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Petascale Direct Simulations to Determine the Growth-Rate Law of Convective Boundary Layers

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The pioneering water tank experiments on convective entrainment by Deardorff et al. in the seventies, laid an important foundation for the now widely used 1/Ri growth-rate law for convective atmospheric boundary layers. Yet a nagging issue is that other water tank experiments, that employ different methods to create stratification and buoyancy, tend to produce significantly different entrainment laws. The essential problem that seems to remain is how to properly extrapolate the findings obtained from moderately low Reynolds/Peclet-number experiments to their huge Re/Pe-number atmospheric counterpart.

In this study we examine this issue by conducting "ground truth" Direct Numerical Simulations of convective boundary layers. Of course one cannot simulate the high Reynolds number of atmospheric turbulence, but present computer resources do allow one to faithfully mimic the classical laboratory experiments, and to even push the Reynolds number by more than an order of magnitude. The simulations were conducted within a European "Extreme Computing Initiative" framework, entailing simulations on five different supercomputing platforms. The largest simulations, which ran on the Juelich Bluegene supercomputer, used 3072-cubed gridpoints employing 32,768 cores.

The simulations shed light on why different laboratory experiments with different set-ups, produced different growth-rate laws. By mimicking these experimental conditions in our simulations, that is by accounting for the actual fluid properties that were used in the experiments, we gain insight into how the Reynolds/Peclet number combination influences the resulting growth-rate behaviour. In addition, the results indicate which entrainment law is most appropriate for the large Reynolds number case associated with atmospheric convection.

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