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Atmospheric gravity waves with small vertical-to-horizontal wavelength ratios

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Governing equations for atmospheric gravity waves with various vertical-to-horizontal wavelength ratios of $O(10^{-3})$–$O(10)$ are investigated through systematic scale analysis for gravity wave perturbations embedded in the quasi-geostrophic large-scale flow. Results of the scale analysis indicate that gravity waves with very small vertical-to-horizontal wavelength ratios of $O(10^{-3})$ can be categorized into an acoustic gravity wave mode given that their total energy is given by the sum of kinetic, potential, and elastic parts. It is found that source terms for the kinetic energies of these waves can be represented by covariances between the horizontal wind perturbations and relative density perturbations terms (e.g., $v'\rho'/\bar{\rho}\partial\bar{p}/\partial y$ for the large-scale geostrophic zonal wind). In the highly baroclinic large-scale flow (i.e., large $\partial\bar{p}/\partial y$), the source terms can also become large. The relative density fluctuation is given by the sum of relative potential temperature and pressure perturbations [i.e., $\rho'/\bar{\rho} = -\theta'/\bar{\theta} + p'/(\bar{\rho}c_s^2)$]. Therefore, the meridional heat fluxes ($v'\theta'$) around the large-scale geostrophic flow with enhanced baroclinicity may contribute to the generation of gravity waves with very small vertical-to-horizontal wavelength ratios. Evaluation of these findings is attempted using the results of a high-resolution global model (Specified Chemistry WACCM) with horizontal resolution of 25 km and vertical resolution of 600 m. This study was supported by research fund PE18020 from Korea Polar Research Institute and funded by the KMA/NMSC's (Korea Meteorological Administration/National Meteorological Satellite Center) project (NMSC-2016-3137).