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When is numerical resolution high enough to resolve cold pool organization?

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It is well-recognized that triggering of convective cells through cold pools is key to the organization of convection, as reviewed in Zuidema *et al.* (2017). Yet, numerous studies have found that both the characterization and parameterization of these effects in numerical models is cumbersome - in part due to the lack of numerical convergence (Δx-> 0) achieved in typical cloud-resolving simulators. Through a comprehensive numerical convergence study, we systematically approach the Δx-> 0 limit in a set of idealized large-eddy simulations capturing key cold pool processes: propagation, merging and collision of gust fronts. We characterize at which Δx convergence is achieved for physically relevant quantities, namely accumulated upwards water mass fluxes, integrated vortical rates and gust front's group velocity.

The gust front vertical size and strength achieves convergence at Δx=100m horizontal resolution (70% drop at Δx=800m), while the probability distribution of updraft fluxes upon frontal collision, ƒ(w), appears satisfactorily resolved at Δx=50m. Interestingly, ƒ(w) exhibits self-similarity as a function of Δx, down to the coarsest case of Δx=800m. A rescaling function is derived that successfully collapses all distributions onto a common solution. Further, the positive water mass perturbation caused upon propagation and collision of the gust front appears well-captured at Δx=200m (35% drop at Δx=800m). Finally, the incidental merging of several cold pools results in a large gust front, as often found in MCS. The group velocity of this merged front is only mildly dependent on resolution (10% drop at Δx=800m), suggesting that the numerical dissipation dominates over dispersion.

The understanding gained from this analysis lays the groundwork to develop robust subgrid models for CP dynamics able to sustain their growth and combat artificial numerical dissipation and dispersion.