FUTURE CLIMATE FOR AFRICA

BUILDING THE FOUNDATION FOR CLIMATE-INFORMED DECISION-MAKING IN AFRICA: THE NEED FOR CONTINUED INVESTMENT IN AFRICAN CLIMATE RESEARCH

KEY MESSAGES

- Long-term decisions need to be informed by accurate and relevant climate information to ensure developments are resilient to climate change.

- The Future Climate for Africa (FCFA) programme made significant improvements in understanding Africa's climate. Advances in the science, coupled with improvements in climate modelling and building the capacity of African climate scientists, helped lay the foundation to produce information that can inform climate-resilient development.

- The collaborative approach adopted by FCFA between researchers from the Global North and South, and between researchers and stakeholders, was vital as it shaped the outcomes of the work and ensured research was addressing real-world problems within Africa.

- Despite the progress made within FCFA, there are still various known gaps that hinder the application of knowledge to inform solutions. These require further investment to strengthen the evidence base for adaptation and climate-resilient development.

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INTRODUCTION

The FCFA programme aimed to fundamentally improve the scientific understanding of Africa's climate and pilot new approaches to improve the uptake of medium- to long-term climate information (5–40 years) into decision-making. While much of the real-world impact of the programme emerged from pilot projects, the underpinning science played a critical role in strengthening the knowledge foundation to understand weather and climate processes, and climate change across the continent. The collaborative research approach allowed researchers to work together and build upon each other's work.

This resulted in rapid advances in improving the understanding of Africa's climate and provides a strong evidence base for future work, as well as decision-making around future climate risks.

This brief aims to encourage further investments from donors in African climate science research. It highlights the advances FCFA has made in advancing the scientific understanding of Africa's climate, improving climate models, and supporting capacity development. The brief then goes on to emphasise the value of investing in climate science within the FCFA programme and the importance of continued investment, including within existing gaps.

ABOUT FCFA

Future Climate For Africa (FCFA) is a £20 million programme funded by the UK Foreign, Commonwealth and Development Office (FCDO) and Natural Environment Research Council (NERC). It is generating fundamentally new climate science focused on Africa and piloting the use of improved medium- to long-term (5 – 40 year) climate change information in development projects. FCFA is made up of five international research consortia and a Coordination, Capacity Development and Knowledge Exchange (CCKE) unit.

RESEARCH WAS CARRIED OUT BY THE FOLLOWING CONSORTIA:

- AMMA-2050 (African Monsoon Multidisciplinary Analysis 2050)
- FRACTAL (Future Resilience for African Cities and Lands)
- IMPALA (Improving Model Processes for African Climate)
- HyCRISTAL (Integrating Hydro-Climate Science into Policy Decisions for Climate-Resilient Infrastructure and Livelihoods in East Africa)
- UMFULA (Uncertainty Reduction in Models for Understanding Development Applications)

FCFA'S STEP CHANGE IN UNDERSTANDING CLIMATE SCIENCE

a. Improving climate modelling over Africa

To support climate change adaptation in Africa, it is crucial to improve the physical basis of climate models in their representation of processes pertinent to Africa's climate, as well as the development of climate change information and advice using current best available models and methods. FCFA, mainly through the IMPALA project, focused on improving climate modelling capability over Africa for global climate and high-resolution regional modelling.

Improvements in understanding key processes of Africa's climate, driven both locally and remotely, from the FCFA programme have been incorporated into the seventh iteration of the Global Atmosphere (GA7) Met Office Unified Model (MetUM), and further improvements emerging from the programme are also being included in later iterations of the MetUM model. Continuous improvements in global models are vital for improving the robustness of future regional climate projections.

IMPALA delivered CP4-Africa, the first Pan-African high-resolution (4.5km) model. This model delivered improvements in simulating convection, to more accurately simulate rainfall extremes, dry spells and high winds, but also continental-scale circulation and regional rainfall. The IMPALA project also produced a guide to accessing and using CP4-Africa data, which supports users to utilise the new data, while understanding the limitations and new information in the context of existing model data.

Building on FCFA's advances in understanding local and remote drivers of key processes for African climate, the Model Evaluation Hub was developed to draw on local expertise to perform targeted, process-based model evaluation for important climate processes over the continent. The first phase of the hub, LaunchPAD, focused on developing region-specific tools for model evaluation in Africa, through key partnerships between UK and African scientists. Research fellows from LaunchPAD have been collaborating with software developers in order to create key diagnostic tools, which are being tested by the Met Office and made available to the wider international modelling community through the evaluation tool ESMValTool.

