FUTURE CLIMATE FOR AFRICA

COUNTRY CLIMATE BRIEF

October 2017

ANNEX: Future climate projections for Malawi

This annex provides the methods and extra figures to support the brief on future climate projections for Malawi[1], which provides an overview of future climate change for the country using the latest available climate model simulations. A two-page summary[2] is also available highlighting key findings.

Data

Observed data

The observations used in the briefs included gridded rainfall and temperature data. We used the CHIRPS v2.0 (Climate Hazards group Infrared Precipitation with Stations) dataset[3] for daily rainfall at a resolution of ~5 km (0.05° x 0.05°) for the period 1981-2016. CHIRPS is a combination of satellite-based rainfall estimates and station observations and has been used for various analyses for Africa[4,5,6]. For temperature, we used the Climate Research Unit (CRU) TS v. 3.24.01[7] monthly data at a resolution of ~50 km (0.5° x 0.5°) for the period 1901-2015, which has been widely used for Africa[8,9,10].

Historical and future climate data

We used the daily temperature and rainfall simulations for historical (1950-2005) and future (2006-2099) periods from 34 General Circulation Models (GCMs) listed in Table 1. These models are from the Coupled Model Inter-comparison Project 5 (CMIP5) corresponding to the Fifth Assessment Report of the Intergovernmental Panel for Climate Change (AR5 IPCC). The historical simulations represent simulated climate variability from the mid-19th century to early 21st century, driven by anthropogenic and natural forcings. As the level of present emissions is just above the Representative Concentration Pathway (RCP) 8.5, we used climate simulations based on the high-emission business as usual pathway, RCP8.5[11,12]. Other lower emission RCPs are available in the CMIP5 database, but we only show results for RCP8.5 here.

Methods

Figure 1 shows the elevation and location map of Malawi. For developing the climate briefs, both temperature and rainfall variables have been extracted over a domain – 8.25°S-17.75°S latitude and 32.25°E-36.75°E longitude for covering the geographical extent of Malawi.

Downscaling of climate data

To analyse variations in future rainfall and temperature at a fine spatial resolution, we used the delta change method[13,14]. This method is widely used for downscaling coarse resolution GCM projections to derive information at finer spatial scale[15] for climate change impact modelling (e.g. hydrological and crop modelling) studies, which require temperature and rainfall changes at higher resolution[16,17,18]. In this method, a change factor is applied to the observed climatology of temperature and rainfall. This change factor represents the climate change signal as derived from the climate models, and is calculated as a difference of mean changes in the future and historical climate simulations of a GCM (Equation 1)[19]. The derived time series provides higher resolution information consistent with future projections of a changing climate[20].

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.

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$$P_{new} = P_{Obs} + (P_{futr} - P_{hist}) \quad (1)$$

where, P_{new}, P_{obs}, P_{futr} and P_{hist} represents the new time series, observations in the historical period, raw GCM output for the future period and raw GCM output for the historical period, respectively. $P_{futr} - P_{hist}$ represents the change factor.

Like other downscaling methods, there are advantages and limitations of using the delta change method. While it preserves the general climate change signal, it does not capture change in variance[21,22] or account for local climatic variations[23,24]. The method requires observations for the representative period[25], which can be challenging in data scarce regions. For this study, the 30-year period from the historical simulations used in Equation 1 (1976-2005) is different from the available observations (1981-2010).

We present results for change in mean annual rainfall and temperature for all 34 CMIP5 models separately, and the Multi-Model Ensemble (MME) of historical and future simulations of temperature and rainfall from 34 CMIP5 models to show spatial patterns of change. We averaged monthly rainfall and temperature over the period 1976-2005 for historical simulations, medium-term (2021-2050), long-term (2070-2099) for future simulations and observed rainfall and temperature over the period 1981-2010. We obtained monthly change factors (12 each) for medium and long-term periods. The change factors were interpolated using bi-cubic interpolation and were added to CHIRPS and CRU observations for preparing new time series for medium and long-term future periods for rainfall and temperature, respectively. Using the monthly change factors we derived annual and seasonal change factors to address seasonal climatic specificities of Malawi.

