Status of UKCA with GLOMAP-mode at GA4.0, version 8.4

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DRAFT

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Introduction

The UKCA code on the UM trunk was updated at vn8.2 using a code merged from various vn7.3 branches. However, the vn7.3 merged code is still the basis for research using UKCA. This is because of various problems affecting both the chemistry and aerosol components of UKCA when using the GA4.0 climate configuration which is described by (Walters et al., 2013).

Here we discuss the development and evaluation of a development version of the model using the TropIsop chemistry, including tropospheric aerosol chemistry and GLOMAP-mode with ACTIVATE. Developments to UKCA affecting vn8.4 include: 1) the implementation of CDNC estimates from UKCA into the radiation and precipitation schemes of the UM; 2) a revision to the lightning NOx scheme; and 3) transfer of the aerosol direct emissions to UKCA_EMISSION_CTL so that emissions are added before GLOMAP-mode is called.

Developments to the Code

The main problem affecting the aerosols in the model at GA4.0 was that the nucleation scavenging routine for aerosols was affected by the adoption of a prognostic rain scheme. This was done at GA3.0 to overcome the problem of overestimation of dynamic rain over ocean areas. At GA4.0, compared to the vn7.3 models, there is less dynamic rain over the open ocean areas with a corresponding increase to the convective component (Figs. 1-4).

The aerosol rainout routine was thus changed from using vertical precipitation differences to using autoconversion and accretion rates. In order to mimic the previous behaviour using vertical differences in dynamic rainfall, the snow and ice melting terms are also included. After this change, the model aerosol mass and optical depth was found to be too large, and this was attributed to the known (Kipling et al., 2013) problem of convective washout in UKCA where time splitting allows the vertical movement of aerosols without any removal to a height where removal processes are slow. The implementation of a plume scavenging scheme similar to that of Kipling et al (2013) has improved the aerosol distributions. It is clear that this code needs extending to the soluble chemical species.

Several other changes to the code have been made:

1. Application of an improved filter to avoid unrealistic aerosol concentrations after advection.

2. Adoption of a better aerosol tracer selection process so that fewer tracers are required.

3. Change to the minimum tracer concentration allowed in the chemical solver in response to solver crashes.

4. At vn8.4 the default nucleation scheme is Vekhamaki, but this was turned back to Kulmala in order to compare with previous runs.

First runs of the code at vn8.2 showed considerable increases to tropical ozone and OH compared to previous runs at vn8.2 and this has been attributed to the increased (but more realistic) lightning NOx emissions. These were diagnosed at 7.9 Tg [N] /yr compared to a total of 0.77 Tg/yr at vn8.2. The last run has the lightning NOx emissions divided by two as a sensitivity test.

