Weather and Climate Numerical Models Development Programme in South Africa

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Abstract

In this document we propose that institutions that are already embarking on model development activities work together and support each other, as well as new entrants to accelerate model development activities in the country and increase the critical mass with an advanced understanding of models faster. The ultimate purpose of this initiative is that South Africa becomes an independent user of models, and develops one or more home-grown models that can be used for operational and research purposes. Each participating institution can make contributions on any model of interest, and these contributions can include work with consortia on international models. These initial steps will help build capacity, which can contribute towards the development of one or more home grown models. The development of a critical mass of researchers that can develop models will require investment in human resource capital development. This programme will enhance collaboration between organisations with modelling capabilities towards jointly informing policy developments and implementation of frameworks in the country. Close collaboration between the South African Weather Service (SAWS) which is a mandated meteorological service organisation, and other research organisations will ensure that all modelling research taking place nationally, that can improve weather and climate early warning systems, is incorporated into the SAWS operations, for the benefit of the society and public in general. Moreover, the Council for Scientific and Industrial Research (CSIR) Earth System Model development programme and related generation of climate change projections for Africa will be furthered by this enhanced collaboration.

Keywords: *numerical modelling, model development, human capital development, collaboration*

Introduction

South African scientists started participating in the development or improvement of weather and climate numerical models in 2002, after being inactive in the area for over a decade. The regeneration of model development activities started at the University of Pretoria (UP) through a Water Research Commission (WRC) funded project where a dynamical core of a nonhydrostatic sigma- coordinate model (NSM) was developed from scratch (Engelbrecht, 2006; Engelbrecht et al., 2007). These activities served to encourage others in the country to also contribute in the model development space. The NSM was later extended to include moisture and microphysics schemes at the CSIR in collaboration with UP (Bopape et al., 2014a; 2014b). This model is currently only available for use in research mode and is written in serial, however, the underlying dynamics are similar to those used in the Conformal Cubic Atmospheric Model (CCAM).

Most other model development activities in the country built on existing modelling systems from first world countries. For example Abiodun et al (2008a and b) improved the dynamical core of CAM to use stretched grid with higher resolution over an area or process of interest while at Iowa State University and continued the development while in the employ of University of Cape Town (UCT). Model development activities in the country also include the coupling of different components of the earth system together. At SAWS, Beraki et al (2015) coupled the ECHAM4.5 model to MOM3.

A recent development is the configuration of the first African-based Earth System Model at the CSIR, through a collaboration with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Engelbrecht et al., 2012, 2018). The Variable-resolution Earth System Model (VrESM) became the first African-based model to register for CMIP6 in 2017. It uses as atmospheric and land-surface components the CCAM and CABLE models of the CSIRO, whilst the ocean component VCOM (Variable-cubic Ocean Model) was developed at the CSIR. Development activities are focused on different aspects of the earth system, including the carbon cycle, and the project will allow Africa to contribute global simulations towards the generation of Assessment Report Six (AR6) of the Intergovernmental Panel on Climate Change (IPCC).

Background to Programme

Despite model development activities having started over a decade ago, the progress in model development activities in the country has been slow, and the number of people who truly understand models and can contribute to the model

development exercise remains low. Discussions on possible collaboration efforts and information sharing amongst those working on model development started in 2017. The intention is that when model developers in the country work together, model development activities will be accelerated. Although the different organisations use different models, similar issues such as a lack of solutions for certain resolutions apply to all models. Some sub-grid schemes are used in a number of models, and so an understanding of the performance of such schemes when linked to different dynamics can be of mutual benefit to all organisations involved. Together, the different organisations can identify common training needs and training workshops that can be co-organised to deal with known shortcomings in the country. Furthermore, through working together the country can become an independent developer of weather and climate models (whilst strengthening collaboration in this field with international model development centres). Randall (1996) suggested that model development should continue at universities to train model developers at a rate matched to the community's demand for developers. This implies that model development can take place at both universities and research institutions.

