**Review of "Constraining Aerosol-Cloud Adjustments by Uniting Surface Observations with a Perturbed Parameter Ensemble" by Mikkelsen et al.**

This paper aims to reduce the uncertainty in aerosol-cloud adjustments by constraining a PPE of a GCM with surface observations of cloud properties from the East North Atlantic (ENA). The surface observations include the variables LWP, precipitation and $N_d$. The PPE is produced from the atmospheric component (CAM6) of CESM2. Gaussian process emulators are created for the median, covariances and PI-PD change in modeled cloud properties. Strong correlations are found between the median state and the covariances and some of the PPE parameters e.g. $N_d$ and subgrid velocity. The emulated properties are then constrained by the observed cloud properties at the ENA surface station, and the impact of the constrained parameters on the change in global mean PI-PD LWP is shown. The constrained parameters include processes that are relevant for ACI in GCMs.

The study looks to constrain aerosol-cloud adjustments in a novel way though using surface observations and emulated model output. It's a nice piece of analysis and well written. I recommend the minor corrections below before publication.

<u>Comments</u>

Figure 2 caption: specify that Figure 2a is from the model.

P8, L196: What was the approach in Eidhammer et al. 2024 designed to sample the uncertainty in and how does that correspond to the parameters that are likely important for ACI?

P9, L205-210: Some more information on the model set is needed to improve this section. How long are the simulations for PD and PI? Do the simulations have all anthropogenic and emissions set to PD and PI respectively, or is it just the anthropogenic aerosol emissions that change between the two simulations? Why was the year 2000 used for PD when the observations are from a different year? How useful is a constraint trend on years with different emissions? What is used for prescribing SSTs, sea ice and land cover?

P9, L209: What model levels are nudged?

P9, L213: It the model output analysed in the gridbox for the ENA surface site is in or is it interpolated in some way?

P10, L218: Does aerosol impact convective precipitation in this model?

P20, L360: Could you remind the reader what criteria is used to rule out an emulate again here, I had to go back to the methods to look it up. Or it might be clearer to reference the constraint process in its own subsection in the methods?

Figure 12 and discussion: In Section 3.1 it is noted how the observable covariation between Nd and LWP in PD may not be predictive of PI-PD LWP changes driven by Nd, and the differences in the predictability of delta Nd for delta LWP between the ENA and globally. These limitations are not really mentioned around Figure 12 or in the discussion. I.e. can you really be confident that constraint of model parameters based on PD observations from one site are representative of PI-PD global changes?

P24, L415: Typo – figure 14 is repeated a few times.