Lidar-based Investigation of the Relationship Among Entrainment Zone Thickness, Turbulence, and Aerosol Variability in the Convective Boundary Layer

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Abstract:

Entrainment zone (EZ) processes have a large influence on many meteorological and environmental processes including turbulence, water vapor budget, trace gas mixing, air quality, and, ultimately, climate variability. Additionally, a better understanding of EZ processes via observations is critical to improve existing ABL parameterization schemes and for the development of new parameterization schemes. By improving our understanding of the EZ and parameterization of the ABL, numerical weather prediction (NWP) inherently benefits as the ABL parameterization is often a large source of error for NWP models and resulting forecasting. Entrainment itself is defined as the exchange of free atmospheric (FA) air into the atmospheric boundary layer (ABL), enabling the ABL to grow and altering the physicochemical properties of the ABL airmass (e.g., entrainment drying boundary layer). Due to the presence of vigorous thermals and extremely turbulent nature of the EZ, direct measurements of thermodynamic variables in EZ using aircraft is often a challenge. Within this work, we explored the potential of a ground-based lidar measurements in an arid region to accurately portray the turbulent and aerosol backscatter characteristics of the EZ.

Within this work, we explore the EZ processes over an arid region (Lubbock, in West Texas region). The measurements of EZ processes in the experimental region are often influenced by observed elevated mixed layers advected off the Mexican Plateaus and passages of the dryline, which are two essential ingredients for thunderstorm development in the region. Additionally, arid regions are of particular interest due to unique land-atmosphere feedback processes resulting from very low soil moisture, extremely high sensible heat fluxes, high near-surface temperature, and negligible latent heat fluxes. The impact of these distinct characteristics on entrainment processes have yet to be identified in the literature.

Our investigation will be centered around analyses of a ground-based vertically pointing scanning Doppler lidar measurements of aerosol backscatter and 3D wind fields. Specifically, we aim to develop an analytical relationship among CBL dynamics (using vertical velocity), turbulence (using variance of aerosol backscatter within the CBL), and EZ thickness (using ABL depth fluctuations). Such a relationship will allow for a better understanding of the role of entrainment in boundary layer growth under various meteorological conditions, particularly over an arid region. The results of this work will benefit the development of ABL parameterizations and provide empirical data on EZ processes over an arid flat terrain region for examining the performance of high-resolution numerical simulations.