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Investigating model nudging as a novel technique to isolate aerosol radiative adjustment mechanisms

Max Coleman[1], William Collins[1], Keith Shine[1], Nicolas Bellouin[1], and Fiona O'Connor[2]
[1]University of Reading, Department of Meteorology, Reading, United Kingdom
[2]Met Office, Exeter, United Kingdom

We investigate a novel use of model nudging to interrogate radiative rapid adjustment mechanisms and their magnitudes in response to aerosol emission perturbations in an earth system model. The radiative effects of a forcing agent can be quantified using the effective radiative forcing (ERF). ERF is the sum of the instantaneous radiative forcing, and radiative adjustments – changes in the atmosphere's state in response to the initial forcing agent that cause a further radiative forcing. Radiative adjustments are particularly important for aerosols, which affect clouds both via microphysical interactions and changes in circulation, stratification and convection. Understanding the different adjustment mechanisms and their contribution to the total ERF of different aerosol emissions is necessary to better understand how their ERF may change with future changes in anthropogenic aerosol emissions. In this work we investigate radiative adjustments resulting from changes in atmospheric temperature (and the resulting changes in stratification and convection) due to anthropogenic sulphate and black carbon aerosol forcing.

We have conducted multiple global atmosphere-only time-slice experiments using the UK Earth System Model (UKESM1). Each experiment has either control, black carbon perturbed, or sulphur dioxide perturbed emissions; and either no nudging, nudged horizontal winds (uv), or nudged horizontal winds and potential temperature (uvθ). The difference between nudged uvθ minus nudged uv simulations determines the atmospheric temperature related adjustments arising from the aerosol perturbation. We have also conducted repeats of each simulation, varying the nudging setup to test sensitivity to different nudging parameters.

We find that nudging horizontal winds affects the resulting ERF very little, whereas nudging potential temperature as well can cause a significant difference from the non-nudged experiments, primarily in the cloud radiative effect. However, this difference is sensitive to the strength of the nudging applied, for which we consider the most appropriate value.