LaunchPad research fellows discussing their work at a workshop in Cape Town, South Africa. Credit- Beth Mackay

b. Examples of key step changes and progress in African climate science

Changes in extreme weather under climate change

Many impacts of climate change are, and will be, felt through changes in the frequency and intensity of severe weather events. The coarse resolution of standard climate models poorly represents convective storms that bring rainfall and heat to the atmosphere. This produces errors in how rainfall is represented and can underestimate of how climate extremes may change. The IMPALA project ran the first pan-African convection-permitting climate change simulations, using the CP4-Africa model. This model was better able to capture these convective storms, improving the representation of rainfall events with more realistic storms and improved storm propagation.

Research from FCFA demonstrated that the ability to model convective activity in CP4-Africa simulations results in a greater increase in future extreme rainfall compared with standard models. For example, in parts of West Africa, Mesoscale Convective Systems (informally known as Megastorms) will become more dominant as opposed to scattered evening storms and storm updrafts, which are not explicitly modelled in standard climate models.

The more realistic representation of storms allows for improved couplings with triggers such as sea and lake breezes, which improves projections of average rainfall & rainfall extremes. The model also shows greater increases in dry spells in West and Central Africa and in humid heatwaves, potentially having significant implications for human health. While the CP4-Africa model improves some aspects of simulating convective activity, it does not accurately represent the response of rainfall to change in winds with heights (wind shear), which is an important aspect of convective activity and increasing over West Africa leading to more frequent severe storms. This, therefore, demonstrates the need for model development, model inter-comparison, and synthesis of evidence when providing predictions to decision-makers.

Finally, CP4-Africa affects other aspects of extreme weather forecasting. In contrast to past studies, CP4-Africa shows no overall increase in lightning, with fewer lightning days and more lightning strikes on these days. Rainfall intensification affects projections of soil erosion, and capturing convection is essential for projections of dust storms.

Future climate projections

Climate projections are important for supporting long-term decisions, but in many tropical and sub-tropical regions, climate models show large spreads in possible changes in temperature, rainfall and whether a region will get wetter or drier.

At the same time conventional climate models do not account for the full range of drivers which affect regional climate change (e.g. global aerosol emissions). The FCFA programme delivered improved projections of future climate change in Africa, through enhancing the understanding of the key global and regional processes which impact the climate of Africa.

HyCRISTAL research within East Africa demonstrated the importance of drivers such as patterns of warming in sea-surface temperatures and cloud-feedback processes. In some cases, the dominant causes of uncertainty were located far from Africa and in mid-latitudes. Observations and combined knowledge of these feedbacks allowed for future-centric evaluation and removed the wettest future projections, as they were determined to be unrealistic, reducing the model uncertainty for this region.

HyCRISTAL also demonstrated the importance of Congo westerlies to East African rainfall variability across timescales. CP4-Africa incorporates changes in these westerlies, changes in seasonality, and more realistic orographic flows, compared to a standard model. This, again, demonstrates the importance of developing ensembles of models like CP4-Africa, and creating and improving global models.

Research undertaken by the UMFULA project aimed to identify key processes or weather systems in observations and satellite images of Southern and Central Africa, and investigate the ability of climate models to simulate these. This led researchers to explore whether projected changes resulted from changes in the frequency, intensity and location of these weather systems, such as tropical lows, cloud bands, and the Congo Air Basin.

Changes in these features seem to correlate with projections of early season drying over Southern Africa by the end of the century. Tropical lows occur less frequently and the Congo-Air Boundary stays in place for several weeks longer than present-day, delaying the onset of the rainfall season over Southern Africa; cloud bands also occur less frequently over the region. Despite these features forming in regions with extremely sparse observations, FCFA research found that conventional models seemed capable of simulating these features with reasonable accuracy.

In addition to improving regional projections, the ability of CP4-Africa models to explicitly simulate convection helped to overcome the failings of conventional climate models. However, this model is constrained by a parent global climate model and there is a need to quantitatively synthesise projections from conventional models, CP4-Africa, observations, and theory. FCFA created new approaches for this, allowing for the development of tailored, context-specific projections.

