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A COMPARISON OF BLOCKING CLIMATOLOGIES FOR SOUTHERN HEMISPHERE BETWEEN NCEP-NCAR REANALYSIS AND HADLEY CENTRE MODEL

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1. INTRODUCTION

To a large extent, the South American middle latitudes climate is controlled by a sequence of disturbances traveling from the southern Pacific Ocean, with period of varying precipitation count alternating with dry periods ranging from the week up to the month scales. Sometimes, this pattern can be disrupted by a temporary change to a situation of predominantly meridional flow (Barry and Chorley, 1998). The meridional circulation favours the formation of strong slow-moving or stationary anticyclones at high latitudes (blocking highs), often accompanied by slow-moving or stationary low-pressure areas at lower latitudes (Treidl et al., 1981). Thus a blocking pattern can be briefly described as an interruption of the normal west-to-east flow at middle and high latitudes.

Blocking episodes in the Southern Hemisphere (SH) are characterized by persistent anticyclones, centred on the 60°S latitudinal belt, and they are important because they induce large meridional displacements of synoptic scale transient eddies (Taljaard, 1972; Trenberth, 1986b and Sinclair, 1996). It has been shown that blocking episodes can induce adverse prolonged atmospheric conditions inducing drought under the anticyclone region and floods in the equatorial and polar flank of the same (Knox and Hay, 1984). Studies of SH blocking have show that blocking episodes are located: a) on the Australian and New Zealand sector, b) over the southwestern and southeastern Pacific, c) over the south Atlantic and (d) Indian Ocean (Marques, 1996, Sinclair, 1996; Marques et al, 2001 and Wiedenmann et al. (2002). Thus, objective circulation indices criteria became frequent (Lejenas e Okland, 1983; Trenberth et al., 1983; Lejenas, 1984; Trenberth, 1986a; Tibaldi e Molteni, 1990; Tibaldi et al., 1994; Marques, 1996; Marques e Rao, 1999/2000 and Trigo et al., 2004). This work has two main objectives, a) develop a comprehensive study of 40-yr blocking climatology for the SH using circulation indices similar to those used for the NH in Tibaldi et al., (1990/1994) and Trigo et al. (2004), b) to make a comparison of blocking episodes for the Southern Hemisphere obtained with the NCEP/NCAR reanalysis and the Hadley Centre model (HadCM3)

2. DATA AND METHODOLOGY

The datasets used in this study are from (NCEP-NCAR) reanalysis for the 1960-2000 period, and output from the Hadley Centre model (HadCM3) for the same period. The geopotential height at 500 hPa was extracted from the NCEP/NCAR

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(HadCM3), with a 2.5° lat by 2.5° long (2.5° lat by 3.75° long) grid, for the entire SH.
The diagnostic of the blocking is compiled in this study referring to events number, duration and onset location. Here, our study has been carried out using the “standard” methodology developed by Tibaldi et al., (1990, 1994), and extended recently by Trigo et al. (2004) for the NH. The same methodology was applied to the SH in Mendes et al (2005). Therefore, two 500hPa geopotential height meridional gradients GHGS (south) and GHGN (north) are evaluated for 2.5º (3.75°) long intervals over the entire SH, for the NCEP data (HadCM3 data):

$$\mathrm{GHGS} = Z(\lambda,\phi_S) - Z(\lambda,\phi_{02}) \quad (1)$$

$$\mathrm{GHGN} = Z(\lambda,\phi_{01}) - Z(\lambda,\phi_n) \quad (2)$$

Where ϕ_n = 40°S +Δ, ϕ_{01} = 55°S +Δ, ϕ_{02} =

50°S +Δ, ϕ_s = 65°S + Δ and Z *(λ,ϕ)* is 500 hPa geopotential height at longitude λ and latitude ϕ. The “Δ” is one latitudinal interval between 0° and -10°. Then, following the procedure developed by Tibaldi et al (1990,1994), a given longitude is defined as “blocked” at a specific instant if the following conditions are satisfied for at least one value of the Δ:

a) GHGN > 0 and b) GHGS < -10 m.

Taking into account previous studies for the SH the characteristics and climatology of the blocking episodes were calculated for each domain region shown in Figure 1, i.e. we applied the defined rules within the limits that characterize each sector for the entire SH. The sectors are: (A1) Southwestern Pacific (180°W to 120°W), (A2) Southeastern Pacific (120°W to 80°W), (A3) South Atlantic (80°W to 10°E), (A4) Indian Ocean (10°E to 100°E) and (A5) Oceania (100°E to 180°E).

