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Decomposing local and remote surface temperature impacts of Asian aerosols

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We investigate how a regionally confined radiative forcing of South and East Asian aerosols translate into local and remote surface temperature responses across the globe. To do so, we carry out equilibrium climate simulations with and without modern day South and East Asian anthropogenic aerosols in two climate models with independent development histories (ECHAM6.1 and NorESM1). We run the models with the same anthropogenic aerosol representations via MACv2-SP (a simple plume implementation of the 2nd version of the Max Planck Institute Aerosol Climatology). This leads to a near identical change in instantaneous direct and indirect aerosol forcing due to removal of Asian aerosols in the two models. We then robustly decompose and compare the energetic pathways that give rise to the global and regional surface temperature effects in the models by a novel temperature response decomposition method, which translated the changes in atmospheric and surface energy fluxes into surface temperature responses by using a concept of planetary emissivity.

We find that the removal of South and East Asian anthropogenic aerosols leads to strong local warming response from increased clear-sky shortwave radiation over the region, combined with opposing warming and cooling responses due to changes in cloud longwave and shortwave radiation. However, the local warming response is strongly modulated by the changes in horizontal atmospheric energy transport. Atmospheric energy transport and changes in clear-sky longwave radiation redistribute the surface temperature responses efficiently across the Northern hemisphere, and to a lesser extent also over the Southern hemisphere. The model-mean global surface temperature response to Asian anthropogenic aerosol removal is 0.26±0.04 °C (0.22±0.03 for ECHAM6.1 and 0.30±0.03 °C for NorESM1) of warming. Model-to-model differences in global surface temperature response mainly arise from differences in longwave cloud (0.01±0.01 for ECHAM6.1 and 0.05±0.01 °C for NorESM1) and shortwave cloud (0.03±0.03 for ECHAM6.1 and 0.07±0.02 °C for NorESM1) responses. The differences in cloud responses between the models also dominate the differences in regional temperature responses. In both models, the Northern hemispheric surface warming amplifies towards the Arctic, where the total temperature response is highly seasonal and modulated by seasonal changes in oceanic heat exchange and clear-sky longwave radiation.

We estimate that under a strong Asian aerosol mitigation policy tied with strong greenhouse gas mitigation (Shared Socioeconomic Pathway 1-1.9) the Asian aerosol reductions can add around 8 years' worth of current day global warming during the next few decades.