FUTURE CLIMATE FOR AFRICA

GUIDE

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Climate models: What they show us and how they can be used in planning

Weather and climate: what's the difference?

Weather is the state of the atmosphere at a particular time, for example in terms of temperature, rainfall, wind speed and humidity. It is what we experience each day.

"Chichiri at 8 am on 29 September: 22°C, relative humidity 64%, light easterly winds."

Climate can be thought of as the average weather over a long period of time. For example, at a given location the climate can be characterised by the average temperature and rainfall, or the average number of very hot days in the dry season, taken from many years of data.

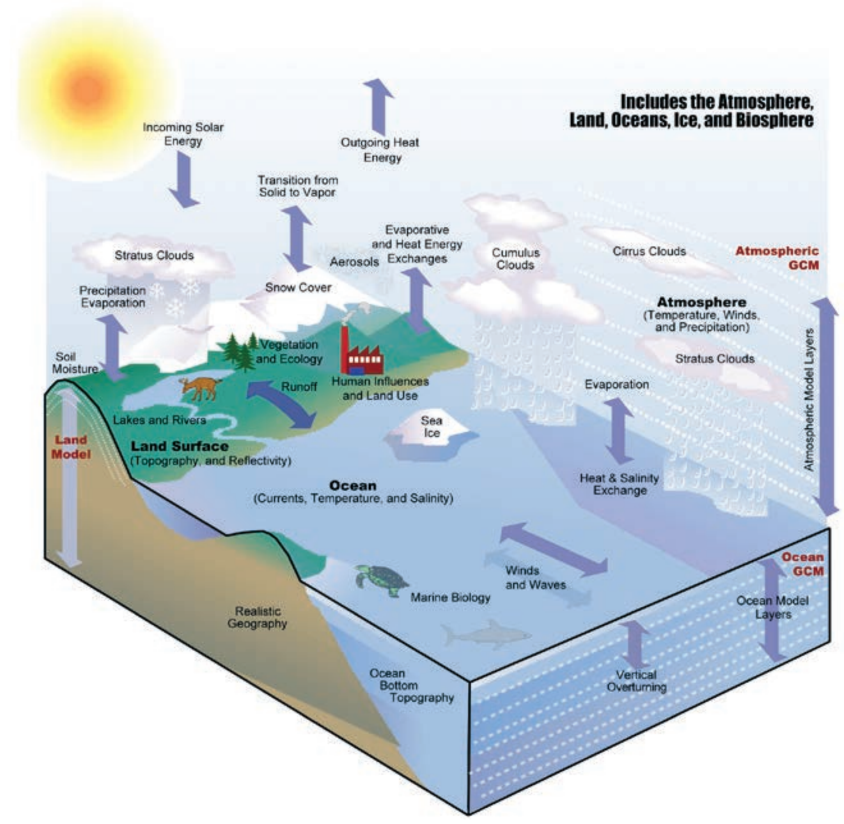
"Malawi has a subtropical climate, which is relatively dry and strongly seasonal. The warm-wet season stretches from November to April, during which 95% of the annual precipitation takes place."[1]

Some people say "climate is what you expect, weather is what you get."

What are global climate models?

The climate conditions that we experience are the result of complex interactions between processes occurring in the atmosphere and in the oceans. These processes operate at global and local scales and are influenced by other factors, including the land surface, polar ice sheets and the sun. This is why different parts of the world experience different climates. Global Climate Models (GCMs) are computer models that attempt to capture and simulate all these processes, based on our current knowledge (Figure 1).

Figure 1: Atmosphere, ocean and land surface processes simulated in GCMs (source: US National Climate Assessment 2014)[2]



About FCFA

Future Climate for Africa (FCFA) aims to generate fundamentally new climate science focused on Africa, and to ensure that this science has an impact on human development across the continent.

www.futureclimateafrica.org

How do GCMs work?