Then a sector is considered to be blocked, on a particular day, if three or more adjacent longitudes within its limits are blocked. These criteria are sufficient to define a local (space) blocking pattern. However, a true synoptic blocking requires a certain time persistence of the events. The typical duration of blocking episodes varies between 5 and 30 days (Treidl *et al.*, 1981; Tibaldi and Molteni, 1990). Here, we adopted a threshold of 5-day consecutive condition of blocking, defined by equations 1 and 2.

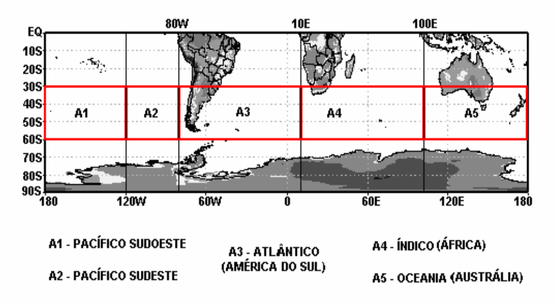


Figure 1 – Longitudinal distribution of the studied areas. The blocking area is represented by the red squares.

3. RESULTS AND DISCUSSION

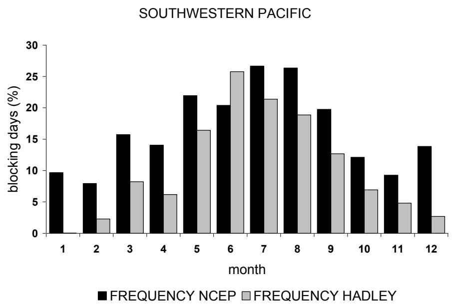
The performance of the simulations of the Hadley Center model is analyzed making a comparison between standard deviation, variances, bias and the root mean square (rms) error with relation to the reanalysis data) applied to each area of Fig.1. The standard deviation is higher in the observations than in the model for all regions. The rms and bias show that the HadCM3 model presents a better agreement in the months of winter over SW Pacific in comparison with other regions and summer (table 1).

	PSO		PSE		ATL		IND		OCN	
Month	Win	Sum	Win	Sum	Win	Sum	Win	Sum	Win	Sum
σ_m	6.78	5.33	6.78	4.67	5.23	4.16	5.03	4.01	5.91	4.34
σ_o	14.72	12.16	15.18	12.01	13.47	10.94	13.62	11.30	13.47	12.02
V	0.212	0.192	0.201	0.151	0.150	0.144	0.136	0.125	0.192	0.130
E	0.166	0.243	0.225	0.235	0.159	0.192	0.204	0.187	0.236	0.235
B	0.101	0.148	0.208	0.138	0.270	0.008	0.167	0.062	0.214	0.159

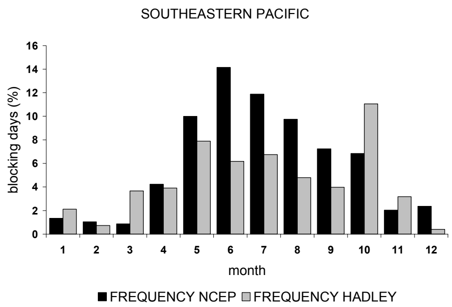
Table 1- Statistical index of the variances, bias binding and the rms of 500 hPa geopotencial height, extracted from the HadCM3 model and NCEP/NCAR reanalysis. The statistical indices were applied to winter (June, July and August) and summer (December, January and February).

During the 41 years studied (1960 to 2000), within the SH, the blockings concentrated (in all seasons of the year) between the longitude of 180°W and 80°W and between 100°E and 180°E. This region of maximum blocking activity over the Pacific Ocean seems to be associated with the presence of maximum velocity of the west wind in the polar and subtropical sectors (polar and subtropical jets) at high levels (Trenberth, 1984 and Trenberth and Mo, 1985).

