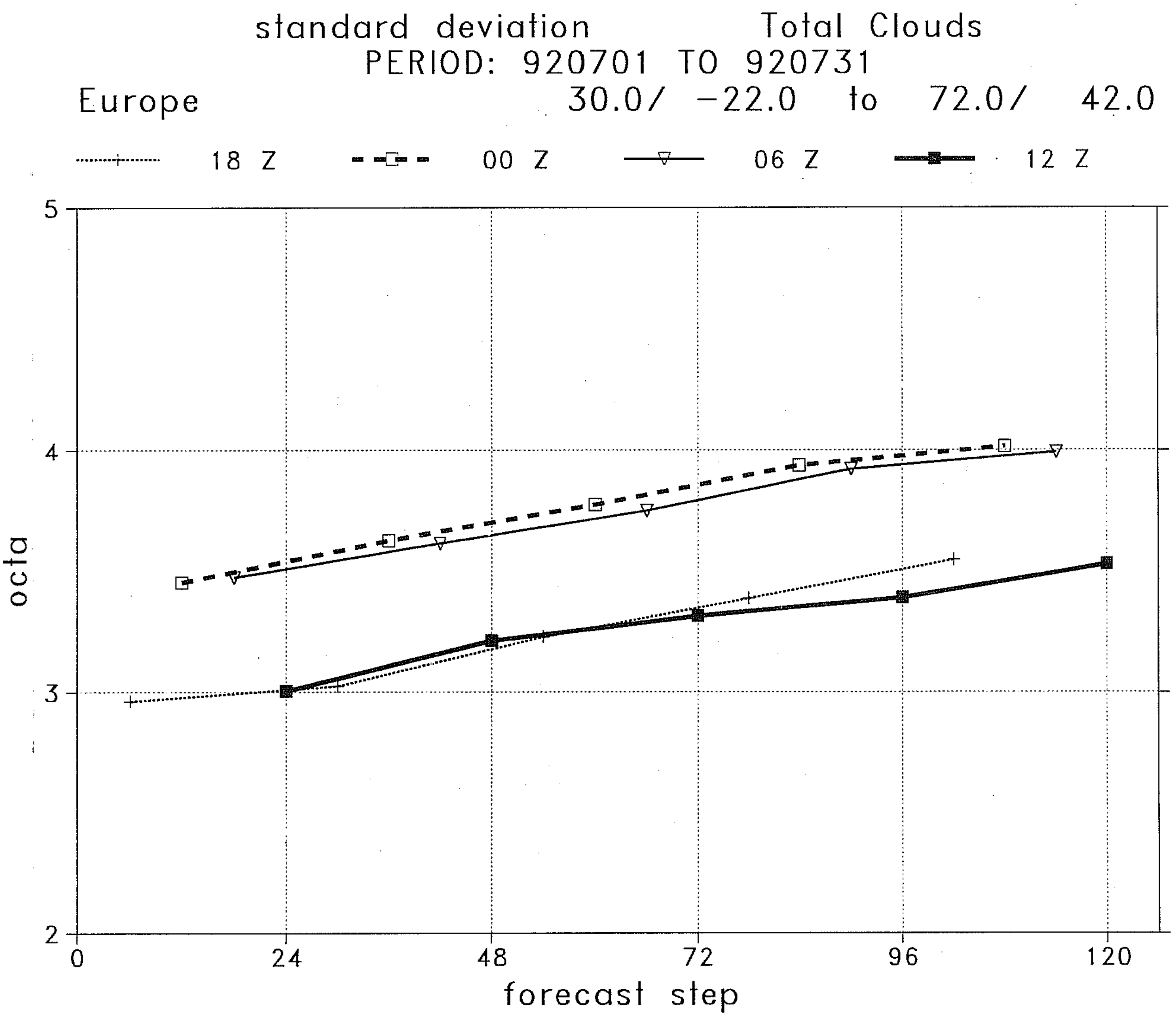


Fig. 3: Evolution of the standard deviation of total cloud cover forecast error from t+6h to t+120h forecast range for Europe in July 1992, separated according to verifying times 18, 00, 06 and 12 UTC as shown in the legend.

