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Numerical Simulation of Atmospheric Blocking and the Analysis of Potential Vorticity using a Simple Barotropic Model

by

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In this study, we conducted a series of numerical experiments to investigate atmospheric blocking, using a simple barotropic model that featured a wavemaker derived by a theory of baroclinic instability. The model has a resolution equivalent to R20 and consists of only five physical processes: baroclinic instability as the wavemaker, topographic forcing, biharmonic diffusion, zonal surface stress, and Ekman pumping. Synoptic waves excited by the wavemaker have a realistic structure and growth rate as observed in the real atmosphere.

Results from long-term integrations show quite reasonable climatology of the model atmosphere. We have demonstrated that realistic and persistent dipole blockings can be simulated by the present model (see Fig. 1), showing a reasonable life-cycle (See Fig. 2). The analysis of potential vorticity (PV) indicates that the onset of blocking is brought by a Rossby wave breaking induced by baroclinic instability. The overturning of high and low PVs tends to occur at the stationary topographic ridge. Once a block is formed by the Rossby wave breaking, subsequent Rossby waves undergo meridional stretch, blocked by the blocking (see Fig. 3). The stretched wave at the western flank of the blocking then breaks down, depositing low PV at the north and high PV at the south of the blocking system. Therefore, the maintenance of the blocking is characterized by the eddy straining mechanism.

We demonstrated that the amplification of synoptic disturbances by baroclinic instability is essential both for the onset of blocking by the Rossby wave breaking and for the maintenance by the eddy straining mechanism.

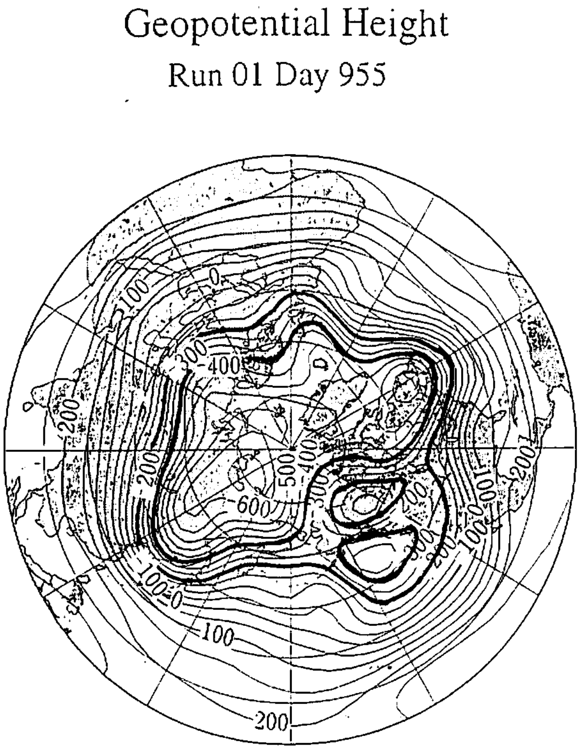

Figure 1. Geopotential height (unit: m, interval: 50 m) for pronounced blockings appeared in the Pacific sector on day 955.

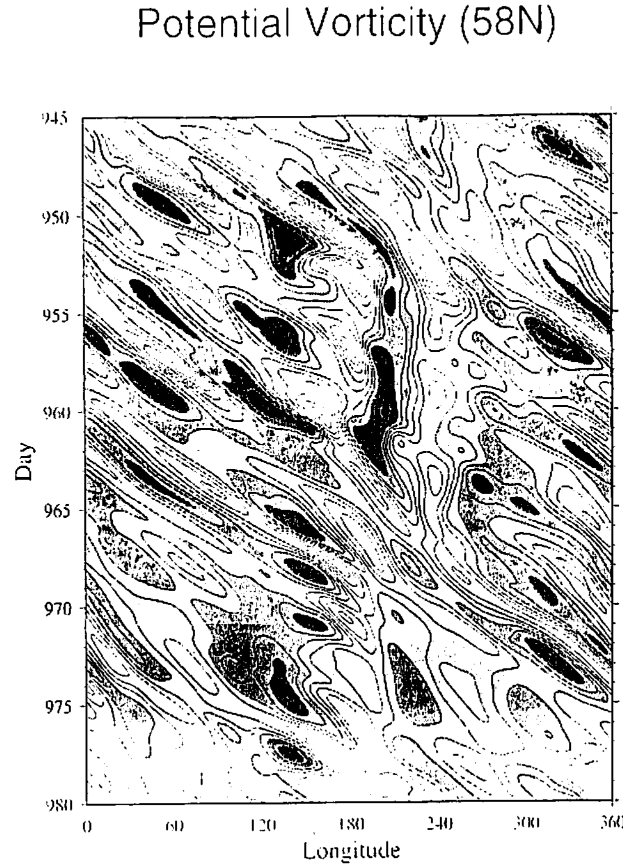

Figure 2. Longitude-time section of potential vorticity q (PV units. interval: 15 PV) along 58°N during days 945 to 970.

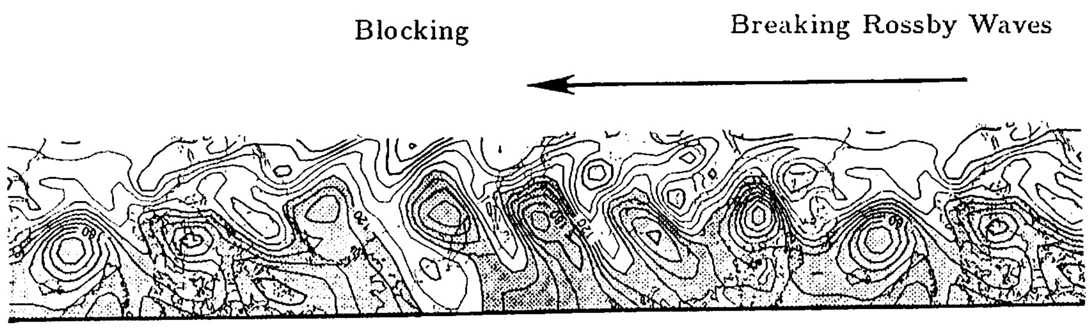

Figure 3. Breaking Rossby waves against the blocking system, drafted from the distribution of PV for day 79. Ordinate and abscissa are the latitudes (70~20°N) and longitudes (360~0°E), respectively, in descending order. The contours of PV are in the units 10^{-10} $m^{-1}s^{-1}$. The high PV in polar region exceeding the value of 120 is hatched.