Release of the Global Coupled 3 (GC3) model

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Global Coupled configuration 3 (GC3) is the most recent global coupled science configuration of the Met Office Unified Model (UM) which was frozen in January 2016. GC3 is a noteworthy configuration as it will be the coupled physical model upon which the UK Earth System Model version 1 (UKESM1) will be developed. The previous configuration, GC2, was shown to be a considerable improvement on HadGEM2 (used for CMIP5) (Williams et al. 2014) and the further improvements in GC3 mean UKESM1 will be based on a world leading physical model core.

GC3 contains numerous revisions to physical parameterizations in all four model components. The global atmosphere (GA7) incorporates a large package of cloud and radiation changes, inclusion of the GLOMAP-mode aerosol scheme, revision to the numerics of the convection scheme, introduction of a seamless stochastic physics package for use in all systems representing an ensemble of weather states, together with a number of more minor changes. The global land surface (GL7) includes a number of changes of which the most significant is a new multi-layer snow scheme. The global ocean (GO6) incorporates a non-linear free surface, revisions to ocean mixing, an extension of the grid around Antarctica and inclusion of an ice shelf scheme. The latter two modifications are introduced to enable UKESM1 to include explicit models for the continental ice sheets over Greenland and Antarctica.. Finally, the global sea ice (GSI7) now includes multi-category ice thermodynamics and a better representation of melt ponds, improving ice albedo.

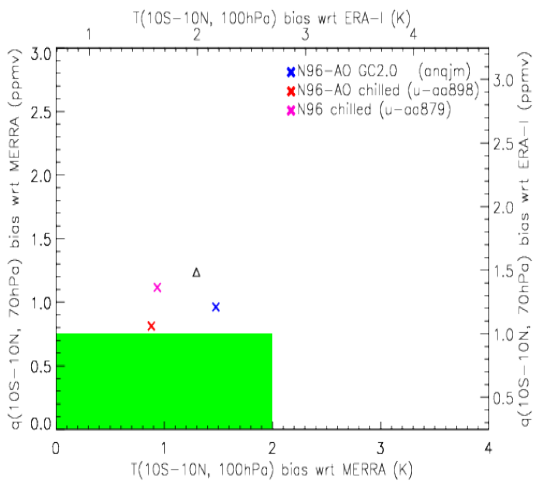

Figure 1: Error in tropical specific humidity at 70hPa (y-axis) against error in temperature at 100hPa (x-axis). GA6 and GA7 are the black triangle and pink cross respectively. GC2 and GC3 are the blue cross and orange cross respectively. The green box marks the desired error range for use of the model with interactive chemistry.

Four 'critical' problems had been identified in GC2 for climate modelling and all four are significantly improved in GC3. These were (1) the warm sea surface temperature (SST) bias over the Southern Ocean (reduced by ~40% in GA7), (2) tropical tropopause layer temperature and humidity errors, (3) tropical monsoon precipitation errors, and (4) conservation of energy and freshwater. In addition there are considerable improvements to the representation of cloud processes. The warm tropical tropopause temperature and relative humidity biases impact stratospheric water vapour concentrations, which can have detrimental impacts on interactive stratospheric chemistry. For an accurate baseline climate in UKESM1 these biases needed to be improved. Figure 1 highlights the improvement in lower stratospheric temperature and humidity biases in the GA7 and GC3 configurations. This is primarily associated with the introduction of Hermite cubic interpolation for vertical advection of specific humidity together with Priestley conservation of potential temperature. For more details see Hardiman et al. (2015).

One of the major developments in GC3 is the implementation of a new aerosol scheme

