

Interactive comment on “Estimations of Global Shortwave Direct Aerosol Radiative Effects Above Opaque Water Clouds Using a Combination of A-Train Satellite Sensors” by Meloë S. Kacenenbogen et al.

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We thank Dr Devasthale for his kind words and thoughtful comments. We are pleased to announce that the manuscript will be shorter after deleting section 3.2.2, 3.2.3, appendix B4 and all of its dependencies (following one of reviewer #3's comments).

We particularly appreciate Dr Devasthale's comment on the impact of assumed aerosol and cloud vertical distribution on DARE_OWC. His suggestion has led us to substantially re-write and improve section 4.5. (“assuming fixed aerosol and cloud vertical

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layers”) to add more discussion of previous work on the subject. We are very grateful as we think this improves this section (and therefore our paper). As written in this section, multiple peer reviewed papers have emphasized the minimal impact of the height of the aerosols above clouds in the calculation of DARE_OWCs, as compared to the effect of changes in other parameters such as the AOD, SSA, or cloud albedo. For this reason we have not included any further sensitivity analysis varying the aerosol and cloud height in our calculations in the present work.

This is how section 4.5 reads now:

“Finally, Long Wave (LW) radiative forcing is particularly dependent on the vertical distribution of aerosols, especially for light absorbing aerosols [Chin et al., 2009]. This is because the energy these aerosols reradiate depends on the temperature, and hence their altitude. For example, Penner et al. [2003] emphasize the importance of soot and smoke aerosol injection height in LW TOA DAREall-sky (see Eq. 1) simulations (higher injection heights tend to enhance the negative LW radiative forcing). Quijano et al. [2000], Chung et al. [2005] and Chin et al. [2009] demonstrate the importance of an aerosol height, in relation to a cloud height (i.e., the aerosols located above, within or below the clouds) in an accurate estimation of SW TOA DAREall-sky. Chung et al. [2005], for example, show that varying the relative vertical distribution of aerosols and clouds leads to a range of global anthropogenic SW TOA DAREall-sky from -0.1 to -0.6 Wm⁻² (using a combination of MODIS satellite, AERONET ground-based observations and CTM simulations, see their Table 2). However, here, we concentrate on cases of aerosol layers overlying clouds in order to compute SW TOA DAREcloudy. Aerosol and cloud layer heights are assumed constant over the globe in our study (see section 2.2). Future studies should incorporate mean gridded (i.e., 4°x5° in this study)-seasonal CALIOP Level 2 aerosol and cloud vertical profiles into the calculation of DAREOWC. However, constraining clouds between 2 and 3km in our study does not seem unreasonable as our AAC AOD calculations using the DR method can only be applied to aerosols overlying specific low opaque water clouds with, among other cri-

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teria, an altitude below 3km (see Table B2). On the other hand, constraining aerosols between 3 and 4km in our study is not realistic over many parts of the globe (e.g., see Fig. 7 of Devasthale et al. [2011]). For example, over the region of South East Atlantic during the ORACLES campaign, the HSRL team observed an aerosol layer located in average between 2 and 5km, and overlying a cloud at an average altitude of 1.2km. According to Zarzycki et al. [2010], the underlying cloud properties are orders of magnitude more crucial to the computation of DAREcloudy than the location of the aerosol layer relative to the cloud, as long as the aerosol is above the cloud. In other words, the forcing does not seem to depend on the height of the aerosols above clouds as much as other parameters such as the AOD, SSA or cloud albedo. Zarzycki et al. [2010] investigated this assumption and found that over low and middle clouds, forcing changed by $\sim 1-3\%$ through the heights where the Black Carbon burden was the largest. These small changes in forcing are likely products of a change in atmospheric transmission above the aerosol layer [Haywood and Ramaswamy, 1998] (e.g., a change in the aerosol height linked to a change in the integrated column water vapor above the aerosol layer and this, in turn, would alter the incident solar radiation).”

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