Response to comment on *Unveiling aerosol-cloud interactions Part 2: Minimizing the effects of aerosol swelling and wet scavenging in ECHAM6-HAM2 for comparison to satellite data*, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2017-449

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We would like to thank the reviewer for the helpful comments and suggestions. They have helped to improve the content of the paper.
The original comments are in black. Responses are in blue. *Modifications to the text are in green and italics*.

Anonymous Referee #1

This illuminating study helps to resolve previous disparities between simulated and observed relationships between clouds and aerosols. I particularly appreciate the physical mechanisms put forth to explain the different relationships under different assumptions. The combination of results for different model configurations is very helpful, and tells a compelling story.

Thank you for this encouraging assessment and your valuable comments and suggestions to improve the manuscript. The anthropogenic CCN increase used in the computation of the forcing estimates was changed in the revised manuscript, which has a large impact on the forcing values. The anthropogenic CCN increase is now estimated from AI instead of AOD changes (from simulations with present day and pre-industrial aerosol emissions). Although a disparity between the simulated and observed ERF_{aci} is present in the revised manuscript the overall conclusions remain valid.

Page 4, line 12. Eqs. (7) and (10) should be Eqs. (6) and (9).
Done.

Page 6 line 12. Replace “divided by to” with “divided by”.
Done.

Page 6 line 20. Move “multiple linear regression could be used in principle” to the front of the sentence.
Done.

Page 6, line 31. How is AODaerosol water calculated? A better way would be to calculate AOD of the dry aerosol given its size and dry composition. It would help the reader to know how AOD is determined from the aerosol components.
AODaerosol water is calculated by weighting AOD with the volume fraction of aerosol water. We agree that it would be better to calculate AOD of the dry aerosol from its size distribution and dry composition. Unfortunately, the necessary diagnostic is not available. We do not expect a change in the qualitative results i.e. that cloud variables are less susceptible to changes in AIdry than AI by using this approximation (or less to AODdry than to AOD).

$$AODdry = AOD - AOD_{aerosol\ water} = AOD \times (1 - volume_{aerosol\ water}/volume_{total\ aerosol}) \quad (1)$$

$AOD_{aerosol\ water}$ is calculated by multiplying AOD by the volume fraction of aerosol water ($volume_{aerosol\ water}/volume_{total\ aerosol}$). All aerosol particles are assumed to be spherical in this calculation.

Page 8, lines 22-25. Should note here the lower bound on droplet number.
Done.

A minimum cloud droplet number concentration of 40/cm^3 is used in ECHAM6-HAM2 and 20/cm^3 in ECHAM5-HAM.

Page 9, lines 1-7. Please explain how the aerosol processing scheme differs from configurations without it. Surely all configurations treat aqueous chemistry and nucleation scavenging in some manner, right?
The description of the aerosol processing scheme has been expanded. The main difference to the standard configuration is that the aerosol masses of the different aerosol species in cloud droplets and ice crystals are prognostic variables and that these masses are traced throughout all processes (nucleation, collisions, evaporation, aqueous chemistry, …). These processes are also computed in the standard configuration but there the aerosol is simply removed or added to the interstitial aerosol at the end of each timestep.

ECHAM-HAM in its standard configuration does not track aerosol particles in hydrometeors. In the standard configuration scavenged aerosol particles (by nucleation and/or impaction scavenging) are removed from the interstitial aerosol (evaporation of rain or sublimation of snow below cloud base release part of the scavenged aerosol particles back to the atmosphere though) and sulphate produced by heterogeneous chemistry is added to the interstitial aerosol. With the aerosol processing scheme on the other hand, aerosol mass transfers to and from in-cloud aerosol tracers by nucleation and impact scavenging, freezing and evaporation of cloud droplets, and melting and sublimation of ice crystals are tracked. These processes are computed explicitly. Sulphate produced by heterogeneous chemistry is added to the in-cloud sulphate aerosol tracer. Aerosol particles from evaporating/sublimating clouds and precipitation are released to the modes that correspond to their size with the aerosol processing scheme.

Page 10, line 8. Relative to what? Why not be quantitative? Say, "exceeds 0.8 in many areas".
Agreed. We changed this sentence to:

The LWP susceptibility is positive almost everywhere (i.e. an increase in AI leads to an increase in LWP and a decrease in AI leads to a decrease in LWP) and the LWP susceptibility exceeds 0.5 in many areas.

