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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Measurement-based climatology of aerosol direct radiative effect, its sensitivities, and uncertainties from a background southeast U.S. site" *by* James P. Sherman and Allison McComiskey

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We thank anonymous reviewer #2 for her/his excellent suggestions, which we hope will lead to improved paper readability. We've gone to great lengths to implement nearly all the suggestions made by both reviewers and believe that these changes have significantly improved the paper. We structure our responses to each reviewer comment/suggestion as follows: (1) Reviewer 2 Comment xx, where xx is the comment number; (2) Authors' response; and (3) Changes to Paper.

Reviewer 2 Comment 1: Aerosol properties are retrieved during daytime in presence of solar radiation. How are then DRE estimated for 24 hours? Or is it estimated for a range of SZA?

Authors' Response: To estimate diurnally-averaged DRE, we apply the daily-averaged aerosol optical properties as inputs to the RTM for each of the 24 hours, as described in the first paragraph of Sect. 4.2. Using daily-averaged aerosol properties as inputs to the RTM for each of the 24 hours basically amounts to integrating over the range of SZA, so that the effect of SZA on diurnally-averaged DRE is averaged out. The in situ aerosol measurements used by the radiative transfer model (ω0 and g) as part of NOAA ESRL are retrieved over all 24 hours so the 'daily-averaged' ω0 and g represent true 24-hour averages. Aerosol optical depth (AOD) measured as part of NASA AERONET requires sunlight and is only measured during presence of solar radiation (i.e. daylight hours), as the reviewer points out. Our 'daily-averaged' AOD is thus calculated based only on these daytime values and may or may not be representative of AOD during nighttime hours. However, AOD during night-time hours does not affect the calculations of the shortwave solar fluxes, since these shortwave fluxes (both with and without aerosols turned on in the RTM) are zero during nighttime, leading to DRE=0 for these hours.

Changes to Paper: We clarify these points by modifying the first paragraph of Sect. 4.2 so that it now reads as follows. We embolden the additions/modifications to the paragraph: "For the study of seasonal DRE variability (Sect. 5.1), we use the SBDART model to calculate diurnally averaged DRE at the TOA and at the surface, for 418 days during the period 14 June 2012 thru 28 June 2016. We then bin the DRE by month (Figs. 4a and 4b). For each of the 418 days, we calculate DRE for each hour to account for the effect of varying solar geometry on the calculation of diurnally-averaged DRE. For each hour, we supply daily-averaged AOD(λ), ω0(λ), and g(λ), along with monthly averaged spectral surface reflectance (R), as inputs to the SBDART model. Upwelling and downwelling broadband shortwave fluxes for that hour are calculated with average measured aerosol properties and then with no aerosols and their difference is used to calculate DRE using Eq. (5). The process is repeated for all 24 hours and the results averaged to yield diurnally averaged DRE. Since AOD is only measured during daytime hours, the daily-averaged AOD used as RTM input may or may not be representative of AOD during night-time hours. However, AOD during night-time hours does not affect the calculation of shortwave solar fluxes, since these fluxes (both with and without aerosols) are zero during night-time (leading to calculated DRE=0 for these hours)."

Reviewer 2 Comment 2: Sec 4.4: what does rho with subscript 'j' represent? Is it another aerosol parameter?

Authors' Response: No. The equation (Eq.6) used to calculate DRE uncertainties due to uncertainties in AOD, $\omega 0$, g, and R is first written as a summation over the four individual uncertainties, before being explicitly spelled out in Eq.7.

Changes to Paper: We clarified the use of the subscripts with the following sentence, after Eq.6: "The double summation 'i' and 'j' is over the four RTM input parameters (AOD, $\omega 0$, g, and R)."

Reviewer 2 Comment 3: How closely do the SBDART aerosol profile and MPLNET profile match?

Authors' Response: Since are APP site was not added to MPLNET until March 2016 (after the period of the current study), our lidar-measured vertical aerosol profiles are not quality-assured and therefore not used in the current study, other than qualitative inspection to verify that aerosols are largely confined to the lowest 1 to 2 km of atmosphere above APP (first paragraph of Sect.3.1). We state in the first paragraph of Sect. 3.1.2 that "Most vertical profiles of aerosol normalized relative backscatter measured by the lidar at APP during part of the study period and afterward (as part of MPLNET) show a qualitatively exponential decay with height and an absence of aerosol layers aloft (unpublished result)" and state in the final paragraph of Sect. 4.1 that "Most vertical profiles of aerosol normalized relative backscatter measured by the lidar at APP

during part of the study period and afterward (as part of MPLNET) show a qualitatively exponential decay with height and an absence of aerosol layers aloft (unpublished result)". These assertions are based on visual inspections of the lidar-measured normalized relative backscatter (NRB) vertical profiles. Most of the NRB profiles decay relatively smoothly with increasing altitude (quasi-exponentially), with NRB dropping to $\sim$1/3 of the peak values at altitudes between 1 and 2 km (more often than not below 1.5km). This decay is similar to the vertical dependence assumed by the standard SBDART vertical profiles used in the study, which treat the aerosol density vertical distribution as exponentially decaying, with scale heights between 1.05-1.51km. The scale heights used by SBDART are calculated from the near-surface aerosol extinction coefficients, which we supply to SBDART. Although vertical distribution of aerosols is believed to be a second-order effect in the calculation of aerosol DRE for primarily scattering aerosols (McComiskey et al., 2008), we plan to study its influence on DRE at APP as part of a future publication. However, MPLNET is currently upgrading their processing to Version 3 and quantitative, quality-assured aerosol profiles from the APP MPLNET site are not yet available for download.

Changes to Paper: We further clarified the final paragraph of Sect. 4.1 to read as follows, with the additions emboldened: "Vertical distribution of aerosols is believed to be a second-order effect in the calculation of aerosol DRE for primarily scattering aerosols (McComiskey et al., 2008) and we use the SBDART default vertical aerosol density profile in this initial study. The default profile uses an assumed exponential decrease in aerosol density with a scale height inversely proportional to surface-level aerosol light extinction coefficient at 550 nm (Ricchiazzi et al., 1998), which is calculated as the sum of the measured σsp and σap (Sect. 3.1.2). The overall curve is scaled by the AOD (Sect.3.1.1). Aerosol density scale heights used by SBDART range from 1.05 to 1.51 km, which qualitatively agree with typical MPL-measured normalized relative backscatter profiles under clear sky conditions at APP (Sect. 2)."

Reviewer 2 Comment 4: Page 22, lines 18-19: mention the range for 'moderate AOD' to have a perspective, similarly for 'low AOD'.

Authors' Response: Done

Changes to Paper: We have clarified the passage mentioned by the reviewer as follows: "Unlike the McComiskey et al.(2008) study, we include the effect of covariances amongst aerosol optical properties in order to determine their effect on DRE uncertainty. Covarience impacts on DRE uncertainty at APP are negligible for low AOD conditions (AOD$\leq$0.05 at 550nm) during winter and surrounding months but do increase ΔDRE by $\sim$0.2 to 0.3 Wm-2 under moderate and high AOD conditions (AOD$\geq$0.10 at 550nm) during summer and surrounding months." We also qualify 'low AOD', 'moderate AOD', and 'high AOD' when they are used in the other sections of the paper.

Please also note the supplement to this comment:
https://www.atmos-chem-phys-discuss.net/acp-2017-513/acp-2017-513-AC2-supplement.pdf

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