17.11 INTERACTION BETWEEN DIFFLUENCE AND POTENTIAL VORTICITY IN A SOUTHERN HEMISPHERE BLOCKING CASE

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1. INTRODUCTION

It is well known from the theoretical studies and observational investigations that locally diffluent flow precedes the onset of blocking. In previous studies carried out by Colucci (2001) , the onset of blocked flow (persistent, large-scale geostrophic easterlies in the mid-latitude middle troposphere) was locally preceded in time by the development and intensification of anomalously negative planetary-scale geostrophic stretching deformation, and this locally decreasing deformation may be thus considered to be a planetary-scale preconditioning for blocking. According to the theory of Shutts(1983), diffluent flow or deformed flow can interact with the vorticity field so as to initiate and maintain the blocking structure.

It would seem that deformation should appear as part of the forcing of geopotential height tendencies or the wind field during block development. Prior to the onset of blocking flow configurations in the atmosphere, a local weakening of the planetary-scale westerlies is often observed, therefore a wind tendency equation can be developed. A diagnostic quasi-geostrophic(QG) equation for geostrophic u-component wind tendency, in which deformation appears as part of a forcing function, is applied to the onset of a blocking episode during August 1988 over the southeast Pacific, to examine the interaction between diffluence and potential vorticity.

2. DATA AND METHODOLOGY

The selected blocking case for the present study occurred during August 1988 over the southeast Pacific, and the blocking onset took place on 15 August over the region of 40°S~60°S, 112.5°W~92.5°W. The quasi-geostrophic height tendency equation from Colucci(2001) is as follows:

$$\{\nabla_p^2 + f_0^2 \frac{\partial}{\partial p}(\frac{1}{\sigma}\frac{\partial}{\partial p})\}(\frac{\partial z}{\partial t}) = -(\frac{f_o}{g})\vec{V}_g \cdot \nabla_p q \qquad (2.1)$$

where $q = (\frac{g}{f_0})\nabla_p^2 z + f + f_0 g \frac{\partial}{\partial p}(\frac{1}{\sigma}\frac{\partial z}{\partial p})$ is the quasi-geostrophic potential vorticity.

Multiplying (2.1) by $-(\frac{g}{f_0})$ and differentiating with respect to y, a diagnostic quasi-geostrophic(QG) equation for the tendency of the geotrophic u-component wind $[u_g = -(\frac{g}{f_0})\frac{\partial z}{\partial y}]$ can be written as follows, in terms of quasi-geostrophic potential vorticity and deformations (shearing deformation and stretching deformation) :

$$\{\nabla_p^2 + f_0^2 \frac{\partial}{\partial p}(\frac{1}{\sigma}\frac{\partial}{\partial p})\}(\frac{\partial u_g}{\partial t}) = \vec{v}_g \cdot \nabla_p(\frac{\partial q}{\partial y}) + (\frac{\partial u_g}{\partial y})(\frac{\partial q}{\partial x}) + (\frac{\partial v_g}{\partial y})(\frac{\partial q}{\partial y}) \qquad (2.2)$$

The first forcing term is the advection of meridionally nonuniform potential vorticity field, such that the advection of poleward increasing anticyclonic potential vorticity would locally force increasing geostrophic easterlies; the second and third forcing terms represent the interaction of shearing deformation and stretching deformation, respectively, with the potential vorticity field. The diagnostic QG wind tendency equation was solved by numerical relaxation for the contributions to geostrophic u-component wind tendency($\frac{\partial u_g}{\partial t}$) from individual forcing function on the RHS of equation. The forcing function and other quantities were calculated from the National Centers for Environmental Prediction (NCEP)-National Center for Atmospheric Research (NCAR) daily average reanalyses of Southern Hemisphere temperatures and geopotential heights (Kalnay et al. 1996) at 10 vertical levels (P=1000, 925, 850, 700, 600, 500, 400, 300, 200, 100) on a 2.5° lat by 2.5° long grid. Calculations were performed at 12-h intervals (0000UTC and 0012UTC) during the period 9-18 August. The instantaneously calculated wind tendencies, at 12-h intervals, were integrated over consecutive time periods to yield calculated 12-h changes in the geostrophic u-component wind . These were then compared to the analyzed changes in u_g over each 12-h period.

3. RESULTS

Fig.1 is the 500-mb geopotential height analyses on blocking onset date 15 August 1988. The blocking onset region is outlined on map.

The calculated and analyzed geostrophic u-component wind tendencies over consecutive 12-h intervals during the period of interest, averaged over the blocking onset region, are presented in Fig.2.

