Reply to Referee #1

This is a nice study that comprehensively investigates the dependence of entrainment-mixing processes on the height in stratocumulus clouds using high-resolution aircraft data. There are two important contributions: (1) It develops a new method for determining the microphysical homogeneous mixing degree that addresses the conventional challenge of determining adiabatic properties, and (2) It combines various measures of microphysical homogeneous mixing degree to conclusively demonstrate the height dependence and explains the physical reasons. The manuscript is well written and the methodology is sound. I only have one concern about the influence of turbulent dissipation rate on the findings: its contribution should be strongly dependent on the decoupling state of the boundary layer, which has not been considered in this study (see details below). After relevant discussions (or analyses) are added, this manuscript should be accepted for publication in ACP.

Major comments:

It is reasonable that the turbulent dissipation decreases with altitude in the cloud layer, which has been proven in prior LES studies. However, the monotonic decrease (from cloud base to top) only occurs for the well-mixed stratocumulus-topped boundary layer. In decoupled conditions, the dissipation rate tends to decrease near the cloud base so that it should maximize somewhere in the middle of the cloud layer. There are two sources of evidence supporting this argument: one from LES (Stevens 2000) and one from observations (Zheng et al., 2016).

Stevens (2000) shows that the boundary layer decoupling causes a decrease of TKE (turbulent kinetic energy) near the cloud base, leading to a local minimum near the cloud base and a maximum in the middle of the cloud layer. (In the TKE equation, turbulent dissipation roughly balances the kinetic energy so the profiles of TKE can be used to infer the profile of turbulent dissipation). This is also demonstrated in the observations by Zheng et al. (2016) who found a significant role of decoupling in weakening the cloud-base updrafts.

Therefore, it is reasonable to conjecture that the contribution of the turbulent dissipation to the findings (height dependence of mixing) may vary in decoupled boundary layers. Since the clouds in this study were sampled near the coast of CA, they must be coupled, which explains the monotonic decrease of dissipation with height. But decoupled clouds should be very common in the downstream regions (e.g., Bretherton and Wyant, 1997) and midlatitudes (e.g., Zheng et al., 2020). Therefore, it worths more discussion on the probable modification of the results in other regions.

References:

Stevens, B., 2000. Cloud transitions and decoupling in shear-free stratocumulus-topped boundary layers. Geophysical research letters, 27(16), pp.2557-2560.

Zheng, Y., Rosenfeld, D. and Li, Z., 2016. Quantifying cloud base updraft speeds of marine stratocumulus from cloud top radiative cooling. Geophysical Research Letters, 43(21), pp.11-407.

Bretherton, C.S. and Wyant, M.C., 1997. Moisture transport, lower-tropospheric stability, and decoupling of cloud-topped boundary layers. Journal of Atmospheric Sciences, 54(1), pp.148-167.

Zheng, Y., Rosenfeld, D. and Li, Z., 2020. A more general paradigm for understanding the decoupling of stratocumulus-topped boundary layers: The importance of horizontal temperature advection. Geophysical Research Letters, 47(14), p.e2020GL087697.

Reply: Thank you very much for your recognition of our work. Yes, we agree that the contribution of dissipation rate should be strongly dependent on the decoupling state of the boundary layer, and we have added the relevant discussion in the manuscript Lines 280-288: "The clouds were sampled in the vicinity of the coast of Santa Cruz/Monterey, California, therefore, these clouds were well-mixed and coupled, which explains the monotonic decrease of ε with the increasing height (Jones et al., 2011;Shupe et al., 2013). Note that the decoupled clouds should be very common in the downstream regions (e.g., Bretherton and Wyant, 1997) and midlatitudes (e.g., Zheng et al., 2020). The boundary layer decoupling causes a decrease of turbulent kinetic energy near the cloud base, leading to a local minimum near the cloud base and a maximum in the middle of cloud layer. The profile of turbulent kinetic energy can be used to infer the profile of ε (Stevens, 2000). This is also demonstrated in the observations by Zheng et al. (2016) who found a significant role of decoupling in weakening the cloud-base updrafts. Therefore, in the future studies of decoupled stratocumulus in other regions, the results about entrainment-mixing mechanisms could be different due to the non-monotonic vertical variation of ε."