Anonymous Referee #3:

The impact of the paper might be greater if the discussion of the results related more directly to specific applications. For example, the discussion of spatial resolution does not specifically state which spatial scales are relevant for cloud models, airborne observations, satellite observations, or global atmospheric models, or how the spatial averaging values chosen in the study relate to these scales. I would encourage the authors to try to make these connections clearer in the discussion so that the relevance of the work to the efforts of the broader community is clearly conveyed.

Response: We thank the reviewer for this suggestion to improve the quality of this paper. We have added text in different areas to clarify connections between our spatial scale choices and how they relate to different applications:

At beginning of Section 3.2:

"The magnitude of aerosol-cloud relationships can be biased by the choice of the spatial resolution used for quantification of aerosol and cloud parameters (e.g. Grandey and Stier, 2011). This is partly due to varying aerosol types, cloud regimes, and meteorological conditions. The following analysis examines the sensitivity of the LWP-dependent behavior of aerosol-cloud constructs to three different LES spatial resolutions that are relatively fine as compared to satellite-based studies that usually examine data at resolutions exceeding 1° x 1°. These finer spatial resolutions apply more to field measurements such as with aircraft."

In Section 3.3:

"The intent of this analysis is not to propose that there be one generally accepted technique to calculate aerosol-cloud parameters, but to carefully consider these factors during intercomparisons between different studies. With regard to specific applications, it is worth noting that climate models benefit from the spatial coverage of satellite observations, which provide data at resolutions coarser than those represented by the "max" values used in Table 1. Therefore, the use of leg-averaged and column-integrated measurements of aerosol-cloud parameters facilitate intercomparisons with satellite datasets. For purposes of intercomparison with remote sensing datasets, the choice of using either column-integrated or leg-averaged aerosol parameters with aircraft data will often depend on how such values are quantified with the remote sensor of choice (e.g. cloud-top or column-integrated data). On the other hand, aircraft data obtained at finer resolution allow for more direct intercomparisons with cloud models with finer resolution such as LES."

1) Figure 2 is very difficult to sort out, perhaps because the curves for different lifecycle stages overlay one another. One must stare at this plot for a while before figuring out which factors relate to different curve shapes. This could be made more clear if the curves for the different lifecycle stages were shown on different axes than the curves for different spatial resolution. Also, the third sentence in section 3.2 does not explain why the coarser spatial averaging "has the effect of compressing the chi-LWP and S0- LWP curves to lower LWP values". Presumably this arises from the skewed distribution of LWP within clouds. This should be clarified.

Response: We have addressed this reviewer concern by separating out Figure 2 into four separate panels to clearly show the separate curves as suggested. Below is the new version:
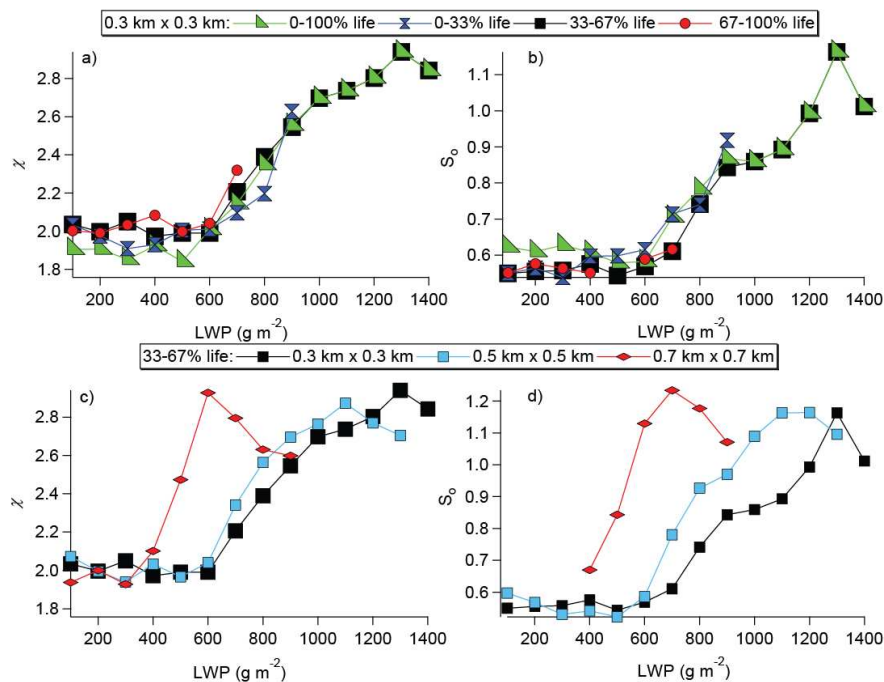

Figure 2. Large eddy simulation analysis of the dependence of (**a**)χ and (**b**) S_o on LWP and cloud lifetime, and also the dependence of (**c**)χ and (**d**) S_o on LWP and spatial resolution over which data for aerosol and cloud properties were obtained from the LES output.

Regarding the third sentence in section 3.2, we have addressed this issue by trying to re-word the explanation. Specifically, we added: "This is thought to be because the mean LWP is reduced at lower resolution while values of χ and S_o are preserved to a greater extent as they are quantified using relative magnitudes of r_e, R, and N_d. (Recall that the highest resolution is centered around the maximum cloud LWP and lower resolutions extend outward.) The values of r_e, R, and N_d will undoubtedly vary if calculated over different spatial scales, however, the analysis here shows that their relationships to one another exhibit less sensitivity than the absolute value of LWP to the change in resolution."