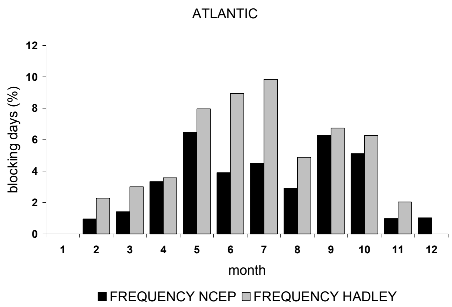
These results were also found by Marques (1996), Marques et al (1999) and Renwinch (2005). The frequency of blocking episodes presented a strong seasonal variation (Figure 2). The higher frequency of blockings occurred in the winter and early spring (from June to September), coherent with results of other authors: e.g. Marques (1996/1999), Sinclair (1996) and Wiedenmann et al (2002). The fact that the blockings occur more often during the months of June to September, somehow seems to be associated with the most intense meridional thermal gradient observed at this time of year and the northernmost position of the polar and subtropical jets. In winter the subtropical jet reaches its maximum intensity over South America. In the summer, the subtropical jet practically disappears, prevailing, thus, the polar or extratropical jet to the south of South America (Pezzi and Cavalcanti, 1994).



(a)

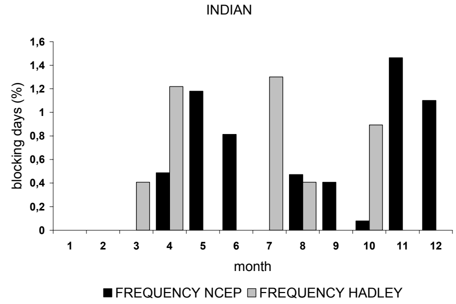


(b)

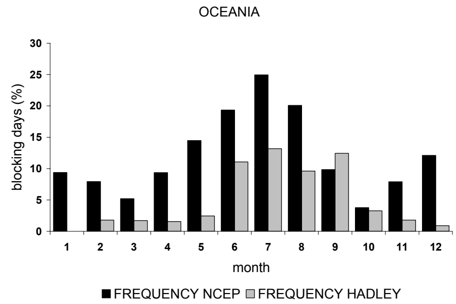


(c)

Figure 2 - Monthly distribution of the blocking days frequency from the HadCM3 (gray) and NCEP reanalysis (black) for the areas of (a) Pacific Southwestern and (b) Southeastern, (c) Atlantic, (d) Indian and (e) the Oceania.



(d)



(e)

Figure 2 – Continuation.

The model monthly variability is similar to the reanalysis in the SW and SE Pacific, and Oceania. However, the model underestimates the blocking days over SW/SE Pacific and Oceania, in some months. In the Atlantic and Indian regions, the overestimation by the model is very high. Considering the interannual variability of blocking events (**Fig. 3**), it is possible to notice that the HadCM3 model presents less blocking frequency, in comparison with reanalysis, on the Southwestern and Southeastern Pacific, and Oceania. The HadCM3 model reveals adequate for the Indian Ocean, with very little activity of the blocking in this region. On the South Atlantic Ocean the number of events is greater than in NCEP/NCAR reanalysis.

Similar to the reanalysis, the model simulates higher blocking frequency in El Nino years (blue column) than in La Nina years (green column), Fig.3. This relation was analyzed by Renwick and Revell (1999) who discussed the connection between blocking over South Pacific Ocean and anomalous convection in the tropics, during ENSO. Rutllant and Fuenzalida (1991) also found an increase of blocking over

Southeastern Pacific during El Nino. An increase of blocking days over South Pacific during El Nino, mainly in the S.H. Spring and Summer (mature El Nino) was also documented by Renwick (1998).