A workshop on model development was held at SAWS on the 28th October 2017 where researchers that have contributed to the space from SAWS, CSIR, UP and UCT met to discuss ideas on how the country can accelerate model development activities. Prof David Randall from Colorado State University in the United States of America (USA), Prof. Robert Plant from the University of Reading in the UK, as well as Dr John McGregor from the CSIRO in Australia were invited to contribute through an online platform and provide advice to the workshop delegates. These three colleagues were invited to the workshop because they are considered as some of the world renowned scientists in model development, and existing close relationships with them are already in place with scientists in the country. Modelling activities taking place in the participating organisations were discussed, as well as future plans to inform the development of a programme that aligns with strategic objectives of each of the participating organisations/institutions. The sections below are informed by resolutions of the workshop.

Goals and Objectives of the Programme

The purpose of the programme is to establish an environment that will make it possible for weather and climate operational obligations of South Africa to be met using home grown models in ten years. The home grown models will also be used for research purposes and to meet policy requirements such as the National Communications on Climate Change and National Adaptation Strategy.

The main goal of the framework is to ensure that there is a coordinated weather and climate numerical model development effort in South Africa which can lead to the following outcomes:

- South Africa becomes an independent developer of numerical weather and climate models;
- South Africa is a part of a new trend in model development instead of waiting for others to develop schemes suitable for Africa;
- Local domain expertise on different systems such as African thunderstorms, aerosols and the southern ocean is incorporated into the models;
- A closer relation is forged between model developers at Universities, and SAWS to ensure that research conducted outside of SAWS benefits operational activities of the SAWS, and Earth System Modelling at the CSIR
- Expertise is developed not only to identify biases and weaknesses in models, but to also improve models;
- Strengthen synergies between the institutions involved in model development and the Centre for High Performance Computing (CHPC), towards also strengthening high-performance computing skills in South Africa;
- There is increased support for postgraduate students working on model development activities at universities and some of the students can be hosted in research organisations;
- Model development activities support policy making and national initiatives;
- Improved understanding of local processes and hence improvement in models.
- Increased collaboration with model developers internationally; and
- Increased opportunities for programming training necessary for model development.

Implementation Mechanism

The implementation of this framework takes account of the fact that model development is a slow process. In order to develop a robust system, a minimum period of five years is required, and this minimum period can also take up to ten years. The plan also recognises that model development activities can result in very few publications. This means that researchers working on model development may not be able to grow smoothly on their research career ladder if they can't use other models. The planned activities also consider the past and ongoing efforts in the country, which will provide a good launch pad to enhanced model development. Contributions to the plan are therefore not model specific and the expectation is that the participating organisations will work on this project, in parallel to other modelling activities where any models of choice can be used. It is also noted that model development activities do not have to be started from scratch but contributions can be made by building on existing models.

Work will be conducted across timescales so that activities are able to benefit weather forecasting as well as climate predictions and projections. When diagnosing sources of errors, different components of models will be considered including sub-grid models as well as the dynamical cores. The plan also considers institutional arrangements to ensure that the contributions are relevant and also contribute to the mandates and strategic objectives of the participating organisations. The coordinated project can lead to publications which are necessary in an academic career, but at the same time can contribute to the operational activities at SAWS and the CSIR. This means that the research conducted across South Africa will be able to contribute to SAWS early warning systems and can therefore inform decision making to save lives and property. This programme should provide an environment wherein SAWS can be in a position to compare local and international models in the recent future for a decision on its main operational model. This will only happen if local models perform at a level that is on par with international models. In the case of the CSIR, the intention of this programme is to involve a larger pool of post-graduate students and university researchers in the continued

development and application of the African-based Earth System Model.

The following activities will be undertaken:

Model contributions: Contributions will be made in two ways:1) Creation of models that are fully developed in South Africa. These may include atmospheric, ocean, land-surface and sea-ice models. This contribution includes model development that builds on existing models with a significant contribution from South Africa to the extent that South Africa can be considered as a lead in the development process. 2) Participate in open/partnership model development activities internationally. This contribution will include model development activities in open models such as CCAM, WRF and CAM, as well as somewhat closed models where a formalised relationship is required before model contributions can be made.

