Development of the 1st version of the UK Earth system model

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The UK Earth system modelling project is a joint venture between the Met Office Hadley Centre (MOHC) and the Natural Environmental Research Council (NERC) to develop and apply future UK Earth system models. To this end, the UKESM core group was established in the summer of 2013 and now consists of 18 scientists. The core group is responsible for developing the 1st UKESM model (UKESM1), bringing together a range of component model developments into a technically functioning and scientifically evaluated Earth system model (ESM)

The core of UKESM1 is the coupled physical climate model HadGEM3 (Hewitt et al. 2010) which represents key physical and dynamical processes in; the atmosphere, ocean, land and sea-ice. HadGEM3 will also be used for seasonal and decadal climate prediction at MOHC and for physical climate modelling studies. In collaboration with a range of NERC and MOHC scientists, the UKESM core group is working to further develop and couple a number of component models into HadGEM3 that represent key biogeochemical, aerosol and cryosphere processes. Inclusion of these models will move HadGEM3 from a physical coupled climate model into the 1st UK Earth system model. These component models include;

- The UK Chemistry and Aerosol (UCKA) model for troposphere-stratosphere trace gas chemistry (Morgenstern et al. 2009, O'Connor et al. 2013), coupled to a two-moment aerosol scheme; GLOMAP-mode (Mann et al. 2010). In addition to the full stratosphere-troposphere scheme a simplified (computationally cheaper) version of UKCA has been developed employing pre-computed oxidants and a tropospheric sulphur cycle linked to the same GLOMAP aerosol scheme.
- The Model of Ecosystem Dynamics, nutrient Utilisation, Sequestration and Acidification (MEDUSA, Yool et al. 2010, 2012) representing ocean biogeochemistry, in particular the marine carbon cycle.
- Further development of the terrestrial carbon cycle and vegetation in the Joint UK Land Environment Simulator (JULES , Best et al. 2011, Clark et al 2011) targeting; (i) inclusion of nitrogen limitation on vegetation and soil carbon processes, (ii) improved treatment of wetlands, (iii) an increased number of plant functional types and (iv) improved representation of permafrost processes
- The model GLIMMER/BISICLES (Rutt et al. 2009, Cornford et al. 2013) to represent ice sheets on Greenland and Antarctic.

Figure 1 provides a schematic of the UKESM1 component models and their coupling through the OASIS coupler (Valcke et al. 2013).

Two versions of UKESM1 are under development, differing only in their resolution. UKESM1-hr is the high-resolution version, employing N216 (~60km) in the atmosphere and 0.25° in the ocean. UKESM1-lr is a low resolution, computationally faster, version, with an atmospheric resolution of N96 (~140km) and an ocean resolution of 1°. Both models fully resolve the troposphere and stratosphere using 85 vertical levels and have 75 levels in the ocean. To the degree possible, we aim to maintain a common set of process parameterizations in both models. Where modifications are necessary for improved performance at a specific resolution, these changes will be documented and the impact on simulation performance and future projection responses analysed. To give users flexibility in the level of process complexity for a given set of experiments, we will provide and support 3-4 configurations within each of the 2 released model resolutions, ranging from: (a) Full Earth system complexity (including stratosphere-troposphere UKCA chemistry and GLOMAP aerosols, full (terrestrial and marine) carbon cycle and inclusion of Antarctic and Greenland Ice sheets). (b) Interactive carbon-cycle with reduced atmospheric chemistry complexity. (c) The core physical model HadGEM3, with

interactive carbon cycle disabled and simplified chemistry linked to the GLOMAP aerosol scheme.

The 2 model versions (UKESM1-lr and –hr) are being developed on a time scale suitable for application to the WCRP 6th Coupled Model Intercomparison Project (CMIP6). We aim to have UKESM1-lr ready by late summer 2016, with UKESM1-hr available a few months later. As each model version becomes scientifically ready for use it will be released to UK researchers contributing to CMIP6, with a subsequent, more formal community release of both versions a few months later.

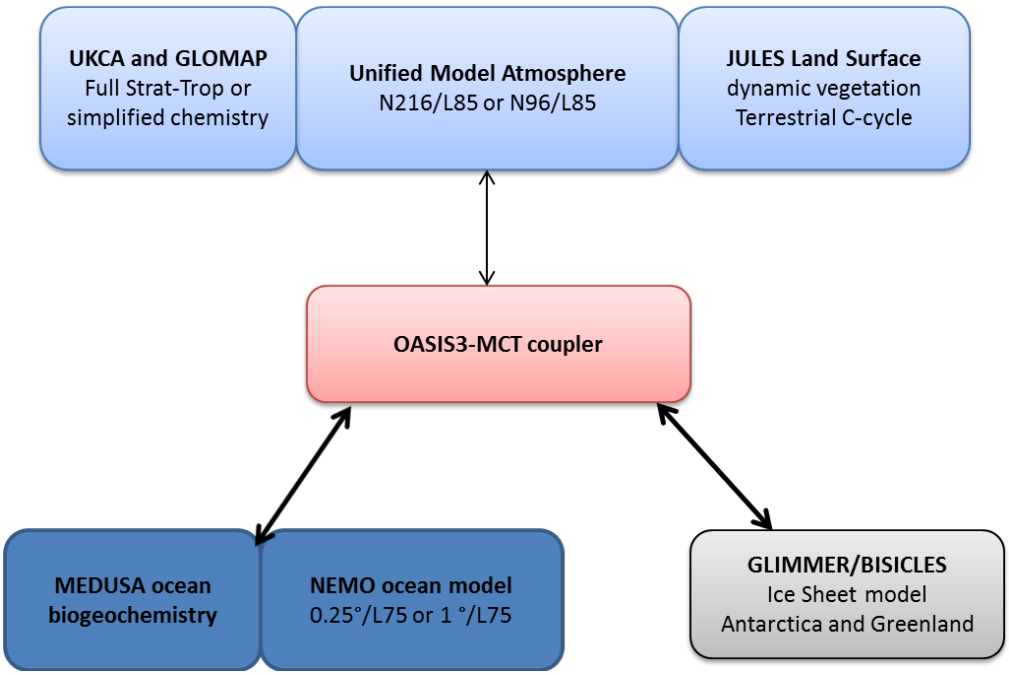

Figure 1. Schematic representation of UKESM1 model components. Three component executables are illustrated that exchange information every coupling time step through the OASIS3-MCT coupler

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