

Interactive comment on “A novel method for estimating shortwave direct radiative effect of above-cloud aerosols using CALIOP and MODIS data” by Z. Zhang et al.

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Manuscript title: A novel method for estimating shortwave direct radiative effect of above-cloud aerosols using CALIOP and MODIS data

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General comments on the manuscript:

The present paper introduced a new satellite-based method for the estimation of short-

C3935

wave direct radiative effects (DRE) of above-cloud aerosols. The method employs a suite of aerosol and cloud products derived from MODIS and CALIOP. This includes joint histogram of cloud optical depth and cloud top pressure from MODIS, and the level-2 aerosol and cloud layer information from CALIOP. Instead of adopting pixel-by-pixel approach, the present method uses grid-level statistics and pre-computed table of the radiative transfer calculation for the computation of DRE. The method has been tested over the global ocean and particularly over the regions where the absorbing aerosols such as carbonaceous aerosols and mineral dust frequently overlay low-level liquid clouds. The resulting estimation of DRE is found to compare well (within 4%) with that of the pixel-by-pixel (PBP) approach.

While the method itself appears to be promising and more efficient than the conventional PBP approach, it requires a combination of the existing aerosol and cloud products available operationally from the A-train sensors. So naturally, the accuracy of the DRE estimation directly depends on the level of uncertainty associated with each product. For instance, the above-cloud aerosol optical depth retrieved by the CALIOP aerosol algorithm is significantly biased low in comparison to other passive sensors/techniques [Jethva et al., 2014, GRL, accepted]. This will lead to a low bias in the correction/adjustment applied to the MODIS cloud optical depth and ultimately to the estimation of DRE. While the results of this method strongly depend on the accuracy of the ingested retrieval products, I assert here that the methodology itself stands alone and is unaffected.

One of the few things I couldn't understand completely is how the CALIOP lidar measurements which have very limited samplings in 1 deg box have been extended to all MODIS 1 km cloud retrieval. Do authors simply average the CALIOP above-cloud AOD and applies to the entire 1 deg region? If so, the spatial variation in AOD outside the lidar's line of measurements can introduce uncertainty in the estimation of DRE. The assumptions of the spectral aerosol properties, the most important one is the single-scattering albedo can be an additional source of uncertainties. But again, I see that the

C3936

main point of the paper is to demonstrate the method using existing retrieval products. When comparing with the PBP approach of Meyer et al. (2013), do author include all the MODIS measurements intercepted in 1 deg region or just the retrieval along the CALIOP overpass?

The manuscript is a good fit to the scope of the Atmos. Meas. Tech. However, before it gets accepted, I would suggest the author to add a section or at least a brief discussion on the various sources of uncertainties in the estimation of DRE. Specific comments to the author are given below.

I am thankful to the Editor for giving me the opportunity to review this manuscript. In fact, we learn many things from reading/reviewing other researchers' papers.

Best,

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Specific comments:

Page 9995, line 25: author can also add Meyer et al. (2013)

Page 9996, line 16: add Wilcox et al. (2009) and Jethva et al. (2013)

Page 9997, line 5: I think Meyer et al. (2013) also used pre-computed look-up-table for estimating the ACA DRE. Please confirm.

Page 9999, line 21: I assume here that the size of grid box is 1 deg. Please confirm.

Page 10000, line 17: If I understand the present method correctly, the above-cloud AOD and layer (top/bottom) information retrieved from CALIOP in a 1 deg grid box is assumed to be uniform and therefore applied to the entire 1 deg grid observations of COD/CTP from MODIS.

C3937

If above is true, then it will have implications on estimated DRE for ACA situations. In comparison, CALIOP observations are significantly under-sampled than those of MODIS Level-2 1-km retrievals. Applying the mean values of CALIOP retrievals to the entire grid box may mask the natural spatial variability in aerosol properties.

Page 10001, line 1-5: I read the abstract of Costantino and Breon. They found strong effects of absorbing aerosols on cloud fraction when aerosols are located above cloud top. This is perfectly in line with the conclusion of Wilcox et al. (2010,2012) papers: a heated layer increases the stability and thus reduces the entrainment from top, thus preserving or even increase LWP and COD. But, now my argument goes like this: if above hypothesis is at work in reality, the apparent COD retrieved by MODIS inherently carries this information (increased LWP/COD) which is further corrected for the above-cloud aerosol presence using CALIOP observations. So, I believe at the end of the day it is reasonable to assume that the above-cloud AOD and underlying COD are statistically independent.

Page 10002, line 7: spectral aerosol properties?

Page 10003, line 1-3: "...DRE of ACA is largely insensitive to cloud effective radius..."

Page 10003, section 3.3, 1st paragraph: The accuracy of the COD correction obviously relies on the accuracy of the above-cloud AOD and assumed model. Recently, in an inter-comparative analysis of the above-cloud AOD retrieved from four sensors on board A-train satellites [Jethva et al., 2014, GRL, accepted], we find that the CALIOP 532-nm ACAOD is consistently under-estimated by a factor of 5 or more relative to the retrievals from passive sensors (MODIS, OMI, POLDER). Such a large bias in AOD will lead to erroneous COD corrections and ultimately biased estimation of DRE. However, I see here that the main point of this paper is to demonstrate the method for the DRE estimation and therefore inaccuracy in the CALIOP/MODIS retrievals used in this work should not be treated as the weakness of the original method. I suggest author to add a small section or at least a paragraph describing the uncertainty associated with

C3938

several assumptions involved in this work.

Page 10007, 1st paragraph: This result essentially resembles the finding of several previous studies which showed based on the RT simulations that the TOA forcing is a strong function of the surface albedo. Over the Arabian Sea, dust frequently overlies low-level clouds during the Indian summer monsoon. However, these clouds are patchy, broken, and shallow and therefore less efficient in reflecting sunlight. The scattering effects, therefore, dominate over the aerosol absorption which results in negative forcing at TOA. More precisely, the sign and magnitude of DRE for ACA situations is modulated by COD. At the same time, above-cloud AOD is also a co-determinant of the DRE.

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