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Entrainment Zone Properties Conditioned on Turbulent and Non-turbulent Regions

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The formation of shallow clouds at the top of a convective boundary layer (CBL) depends delicately on the buoyancy and specific humidity fields in the entrainment zone. This region is characterised by external turbulent intermittency, defined as the alternation between regions of strong and weak vorticity fluctuations, which poses a challenge for modelling the evolution of entrainment zone properties. Previous efforts to provide scaling laws for buoyancy and specific humidity statistics in the shear-free CBL relied on several assumptions regarding the behaviour within turbulent and non-turbulent regions (Garcia & Mellado, 2014; Mellado, Puche & van Heerwaarden, 2017). In the present study, we employ conditional analysis on direct numerical simulation data to partition the entrainment zone into turbulent and non-turbulent regions, enabling us to assess the validity of previous assumptions and identify physically tenable scaling laws.

Our first results deal with the partitioning procedure. Previous studies of shear boundary-layers and stratified turbulence have considered probability density functions (PDFs) of the enstrophy or potential enstrophy to distinguish between turbulent and non-turbulent regions (Borrell & Jimenez, 2016; Watanabe et al., 2016). When this method is appplied to the shear-free CBL, we find that both enstrophy and potential enstrophy are equally suitable as turbulence indicators and yield similar results. The PDFs both contain two peaks: a high enstrophy peak marking the boundary layer characterised by turbulence and a low enstrophy peak marking the free atmosphere characterised by gravity waves. We also find that the saddle point between the two peaks in the enstrophy PDF and that in the potential enstrophy PDF are located at similar heights within the entrainment zone, between the height of minimum buoyancy flux and the height marking the transition from the lower to the upper entrainment zone sublayer. Using the saddle point as a threshold, we then investigate the scaling behaviour of the mean and variance of buoyancy and specific humidity within turbulent and non-turbulent regions.