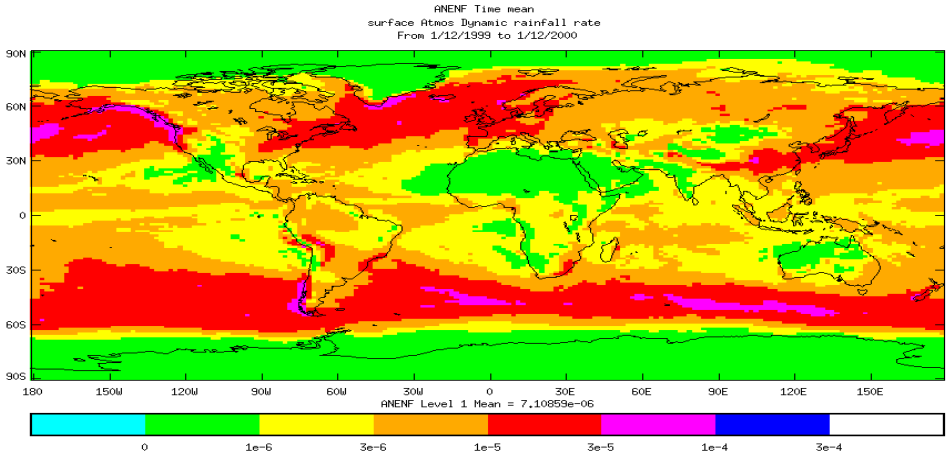


Illustration 1: vn8.4 dynamic rainfall rate

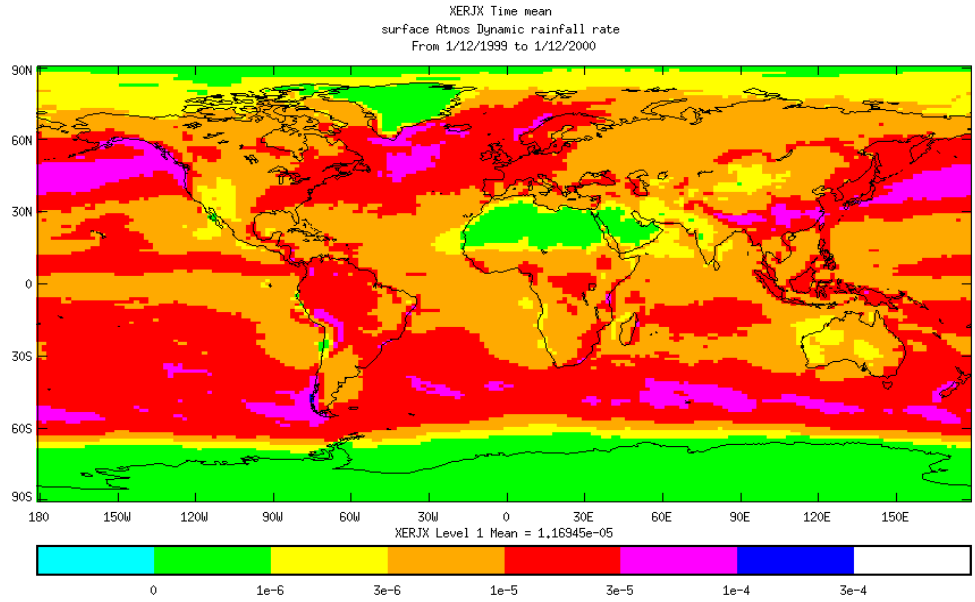


Illustration 2: vn7.3 dynamic rainfall rate

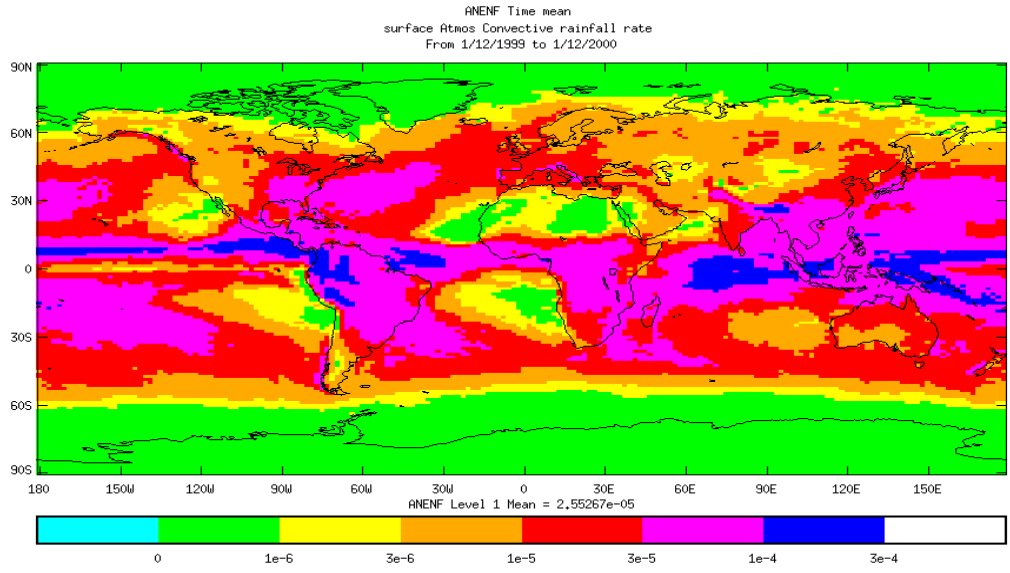


Illustration 3: vn8.4 convective rainfall rate

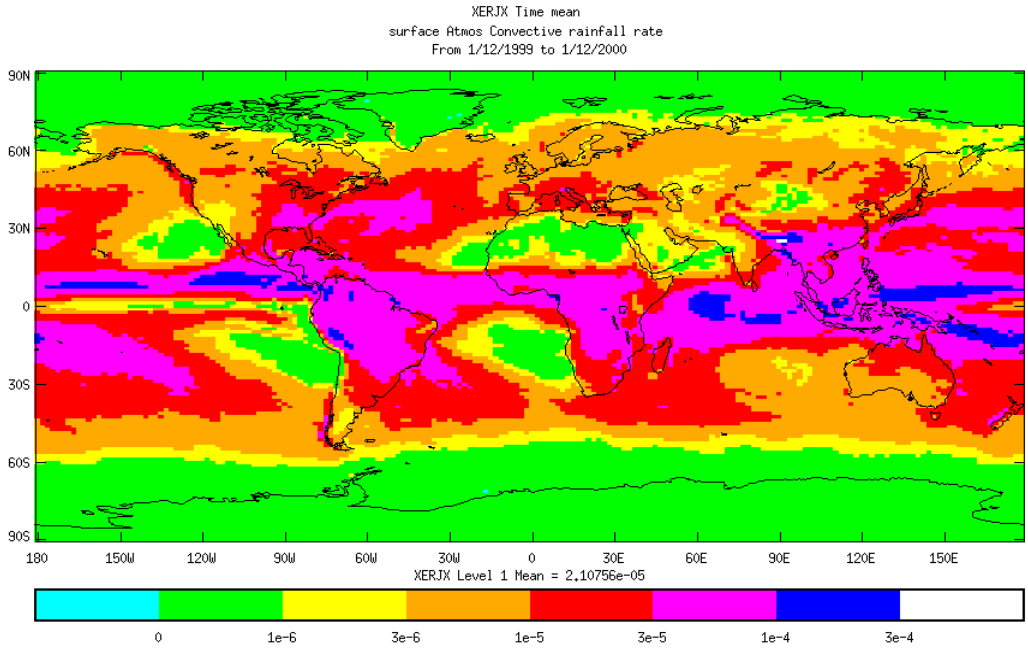


Illustration 4: vn7.3 convective rainfall rate

Known Defects

The TropIsop chemical scheme has not had its rate coefficients updated as has the Strattrop scheme.

Evaluation

Evaluation of this model is at an early stage, however, the UKCA evaluation suite has been used for the aerosols. This shows little difference between the two runs with differing lightning NOx emissions. The figures below are from the evaluation.

