AFRICA’S CLIMATE
HELPING DECISION-MAKERS
MAKE SENSE OF
CLIMATE INFORMATION
INTRODUCTION

There are two strong forces shaping society in southern Africa today: urbanisation and climate change. While most urbanisation in the 20th century was concentrated in the global north, the highest rates of urbanisation over the next 40 years are expected to be concentrated in Asia and Africa.\(^1\)

At the same time, some regions of Africa, including areas of southern Africa, are likely to experience climate change more rapidly and intensely than the global average.\(^2\) The combination of rapid urbanisation and climate change will produce a potential crisis of urban development in the region in the coming decades.

The ability to avert this crisis, and eventually capitalising on emerging opportunities, rests on good decision-making across regional, national, and urban scales, and requires robust evidence to support these decisions.

THREE TYPES OF MODELS

Climate projections are the starting point for one important line of such evidence. These are produced primarily through a cascading process of modelling, using three main approaches:

1. Modelling starts with Global Climate Models (GCM) producing projections of large scale changes.
2. Downscaling (empirical or dynamical) then attempts to resolve finer-scale features, for instance, how climate across the region influences thunderstorm activity that happens at a smaller-than-100km scale.
3. Impacts models relate changes in climate to changes in phenomena such as water availability, crop yields, and even economic systems.

1 United Nations, Department of Economic and Social Affairs, Population Division, 2014.
Each model in this chain is built on a set of assumptions, limitations and constraints. The resultant messages of change delivered to decision-makers therefore rests on complex layers of assumptions and limitations that are currently poorly described and understood.

Added to this is the necessity of using multiple models in order to capture specific elements of uncertainty. The apparently contradictory messages that result can cause confusion and lack of trust amongst decision-makers. While disagreements between models are typically conflated under the label of ‘uncertainty’, much of the apparent contradiction is actually the result of natural variability of the climate system, and not model disagreement. The same climate model, initialised differently, can produce different projected future climates as it represents natural climate variability. These are apparent contradictions rather than real contradictions. The conflation of real and apparent contradictions is seldom, if ever, described or unpacked in the process of producing climate change evidence.

A key focus for the climate science team working in this area is to understand, describe, and unpack contradictions, and their consequences, in this process of producing evidence.

AVAILABLE PROJECTIONS AND DOWNSCALED PRODUCTS

There is at present an unprecedented volume of climate simulation data available to researchers. This is largely captured by initiatives such as the Coupled Model Intercomparison Project (CMIP) and the COordinated Regional Downscaling Experiment (CORDEX) projects – described in some detail below – although other more specialised data is also available. For example, the Climate Prediction.net3 project produces very large sets of simulations for the purposes of attributing extreme events to climate change.

A GLOBAL MODELLING PROJECT: CMIP5

At present the CMIP provides the most definitive suite of Global Climate Model simulations for researchers. The most recent iteration is the CMIP5 project, which includes simulations produced by around 40 models to which 17 research institutions contribute.

CMIP has evolved through several generations of model development, culminating in the most recent one, CMIP5. While it represents some significant changes in the ability to simulate Earth’s climate, compared with previous iterations, the reality is that the climate projections produced by CMIP5 do not differ strongly from the previous CMIP3 project.

In the paper by Knutti and Sedláček4 (Figure 1 below), for example we see that projected changes in rainfall do not differ strongly between CMIP3 and CMIP5. This does not mean that the models are not improving. Whereas many of them are representing far more detail and have improved significantly, the resultant projections are not substantively different.

CMIP5’s projected changes for southern Africa show a high degree of disagreement. Figure 2 below shows projected changes in rainfall across the southern African region produced by a subset of 11 of the CMIP5 GCMs. The figure illustrates the level of disagreement between the different GCMs.

3 www.climateprediction.net
A ‘DOWNSCALED’ MODEL PROJECT: CORDEX

CORDEX is similar to CMIP in that it attempts to coordinate a set of simulations run by multiple research institutions. CORDEX, however, focuses on regional climate simulations. CORDEX currently contains data from six different Regional Climate Models (RCMs) that have been used to downscale 12 GCMs from the CMIP5. In this downscaling process, GCM data is used to drive (or force) the RCM model that represents a smaller area of the globe, but at higher resolution than the ‘parent’ or driving global model. Each RCM is unique, and has a different way of representing features such as land surface, vegetation types, and clouds. There is no data yet for every combination of RCM and GCM in CORDEX. This data is currently available at Earth System Grid Federation (ESGF).

The CORDEX Africa project has focussed on simulation of the African climate system. Figure 3 below compares CORDEX model simulations of past climate with different observed datasets, and shows that different regional models perform differently when attempting to simulate historical climate over Africa, particularly in the case of rainfall. All models show errors in some regions, though some models are clearly better at simulating past climate than others. The figure also highlights the differences between different observed climatologies for Africa, as discussed in detail in our regional overview factsheet, ‘Tools for observing and modelling climate’.

Climate scientists who focus on southern Africa, are trying to better understand why models disagree with each other. More specifically, they focus on why regional models driven by global models can produce different future projected changes compared to their driving global models.