Global Climate Models are run on supercomputers at a number of centres around the world, including the Max Planck Institute in Germany, the UK Met Office Hadley Centre, and the National Oceanic and Atmospheric Administration in the USA. The models use physical laws and mathematical equations that reflect our understanding of atmospheric and oceanic processes.

How do we know if GCMs are reliable?

To test how well GCMs capture climate processes, they can be validated in various ways. This might be done by testing based on what we know about past climate patterns, for example from recorded observations on temperature and rainfall conditions. If a model can accurately predict historical climate trends (e.g. trends in temperature and rainfall), then we will have more confidence that the model can accurately represent relevant atmospheric and oceanic processes. We can also test how well the model simulates key large-scale weather patterns. If models are able to do this reliably, we will have further confidence that they can be used to predict, with reasonable certainty, what climates are possible in the future. The poor availability of historical weather observations in some parts of Africa limits our understanding of how reliable these models are.

How do GCMs project future climate?

No predictions of the future can be made with 100% certainty. We know that the amounts of greenhouse gases in the atmosphere affect the climate, and that human activities are contributing to increases in these greenhouse gases. To predict the future climate, we need to have an idea of what the future levels of atmospheric greenhouse gases are likely to be. If, for example, we continue on a carbon-intensive economic growth path burning high quantities of fossil fuels, there will be higher concentrations of greenhouse gases in the atmosphere. In that case, the effect on climate is likely to be greater than if society decides to reduce emissions (for example through the United Nations Framework Convention on Climate Change). To take these possible futures into account, scenarios – or plausible socio-economic futures – are used. Models are typically run under different scenarios to give a range of potential future climate conditions.

As well as the uncertainty in human activities, our understanding of the smaller-scale processes that affect climate is incomplete. For example, although the Congo Basin plays a key role in determining the climate system of central and southern Africa, the lack of data means we have limited understanding about the processes involved. There are also likely to be thresholds and tipping points in the system. For example, warmer air holds more moisture so, as temperatures increase, more water vapour will be held in the atmosphere. Water vapour is itself a greenhouse gas, and so more moisture in the atmosphere may, in turn, exacerbate the increase in temperature.

What can GCMs tell us about the future climate?

GCMs model processes and interactions at global scale. As this is a complex task, the models are built to emphasise particular trends (averages of weather over longer-term time periods). Examples of what a climate model can feasibly tell us include that spring temperatures are likely to increase (and approximately by how much); or that rainfall in the early summer is likely to decrease.

Because they work at global scale, the resolution of GCM projections is typically coarse. As computing

Africa's climate: Helping decision-makers make sense of climate information

More information on what we know, and still need to know, about central and southern Africa's climate can be found in the report *Africa's climate.*[3] The report includes the following relevant sections:

- *Southern Africa: Tools for observing and modelling climate* – an overview of the various data sources we use to understand climate, and how what we want to know determines which data source to use.
- *Central Africa's climate system* – an overview of why the Congo Basin plays such a key role in affecting the climate of central and southern Africa.
- *Southern Africa: Studying variability and future change* – what we know and what we still need to find out about the current climate system of southern Africa.
- *Central and Southern Africa: Burning questions for climate science* – what scientists need to know to better understand the climate of central and southern Africa to inform modelling of future climate conditions.

How are climate projections different from weather forecasts?

The models that predict both weather and climate are similar in structure. But the predictions made using weather models are always being tested: for example, in the case of a 5-day forecast, we can see if the prediction was correct within those 5 days. In contrast, climate models predict a future we have yet to experience, so we test GCMs differently.

We talk about projections of future climate (as opposed to predictions of weather). *Projections* give us a description of the future in the long term, and are dependent on the future evolution of a number of atmospheric processes.

When we look at the short term, we can be more certain and we can *predict* weather based on what we know for sure today. For example, if there is a high-pressure anticyclone, that particular atmospheric condition is likely to give rise to clear, sunny weather tomorrow – so we can predict clear, sunny weather.

power has increased, the detail and resolution has improved over time. In the 1970s the first GCMs had grid cells of 700 × 500 km, whereas today that has improved to 100 × 100 km (Figure 2).