Page 11, line 15. Make it clear that figure 2g is without aerosol processing.
Done.

AODdry is less sensitive to aerosol size than AIdry so the negative LWP susceptibility shown in Fig. 2e should rather be due to changes in aerosol size than in aerosol number or mass (for comparison the LWP susceptibility to changes in AODdry of E6_Ref (i.e. without aerosol processing) is shown in Fig. 2g).

Page 11, lines 15-16. How is this statement support by the results? CCN depends on particles that do not contribute much to AOD, so why should AOD be better than AI? I think what you mean to say is AI includes the effects of aerosol processing, while AOD isolates CCN effects on cloud before cloud processing (line 14). I don't agree with that statement; you can't isolate processes when interactions are strong; you have to look at relationships between the variables that control the processes, which is why CCN is best.
This statement was not well formulated and AOD should indeed not be a better proxy for CCN than AI (Nakajima et al., 2001) because, as you point out, AOD does not correlate well with aerosol number. We therefore removed this statement from the text and abstract and only point out the need to investigate the effect of aerosol processing on this kind of statistical relationships.

Further research for example using a bin representation of aerosol size could give further insight of the effect of aerosol processing on aerosol-cloud interactions.

Page 11, line 27. Insert "averaged" before "over". Figure 3 caption should make this clear.
A sentence at the beginning of subsection 1.4.2 was added to make clear that only grid boxes over the global oceans are analysed. "over oceans" was replaced by "averaged over global oceans" in subsection 1.4.2 and captions of Figure 3 and 9.

In the weighted averaging only grid boxes over the global oceans are taken into account.

Page 11, lines 27-32. Why not discuss AATSR-CAPA and MODIS-CERES results here?
We wanted to focus on the difference between AI and AIdry for the CDNC susceptibility and therefore only discussed ECHAM6-HAM2 results. But as we discuss AATSR-CAPA and MODIS-CERES results for the other susceptibilities it is more consistent to add them for the CDNC susceptibility as well. Therefore, the discussion of AATSR-CAPA and MODIS-CERES results was added to the discussion of ECHAM6-HAM2 results.

For ECHAM6-HAM2, AATSR-CAPA and MODIS-CERES the CDNC susceptibility to AI varies only little between moist or dry free tropospheric conditions and a stable or unstable lower troposphere. The CDNC susceptibility of ECHAM6-HAM2 to AIdry is generally smaller, up to 50% less depending on the regime. The CDNC susceptibility of AATSR-CAPA is smaller than for MODIS-CERES or ECHAM6-HAM2 (AI or AIdry). The minimum distance of the CAPA-algorithm should reduce the effects of aerosol swelling, cloud contamination and 3D radiative effects by selecting aerosols farther away from clouds where these satellite artefacts should be minimal. For AATSR-CAPA this seems to lead to a small CDNC susceptibility. For ECHAM6-HAM2 and MODIS-CERES the differences between non-raining and raining scenes are small and in general the CDNC susceptibility is smaller in the raining scenes than in the non-raining scenes which is an indication of wet scavenging affecting aerosol concentrations in the raining scenes. For AATSR-CAPA the CDNC susceptibility to AI is smaller in the moist stable regime in the raining than in the non-raining scenes and even negative in the other regimes in the raining scenes, also indicative of wet scavenging in the raining scenes.

Page 12, line 1. Make it clear this is averaged over the oceans.
Done.

The response of LWP to changes in AI (dlnLWP/dlnAI), averaged over the global oceans, shown in Fig. 4, reveals larger susceptibilities and lower variability in susceptibilities between environmental regimes in ECHAM6-HAM2 than in satellite observations.

Page 12 lines 34-35. “Also” used twice. Page 13, line 24. New paragraph.
Both done.

Page 16, lines 8-11. Again, I question this conclusion. Aerosol processing is an important part of cloud-aerosol interactions.
See our response to your comment above. We removed the statement that AOD could be a better CCN proxy than AI and only point out the need to investigate the effect of aerosol processing on this kind of statistical relationships.

This calls for further research on the effect of aerosol processing when analysing the effects of changes in CCN on cloud properties.