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Aerosol components modulate pre-monsoon extreme heat in South Asia

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South Asia is a global hotspot of extreme heat and aerosol pollution. Observations and climate projections consistently show an intensification of heat extremes across the region, particularly during the pre-monsoon season when the most deadly heatwaves occur. At the same time, South Asia experiences persistently high aerosol loading due to rapid industrialisation and urbanisation, with sulphate representing the dominant anthropogenic scattering component of the regional aerosol burden. While reductions in aerosol emissions are crucial for improving air quality and public health, changes in aerosol concentrations can also modify extreme heat through direct radiative effects and indirect impacts on clouds and circulation.

Previous observational studies have explored links between aerosols and extreme heat in South Asia, but most rely on direct comparisons of their spatial patterns or long-term trends, providing limited evidence for a causal relationship. Only a few studies have directly examined correlations between aerosol optical depth (AOD) and temperature, often using absolute values that may introduce spurious relationships due to shared seasonality or long-term trends. Moreover, both reanalysis-based and modelling studies rarely distinguish between absorbing and scattering aerosol components, despite their fundamentally different radiative and thermodynamic effects. These limitations hinder a physically interpretable quantification of temperature sensitivity to aerosols.

Here, we combine reanalysis data with CMIP6 experiments to investigate how different aerosol components influence extreme heat in South Asia. Focusing on pre-monsoon daily maximum temperature (Tmax) as a proxy for extreme heat, we find that sulphate aerosols exert a robust cooling effect on extreme heat, particularly over major megacity regions along the Indo-Gangetic Plain. CMIP6 experiments indicate a typical sensitivity of -2 to -6 K per unit sulphate AOD in these densely populated regions, a signal that is broadly consistent in sign with reanalysis-based estimates but more spatially coherent in the model framework. This study provides the first component-specific assessment of aerosol impacts on extreme heat in South Asia.