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Mechanism of vortex movement in environmental vorticity gradient and its estimation

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Yamazaki and Itoh(2013) proposed SAM(selective absorption mechanism) as the maintenance mechanism of the blocking which is known as quasi-steady state of the atmosphere. The essence of SAM is vortex-vortex interaction and the blocking can subsist for a prolonged period by absorbing eddies of the same polarity. The movement of tropical cyclones and mid-latitude cyclones have also been investigated by vortex-vortex interaction (e.g. Fiorino and Elsberry, 1989; Oruba et al., 2012). Also, it has been indicated that the key parameters of vortex movement are the absolute vorticity gradient of the environment, the radius of vortex and its strength (e.g. DeMaria, 1985; Chan and Williams, 1987), but these researches remain at a posteriori argument of the results of the numerical simulations. In this study, we conducted numerical simulations using variety of combinations of these parameters by means of two-dimensional nondivergent barotropic model. Besides, we investigated the mechanism of the vortex movement by vortex-vortex interaction and evaluated it quantitatively.

It was found that the time-development of the vortex movement is divided into two periods with different features: the acceleration regime at the initial stage and the vortex pair translation regime with quasi-steady movement. In each regime, the vortex excites characteristic vorticity field around it and the vortex movement showed different dependence on the parameters. While the vortex slightly rotates and deforms the background field in the acceleration regime, another prolonged vortex with opposite sign appears in the eastside of the original vortex in the vortex pair translation regime.

In the acceleration regime, we evaluated the acceleration by applying directly the concept of SAM and obtained the results that the movement velocity is proportional to the product of the absolute vorticity gradient, the circulation of the vortex and the elapsed time. In the vortex pair translation regime, the velocity of the vortex movement can be evaluated by a few number of the parameters which characterize the counterrotating vortex beside, considering the mechanism of the vortex pair propagation. As a result, it is shown that the velocity is proportional to the product of the two-thirds power of the circulation of the vortex and the one third power of the planetary vorticity gradient. These estimations represent the dependence of the each-period velocity on the parameters well, and we succeeded in clarification of the physical effect on the vortex movement by the parameters and estimation of the vortex displacement.

We evaluated these parameters of the experiments for the effective beta and revealed that the difference of the influence of the planetary vorticity gradient and the relative vorticity gradient on the vortex movements results in the shear of the background flow, which has not clearly shown by previous researches.

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