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Predictability of Blocking

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These are preliminary lecture notes, intended only for distribution to participants

Predictability of Blocking.

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1. INTRODUCTION

Tibaldi and Molteni (1990, hereafter referred to as TM) had previously investigated operational blocking predictability by the ECMWF model and the possible relationships between model systematic error and blocking in the winter season of the Northern Hemisphere, using seven years of ECMWF operational archives of analyses and day 1 to 10 forecasts. They showed that fewer blocking episodes than in the real atmosphere were generally simulated by the model, and that this deficiency increased with increasing forecast time. As a consequence of this, a major contribution to the systematic error in the winter season was shown to derive from the inability of the model to properly forecast blocking.

The inability shown by forecasting models to properly enter into a blocked state (both in the initial value problem sense and in a climatic sense) and the consequential existence of large systematic errors are limiting factors of paramount importance also for extended range forecasts (*Tracton et al*, 1989; *Tracton*, 1990; *Miyakoda and Sirutis*, 1990; *Tibaldi et al*, 1991; *Branković and Ferranti*, 1992), where the consequences of such errors are amplified by the longer integration time. An improved understanding of the reasons for blocking forecast failures and of the positive relationship between such failures and model systematic errors would therefore have an even larger positive impact on extended range dynamical forecasts, and climate simulation.

In this study, the analysis performed in TM for the first seven winter season of the ECMWF operational model is extended to the subsequent five winters, during which model development, reflecting in both resolution increases and parametrisation modifications, continued unabated. In addition the objective blocking index developed by TM has been applied to the observed data to study the natural low frequency variablity of blocking. The ability to simulate blocking of some climate models (developed at the Deutsches Klimarechenzentrum, Hamburg,FRG) as also been tested.

2. DESCRIPTION OF THE DATA SET AND OF THE ANALYSIS PROCEDURES

The database for the study of the performance of the operational ECMWF model consists of daily Northern Hemisphere winter 500 hPa geopotential heights analyses and the corresponding day 1 to day 10 forecasts. Winter is here defined as the 90-day period spanning the months of December, January and February (DJF period). For each winter day, eleven fields are then available: analysis and day one to day ten forecasts, all verifying on the same day but started from progressively lagging initial conditions. Such an arrangement of analysis and forecast fields is commonly known as a "Lorenz files" dataset (*Lorenz*, 1982). The total set includes twelve complete winters, from DJF 1980-81 to DJF19 91-92.

The database for the study of the natural low frequency variablity of blocking consists of daily Northern Hemisphere winter 500 hPa geopotential heights analyses, from the NMC and ECMWF archives, from the winter 1949-50 to the winter 1991-92.

For the climate models 5 different runs with two different models have been analyzed. The models are ECHAM2 and ECHAM3 (developed starting from the ECMWF model at the Deutsches Klimarechenzentrum) which differ for the physical package and for the fact that ECHAM2 can run only with orizontal resolution of T21 (both models are spectral and T21 stands for triangular truncation at the 21st spherical harmonic). Climatic or observed sea surface temperatures (SSTs) have been used. The main characterisic of the runs are reported in Table 1.

The TM blocking index has been used on the different data sets. The geopotential height gradients GHGS and GHGN are computed for each longitude

$$GHGS = \frac{Z(\phi_0) - Z(\phi_s)}{(\phi_0 - \phi_s)},$$

$$GHGN = \frac{Z(\phi_n) - Z(\phi_0)}{(\phi_n - \phi_0)},$$

where

$$\phi_n = 80°N+\Delta$$

$$\phi_0 = 60°N+\Delta$$

$$\phi_s = 40°N+\Delta$$

$$\Delta = -4°, 0°, +4°$$

A given longitude is defined as blocked at a specific day if the following condition are satisfied for at least one value of Δ:

(1) GHGS> 0,

(2) GHGN < -10 m/deg lat.

Similarly to TM, the two main NH sectors are then identified and defined, with the following longitudinal limits:

Euro-Atlantic:	25.5° W	33.5° E
Pacific:	110.0° E	170.0° W

A sector is then considered to be blocked if three or more adjacent longitudes contained in it are blocked according to the local and instantaneous TM index definition.