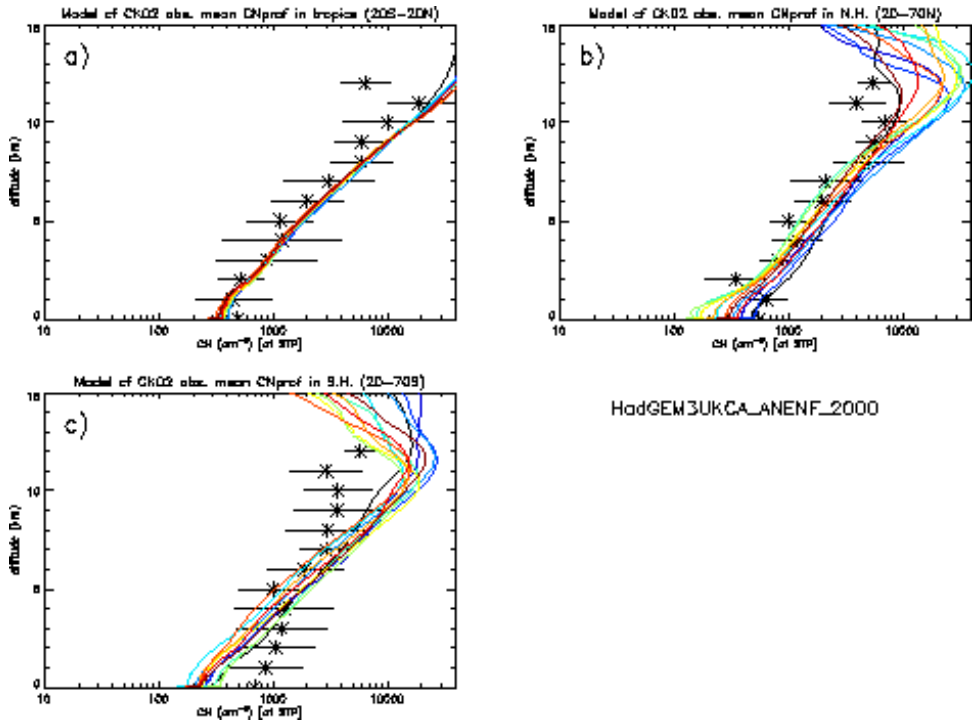
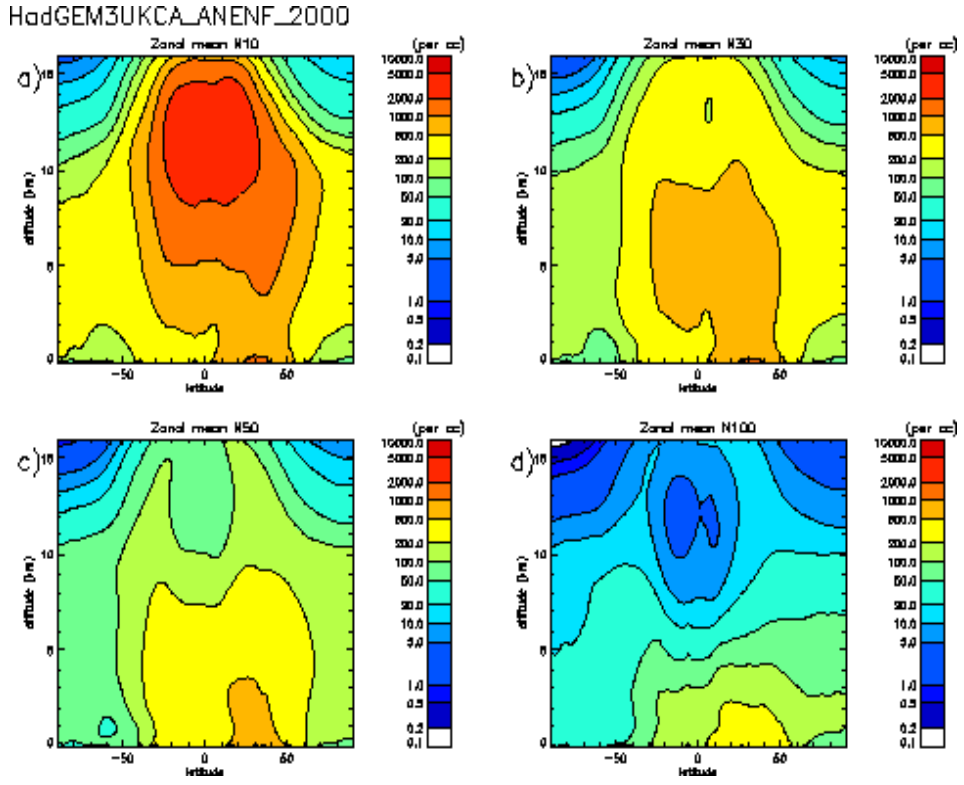


Illustration 5: UKCA Condensation nuclei against observations in tropics, northern hemisphere and southern hemisphere