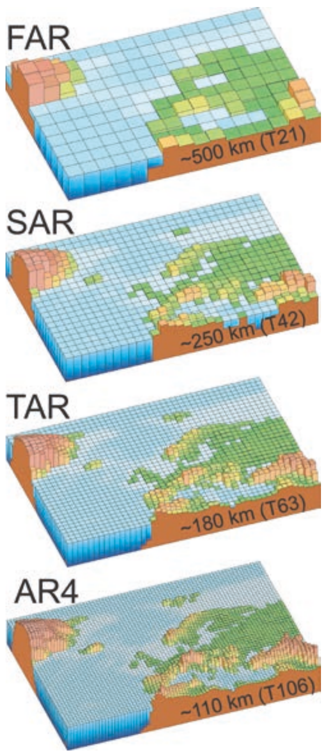
Another key consideration with regard to GCMs is that temperature is easier to project than rainfall. There are various reasons for this. Systems that affect rainfall are more localised than those which affect temperature (e.g. presence of mountains and their role in influencing cloud cover; major forest basins such as the Congo). Models are unable to skilfully model the El Niño Southern Oscillation phenomenon, which is also a major driver of rainfall in southern Africa.

The projections generated by GCMs can be displayed as a map, or as a graph (see the box on evaluating outputs of GCMs).

How can we use GCMs for planning?

When we plan for the future, we take a variety of information into account. This might include population projections, for example, or anticipated demand based on economic growth

Figure 2: Improved resolution of GCMs from the First (1992) to Fourth (2007) Assessment Reports of the Intergovernmental Panel on Climate Change, reflecting the greater layer of complexity that can now be modelled (source: IPCC, 2007)[4]



AR5: 70 km maximum horizontal resolution; up to 90 layers in the atmosphere and over 60 in the ocean.

trajectories. In order to take the impact of climate change into account, we first need to understand what aspects of climate might affect planning decisions. With that understanding we can move to the second stage, which is to seek the relevant information in the projections.

Projections of future climate have many uses for planning over medium to long time frames (e.g. 5–40 years). Infrastructural interventions have a long lifespan and therefore require consideration of both current and future conditions. When designing an irrigation scheme, for example, it is useful to know what rainfall might be in 40 years' time to inform design, manage operations, and ensure the intended benefits will be sustainable. The location of the dam may need to change, and its design could be less costly if it will need to hold less water.

> ***"All models are wrong, but some are useful"***
>
> – British mathematician George Box[6]

If the onset of the rainy season is going to continue to be later than in the past, a 5-year agricultural plan may wish to consider a strategic move to promote switching to early maturing varieties or crops that can withstand lower water availability. Our understanding of current weather patterns can be used to contextualise future projections. Current weather patterns will vary throughout a country. If a high rainfall area were projected to become drier, the crops that could grow successfully would be different from those that could be sustained in a low-rainfall area if the region were projected to experience a later onset to the rainy season.

Evaluating outputs of GCMs

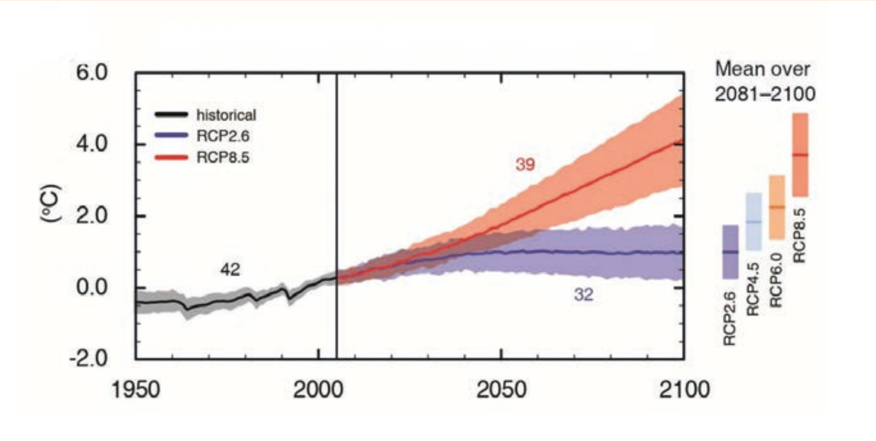
If someone tells you that the global temperature will increase by 4°C by 2080, two questions that you should definitely ask are:

- according to which model?
- according to which scenario?