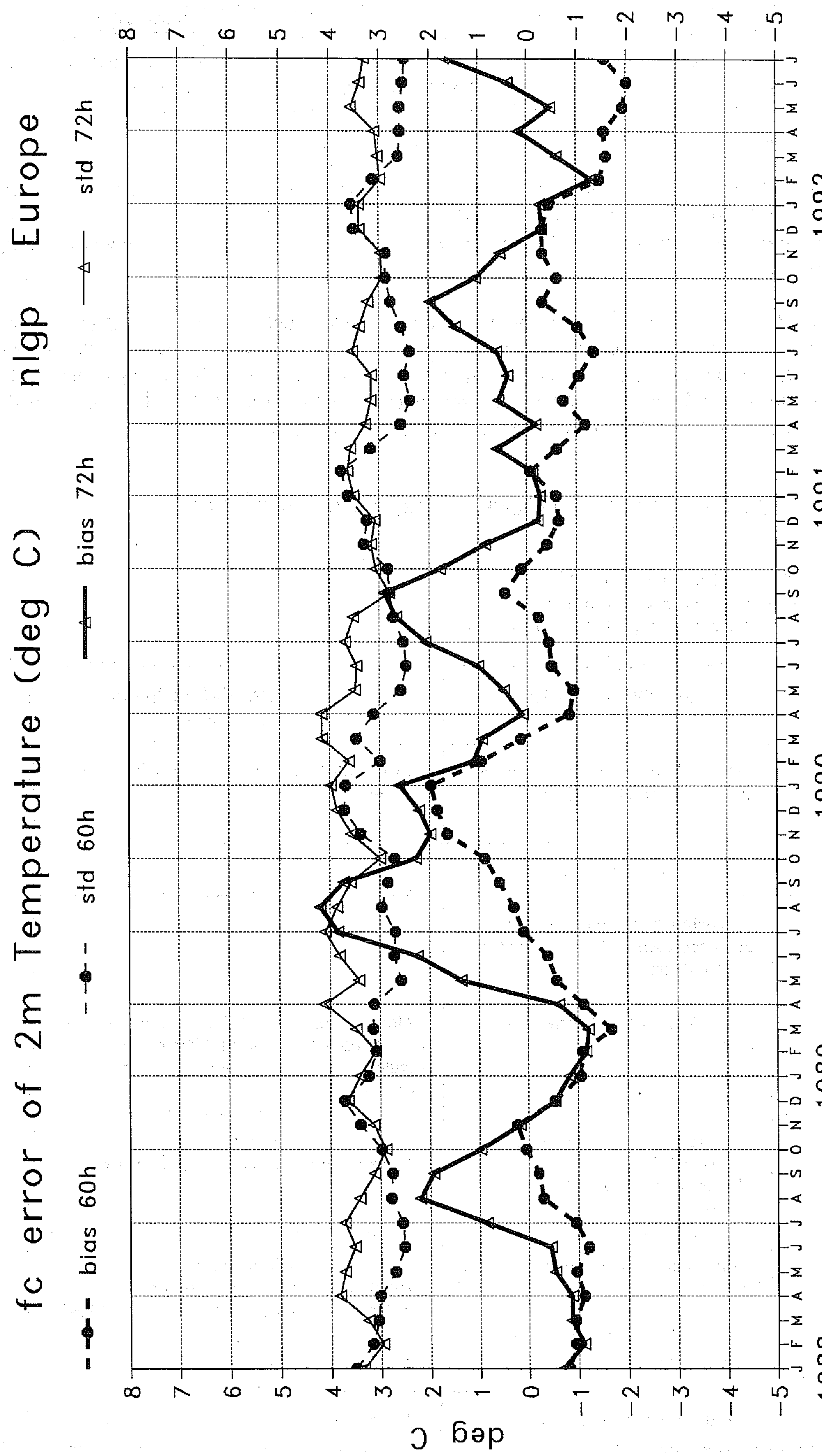


Fig. 4: Monthly mean (bold curves) and standard deviation (thin curves) of 2m Temperature forecast error for Europe from January 1988 to July 1992. Dashed: t+60h forecast night time; solid: t+72h, day time.

The correlation between cloud forecast errors and temperature forecast errors is illustrated in figure 6, which shows the mean temperature error in July 1992 for various classes of observed vs. predicted cloud cover. The tendency of the forecast to be too cold during the night is confirmed, whereas during the day temperatures are too high in all cases. On average when the cloud cover is correctly predicted, the temperature is too warm by around 2 degrees in the cases with 0 or 8 octas, and around 1 degree in the intermediate cases. However, it should be noted that the impact of cloud forecast error during the range of the forecast before the verification time is not taken into account in these statistics.

