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An eddy-feedback mechanism for the maintenance of atmospheric blocking

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Atmospheric blocking is a stationary coherent dipole-eddy with an anticyclone (blocking-high) centered to the north of a cyclone (blocking-low) in the westerly jetstream at mid-latitude, and has the recursiveness and persistency. Blocking is the phenomenon that the dynamical mechanism is not succinctly understood although they appear in simple dynamical models such as that of the quasi-geostrophic shallow-water equations, so it should be studied by the approach from the geophysical fluid dynamics.

About the notable persistency of blocking, in its dynamics, many studies have been devoted to the maintenance mechanism after the work of Green (1977) in which a feedback mechanism in the system between blocking and synoptic eddies (migrating highs and lows) is proposed. Hereafter, it is called the eddy-feedback mechanism. In this manner, Shutts (1983) particularly discussed about the essential points of the eddy-feedback mechanism by using both an analytical method and simple numerical experiments, and proposed the Eddy Straining Mechanism (hereafter referred to as ESM). It is the mechanism that synoptic eddies strained in the north-south direction by blocking provide negative/positive vorticity to a blocking high/low and this vorticity forcing, i.e., the second-order flow maintains the blocking dipole structure against dissipation such as friction. Some recent studies, however, showed that the ESM can act efficiently only when the eddies or the stormtrack which corresponds the ensemble-behavior of eddies satisfies some specific conditions that is difficult for the persistent periods of blocking in the real. Then, we propose and consider a more realistic eddy-feedback mechanism alternative to the ESM.

The eddy-feedback mechanism is based on the following two views in terms of potential vorticity (PV), which is a conserved quantity in a frictionless and adiabatic atmosphere. The first is to grasp the maintenance mechanism as the supply mechanism of anticyclonic/cyclonic PV air to a blocking high/low, and the second is the vortex-vortex interaction mechanism that an eddy actively attracts and absorbs one with the same polarity selectively, whereas separates one with the reverse polarity. The latter is essentially the same as the 'Fujiwhara-effect' or the 'beta-drift' but the more quantified mechanism by the use of PV. In this mechanism, a blocking anticyclone (cyclone) actively and selectively absorbs synoptic eddies with the same polarity, and then makes a feedback system by reinforcing its own persistence. The heart of this mechanism is the vortex-vortex interaction so it is a different mechanism from the ESM. The difference between these two mechanisms can also be discussed from the mathematical formulations (Yamazaki and Itoh 2009). In this study we verify our proposed mechanism by conducting a numerical experiment with some different conditions.

Using the nonlinear equivalent-barotropic PV equation model as Shutts (1983), the effectiveness of our mechanism is investigated. In this mechanism, a blocking could persist not depending on some valiabilities of stormtrack. As an experimental design, the blocking flows as modon solutions are put on the center of the model-domain. Experiments are performed for the following 3 cases; i) there is no stormtrack, ii) the stormtrack is put on the same latitude as the blocking center (the center latitude of the domain), and iii) the stormtrack is put on the latitude of 1,000 km south of the blocking center, which is too large variability for the ESM to acts effectively. The results show that, on both a beta-plane channel and sphere, our eddy-feedback mechanism effectively works to maintain the blocking without depending on the characteristics of stormtrack (synoptic eddies).

Keywords: Atmospheric dynamics, Low-frequency valiability, Synoptic-scale meteorology, atmospheric blocking, nonlinear, Tropospheric Science