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Optimizing the number of convective plumes in EDMF cloud parameterization schemes using data from high-resolution LES simulations

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Abstract

The parameterization of turbulence and convection at the sub-grid scale remains a major cause of the inter-model spread in climate predictions. The Eddy-Diffusivity/Mass-Flux (EDMF) parameterization unifies these two physical regimes by decomposing the grid box of a global climate model into two area fractions: one containing coherent updrafts and another containing the turbulent environment. To reduce computational cost, the EDMF parameterization currently neglects the variance of updraft activity and instead represents the updrafts solely by their mean values, this is referred to as the *EDMF assumption*. In this project we investigate whether by including multiple updrafts in the EDMF scheme (rather than a single bulk plume, as currently used) it is possible to account for the variance of updraft activity, diagnosed from Large Eddy Simulations (LES).

To this end, we ran high-resolution LES simulations for various different convective cases and domain sizes (corresponding to the grid size of a climate model) and used tracer fluxes to diagnose coherent updrafts within these simulations. From this we were able to gather how various quantities were distributed within these updrafts, and found that the distributions of liquid water potential temperature and vertical velocity are both approximately Gaussian. We then used kernel density estimation (KDE) - with N Gaussian kernels representing the N individual updrafts in the EDMF parameterization - to approximate these distributions of updraft activity generated from LES. For the variance of the Gaussian kernels, we allowed them each the maximum variance which satisfies the aforementioned *EDMF assumption* on the Reynolds-averaged sub-grid scale variance of updraft activity.

In the end, we found that for all cases tested there exists an optimal number of updrafts - i.e. Gaussian kernels - which minimizes the Kolmogorov-Smirnov error between the distribution of updraft activity from LES and the approximate distribution using KDE. This optimal number of updrafts, $N_{optimal}$ was found to vary strongly with domain size, while also being correlated with the maximum variance of updraft activity within each simulation. This result indicates that if the EDMF scheme was to be utilized within a global climate model, it may be possible to automatically adjust the number of updrafts it uses depending on certain properties within each grid box so as to minimize the error in the parameterization.