Forecasting Research

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Blocking in the Global Unified Model - It's Characteristics and Predictability

by

Anette Van der Wal

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Meteorological Office
London Road
Bracknell
Berkshire
RG12 2SZ
United Kingdom

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1. A Description

Blocking is a condition where the westerlies are locally, but persistently weakened by the presence of an anticyclone or ridge. This generally results in different weather to the time-mean climatological conditions, since the cyclone track is displaced causing a change in the origin of the local air mass.

Many GCMs are particularly poor at representing blocking events. They have difficulty in

- properly predicting blocking onset beyond a few forecast days
- simulating the number of blocking episodes (there is usually under-estimation)
- maintaining a block
- positioning the block beyond a few forecast days

This work examines the ability of the UKMO operational global model to correctly forecast blocking and compares it with the model at ECMWF. The objective blocking index devised by Tibaldi and Molteni (1988 - hereafter referred to as TM) is used, and is described below.

The 500mb geopotential height gradients GHGS and GHGN are computed at 5^0 longitude intervals according to the following formulae:

$$GHGS=(Z(x_o)-Z(x_s))/(x_o-x_s)$$
$$GHGN=(Z(x_n)-Z(x_o))/(x_n-x_o)$$

where

$$x_n=80^0+d$$
$$x_o=60^0+d$$
$$x_s=40^0+d$$

and

$$d=-5,0 \text{ and } 5$$

A given latitude is then defined as blocked (at a specific instance in time) if the following conditions are satisfied for at least one value of d:

$GHGS > 0$

i.e. there is a high pressure cell to the north of a low, causing easterly flow

and

$GHGN < -10$ (metres/degree latitude)

i.e. situations of large southward displacement of the mid-latitude westerly jet that would not be recognized as blocked, but would satisfy $GHGS > 0$ are eliminated.

2. Preliminary Findings

2.1 Blocking Frequency

Figures 1 and 2 show the blocking frequency, as a function of longitude, over a 90 day period for the 2 successive winters of 1993 and 1994. The shaded regions define the Atlantic (28W - 32E) and Pacific (152E - 136W) sectors respectively. Turning first to the 1993 period, the gradual degradation of the Unified Model (UM) performance with increasing forecast time is evident. Firstly, there is a loss in amplitude of the Atlantic blocking frequency maximum; by T+120, the forecast maximum is half of the analysed amplitude. Secondly, although somewhat less pronounced, is a phase shift; the Atlantic maximum has moved eastward. Similar behaviour can be seen in the ECMWF model, although the amplitude decay is much less.

In 1994, there are fewer blocked days in the Atlantic sector than in the previous year; even so, there is still a decay in amplitude, and more noticeably an eastward phase shift of perhaps 15^0 by day 5 of the forecast. Prediction of the Pacific sector blocks at this time is particularly poor, with the number of forecast blocked days falling to less than half of the amount analysed. ECMWF captures the number of blocking events with a high level of accuracy, even out to 5 days, and there is virtually no positional error in the maximum of either sector.

2.2 Forecast Skill

From figures 1 and 2 alone, it is not possible to verify the accuracy of the forecasts of blocking as we have no information as to whether the precicted blocks coincide with those in the analysis. For example a model can have a correct blocking frequency, but the predicted blocks all occur at different times to the analysed blocks, in which case the model would be deemed to have no skill in predicting blocking. What needs to be identified is the number of occasions that were forecast to be blocked but had no block in the verifying analysis (i.e. the false alarm rate). Figure 3 shows the total number of blocked days in the UM and ECMWF forecasts of the Atlantic and Pacific sectors for 1993 and 1994 as a function of forecast lead time. A sector is considered to be blocked if at least 8 adjacent grid points (within that sector) are blocked. Forecast day 0 represents the analysed values, and days 1 to 5 indicate lead times of forecasts all verifying at day 0. The shaded part of the bars is the number of days correctly forecast as blocked, and the white section at the top of the bars illustrates the number of days which were blocked in the forecast, but not in the verifying analysis. So the total number of days forecast as blocked is given by the overall height of the bar, and it is this which is related to the forecast blocking frequency shown in figs. 1 and 2.

