EGU2020-17044, updated on 24 Oct 2020
https://doi.org/10.5194/egusphere-egu2020-17044
EGU General Assembly 2020

Constraining direct aerosol radiative forcing using remote sensing and in-situ constraints

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Absorbing aerosols affect the climate system (radiative forcing, cloud formation, precipitation and more) by strongly absorbing solar radiation, particularly at ultraviolet and visible wavelengths. The environmental impacts of an absorbing aerosol layer are influenced by its single scattering albedo (SSA), the albedo of the underlying surface, and also by the atmospheric residence time and column concentration of the aerosols.

Black-carbon (BC), the collective term used for strongly absorbing, carbonaceous aerosols, emitted by incomplete combustion of fossil fuel, biofuel and biomass, is a significant contributor to atmospheric absorption and probably a main-driver in inter-model differences and large uncertainties in estimating the aerosol radiative forcing due to aerosol-radiation interaction (RFari). Estimates of BC direct radiative forcing suggest a positive effect of +0.71 Wm^{-2} (Bond and Bergstrom (2006)) with large uncertainties [+0.08, +1.27] Wm^{-2}. These uncertainties result from poor estimates of BC atmospheric burden (emissions and removal rates) and its radiative properties. The uncertainty in the burden is due to the uncertainty in emissions (7.5 [2, 29] Tg yr^{-1}) and lifetime (removal rates). In comparison with the available observations, global climate models (GCMs) tend to under-predict absorption near source (e.g. at AERONET stations), and over-predict concentrations in remote regions (e.g. as measured by aircraft campaigns). This may be due to GCM's weak emissions at the source, but longer lifetime of aerosols in the atmosphere.

This study aims to address the parametric uncertainty of GCMs and constrain the direct radiative forcing using a perturbed parameter ensemble (PPE) and a collection of observations, from remote sensing to in-situ measurements. Total atmospheric aerosol extinction is quantified using satellite observations that provide aerosol optical depth (AOD), while the SSA is constrained by the use of high-temporal resolution aerosol absorption optical depth (AAOD) measured with AERONET sun-photometers (for near-source columnar information of aerosol absorption) and airborne black-carbon in-situ measurements collected and synthesised in the Global Aerosol Synthesis and Science Project (GASSP) (for properties of long-range transported aerosols). Measurements from the airborne campaigns ATOM and HIPPO are valuable for constraining aerosol absorption in remote areas, while CLARIFY and ORACLES, that were employed over Southeast Atlantic, are considered in our study for near source observations of biomass burning aerosols transported over the bright surface of stratocumulus clouds.

Using the PPE to explore the uncertainties in the aerosol absorption as well as the dominant emission and removal processes, and by comparing with a variety of observations we have confidence to better constrain the aerosol direct radiative forcing.