

**Review for: “*Untangling causality in midlatitude aerosol-cloud adjustments*” by McCoy et al
submitted to ACPD**

Summary:

The authors address the issue of covariability between LWP and Nd that is not representative of cloud adjustments and provide an estimate of the radiative forcing due to cloud adjustments in Northern Hemisphere low clouds based on UM simulations constrained by observations. In particular, the authors focus on the fact that Nd variability is not only generated through variability in aerosol and cloud microphysical processes, which then may impact LWP, but that vice versa large LWP are associated with an increased likelihood in precipitation and thus scavenging of Nd. The latter may also contribute substantially to overall Nd variability in low clouds of the Northern Hemisphere, but is not representative of cloud adjustments to a perturbation in aerosol concentrations. To address this question the authors use a combined approach of remote sensing cloud retrievals and climate model simulations. The authors further argue that their simulation approach generally allows one to remove the Nd-LWP covariance representative of cloud adjustments from other compounding factors in addition to precipitation scavenging. They show that following their approach the sign and magnitude of the estimated cloud adjustment is impacted in global climate model simulations of present-day and preindustrial aerosol conditions.

General Comments:

This paper suggests a new approach to quantify the cloud adjustment in low-level clouds over the ocean and in particular, the Northern Hemisphere. The authors address one of the key scientific challenges in the quantification of the effective radiative forcing of anthropogenic aerosols and thus this paper is an excellent fit for this journal. The paper is well written, comprehensive, and I appreciate the careful discussion of correlation and the inference of causality throughout the manuscript. Prior to publication, I would like further clarification on their Ansatz as outlined below.

Specific comments:

- I am not sure I follow the author’s argumentation for $Nd = Nd_{cloud} + Nd_{scav}$. Based on your simulation strategy, you can have $Nd = Nd_{scav}$, or $Nd = Nd_{cloud}$ by decoupling individual processes from Nd variability. However, the observed variability in Nd will always be a combination of the two. That is, a fraction of the change in Nd is due to changes in Nd that could impact LWP and the remaining fraction is representative of clouds impacting Nd + environmental factors.
I agree with your point that some of the signal (or perhaps a large fraction) in the LWP-Nd relationship inferred from observations may be misinterpreted as a negative LWP adjustment, which is in truth driven by scavenging processes. However, I don’t follow the logic from Equ. 8 to Equ. 9. In my mind, the terms $d\ln Nd_{scav}/d\ln Nd$ and $d\ln Nd_{cloud}/d\ln Nd$ do not always equal 1, but range between 0 and 1. Please clarify.
- You nudge winds and temperature down to 1.7km altitude, yet analyse boundary layer clouds up to 3.2km in altitude. Can you be sure that your nudging has no impact on your derived relationships? And why do you nudge different variables for the different model experiments (Table 2)?
- Equ. 4: Have you performed tests on overfitting? For instance what is the reasoning for fitting both EIS and omega_550? Is there really additional skill added to the fit by including both?

- P8L7ff: I found this sentence confusing (see general comment above). Isn't it rather that precipitation scavenging is the only source of Nd variability? And that this variability is not representative of cloud adjustments?
- P9L25 & Fig 4. “there is significant variability in LWP associated with Nd”. This is only true if the full residual LWP-LWP_fitted is entirely flat and has no remaining functional dependence (i.e. your predictors describe all of the variability, which may not be the case). Have you checked for this?
- P12L7: It is interesting that you find the settling Nd to have the dominant effect over autoconversion. I would argue that this deserves further comment. Is there any support from this from observations? If it would be specific to the UM model, how would that affect your conclusions?

Typos & Text edits:

- P2L17: suggest rephrase “Because of this constraining the...” to “Because of this, constraining the...”
- P2L27: suggest rephrase “Simulation of deep...” to “A simulation of deep...”
- P3L18: rephrase “have an overall” to “has an overall”
- P4L13: rephrase “is explain” to “is to explain”
- P13L28: rephrase “may not be perfectly reflect”
- Table 2: Simulation acronyms not clear
- Fig. 2: What is the contour spacing of the white contours?