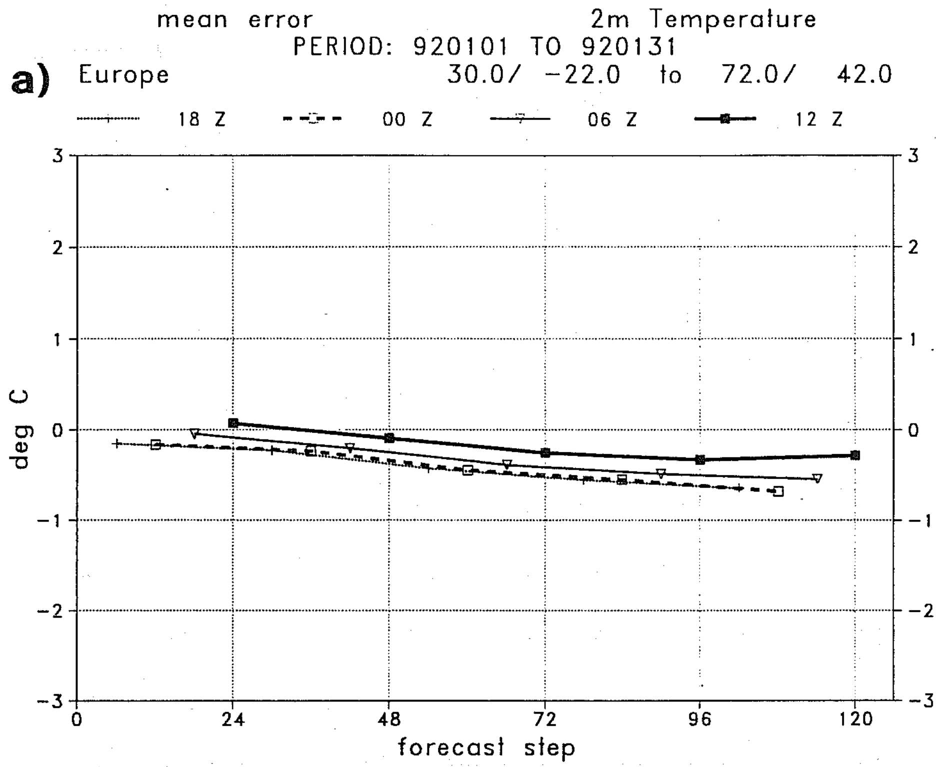
Figure 7 illustrates the ability of the model to catch changes in the flow pattern. It shows the conditional distribution of forecast error of the tendency. It can be seen that marked changes of temperature are on average well captured in the forecast, even though their amplitude is under-estimated (as should be expected with a numerical model).

The impact of model changes since 1987 on the forecast of 2 metre temperature is summarized in table 1. A very significant change was introduced in May 1990, to reduce the continental warm bias, and to address a problem with the temperature forecast over melting snow in spring. After that change, the predicted temperature over snow could rise well above 0 degree, whereas before, the impact of the snow was too strong. Figure 8 shows the reduction of the error achieved by this change.

Table 1: IMPACT OF MODEL CHANGES ON T2m FORECAST

Before Apr-87:
- Night minima much too high
- Cold bias over snow in Spring
- Day maxima too high in continental areas

	MODEL CHANGES	IMPACT ON THE PERFORMANCE OF THE FORECAST
Apr - 87	- Revised surface scheme (improve logarithmic profiles in PBL)	- **Night minima realistic,** although slightly too low
Jan - 88	- T2m can be positive over snow	
Nov - 88	- Adjustment of the root profile; decrease vegetation cover under dry conditions	
May - 89	- New radiation and convection schemes.	- Mean T increased by 1.5° on average, up to 3° in continental areas (where the resulting mean error is around +6° in summer)
May - 90	- Reduced run-off of convective precipi-tation - Modified treatment of snow covered surfaces	- T bias back to pre-89 status **- Spring bias over snow much reduced**
Apr - 91	- Maximum cloud overlap assumption;	- Daytime bias slightly reduced, but night minima sometimes much too low. On average over Europe, T2m reduced by 0.5°
Sep - 91	- T213 L 31	- Impact under review
Aug - 92	- Modified low level clouds	- Impact under review