Illustration 6: Model number concentrations



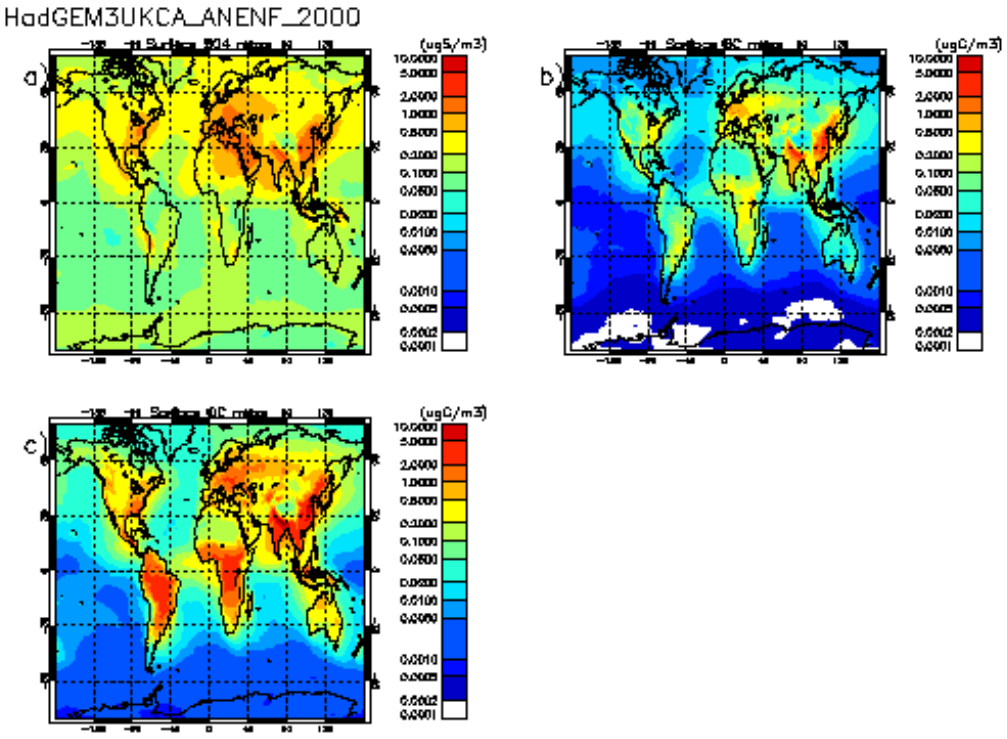


Illustration 7: Surface SO4, BC, and OC concentrations in microgram per cubic metre