In both 1993 and 1994, as lead time increases there is a clear decrease in the number of days forecast to be blocked in the UM. The Atlantic sector blocks appear to be more difficult to predict, with the predicted frequency at day 5 only 50% of the analysed frequency, and in 1994 just over 50% of the predicted blocks were forecast correctly (i.e. there was also a block in the analysis). This means only 25% of the total number of analysed blocks were accurately predicted 5 days in advance. The frequency of predicted Pacific sector blocks at day 5 is more accurate, although there is still a high percentage of blocks incorrectly forecast as lead time increases. ECMWF do better at predicting the total number of days blocked for all lead times (as noted in figures 1 and 2), but they also show a large proportion of the days forecast as blocked when there is no block in the analysis. This is worst in the Atlantic sector during 1994, although they managed to correctly predict 11 out of 20 of the blocks at day 5, which is 55% predicted correctly compared to 25% for the UM.

2.3 Amplitude and Phase

The error in amplitude and phase can be quantified, by taking the maximum value of the GHGS index in each sector to be a measure of the amplitude of the block, and the longitude of this maximum to represent the phase. This is by no means a definitive evaluation of position or magnitude errors, and should be used as a guideline only. Figures 4 and 5 show the mean errors in the value and longitude of the block with forecast time, for 1993 and 1994 respectively.

From figure 4, it is clear that for both centres there is a general increase in the amplitude of the Pacific sector block as forecast range increases, and a corresponding decline in the maximum index of the Atlantic sector. Smaller mean errors from the ECMWF model suggest a more accurate prediction of the index throughout all forecast periods. Positionally, this maximum moves eastward for both sectors in both models, contrary to the findings of TM, who found a westward shift in the Pacific block. This difference is most likely due to the large interannual variability discussed by TM. What is perhaps of more use, is the comparison between the mean positional errors of the 2 models. The UM is particularly poor at siting Atlantic blocks beyond 3 days ahead, and even worse at predicting the placement of Pacific blocks. With the exception of the 3 day ahead forecast of Pacific blocks, ECMWF's mean errors lie between 2 and -6 for both sectors, whilst UM errors are as much as 3 times greater than this.

In 1994, the UM has improved upon the 1993 error scores for both block amplitude and position, although it is still out-performed by ECMWF. Once again, in the UM, there is a decay in amplitude of the Atlantic sector block, and to a lesser extent, the Pacific block too. ECMWF gives an accurate forecast of the maximum index for both sectors at all forecast lead times. Longitude errors show that there is still a tendency for the blocks in both sectors to be shifted eastward in the UM, throughout the forecast. A similar movement is detectable in the ECMWF Pacific block, but the Atlantic maximum shows little displacement at all.

3. Summary

Because of the large amount of interannual variability associated with model blocking, it is difficult to determine whether apparent improvements in the forecast of blocking amplitude and phase are due to model changes, or a more synoptically predictable state of the atmosphere. For this reason, it is useful to compute the statistics of 2 (or more) models over identical time periods, and gauge the relative performance of one when compared against the other. The ECMWF operational model has been used in this context.

The UM is consistently out-performed by the ECMWF model in predicting blocking frequency, amplitude and phase. Continued monitoring of this diagnostic is important if any statistical inferences are to be made. With such a small sample size, it is not possible to say whether the differences between years are significant.

4. Future Work

Further investigations into model blocking will aim to discover

- how well the UM can predict the onset and decay of blocks
- the impact of model changes (e.g. New GWD and orographic roughness parametrizations)
- how objective verification scores correlate to blocking episodes

5. References

Tibaldi, S. and Molteni, F. (1988) - On the Operational Predictability of Blocking, *ECMWF seminar proceedings on 'The Nature and Prediction of Extra-Tropical Weather Systems', 7-11 Sept. 1987, Volume II, pp329-371.*

6. Figure Captions

Figure 1 The percentage of days blocked out of a total of 90 days in the winter (Dec 1st to Feb 28th) of 1992/1993, as a function of longitude.
(a) UKMO analysed frequency
(b) UKMO day 3 frequency (full line) against analysis (dashed line)
(c) UKMO day 5 frequency (full line) against analysis (dashed line)
(d) ECMWF analysed frequency
(e) ECMWF day 3 frequency (full line) against analysis (dashed line)
(f) ECMWF day 5 frequency (full line) against analysis (dashed line)

Figure 2 As figure 1, but for the winter of 1993/1994.