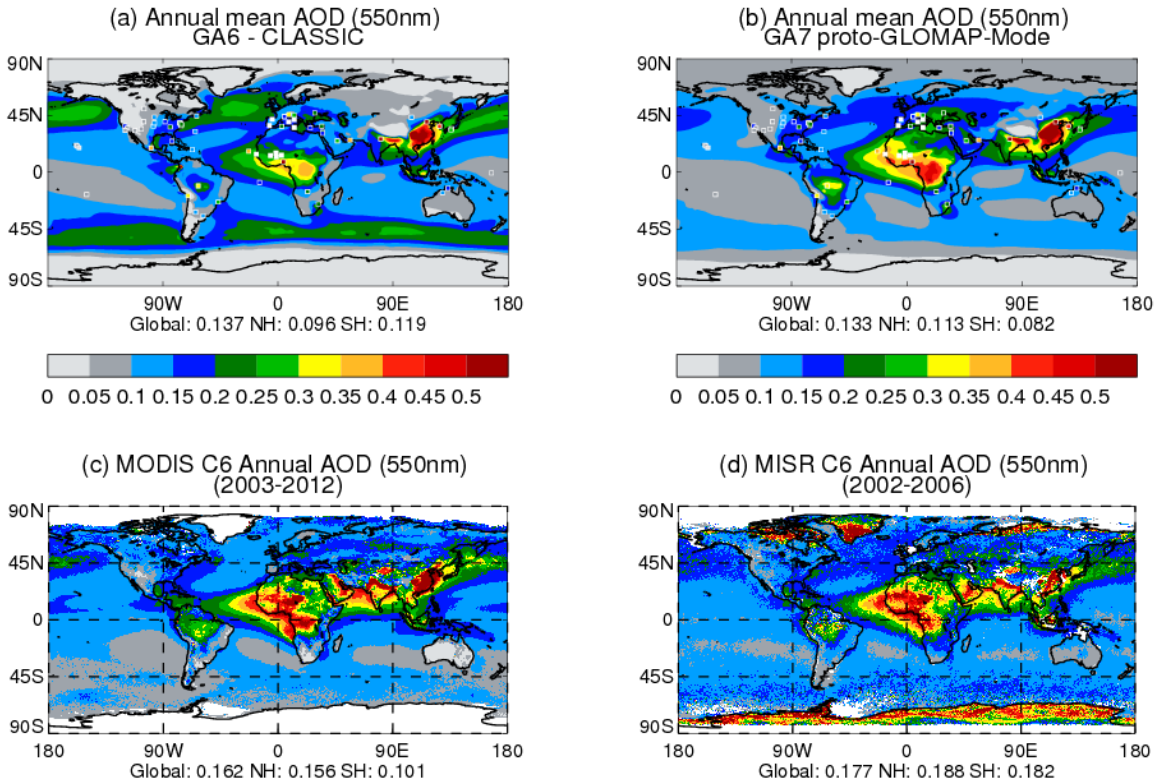

Figure 2: Annual mean AOD at 550nm in (a) GA6 CLASSIC simulation, (b) GA7 prototype simulation with GLOMAP-Mode, (c) MODIS and (d) MISR observations. Model simulations are taken from years 2002-2008 of a 20 year free-running AMIP simulation. Observations cover the period 2003-2012 for MODIS and 2002-2006 for MISR.

GLOMAP-Mode (Mann et al, 2010), replacing the older CLASSIC scheme. GLOMAP-Mode has been developed in collaboration with the UK academic community through the United Kingdom Chemistry and Aerosol (UKCA) project and represents a step change in the level of complexity with which aerosols are modeled in the UM. It is a 2-moment modal scheme simulating both aerosol mass and number of four aerosol species: sulphate, black carbon, organic carbon and sea salt. Aerosol number, size distribution, composition and optical properties are predicted from a detailed, physically-based treatment of aerosol microphysics and chemistry. Activation of aerosol particles to form cloud droplets is parameterized using the UKCA-Activate activation scheme (West et al., 2014). GLOMAP-mode will enable an improved representation of aerosol radiative effects and aerosol cloud interactions in UKESM1. Inclusion of modal dust is currently under development and so GC3 will continue to use the CLASSIC 6 bin dust scheme. Figure 2 shows the annual mean aerosol optical depth (AOD) from a GA6 (CLASSIC) AMIP and a GA7 prototype (GLOMAP-Mode) simulation along with remotely sensed AOD retrievals from the MODIS and MISR satellite instruments. Improvements in the AOD can be seen over high latitude ocean regions, tropical biomass burning regions and northern hemisphere continents.

A thorough assessment of GC3 will take place during 2016 and this will be drawn together into a series of papers and an assessment workshop to be held in the Met Office in June 2016.

References:

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