In Figure 4 below, for instance, we can see a set of global models in the top row, and their projected rainfall changes for the 2069 to 2098 period. In the second row, we can see the COSMO Climate Limited-area Model (CCLM) forced by the GCM from the row above, and its projected change in rainfall. And in the third row, a different regional model forced by the same GCM and its projected change in rainfall. Some initial work is currently being written up in an academic paper but it seems to indicate that regional climate simulations are fairly ‘free’ to simulate quite different climate compared to their driving global models.

A PROCESS-BASED VIEW

Understanding model-based projections, and apparent versus real contradictions, is made more difficult by focussing on surface responses, such as rainfall and temperature. We know that dynamical models, particular GCMs, are often unable to represent local surface responses well. It is likely that many apparent contradictions between model projections are only present in the surface responses (such as local rainfall), rather than the fundamental physical process changes (such as atmospheric circulation). It is noted, for example that every model in the CMIP5 archive projects a shift in the mid-latitude jet system towards the south, even though the closely related projected changes in rainfall in South Africa show disagreements across the models.

This is the primary driver behind a process-based view on climate modelling and projections. In a process-based view, models are evaluated based on how they represent key regional climate process. The processes that are relevant depend on the region, and deciding what the key processes are, is a parallel area of ongoing research. The processes that are relevant depend on the region, and deciding what the key processes are, is a parallel area of ongoing research. An example in the southern African context is some key processes and features, which include Tropical...
Temperate Troughs, the Angola low pressure system, cloud bands, and the Inter Tropical Convergence Zone (ITCZ). However, other processes may also be important, such as land surface and vegetation interactions with the atmosphere, and key regional ocean process such as the Agulhas current dynamics.

While prior work has attempted to use process-based model evaluation,5 climate researchers have undertaken a comprehensive process-based analysis of the southern African regional climate, and both global and regional model representations of processes. The process-based approach will also allow them to understand the contradictions between model projections described above. Science’s contribution to southern African climate modelling will therefore provide a rigorous framework and example implementations of a process-based regional climate analysis and model performance analysis.

**CONSEQUENCES FOR CLIMATE SCIENCE AND DECISION-MAKING**

With ever increasing pressure to provide detailed information about future changes in climate, researchers and climate services practitioners are digging deep into the available climate data.

However, with many disagreements between products producing contradicting messages of past and future change, it is more important than ever that climate data products are well studied, understood, and described. Climate researchers and practitioners should be fully aware of the underlying assumptions, caveats, and limitations of the data products they are using.

There are many documented cases where poor selection or understanding of climate data products, whether historical or future projections, has led to poor information being made available to decision-makers. This poor information can take many forms, including misrepresentation of uncertainties, misrepresentation of the real information content, or misunderstanding of the limitations in accuracy of the information.

Climate researchers see that contributing to both the understanding of the products, as well as informing downstream users of the products about best practice, is a key contribution to the science and practice of climate change projections.

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FCFA’S FRACTAL PROJECT

Project objectives
One of the chief scientific challenges for understanding southern Africa’s climate is that different models give contradictory scenarios for climate trends in the next five to 40 years. FRACTAL’s team will advance scientific knowledge about regional climate responses to human activities and work with decision-makers to integrate this scientific knowledge into climate-sensitive decisions at the city-regional scale (particularly decisions relating to water, energy and food with a lifetime of five to 40 years).

Through scientific research, FRACTAL will contribute to improved understanding of climate processes that drive the African climate system’s natural variability and response to global change. By bringing together scientists and people who use climate information for decision-making, the project will enhance understanding of the role of such information. FRACTAL will distil relevant climate information that is informed by and tailored to urban decision-making and risk management. The team’s activities will understanding of how scientists from different disciplines can work effectively together. See www.futureclimateafrica.org/project/fractal/

The institutions involved in FRACTAL are:
- University of Cape Town
- Met Office (UK)
- Stockholm Environment Institute
- START
- ICLEI–Local Governments for Sustainability
- Swedish Meteorological and Hydrological Institute/ Sveriges Meteorologiska och Hydrologiska Institut
- Red Cross Red Crescent Climate Centre
- University of Oxford
- Aurecon
- Council for Scientific and Industrial Research
- US National Atmospheric and Space Administration
- Lawrence Berkeley National Laboratory
- European Commission Joint Research Centre
- City of Cape Town
- City of eThekwini
FIGURES

Figure 1
Multi-model mean relative precipitation change for two seasons (December–February, DJF, and June–August, JJA) and two 20-year time periods centred around 2025 and 2090, relative to 1986–2005, for CMIP5 (left) and CMIP3 (right). Stippling marks high robustness, hatching marks no significant change, and white areas mark inconsistent model responses.6

Figure 2
Projected changes in December–February rainfall produced by 11 different CMIP5 GCMs for southern Africa for the period 2046–2065 (relative to the 1986 to 2005 period).

Figure 3
GPCP mean July–September (JAS) precipitation for 1998–2008 and differences compared to GPCP in the other gridded observations (top row), the individual RCMs (rows 2 to 4), and their ensemble average (row 2 column 2).

7 Maps: produced by the authors.
Figure 4
Temporally averaged changes in mean daily precipitation by 2069–2098 under RCP8.5 relative to the reference period 1976–2005. a-d shows the GCMs, e-h shows the CCLM forced by GCMs and i-l shows RCA forced by GCMs.

Maps: produced by the authors.