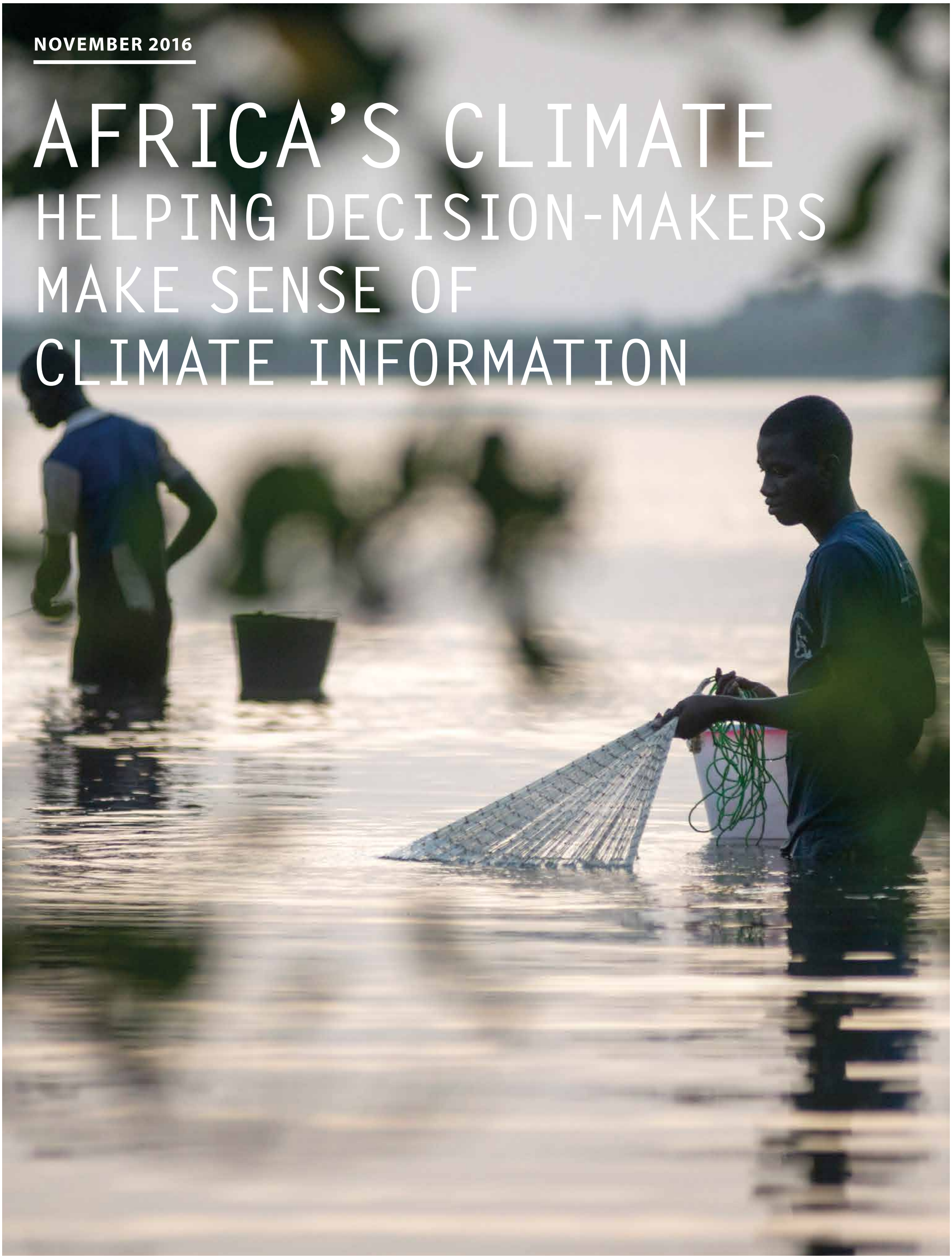

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# AFRICA'S CLIMATE

## HELPING DECISION-MAKERS MAKE SENSE OF CLIMATE INFORMATION

FUTURE CLIMATE FOR AFRICA

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SCIENTISTS

**ALL OF AFRICA**
BURNING QUESTIONS

# IMPROVING CLIMATE MODELLING FOR AFRICA

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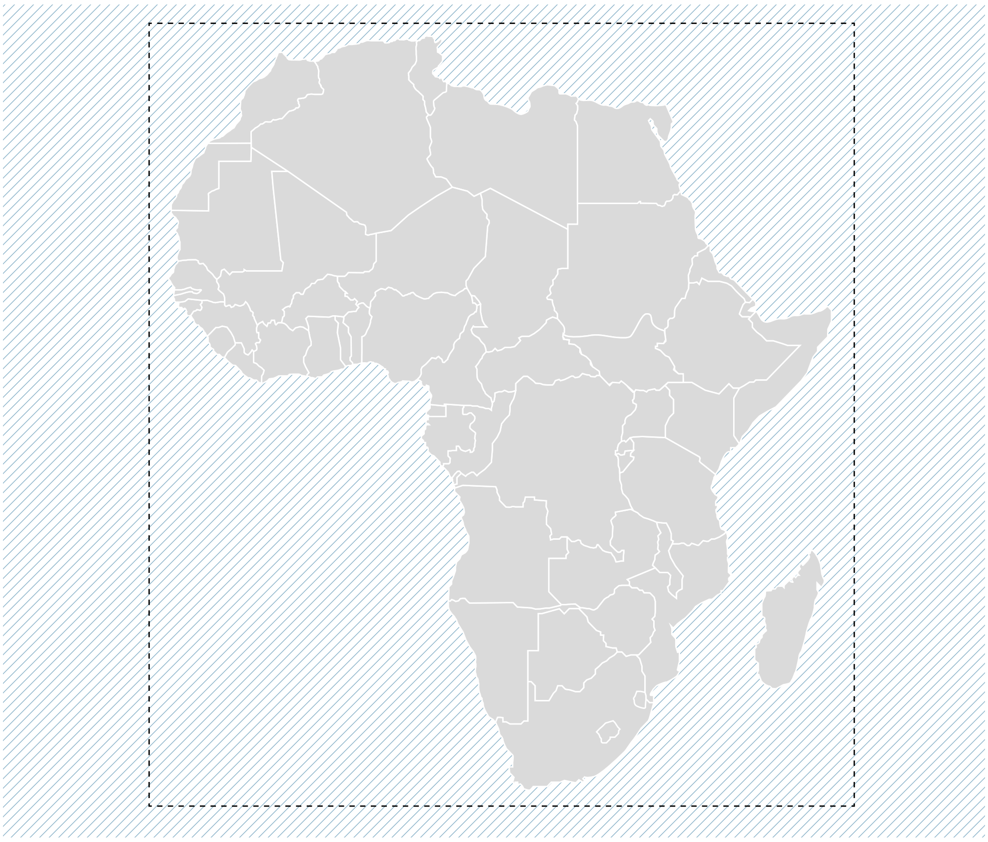

# NEED TO KNOW

The climate models used to project Africa's likely future climate only have a modest ability to capture the physical processes driving the climate on the continent. But work is now being done to improve them in order to produce information that can better assist African decision-makers. Researchers are endeavouring to:

- better understand the physical drivers of climate on the continent, especially how local processes interact with more distant influences
- gain better observations of the processes driving African climate variability and change
- improve modelling techniques including refining model grids to represent individual cloud systems
- target regional evaluation of how these physical processes work in the models by applying an 'Africa lens' to the problem.

## INTRODUCTION

There is an urgent need to deliver actionable climate information for sub-Saharan Africa, to support planning for climate resilience and adaptation, in order to better inform sustainable poverty alleviation strategies.