We used well-defined seasons for Malawi; March to May (MAM), September to November (SON) and December to February (DJF). These seasons were considered important in terms of water resource availability at the time of planting and crop growth stages by the Malawi Department for Climate Change and Meteorological Services (DCCMS).

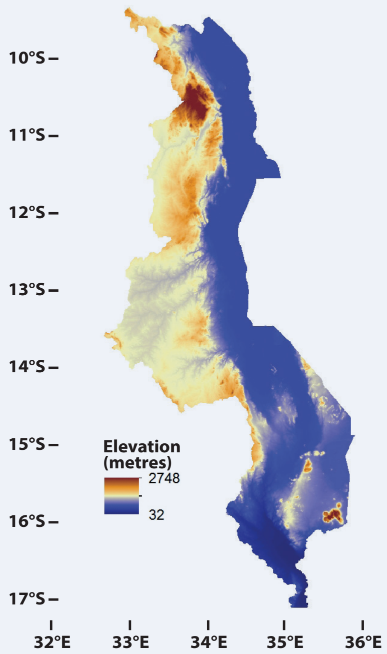


Figure 1: Elevation map of Malawi based on 30-metres Shuttle Radar Topography Mission data[26]

Table 1: List of 34 CMIP5 climate models used for analysing future climate change for Malawi

	Model	Modelling Centre/Group
1	ACCESS1-0	Commonwealth Scientific and Industrial Research Organization (CSIRO) and Bureau of Meteorology (BOM), Australia
2	ACCESS1-3	
3	bcc-csm1-1	Beijing Climate Center, China Meteorological Administration, China
4	bcc-csm1-1-m	
5	BNU-ESM	College of Global Change and Earth System Science, Beijing Normal University, China
6	CanESM2	Canadian Centre for Climate Modelling and Analysis, Canada
7	CCSM4	University of Miami – RSMAS, United States
8	CESM1-BGC	Community Earth System Model Contributors, NSF–DOE–NCAR, United States
9	CESM1-CAM5	
10	CMCC-CESM	Centro Euro-Mediterraneo per I Cambiamenti Climatici, Italy
11	CMCC-CM	
12	CMCC-CMS	
13	CNRM-CM5	Centre National de Recherches Météorologiques, France
14	CSIRO-Mk3-6-0	CSIRO - Queensland Climate Change Centre of Excellence, Australia
15	EC-EARTH	Irish Centre for High-End Computing (ICHEC), Ireland
16	FGOALS-g2	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences and CESS, Tsinghua University, China
17	GFDL-CM3	NOAA Geophysical Fluid Dynamics Laboratory, United States
18	GFDL-ESM2G	
19	GFDL-ESM2M	
20	HadGEM2-AO	National Institute of Meteorological Research/Korea Meteorological Administration, South Korea
21	HadGEM2-CC	Met Office Hadley Centre, United Kingdom
22	HadGEM2-ES	
23	INM-CM4	Institute for Numerical Mathematics, Russia
24	IPSL-CM5A-LR	Institut Pierre-Simon Laplace, France
25	IPSL-CM5A-MR	
26	IPSL-CM5B-LR	
27	MIROC5	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies, Japan
28	MIROC-ESM	
29	MIROC-ESM-CHEM	
30	MPI-ESM-LR	Max Planck Institute for Meteorology, Germany
31	MPI-ESM-MR	
32	MRI-CGCM3	Meteorological Research Institute, Japan
33	MRI-ESM1	
34	NorESM1-M	Norwegian Climate Centre, Norway

Recent climate variability and extremes from observations

Figure 2: CHIRPS observed annual and seasonal rainfall trend (linear trend by grid cell in mm/year) for 1981-2016. Seasons are March to May (MAM), September to November (SON) and December to February (DJF)

