Microphysical Insights into Extreme and Extremely Heavy Rainfall events in Taiwan

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Abstract

Extreme rainfall over Taiwan frequently results in severe flooding and landslide hazards, yet the microphysical distinctions between extreme rainfall and extremely heavy rainfall events remain poorly understood. Using rain-gauge observations and Global Precipitation Measurement (GPM) Dual-frequency Precipitation Radar (DPR) data during 2014–2023, this study investigates the vertical structure and microphysical characteristics of extreme rainfall (50–130 mm day^{-1}) and extremely heavy rainfall (>130 mm day^{-1}) events over Taiwan. Results show that extreme rainfall events are associated with deeper convective structures, with 30 dBZ echo-top heights reaching ~8–10 km and near-surface rainfall rates typically ranging from 10 to 20 mm h^{-1}. In contrast, extremely heavy rainfall events exhibit comparatively shallower vertical structures but substantially enhanced near-surface rainfall intensity, frequently exceeding 25–30 mm h^{-1}. Microphysical analysis reveals that extremely heavy rainfall events are characterized by larger near-surface mass-weighted mean diameters ($D_m \approx$ 1.8–2.2 mm) and higher raindrop concentrations (dBN_w increased by ~3–6 dB) compared to extreme rainfall events ($D_m \approx$ 1.4–1.7 mm). Vertical profiles and CFAD analyses further indicate a transition from mixed-phase and breakup-dominated processes in extreme rainfall to highly efficient warm-rain collision–coalescence processes during extremely heavy rainfall events. These findings highlight the critical role of warm-rain microphysics in producing extremely heavy rainfall over Taiwan and provide important insights for satellite-based precipitation monitoring and hydrometeorological hazard assessment.

Key words : Extreme rainfall, extremely heavy rainfall, GPM DPR, Taiwan