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A Reduced Model for Nonlinear Interactions of Gravity Waves with Deep Convective Clouds

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Interactions between gravity waves and moisture in the atmosphere are usually investigated by numerically integrating a discretized set of equations for the flow dynamics coupled with some bulk micro-physics model. While this allows to model and simulate effects on a broad range of scales, the complexity of the involved equations makes an analysis by mathematical means very difficult. Reduced models, which are only valid for very specific length and time scales, often have a simpler structure and are much more accessible to mathematical investigation.

Based on the results in [1], a reduced model for the modulation of non-hydrostatic, internal gravity waves by deep convective clouds on short time scales ($\sim$ 100 s) is derived and analyzed in [2]. The derivation relies on multiple scale asymptotic techniques to extract a model for the leading order dynamics on the selected scales from the governing equations. In this case, these are the conservation laws for mass, momentum and energy in compressible flows, coupled with a bulk micro-physics scheme. Because of the short time scale, vertical displacements in the investigated regime are also small and the amount of cloud water generated by condensation in non-saturated regions is of higher order and does not contribute to the leading order dynamics. Hence the clouds constitute a passive background, modulating the propagation characteristics of gravity waves.

If assuming a systematically small saturation deficit, the small amounts of generated cloud water are sufficient to introduce changes of the area of the saturated regions at leading order. Using similar techniques as in [2] allows for the derivation of an extended model. The key part is the derivation of equations for the net effects of the micro-physics on the wave-scale by applying conditional averages over the cloud length scale. In the final closed model, the essential cloud-related parameter is again the saturated area fraction σ on the cloud length scale, but it now depends nonlinearly on the vertical velocity. As σ modifies in return the effective stability in the equation for the potential temperature, the model features a nonlinear interaction between the wave-scale dynamics and the effective micro-physics.

The presentation explains the key steps in the derivation of the nonlinear model and shows some first results of the analysis.

References

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