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Forced Gravity Waves and the Tropospheric Response to Convection

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It has been known for some time that gravity waves facilitate atmospheric adjustment to convective heating. Further, convectively forced gravity waves condition the neighbouring atmosphere for the initiation and / or suppression of convection. Despite this, the radiation of gravity waves in macro-scale models (which are typically forced at the grid-scale, by existing parameterization schemes) is not well understood. We present here theoretical and numerical work directed toward improving our understanding of convectively forced gravity wave effects at the mesoscale. Using the linear hydrostatic equations of motion for an incompressible (but non-Boussinesq) fluid with vertically varying buoyancy frequency, we find a radiating solution to prescribed sensible heating. We then interrogate the spatial and temporal sensitivity of the vertical velocity and potential temperature response to different heating functions, considering the remote and near-field forced response both to steady and pulsed heating. We find that the meso-scale tropospheric response to convection is significantly dependent on the upward radiation characteristics of the gravity waves, which are in turn dependent upon the temporal and spatial structure of the source, and stratification of the domain. Moving from a trapped to upwardly-radiating solution there is a 50% reduction in tropospherically averaged vertical velocity, but significant perturbations persist for up to 4 hours in the far-field. Furthermore, we find the tropospheric adjustment to be sensitive to the horizontal length scale of the heating, observing a 20% reduction in vertical velocity when comparing the response from a 10 km to a 100 km heat source. We assess the implications for parameterization of convection in coarse-grained models in the light of these findings and argue that an idealized 'full-physics' nonlinear simulation of deep convection in the MetUM is qualitatively described by the linear solution: departures are quantified and explored.