Figure 3 shows the modelled change in global temperature based on two scenarios for Representative Concentration Pathways (RCPs) for greenhouse gas concentrations, as reported in the most recent assessment report by the IPCC.[5] RCP8.5 is a scenario where greenhouse gas emissions continue to rise rapidly, whereas RCP2.6 is a scenario where active management causes emissions to level off.

As no model can be perfect, more confidence is added if projections from several models under the same scenarios can be used (known as an ensemble of models). In Figure 3, 39 models were run under the RCP8.5 scenario and 32 under the RCP2.6 scenario. The differences in what each model projects for the future under each scenario are represented by the pink and blue areas, respectively. For the RCP8.5 scenario, for example, the temperature increase by 2100 is likely to be 2.6–4.8°C (this is the range of temperature increase projected by the 39 models). Having such an "envelope" of projected change is much more robust than a single figure.

Figure 3: Global average surface temperature change (source: IPCC, 2014)[7]



Medium-term planning can take into account the effect of likely future conditions based on projections, in conjunction with current knowledge of weather conditions and how they vary from place to place. This enables identification of robust strategies for what crops to promote and what farming techniques to investigate. The specifics of decisions – in terms of exactly what to plant and when in different places – can be part of short-term planning (e.g. annual), and can be informed by weather information such as seasonal forecasts. However, knowing the likely longer-term situation can enable adaptive planning to meet national strategic goals, such as long-term food security and livelihood resilience. Longer-term decisions that may result from such planning include training staff in the use of early maturing crops and the practices required to farm them optimally, informing seed-breeding activities and technology development, and setting supply chains in place.

The nature of planning decisions that we make over the medium term is different from those that we make in the short term. So what we require from climate projections is different from what we need from shorter-term weather predictions. The resolution provided by GCMs is useful to inform medium- to long-term planning decisions. Over these time frames, for example, whether the temperature will increase by 2.1°C or 2.2°C is not usually as important as knowing that there will be an increase in temperature.

Decision-making in Malawi and Tanzania

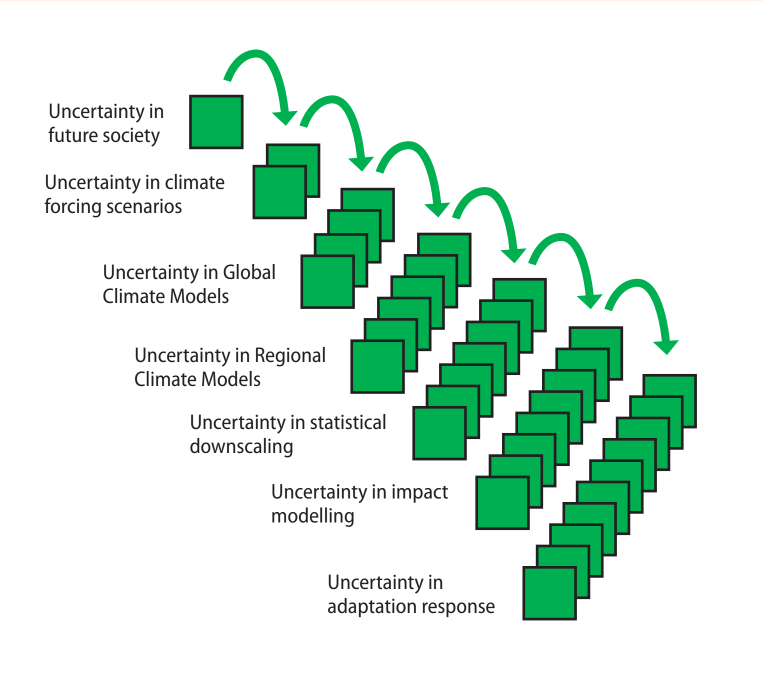
For more information on the actual and potential uses of weather and climate information in Malawi and Tanzania – how weather and climate information is currently used in public sector decision-making in each country, and how to improve its use – see *Africa's climate*.[8]

