2.5 A POTENTIAL VORTICITY VIEW OF SOUTHERN HEMISPHERE BLOCKING

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1. INTRODUCTION

The vast majority of blocking studies have focused on the Northern Hemisphere (NH), whilst Southern Hemisphere (SH) blocking has received far less attention. Climatology studies (eg Sinclair, 1996) show that SH blocking anticyclones, or 'blocks', primarily occur in the Pacific, to the South and East of New Zealand. Blocking has also been shown to occur less frequently to the south of Africa and South America.

Following the review paper of Hoskins et al. (1985), Shutts (1986) has shown the value of analysing blocks in terms of the Ertel Potential Vorticity on an isentropic surface. Isentropic PV is often used as a diagnostic because it is conserved for frictionless, inviscid flow on an isentropic surface. Moreover, under certain conditions, PV may be 'inverted' to retrieve conventional dynamical fields such as winds and temperature. In isentropic coordinates (x, y, θ), the expression for Ertel PV, P, is

$$P = -g\left(\zeta_\theta + f\right)\frac{\partial \theta}{\partial p} \qquad (1)$$

where g is the acceleration due to gravity, ζ_θ is the vertical component of the relative vorticity on the isentropic surface, f coriolis parameter, θ is the potential temperature and p is the pressure. PV has units of $Km^2s^{-1}kg$, although for convenience, the units of PVU = 10^{-6} $Km^2s^{-1}kg$ will be used. Note also, that although PV is generally negative in the SH, it will be multiplied by –1, so as to appear positive. Since static stability is much higher in the stratosphere, much larger values of PV are found there than in the troposphere, and the PVU=2 surface is considered as a definition for the 'dynamical tropopause'.

2. DATA

This study will make use of the National Centers for Environmental Prediction (NCEP) and National Center for Atmospheric Research (NCAR) reanalyses (Kalnay et al., 1996). The data set contains 2.5° by 2.5° gridded fields of a number of reanalysed variables on isentropic surfaces, including PV, winds and temperature, four times daily from 00z. The data are available on 11 isentropic levels, however, data on the 315K surface is of interest in this study as it lies in the middle to upper troposphere and does not intersect topography in the SH, except for occasionally in the vicinity of the Andes. The NCEP/NCAR reanalyses also contain data on pressure surfaces. Some of these fields, such as geopotential height, will be utilised. Some means of quantities from the NCEP/NCAR reanalyses were obtained from the NOAA-CIRES Climate Diagnostics Center, Boulder, Colorado, USA, via their Web site http://www.cdc.noaa.gov/.

By processing the data with a low-pass filter, the effects of the high frequency transient systems on the PV field are removed. This study will use a 101 weight Lanczos filter as described by Duchon (1979) with a cut-off limit of 10 days.

3. CASE STUDY

In July and August 1999, a large anticyclone formed in the southwest Pacific Ocean. On July 21, it was between longitudes 135°W and 180°W, and was centred near 65°S. It remained in this region, with geopotential height anomalies at 500 hPa of over 300m on all 13 days of the episode. On July 31 the system's peak anomaly was over 350m, but by the following day, it had reduced to just over 150m, before disappearing completely by August 3. Figure 1 shows a plot of geopotential height anomalies for 00Z on July 25 (this anomaly was found by removing the long-term daily mean, using data obtained from the CDC website, as described above). The block is represented by the large positive anomaly to the east of New Zealand. This anomaly is visible over the 13 days of the episode and large anomalies appear at all levels in the troposphere.

On a PV chart (that is, PV plotted on an isentropic surface), blocks appear as large incursions of low latitude, tropospheric air swept along the isentropic surface into high latitudes. Absolute values of PV within the block are relatively low, compared to the air surrounding the block, which is of stratospheric origin and has higher absolute values of PV due to the increased static stability of the stratosphere. Figure 2a shows the 315K low-pass filtered PV field for 00Z on July 25, with values above 2PVU shaded to indicate stratospheric air. Clearly the block appears as a large isolated region of low magnitude PV air. Fields from earlier days (not shown) indicate that this low PV anomaly is in fact tropospheric air from low latitudes that has been entrained into higher latitudes. This observation follows the NH case studies of Hoskins et al. (1985) and Shutts (1986), the former suggesting this indicates a 'conceptual duality' between blocks and cut-off lows.

