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Defining a cold pool-resolving scale for numerical simulations of convective self-organisation

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Spontaneous aggregation of clouds is a puzzling phenomenon observed in field studies [Holloway et al. (2017)] and idealized simulations alike [Held et al. (1993), Bretherton et al. (2005)]. With its relevance to climate sensitivity and extreme events, aggregation continues to be heavily studied, [Wing et al., 2017 for a review], with radiative-convective feedbacks emerging as main drivers of simulated convective self-aggregation (CSA) [Mueller & Bony (2015)].

In state-of-the art cloud-resolving models, CSA finds itself consistently hampered by finer horizontal resolutions [Muller & Held (2012), Yanase et al. (2020)]. This feature was ascribed to the effect of cold pool (CP) gust fronts in opposing the positive moisture feedback underlying CSA [Jeevanjee & Romps (2013)]. In contrast, recent numerical experiments [Haerter et al. (2020)] with diurnally oscillating surface temperature highlights an orthogonal effect: stronger CPs, driven by small-scale density gradients, promote cloud field self-organization into mesoscale convective systems (MCS). Interestingly, this upscale growth, which we here term diurnal self-organisation (DSO), differs from classical CSA as it is driven by CPs rather than large-scale radiative imbalances. In stark contrast to CSA, strengthening CPs promotes this organization effect.

Hence, numerical simulations of CSA and DSO should go beyond the typical cloud-resolving paradigm and achieve cold pool-resolving capabilities. The current study systematically examines the impact of model resolution on CP effects. First, numerical convergence is probed in a 12km x 20km laterally periodic domain where a single CP propagates and self-collides at the domain's edges. As the spatial resolution is stepwise increased from 250 to 25m, it is shown that the initially coarsely resolved density current dissipates and collision and updraft effects are weak. As finer resolution is approached, we identify a cold pool resolving resolution D, which is deemed satisfactory for propagation and collision properties. Second, convergence for a (250km)2 domain under a diurnal radiative cycle is assessed at various spatial resolutions, including the scale D. This mesoscale configuration allows us to quantify the impact of resolution of cold pool dynamics on DSO.

Together, this work systematically lays out the numerical requirements to study mesoscale clustering by means of explicit numerical simulations.