Standard global projections do not account for the possible range of future aerosol changes that will drive transformations in the regional climate. Model analysis for HyCRISTAL showed that future reductions in anthropogenic aerosol may affect East African rainfall, and must, therefore, be accounted for in projections. Another major advance FCFA made in projections, was through developing effective communication methods to improve the use of climate projects in decision-making. The Climate Risk Narrative approaches, combine future scenarios with high-level climate messages and socio-economic impacts to highlight the potential range of future outcomes. Combining future projected extremes in the context of current extremes, and using current events to point to potential future scenarios supports the interest of decision-makers in using long-term information.

c. Developing the capacity of African climate scientists

Access to modelled and observed climate data, and experience in its analysis, can support and facilitate decision-making, as well as assist in the development of relevant adaptation measures. However, many climate scientists in Africa face enormous difficulties in generating usable climate information and plausible climate scenarios at regional and local scales to meet the needs of impact and adaptation projects. This is largely due to the lack of continuous quality observations, internet connectivity, storage capacity, and quality training on data processing in the region.
Substantial progress has been made on these fronts during the FCFA programme, with multiple parallel approaches adopted. Through evaluating user-relevant climate metrics to develop a series of stakeholder atlases (AMMA-2050), adopting an "African-lens" in evaluation of climate models (IMPALA/LaunchPad), and collaborative research to understand model errors (HyCRISTAL), FCFA helped to build capacity in python coding and analysis techniques, while focusing on real-world problem.

In the UMFULA project, the research agenda was informed by the contributions of local climate experts who had a good comprehension of the poorly understood region of Central Africa. Researchers from the Global North and South adopted a collective approach to the generation of research ideas and approaches, and developed these into outputs such as peer-reviewed papers. There was an emphasis on efficiency in the production of these research outputs, which recognised the time constraints faced by African climate scientists and ensured they were not left behind in these stages of the process.

FCFA also supported African scientific expertise via specialised training workshops, lectures, and webinars, with the latter archived as part of the programme's legacy. Critically, these were often supplemented with ongoing one-to-one mentor relationships, clinics, exchange visits aided by the FCFA Mobility Fund, as well as annual whole-team project meetings that enabled further exchange of scientific research ideas and plans. The issue of in-country access to climate model data was resolved through tailored support to directly access the UK Universities' JASMIN facility (including workspace for data processing), or via shipment of external hard disk drives.

The development of interdisciplinary engagement skills was also a critical focus, benefitting both in-country scientists and stakeholders, and those from the Global North. For example, UMFULA scientists cooperated to produce tailored Country Climate Briefs, and AMMA-2050 facilitated the cross-institutional coproduction of decision-relevant information on hydrological extremes. HyCRISTAL has been working extensively alongside ICPAC – East Africa's regional climate centre – to successfully support their objective of extending the triennial Greater Horn of Africa Climate Outlook Forums (GHACOF) seasonal outlook forums to include the exchange of information at multi-decadal timescales between scientists and stakeholders.

The impacts of these activities have not only directly benefited African science and the young African scientists involved, but has also organically led to wider reach and autonomy as these scientists have shared their knowledge and skills with institutional colleagues. Collaborations focused on the 'African lens' approach to climate model evaluation have also aided important climate model developments. Longer-term in-country and North-South partnerships have also been forged and, from an academic stand-point, a number of collaborative papers have been published. More broadly, feedback has highlighted how engaging with projects has strengthened scientists' ability to produce decision-relevant climate information in terms of effective engagement with decision-makers and technical capacity. This enhanced interdisciplinary collaboration between African universities and National Services continues as a fundamental legacy of FCFA.

Further investment in these areas will be critical to develop and capitalise on the following advances:

- Further underpinning capacity for African science to access remote computational facilities to process or download large climate model datasets (local storage capacity is also required for downloads);
- Improved bandwidth;
- Greater engagement in online coding support communities; and
- Parallel opportunities for scientific collaboration, training and mentoring.

THE FACTORS WHICH CONTRIBUTED TO THE VALUE OF FCFA'S INVESTMENT IN CLIMATE SCIENCE

At the time, FCFA was the largest single investment dedicated to improving African climate science. While many of the tangible outcomes of the programme were a result of co-production processes and engagements within the pilot studies, the FCFA contribution to the climate science field was considerable. The advances made within the programme provide a springboard from which future research can continue to make breakthroughs to improve the availability of accurate and defensible climate information for decision making. There were several success factors that contributed to the investments' payoff within FCFA.

