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An analytical mixed-phase, bulk orographic precipitation model with embedded convection

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Orographic precipitation typically involves complex interactions between non-linear dynamical and microphysical processes, and hence a full conceptual understanding remains elusive. Ideally, such an understanding should be conveyed by analytical models that capture the dominant processes yet allow for simplified physical interpretations. To date however, few analytical models have considered the important impacts of mixed-phase microphysics and none have considered the impact of embedded moist convection, which commonly develops in orographic clouds and can be critically important for precipitation enhancement.

Here we describe a novel analytical model for mixed-phase orographic precipitation that includes embedded convection. The model takes an idealised background flow and terrain geometry, and calculates the area-averaged precipitation rate and other microphysical quantities. The results provide insight into key physical processes, including cloud condensation, vapour deposition, evaporation, sublimation, as well as precipitation formation and sedimentation (fallout). To account for embedded convection in nominally stratiform clouds, diagnostics for purely convective and purely stratiform clouds are calculated independently and combined using weighting functions based on relevant dynamical and microphysical time scales. The performance of the model is quantitatively assessed against idealised, convection-permitting numerical simulations with a sophisticated microphysics parameterisation. The model is found to accurately reproduce the simulation diagnostics over most of the parameter space considered.