Beyond Traditional Limits of Gravity-Wave Parameterizations: Unbalanced Mean Flows

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It is common practice in atmospheric models to parameterize gravity waves by pseudo-momentum or Eliassen-Palm flux convergence in the horizontal momentum equation. This approach is justified as long as resolved flow features of interest are in geostrophic and hydrostatic balance (Achatz et al 2017, Wei et al 2018). The present study probes the limits of this 'balanced' approach in a twofold manner. (1) For the case of unbalanced synoptic-scale and planetary-scale flows, e.g. the residual circulation, it is shown that the effect of mesoscale inertia-gravity waves is considerably better captured if (a) the momentum equation is forced by anelastic momentum-flux convergence and an elastic term taking into account the effect of gravity-wave density fluctuations and (b) thermodynamics is supplemented by an entropy-flux convergence term (Wei et al 2018). (2) For the case of subgrid-scale gravity waves in mesoscale-resolving models the theory for the corresponding parameterization is developed. It is shown that gravity waves with scales below the resolution of present-day weather-forecast models can affect the resolved flow, and that their parameterization is possible (Wilhelm et al 2018). In both cases (1) and (2), comparisons between gravity-wave resolving simulations and gravity-wave parameterizing WKB simulations, using an efficient Lagrangian ray-volume technique (Muraschko et al 2015), are used for demonstration. Hence, gravity-wave parameterizations in global and regional models should be modified accordingly.

Key words: gravity waves, vertical coupling, climate modeling, weather prediction, unbalanced mean flows

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