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(Direct) Radiative Forcing by Anthropogenic Aerosol. Why is it so difficult to reach a quantitative consensus?

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The impact of a changing atmospheric agent is commonly quantified by its influence on the radiative energy balance, its radiative forcing. Of particular interest, in understanding current and future climates is the radiative forcing resulting from man-made atmospheric modifications. Enhancements to greenhouse gas concentrations have retained (to the Earth-Atmosphere-System) radiative energy, which is warming our planet. The impact of anthropogenic aerosol, in contrast, is less clear and spatially much more diverse. On a global annual basis (anthropogenic) aerosol is expected to slow greenhouse gas warming. Even when excluding indirect (feedback) effects on clouds and the hydrological cycle, the impact uncertainty due to the presence of anthropogenic aerosol is large. This direct impact uncertainty mainly results from the difficulty to quantify anthropogenic aerosol and the impact dependence on its environment (e.g. clouds, surface below, available sun-light). Both aerosol and environmental properties are high variable and often not available at the needed accuracy. This led to a wide range of impact estimates for aerosol, even for temporal and spatial averages. For instance, annual global averages based on simulations with nine different models with state of the art aerosol component modules (as part of an AeroCom exercise) suggest that added aerosol since pre-industrial times at all-sky conditions modified the (solar) radiative energy balance at the top of the atmosphere (ToA forcing) from +0.1 to -0.4 W/m2. Global estimates of data-tied approaches suggest more cooling, ranging from -0.3 to more negative than -1.0 W/m2. To reduce the uncertainty range, individual results are assessed, also in the context of uncertainties to the underlying assumptions for aerosol and environmental (regional) properties.