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Towards the IPCC 6th Assessment Report: building Africa's first global model for climate change projections

Climate change is the most serious collective environmental challenge ever faced by modern humankind. It is a problem with global reach, but the research effort to address it is disproportionately concentrated in the northern hemisphere and in developed countries. Southern hemispheric and African climate issues differ from those that drive the research and modelling effort in the north. In particular, oceans dominate the southern hemisphere and the land is largely occupied by arid systems and tropical forests. African terrestrial ecosystems and processes, Southern Ocean physics, biochemistry and circulation dynamics as well as Southern Hemisphere atmospheric processes are under-studied and poorly represented in global models - despite being globally important contributors to earth system processes. In particular, of the about thirty currently existing coupled ocean-atmosphere global circulation models (CGCMs) and Earth System Models (ESMs) suitable for the projection of future climate change, only one model had its genesis in the Southern Hemisphere. Towards addressing this disproportionality, and in alignment with the South African Department of Science & Technology's Global Change Grand Challenge, the CSIR and partners are invested in building a Variable-resolution Earth System Model (VrESM), with the aim of contributing projections of future climate change to the Coupled Model Intercomparison Project Phase 6 (CMIP6) and Assessment Report 6 (AR6) of the IPCC. VrESM is the first African-based Earth System Model (ESM) and has as component models the variable-cubic atmospheric model (VCAM) of the CSIRO, a dynamic land-surface model (CABLE), the variable cubic ocean model (VCOM) and an ocean biogeochemistry model (PISCES).
VrESM is formulated on the non-orthogonal, quasi-uniform cubic grid of Purser and Rancic (1998). Its atmospheric component VCAM has been developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). VCAM is a σ-coordinate model that uses a semi-implicit semi-Lagrangian approach to solve the hydrostatic primitive equations. VCAM has inherited the comprehensive physical parameterisations of the Conformal-Cubic Atmospheric Model (CCAM) (McGregor, 2005b). The dynamic land-surface model used is the CSIRO Atmosphere Biosphere Land Exchange model (CABLE). CABLE includes a dynamic river routing scheme adapted from the CSIRO Mk3.5 CGCM. The VrESM ocean component VCOM has been developed by the CSIR. This model solves the Boussinesq hydrostatic equations in a z-coordinate in momentum-conservation form, using a split-explicit solution procedure. VCOM is coupled to the PISCES ocean biochemistry model. Coupling of the ocean, atmospheric and land-surface components takes place every time-step. It is envisaged that VrESM will be applied on a 100 km horizontal resolution grid within CMIP6, with a longer-term plan of performing global eddy-resolving (10 km resolution) simulations depending on the availability of supercomputing resources at the Centre for High Performance Computing (CHPC) of the CSIR. Our path over the next 5 years (towards and beyond AR6) is firstly technical, in further developing and optimising the VrESM on the computer cluster at the CHPC and secondly scientific, in understanding the underlying mechanisms that are often parameterized rather than resolved in global climate models – followed by subsequent improvements and optimizing the model with this new knowledge. In particular, South Africa has invested significantly in resources to investigate and undertake long term observations that resolve critical dynamics in the oceans to our south. From this investment has emerged a competitive edge in building the first ESM that realistically represent Southern Ocean biochemistry and the role of the Southern Ocean in the African and global climate systems. In this presentation, we will present the unique aspects of the VrESM numerical solution procedure as applied on the cube-based grid. A variety of model applications (including simulations of present-day and future climate) will also be shown, with a focus on Southern Hemisphere and African

climate processes.

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