Following Hoskins et al. (1985) and Shutts (1986), analysis of the time evolution of a blocking system shows the injection of equatorial low magnitude PV air into the block, following the passage of deflected transient synoptic weather system. This interaction between the block and the higher frequency

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components of the field is thought by many to play a major role in influencing the evolution of blocks.

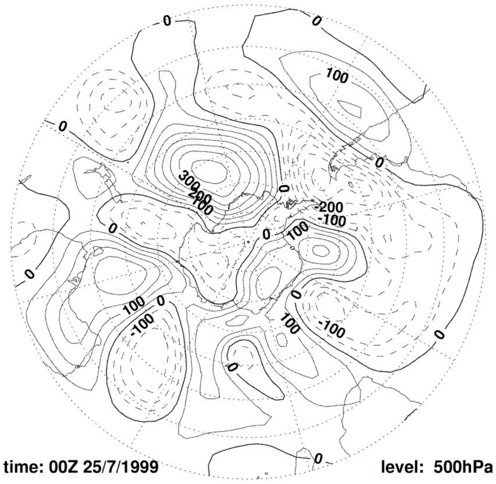

Figure 1: Anomaly of geopotential height at 500hpa for 00Z 25 July 1999. The contour interval is 50m and negative contours are dashed.

If the full, unfiltered field of PV is examined for the same day (figure 2b), such effects of such transient systems become apparent. The low magnitude PV anomaly is no longer cut off from the main region of tropospheric PV at low latitudes and the field is less uniform with smaller scale features. The isentropic wind vectors included on the field of unfiltered PV show the anticyclonic circulation associated with the block. The winds also show how filamentary regions of high PV, corresponding to transient cyclonic systems, are advected equatorward whilst low PV from lower latitudes is injected into the block. By comparing the field of high frequency PV (figure 2c) and figure 2b, it can be seen that on the western side of the block, there is a high-frequency negative PV anomaly (ie tropospheric PV) where the wind is strong and blowing into the block.

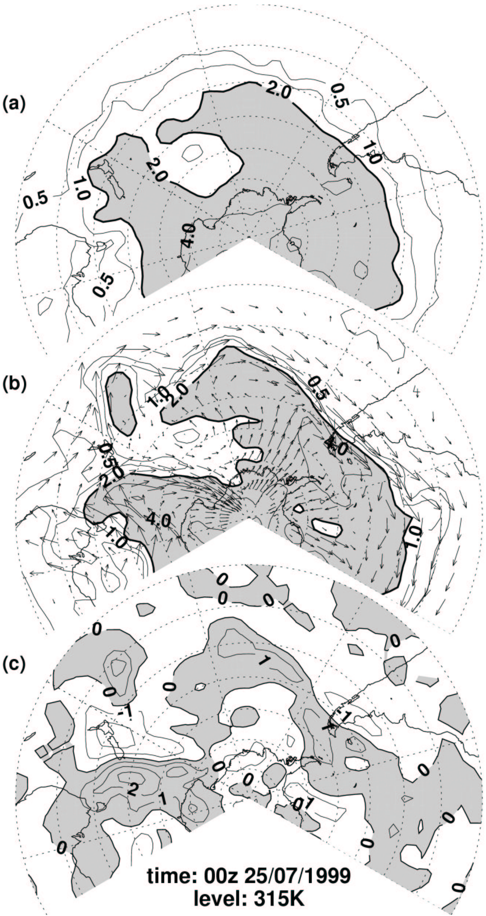

Figure 2: a) Low-pass filtered PV on the 315K surface at 00Z 25 July 1999. Units are PVU (see text) with values above 2PVU shaded. Contours are plotted at 0.5 and 1 PVU, and every 1 PVU thereafter. **b)** As for figure 2a, but unfiltered PV. Vectors are winds on the 315K surface. **c)** High-pass filtered PV on the 315K surface in units of PVU. Positive values are shaded. Contours interval is 1 PVU.

4. CONCLUSIONS

It has been demonstrated, albeit qualitatively, that interactions between a blocking system and transient systems interact to produce an injection of PV into the block. These results extend on and to some degree unify the ideas of Shutts (1986) and Trenberth (1986), whom each observed this behaviour using different techniques. The next stage of this study will be to quantify the processes described here, a task that is currently being completed.

5. REFERENCES

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