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Spatial patterns of substantial climate impact from anthropogenic aerosols in the early instrumental period

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While many aspects of climate variation in the early instrumental period (1860-1950) are still unexplained, for instance the early twentieth-century warming from the 1910s to the 1940s, the role of anthropogenic aerosols in this period has been overlooked. Yet, the period is also an interesting case study to isolate aerosol impacts since it is characterised by the increase of North American and especially European aerosol emissions concurrently with negligible Asian emissions and relatively low carbon dioxide concentrations.

We thus analyse the spatial and temporal patterns of aerosol impact for this period in available observations (NOAA 20th-century reanalysis, etc.) and historical single-forcing and all-forcing experiments with state-of-the-art CMIP5 models. We make use of coupled empirical orthogonal functions (EOFs) applied to surface temperature -the most reliable variable in observations- and different aerosol indicating variables such as aerosol optical depth and short-wave downward radiation, some of which include aerosol indirect effects. The principal components of the most important EOFs are then regressed onto sea level pressure, winds, and other variables to identify associated circulation patterns. A decomposition into multi-decadal and longer time scales is performed by filtering the data prior to the analysis.

Our analysis reveals both statistically significant local and non-local aerosol impact and identifies circulation states associated with the temperature response. The results are consistent across different aerosol variables, and show a strong non-local response as well as specific differences between time scales. We find a distinctive circulation pattern which strongly resembles observations and might explain the observed early twentieth century warming in the Arctic.