**A key building block for adaptation is reliable, robust projections of future climate over the coming decades**

A key building block for adaptation is reliable, robust projections of the future climate over the coming decades, as well as across regional, national, and smaller space scales. However, current climate models have a modest ability to capture the processes driving the African climate. There has been slow progress in improving their performance over the past six years.[1] This limits confidence in the climate projections, and thus how useful they are for supporting decision-makers in Africa.

This factsheet discusses the key questions relating to the capability of climate models used to study Africa's climate, and aims to describe some of the reasons for the lack of progress in improving these models. It considers why there are now real opportunities to speed up the rate of improvement, and how this can deliver both advice and data to impact scientists and decision-makers on the continent.

## LIMITATIONS OF MODELS FOR AFRICA'S CLIMATE

### Interacting time and space scales

The distribution of sub-Saharan rainfall is largely determined by atmospheric deep convection that develops as a result of the interaction of regional circulations with local gradients in surface heating and moisture. These regional circulations are driven by local radiative heating and land surface conditions, as well as by more distant tropics-wide

1 Flato, G., J. Marotzke, B. Abiodun, P. Braconnot, S. C. Chou, W. Collins, P. Cox, F. Dri-ouech, S. Emori, V. Eyring, C. Forest, P. Gleckler, E. Guilyardi, C. Jakob, V. Kattsov, C. Reason, and M. Rummukainen, 2013. Evaluation of climate models: IPCC WGI Fifth Assessment Report, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, chapter 9.

circulation patterns. Africa's climate is therefore highly susceptible to fluctuations of patterns of the global climate and their links (or 'teleconnection pathways') to the continent. Consequently, to predict future trends in African rainfall variability, global climate models (GCMs) must be able to capture the multi-scale nature of the problem. This includes the interaction of locally occurring small-scale processes with wider weather patterns across Africa and how warming sea surface temperatures far from the continent can influence these.

### The challenge of convection

Contemporary climate models have typical grid-spacing of around 100km. Processes and feedbacks such as convection, atmosphere-land interactions, or aerosols that work on a smaller scale than this 100km x 100km grid thus have to be simplified when they are included in these models. This involves relating these complex processes to the large-scale properties of the atmosphere, such as wind, temperature and humidity. The different choices made in this process of simplification are often a result of our limited knowledge of how the local climate system works, or a lack of good scientific observations. These are a major reason for the uncertainty in future projections of climate from GCMs, and for a lack of confidence in the representation, particularly for convective processes.

### Historical lack of 'Africa lens' in model development

**The cycle of model evaluation and development has often been most focused on regions of prime interest to research funders**

The cycle of model evaluation and development has often been most focused on regions of prime interest to research funders, whose priority has typically been the developed countries of the northern hemisphere. Hence more rapid progress has been made in the modelling of drivers of the climate in these regions. The current generation of GCMs show a range of biases in their simulation of Africa's climate and the key driving processes. They can capture some important modes of climate variability,[2] but often the teleconnections with African rainfall on inter-annual and decadal timescales are weaker than observed.[3, 4, 5, 6] Most models show similar biases in the timing, organisation and propagation of convective storms.[7, 8, 9, 10] These are at least partly as a result of inadequate coupling in the models

2 Rowell D. P., 2013. Simulating SST teleconnections to Africa: what is the state of the Art? J Climate 26:5397–5418. doi:10.1175/JCLI-D-12-00761.1.

3 Ault, T. R., J. E. Cole and S. St. George, 2012. The amplitude of decadal to multi-decadal variability in precipitation simulated by state-of-the-art climate models, *Geophysical Re-search Letters* 39, L21705, doi:10.1029/2012GL053424.

4 Biasutti, M., I. M. Held, A. H. Sobel, A. Giannini, 2008. SST forcings and Sahel rainfall variability in simulations of the twentieth and twenty-first centuries. *J. Clim*., 21, 3471–3486.

5 Vellinga, M., A. Arribas, and R. Graham, 2013. Seasonal forecasts for regional onset of the West African monsoon, *Climate Dynamics*., 40, 3047–3070, doi:10.1007/s00382-012-1520-z.

