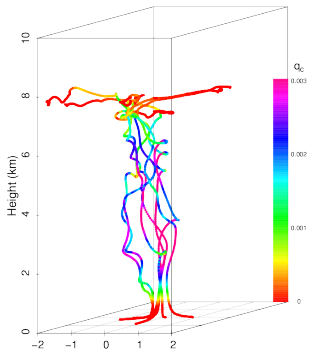
Measurement of Convective Entrainment Using Lagrangian Particles

Research Highlight

Previous work by Romps (2010) found large entrainment rates of ~100% per kilometer for deep convection using a new technique for large-eddy simulations (LES) called “Eulerian direct measurement”. These results were confirmed by Dawe and Austin (2011) using a related approach. These techniques, however, are unable to pinpoint the reasons for the high entrainment rate. In this study, massless Lagrangian particles are used to perform “Lagrangian direct measurement” of the convective entrainment rate. By recording the histories of individual particles, it is possible to explore the processes responsible for large entrainment rates.

Individual cumuli congesti are simulated using LES with an isotropic 50-meter grid spacing. The simulations are peppered with 40 million Lagrangian particles that are initially distributed so as to have a statistically constant specific number density (i.e., a constant number of particles per kilogram of dry air). This choice, along with a careful selection of numerical methods (third-order WENO interpolation and a total-variation-diminishing third-order Runge-Kutta time stepping for both the Eulerian fields and Lagrangian particles), guarantees that the statistics of the Lagrangian particles faithfully replicates the statistics of the Eulerian fields.

The results using “Lagrangian direct measurement” confirm the large entrainment rates found previously with “Eulerian direct measurement.” Furthermore, the particle histories provide an explanation for the large entrainment rate: fast recycling of air into and out of the cloud. These results show that clouds rapidly entrain both environmental air and their own detritus.



Trajectories of seven particles that are entrained at the cloud base and transported to the cloud top. Colors denote the mixing ratio of condensed water.

Reference(s)

Yeo K and DM Romps. 2013. "Measurement of convective entrainment using Lagrangian particles." Journal of the Atmospheric Sciences, 70(1), doi:10.1175/JAS-D-12-0144.1.

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Cloud Life Cycle