Figure 3 The number of blocked days in the forecast as a function of forecast time. Forecast day 0 represents the analysed values, and days 1 to 5 indicate lead times of forecasts all verifying at day 0. The shaded part of the bars is the number of days correctly forecast as blocked, and the white section at the top of the bars illustrates the number of days which were blocked in the forecast, but not in the verifying analysis.
(a) UKMO, 1992/93, Atlantic Sector
(b) UKMO, 1992/93, Pacific Sector
(c) ECMWF, 1992/93, Atlantic Sector
(d) ECMWF, 1992/93, Pacific Sector
(e) UKMO, 1993/94, Atlantic Sector
(f) UKMO, 1993/94, Pacific Sector
(g) ECMWF, 1993/94, Atlantic Sector
(h) ECMWF, 1993/94, Pacific Sector

Figure 4 Mean errors in the maximum value of the blocking (GHGS) index, measuring amplitude errors
(a) UKMO, 1992/93
(b) ECMWF, 1992/93
and the corresponding longitude, measuring phase errors
(c) UKMO, 1992/93
(b) ECMWF, 1992/93
as a function of forecast lead time.

Figure 5 As figure 4, but for the winter of 1993/94.

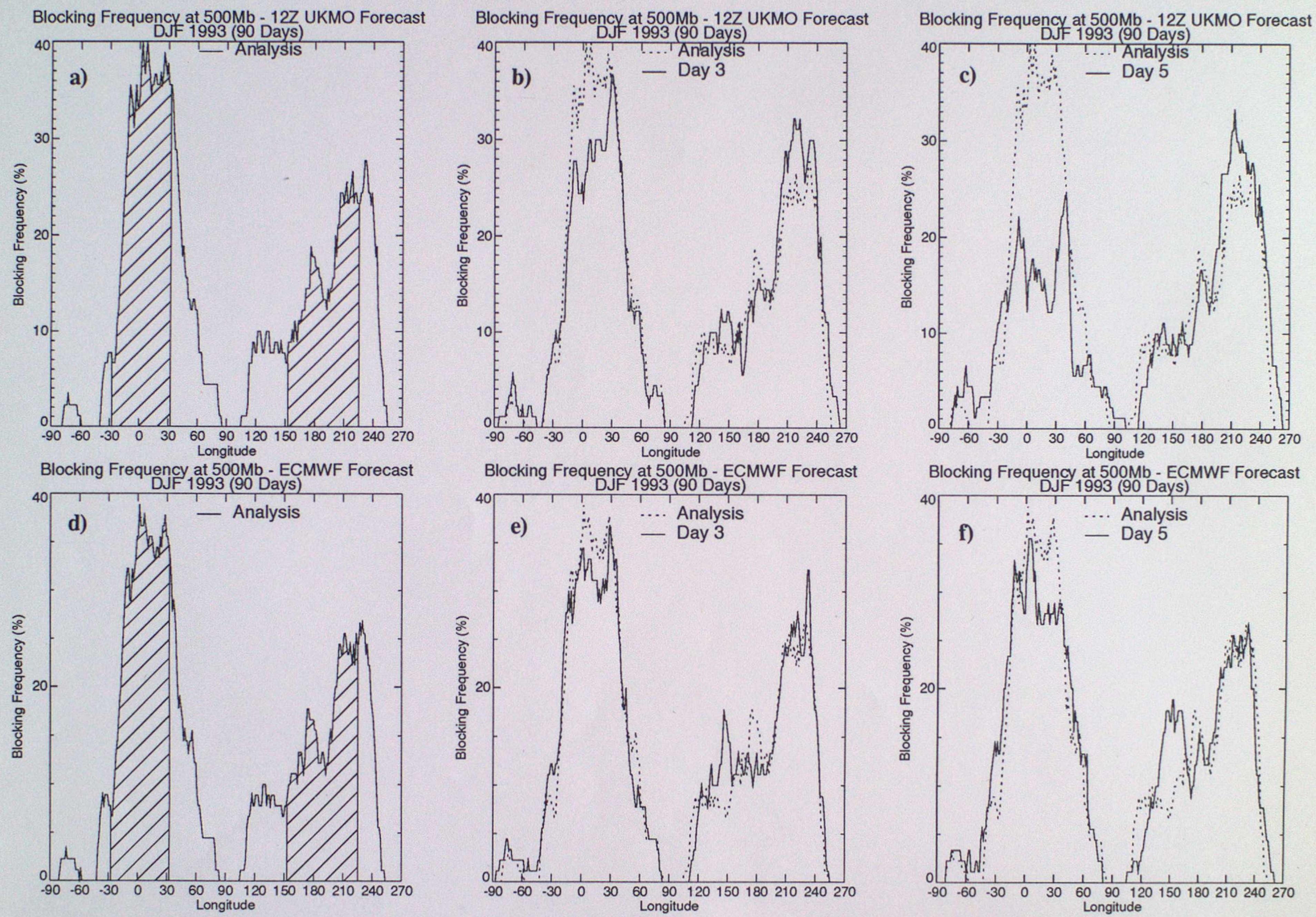
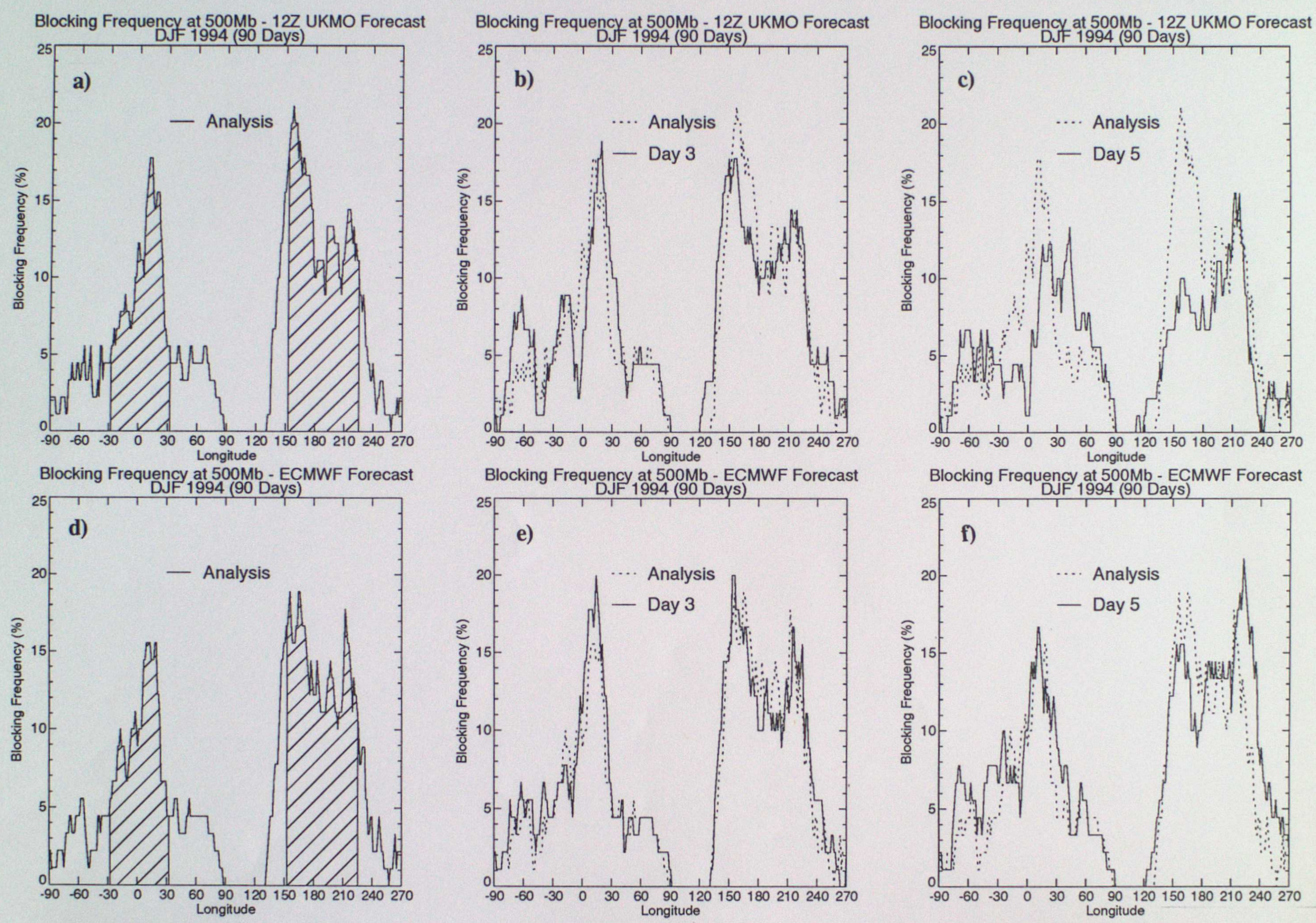
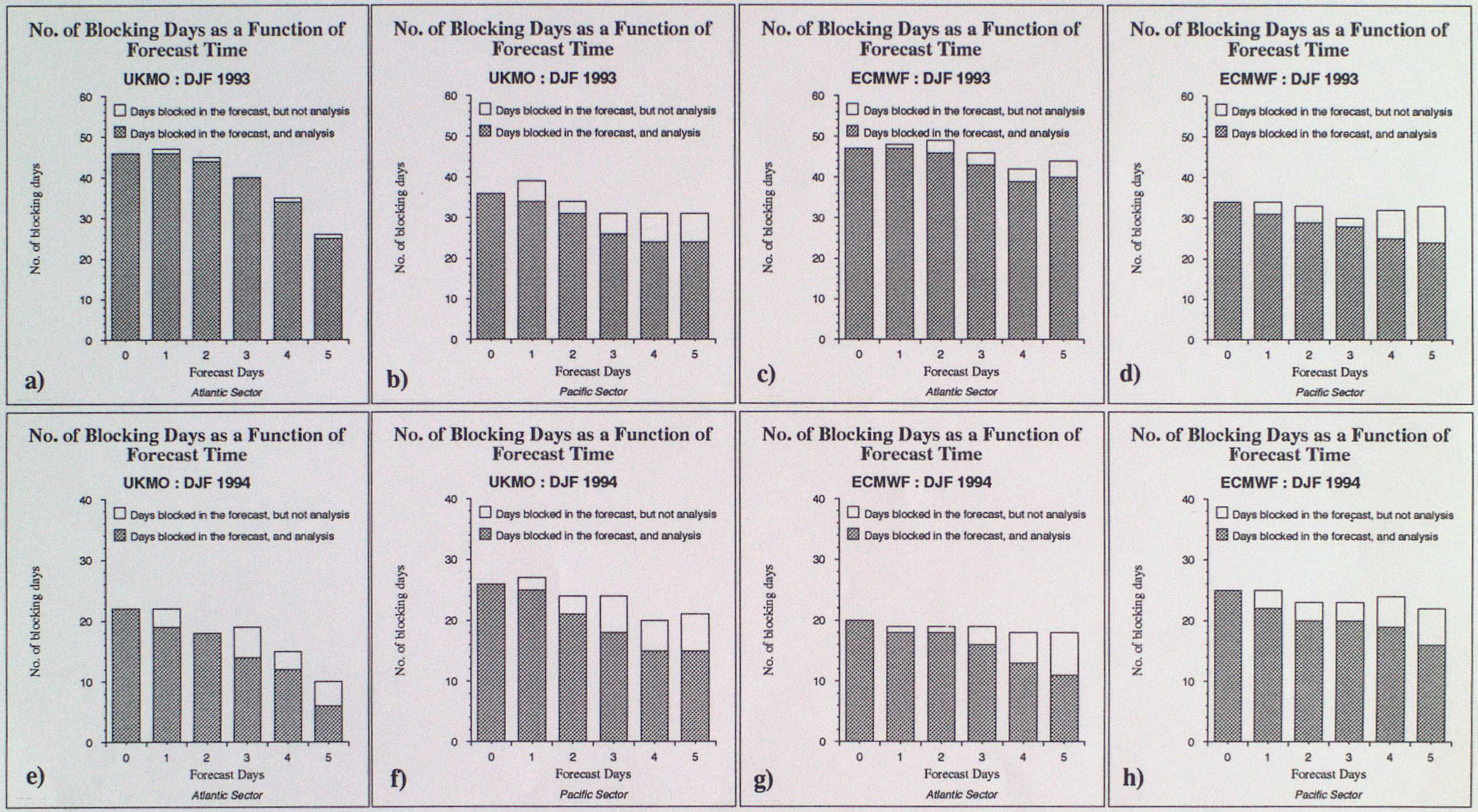