6 Philippon N, Doblas-Reyes FJ, Ruti PM., 2010. Skill, reproducibility and potential pre-dictability of the West African monsoon in coupled GCMs. *Climate Dynamics* 35: 53–74. DOI: 10.1007/s00382-010-0856-5.

7 Birch, C. E., D. J. Parker, J. H. Marsham, D. Copsey, and L. Garcia-Carreras, 2014a. A seamless assessment of the role of convection in the water cycle of the West African monsoon, J. *Geophys. Res. Atmos*., 119, 2890–2912, doi:10.1002/2013JD020887.

8 Taylor, C. M., C. E. Birch, D. J. Parker, N. Dixon, F. Guichard, G. Nikulin, and G. M. S. Lister, 2013. Modelling soil moisture-precipitation feedback in the Sahel: Importance of spatial scale versus convective parameterization, *Geophys. Res. Lett*., 40, 6213–6218, doi:10.1002/2013GL058511.

9 Birch, C. E., J. H. Marsham, D. J. Parker, and C. M. Taylor, 2014b. The scale depend-ence and structure of convergence fields preceding the initiation of deep convection. *Geophys. Res. Lett*., 41 (13), 4769–4776, doi:10.1002/2014GL060493.

10 Pearson K.J., G. M. S. Lister, C. E. Birch, R. P. Allan, R. J. Hogan, S. J. Woolnough, 2014. Modelling the Diurnal Cycle of Tropical Convection Across the 'Grey Zone', *QJRMS*, 140, 491–499, doi: 10.1002/qj.2145.

between local convection and the larger-scale monsoon circulation.[11] Furthermore, synoptic weather systems, such as African Easterly Waves (the passage of which are typically associated with enhanced rainfall), are also often too weak and infrequent in models, and only weakly connected to en-hanced rainfall.[12] The shortage of scientific observations over the African continent has also resulted in land surface processes not being well represented in models, hence key processes such as evaporation from bare soil or fluxes in a drying landscape are not well captured.

## A ROADMAP FOR MODEL IMPROVEMENT

**The ability of models to simulate important features of the African climate, such as rainfall, heatwaves, and dust storms, depends critically on the representation of key processes and feedbacks**

As outlined above, the ability of models to simulate important features of the African climate, such as rainfall, heatwaves, and dust storms, depends critically on the representation of key processes and feedbacks. The most notable of these involve convection, land surface, and aerosols.

These processes include:

- convective processes, and convective organisation, which take place across time as well as spatial scales
- the impact of clouds and aerosol on radiative heating
- the influence of convective dynamics on aerosol transport
- important stores of moisture in the soil and heat in the oceans that influence surface fluxes.

Uncertainties in all these aspects are the result of imperfect knowledge of the relevant physical and dynamical processes, compounded by lack of scientific observations over the African continent. However, in the past decade, the knowledge gained from detailed field experiments and increased use of remote sensing, combined with the ability to run numerical models at a resolution that can incorporate convective processes (100m–1km), make this an ideal time to advance our understanding of these key processes and improve their representation in the GCMs.

A better understanding and representation of global climate variability and its teleconnection pathways to Africa is also starting to emerge, at least in part, from the use of higher resolution global models. These use improved horizontal grid spacing, so that we are now starting to capture weather systems. They also use increased numbers of vertical levels, capturing better the exchanges between the troposphere and stratosphere, which can play an important role in teleconnection pathways.

Recent work[13] has highlighted the importance of large-scale energetic constraints on drivers of African rainfall through influencing the location of the Inter Tropical Convergence Zone (ITCZ) and locally the location of the West African Monsoon (WAM). This opens up the potential for the application of such 'emergent constraints' from newly available global observations.