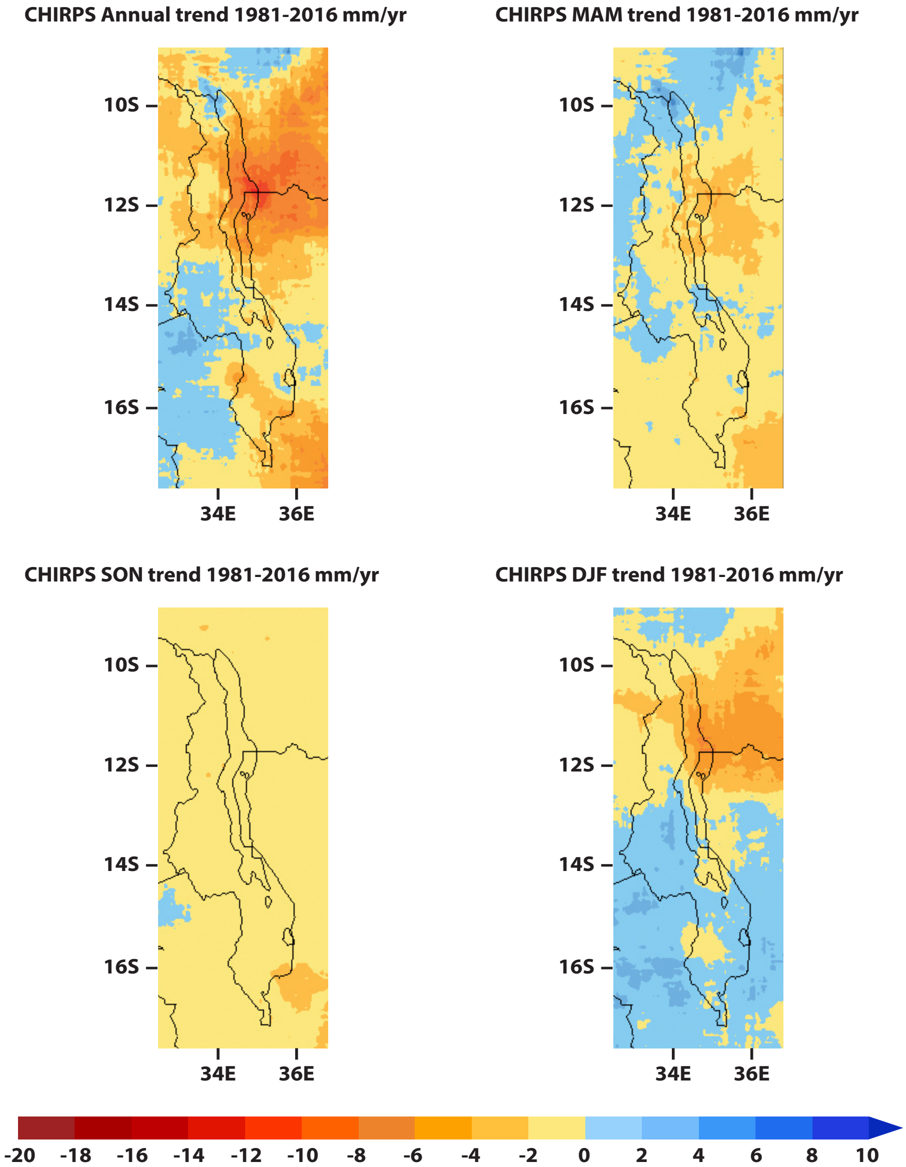


Figure 3: CHIRPS observed mean seasonal precipitation anomaly (%) for the wettest year 1989, driest year 2005 and recent dry year 2014/15 with respect to the mean for 1981-2016. Seasons are December to February (DJF) and March to May (MAM)