3. OBSERVED AND PREDICTED BLOCKING

Figure 1 shows the longitudinal dependency of blocking frequency as measured by the index applied on subsets of ten years of the observaed winters (1949-50 to 91-92) of 500 hPa geopotential height, and is shown here only to give a measure of the different behaviour of the atmosphere, that shows appreciable intradecadal variability. This behaviour is of particular interest when the performance of climate models has to be assessed.

The four panels of Figure 2 show the blocking frequency relative to the first seven winters of ECMWF operations. Panel (a) shows observations alone, while in panels (b) to (d) forecast day 3, 6 and 10 respectively are superimposed on the observed longitudinal frequency. The disruption of the observed maxima in correspondence of both the Pacific and the Atlantic sectors is quite evident already at day 6 and is almost complete by day 10. Figure 3 has the same layout of Figure 2, but refers to the last five ECMWF operational winters, 1987-88 to 91-92. Now the picture is quite different and shows a marked improvement in model climatology of blocking, with the model-produced frequency profile becoming measurably different from observations only by day 10.

Figure 4 summarizes the analysis performed on the climate models. The two top panels show the longitudinal dependence of the blocking freqiuency used for comparison, the right panel is relative to the years for which observed SSTs where used in the simulation. The improvements in the phisical parametrizations from ECHAM2 T21 to ECHAM3 T21 do not produce relevant changes in the simulation of blocking. The increase of resolution from ECHAM3 T21 to ECHAM3 T42 has a positive effect on the simulation of Euro-Atlantic blocking, but does not affect Pacific blocking. The use of observed SSts seemes again to have better effects on the Euro-Atlantic blocking. The lack of an ECHAM2 T42 makes impossible a valutation of the effects of increasing resolution without changing the physical parametrizations.

4. CONCLUSIONS

Measurable improvements have been achieved by the ECMWF operational forecasting system in modelling blocking. Such improvements range from a better overall model blocking climatology to an improved deterministic predictability of the phenomenon. Such improvements make it more realistic to plan for extended range forecasts. Unfortunately, the practical set-up of operational forecasting and the related model development efforts make it impossible to ascribe such improvements to a precise cause, be it model resolution (horizontal or vertical) or improvements in the physical parametrisation package.

Blocking diagnostics in climate models show that improvements in resolution and in the physical parametrisation package produce a better blocking climatology, but also in this case a clear distinction between the effects of resolution and physics are impossible.

Acknowledgements

Dr. E. Roeckner of Max Plank Institute, Hamburg, and Dr. U. Cubash of Deutsches Klimarechenzentrum, Hamburg, are gratefully acknoledged for giving us the opprtunity of analysing the rúns of their climate models.

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Table and Figure Captions

Table 1. Main characteristics of the five climatic runs analyzed.

Figure 1 Longitudinal distribution of winter (DJF) blocking frequency for differen decades. a) 1949-50 to 1958-59, b) 1959-60 to 1968-69, c) 1969-70 to 1978-79, d) 1979-80 to 1991-92.

Figure 2 TM blocking index applied to the first seven ECMWF operational winters (80/81 to 86/87). (a) analyzed data; (b) forecast day 3 and analysis (dashed); (c) forecast day 6 and analysis (dashed); (d) forecast day 10 and analysis (dashed).

Figure 3 As Figure 2, but for the last five ECMWF operational winters (87/88 to 91/92).

Figure 4 Longitudinal distribution of winter (DJF) blocking frequency for observations and climate models runs. a) for the complete data set available, b) for the ten winters from 1979-80 to 1987-88. panels c to e for 20 years runs of ECHAM2 T21, ECHAM3 T21 and ECHAM3 T42, all with climatic SSTs. Panels f and g for 10 years runs of ECHAM3 T21 and ECHAM3 T42, with observed SSTs. The dotted line on panels c to g are the observed frequencies.