- The collaborative nature of FCFA allowed for large groups of researchers with different expertise and skill sets to work together and learn from each other. This meant the science was able to advance rapidly due to researchers working together and sharing findings to build off of wemerging breakthroughs.
- Collaboration between researchers from the Global North and South was particularly important in combining the expertise and capabilities of partners. This ensured that research was context specific, informed by local expertise, and supported capacity development for African climate scientists. Through on-going relationships, knowledge exchange, training activities and providing access to technologies and data, Northern partners were able to help their Southern counterparts overcome limitations within their home institutions, allowing them to carry out their research capabilities.
- Co-production and stakeholder engagement were core research strategies within the FCFA programme. These processes were not only beneficial in providing stakeholders and decision-makers with the opportunity to define their needs to shape research, but helped forge vital links between science and practice. Not many climate scientists prior to the FCFA programme were accustomed to engaging with decision-makers to feed into on-the-ground decisions. Connecting scientists to those who could use their research to inform long-term decisions, played an important role in building the capacity of climate scientists to produce relevant and actionable climate information for decision-making. This process was also beneficial in building decision-makers' understanding of climate science (particularly in terms of the limitations and uncertainty) and to apply this knowledge to long-term decision-making.
- Ring-fenced funding to support both climate science and model development was particularly important within FCFA. This allowed advances made within climate science to be integrated into global models, and supported the development of the new CP4-Africa model, which was able to overcome some of the shortcomings of conventional models.

Participants at the AMMA-2050 2019 annual meeting in Dakar, Senegal. Credit- Beth Mackay

THE NEED FOR CONTINUED INVESTMENTS IN CLIMATE SCIENCE AND CLIMATE MODELLING FOR AFRICA TO SUPPORT CLIMATE-RESILIENT DEVELOPMENT

Although FCFA has improved the understanding of regional climates and climate change across Africa, particularly in terms of rainfall extremes (such as extreme rainfall and dry spells) and changes in regional circulation which affect seasonal conditions, there remain numerous critical gaps within Africa. Many long-standing questions posed by decision-makers can still not be addressed by climate science (for example the challenge with water cycle predictions), which impacts the confidence of long-term decisions.

Global climate models are advancing in resolution and performance, particularly with a new generation of convection-permitting global models. We need to ensure that the models continue to be developed and evaluated with the "African lens" and to exploit the new generation of convection permitting models to explore sensitivities to model boundary conditions and emissions. This implies the need to maintain momentum on African-focused model evaluation and development. Increased resolution also results in challenges with the availability of appropriate and accurate observed data sets with which to compare the high resolution models.

Convection Permitting models cannot yet give large ensembles nor long statistics. Combining these to provide informed guidance on water cycle changes is difficult. Emerging research from FCFA proposes methods to do this for two contexts (West African extreme rain and East African tea production), but research is needed to apply the methods in more regions and to a wider range of high-impact climatic factors. Furthermore, some of the causes of changes in African climate, and some of the drivers of uncertainty in the future projections, lie outside the continent in the global climate system (see: Rowell 2019). It is important to note that the causes and uncertainties in exploring African climate impacts often lie in understanding the global system.

The future development and co-production of climate services cannot be undertaken in isolation from climate science. The essence of co-production is that the knowledge of stakeholders informs the climate science to ensure that the response of the research meets the users' needs. For example, in FCFA, stakeholders made clear that they need specific guidance on rainfall onset dates (as opposed to total seasonal rainfall), and researchers were able to respond to this by providing insight into the observed trends.

In a future co-production process, stakeholders may ask new and better-informed questions of the climate science community and the scientists, especially the African scientists, must be ready to conduct the research needed to answer those questions. Similarly, emergent climate science breakthroughs late in FCFA could not, by virtue of the programme having a set end-point, be tested in a decision-making environment. This is in contrast with discoveries in climate science emerging in the beginning of the programme, which were available for stress-testing in terms of influencing decision-making.

