Reply to reviewer #2

The authors would like to thank 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

As the authors themselves point out, even in their conclusions, the necessary assumption that aerosols and clouds do not have diurnal variations may introduce significant biases. Would it not be possible to assess the importance of this e.g. using the PDFs used for Equation 10 as input to a simple Monte-Carlo scheme? If so (and if I have understood their methods for calculating DRF correctly), this should not be much more work than the two other, very useful sensitivity studies already presented.

Reply: The other reviewer also had the same question. We completely agree (and we pointed it out clearly in the manuscript) that the ignorance of cloud diurnal cycle could induce large uncertainty. 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 uncertainty is very challenging and frankly we do not have the capability to do it yet. One problem is the lack of observation to constrain the suggested PDF. 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. We are not aware of any dataset that provides 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 a global scale.

Even regional cloud diurnal cycle is hard to get. 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 Generation spacecraft), 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:CM:MSG:CLAAS_V001), and it only provides *monthly mean* cloud diurnal observations. We are not sure how useful this dataset is for the DRE computation, 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 European team to develop a MODIS-like diurnal cloud property retrieval data set from SEVIRI.

We plan to use this newly developed SEVIRI data set in combination 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 an on-going research that needs substantial efforts. We have to leave it as “future work” in this study.

Also: In the present analysis, little use is made of the altitude of the aerosol layer. For absorbing aerosols, the radiative efficiency is expected to increase with altitude, which may be a significant part of regional DRF variations for smoke aerosol if there are difference in mean altitude of the aerosol layer. Is this possible to diagnose from the present dataset?

Reply: First of all, we actually use the altitude of the aerosol layer in our DRE computation. As shown in the Figure 1 below (Figure 1 of [*Zhang et al.*, 2014]), we use the CALIOP aerosol layer altitude information to figure out the fraction of cloud below the aerosol layer using the joint histogram of cloud optical thickness vs. cloud top pressure in MODIS level-3 product. For details, please see [*Zhang et al.*, 2014].

Moreover, in the SE Atlantic region, the altitude of the above-cloud smoke layer varies only about 1km from coast region to open ocean as shown in Figure 2 below, which has negligible impact on SW radiative transfer simulation according to our sensitivity study.

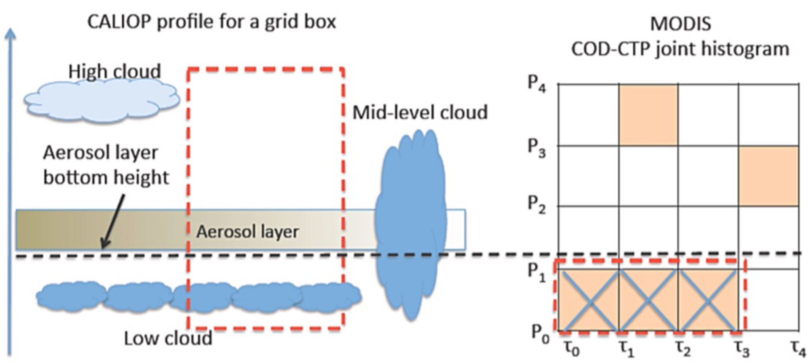

Figure 1 A schematic example to illustrate how CALIOP aerosol layer height information is used in our method to determine the population of liquid-phase clouds below the aerosol layer in the MODIS COD–CTP joint histogram. (Figure 1 from {Zhang:2014ex})

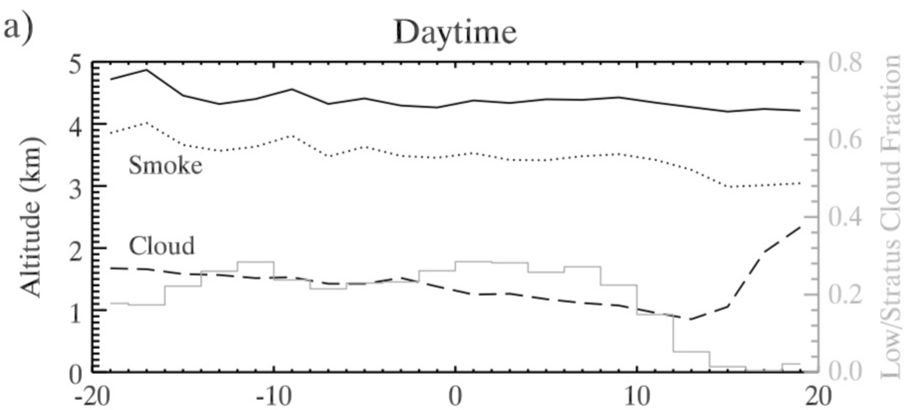

Figure 2 Meridionally averaged smoke aerosol subtype top and bottom heights (solid and dotted lines, respectively), and low/stratus cloud top height (dashed line) and cloud fraction (gray line), calculated from 6 years of August and September CALIOP daytime observations (2006–2011). Data are located between 6 N and 30 S. (Figure 5 from {Meyer:2013ek})

Minor comments:

Throughout the manuscript, and especially in the figure captions, key terms such as "global mean" or "annual mean" are often missing. The meaning is clear from the context, but not always if one just looks up a figure.

Reply: We added more specific terms in the figure captions.

The region boxes are not drawn on Figure 1.

Reply: We added the ACA active regions in both Figure 1 and Figure 2.

P2636 l 12-17: If CALIOP proves AOT of ACA, what do the regional research algorithms provide in addition? The sentences seem to contradict each other.

Reply: Indeed, these sentences are confusing and actually not very relevant to this study. So we simply removed them from the revised manuscript.

P26361 l 24: ? should be 's (Earth's)

Reply: Yes and we corrected it.

Meyer, K., S. Platnick, and Z. Zhang (2015), Simultaneously inferring above-cloud 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.

Zhang, Z., K. Meyer, S. Platnick, L. Oreopoulos, D. Lee, and H. Yu (2014), A novel method for estimating shortwave direct radiative effect of above-cloud aerosols using CALIOP and MODIS data, *Atmos. Meas. Tech.*, *7*(6), 1777–1789, doi:10.5194/amt-7-1777-2014.