

## ***Interactive comment on “Unveiling aerosol-cloud interactions Part 1: Cloud contamination in satellite products enhances the aerosol indirect forcing estimate” by Matthew W. Christensen et al.***

### **Anonymous Referee #2**

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The paper addresses a very important question, whether using satellite data obtained right near clouds may bias satellite estimates of indirect aerosol radiative forcing. This may occur if complications (such as the presence of cloud drops in supposedly clear areas, aerosol swelling, cloud shadows, or enhanced scattering from clouds into aerosol fields) made aerosol observations near clouds unreliable or unrepresentative. The paper presents a new approach, which avoids these dangers by excluding the potentially compromised aerosol data that was obtained right near clouds. The authors then find that this approach greatly reduces the estimated indirect aerosol radiative forcing values. The overall approach seems reasonable, but I have some significant concerns. The two most important ones are (1) whether random sampling uncertainties have

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a large influence on the conclusions, and (2) whether the proposed method yields weaker aerosol-cloud relationships because it uses aerosol data obtained farther away from clouds, where the aerosol population may be less representative of the aerosol population that enters the clouds. Because of these and other concerns, I recommend major revisions to the manuscript.

#### Most important comments

Page 8, Lines 20-21: It would be important to discuss whether the relationship between cloud and aerosol properties (and so the estimated indirect aerosol radiative forcing values) may be weaker for aerosols farther than 15 km (that is, for CAPA-L2\_15km) simply because aerosols farther away are more likely to be in a different air mass (and therefore are not representative of the aerosols that actually interact with the clouds). I am concerned about this, because Line 8 of Page 7 mentions that the median distance between the cloud and aerosol pixels paired up by CAPA-L2\_15km is 27 km, which implies even larger distances in some cases.

Figure 7: The large and overlapping error bars raise some questions about the statistical reliability of results. Could it be that the results from CAPA-L2\_15km are smaller than the results from the other methods only because of random statistical fluctuations? The similarity of MODIS and AATSR results, and the similar tendencies in Figs. 8 & 9 suggest that the qualitative behavior in Figure 7 is correct despite the large error bars, but it would be important to address the issue of statistical reliability.

#### Other comments

Page 5, Lines 6-7: Should clarify the definition of  $c_{m\_overbar}$ , which is now: “ $c_m$  is the climatology of low-level clouds having cloud top pressure greater than 500 hPa and composed of liquid phase droplets over ocean regions” to show that the climatology is the climatological mean of \*\*\*cloud cover fraction\*\*\* of liquid water clouds with top pressures exceeding 500 hPa over ocean. Also, it seems best to delete “low-level” from the sentence, as 500 hPa serves as the definition for low levels, and the current wording

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could be misunderstood as  $c_{m\_overbar}$  telling what fraction of low-level clouds occur below the 500 hPa level (which would imply a remaining fraction of low-level clouds that occurs above the 500 hPa level).

Page 5, Line 10: the first term represents changes not in cloud albedo alone, but in the difference between cloud and clear sky albedos (with clear sky albedo also changing with aerosol loading). So perhaps the word “represents” could be replaced by something like “includes”. Or, perhaps even better, the text could specify that the first term represents the fact that aerosol loading (AI) has different impacts on the albedos of cloudy and clear columns. (If it had the same impact on both columns, this term would vanish.)

Page 5, Line 15: At the end of the line, what does  $F_{anth}$  represent and where does it come from? (In other words, how does  $F_{anth}$  relate to  $\tau_{anth}$ ?)

Page 6, first paragraph: While it is clear why the adopted hybrid approach is faster than the brute force approach (used for high cloud fractions), it would help to also discuss why the hybrid approach is faster than always using the low-cloud-fraction approach.

Page 6: It would help to clarify somewhere, what happens when there are two or more aerosol pixels that are at the same distance from a certain cloud: Does CAPA use only one of these pixels, or does it average the aerosol properties over all of these pixels?

Page 7, line 6: In order to clarify that clouds are paired with aerosols and not with other clouds, I suggest changing “clouds are paired based on the nearest located aerosol (CAPA-L2) and based on the nearest aerosol” to something like “clouds are paired with the nearest located aerosol (CAPA-L2) and with the nearest aerosol. . .”

Page 7, Line 18: I suggest either clarifying what “1-sigma regression estimate” refers to, or deleting “1-sigma”. The same applies to Page 9, Line 11.

Page 8, Line 13: The word “stronger” should be changed to “steeper”, which is a more suitable word for describing slopes.

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Page 8, Line 24: “MODIS afternoon-train” should be changed to “MODIS Aqua”.

Page 18: “CAPA-L2\_15km; blue” should be changed to “CAPA-L2\_15km; green”.

Page 8, Line 31: I suggest replacing “shown in Figure 9” by “shown in Figures 8 and 9”; otherwise the order of the two figures should be reversed (so that Figure 8 is referenced before Figure 9).

Page 9, Lines 8-9: In the sentence “we have reconstructed the pre-averaged aerosol product at first through the removal of near-cloud aerosols in the standard AATSR and MODIS data”, it would be important to clarify what is meant by “removal of near-cloud aerosols”: Does this mean removing aerosol data for 10X10 km areas that have clouds within 15 km? If so, how was this removal implemented: Was a 10X10 km area removed if any part of it was within 15 km from the nearest cloud? My guess would be that 1 km pixels within 15 km to the nearest cloud were eliminated first, and then the remaining pixels were processed by the 10 km-resolution algorithm.

Page 9, Line 19-20: Does Table 2 show results for all oceans, or does it exclude polar regions or covered by sea ice?

Page 21: Table 2 (along with the lack of CAPA in Figs. 8 & 9) points to an inherent limitation of CAPA: It cannot be used to estimate the extrinsic (or overall) forcing, only the intrinsic forcing. This important limitation of CAPA should be mentioned somewhere prominently, and probably even in the summary or abstract.

Page 10: The text of Section 8 seems to be missing.

Page 10, first line of Section 9: A typo: ATSR should probably be changed to AATSR.

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