Why high resolution doesn't necessarily give better climate projections

A common myth is that high-resolution or "downscaled" climate projections are better than the coarser projections from GCMs. As noted above, expectations of climate projections cannot be the same as for weather forecasts. Climate projections take into account large-scale processes that affect weather systems. Because they are projecting far into the future, they are driven by scenarios (of greenhouse gas emissions) that are never likely to represent exactly what will unfold in the future. As with any model, there is an element of uncertainty.

Although there are various methods of downscaling, they are all contingent on starting with outputs from GCMs. When model data are further manipulated in another modelling process, there is a risk that the uncertainty can increase (see Figure 4). The outputs of downscaled models appear to be more precise as they show differences on a smaller scale – but that can give a false level of confidence. The likely future states projected by GCMs are typically sufficient to inform the kinds of planning decisions that are made over the same medium to long time frames.

Figure 4: The cascade of uncertainty in projecting future climate (source: RiskChange)[9]



For more information see the section *Southern Africa: Climate science and refining the models* in the *Africa's climate* report.[10] This section describes the three main tiers of modelling (global, downscaled and impacts models), where they work, and where the gaps are.

Further information on GCMs and generating climate projections

- Educational Global Climate Modeling: http://edgcm.columbia.edu/

  This site, targeted at students, provides access to a GCM and enables the user to undertake model experiments and manage aspects of working with a GCM.

- Climate Change in Australia: www.climatechangeinaustralia.gov.au/en/

  This site provides easily accessible information on climate change, how we know about it, and how GCMs work and can be evaluated (www.climatechangeinaustralia.gov.au/en/climate-campus/modelling-and-projections/).

- Climate Systems Analysis Group (CSAG) e-learning: www.csag.uct.ac.za/elearning

  This series of modules provides an introduction to climate science and its use. It includes modules on climate models, future projections and downscaling.

Endnotes

1 Ministry of Natural Resources, Energy and Environment: Climate of Malawi. www.metmalawi.com/climate/climate.php

2 National Climate Assessment: Full report. http://nca2014.globalchange.gov/report

3 FCFA (2016) *Africa's climate: Helping decisionmakers make sense of climate information*. Cape Town: Future Climate for Africa. www.futureclimateafrica.org/wp-content/uploads/2016/11/africas-climate-final-report-4nov16.pdf

4 IPCC (2007) *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L., eds]. Cambridge, UK: Cambridge University Press. www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html

5 IPCC (2014) *Climate Change 2014: Synthesis Report. Summary for Policymakers*. www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf

6 Box, G.E.P. and Draper, N.R. (1987) *Empirical model-building and response surfaces*. Oxford: Wiley, p. 424.

7 IPCC (2014) Op. cit.

8 FCFA (2016) Op. cit.

9 RiskChange: Work Package 2: Downscaling and uncertainty estimation. www.riskchange.dhigroup.com/activities/wp2_downscaling_and_uncertainty_estimation.html

10 FCFA (2016) Op. cit.

About Future Climate for Africa

Future Climate for Africa (FCFA) aims to generate fundamentally new climate science focused on Africa, and to ensure that this science has an impact on human development across the continent. Members of the UMFULA and FRACTAL research teams, covering central and southern Africa, contributed jointly to writing this guide. You can find out more about their work under 'research teams' on www.futureclimateafrica.org

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