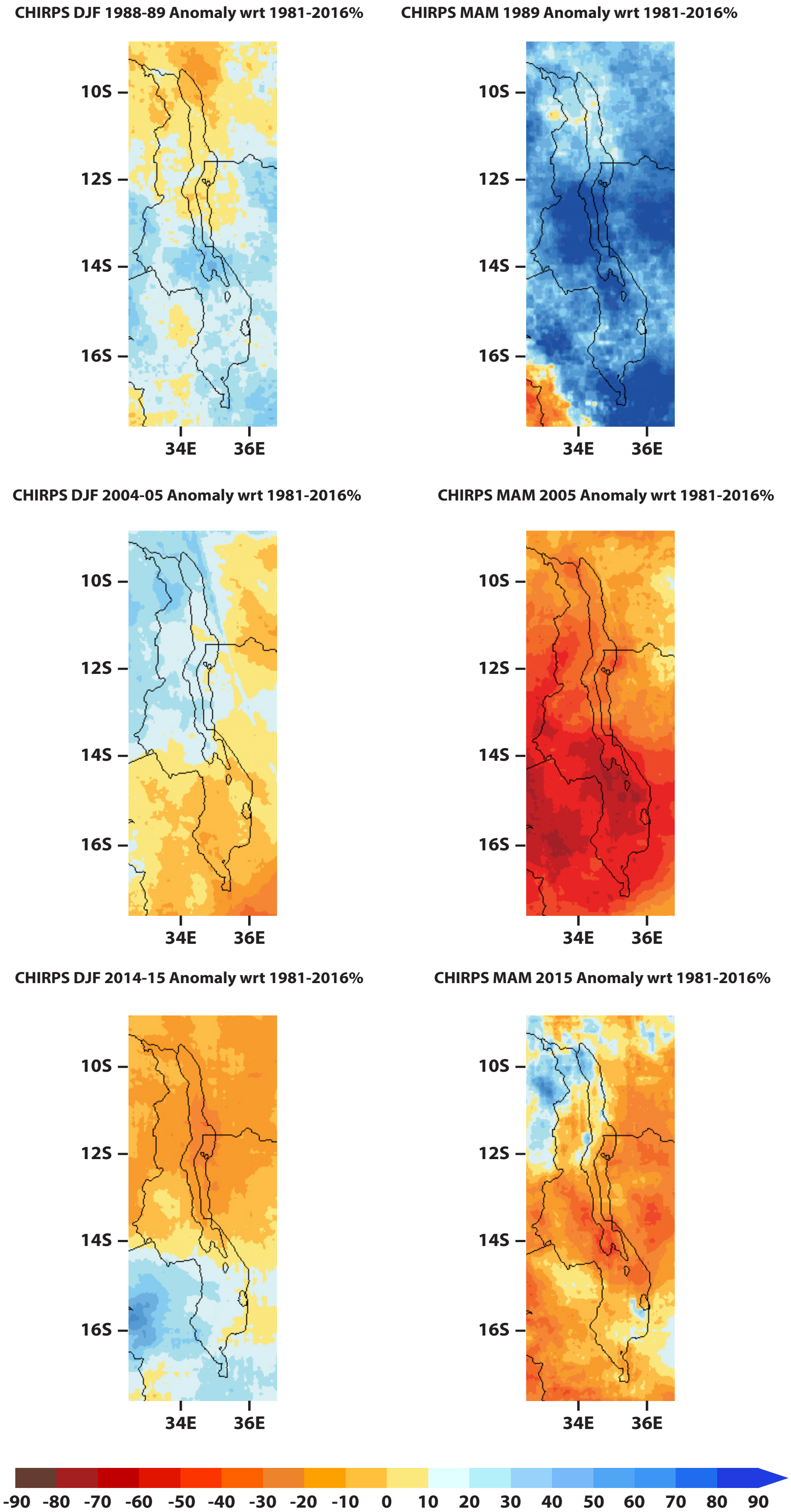