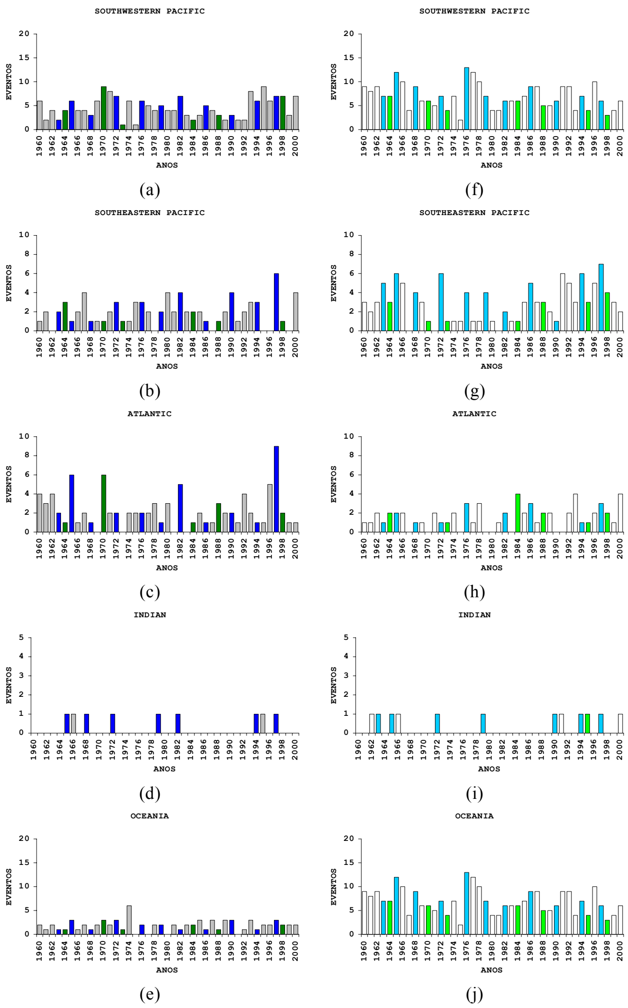


Figure 3 - Interannual variability of the total blocking events from the HadCM3 model (a, b, c, d, e) and of reanalysis of the NCEP (f, g, h, i, j) for Southwestern and Southeastern Pacific, South Atlantic, Indian and Oceania for the period of 1960 the 2000. The columns in blue correspond to El Niño years and the columns in green correspond to La Niña years.

Scatter plots comparing the HadCM3 and NCEP of geopotential height 500 hPa for several points over the Pacific Ocean are shown in Fig.4. This figure clearly shows that the GCM can reproduce the mid-troposphere geopotential height over certain regions of subtropical and middle latitudes, but shows remarkable difficulties in others at high latitude.

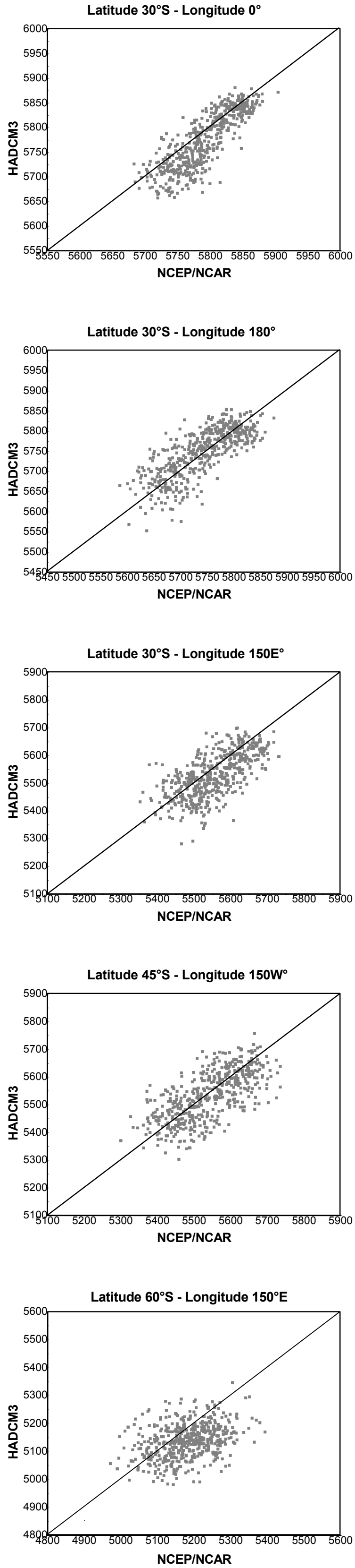


Figure 4 – Scatter plot of the 500 hPa height geopotential comparing grid-point data retrieved from the NCEP and HadCM3 model for several points over the Pacific Ocean.

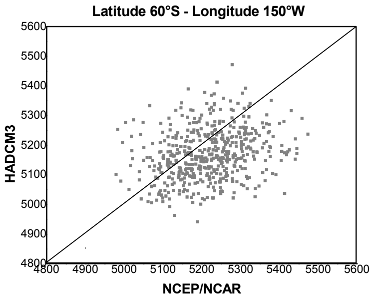


Figure 4 – Continuation.

4. CONCLUDING REMARKS

The HadCM3 model reveals a reasonable capacity to reproduce the seasonal variability of blocking frequency as well as the spatial patterns derived from the NCEP reanalysis. However, it is necessary to provide a more in depth validation of the GCM to reproduce surface and upper level circulation variables (such as SLP or 200 hPa wind flow)

Generally, the HadCM3 is capable of reproducing the most important features of SH blocking episodes:

- ✓ The blocking episodes are more frequent in the winter and less frequent in the summer;
- ✓ The blocking episodes are more frequent in the Pacific sectors and Oceania. In the Atlantic region the model overestimates the observed frequency. The small frequency over the Indian Ocean is well represented by the model.
- ✓

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