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It shows that the calculated and analyzed u-component wind changes agree qualitatively at each interval, except on 11 August, but generally the magnitudes of calculated changes are smaller compared to analyzed ones. The differences may be due to non-quasigeostrophic processes neglected in the derivation of QG wind tendency equation as well as to numerical errors. In both the calculations and analyses, the weakening westerly geostrophic flow ($u_g > 0$) or increasing easterly flow($u_g < 0$) reaches the largest time rate of change in magnitude just prior to blocking onset.

The calculated geostrophic u-component wind tendencies, due to individual forcing terms, namely, meridional potential vorticity advection forcing, shearing deformation forcing and stretching deformation forcing, over consecutive 12-h intervals, averaged over the blocking onset region, are presented in Fig.3. Apparently, contribution due to meridional potential vorticity advection forcing is dominant compared to other terms, and forces geostrophic u-component wind to reach its largest negative time rate of change on 13 August. Regarding the two deformation terms, the stretching deformation forcing has a comparable impact on u-component wind tendency compared to meridional potential vorticity advection forcing, and during the preconditioning blocking period(9-14 August), the u-component wind tendency due to this term is persistently negative, which means the stretching deformation forcing contributes to anomalously enhanced diffluent flow, which in turn results in the weakening westerlies or increasing easterlies. Furthermore, the shearing deformation forcing also plays an important role on forcing weakening westerlies or increasing easterlies, especially on one day prior to blocking onset, in which the geostrophic u-component wind tendency has a largest negative value, approximately -2.5m/s per 12hr.

Fig.1 500-mb geopotential height analyses(m) on blocking onset date 15 August 1988 . The blocking onset region is outlined over 40°S~60°S,112.5°W~92.5°W

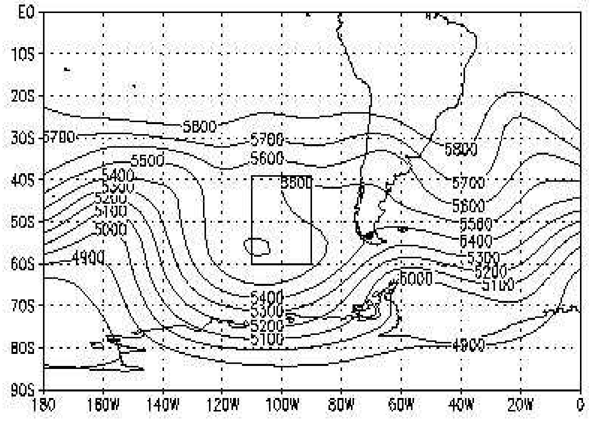


Fig.2 Comparison of calculated and analyzed geostrophic u-component wind tendencies (m/s per 12hr) averaged over blocking onset region during August 1988 blocking episode.

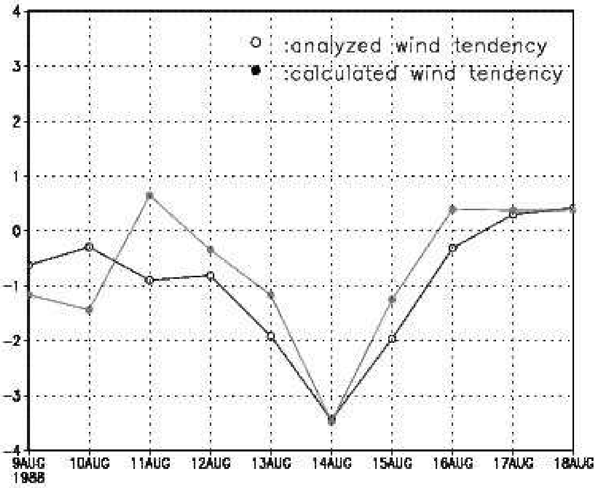
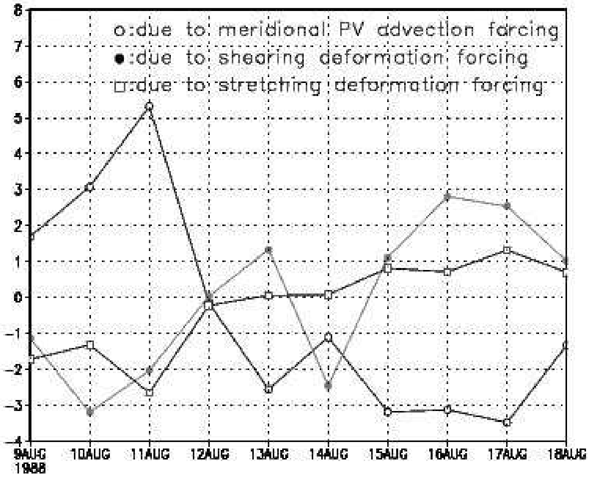


Fig.3 Comparison of each calculated geostrophic u-component wind tendency (m/s per 12hr) due to individual forcing term during August 1988 blocking episode.



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