Bias in CMIP6 models compared to observed regional dimming and brightening trends (1961-2014)

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Anthropogenic aerosol emissions have increased considerably over the last century, but climate effects and quantification of the emissions are highly uncertain as one goes back in time. This uncertainty is partly due to a lack of observations in the pre-satellite era, and previous studies show that Earth system models (ESMs) do not adequately represent surface energy fluxes over the historical era. We investigated global and regional aerosol effects over the time period 1961-2014 by looking at surface downwelling shortwave radiation (SDSR).

We used observations from ground stations as well as multiple experiments from five ESMs participating in the Coupled Model Intercomparison Project Version 6 (CMIP6). Our results show that this subset of models reproduces the observed transient SDSR well in Europe, but poorly in China.

The models do not reproduce the observed trend reversal in SDSR in China in the late 1980s, which is attributed to a change in the emission of SO\textsubscript{2} in this region. The emissions of SO\textsubscript{2} show no sign of a trend reversal that could explain the observed SDSR evolution over China, and neither do other aerosols relevant to SDSR. The results from various aerosol emission perturbation experiments from DAMIP, RFMIP and AerChemMIP suggest that its likely, that aerosol effects are responsible for the dimming signal, although not its full amplitude. Simulated cloud cover changes in the different models are not correlated with observed changes over China. Therefore we suggest that the discrepancy between modeled and observed SDSR evolution is partly caused by erroneous aerosol and aerosol precursor emission inventories. This is an important finding as it may help interpreting whether ESMs reproduce the historical climate evolution for the right or wrong reason.