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Interactive comment on "Understanding Aerosol-Cloud-Radiation Interactions Using Local Meteorology and Cloud State Constraints" *by* Alyson Douglas and Tristan L'Ecuyer

Anonymous Referee #1

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General comment: The paper investigates the effect of aerosols on cloud radiative effect while taking into account the covarying influence of meteorological factors. The sensitivity of the cloud radiative effect to aerosols is derived by sorting the data by LWP, stability and entrainment. The data is retrieved from satellite observations and reanalysis, with AI serves as a proxy for the aerosols load in the atmosphere. The results show that the global aerosol indirect effect is over estimated when not accounting for the covariability. This is probably due to buffering of the clouds response by meteorology.

Major comments: 1. The authors use the term "inverse Twomey effect" which sounds

physically strange. I think that the darkening of the clouds, which refers here as "inverse Twomey effect", is the response of the LWP. The LWP decreases when cloud droplets are smaller due to evaporation (entrainment), resulting in less bright clouds. This explanation is also given in the literature that the authors cite. In addition, the "inverse Twomey effect" gets much attention in the paper, perhaps more than it should. It seems to be a rather minor effect as it occupies only a small fraction of the overall samples, as shown in most of the figures.

2. The authors write: "Constraining aerosol-cloud interactions using the local meteorology and cloud liquid water". It sounds like LWP is not part of the meteorology. However, meteorology determines boundary layer depth, and therefore also the cloud depth and LWP. Furthermore, moisture, which also controlled by meteorology in part, can alter cloud base height, and thus LWP. The authors should make it clear what they mean by meteorology.

3. The terminology used along the manuscript is inconsistent. For example, the authors use the term stability for both low level stability and inversion strength (though are similar). The same with entrainment and RH, cloud regimes and cloud states/morphologies. This is confusing.

4. Instead of using aerosols indirect effect and CRE, the authors are encourage to use the IPCC new terminology that more clearly distinguishes the key mechanisms by which anthropogenic aerosols alter the energy balance of the earth (e.g., https://doi.org/10.1175/AMSMONOGRAPHS-D-15-0033.1).

5. The captions are short and do not provide sufficient information to understand the Figures without digging into the text. Also, the captions sometimes do not present all the subplots in some of the Figures.

6. "Local Meteorology" seems to be a key factor in the study (the authors chose to have it in the title). I think that this point is not enough explained in the introduction and should be emphasized more in the conclusions.

Specific comments:

P1 L24 Provide a reference.

P2 L1-2. This is a 1.5 line paragraph. Perhaps you can discuss here the relative contribution of the cloud life time effect and cloud albedo effect.

P3 L17. I'm not sure a paper from 2014 can be considered "recent".

P3 26. Decoupling between cloud and ocean? Provide references here and in the following sentences to establish the relationship between RH and decoupling.

P3 L33. I would change effective radius to droplet size, and LWP to optical thickness.

P3 L33-35. The response of LWP to aerosols is not clear. The response is not solely due to precipitation suppression, also evaporation due to smaller drops (inverse Twomet effect?) and retrieval errors may alter observed relationships between aerosols and LWP.

Some studies show it increases, others decreases.

P4 L1. AMF?

P4 section 2.2. Please provide the spatial resolution of the data. Is the data from the different instruments is co-located to a single resolution? Why did you decide the upper threshold of LWP to be 400? Did you use optical thickness threshold to avoid additional uncertainties (see e.g. https://doi.org/10.1002/qj.2405).

If I understand correctly, the CF is determined based on a 12 km segment (P4 L29). A single open cell for example can cover 12km, which would give 100% CF, while the clear area in between cells would give 0% CF. Scaling is very important in determining the CF. You also exclude clouds with LWP<20, those are also excluded from the total CF? Such thin clouds can occupy a significant fraction over a given scene.

P5. The Equations have no numbering. Make it clear in the second eq. that the F_all

sky is only for the SW.

P5 section 2.3. You use AI as a proxy for aerosols. However, AI is retrieved only where there are no clouds. This is something that should be discussed.

P5 L22. "The cloud sensitivity" suppose to be cloud albedo sensitivity?

P6 L6 "inversion strength" is first mentioned here, which seems to be equivalent to the stability.

P6. What do the numbers above the sigma mean?

P7 section 2.6. The cloud regimes are simply LWP bins? Definition of cloud regimes is far more complex (e.g. https://doi.org/10.1002/2016JD026120).

Also note that later on in the manuscript regimes is replaced by "states" and "morphologies".

P7 L30 "Low LWP clouds are less sensitive to aerosol" - but it is the thinnest clouds that response the strongest to the Twomey effect.

P8 L9-10 Define the LWP bins.

Figure 3 (b) seems to be only a small fraction of the data.

Did you do any significant tests?

I suggest to replace the order of Figure 5 and Figure 4.

Figure 6 panel (h) is not mentioned in the caption. What does the color bar means?

P14 L1. This sentence needs context and further discussion, rather than just stating it.

P16 L5 "top" of what?

P16 L7 "stability, entrainment and cloud morphology" are equal to EIS, RH and LWP?

P16 L18. An explanation regarding the relationship between entrainment and particle size is needed here.

Consider adding Figure 9 to Figure 8.

P7 L19. How your sensitivities (here and later) are with respect to previous studies?

P18 L16-18. I'm not sure about the context of Jiang et al. 2006 here. In their study the additional aerosols were related to enhanced evaporation, which limited the cloud life time. The study was focused on cumulus field.

P18 L19. How turbulence decreases the activation efficiency of aerosols? Turbulence can also lead to secondary nucleation due to super saturation fluctuations.

P18 L26. You mention here that wind speed can affect cloud cover. Why didn't you include also wind speed in your parameters?

P19 L19-21. I would expect decreasing stability not to decouple clouds from the surface due to more mixing. Also note that decoupling that occurs when the stability is increased can inhibit cloud breakup (https://doi.org/10.1029/2018GL078122). Please clarify. Where is the role of aerosol here?

P20 L10-11. It would be helpful to reference the relevant figures here and in the last paragraph where the sensitives are given.

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