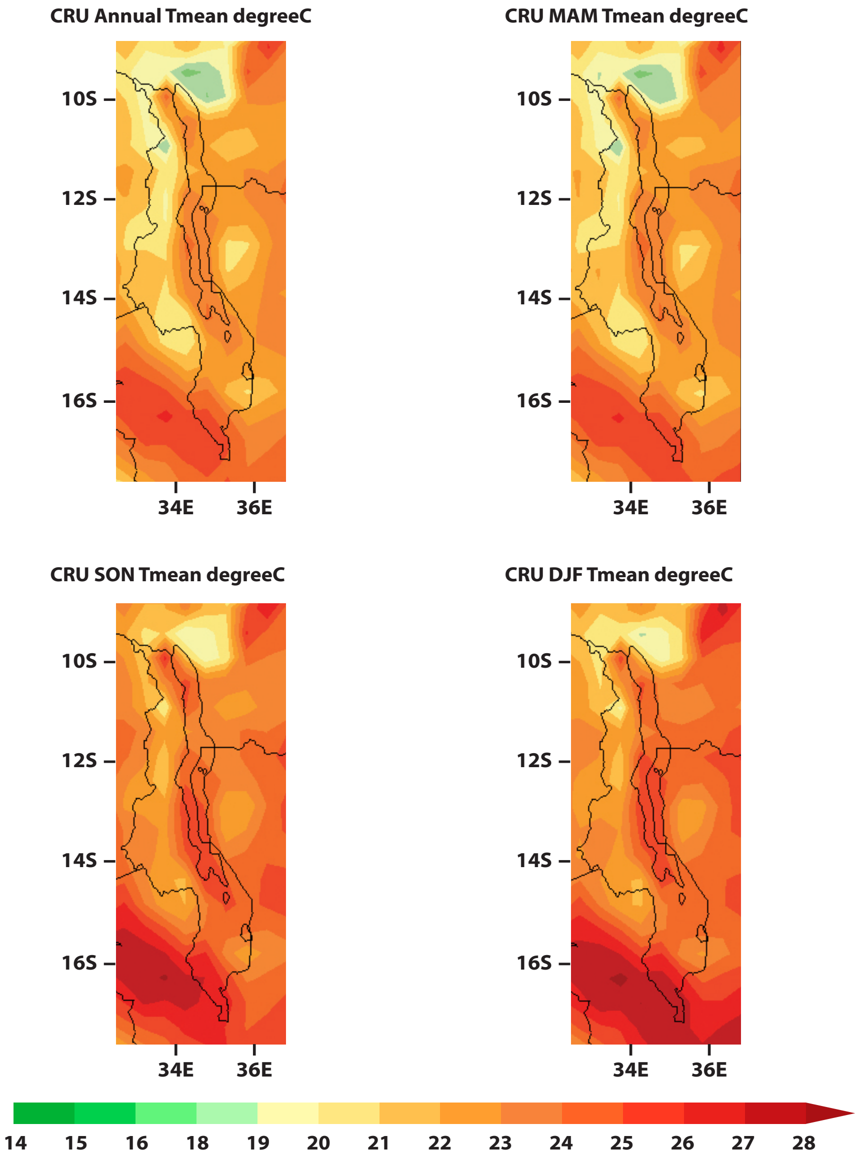