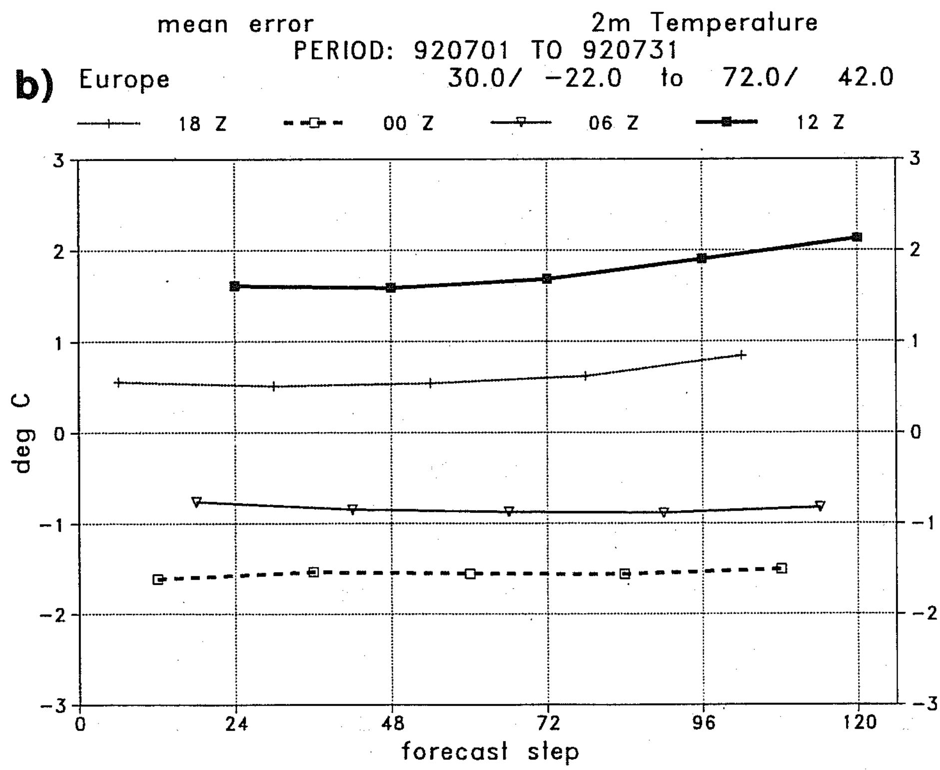
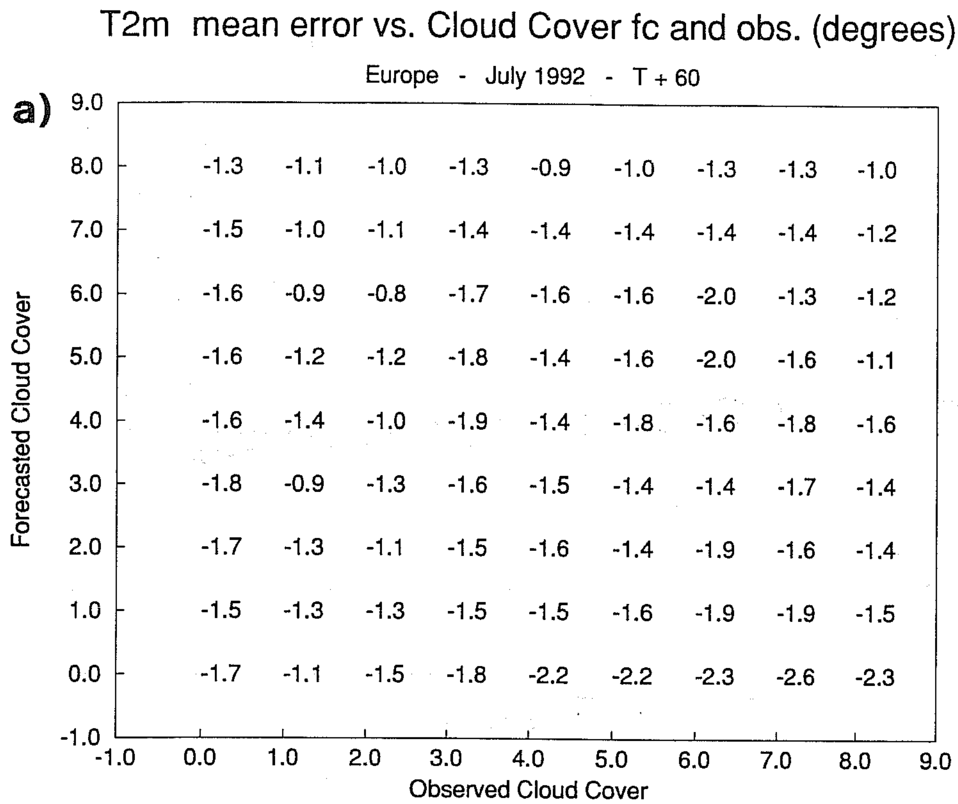


Fig. 5: Evolution of 2m Temperature mean forecast error from t+6h to t+120h forecast range for Europe, seperated according to verifying time as shown in the plot legend. a) January 1992; b) July 1992.



