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Reassessing the Cohen and Craig (2006) theory: Fluctuations in an equilibrium convective cloud ensemble at horizontal resolutions ranging from 2 km to 125 m

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About 15 years ago, Cohen and Craig (2006, CC06) proposed a general theory describing the fluctuations of the properties characterising a convective cloud ensemble developing under fixed external forcing. This theory later served as the basis of the Plant-Craig stochastic convection scheme which has been in particular implemented in the ICON model operated by the German weather service.
Unfortunately, due to limitations in computational power available at the time, the theory could only be validated using Cloud Resolving Model (CRM) simulations in Radiative Convective Equilibrium (RCE) at a horizontal resolution of 2 km, which can be considered as relatively coarse by today's standards. At this resolution, convection organisation is very weak, and clouds can be considered as developing randomly in space, independently of each other. It is however a common knowledge now that as resolution is increased, spatial organisation emerges specifically driven by cold pool dynamics in the boundary layer and moisture patterns in the troposphere.
In this work, fluctuations of general cloud properties are investigated in a numerical setup similar to CC06, but at horizontal resolutions ranging from 2 km to 125 m. As expected, convective organisation arising at resolutions < 1 km significantly affects the cloud number and mass flux distributions. The original CC06 theory, stating that clouds follow a spatial Poisson point process with exponentially distributed mass fluxes, no longer holds at the domain scale. It is however demonstrated that the above mentioned characteristics are recovered when individual cloud cores are isolated (the biggest clouds at high resolution are composed of several merged cores), and when restricting the analysis to regions of high cloud density where clouds appear to cluster. Even at 125 m resolution, cloud core mass fluxes are reasonably well approximated by exponential functions, whereas cloud cores appear to be randomly distributed in space (Poisson) where convective activity is the strongest. Under these assumptions, the CC06 theory therefore also provides a reasonably good description of cloud number and mass flux fluctuations occurring in an organised cloud ensemble at equilibrium.

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