The Reynolds Stress Produced by Accumulation of Axisymmetric Oceanic Eddies

*青木 邦弘[1]、升本 順夫[1]
*Kunihiro Aoki[1], Yukio Masumoto[1]

1. 東京大学大学院理学系研究科地球惑星科学専攻
1. Department of Earth and Planetary Science, Graduate School of Science, the University of Tokyo

The aim of this study is to analytically reveal a fundamental nature of the horizontal Reynolds stress caused by axisymmetric mesoscale eddies widely populated in the ocean. To accomplish our objective, we consider an idealized model, in which the eddies having the same amplitude emerge with probability whose horizontal distribution follows a two-dimensional Gaussian function corresponding to the number of eddies observed at a location during a certain period. We examine the Reynolds stress by decomposing into isotropic component equivalent to eddy kinetic energy and anisotropic component. The result shows that the isotropic component dominates near a site of the highest probability, while the anisotropic component becomes large as increasing distance from the location of the highest probability. This feature can be interpreted as isotropization of velocity field associated with eddies that intensively occurs near the region of the highest probability. The degree of isotropization depends on a horizontal scale of eddy relative to that of the probability distribution: an area of isotropy expands (shrinks) as the scale of the probability distribution becomes large (small) under the same eddy size. Application to a condition near a mid-latitude oceanic jet, such as the Kuroshio extension region, indicates that this Reynolds stress, resulting from incompleteness of isotropization, contributes to deceleration and acceleration of the jet in its upstream and downstream regions, respectively, This pattern is consistent with stabilization and destabilization of the jet due to eddy-mean flow interactions in these two regions. The Reynolds stress excited by axisymmetric eddies, however, yields dynamic pressure, which has no contribution to dynamics of incompressible fluid such as quasi-geostrophy, but yields ageostrophic circulation over the jet’s region. This suggests that occurrence of the axisymmetric eddies obscures the Reynolds stress that is meaningful for the dynamics in the real ocean. To eliminate contamination by the axisymmetric eddy in the Reynolds stress, we propose a shape-dependent calculus of the Reynolds stress, which may be applicable to studies on parameterization of eddy influences.

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