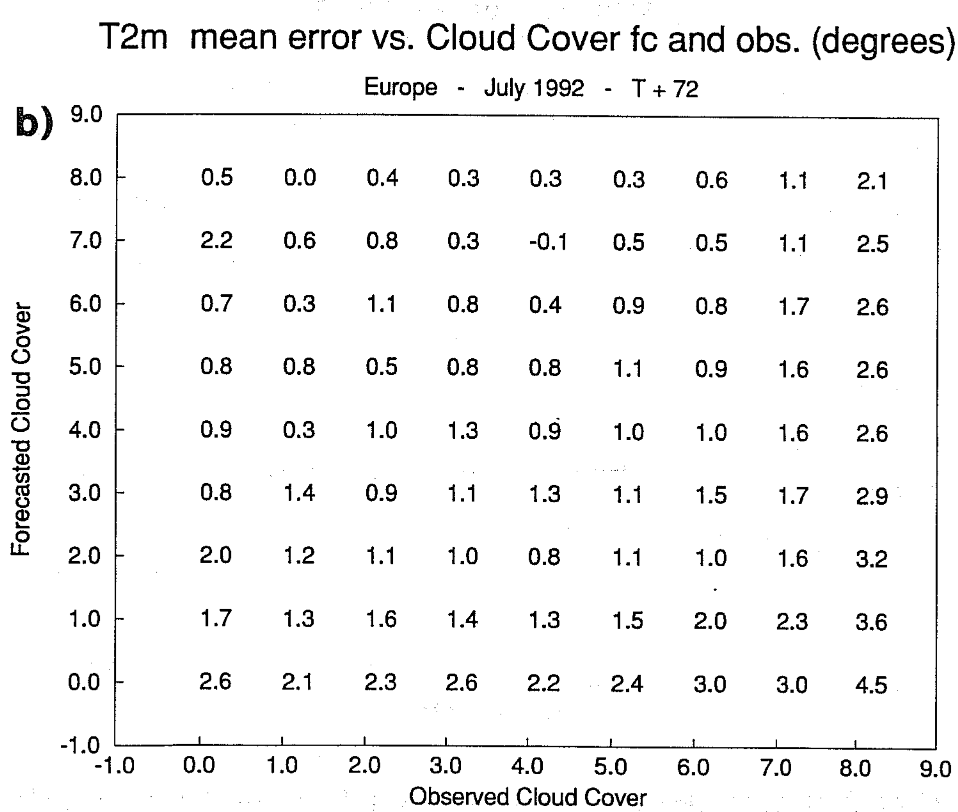
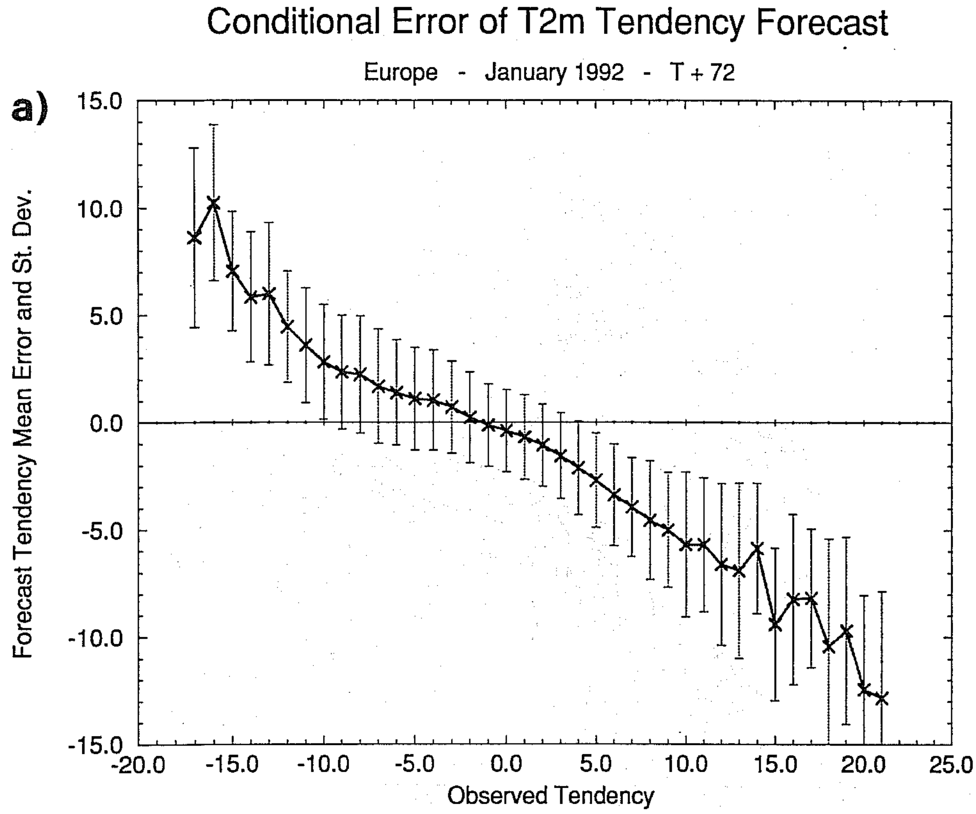