Figure 4: CRU observed annual and seasonal mean temperature (°C) for 1976-2005. Seasons are March to May (MAM), September to November (SON) and December to February (DJF)



Projections of future climate

We use the daily temperature and rainfall simulations for historical (1950-2005) and future (2006-2099) periods from 34 global climate models from CMIP5 corresponding to the IPCC's AR5. We present climate simulations based only on a high greenhouse gas emission pathway, RCP8.5 (projections with other rates of emissions are available).

Rainfall

Figure 5: Per cent change in annual mean rainfall for all Malawi between the GCM simulated current period (1976-2005) and 2070-2099 for 34 GCMs

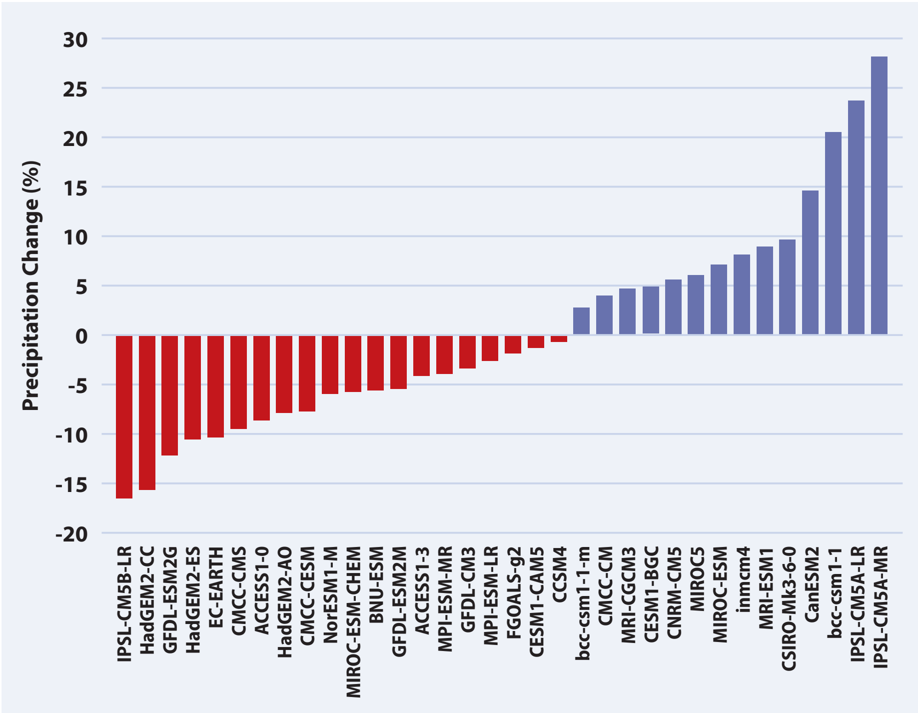
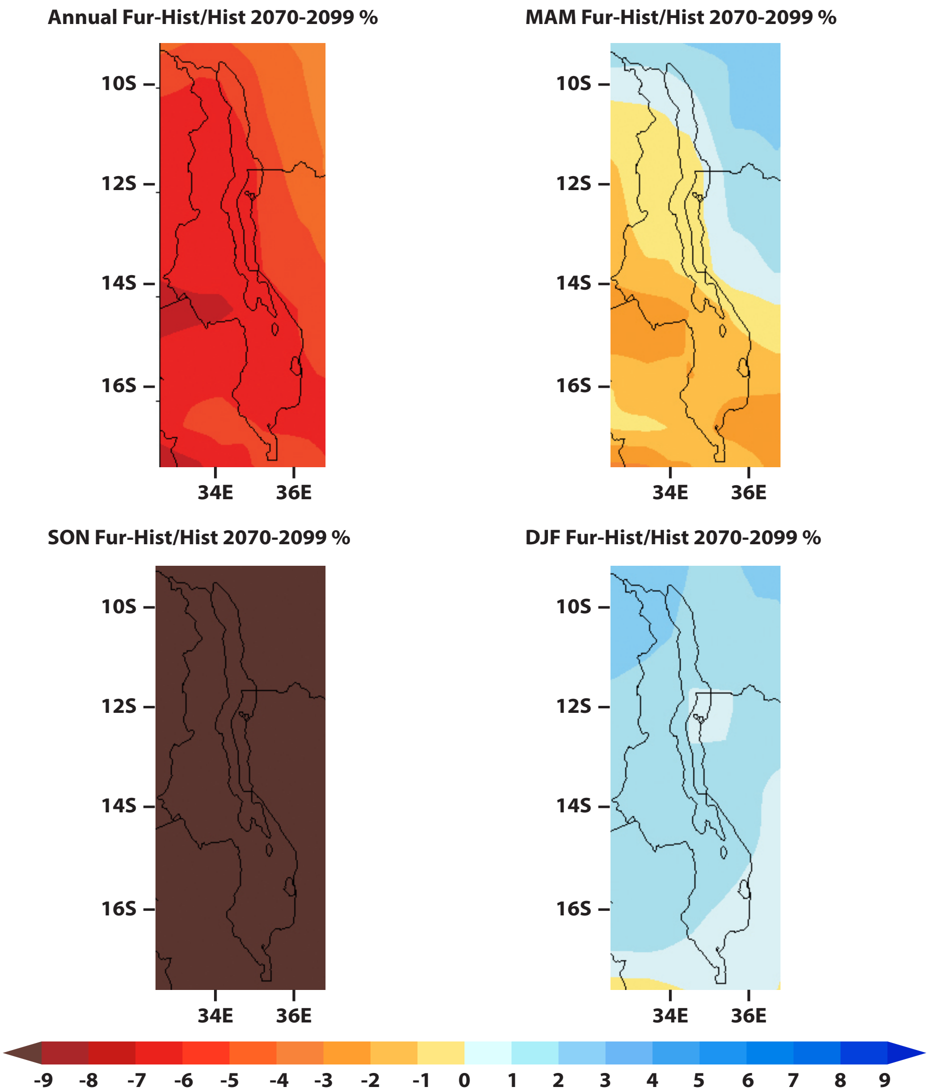


Figure 6: Per cent change in mean annual and seasonal precipitation change for the 2090s (2070-2099) compared to current period 1976-2005 using ensemble mean of 34 CMIP5 models for annual, March to May (MAM), September to November (SON) and December to February (DJF)



