Height-dependent expression for the energy flux of equatorial waves: exact and approximate versions for unified model diagnosis

*Hidenori AIKI[1,2], Fukutomi Yoshiki[1], Yuki Kanno[2], Tomomichi Ogata[2], Takahiro Toyoda[3], Hideyuki Nakano[3]

1. Nagoya University, 2. Japan Agency for Marine-Earth Science and Technology, 3. Meteorological Research Institute

Synoptic scale waves in the atmosphere and ocean play an important role in the teleconnection of tropical and subtropical regions. For mid-latitude Rossby waves in the atmosphere, the expression for the energy flux for use in a model diagnosis, and without relying on a Fourier analysis or a ray theory, has previously been derived using quasi-geostrophic equations and is singular at the equator. A recent analytical study has derived an exact universal expression for the energy flux which can indicate the direction of the group velocity at latitudes for linear shallow water waves (Aiki et al., 2017 PEPS, doi:10.1186/s40645-017-0121-1). This analytical result is extended in the present study to a height-dependent framework for zonally and vertically propagating equatorial waves in the atmosphere. This is achieved by investigating the classical analytical solution of equatorial inertia-gravity waves, Rossby waves, mixed Rossby-gravity waves, and Kelvin waves. Expressions for the horizontal component of the energy flux are similar to each other between the height-dependent framework given by the present study and the height-independent framework given by Aiki et al. (2017), both of which are linked to a scalar quantity associated with the inversion of Ertel’ s potential vorticity (EPV). This EPV- inverted scalar quantity reduces to geostrophic streamfunction for mid-latitude Rossby waves and vanishes for gravity waves, a novel aspect for considering the energy flux. The expression of the vertical component of the energy flux, as given by the present study, requires computation of another scalar quantity based on a three-dimensional Fourier analysis in the combination of a zonal-vertical section and time space. For ease of diagnosis from a model, an approximate version of the universal expression is explored and illustrated for the development of tropical synoptic-scale waves observed in the Indian Ocean–Maritime Continent region during Austral summer.

Keywords: group velocity, tropical-extratropical interaction