Blocking Frequency at 500Mb - 12Z UKMO Forecast
DJF 1993 (90 Days)
Analysis
a)
Blocking Frequency at 500Mb - 12Z UKMO Forecast
DJF 1993 (90 Days)
Analysis
Day 3
b)
Blocking Frequency at 500Mb - 12Z UKMO Forecast
DJF 1993 (90 Days)
Analysis
Day 5
c)
Blocking Frequency at 500Mb - ECMWF Forecast
DJF 1993 (90 Days)
Analysis
d)
Blocking Frequency at 500Mb - ECMWF Forecast
DJF 1993 (90 Days)
Analysis
Day 3
e)
Blocking Frequency at 500Mb - ECMWF Forecast
DJF 1993 (90 Days)
Analysis
Day 5
f)
Blocking Frequency (%)
Longitude
-90 -60 -30 0 30 60 90 120 150 180 210 240 270

Figure 1



Blocking Frequency at 500Mb - 12Z UKMO Forecast
DJF 1994 (90 Days)
a)
Analysis
Blocking Frequency (%)
Longitude
Blocking Frequency at 500Mb - 12Z UKMO Forecast
DJF 1994 (90 Days)
b)
Analysis
Day 3
Blocking Frequency (%)
Longitude
Blocking Frequency at 500Mb - 12Z UKMO Forecast
DJF 1994 (90 Days)
c)
Analysis
Day 5
Blocking Frequency (%)
Longitude
Blocking Frequency at 500Mb - ECMWF Forecast
DJF 1994 (90 Days)
d)
Analysis
Blocking Frequency (%)
Longitude
Blocking Frequency at 500Mb - ECMWF Forecast
DJF 1994 (90 Days)
e)
Analysis
Day 3
Blocking Frequency (%)
Longitude
Blocking Frequency at 500Mb - ECMWF Forecast
DJF 1994 (90 Days)
f)
Analysis
Day 5
Blocking Frequency (%)
Longitude

Figure 2



No. of Blocking Days as a Function of Forecast Time
UKMO : DJF 1993
Days blocked in the forecast, but not analysis
Days blocked in the forecast, and analysis
No. of blocking days
Forecast Days
Atlantic Sector
a)
No. of Blocking Days as a Function of Forecast Time
UKMO : DJF 1993
Forecast Days
Pacific Sector
b)
No. of Blocking Days as a Function of Forecast Time
ECMWF : DJF 1993
Forecast Days
Atlantic Sector
c)
No. of Blocking Days as a Function of Forecast Time
ECMWF : DJF 1993
Forecast Days
Pacific Sector
d)
No. of Blocking Days as a Function of Forecast Time
UKMO : DJF 1994
Forecast Days
Atlantic Sector
e)
No. of Blocking Days as a Function of Forecast Time
UKMO : DJF 1994
Forecast Days
Pacific Sector
f)
No. of Blocking Days as a Function of Forecast Time
ECMWF : DJF 1994
Forecast Days
Atlantic Sector
g)
No. of Blocking Days as a Function of Forecast Time
ECMWF : DJF 1994
Forecast Days
Pacific Sector
h)