Temperature

Figure 7: Change in annual mean temperature (°C) for all Malawi between the GCM simulated current period (1976-2005) and 2021-50 for 34 GCMs

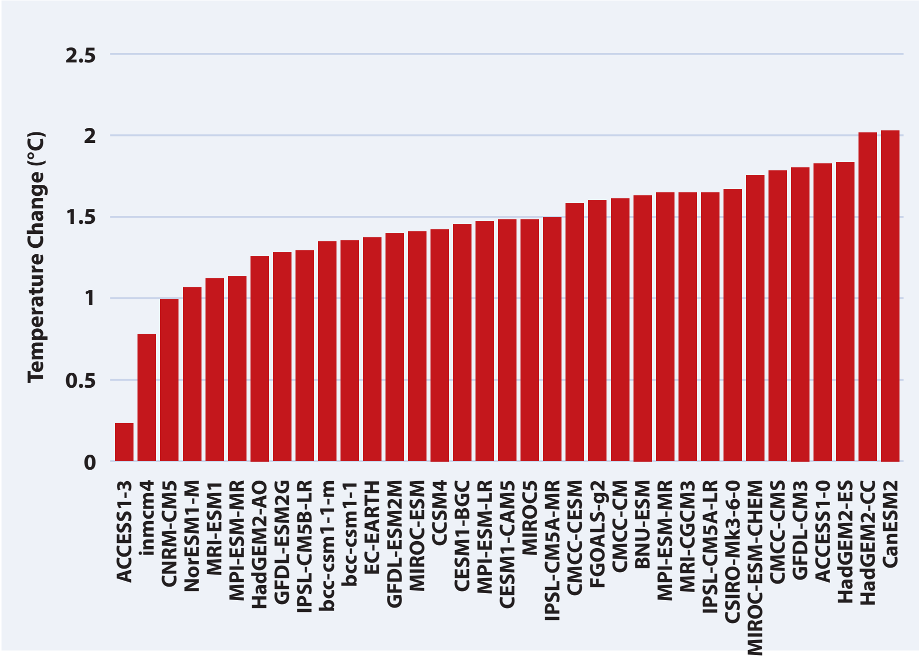


Figure 8: Change in annual mean temperature (°C) between the GCM simulated current period (1976-2005) and 2070-99 for 34 GCMs

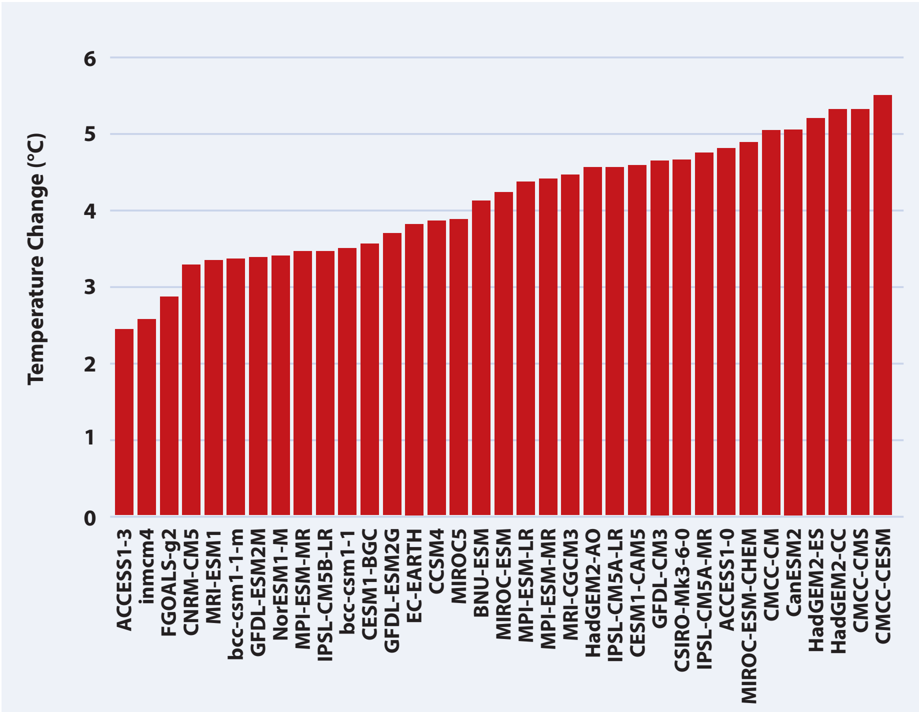


Figure 9: Mean seasonal temperature change (°C) for near-term 2021-2050 compared to current period 1976-2005 using ensemble mean of 34 CMIP5 models for annual, March to May (MAM), September to November (SON) and December to February (DJF)