Fig. 6: 2m Temperature mean forecast error for classes of forecasted vs. observed total cloud cover for Europe in July 1992. a) t+60h; b) t+72h.



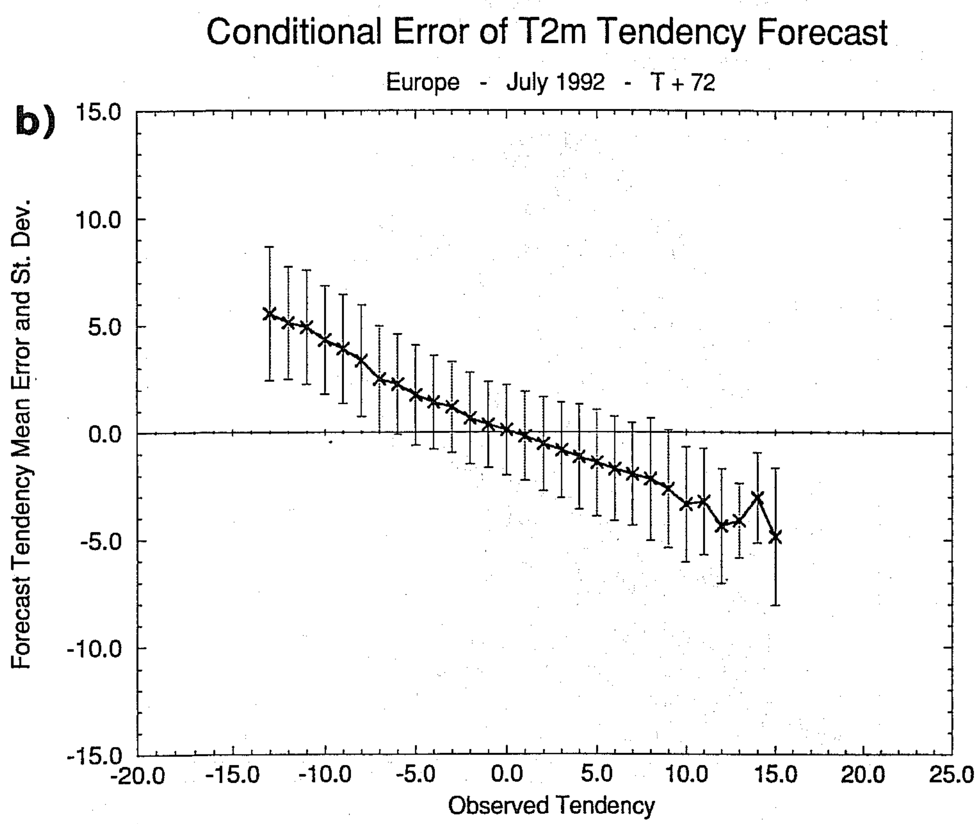


Fig. 7: Forecast error of 72h 2m Temperature tendency as a function of observed tendency, with standard deviation (error bars) for Europe. a) for January 1992; b) July 1992.

