Self-organization of convective cloud as the driver for extreme precipitation

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The representation of convective cloud is one of the key uncertainties in climate models. One aspect highlighting this uncertainty is that extreme rainfall from convective cloud is very hard to predict – not to mention its possible change in a different climate. Observationally, extreme convective-type rain was found to exceed expectations from equilibrium thermodynamics, i.e. the precipitation rate increases at more than the Clausius-Clapeyron rate under increasing near-surface temperatures. This is remarkable because it points to a crucial role of the atmospheric dynamics in strengthening extremes, i.e. the variance of updraft speed. Simulations support such intensification and suggest it to be tied to cloud organization by so-called “cold pools” – that is, characteristic near-surface areas of colder, therefore denser, air.

We find that individual rain cell intensities are often larger at times when the overall precipitation area is on the decrease. This is indeed often the case in the late afternoon of a typical convective day, where isolated areas receive very heavy precipitation. Such reductions of density are generically encountered across our different large-eddy simulation setups. The spatial correlation length, measured throughout the model day, increases approximately linearly for all simulations – at comparable rates. To describe this linear increase, we suggest a simple conceptual model, based on iterative Voronoi triangulations. The model uses a repeated sequence of “firing” precipitation events and a “reproduction” process which is set off by the corresponding cold pool currents.

Our model may have implications for the description of extreme precipitation events and the better understanding of the super-Clausius-Clapeyron relation. We offer an outlook on how the self-organization of the convective cloud field might be measured using remote sensing data, especially combining ground-based radar, lidar and satellite.