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Modulation of Internal Gravity Waves by Deep Convective Towers

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Results are presented from the analysis of a reduced model for propagation of internal waves in an atmosphere containing deep convective towers. The model is an extension of the linearized anelastic equations and includes a representation of net effects from tower-scale moist dynamics. Saturated area fraction over the tower-scale in horizontal slices turns out to be the essential cloud-related parameter in the model.

Important results of the analysis include

1. the introduction of a lower cut-off horizontal wave number *in addition* to the well-known upper wave number cut-off arising in the dry dynamics,
2. a reduction of the modulus of group velocity and thus inhibition of wave propagation,
3. reduced vertical flux of horizontal momentum.

As the latter quantity is closely related to gravity wave-drag (GWD), i.e. the force exerted by breaking internal waves on mid-atmospheric flow, the results are potentially interesting for improving parameterization of GWD in global circulation models.

Analytically obtained results as well as numerical simulations are shown to demonstrate the findings, including examples of how orographic wave-patterns change compared to the dry, anelastic model. A compressible code featuring a full bulk micro-physics scheme is employed to confirm some results of the analysis of the reduced model.

The derivation adopts the ansatz from [1]. The ansatz employs as governing equations the conservation laws for mass, momentum and energy for compressible flows together with a bulk micro-physics model. It relies on multi-scale asymptotic techniques to derive a reduced model, capturing only the essential effects for the dynamics of flows on the selected scales. The used time- and spatial scales of 100 s, 10 km correspond to the regime of non-hydrostatic internal waves, while an additional horizontal scale of 1 km resolves variations on the lengthscale of the convective towers. Applying conditional averages to the resulting leading order system yields a closed model for the wave-scale, that includes terms describing the net effects of tower-scale dynamics. The comparatively simple structure of the reduced model allows for a mathematical analysis, including the derivation of the dispersion relation, group velocity and Taylor-Goldstein equation. The derivation and important parts of the analysis can be found in [2,3].

References

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