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Significant amplification of instantaneous extreme precipitation with convective self-aggregation

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Convective organization has been associated with extreme precipitation in the tropics. Here we investigate the impact of convective self-aggregation on extreme rainfall rates. We find that convective self-aggregation significantly increases precipitation extremes, for 3-hourly accumulations (+70%) consistent with earlier studies, but also surprisingly for instantaneous rates (+30%). We show that this latter enhanced instantaneous precipitation is mainly due to the local increase in relative humidity which drives larger accretion efficiency and lower re-evaporation and thus a higher precipitation efficiency.

An in-depth analysis based on an adapted scaling of precipitation extremes, reveals that the dynamic contribution decreases (- 25 %) while the thermodynamic is slightly enhanced (+ 5%) with convective self-aggregation, leading to lower condensation rates (- 20 %). When the atmosphere is more organized into a moist convecting region, and a dry convection-free region, deep convective updrafts are surrounded by a warmer environment which reduces convective instability and thus the dynamic contribution. The moister boundary-layer explains the positive thermodynamic contribution. The microphysic contribution is increased by + 50 % with aggregation. The latter is partly due to reduced evaporation of rain falling through a moister near-cloud environment (+ 30 %), but also to the associated larger accretion efficiency (+ 20 %).

Extreme rainfall intensity, frequency and duration are all important for floods and risks. And the role of aggregation may depend on the time scale chosen, as suggested by larger amplification of rainfall accumulations than rainfall rates with aggregation, a result in line with recent studies.

Thus, the change of convective organization regimes in a warming climate could lead to a significantly different evolution of tropical precipitation extremes than expected from thermodynamical considerations.

Improved fundamental understanding of convective organization and its sensitivity to warming, as well as its impact on precipitation extremes, is hence crucial to achieve accurate rainfall projections in a warming climate.

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