11 Marsham, J. H., N. S. Dixon, L. Garcia-Carreras, G. Lister, D. J. Parker, P. Knippertz, and C. E. Birch, 2013a. The role of moist convection in the West African monsoon sys-tem: Insights from continental-scale convection-permitting simulations. *Geophys. Res. Lett*., 40 (9), 1843–1849, doi:10.1002/grl.50347.

12 Bain, C. L., K. D. Williams, S. F. Milton, J. T. Heming, 2013. Objective tracking of African Easter-ly Waves in Met Office models. Q. J. R. *Meteorol. Soc.* 140: 47–57, doi: 10.1002/qj.2110.

13 Haywood, J. M., Jones, A., Bellouin, N. & Stephenson, D., 2013. Asymmetric forcing from stratospheric aerosols impacts Sahelian rainfall. *Nature Clim. Change* 3, 660–665.

## PROGRESS IN TACKLING THESE CHALLENGES

**The reasons for poor climate model simulations are complex and therefore this research may not deliver 'quick wins', but it is fundamental for longer-term improvements in GCM performance**

Climate scientists working in this area of research are building on previous African-focused model development projects through collaborations between the Met Office, UK universities, and African researchers from across the continent. A key part of this work is to build the link between improved modelling of local processes, and the drivers of five to 40 year African climate variability and teleconnections.

The reasons for poor climate model simulations are complex and therefore this research may not deliver 'quick wins', but it is fundamental for longer-term improvements in GCM performance. In parallel, researchers will focus on the fundamentals of the representation of smaller-scale convective processes in GCMs. Crucially, this challenge can, for the first time, be addressed through the use of high resolution simulations representing individual convective cloud systems across the whole of Africa.

Additionally, researchers will use newly extended scientific observations to tackle long-standing issues of how to model the daily to seasonal variations in surface fluxes of heat and moisture. Refined modelling of the impact of African mineral dust, and ash and smoke from burning biomass have the potential to deliver 'quick wins'.

## BETTER MODELS MEAN BETTER CLIMATE PROJECTIONS

The aim of this work is to deliver a step-change in climate modelling capability for Africa. It will come through an improved, physically credible representation of key driving processes. It will deliver more robust, less uncertain, future projections, and new understanding of the remaining limitations of climate models as the basis for actionable advice.

High-resolution regional information will more accurately simulate the key processes and local-scale weather phenomena, including extreme events. This will provide a new source of regional and local scale data for impact studies across a range of important sectors, such as agriculture, health, urban water resources and infrastructure. These can be used in combination with multi-model projections of regional or extreme signals of climate change to identify robust signals and highlight extreme risks.

Nowhere are model developments more urgently needed than over tropical Africa. These will provide greater confidence in future climate projections of key measures, such as timing of the onset of the monsoon, or active and break cycles. More confident, targeted projections will increase their utility for planning and development across many critical sectors including health, agriculture, water management and renewable energy.

# FCFA'S IMPALA PROJECT

**Project objectives**

The project aims to tackle a major scientific hurdle that limits decision-makers from using climate information: current climate models have only a modest ability to capture African climate systems. Because of this, there is large uncertainty and low scientific confidence in important aspects of the projections for Africa's climate in the next five to 40 years.

This project will focus on a single climate model, the Met Office Unified Model, to improve its simulation of African climate through a better understanding and representation of weather and climate processes. This will result in reduced uncertainty in future projections of the African climate and provide valuable information to climate scientists and modellers within Africa and worldwide, and empower decision-makers with information that can be used to reduce risks and help protect the livelihoods of the most vulnerable.

The initiative aims to deliver a step change in global climate model capability that will reduce uncertainty and enable better informed evaluation of the robustness of future projections. See www.futureclimateafrica.org/project/impala/

**The institutions involved in IMPALA are:**

- Met Office (UK)
- African Centre of Meteorological Applications for Development
- Centre for Ecology and Hydrology (UK)
- University of Cape Town
- University of Exeter
- University of Leeds
- University of Nairobi
- University of Oxford
- University of Reading
- University of Yaoundé

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