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The effects of small-scale turbulence for ice growth in mixed-phase clouds

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Mixed-phase clouds contain both liquid water droplets and ice crystals, subject to turbulent fluctuations of water vapor concentration. When ice grows by evaporation of liquid droplets (Wegener-Bergeron-Findeisen process)[1], mixed-phase clouds may transition into pure ice clouds. Representing the glaciation of mixed-phase clouds in terms of the Wegener-Bergeron-Findeisen process is a challenge for many weather and climate models. These models tend to overestimate the intensity of the glaciation process because cloud dynamics and microphysics are not accurately represented. Turbulence is essential for the transport of water vapor from evaporating liquid droplets to ice crystals and is particularly hard to accurately account for.

We developed a statistical model for the growth of ice crystals in a mixed-phase cloud using established closures to represent turbulent mixing of water vapor. To assess the accuracy of the model, we compare its predictions to DNS results, for the parameters of Ref. [2], and for the Pi-chamber test case [3]. The model successfully captures results of direct numerical simulations, and we use it to assess the role of small-scale turbulence.

We find that small-scale turbulence broadens the droplet-size distribution somewhat, but it does not significantly affect the glaciation time on submeter scales (Fig. 1). However, our analysis indicates that turbulence on larger spatial scales is likely to affect ice growth. While the model must be amended to describe larger scales, the present work facilitates a path forward to understanding the role of turbulence in the Wegener-Bergeron-Findeisen process.

More details can be found in our manuscript submitted to Physical Review Fluids.[4]

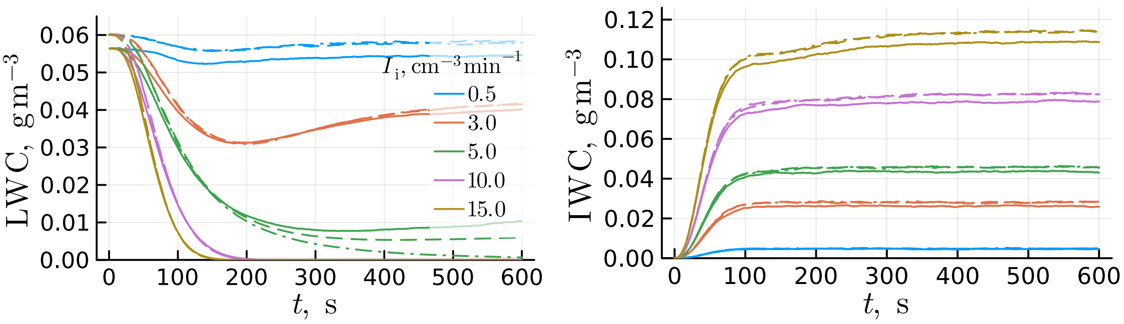

Figure 1: Model results for liquid water evaporation and ice growth in the core of the Pi chamber[3]. Shown are the DNS results (solid lines) for the liquid water content (LWC, left) and the ice water content (IWC, right) as functions of time. In each panel, curves for five different ice-particle injection rates [cm^{-3} min^{-1}] are shown, the parameter values are given in the insets. Also shown are simulations of the statistical model (dashed lines), and of its no-turbulence limit (dash-dotted lines). In most but not all cases, the no-turbulence limit is so close to the full statistical model results that the lines are hard to distinguish.

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