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Untangling microphysical impacts on moist convection applying piggybacking methodology

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Formation and growth of cloud and precipitation particles ("cloud microphysics") affect such macroscopic cloud field properties as the mean surface rainfall, cloud cover, and liquid/ice water paths. Indirect aerosol effects (e.g., through different CCN concentrations) are examples of the impact on shallow convection. For deep convection, hypothesized convective invigoration in polluted environments (because of additional latent heating due to freezing of the liquid water advected above the freezing level) is another example. In-situ and remote–sensing observations cannot provide sufficiently accurate estimates of such effects and are not capable in distinguishing between correlation and causality. Numerical modeling is then more reliable approach to study the impacts. However, traditional approaches that rely on parallel simulations (e.g., contrasting cloud fields developing in different CCN or IN environments) are not reliable because of natural variability of a cloud field that is affected by the feedback between cloud microphysics and dynamics. We present a novel modeling approach to assess the impact of cloud microphysics on macroscopic cloud field characteristics. The main idea is to use two sets of microphysical variables in a single simulation, one set coupled to the dynamics and driving the simulation, and the other one applied as in the kinematic model, that is, piggybacking the simulated flow but not affecting it. The two sets can either apply different microphysical schemes or the same scheme with different scheme parameters. Replacing the scheme driving the simulation with the one piggybacking it in a parallel simulation hints the impact on the dynamics. We will present application of this methodology to cloud field simulations of shallow and deep convection. We will show that the piggybacking allows assessing the impact of cloud microphysics on cloud field macroscopic properties with unprecedented fidelity. In particular, we will present results questioning the deep convection invigoration hypothesis, at least in the case of scattered unorganized deep convection considered in the initial study.