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A stochastic model of mixed-phase cloud micro-physics

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Mixed-phase clouds, i.e., clouds that contain both super-cooled water droplets and ice crystals, are ubiquitous in the atmosphere and play an important role in the climate system. The mixture of liquid and solid water in sub-zero temperatures leads to a condensational instability, in which ice particles tend to grow at the expense of droplet evaporation. Nonetheless, mixed-phase clouds are unexpectedly long-lived. Earlier mean-field stochastic models are based on the picture of turbulence-induced large-scale dynamical forcing of cloud parcels to explain the longevity of mixed-phase clouds. We claim that small-scale turbulence is key to explain the persistence of such systems. Due to limited computational resources, weather simulation on a global scale is limited to coarse grids with a resolution of kilometers at best. On the other hand, a typical turbulent flow inside a cloud will display an intricate structure of eddies down to the scale of millimeters. A recent study using the linear eddy model showed that small scale turbulence does play a role in slowing down cloud glaciation. We propose a more computationally tractable Lagrangian stochastic micro-physical scheme to account for sub-grid fluctuations in velocity, temperature and water vapor fields. The impact of our scheme on phase partitioning is tested in a synthetic, turbulent-like flow that mimics an Arctic mixed-phase stratocumulus (AMPS) cloud. Results are confronted with idealized reference simulations that use Eulerian bulk micro-physics based on an assumed (temperature-dependent) phase partitioning function. Our study suggests that accounting for local variability in a turbulent cloud is important for reproducing steady-state mixed-phase conditions.