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Robustness and underlying mechanisms of the temperature response to the recent increase in Asian anthropogenic aerosol emissions

Laura Wilcox (1), Massimo Bollasina (2), Nick Dunstone (3), Annica Ekman (4), Eleanor Highwood (1), Anna Lewinschal (4), David Paynter (5), and Stephen Thomson (6)

(1) University of Reading, Department of Meteorology, Reading, United Kingdom (l.j.wilcox@reading.ac.uk), (2) University of Edinburgh, Edinburgh, UK, (3) Met Office Hadley Centre, Exeter, UK, (4) Department of Meteorology, Stockholm University, Stockholm, Sweden, (5) Geophysical Fluid Dynamics Laboratory, Princeton, USA, (6) Department of Mathematics, University of Exeter, Exeter, UK

There have been large, rapid increases in Asian anthropogenic aerosol emissions since 1980, which have been linked to a decline in local air quality. We use three state-of-the art Earth system models, HadGEM3-GC2, GFDL-CM3, and NorESM1-M, to determine whether these regional aerosol emissions have had a robust impact on global temperature, focussing on boreal winter (DJF) when the Northern Hemisphere circulation is strongest.

HadGEM3-GC2 simulates statistically significant, physically robust, decreases in Arctic temperature, and increases in central Asian temperature, in response to Asian emission increases. However, due to poor signal to noise ratios in NorESM1-M and GFDL-CM3, there are very few geographical regions where these responses are robust across all three models.

When driven with 5x Asian emission increases, GFDL-CM3 and NorESM1-M produce large-scale responses with similar patterns to HadGEM3-GC2. This suggests that a similar physical mechanism determines the structure of the response in the models, but that GFDL-CM3 and NorESM1-M are less sensitive to realistic Asian aerosol changes than HadGEM3-GC2. We find that, for our period of study, the aerosol indirect effect is buffered over Asia, particularly in GFDL-CM3. Thus, historical forcing and simulated changes in aerosol-optical depth are not good predictors of near-term climate responses.

We further investigated the role of atmospheric circulation adjustments in generating the near-global response to Asian aerosol increases using an intermediate complexity model, Isca, and a linear baroclinic model, LUMA. We show that precipitation and associated diabatic heating changes over the China and Philippine Seas, and the Aleutian Islands, are most important in driving Rossby wave trains that lead to circulation changes in North America and Europe.