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Boundary layer height, buoyancy, and the size of convective self-aggregation

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Organized rainstorms and their associated overturning circulations can self-emerge over an ocean surface with uniform temperature in cloud resolving model (CRM) simulations. This phenomenon is referred to as convective self-aggregation. Convective self-aggregation is argued to be an important building block for tropical weather systems and may help regulate tropical atmospheric humidity and thereby tropical climate stability. Here we present a boundary-layer theory for the horizontal wavelength of 2D (x, z) convective self-aggregation by considering both the momentum and energy constraints for steady circulations. This theory suggests that the horizontal wavelength scales with the product of the boundary layer height and the square root of buoyancy in the boundary layer, the latter of which is significantly influenced by the moisture variation due to the virtual effect of water vapor. This theory successfully predicts the order of magnitude of the wavelength and its non-monotonic variation with surface temperature in a suite of CRM simulations spanning a wide range of climates. The causal relation between the virtual effect and the scale of convective self-aggregation is further demonstrated by mechanism-denial CRM experiments with the virtual effect disabled. This study may help explain what determines the horizontal scale of tropical mesoscale convective systems.