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Radiative forcing efficiency of a forest fire smoke plume at the surface and TOA

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On 6 Sept. 2010 at about 10:00 AM LST an isolated forest fire developed in the hills northwest of Boulder, Colorado, U.S.A. Under very clean and dry conditions a narrow smoke plume (∼10 km wide) was carried eastward by strong westerly winds through a cloudless sky. By chance, it drifted over several sets of instruments that were ideal for computing the surface radiative forcing efficiency (RFE) of the smoke aerosol [Stone et al. 2011]. These included two operational surface radiation budget (SRB) stations with collocated AOD measurements, four GPS water vapor sites, and three Weather Underground stations. Air samples were also analyzed for the optical properties of the smoke. The ideal nature of this situation was bolstered by persistent clear skies that permitted unrestrained AOD calculations throughout the day. Thus, direct calculations of the RFE for shortwave (SW), longwave (LW) and all-wave radiation could be made with few assumptions. Measured AOD at 500nm ranged from background values of 0.045 prior to the event to a peak of ∼3.5. The primary result was the documentation of the surface RFE over a wide range of solar zenith angles (SZA) and a surface albedo of 0.15. Surface RFE-SW varied from -194±10 W/m2/AOD500 at high sun (35° SZA) to -81±9 W/m2/AOD500 at low sun (73° SZA), while RFE-LW remained stable at +10±7 W/m2/AOD500 throughout the day and night. Assuming that RFE-SW went to zero at sunset, diurnally averaged RFE for SW, LW and all-wave net radiation at the surface were -61.5, +10.0, and -51.5 W/m2/AOD500, respectively. The loss of incoming energy resulted in daytime cooling of the surface air temperature of up to 5°C under the plume. Computation of the plume's radiative effect at the top of the atmosphere (TOA) and the inferred atmospheric heating induced by the plume requires space-borne measurements of outgoing SW and LW irradiance. CERES broadband measurements from NASA's Terra and Aqua satellites would be ideal for this purpose but the plume was too small compared to the processed CERES footprint. The higher resolution (500 m) MODIS imager did sample the smoke plume about two hours after the fire started. MODIS does not have broadband sensors but rather samples spectral radiance at several solar wavelengths. For this paper we will estimate the radiative effect of the smoke plume at TOA using MODIS data. First we will convert the MODIS spectral sampling to broadband SW using established methods, and then analyze the MODIS-derived outgoing broadband irradiance from the plume and from clear areas outside of the plume to infer the RFE-SW at TOA. Results will be compared with radiative transfer model calculations. The atmospheric heating rate for a single point at the time of passage will also be investigated.

Reference

R. S. Stone, J. A. Augustine, E. G. Dutton, N. T. O'Neill, and A. Saha (2011), Empirical determinations of the longwave and shortwave radiative forcing efficiencies of wildfire smoke, J. Geophys. Res., 116, D12207, doi:10.1029/2010JD015471.