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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Shortwave direct radiative effects of above cloud aerosols over global oceans derived from eight years of CALIOP and MODIS observations" *by* Z. Zhang et al.

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The authors would like toÂăthank the reviewer for the positive evaluation of the manuscript, the careful reading and the useful comments and suggestions.

The following are our point-to-point responses to the reviewer's comments. Reviewer's comments are in italic type.

However, my main criticism on the manuscript is that the authors present diurnally averaged aerosol DRE based on instantaneous measurements only, and argue that this is better than previous studies that presented instantaneous DRE, with the argu-

ment that diurnally averaged values are easier to compare. However, the assumptions made by the authors in order to derive diurnally averaged aerosol DRE, introduce large uncertainties in the presented results which are not evaluated. Instead of a diurnally averaged DRE, the authors in fact derive an instantaneous DRE, convolved with the diurnally varying solar radiation. In the error analysis, all or most uncertainties in the retrieval are evaluated, but the uncertainties of keeping the AOD, COD and cloud fraction constant over the day are not, which will have a much larger effects on the diurnally averaged aerosol DRE than aerosol microphysical property assumption or retrieval uncertainties. Therefore, the manuscript should clearly state that the retrieved parameter is in fact instantaneous ACA DRE for cloud scenes only, while the presented results are an estimation of the global, diurnally averaged, ACA DRE using the very simple assumption that all cloud and aerosol parameters are kept constant throughout the day. The argument that it makes the quantity more easily comparable is not convincing, since an instantaneous DRE multiplied by cloud fraction and diurnally averaged solar irradiance will give similar results, at least with the same large uncertainties.

Reply: We completely agree (and we pointed it out clearly in the manuscript) that ignoring the cloud diurnal cycle induces substantial uncertainty in our DRE computation. In fact the leading author is among the first to elucidate this uncertainty in a theoretical study [Min and Zhang, 2014].

However, accounting for the cloud diurnal cycle is very challenging and something we do not have the capability to do at present. The main problem is the lack of observations. Polar-orbiting satellite like MODIS only provides observations once a day in most part of the globe. Geostationary satellites provide continuous observation only in certain regions. Simply put there are no satellite datasets that provide high-frequency (e.g., hourly) cloud property retrievals (at least cloud fraction, cloud phase, cloud top height, cloud optical thickness and cloud effective radius) on global scales.

The cloud diurnal cycle is hard to get even at regional scales. As we pointed out at the end of the manuscript, the SEVIRI (Spinning Enhanced Visible and

Infrared Imager) on board of the European satellite MSG (Meteosat Second GenerationÂăspacecraft), provides diurnal observation in the SE and TNE Atlantic region. But we checked the operational SEVIRI data product from eumetsat (http://navigator.eumetsat.int/discovery/Start/DirectSearch/DetailResult.do?f(r0)=EO:EUM:C and it only provides monthly mean cloud diurnal observations. We are not sure how useful this dataset is for DRE computations, because of the day-to-day variations of both clouds and aerosols. The MODIS science team led by Dr. Steven Platnick and Kerry Meyer, are collaborating with a European team to develop a MODIS-like diurnal cloud property retrieval data set from SEVIRI, but this is not available yet. When this dataset becomes available, we plan to use it in conjunction with CALIOP or a new MODIS [Meyer et al., 2015] ACA retrievals to derive the "true" diurnally averaged DRE for ACA. But this is still at the research stage and will require substantial additional effort, so it has to be left as future work.

My main concerns are with section 4.1: eq 1: the 1/24 normalisation factor seems strange. It is probably based on some integration over time in steps of one hour, but this is nowhere explained. Furthermore, only integration over solar irradiance remain, which is likely available in higher resolution than once per hour.

Reply: Thanks for bringing this up. In this study we compute the instantaneous DRE every hour during the daytime and obtain the diurnal mean DRE from the hourly instantaneous values. The normalization factor 1/24 is applied to obtain the diurnal mean from the integration of hourly DRE. We added this explanations in the revision after both Eq. (2) and Eq. (4) to clarify the meaning of normalization factor and we also point out that "it needs to be changed accordingly if the instantaneous DREs are computed at a different frequency".

Going from eq2. to eq3. the authors remove cloud fraction from the integral, keeping it constant over the day. This step is understandable, but introduces such large uncertainties that one cannot suggest the quantity is still a diurnally averaged DRE, as argued above. Even the authors themselves in section 3.1 remark that clouds have a

strong diurnal cycle. Not only the frequency of occurrence of ACA is strongly affected by this, but more importantly the aerosol DRE itself, since it so strongly depends on the brightness of the background.

Reply: Please see our comments above.

Eq. 5: the first term can be removed. It makes no sense to denote terms of zero. Describing what has not been considered is enough.

Reply: we removed the first term and pointed out after the equation that "An important implicit assumption in Eq. (5) is that when CALIOP cannot detect an aerosol layer, the DRE is essentially zero."

Section 6 Also, it should be mentioned that the presented uncertainties are only valid for the instantaneous DRE, not the presented numbers of diurnally averaged aerosol DRE. If the latter is presented, the uncertainty should include an estimate of the diurnal variation of cloud fraction, COT and AOT at a global scale, and it's impact on the diurnally averaged DRE. This is currently missing.

Reply: Good point, we clarify this in the revised manuscript at the end of the section 6.3 "Summary of uncertainty study".

Textual issues: In the abstract a mention of which eight years are presented might be helpful.

Reply: Good point. We added the information (2007$\sim$2014) in the revised abstract.

Page 26370. It seems that four primary ACA regions should be defined in Fig 1, but these are missing.

Reply: We have added the ACA active regions in Fig. 2

Section 4.3 "observed" cloud reflectances are not inferred, but 'reflectances (from a contaminated cloud scene) are observed', from which biased COT are retrieved.

Reply: Yes, correct. It is simply the observation. We revised this part to make it clear.

"the above COT correction process is dependent on the radiative properties of the ACA." -> The bias is dependent on the radiative properties of the ACA, and the correction process is dependent on the assumed aerosol model.

Reply: We revised the text following your suggestion. Thanks.

References:

Meyer, K., S. Platnick, and Z. Zhang (2015), Simultaneously inferring aboveâĂŘcloud absorbing aerosol optical thickness and underlying liquid phase cloud optical and microphysical properties using MODIS, Journal of Geophysical Research-Atmospheres, 120(11), 5524–5547, doi:10.1002/2015JD023128.

Min, M., and Z. Zhang (2014), On the influence of cloud fraction diurnal cycle and sub-grid cloud optical thickness variability on all-sky direct aerosol radiative forcing, Journal of Quantitative Spectroscopy and Radiative Transfer, 142 IS -, 25–36, doi:10.1016/j.jqsrt.2014.03.014.

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