The Route to Raindrop Formation in a Shallow Cumulus Cloud Simulated by a Lagrangian Cloud Model

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The mechanism of raindrop formation in a shallow cumulus cloud is investigated using a Lagrangian cloud model (LCM). The analysis is focused on how and under which conditions a cloud droplet grows to a raindrop by tracking the history of individual Lagrangian droplets. It is found that the rapid collisional growth, leading to raindrop formation, is triggered when single droplets with a radius of 20 \( \mu m \) appear in the region near the cloud top, characterized by a large liquid water content, strong turbulence, large mean droplet size, a broad drop size distribution (DSD), and high supersaturations. Raindrop formation easily occurs when turbulence-induced collision enhancement (TICE) is considered, with or without any extra broadening of the DSD by another mechanism (such as entrainment and mixing). In contrast, when TICE is not considered, raindrop formation is severely delayed if no other broadening mechanism is active. The reason leading to the difference is clarified by the additional analysis of idealized box-simulations of the collisional growth process for different DSDs in varied turbulent environments. It is found that TICE does not accelerate the timing of the raindrop formation for individual droplets, but it enhances the collisional growth rate significantly afterward.

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