Title: Quantifying the aerosol semi-direct effect in the NASA GEOS-5 AGCM

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Abstract:

Aerosols such as black carbon, dust, and some organic carbon species both scatter and absorb incoming solar radiation. This direct aerosol radiative forcing (DARF) redistributes solar energy both by cooling the surface and warming the atmosphere. As a result, these aerosols affect atmospheric stability and cloud cover (the semi-direct effect, or SDE). Furthermore, in regions with persistent high loadings of absorbing aerosols (e.g. Asia), regional circulation patterns may be altered, potentially resulting in changes in precipitation patterns.

Here we investigate aerosol-climate coupling using the NASA Goddard Earth Observing System model version 5 (GEOS-5) atmospheric general circulation model (AGCM), in which we have implemented an online version of the Goddard Chemistry, Aerosol, Radiation and Transport (GOCART) model. GOCART includes representations of the sources, sinks, and chemical transformation of externally mixed dust, sea salt, sulfate, and carbonaceous aerosols. We examine a series of *free-running* ensemble climate simulations of the present-day period (2000-2009) forced by observed sea surface temperatures to determine the impact of aerosols on the model climate. The SDE and response of each simulation is determined by differencing with respect to the control simulation (no aerosol forcing).

In a *free-running* model, any estimate of the SDE includes changes in clouds due both to atmospheric heating from aerosols *and* changes in circulation. To try and quantify the SDE *without* these circulation changes we then examine the DARF and SDE in GEOS-5 with prescribed meteorological analyses introduced by the MERRA analysis. By doing so, we are able to examine changes in model clouds that occur on shorter scales (six hours). In the GEOS-5 data assimilation system (DAS), the analysis is defined as the best estimate of the atmospheric state at any given time, and it is determined by optimally combining a first-guess short-term GCM forecast with all available observations. The Incremental Analysis Update (IAU) is added to the model forecast tendencies to align them with the analysis every six hours, thus preventing longer timescale feedbacks due to the aerosol forcing. We calculate the SDE by comparing model runs with and without aerosols, and the difference in the IAU between these runs is a useful metric with which to evaluate the impact of the SDE on the model atmosphere and clouds. Decreasing the IAU indicates that the aerosol direct and semi-direct effects act to reduce the bias between the model and observations and vice versa.