Spectral broadening in clouds is affected by turbulence

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Shallow cumulus clouds. Photo taken at York University Campus in Toronto, Canada. Credit: Haiyang Gao

Warm rain accounts for 31 percent of the total rain amount and 72 percent of the total rain area in the tropics. Understanding warm rain initiation and cloud droplet size distribution broadening is one of the main challenges of cloud physics due to complicated effects of turbulence on cloud microphysics.

In a paper published in *Atmospheric and Oceanic Science Letters*, Prof. Chunsong Lu (Nanjing University of Information Science & Technology) and co-authors review recent progress on turbulent broadening of cloud droplet size distributions and warm rain initiation.

"Chinese scientists have done a wonderful job on this topic ever since the 1950s," says Prof. Lu. The work Prof. He describes in the paper includes in-situ observations on turbulent fluctuations in clouds over Hengshan Mountain (27.25°N, 112.86°E) in Hunan Province and Taishan Mountain (36.18°N, 117.13°E) in Shandong Province around 1960. Also, in addition to observational studies, scientists have theoretically derived equations that can be used to study the effects of fluctuations on spectral broadening, including fluctuations of supersaturation, number concentration, liquid water content, vertical velocity and the existence of cell structures. By relating spectral broadening to various turbulent fluctuations, Chinese and Russian scientists were the first to introduce the idea of stochastic condensation into cloud physics—a topic that has since been widely studied throughout the world. Many studies have concluded that stochastic condensation in a turbulent environment contributes to spectral broadening, while opposite effects have been found in others. In contrast, there is greater consensus that turbulent fluctuations play significant roles in the collision-coalescence process.

Besides turbulent fluctuations, turbulence also causes entrainment of dry air into clouds, and entrainment-mixing affects cloud microphysics. Several types of turbulent entrainment-mixing mechanisms are reviewed in the paper, such as homogeneous/inhomogeneous entrainment-mixing, entity-type entrainment-mixing, and vertical circulation mixing. The mechanism most studied is homogeneous/inhomogeneous mixing.

"Interestingly, turbulent fluctuations and entrainment-mixing have been mainly studied separately, until a systems theory was developed in the 1990s," says Prof. Lu. This theory provides a theoretical framework for explaining the shapes of cloud droplet size distributions. It predicts that the most probable size distribution is the Weibull distribution, which approaches the delta distribution—the least probable distribution—if turbulent fluctuations decrease.

More information: Chun-Song LU et al, Broadening of cloud droplet size distributions and warm rain initiation associated with turbulence: an overview, *Atmospheric and Oceanic Science Letters* (2017). DOI: 10.1080/16742834.2018.1410057

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