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A Generalized Transformed Eulerian Mean (GTEM) description for Boussinesq fluids

Akira Noda
RIGC/JAMSTEC, Yokohama, Japan (nodaa@jamstec.go.jp)

The transformed Eulerian mean (TEM) description has been widely used as a standard basic analysis tool for describing wave-mean flow interactions in geofluid dynamics. However, the TEM has implicitly assumed that the eddy-diffusion tensor is anti-symmetric even though the assumption does not hold in general data analyses. In order to remedy the defect, a generalized transformed Eulerian mean (GTEM) set of equations are derived based on a non-neutral (unstable/dissipative) wave including that excited by the eddy forcing and/or diabatic heating in a Boussinesq stratified fluid. All the nine components of the three-dimensional eddy diffusion tensor are derived in the form that no explicit information of wave frequency and wave number of eddies is required for the application to real atmospheric and ocean data analyses. In the present GTEM, the symmetric part of the eddy diffusion tensor is proportional to the growth rate of the non-neutral wave, and the divergence of the eddy-diffusion tensor acts as a transport velocity. It is shown that the Stokes drift velocity defined in the generalized Lagrangian mean (GLM) description agrees with the divergence of the eddy-diffusion tensor with the matrix components transposed and the sign reversed, so that the direction of the transport velocity induced by the symmetric (anti-symmetric) part is opposite (same) to the Stokes drift velocity. An application to the Eady unstable wave is made to illustrate differences between TEM, GLM and GTEM.