Key remaining gaps

- Water cycle changes remain uncertain in Global Climate Models including the details of changes to seasonal rainfall (onset and length), which have many ramifications for stakeholders. Although researchers are more confident in an intensification of the water cycle (more extreme rainfall and more dry spells within a rainy season), there is less confidence in the degree of these changes.
- Numerous insights relating to climate processes or features have emerged from the analysis of CP4-Africa and other high resolution models, the specific mechanisms for which seem to diverge between simulations. This calls for targeted field campaigns (which were not the goal of FCFA) to retrieve the necessary observed data with which to properly understand models. For example, reliance on models for understanding Lake Victoria rainfall motivated a HyVic-pilot campaign in the region, and the work on delayed Southern African rainfall onset in UMFULA has led to an observational campaign in north west Zambia (NERC funded DRYCAB). This serves as an example of where progress in the climate science element of FCFA was not necessarily informed by co-production or immediate policy or development needs, but rather a natural progression of a key line of questioning within science itself. Some advances in the science evolved late within FCFA and, therefore, did not have the opportunity to mature in terms of development outcomes. This is a normal progression in any large programme and, since FCFA will not by any means be the last effort in African climate research, it should be viewed as a point of departure for future programmes rather than a loose-end within FCFA.
- As part of the water cycle, feedbacks with soil moisture and land-use are uncertain and are poorly handled in Global Climate Models. The processes are highly localised, on scales of 10s of km, and need to be considered for different climatic zones. Through these physical climate feedbacks, policy decisions influencing land-use can change the distribution of rainfall, with positive or negative (and currently very uncertain) consequences for local or remote communities.
- More complex, but very high-impact water cycle phenomena have not been investigated in FCFA, but are critical. For instance, the occurrence of hail, fog and wind-squalls are all tricky to handle in models but create significant impacts.
- Aside from the critical role of the water cycle, both in climate projection and in the impacts of climate, there are also uncertainties in the behaviour and impacts of atmospheric aerosols. Global aerosol distributions have impacts on African circulation, both through remote forcing from outside Africa, and through direct thermodynamic impacts over Africa. Regional aerosol then has a direct climate impact in some sectors, including transportation (impact of visibility), solar power generation, agriculture and the effects of air quality.
- It will be vital to deliver local applications of climate science on the country scale as the answers to many stakeholders' questions are regionally dependent. For example, the future changes in the hydrological cycle associated with weather patterns - extreme rain, floods, and drought in particular - are regionally and locally (e.g. scales of 100s of km) dependent on topography, land-use, local circulation and climate dynamics. FCFA successfully developed case-studies in some regions and sectors, but the scaling-up of these approaches to different areas requires more scientific research, ideally conducted in Africa. In order to roll out the climate information at scale across the continent, researchers need to be versatile in applying scientific knowledge in a range of detailed contexts. This demands the empowerment of the African research community to take greater ownership of the region's scientific research. This is important to fulfil the scientific contribution to the co-production process, and to be able to develop climate solutions at scale, with less dependence on the Global North.

Participants discussing poster presentations at the African Climate Risks Conference 2019 in Addis Ababa, Ethiopia. Credit IISD/ENB - Kiara Worth

Recommendations for future investments

- **Future investments should be tailored towards collaborative research**. Within FCFA collaborative research had numerous tangible and intangible outcomes, and was particularly crucial in leading to rapid advances within climate science across the continent. This offers donors more value-for-money, as opposed to single research projects which have a much slower process of uptake.
- **Further funding needs to be dedicated to understanding regions within Africa that are poorly understood and have sparse observational records.** There are various regions where climate processes and how they influence the climate over other regions are poorly understood. Improving the quality of projections for these regions, and the regions they influence, are important in reducing uncertainty and supporting climate informed decision-making.
- **Funding should emphasise the value of North-South partnerships to support mutual capacity building**. North-South partnerships within FCFA presented valuable opportunities for knowledge and skill sharing between researchers from the Global North and Africa, while also helping African institutions to overcome some of the limitations at their home institutions, such as access to technology and data.
- **Funders should capitalise on the momentum built around Africa-focused model development and evaluation**. FCFA has supported improvements in climate models and methods to assess their performance, but there is a need to replicate, upscale and maintain these efforts to ensure models are more accurately able to simulate Africa's climate. There is a need to build on CP4-Africa to provide robust projections that cannot be generated from a single simulation, while developing the global models on which projections rely.
- **Targeted funding is needed to address known knowledge gaps across Africa.** Despite FCFA delivering significant improvements in African climate science, there are still various questions from stakeholders that can not be addressed with the current state of science. Opportunities exist to replicate and scale up approaches adopted within FCFA to close knowledge gaps and provide climate information, which can translate into long-term climate-resilient decisions.

African Climate Risks Conference 2019 in Addis Ababa, Ethiopia. Credit IISD/ENB - Kiara Worth