**Review of „Can GCMs represent cloud adjustments to aerosol–cloud interactions?“ by Mülmenstädt et al.**

The manuscript presents some thought provoking anlysis on the disrepancy of short-term, limited area qunatifications of the liquid water path (LWP) adjustment to changes in anthropogenic aerosol. The authors show that GCMs that simulate a negative LWP adjustment in response to entrainment drying in a SCM case study, and when considering interannual variability in the present-day climate, quantify a non-existant or even slightly positive LWP adjustment when considering differences between the present-day and preindustrial climatological state.
The manusript fits well into the scope of ACP and provides a novel perspective, which will be of interest for a broad community. Some statements made by the authors are not sufficiently backed up by their analysis in my opinion (see comment below). Either further proof is required, or made statements will have to be softened considerably prior publication.

My main comment is with respect to your assertion, that the simulated mixing is free of numerical artifacts as you define them. Your shown associations to large-scale parameters and comparisons against LES in SCM, are a necessary, but by no means sufficient condition to support this statement. You still could get the right answer for the wrong reasons. Your analysis does not prove that you get the right answer for the right reasons.
One such proof could be a tracer mixing analysis in your SCM setup. If you had a tracer field above the BL, how consistent is your accumulation of tracer within the BL with your expected terms (given the very minor contribution of R, you can predict E given the initial conditions and large-scale forcing) and how is it affected by changes in vertical resolution? Such experiments would at least demonstrate the impact of numerical diffusion due the involved sharp gradients.
Secondly, equations 3-5 neglect the contribution of the convective mass flux. How sensitive are your SCM results to the shallow convection parameterisation and what percentage of grid points in the analysed GCM regions is impacted by the convection scheme? If that percentage is low, than you may be ok with neglecting this term.
Finally, the timescales of entrainment and deepening in the SCM ModelE3 analysis indicate a discrepancy with the timescales of LWP adjustment through entrainment and boundary layer deepening. These have been shown to be longer than a day, not within the first 6h. Thus the entrainment simulated, is still not in line with the physical mechanism. Furthermore, there does not seem to be a relation between the timing of the level jump in h and the time-integrated diagnosed Eq between the different model experiments. Combined with the fact that the vertical level jump occurs in the Na=120cm-3 run before the Na=160m-3, does suggest that the parameterised entrainment is not entirely physical.

Edits/Clarifications:

- L161 why A with caret and angular brackets to denote the same thing?
- Equ.7: what is $h^-$? Typo?
- L166: How are $E_{theta}$ and $E_q$ computed? By rearranging equs. 3-5 using equ. 7 for the material derivative? Please clarify.
- L185: Please rephrase „..., that is, lead to numerical diffusion“
- L187: what is a host of a perturbation? I suggest to rephrase.
- L201: Take sentence („In an Eulerian model,...“) out of bracket. Its stand-alone and of equal importance to the previous statement made.
- L204: I assume you mean the convective mass flux here specifically? Please clarify.
- L364: Please rephrase, at the moment it reads like you have to adjust the filtering to the signal you want. In my oppinion the conclusion is, that NEP and SEP do not show a

response. This is only found in completely cloud-covered regions. Follow up question: Do you have a reason for why this is the case?

- L375-385: I agree with the first part of the argument presented in this paragraph. That E does not continue to increase as LWP decreases in response to the Nd increase. Eventually it decreases again in this self-limiting manner as the authors discuss.
  However, the link to a further increase in Nd is not clear to me. What is the evidence that Nd usually continues to increase during the LWP adjustment? Timescale analyses of ACI seem to suggest the opposite: quick microphysical response and change in Nd, longer manifestation of LWP. It is does not clear to me, how the decrease in E with increasing Nd is of relevance for a self-regulating process.
- L 376: This should not be in brackets. Its just as likely as the other hypothesis. Your analysis does not provide a proof in one or the other direction.
- 379: Comment: „increased entrainment leads to loss of LWP“. This is under the assumption that the cloud dynamics and morphology do not change. As the BL deepens, stronger updrafts are needed to maintain the coupling with deeper cloud cores and higher LWP.
- L388: „In terms of mechanistic...“ Does this statement refer to RA or the Nd-L PD relationship? If the first, I agree, if the latter, where is the evidence?
- L401: comment on: „the buffering mechanism is that enhanced entrainment leads to sufficient liquid-water loss to shut off entrainment driven by cloud-top radiative cooling, protecting the clouds from further liquid loss“ Changes in cloud dynamics as the BL deepens through entrainment may also contribute
- L404/405: Please rephrase and clarify „First, negative relationships...“ This statement applies to in GCMs. You do not provide evidence that this is the case in opportunistic experiments (in and outside (!) the sub tropics) or LES. To my understanding you provide evidence, that limited short-term studies on limited domain, or isolated features, may not provide the entire picture. I.e. other processes may be at play that buffer the initial response.
- Fig.4: Please add the observed range of values to the simulated range to obtain a feeling of the realism of the simulations right away
- Fig. 5: I would argue that the E3SM SCM simulations are unsuitable to address the question at hand, since you simulate a completely different cloud evolution than observed.