17.9 SOUTHERN HEMISPHERE BLOCKING ONSET MECHANISMS ASSOCIATED WITH DIVERGENCE ANOMALIES IN THE UPPER TROPOSPHERE

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1. INTRODUCTION

Atmospheric blocking remains one of the most poorly understood phenomena in meteorology. It was not until recently that Southern Hemisphere (SH) blocking was extensively studied. Most of the SH studies so far have dealt with blocking climatologies and their dynamics in terms of barotropic and baroclinic processes, transient eddies and energy conversions. Furthermore, blocking has also been studied in the context of ENSO to establish interdecadal and internannual variabilities and tropical-extratropical correlations.

The present research is aimed at finding some tropical-extratropical linear links between atmospheric blocking and antecedent upstream divergence anomalies and divergence tendencies. The study first constructs a climatology of blocking for the Southern Hemisphere, and a climatology of divergence for the Southern Pacific (100°E-60°W). Moreover, regions of greater divergence anomalies are defined and, by using a full divergence equation, analyzed divergence tendencies are compared to those numerically calculated, for the blocking episodes selected.

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2. DATA AND METHODOLOGY

A modified Tibaldi index (MTI, Tibaldi et al. 1994) was used to construct a climatology of blocking from the 4-times daily averaged global 500 hPa NCEP-NCAR Reanalysis data geopotential heights for the period 1948-1999. The data were searched for all longitudes meeting the requirements for instantaneous blocking and screened to find blocking systems that spanned twenty or more degrees of longitude and lasted for five or more days. For the climatology of divergence, the data utilized was the NCEP-NCAR daily averaged u-wind and v-wind at 250 hPa for the blocking cases selected. Finally, in the calculation of divergence tendencies the data used was the NCEP-NCAR four times daily u-wind and v-wind, omega (dp/dt) , and geopotential heights at 250 hPa, for the same selected cases.

A vital task in this research is the state of the atmosphere prior to the onset of the blocking events. It was hypothesized that divergence anomalies prior to the formation of the block, and correlated to some extent to ENSO activity, should explain at least partially the formation of these anomalously strong anticyclones. This could be explained by the fact that divergence may locally create anticyclonic vorticity (from vorticity equation) which may be advected by the flow toward the incipient block.

For the purpose of this study, 30 blocking cases were chosen, 10 for each phase of ENSO. Regions of maximum divergence ($\nabla_p \cdot \mathbf{V}_h' > 0$) and convergence ($\nabla_p \cdot \mathbf{V}_h' < 0$)

anomalies were selected for each case and for the pre-block, block and post-block periods. Divergence anomalies were also evaluated in terms of the ENSO phase and their location in the Southern Pacific.

A final step in this project was the study of divergence tendencies, which may connect tropical convection and the onset of blocking. Divergence tendencies ($sec^{-1}(12h)^{-1}$) were calculated for each of the 30 blocking cases using the following full divergence equation derived from the basic equations of motion with pressure as vertical coordinate and neglecting viscous terms:

$$\frac{\partial D}{\partial t} = -V_h \bullet \nabla_p D - \omega\frac{\partial D}{\partial p} + f\zeta_a - u\beta - \nabla_p \omega \bullet \frac{\partial V_h}{\partial p} - DD_1 - 2\left[\frac{\partial v}{\partial y}\right]^2 - 2\frac{\partial v}{\partial x}\frac{\partial u}{\partial y} \qquad (1),$$

where V_h= **V(**u,v) and D_1 (stretching deformation) =(∂u/∂x–∂v/∂y).

Equation (1) is similar to the one proposed by Fankhauser (1974) in an attempt to evaluate the divergence equation and achieve physically realistic results for vertical motion in the upper troposphere. The difference in equation (1) is in the introduction of stretching deformation, the use of ageostrophic relative vorticity and in the horizontal velocities represented by the last two terms.

Analyzed divergence tendencies at a particular time were estimated by the difference in divergence over a 12-hour -interval centered at that time. These were compared to calculated contributions to divergence tendency numerically integrated, using the trapezoid rule, over the 12-hour period centered on that same time.

3. RESULTS

Most blocks identified in previous research efforts (Sinclair, 1996; Marques and Rao, 1999) were selected by the MTI procedure. Tibaldi et al. (1994) established regions of maximum frequency of blocking between 150°E and 70°W. Fig. 1 represents the Southern Hemisphere relative blocking frequency applying the MTI index, with the region of maximum frequency between 160°E and 75°W, the highest values between 120°W and 150°W, and the absolute maximum at approximately 140°W.

