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MEASURING THE UNMEASURABLE: WHY MEASUREMENTS ALONE CANNOT QUANTIFY AEROSOL RADIATIVE FORCING OF CLIMATE CHANGE

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Abstract

Present estimates of radiative forcing of climate change by aerosols, based mainly on modeled aerosol loading and properties, vary greatly. This situation has given rise to suggestions that aerosol forcing be measured rather than modeled. In principle, aerosol direct forcing might be determined from satellite measurements of irradiance or radiance. However irradiance measurements are problematic because of the need for extensive homogeneous cloud-free scenes; radiance measurements, albeit with much less stringent spatial homogeneity requirements, rely on radiance-to-flux conversion with attendant need for aerosol phase function. Both approaches require accurate surface albedo, including spectral bi-directional reflectance for the radiance approach. Alternatively surface-based measurement of direct and diffuse downwelling surface irradiance relative to that of a Rayleigh sky yield instantaneous aerosol forcing of surface irradiance to a few watts per square meter, but transferring this surface forcing to top-of-atmosphere forcing requires aerosol single scattering albedo and asymmetry parameter. Restriction of measurements to cloud-free situations, would limit measurements to situations of low relative humidity, a concern given the great increase in forcing by hygroscopic aerosols with increasing RH. Generalization from times and locations of measurement requires knowledge of the geographical and vertical distribution of aerosol extensive and intensive optical properties, including humidity dependence. Similar considerations apply to direct measurement of aerosol indirect forcing due to enhancement of cloud reflectance and/or persistence. Determination of aerosol forcing of climate change over the industrial period requires attribution of aerosol influences to natural vs. anthropogenic aerosol as a function of secular time. All these considerations speak to the need for understanding and model-based representation of aerosol amount, composition, and microphysical properties and their dependence on emissions. Central to developing such understanding and model-based representation are measurements of the properties and evolution of aerosols and characterization of the cloud drop activation process and its relation to controlling variables. These considerations suggest that estimates of aerosol forcing will remain strongly model-dependent, with attendant need for rigorous evaluation of the performance of model components that describe aerosol loading and properties and radiative forcing and cloud modification by aerosols of well specified properties.

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