Press Release: May 2019

Met Office leads ground-breaking research collaboration on modelling African climate, showing enhanced future changes in wet and dry extremes

A 4-year investment into one of the most ambitious research collaborations to date that focuses on African climate has delivered far-reaching results to advance international climate science. The international collaboration, led by the Met Office, the UK's national meteorological service, has developed the first pan-African convective-permitting regional climate model, known as CP4-Africa. CP4-Africa provides improvement in the simulation of convective storms, which provide most African rainfall, with consequent impacts on regional circulations, weather and climate change. These simulations show future changes in extreme weather are likely greater than those predicted by past models. They also provide the international weather and climate change science community with a new tool to improve our understanding of how climate change and extreme weather events will affect the African continent, and in turn, will support policy makers and planners to respond better to climate risks.

Lead author of the first paper on future climate change from the CP4-Africa simulations in Nature Communications, Dr Elizabeth Kendon of the Met Office, explains that, "Very high resolution climate projections provide a glimpse into future weather and climate extremes over Africa. CP4-A suggests that extreme heavy rainfall events that occur about once every 30 years now, may occur once every 3-4 years by the end of the century if emissions continue to rise throughout the 21st century following 'business as usual'. Dry spells during the wet season exceeding 10 days in length are almost twice as frequent in the future compared to the present-day: a signal which is not seen in a coarser resolution 25km model. The results show that future changes in extremes over Africa may be more severe than we previously thought, if we do not curb emissions of greenhouse gases. These results are of major concern."

Whilst Africa is highly vulnerable to climate change and already experiencing the first devastating impacts, the scientific understanding of African climate change remains poor. This is partially because all climate models struggle to represent the small-scale processes, such as convection, which dominate tropical climate, when compared with the larger scale weather systems that tend to dominate in more mid-latitude regions such as Europe and North America. In 2014 the UK Government's Department for International Development (DFID) and the Natural Environment Research Council (NERC), allocated one of the single largest research investments into improving the scientific understanding of African climate change under the Future Climate for Africa (FCFA) programme to help address this. Four years later, the team of scientists working on one of the FCFA research projects, Improving Model Processes for African Climate (IMPALA), have a lot to show for it.

The IMPALA research group has developed and run a ground-breaking pan-Africa high resolution model called CP4-Africa, which gives new insight into future projections of climate for the African continent. CP4-Africa provides the first ever convective-permitting resolution, multi-year climate simulations for present-day and idealised future climates on an African-wide domain. With a grid-spacing of around 4.5km x 4.5km, CP4-Africa can start to simulate convective storms explicitly, which are the main source of rainfall over most of the continent, and directly contribute to continental-scale circulations.

“The CP4-Africa simulations are delivering new information on how important the simulation of convective processes are for African climate – today and in the future. These new results, in combination with existing model projections, will give impact scientists and policy makers in Africa more robust, useable information for decision making” says Dr Cath Senior, Principle Investigator for IMPALA, at the Met Office.

Early evaluation of CP4-Africa’s performance compared to lower resolution climate models show exciting improvements. Representing local weather features explicitly in simulations improves the model’s projections of rainfall intensity and duration in present-day simulations. This includes, for example, reducing the persistent under-estimation of rainfall in West Africa seen in the coarser-resolution models. In East Africa, simulating local terrain and convective processes in the Lake Victoria Basin has improved representation of the daily rainfall cycle and storms over the basin. This has major implications for one of the fast growing population centres on the continent, which is centered around the lake, and largely fed by on-lake rainfall, rather than rivers.

Achieving breakthroughs like CP4-Africa required extensive human and computing resources. IMPALA consisted of 40 scientists and software engineers, working in partnership across five British and four African institutions on CP4-Africa and understanding and improving global model processes driving African climate.

The scientific ambition behind IMPALA enabled key partnerships to overcome another prohibitive barrier to improving climate model simulations: available computing power. The Met Office Hadley Centre Climate Programme contributed supercomputing time to IMPALA as CP4-Africa simulations will inform improvements to the Met Office’s world leading weather and climate model(s). CP4-Africa’s computing requirements were gargantuan: simulating 20 years of climate on a continent-wide domain at a kilometre-scale, took two and a half years to complete and generated three petabytes of data.

The CP4-Africa simulations, when combined with the international global models available through the World Climate Research Programme’s (WCRP) Coupled Model Intercomparison Project (CMIP), provide an invaluable resource for the international scientific community on which to build future research agendas and practical tools. Studying climate change and its impacts driven by the CP4-Africa simulations will take many years.

One of the early initiatives building on the partnerships and tools developed in IMPALA is the first-ever African Model Evaluation Hub, a partnership between

Oxford University, University of Yaounde I, University of Nairobi, University of Cape Town, Kwame Nkrumah University of Science and Technology, and the Met Office. The Hub will fast-track understanding of how climate models simulate African regions: “There’s a lot of demand to use climate model data, but for some regions we don’t know very much about how the modelled climate works. IMPALA has given us an exciting opportunity to collaborate with experts in these regions, to identify key weather features, which we can examine together. Now, through the Hub, we are planning to automate our analysis, so that when new models are developed we can very quickly get lots of information about how they perform over Africa. In the long run this will help improve models over Africa, and help inform the use of models for climate change adaptation planning,” explains Dr Rachel James, Researcher at the University of Oxford.

The IMPALA team is now developing guidance documentation to steer appropriate use of CP4-Africa results, including guidance on accessing and processing the data. CP4-Africa data is being made available via the UK’s Centre for Environmental Data Analysis’ JASMIN super computer and data centre, which delivers world-leading infrastructure for big data analysis.

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IMPALA stands for Improving Model Processes for African Climate. It was funded by the UK Government’s Department for International Development and the Natural Environment Research Council under the Future Climate for Africa programme.

For more information please visit the **Future Climate for Africa Website**: http://www.futureclimateafrica.org/

Selected academic outputs from the research:

Enhanced future changes in wet and dry extremes over Africa at convection permitting scale: https://www.nature.com/articles/s41467-019-09776-9

A Pan-African Convection-Permitting Regional Climate Simulation with the Met Office Unified Model: CP4-Africa: **https://journals.ametsoc.org/doi/10.1175/JCLI-D-17-0503.1**

Implications of Improved Representation of Convection for the East Africa Water Budget Using a Convection-Permitting Model: https://doi.org/10.1175/JCLI-D-18-0387.1

Evaluating Climate models with an African Lens paper: https://journals.ametsoc.org/doi/10.1175/BAMS-D-16-0090.1

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