Bio:
Pratapaditya Ghosh is a postdoctoral researcher at Lawrence Livermore National Laboratory. His research focuses on better understanding aerosol–cloud interactions and developing parameterizations for cloud microphysical processes in weather and climate models. He received his bachelor's from Jadavpur University, a master's from IIT Kanpur, and his Ph.D. from Carnegie Mellon University in 2025.

Abstract:
One of the largest uncertainties in future projections of climate change is how atmospheric particles (aerosols) impact cloud properties. Aerosols can act as cloud condensation nuclei (CCN), on which cloud droplets form (Activate) and grow. Climate models commonly represent activation using the popular Abdul-Razzak and Ghan (ARG) parameterization, which estimates droplet number concentrations (Nd) based on simulated aerosol properties, updraft velocity, and atmospheric thermodynamic conditions. We recommend adjustments to three constant parameters in the ARG equations that improve agreement with simulations from a detailed cloud parcel model. The revised scheme, when implemented in the UK Met Office Unified Model (UM; a unified weather and climate model), reduces bias in cloud-top Nd and affects simulated cloud radiative effects.

We further apply these developments to fog simulations at a horizontal grid spacing of 500 m. Evaluation against observations from the ParisFog and LANFEX field campaigns shows that the default model substantially underestimates Nd, despite only slightly underestimating CCN concentrations. The revised activation scheme better simulates Nd, while updates to aerosol hygroscopicity have a smaller effect. We also extend the scheme to represent droplet activation by radiative cooling. This improves the simulated liquid water path and vertical structure of fog but can produce substantial overestimates of Nd. Sensitivity experiments show that these biases can be reduced by accounting for unresolved updrafts, droplet interception by trees and buildings, and droplet deactivation.

While complex parameterizations improve physical processes, they also introduce poorly constrained uncertain parameters. We investigate parametric uncertainty in warm-rain microphysics using a perturbed-parameter ensemble of storm-resolving simulations of a stratocumulus-to-cumulus transition observed during the MAGIC field campaign, using the DOE DP-EAMxx model. Machine-learning emulators constrained by observations show that parameter combinations that improve liquid water path in the stratocumulus and transition regimes do not perform equally well in the cumulus regime. Together, these studies demonstrate both the benefits and limitations of

improving individual parameterizations and constraining uncertain parameter values across different cloud regimes.

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