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Comment on acp-2021-754

Anonymous Referee #3

Referee comment on "Albedo susceptibility of northeastern Pacific stratocumulus: the role of covarying meteorological conditions" by Jianhao Zhang et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-754-RC3, 2021

Summary comment

This research builds upon a growing body of literature seeking to understand the causal relationship between cloud droplet number concentration, liquid water path, and cloud albedo. The analysis quantifies the impact of meteorology and frequency of occurrence in which stratocumulus clouds reside within brightening and entrainment regimes. This is useful to constrain model responses of stratocumulus clouds to changes in N_d. The paper is well written, and the concepts come across very clearly. However, my main concern rests on the methodology used to filter the data. First, the methodology needs some clarification to be reproducible and convincing. Second, because the cloud albedo effect is sensitive to base state variables (LWP and N_d) it should be shown that filtering by cloud fraction, solar zenith angle, etc (necessary to remove untrustworthy satellite retrievals) does not adversely affect the population of the samples and bias the N_d-LWP-albedo relationship. These changes may require major revision. Overall, I think this work makes a great contribution to the field. I have provided some comments and suggested changes below.

Other comments

L4: Changes in "cloud fraction" are potentially as important, if not more so, than changes in LWP and Twomey on "modifying cloud radiative properties" to perturbations in N_d (e.g. see Goren and Rosenfeld, 2014, https://doi.org/10.1016/j.atmosres.2013.12.008).

L6: It is difficult to relate this brightening potential to other papers and climate reports

(e.g. IPCC) when the units are in W m^{-2} $ln(Nd)^{-1}$. Can this be related to an effective radiative forcing by aerosol-cloud interactions in units of W m^{-2}?

L8: Gryspeerdt et al. (2019), https://doi.org/10.5194/acp-19-5331-2019 discuss hypotheses involving similar regimes (entrainment-darkening and precipitation-brightening) as it relates to the Nd-LWP state-space. The word "identify" seems to suggest that this is a new discovery. I would recommend that this specific wording be changed to something along the lines of "we discuss the results of two susceptibility regimes: the entrainment….".

L14: Consider rephrasing the word "positively" – the word could be misconstrued as something that is "good" in this context.

Abstract: I think one of the novel results of this study is the analysis of cloud albedo in the N_d-LWP state space and that it exhibits a non-linear behavior as a function of N_d described in L201 – 205. I would recommend noting this behavior in the abstract and condensing the discussion on the intricate details with respect to meteorological drivers.

L32: "quantify/constrain" which is it?

L34: While this is true, Boucher et al., 2013 is a bit out of date, Bellouin et al. (2020) would be better to cite here.

L37: "These processes occur at short timescales (order 5 – 10 min)" needs to be supported with a reference.

L72: I'm not sure the reference of Gryspeerdt et al. (2014) is appropriate here (saying that it is capable of "consecutive snapshots of an evolving cloud field"). They examined the time difference in MODIS between Aqua and Terra satellites (two points in time) of cloud systems and their change with AI. I would recommend citing a study that uses geostationary satellite observations with many more "snapshots" in time instead to make this point.

L92: need to define SZA

L97: "aggregated to *the*"

L105: Why do you require such a strict criteria for $f_c > 0.99$? Grosvenor et al. (2018), shows that a threshold of 0.8 over 1-degree regions is sufficient to ensure the cloud field is homogenous. What effect does only including overcast clouds have on the analysis? I would think this could introduce a bias by removing partly cloudy cases where the clouds are likely to be more convective and possibly rainy. If N_d is correlated to fc this may introduce an unwanted bias into the results.

L108: No justification is provided for the 600 cm^{-3} threshold. Why?

L130: "Moreover, although" is redundant, I would suggest removing "although"

L130 – 135: Is a longwinded sentence, can this be split into two? I'm also not clear after reading it why joint histograms built upon a composite of satellite snapshots better determine the conditional probability distributions. Better than what?

L140: Justification is needed. It is stated that a correlation of greater than 0.2 is required to limit "highly questionable and thereby unreliable" cloudy scenes but I don't understand why this argument is only applicable to low correlations? How many cases are being removed to fit this requirement? What about negative correlations (more negative than -0.2)? More information on filtering is necessary here to understand which cloud conditions are removed from the analysis so that the uncertainties are better understood.

L150: remove the apostrophe for the word sensors'

L169 – L181: This discussion on filtering is unclear to me. The phrase "overcast footprints are weighted heavily over partially cloudy footprints" implies that the analysis uses clouds which have a cloud fraction of $0 < f_c <= 1$ but the next sentence says that Nd is only calculated when the footprint is overcast $f_c > 0.99$. What I am unclear about is whether the data are grouped or ungrouped in this study. Do the population of clouds in calculations involving cloud albedo (equation 1) differ from those which use calculations that involve Nd (equation 2)? It may be that I am missing a subtle point here but some clarification would be helpful regardless.

Title: I would recommend adding the word "overcast" next to stratocumulus since these are the clouds which are being filtered in this study (as per my point above, unless I am wrongly misinterpreting the filtering of the data in this study).

L188: How is SZA "adjusted" to become 0 degrees. It is explained in the following sentence, but it is still unclear to me how you remove the seasonally varying SZA? Is the bias minimization function based on a theoretical or empirical calculation? Please explain.

L233: Are these single-layer liquid “overcast” clouds?

L242: Again, can you confirm that these are overcast single-layer clouds?

Figure 1: “for all non-precipitating clouds (red)” while I understand this text refers to the slope value, consider changing it to a different color because OLWP < 500 g/m^2 is also displayed and red and is slightly confusing.

Figure 2: Can you say a little more about how the “Size of the filled circles in each panel indicates the relative frequency of occurrence” represents the data in this analysis? There appears to be a cutoff in which the diameter of one of the circles cannot be smaller than a certain size. What is that threshold and can it be included in the caption? Also, can “Occurrence-weighted mean radiative susceptibility” be clarified further? Presumably this means that larger circles will have more weight than smaller circles to the total radiative effect.