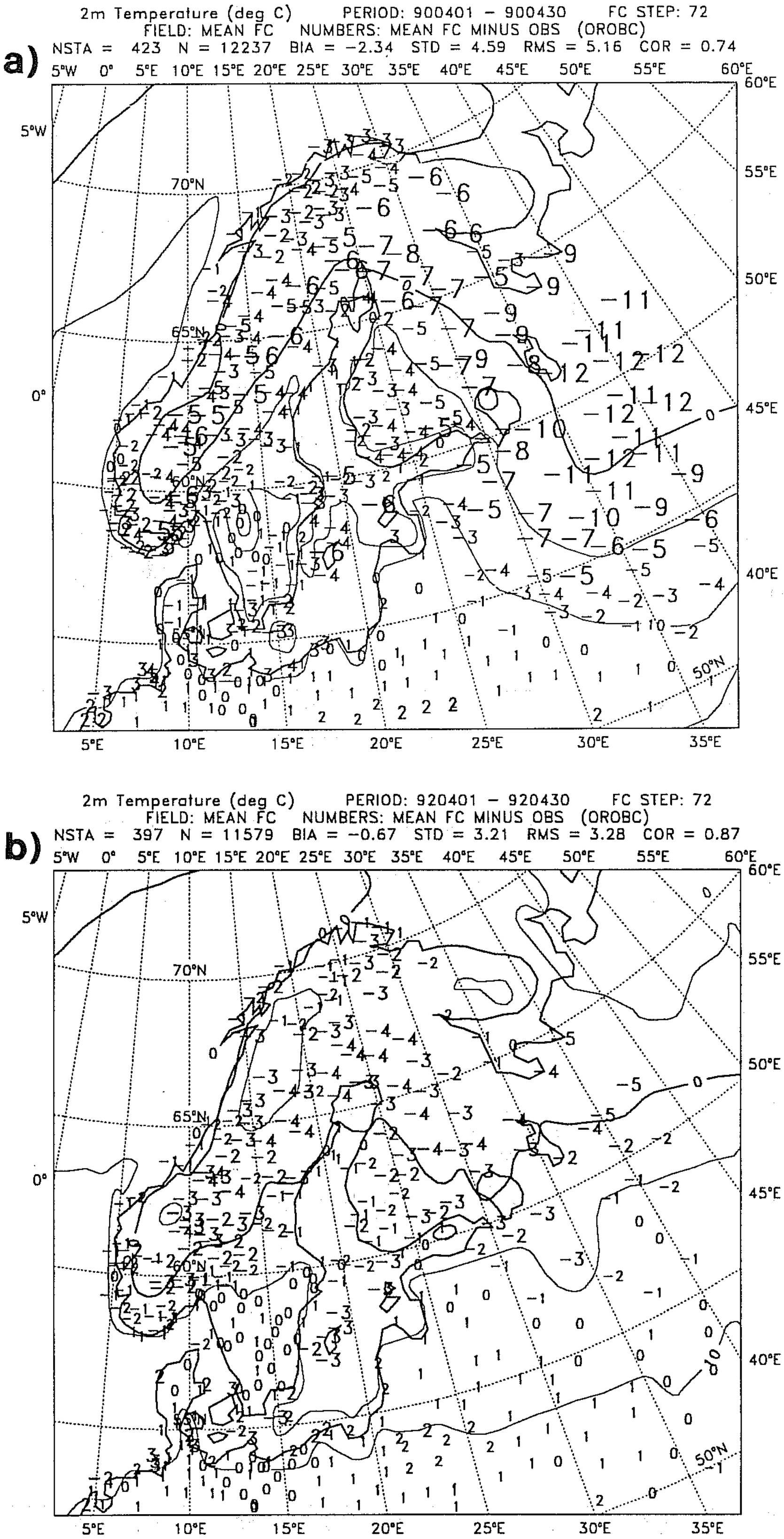


Fig. 8: 2m Temperature mean t+72h forecast errors at observation locations. a) April 1990; b) April 1992.

4. PRECIPITATION

The monthly bias of 6-hour accumulated precipitation forecasts over Europe is plotted in figure 9 (forecast from T+48 to T+72 hours). The behaviour depends very much on the time of the year: from around October to May, the bias is very small throughout the day. This corresponds well to what is seen in daily monitoring, namely that in winter situations the forecasted amounts are on average correct (obviously with large day-to-day variations). Also the forecast of occurrence is generally right. On the other hand, in the summer months and more generally when marked convective processes are taking place, the model has a tendency to over-predict both the occurrence and the amount of precipitation. This effect is particularly pronounced over orography. However, the problem has been reduced by an analysis change introduced in June 1992, whereby humidity data deduced from SYNOP observations are now excluded from the analysis. Research experiments have shown this change to be beneficial for the precipitation forecasts, and this is confirmed by the operational verification for the months of July and August (although the convective activity was not so intense as in May and June).

5. CONCLUSION

For the forecast range when errors in the synoptics are small, at the moment the main characteristics of the forecasts of weather elements can be summarised as follows:

- the cloud cover forecast shows a limited level of skill, with generally a negative bias and large random errors. Only in frontal situations does the direct forecast of cloud cover exhibit an appreciable skill;

- the forecast of 2m temperature shows a slight negative bias, except in summer over continental areas when there is a large positive bias during the day (but the random errors remain at the same level as during the rest of the year). There is a fair amount of skill in the forecasts of temperature tendencies. Overall, high quality end products can be obtained with adequate post-processing (MOS or Kalman filter), as has been shown in several Member States;

- the forecast of precipitation is usually fairly reliable; it is overestimated during the day in convective situations, especially over orography.