Table 1

MODEL	HORIZONTAL REPRESENTATION	VERTICAL LEVELS	SSTs	GWD	Length of integration
ECHAM2	T21	19	Climatological	No	20 years
ECHAM3	T21	19	Climatological	No	33(20) years
ECHAM3 GAGO	T21	19	Observed	No	10 years
ECHAM3	T42	19	Climatological	Yes	20 years
ECHAM3 GAGO	T42	19	Observed	Yes	10 years

DJF

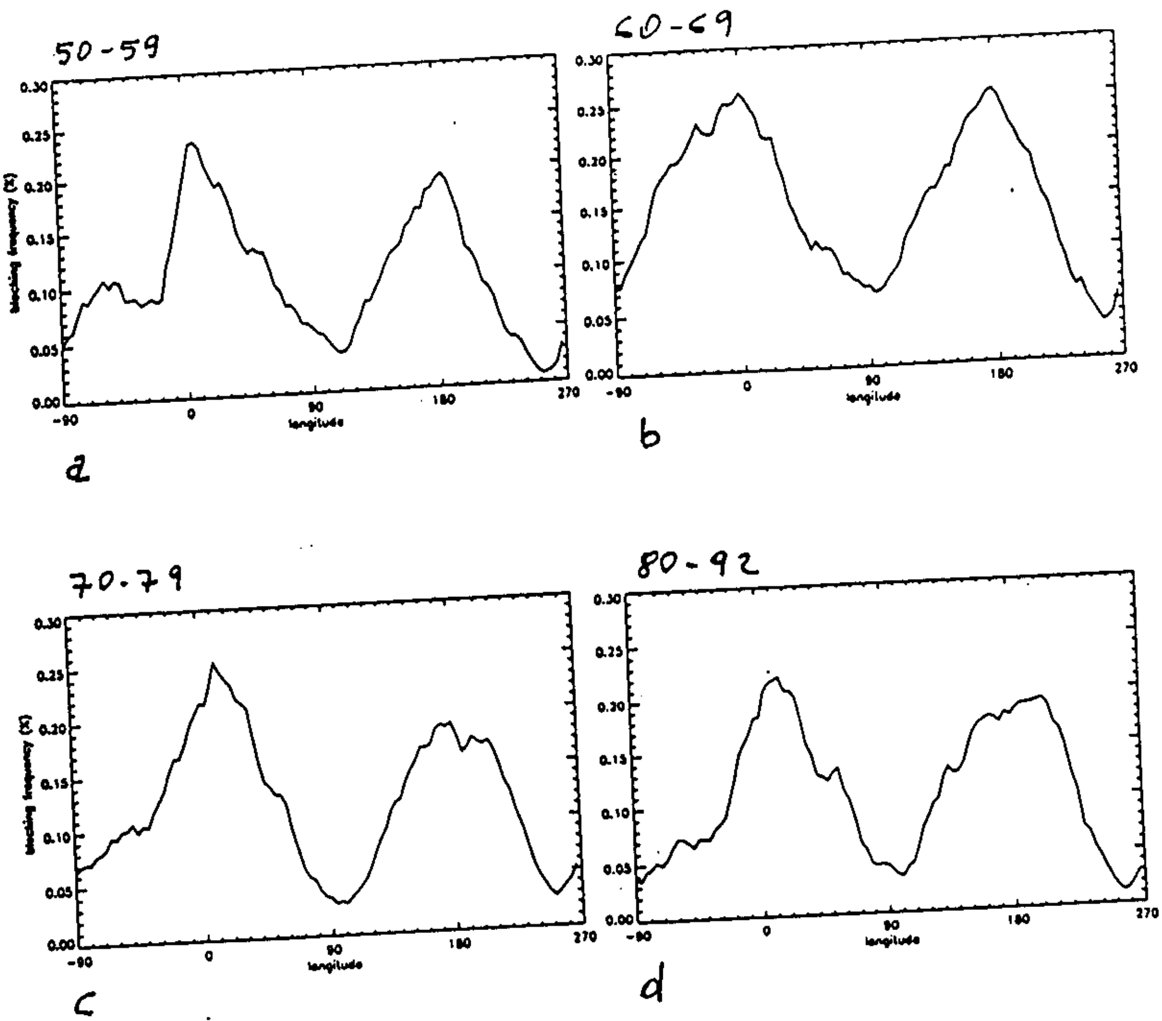
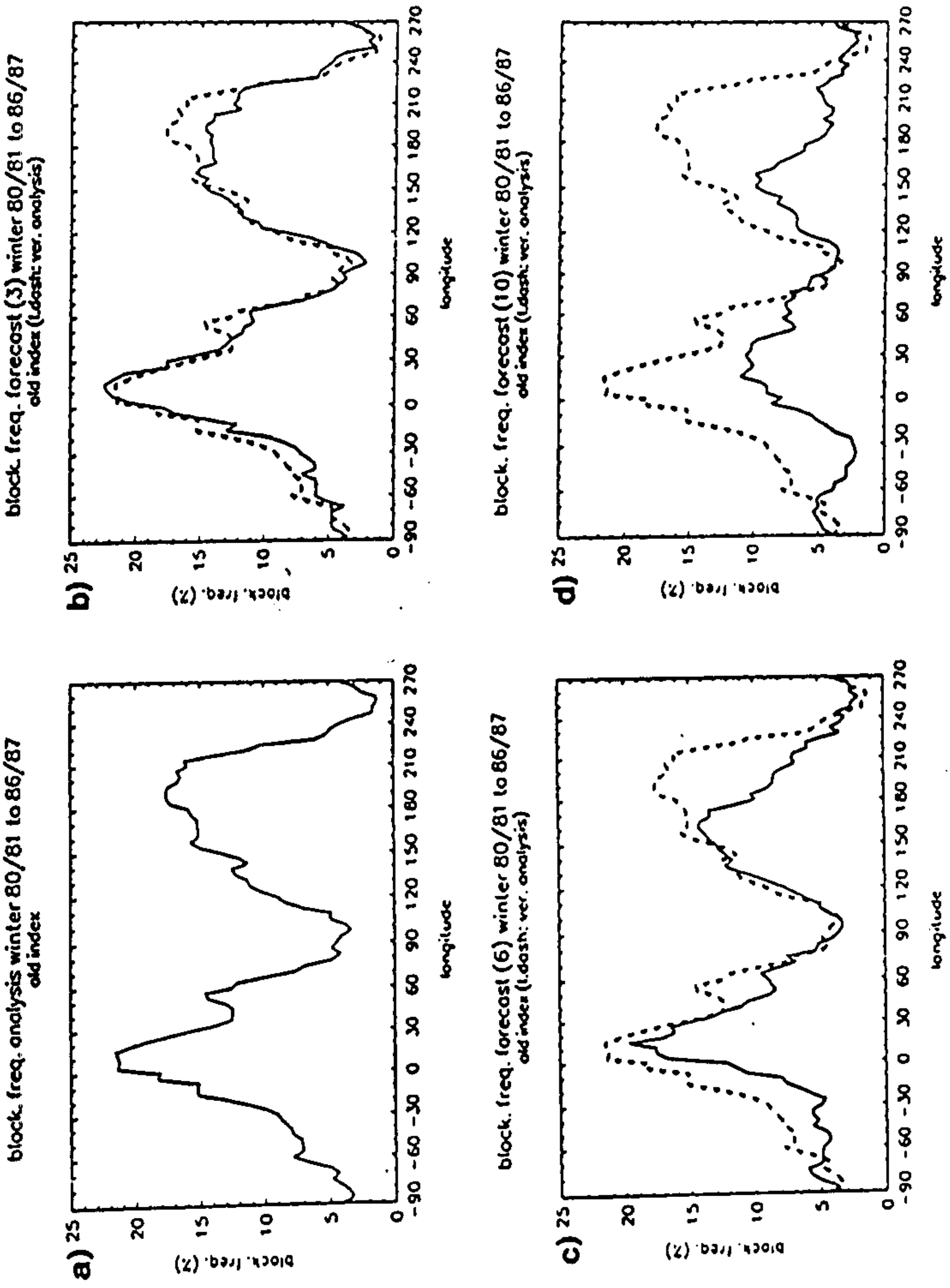

