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Evaluating Aerosol Trends from 1960 to 2010 using HadGEM3-UKCA and EMEP Data

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Atmospheric aerosols are an important component of the Earth system, interacting strongly with the Earth's radiative balance and climate. Substantial changes in anthropogenic aerosol emissions (and their precursors) have occurred in the last few decades with further large changes projected in the future. The response of atmospheric aerosols to these changes and the impact on climate are poorly constrained. Studies using detailed aerosol chemistry climate models and evaluation against observed changes over the latter half of the 20th Century are currently lacking.

We use the HadGEM3-UKCA coupled chemistry-climate model to simulate changes in atmospheric aerosol concentrations over the period 1960 to 2010. The model includes a modal aerosol microphysics scheme and online tropospheric chemistry. Anthropogenic emissions are from MACCity inventory and the model is nudged to reanalysis meteorology from ECMWF.

We evaluate simulated total and sulphate particulate matter against selected monitoring sites from the European Monitoring and Evaluation Programme (EMEP). The model's ability to reproduce the observed trends has been assessed in terms of the normalised mean bias factor (NMBF) and correlation coefficient (r^2). Average NMBF for total aerosol mass was -1.05 and -0.43 for sulphate mass. Throughout the entire evaluation time period model biases have tended to become more negative for sulphate mass but less negative for total mass. The spatial correlation coefficient of modelled and observed sulphate mass for each year has remained similar throughout 1978-2010 with an r^2 between 0.2 to 0.4, whereas for total mass it has been consistently low ($<$0.2).

Average observed total aerosol mass concentrations have declined by 65% at a relatively linear rate of 1.1 μg m^{-3} per annum over the period 1978-2010. A decrease in sulphate mass concentration of 70%, at a relatively linear rate of 0.05 μg S m^{-3} per annum was reported from observations over the same period. The model is able to reproduce a similar decrease in mass concentrations of both components but not the same absolute magnitude of change, as reported in the measurements.

We discuss potential explanations for low model bias including insufficient wintertime oxidants and lack of secondary organic aerosol from anthropogenic sources.