These verification results correspond to a snapshot at the time of this seminar. It should be noted that the situation in that area is changing rapidly; in particular, several changes to the boundary layer parametrization and to the surface scheme are in preparation, as well as a new cloud scheme. When they are implemented operationally, a major impact on some of the results should be expected.

Reference:

Strauss, B., 1988: Validation of surface and near surface parameters at ECMWF
ECMWF Workshop proceedings, October 1988.

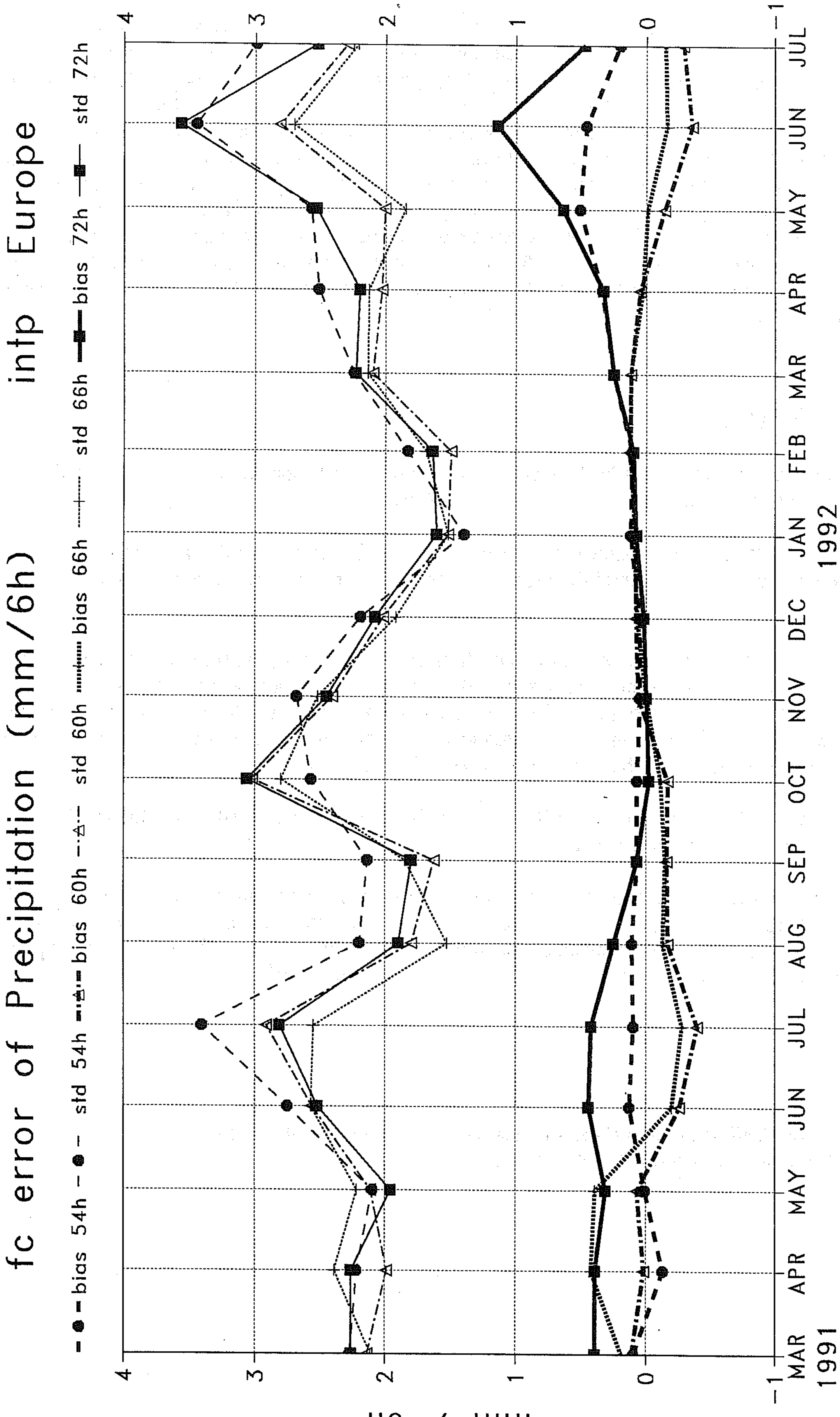


Fig. 9: Monthly mean (bold curves) and standard deviation (thin curves) of 6h-precipitation forecast error for Europe from March 1991 to July 1992.