50-59
60-69
70-79
80-92
blocking frequency (%)
longitude
0.00
0.05
0.10
0.15
0.20
0.25
0.30
-90
0
90
180
270
a
b
c
d

Fig 1



a) block. freq. analysis winter 80/81 to 86/87
old index
b) block. freq. forecast (3) winter 80/81 to 86/87
old index (l.dash: ver. analysis)
c) block. freq. forecast (6) winter 80/81 to 86/87
old index (l.dash: ver. analysis)
d) block. freq. forecast (10) winter 80/81 to 86/87
old index (l.dash: ver. analysis)
block. freq. (%)
longitude

Fig 2

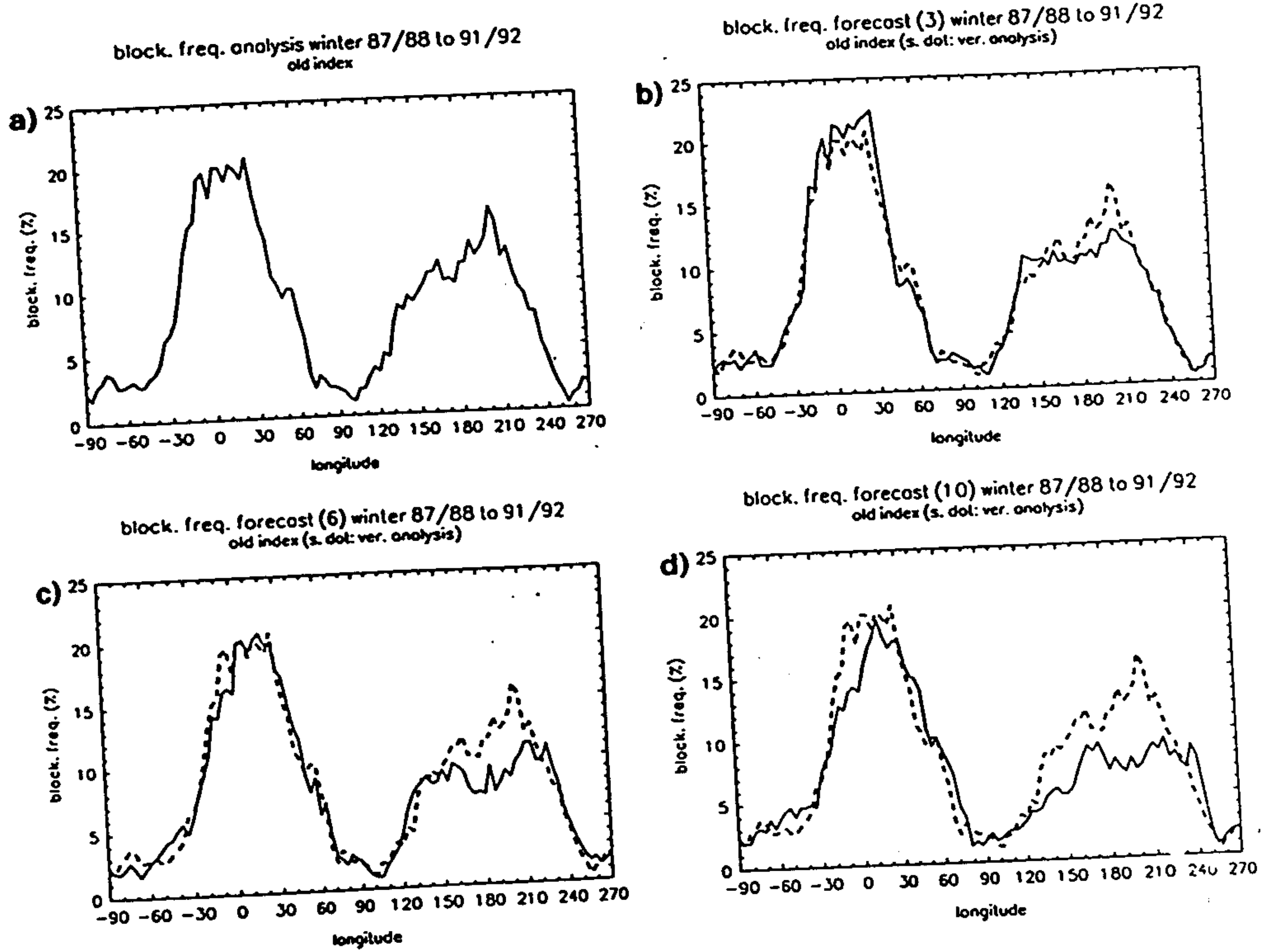

a)
block. freq. analysis winter 87/88 to 91/92
old index
block. freq. (%)
longitude
b)
block. freq. forecast (3) winter 87/88 to 91/92
old index (s. dot: ver. analysis)
block. freq. (%)
longitude
c)
block. freq. forecast (6) winter 87/88 to 91/92
old index (s. dot: ver. analysis)
block. freq. (%)
longitude
d)
block. freq. forecast (10) winter 87/88 to 91/92
old index (s. dot: ver. analysis)
block. freq. (%)
longitude

