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A new estimation method of the momentum fluxes associated with gravity waves

Tomoki Ohno[1*], Kaoru Sato[1], Shingo Watanabe[2]

[1]The University of Tokyo, [2]JAMSTEC

The momentum flux associated with gravity waves is an important quantity to evaluate their effects on global circulations. As the gravity waves have various sources, it is likely that multiple gravity waves propagating in different directions are usually superposed. In such situation, even if all physical quantities are available, it is difficult to estimate the total momentum flux of gravity waves (i.e., a sum of absolute values of momentum fluxes of respective waves).

In the present study, a new formula was derived to estimate the total momentum fluxes. This theoretical formula contains variances of three dimensional wind and temperature fluctuations and includes neither wavenumbers nor frequencies explicitly. This formula requires that wave fields are decomposed into monochromatic waves and momentum fluxes are overestimated whenever wave fields are not decomposed. Formulas to estimate intrinsic frequencies, horizontal and vertical wave numbers, absolute value of zonal and meridional components of total momentum fluxes are also derived. The momentum fluxes were estimated by applying this formula to a gravity-wave resolving general circulation model data. The model has T213 spectral horizontal resolution and 256 vertical levels extending from the surface to a height of 85 km with a uniform vertical spacing of 300 m in the middle atmosphere (Watanabe et al., JGR, 2008). As no gravity wave parameterization is used, all gravity waves in the model are spontaneously emitted from sources (convections, topographies, instabilities, jet imbalances, etc). Watanabe et al. showed that the model represents realistic general circulation and thermal structure in the middle atmosphere.

Disturbances whose horizontal wavenumbers are greater than 22 are defined as gravity waves. Estimation was made for the following 3 cases whose degree of monochromatic wave assumption at each grid is different. 1) The fluctuations are assumed to be due to a monochromatic gravity wave. 2) The fluctuations can be decomposed only by vertical wavenumbers. 3) The fluctuations can be decomposed by both vertical wavenumbers and frequencies. The differences between the resultant momentum fluxes from 1) and 2) are, though they reach nearly 40% in some region at the lower stratosphere, in the range of about 20% in most regions. The regions in which the difference between the resultant momentum fluxes are the regions in which those are relatively small. The resultant momentum fluxes from 2) and 3) are similar. This means that the resultant momentum fluxes from 2) and 3) can be regarded as true values. These results indicate that the total momentum fluxes can be estimated with about 20% error under the assumption 1).Under the assumption, three dimensional total momentum flux distribution can be obtained with use of time series variances, and three dimensional distributions of other properties (i.e. intrinsic frequencies, horizontal and vertical wave numbers, absolute value of zonal and meridional components of total momentum fluxes) can be also estimated.

Keywords: Gravity wave, High resolution GCM