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

Summary: This manuscript presents a use case of the CAM6 perturbed parameter ensemble (PPE), deployed to constrain aerosol-cloud adjustments in conjunction with surface observations from an atmospheric observatory. A set of previously established parameters are perturbed within the model, and a series of emulators are then developed to sample the space defined by the 45 parameters. Leveraging cloud and precipitation observations, the authors are able to constrain the range of global delta LWP from preindustrial to present day, relevant to understanding the effective radiative forcing of the climate. Importantly, the range of the global aerosol-cloud adjustments is entirely positive, implying a cooling over the historical period. Minor revisions before publication are suggested.

Revisions:

1. Section 1 (95-105) and Section 2.1 (125-130) both contain discussions about the utility of surface observations to constrain aerosol-cloud adjustments. Suggest re-arranging and/or merging these comments and keeping 2.1 focused on the features of the ENA observatory.
2. While the paper focuses largely on the LWP response to aerosol perturbations, no mention is made of the cloud fraction (CF) adjustment. Typically, SW ERFaci is decomposed into the Twomey effect, LWP, and CF adjustments. The emphasis on cloud water changes is clear throughout the paper, but the CF adjustment might merit a mention in the Introduction to fully address the scope of what "aerosol-cloud adjustments" implies to readers.
3. Section 2.1.2 mentions that the observations of surface rain rate may miss those in the "drizzle domain," and Figure 6 shows that the ENA observations approach the upper range of PPE values for mean rain rate. How might a more accurate precipitation observation (that captures drizzle) impact this result, and can you be certain that differences can be attributed to sampling (grid cell mean vs station)? If the precipitation observations were out of the range of the PPE, how would that change your analysis? Given the importance placed on mean-state precipitation as a constraint (line 370), this may bear further discussion.
4. How does the 15% reduction in spread of global delta LWP compare to the results in Song et al. (2024)? Would you expect the constraint found here to be weaker due to the use of surface observations as a constraint? The use of an identical PPE could be cause for assessing the constraint found here.
5. How relevant is a constraint on the spread of global delta LWP when the prior range is entirely positive, given that there is a well-documented tendency for GCMs to predict uniformly positive LWP responses to aerosol perturbations, which disagrees with conclusions from many observational studies? There is relatively little acknowledgement of this in the introduction and conclusion, but it merits consideration.
6. Can the findings in Figure 13 be utilized by CAM6 developers for parameter tuning the next version of CAM? And can any of your findings inform future PPE studies - are there parameter ranges that should be widened or narrowed? Are there parameters that

should be omitted due to showing little influence on ACI and related processes? Some of this is briefly discussed in line 510, but could be expanded to widen the implications of this study.

a) Line 469: (2) and (6 → (2) and (6)
b) Line 483: Figure1Figure4 may be a typo
c) Line 416: Figure4 is repeated. Typo
d) Line 548: 6.87 g/m to g/m2
e) Figure 3: bottom right panel may be duplicated or cropped incorrectly
f) Some figure labels are unclear whether they refer to ENA or global. Suggest adding subscripts to denote for clarity.