Figure 3

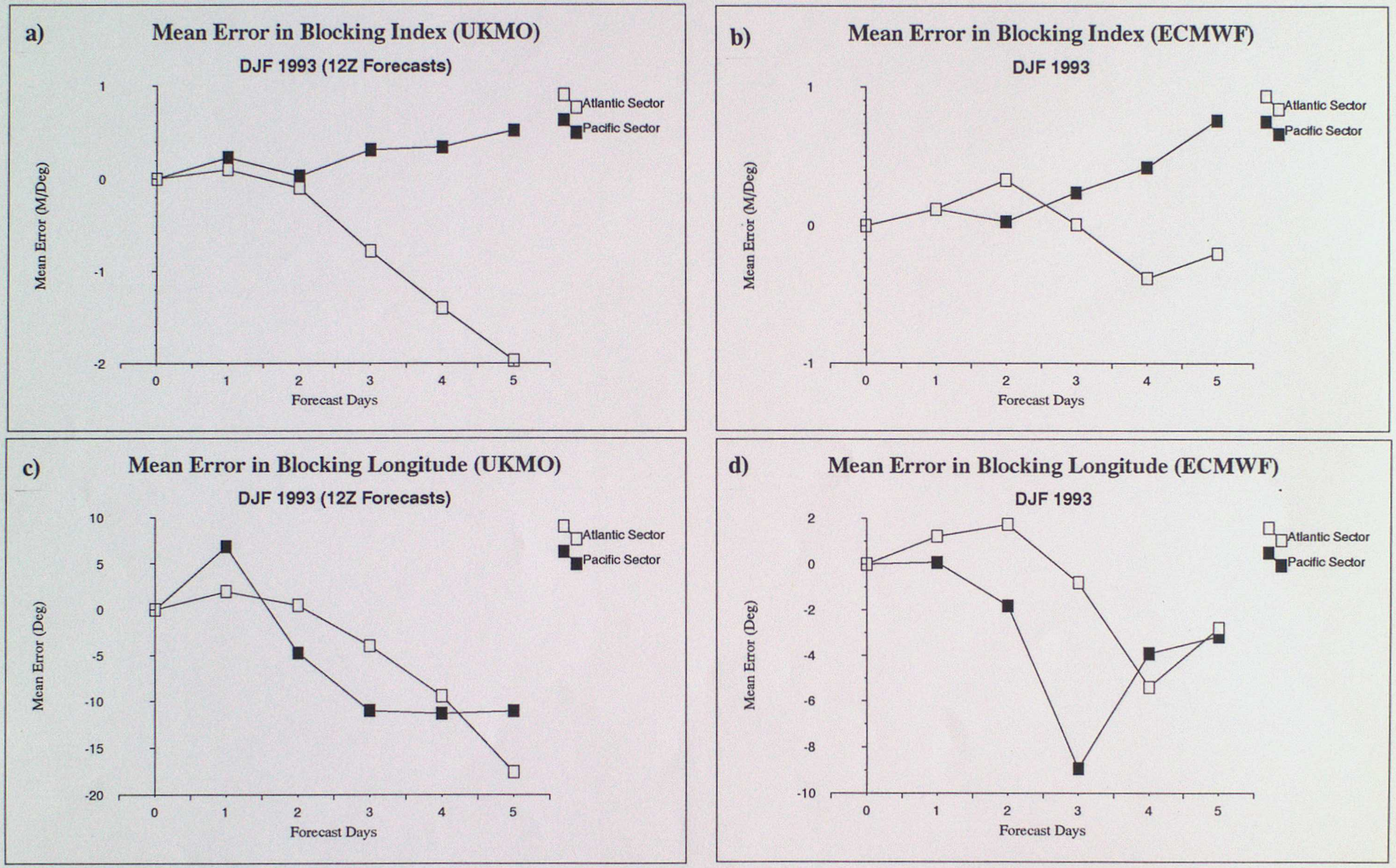

a)
Mean Error in Blocking Index (UKMO)
DJF 1993 (12Z Forecasts)
Mean Error (M/Deg)
1
0
-1
-2
0
1
2
3
4
5
Forecast Days
Atlantic Sector
Pacific Sector
b)
Mean Error in Blocking Index (ECMWF)
DJF 1993
Mean Error (M/Deg)
1
0
-1
0
1
2
3
4
5
Forecast Days
Atlantic Sector
Pacific Sector
c)
Mean Error in Blocking Longitude (UKMO)
DJF 1993 (12Z Forecasts)
Mean Error (Deg)
10
5
0
-5
-10
-15
-20
0
1
2
3
4
5
Forecast Days
Atlantic Sector
Pacific Sector
d)
Mean Error in Blocking Longitude (ECMWF)
DJF 1993
Mean Error (Deg)
2
0
-2
-4
-6
-8
-10
0
1
2
3
4
5
Forecast Days
Atlantic Sector
Pacific Sector

