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Observationally-constrained aerosol-cloud semi-direct effect in multiple GCMs

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Absorbing aerosols like black carbon (BC) give rise to rapid adjustments and the associated perturbation to the atmospheric temperature structure alters the cloud distribution. These "semi-direct effects" (SDEs) depend on the vertical co-location of absorbing aerosol and cloud and include relative humidity reductions and cloud burn-off when BC and cloud are co-located, but also enhanced low-level cloud due to increases in stability when BC is located above the cloud. The level of scientific understanding of the SDE is considered low, with models indicating a likely negative (-0.44 to +0.1 W/m^2) forcing. Recent studies suggest this negative SDE is primarily driven by decreases in high-level clouds and enhanced longwave cooling. Here, we investigate the SDE using multiple models driven by observationally constrained fine-mode aerosol forcing without dust and sea salt. Unlike aerosol simulations, which yield a relatively vertically uniform aerosol atmospheric heating profile with significant upper-tropospheric heating, observation-based heating peaks in the lower-troposphere and then decays to zero in the mid-troposphere. We find a significant global annual mean decrease in low and mid-level clouds, and weaker decreases in high-level clouds, which leads to a positive SDE dominated by shortwave radiation. Thus, in contrast to most studies, we find a robust positive SDE, implying cloud adjustments act to warm the climate system. Sensitivity tests with identical average, but vertically uniform observationally-constrained aerosol atmospheric heating result in a negative SDE, due to enhanced longwave cooling as a result of large reductions in high-level clouds. Our results therefore suggest that model simulations lead to a negatively biased SDE, due to an aerosol atmospheric heating profile that is too vertically uniform.