Reducing Uncertainty in Aerosol Direct Radiative Effect Through Synergistic Use of Long-term Satellite and Ground-based Measurements

J.P. Sherman, I. Krintz and H. Suthers

Appalachian State University, Department of Physics and Astronomy, Boone, NC 28608; 828-262-2438, E-mail: shermanjp@appstate.edu

Based on current uncertainties in satellite-retrieved aerosol optical depth (AOD) and especially the particle properties (i.e. single-scattering albedo and asymmetry parameter) used by radiative transfer models to calculate aerosol direct radiative effect (DRE), Kahn (2011) concluded that satellite data alone cannot provide enough quantitative detail to yield the required improvements in DRE estimates. Reducing the uncertainty in measurement-based DRE to ~1 Wm^{-2} necessitates uncertainties in AOD and single-scattering albedo (ω_0) of ≤ 0.02 (Sherman and McComiskey 2018). Ground-based Cimel sunphotometers (as part of NASA AERONET) and multi-filter rotating shadowband radiometers (MFRSRs) can measure AOD to within ~0.01 (Eck et al. 1999, Hallar-personal correspondence). *In situ* measurements of ω_0 at ESRL/GMD sites possess ambient relative humidity (RH) ω_0 uncertainties of ~0.02 (Sherman and McComiskey 2018), although humidified light scattering measurements are necessary to correct the dry aerosol optical properties to ambient RH at humid sites. Aerosol DRE calculated using the ground-based aerosol optical properties as inputs possess uncertainties of ~1 Wm^{-2} (Figure 1; Sherman and McComiskey 2018). However, there are currently only two co-located AERONET/ESRL sites in the U.S. possessing such measurement capabilities (Southern Great Plains [SGP] and Appalachian State [APP]), along with one co-located MFRSR/ESRL site (Storm Peak Lab). As part of a proposed strategy for reducing DRE uncertainty, Kahn et al. (2017) have the goal to acquire enough sub-orbital *in situ* measurements of aerosol optical and microphysical properties corresponding to major aerosol types to construct probability density functions (PDFs) of the key properties corresponding to each major aerosol air mass type. The PDFs can then be used to prescribe aerosol optical properties and calculate aerosol DRE at any location, using satellite-retrieved AOD and aerosol type (Kahn et al. 2017).

We will present a modified version of the strategy proposed by Kahn et al. (2017) to better constrain aerosol DRE, using (1) ground-based aerosol properties measured at APP's AERONET and ESRL/GMD sites; (2) AOD and surface albedo retrieved by Multi-angle Imaging SpectroRadiometer (MISR) and/or MODIS; (3) aerosol type retrieved by MISR; and (4) sub-pixel AOD measurements made by Citizen Scientists, using handheld sunphotometers developed and calibrated at APP. We also present a method for evaluating the strategy. While our focus is on evaluating and improving upon DRE estimates over mountainous sites (where satellite aerosol retrievals often perform poorly, if they are even attempted), the strategy can easily be extended to any ESRL/GMD aerosol monitoring site with a continuous, long-term record of particle property measurements (and their RH-dependence, for humid regions).

	MAR	JUN	SEP	DEC
ΔDRE_{AOD}	0.47 (2.3)	0.35 (1.8)	0.34 (1.7)	0.43 (2.1)
$\Delta DRE_{\omega 0}$	0.27	0.77	0.36	0.079
ΔDRE_g	0.059	0.18	0.12	0.018
ΔDRE_R	0.16	0.34	0.18	0.04
DRE (Base case)	-2.4	-5.7	-3.6	-0.91
ΔDRE / DRE (Base Case)	0.24 (0.97)	0.20 (0.39)	0.20 (0.56)	0.49 (2.4)

Figure 1. Calculated measurement uncertainties in DRE at the top of atmosphere above APP, including the contributions due to uncertainties in aerosol optical depth (AOD), single-scattering albedo (ω_0), scattering asymmetry parameter (g), and broadband surface reflectance (R). Units of ΔDRE are W m^{-2}. Uncertainties are also calculated as a fraction of DRE calculated using seasonal median aerosol optical properties (base-case values). The uncertainties associated with AOD are calculated twice; once using AERONET AOD uncertainties and once using the lower bound for MODIS AOD uncertainty (shown in parentheses).