Fig 3

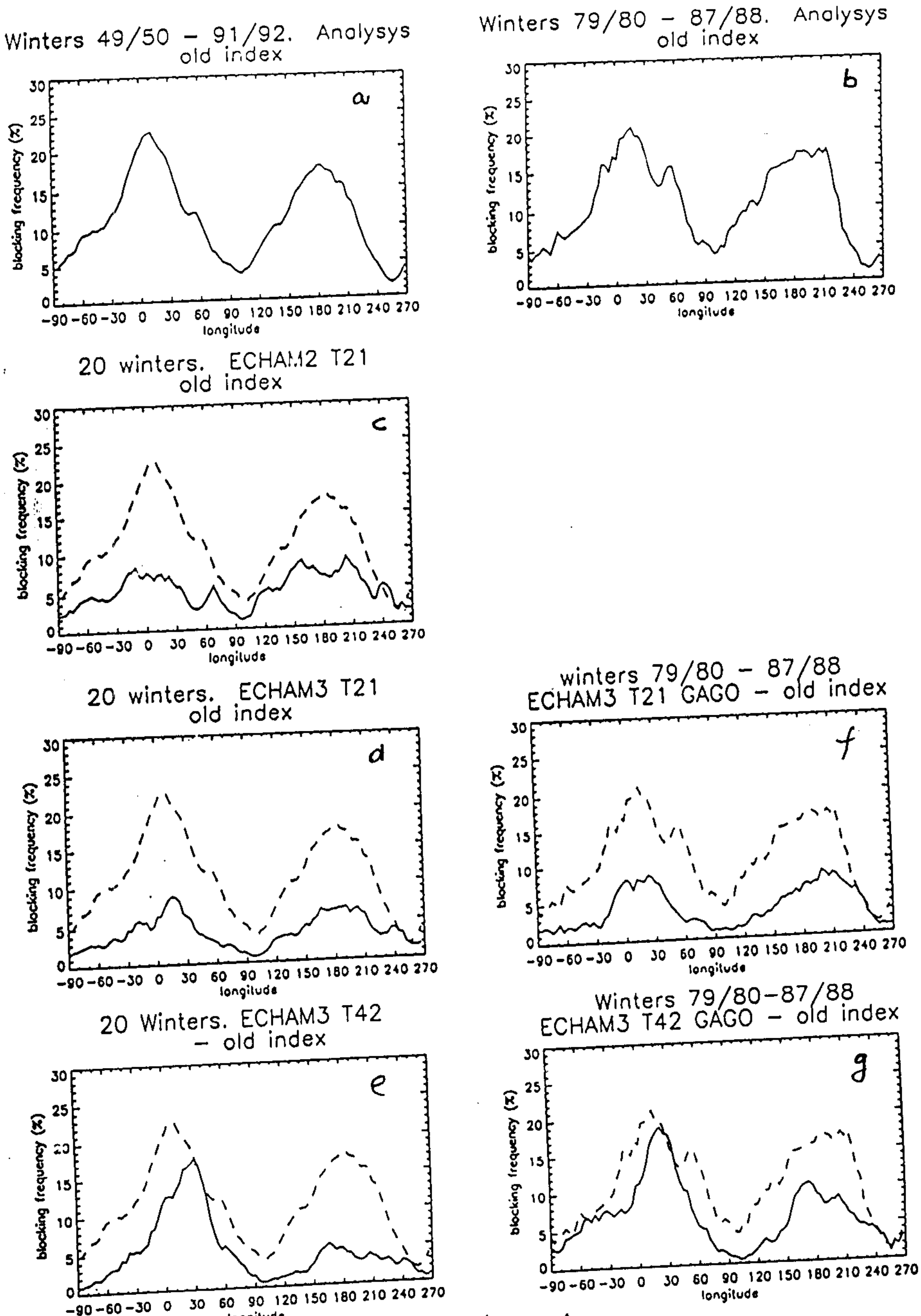

Winters 49/50 – 91/92. Analysys
old index
a
blocking frequency (%)
longitude
Winters 79/80 – 87/88. Analysys
old index
b
20 winters. ECHAM2 T21
old index
c
20 winters. ECHAM3 T21
old index
d
winters 79/80 – 87/88
ECHAM3 T21 GAGO – old index
f
20 Winters. ECHAM3 T42
– old index
e
Winters 79/80–87/88
ECHAM3 T42 GAGO – old index
g

Fig 4