Steering Committee: The implementation of the programme will be led by a steering committee which will be identified as soon as the programme is approved. The committee will be comprised of at least five individuals from participating local organisations. The steering committee will also include at least two international experts (i.e. not based in South Africa) who will serve as advisors to the committee. The committee will also include at least one PhD student to ensure that views and needs of students are represented.

Local experts and active international collaborators data: A list will be compiled with South African based scientists who have worked on model development, with details of contributions made. The list will also include international experts that have or are working closely with the South African scientists.

Intercomparison study: The first five years of the project will focus on two topics identified in a way that allows all participating institutions to contribute to at least one of the topics. The two topics to be considered are 1) Thunderstorms, while the second topic will focus on 2) seasonal rainfall predictability. A list of variables, number of levels, and required format of the model output data which will be submitted for the intercomparison study will be identified, discussed and finalised by the steering committee. The experimental design which will include amongst others, the minimum domain size, the grid spacing, the simulation period as well as a testing framework which will be finalised during the second implementation quarter of the framework. The simulations and observations will be compared against each other as informed by a testing framework that will be developed when the configuration is decided on. Results from the comparison study will be discussed and submitted to an accredited journals.

Sensitivity studies and model improvements: In diagnosing sources of errors identified in the inter-comparison study, sensitivity studies will consider different aspects of the model. The sensitivity studies will consider both the dynamics and the physics in the model.

Working group meetings: Two working groups, one focusing on the thunderstorms and another will focus on the seasonal rainfall predictability. Each working group will include at least one individual from the organisations that are contributing simulations to the topic. The working groups will meet at least once a quarter to report on progress on an online platform, and in person at least once a year. Meetings can be arranged to take advantage of events such as the CHPC National Meeting, the South African Society for Atmospheric Sciences (SASAS) annual conference and other symposia. The working groups are not organised as informed by different components of the models because the community is still currently spread thinly. Furthermore the diagnoses of the causes of errors will not make pre-determined decisions on where the models go wrong.

Postgraduate studies: Increasing the critical mass that will ensure that South Africa is an independent model developer, requires investment, and postgraduates working in the space. Both the CSIR and SAWS have a research institution status which means they can host PhD students. At Masters level and below, students will not be expected to contribute towards model development by modifying any of the codes that are in use. Students who majored in physics, meteorology, atmospheric science, and applied mathematics have and will be increasingly recruited to address different aspects of model development.

Postdoctoral fellows: Postdoctoral fellows will be recruited by the institutions of higher learning and research institutions to work on different aspects of the models, on work that needs to be done on the project. Attention will also be given to the recruitment of internationals who can contribute to the project for a period of two to three years. Such recruits will bring a different perspective and experience from other countries that have experience in the development of models.

Tutorials and Workshops: Tutorials and workshops will be organised such that a minimum of one takes place per year. These workshops will be organised as side events as well as independent of national or international conferences. Different institutions will lead the organisation of the workshops in different years, and co-hosting will also be possible depending on what is convenient. SAWS and the Universities have computer labs that can be used for such training, and therefore the majority of the events will be hosted by project partners. At SAWS the training will conducted in cooperation with World Meteorological Organization (WMO) Regional Training Centre (RTC).

International Meetings held in South Africa: The South African model development community will work with the international modelling community to propose to host some international meetings. These include WCRP in general or specific working groups such as WGNE and Pan GASS.

International Meetings outside South Africa: The South African scientists will be encouraged to attend international meetings. An email list with South Africans interested in model development will be set-up where international modelling conferences, seasonal schools, or tutorials will be advertised. Where international funding is provided, early career scientists will be encouraged to apply. Where international funding is not provided, national resources will be mobilised. It may be noted that some workshops are streamed to allow remote participation, information on such meetings will be distributed.

Conclusions

Any institution interested in participating in the programme can get in touch with the corresponding author. The programme document is dynamic, other contributions are welcomed.

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