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Universality in the spatial evolution of self-aggregation of tropical convection

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Numerical model simulations of the tropical atmosphere in radiative-convective equilibrium have shown the formation and upscale growth of moist and dry regions, even in the absence of large-scale instabilities or external forcings. As convection is confined to the moist regions this increasingly organized state is referred to as self-aggregation of convection. The spatial evolution of self-aggregation is surprisingly universal, which is notable as different relevant feedback mechanisms have been identified, depending on the chosen model, the chosen setup and the stage of self-aggregation. Understanding the spatial evolution of self-aggregation has, in contrast to determining the relevant positive feedback mechanism, received little attention.

We suggest that self-aggregation is described by a pattern-formation mechanism called coarsening, which is insensitive to the details of the feedback mechanism as long as they lead to an intensification of local humidity perturbations. Coarsening has already been proposed to describe the spatial evolution of self-aggregation in a previous study using a specific convection-humidity feedback. Instead of focussing on a single feedback mechanism to derive a spatial evolution equation for self-aggregation, we here combine each of the three quantitative feedback models introduced in the literature with a spatial interaction term. As spatial interaction term, which describes how humidity is exchanged between neighboring columns, we choose a diffusive interaction which, as we show, approximates convective moistening within a finite region around convective cores.

Understanding self-aggregation as a coarsening process, we can understand a number of frequently observed properties. In particular, we can readily explain why the shape of the final moist region changes with domain shape (channel vs. square) and why self-aggregation depends on domain size. Comparison of the upscale growth of the moist and dry regions in a radiative-convective equilibrium simulation with the predictions from coarsening are however ambiguous, suggesting that coarsening is relevant mainly during the early stages of self-aggregation, potentially followed by a phase where moisture advection dominates the horizontal moisture exchange.