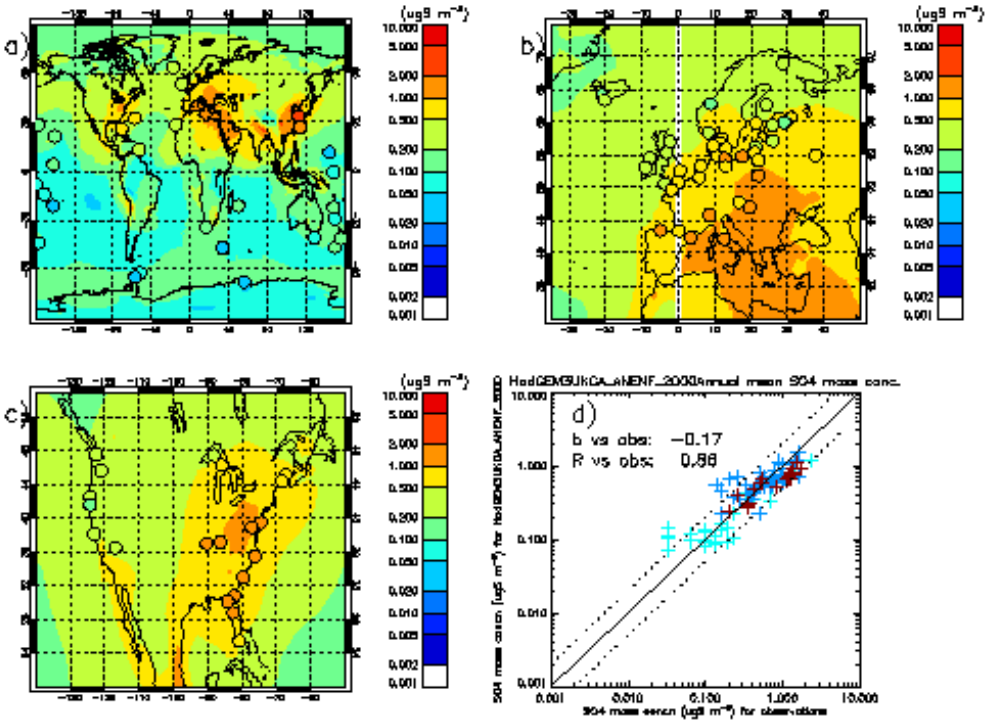


Illustration 8: Surface SO4 concentrations compared to observations

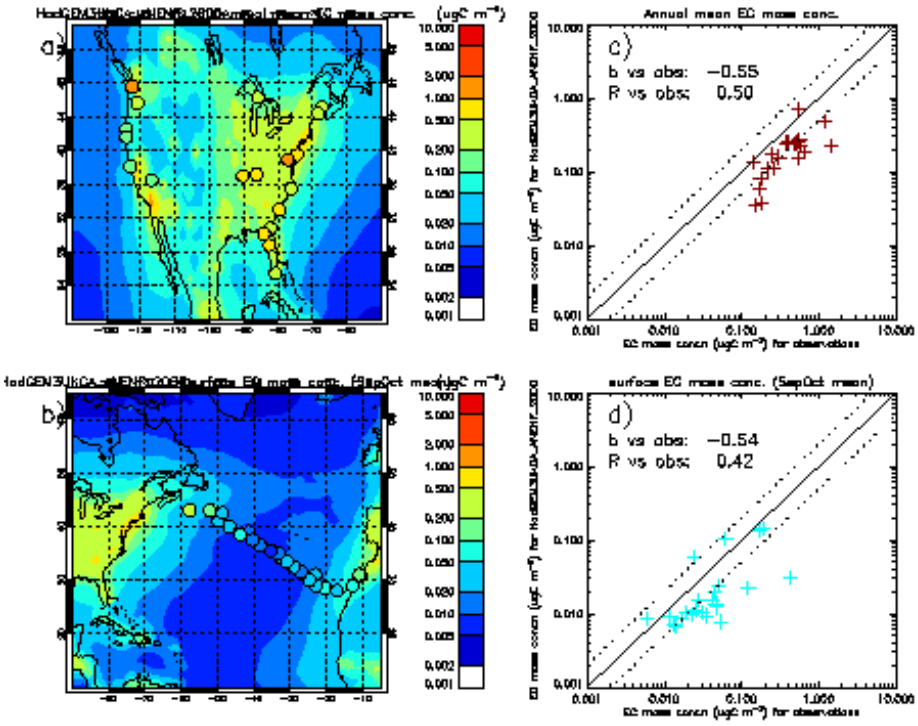


Illustration 9: Surface elemental carbon compared to observations

Cloud droplet number

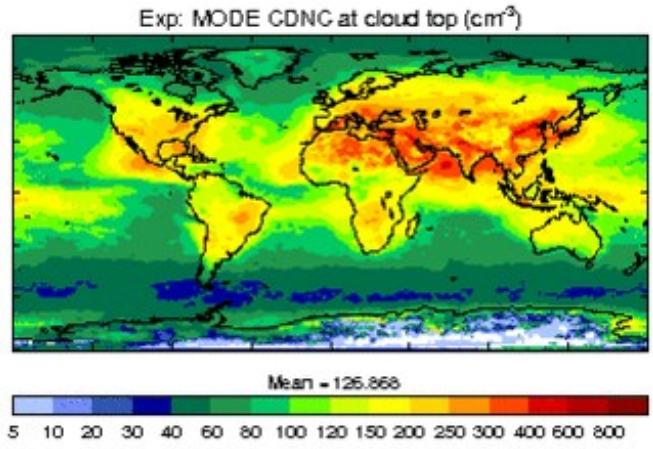


Illustration 10: Cloud droplet number concentration for amtjn

Aerosol Optical Depth

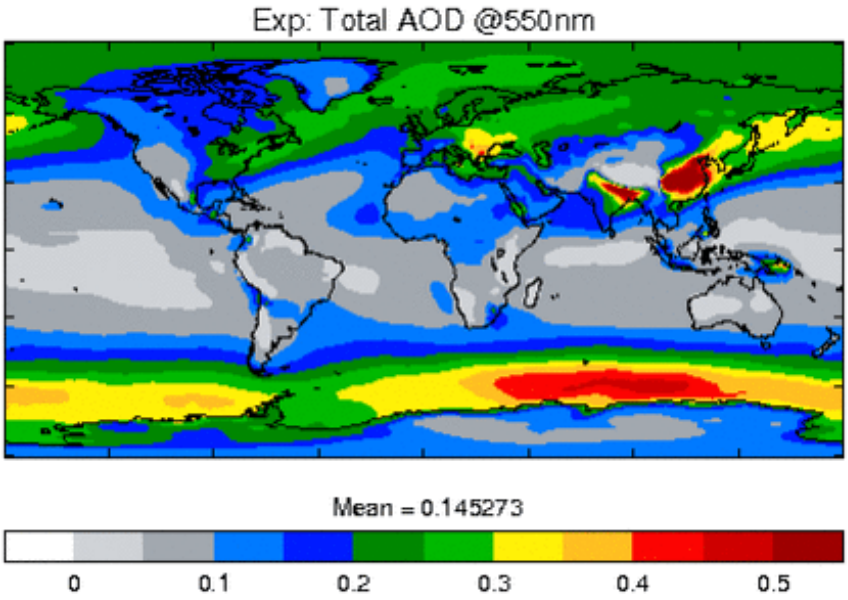


Illustration 11: Aerosol optical depth at 550 nm for amtjn

Burdens and lifetimes

A complete budget analysis has been done for the model runs completed, the table below shows a summary of the burdens and lifetimes for UKCA at vn8.2 (with and without plume scavenging) and vn8.4, together with the results from the AEROCOM model intercomparison project.

	vn8.2, no PS	vn8.2 with PS	vn8.4 with PS	AEROCOM
Sulphate	1.02	0.79	0.69	0.66
Sea-salt	16.7	12.9	12.8	6.4
BC	0.13	0.07	0.07	0.21
OC	0.88	0.49	0.38	1.21

Table 1: Atmospheric burdens for sulphate, sea-salt, black carbon and organic carbon (Tg). The vn8.2 results are for simulations with and without plume scavenging (PS).

	vn8.2, no PS	vn8.2 with PS	vn8.4 with PS	AEROCOM
Sulphate	7.4	5.8	4.7	4.1 (3.0 - 5.5)
Sea-salt	1.45	1.1	1.1	0.4 (0.2 - 1.0)
BC	6.9	3.7	3.4	6.5 (5.2 - 15)
OC	12.3	7.1	5.3	6.2 (4.2 - 11)

Table 2: Lifetimes (days) for aerosol in UKCA compared with the AEROCOM median value. The range of model results in the AEROCOM project is shown.

References

Walters, D.N., et al., 2013, The Met Office Unified Model global atmosphere 4.0 and JULES global land 4.0 configurations, *Geosci. Model Dev. Discuss.,* **6**, 2813-2881.

Kipling, Z., *et al.,* 2013, Constraints on aerosol processes in climate models from vertically-resolved aircraft observations of black carbon, *Atmos. Chem. Phys.,* **13**, 5969-5986.