Simplified aerosol chemistry in UKCA

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At its core, UKESM1 will use the HadGEM3 atmosphere-ocean physical climate model. The goal for CMIP6 is to have versions of UKESM and HadGEM3 which are consistent with each other in order to explore the impact of the additional Earth system processes. The roles of the physical model and ESM are complementary, with the former used to model the physical climate at high resolution or with a large number of realisations and the latter to understand the feedback effects of biogeochemical cycles on the climate. The additional process complexity of the Earth system model makes it more computationally expensive than the physical model.

Both models will use the GLOMAP-mode (Mann et al, 2010) aerosol scheme as part of UKCA (the UK Chemistry and Aerosol model). However, the UKCA chemistry scheme used in UKESM is highly complex with a large number of advected chemical species and would be prohibitively expensive for use in the physical model: it increases the cost of the atmosphere component of the model by a factor of 5. There was therefore a need for a minimal aerosol chemistry scheme within UKCA to support GLOMAP-mode without the cost of the full chemistry.

Colin Johnson in the ESM Core Group developed a chemistry scheme known as “offline oxidants”, which makes use of a monthly climatology of oxidant fields (O_3, OH, H_2O_2, HO_2, NO_3) which are pre-computed using the more complex chemistry scheme. Taking these inputs, the new scheme then uses the same aerosol precursor chemical mechanism as in the more detailed scheme, i.e. the degradation of SO2, DMS, and monoterpene. The monthly temporal resolution is a limitation for short-lived oxidant species which are in reality subject to destruction by photolytic reactions, and therefore a parameterised diurnal cycle of OH, HO_2, and NO_3 is superimposed on the monthly climatological fields. Full details of the scheme can be found in UM documentation paper 84.

To achieve consistency of radiative forcing between the physical and Earth system models, it is crucial that the two chemistry schemes are consistent with one another and result in similar simulation of aerosol loading. This consistency has been verified by comparison of aerosol and gas-phase precursor species. Figure 1 shows an example comparison for accumulation-soluble mode aerosol number, which illustrates the similarity in the simulations.

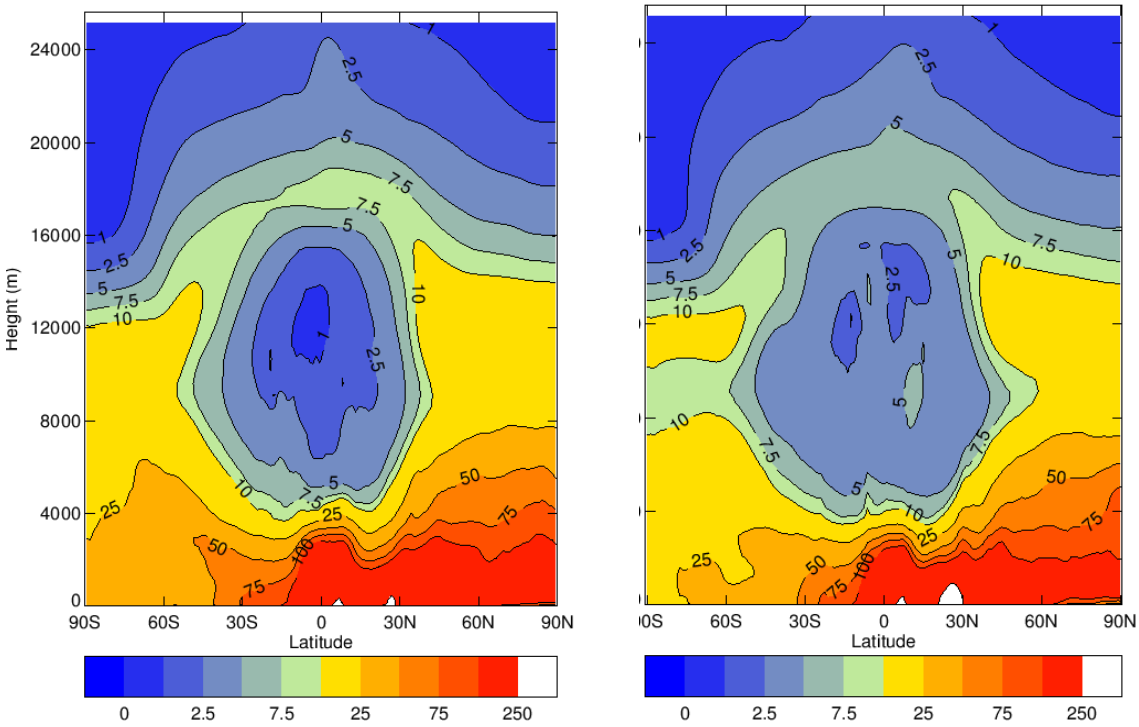

Figure 1: Zonal mean aerosol number (cm^{-3}) in accumulation-soluble mode for the month of December after 16 months of simulation. Left: full stratosphere-troposphere chemistry, right: offline oxidants chemistry.

References:

Mann G.W. And co-authors (2010) Description and evaluation of GLOMAP-mode: a modal global aerosol microphysics model for the UKCA composition-climate model, *Geosci. model dev.*, **3**, pp.651-734. doi: 10.5194/gmdd-3-651-2010

Unified Model Documentation Paper 84: United Kingdom Chemistry and Aerosol (UKCA) Technical Description. https://code.metoffice.gov.uk/doc/um/vn10.1/umdp.html