

Atmos. Chem. Phys. Discuss., referee comment RC1  
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## Comment on acp-2021-859

Anonymous Referee #1

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Referee comment on "Quantifying albedo susceptibility biases in shallow clouds" by  
Graham Feingold et al., Atmos. Chem. Phys. Discuss.,  
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### Overall comment

This study explores roles of spatial and temporal aggregation on quantifying albedo susceptibility ( $S_o$ ) biases by analyzing the outputs of an ensemble of 127 large eddy simulations of marine stratocumulus. The authors designed three methodologies (L2, L3, and L2<sub>N</sub>), which mimic common satellite-based analyses in different ways, to identify the influences of the adiabatic drop concentration Nd retrieval, the correlation between aerosol and cloud fields, and the extent of reduced variance in cloud albedo and Nd. The LES simulations also provide an opportunity to obtain the 'true' Nd, by which the effectiveness of adiabatic assumption used in satellite retrievals can be assessed. As a consequence of such an analysis, the authors obtained a series of interesting results regarding the influencing factors on albedo susceptibility biases. I think this is a very nice study, and the results presented also have significant implications for reconciling currently diverse observation-based estimates of aerosol indirect effects.

I would recommend this paper be published in Atmospheric Chemistry and Physics after my specific questions/concerns listed below are addressed appropriately.

### Specific comments

Line 106-111: If I understand correctly, B (in Eq. 9) is only relevant to the sensitivity of L to Nd, i.e.,  $d\ln(L)/d\ln(Nd)$ , not to the whole albedo sensitivity. It's a bit confusing for me how authors translate B to the theoretical calculation of the  $S_o$  biases?

Line 128: As for the LES, why did the authors only choose “nocturnal” instead of “diurnal” simulations or both?

Line 139: How did the authors determine  $\gamma$  value in the calculation of  $A_c$  from simulated cloud optical depth?

Line 184: At what spatial resolution is cloud fraction defined here? Is it at 48km x 48km, or defined at 800m and 6 km respectively and then averaged up for whole domain?

Line 186: It is expected that high  $f_c$  (homogeneous clouds) would be associated with low bias in  $S$ . Why is the opposite here?

Line 184-192: The comparison between L2 and L3 methods here is to illustrate the aggregation biases associated with Jensen’s inequality. Actually, there is already another practical method accounting for this issue based on satellite observations. For example, the MODIS L3 product includes a cloud optical depth-effective radius joint histogram which was suggested to consider the non-linearity in the calculation of  $N_d$  (e.g. Quaas et al., 2008; Grandey and Stier, 2010). Thus, it might be interesting to evaluate the effectiveness of this method from the LES data in this study.

Line 274: How did the authors select these 58 simulations? Is there an objective criterion? Will it introduce artificial selection on cloud regimes? To show the robustness, it is useful to present the results from all 127 simulations, at least in the supplement information.

Line 280: It’s interesting that the separation of these branches for  $L2_N$  is not as evident as L2 and L3. What is the underlying reason? The authors should explain in more detail.

Line 300: Generally, a negative bias in retrieved  $N_d$  is expected duo to a positive bias in CER and a negative bias in COT for spatially inhomogeneous scenes according to the Eq.2 (Grosvenor et al., 2018). Thus, it is kind of surprising that the retrieved  $N_d$  for open-cellular clouds is larger than the true  $N_d$ .

Line 317: It is not quite clear that how the authors conducted the regression fits. As for  $\Sigma S_o$ , does the ‘individual scenes’ here mean the whole domain? In this case, the regression fit was conducted over all 4x4- (or 30x30-) resolved grids in each scene, and then  $\Sigma S_o$  was calculated by averaging up the individual  $S$  over all scenes (including the variations along both time and different simulations). Please clarify more detail on how the authors conducted the analysis.

Grandey, B. S., and P. Stier (2010), A critical look at spatial scale choices in satellite-based aerosol indirect effect studies, *Atmos. Chem. Phys.*, 10(23), 11459–11470, doi:10.5194/acp-10-11459-2010.

Grosvenor, D. P. et al. Remote sensing of cloud droplet number concentration in warm clouds: a review of the current state of knowledge and perspectives. *Rev. Geophys.* 56, 409–453 (2018)

Quaas, J., O. Boucher, N. Bellouin, and S. Kinne (2008), Satellite-based estimate of the direct and indirect aerosol climate forcing, *J. Geophys. Res.*, 113, 05204, doi:10.1029/2007JD008962.