Review of "Can GCMs represent cloud adjustments to aerosol–cloud interactions?" by Mülmenstädt et al. (egusphere-2024-778)

Process-level modeling predicts a decrease in cloud water with aerosol through enhanced entrainment. However, these so-called negative cloud water adjustments are not captured in general circulation models (GCMs). To solve this apparent contradiction, this study presents and discusses a set of single-column model (SCM) simulations that use GCM model physics, as well as corresponding three-dimensional GCM simulations. Most interestingly, the presented SCM simulations show negative cloud water adjustments, which are missing in the GCM simulations. As the model physics are the same in SCMs and GCMs, the authors conclude that the absence of negative cloud water adjustments can result from internal feedbacks in the climate system. All in all, this is an exciting study that fits the scope of Atmospheric Chemistry and Physics. While I do not have any substantial concerns, I would like to make some suggestions below that the authors may want to address in a revised version.

Minor Comments

Ll. 22, 323 – 326.: To understand the integrated effect of clouds on the radiation budget, it makes no sense to express RA_L as a function of N_d. However, to increase process-level understanding, separating RA_L for low and high N_d might be helpful.

Ll. 73 – 74: I suggest briefly summarizing the criteria of Medeiros and Stevens (2011).

Eq. 5: The term describing horizontal advection should also be multiplied by the air density.

Ll. 161 – 164: Why must two different notations be introduced to indicate mass-weighted vertical averages?

Eq. 7: The third term on the right-hand side of (7) might require a comment.

Ll. 179 – 181: Sub-meter turbulence plays an important role in the entrainment process by preconditioning the free-tropospheric air before entrainment, but it is the large-scale boundary layer circulation [O(1 km)] that drags the neutrally buoyant free-tropospheric air into the boundary layer (e.g., Yamaguchi and Randall 2012).

Ll. 219 – 222: A drier free troposphere (a more negative moisture jump) decreases the buoyancy jump, increasing entrainment. Thus, the displayed decrease in entrainment with the moisture jump is probably only due to the mentioned correlation with the temperature jump.

Ll. 300 – 302: $d\ln(L)/d\ln(N_d)$ is slightly negative for $Q_{sed} > 0$. Are these values negligible?

Ll. 320 – 321: Shortwave radiative heating should be saturated for sufficiently large L. How large can L be to be affected by this effect?

Ll. 333 – 335: Introduce the "three Sc regions" here?

Ll. 447 – 448: Should "subadiabaticity" be an additional model variable? Please clarify.

Technical Comments

Title: "cloud adjustments" to "cloud water adjustments"

L. 125: "u^*" to "u_*"

Fig. 1: Display y-axis in meters?

L. 307: "increases" to "decreases"?

References

Yamaguchi, T., & Randall, D. A. (2012). Cooling of entrained parcels in a large-eddy simulation. *Journal of the Atmospheric Sciences*, *69*(3), 1118-1136.