Figure 4

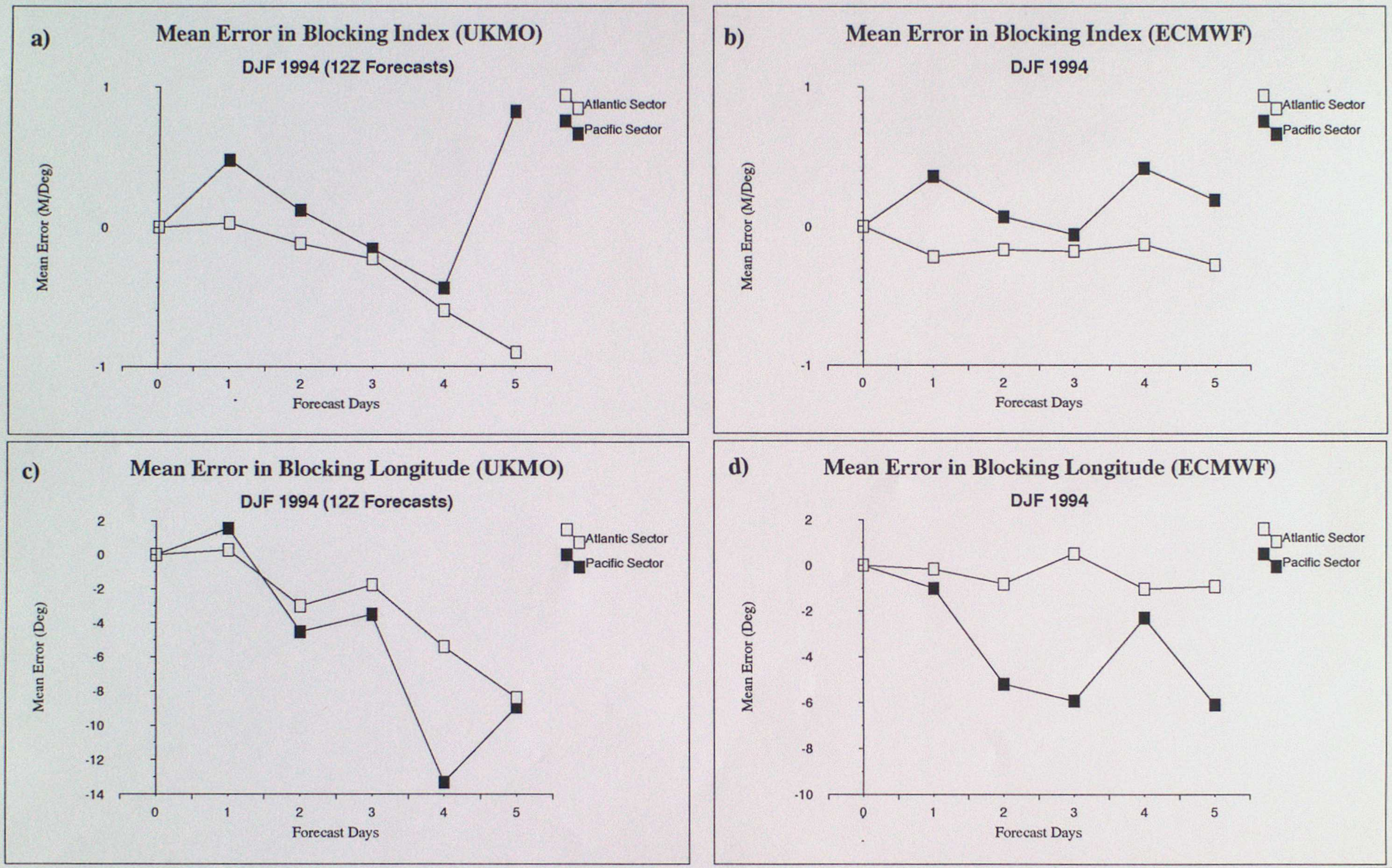

a)
Mean Error in Blocking Index (UKMO)
DJF 1994 (12Z Forecasts)
Mean Error (M/Deg)
1
0
-1
0
1
2
3
4
5
Forecast Days
Atlantic Sector
Pacific Sector
b)
Mean Error in Blocking Index (ECMWF)
DJF 1994
Mean Error (M/Deg)
1
0
-1
0
1
2
3
4
5
Forecast Days
Atlantic Sector
Pacific Sector
c)
Mean Error in Blocking Longitude (UKMO)
DJF 1994 (12Z Forecasts)
Mean Error (Deg)
2
0
-2
-4
-6
-8
-10
-12
-14
0
1
2
3
4
5
Forecast Days
Atlantic Sector
Pacific Sector
d)
Mean Error in Blocking Longitude (ECMWF)
DJF 1994
Mean Error (Deg)
2
0
-2
-4
-6
-8
-10
0
1
2
3
4
5
Forecast Days
Atlantic Sector
Pacific Sector

Figure 5