2) Likewise, I am confused about the physics underlying the discussion in section 3.3 about the analysis of aircraft observations (p.29907, lines 7-28). Here it states "the -dln(re)/dln(Nd) values tend to approach 0.33 when using the Nd and re combinations that exhibit the widest range of values. Similar reasoning explains why values of chi and S0…" However, it is the reasoning that is missing from that first sentence. Is there a physical reason why one would choose to use the maximum value of Nd or re rather than some vertical or horizontal average? Which choice makes the most sense for characterizing the interaction of aerosols with clouds, since that is the goal? In the next paragraph it is implied that these choices have quantitatively the same effect as changing the spatial averaging distance of the aircraft data. But this is only true because of how Nd, re, and LWP are distributed within a cloud. These discussions accurately describe what is shown in the tables and plots, but they do not adequately describe why. Therefore, we get a quantitative description of how different choices for processing the data give different results, but no insight into which approach makes the most sense for characterizing the interactions of aerosols and clouds.

Response: To address the broader issue of which choices make the most sense and why the metrics are higher in value when using the N_d/r_e/R combinations exhibiting the widest range of values, we add the following text in the manuscript section noted above (Section 3.3).

"The choice of how to quantify each of these parameters to examine aerosol-cloud interactions is dependent to a large extent on the intent of the analysis including the following: (i) meaningful intercomparisons with other aerosol-cloud datasets (e.g. other aircraft datasets, remote sensing data, and simulations such as LES); (ii) time synchronization with other measurements such as aerosol composition, size distributions, and hygroscopicity; and (iii) to directly improve climate model parameterizations that represent aerosol-cloud interactions at coarse spatial resolution.

Also, we add the following two paragraphs:

"The metric values and correlation coefficients in Table 1 are highest when quantifying the sub-components in ways that increase their dynamic range at least partly because the strength of the relationship between an aerosol perturbation and drop size (or R) at fixed LWP decreases over larger spatial scales. Furthermore, McComiskey et al. (2009) showed that ACI

decreases over larger spatial domains because of the reduction in the correlative relationship between aerosol and cloud fields.

The intent of this analysis is not to propose that there be one generally accepted technique to calculate aerosol-cloud parameters, but to carefully consider these factors during intercomparisons between different studies. With regard to specific applications, it is worth noting that climate models benefit from the spatial coverage of satellite observations, which provide data at resolutions coarser than those represented by the "max" values used in Table 1. Therefore, the use of leg-averaged and column-integrated measurements of aerosol-cloud parameters better facilitate intercomparisons with satellite datasets. For purposes of intercomparison with remote sensing datasets, the choice of using either column-integrated or leg-averaged aerosol parameters with aircraft data will often depend on how such values are quantified with the remote sensor of choice (e.g. cloud-top or column-integrated data). On the other hand, aircraft data obtained at finer resolution allow for more direct intercomparisons with cloud models with comparably high resolution such as LES."

We also remove Figure 3 from the original draft since the reviewer pointed out that it could be misleading with regard to explaining why the values of the three aerosol-cloud metrics tend to be enhanced in value when quantified using sub-components with wider dynamic ranges. Also, since Table 1 is concerned with data across a set of clouds, it is not the best comparison to show data from a single leg of aircraft data, where as the reviewer points out, there is variation in N_d, r_e, LWP, and R.

Other minor issues:

3) Is there a reference that discusses the utility of the aerosol index (product of optical thickness and Angstrom exponent) as a CCN proxy (p.29904 line 1)?

Response: We have added two references to address this issue in the text. We also specifically add the following text: "AI serves as a sub-cloud CCN proxy in the analysis as it has been shown to correlate better than AOD with columnar CCN concentrations [Nakajima et al., 2001; Bréon et al., 2002]."

Bréon, F. M., Tanre, D. and Generoso, S.: Aerosol effect on cloud droplet size monitored from satellite, Science, 295(5556), 834–838, 2002.

Nakajima, T., Higurashi, A., Kawamoto, K., and Penner, J. E.: A possible correlation between satellite-derived cloud and aerosol microphysical parameters, Geophys. Res. Lett., 28, 1171–1174, doi:10.1029/2000GL012186, 2001.

4) Section 3.4 should include a reference to Costantino and Breon (Geophys. Res. Lett., 37, L11801, doi:10.1029/2009GL041828, 2010) and a comparison with their results, which address the same problem of the vertical distribution of aerosols.

Response: We make a reference to this manuscript and also provide a brief discussion of how it relates to our study. We specifically add the following text: "These results are in agreement with the recent work of Costantino and Bréon (2010), who examined the relationship between AI and r_e off the coast of Africa for cases when aerosols were in contact with clouds and when aerosols were clearly separated from cloud layers. They only detected a clear inverse relationship between AI and r_e for the former case."

Costantino, L., Bréon, F. M.: Analysis of aerosol-cloud interaction from multi-sensor satellite observations, Geophys. Res. Lett., 37, L11801, doi:10.1029/2009GL041828, 2010.