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Entrainment processes at the top of the convectively-driven atmospheric boundary layer

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We revisit and discuss the entrainment law at the top of the convectively-driven atmospheric boundary layer using both a theoretical point of view and data from high-resolution (256^3 grid points) large-eddy simulation (LES) and measurements. We investigate the mixed-layer dynamics from a deterministic and statistical point of view. Flow visualisation shows that organized turbulent structures within the well-developed mixed layer erode the interfacial layer and entrain the stably-stratified fluid from the free atmosphere above. Spatial and temporal spectra within the mixed layer satisfy the Kolmogorov law valid for isotropic homogeneous turbulence and show that the Taylor's (1938) frozen turbulence hypothesis is verified. The normalized entrainment velocity expressed as $w_e/w_\star$, where w_e and $w_\star$ are the entrainment and convective velocities, respectively, is found to vary as the bulk Froude number squared Fr_B^2 at the interface, with a multiplicative constant of order 1. This result is in good agreement with theoretical approach and both experimental and numerical data. A particle dispersion approach using LES coupled with a Lagrangian stochastic model has also been used to investigate the entrainment law. The Fr_B^2 dependence of the dimensionless entrainment rate is retrieved. These results may help to improve entrainment parameterization at the interface and may also have applications for remote sensing of the mixed-layer top.