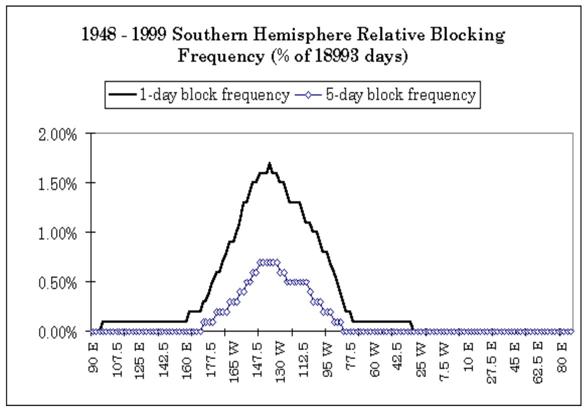

Fig.1 Southern Hemisphere relative blocking frequency applying the MTI index

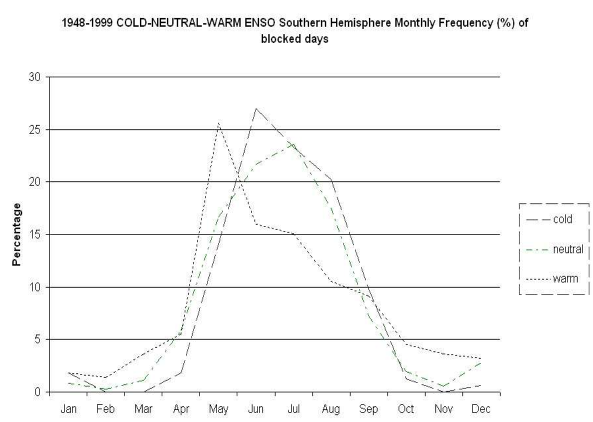

Fig.2 Southern Hemisphere monthly blocking frequency (1948-1999) (% of blocked days)

The region of maximum relative frequency did not change qualitatively whether the conditions for 1-day block frequency or 5-day block frequency were applied. The present study used a 1-day blocking frequency simply because it rendered a higher number of blocking days.

Fig.2 shows the monthly frequency of blocked days for each ENSO phase. The distribution is more homogeneous over a larger number of months during the warm ENSO, with a distinctive maximum frequency in May around 25%. The cold phase has a maximum frequency of blocked days of 27% during June, and for the neutral phase July with 23% is the month with the highest frequency of blocked days.

Four regions of maximum $\nabla_p \cdot \mathbf{V}_h' > 0$ or $\nabla_p \cdot \mathbf{V}_h' < 0$ were found, two in the southern tropical Pacific, from 10°S to 30°S and two in mid-latitudes, from 40°S to 60°S. Anomalies were greater in magnitude during the block stage and during the warm ENSO.

The study suggests that, at least partially, the temporal increase of divergence near the block onset region in some cases was forced by ageostrophic relative vorticity.

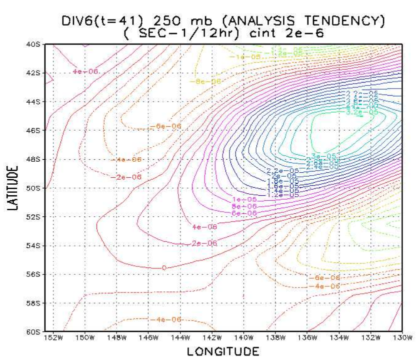

Fig.3 Analyzed divergence tendencies centered at the block-onset at 00Z, September 1st 1968

For example, analyzed divergence tendencies (left-hand side on eq.1) are shown in Fig.3 at the onset of a particular block. The temporal increase in divergence appears to be due in part to the contribution from the $f\zeta_a$ term in eq.1 (Fig.4), or to the presence of cyclonic ageostrophic relative vorticity ($\zeta_a < 0$), considering that $f < 0$ in the SH.

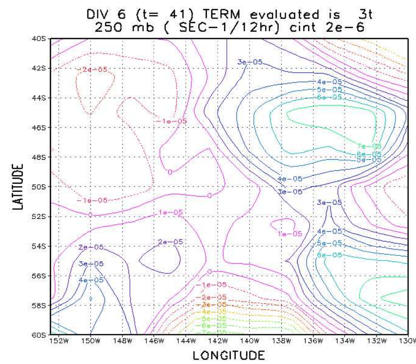

Fig.4 Calculated divergence tendencies centered at the block-onset in Fig.3, showing the contribution from the ageostrophic relative vorticity term.

4. REFERENCES

Fankhauser, J. C., 1974: The Derivation of Consistent Fields of Wind and Geopotential Height from Mesoscale Rawinsonde Data. *J. Appl. Meteor.,* **13**, 637-646.

Marques, R. F. C., and Rao, V. Brahmananda, 1999: A Diagnosis of a Long-Lasting Blocking Event over the Southeast Pacific Ocean. *Mon. Wea. Rev*., **127**, 1761-1776.

Sinclair, Mark. R., 1996: A Climatology of Anticyclones and Blocking for the Southern Hemisphere. *Mon. Wea. Rev*., **124**, 245-263

Tibaldi, S; Tosi, E; Navarra, A., and Pedulli, L, 1994: Northern and Southern Hemisphere Seasonal Variability of Blocking Frequency and Predictability. *Mon. Wea. Rev*., **122**, 1971-1998.