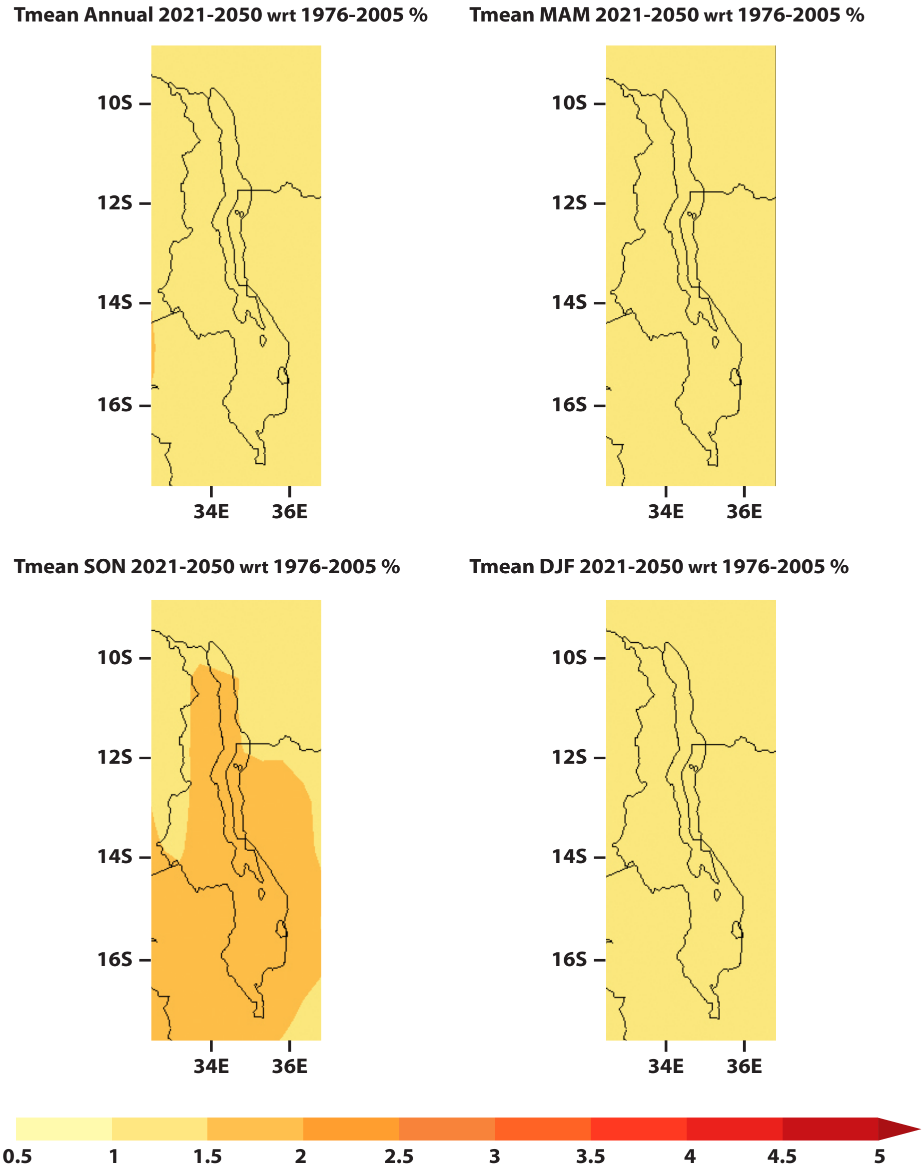


Figure 10: Mean seasonal temperature change (°C) for the long-term 2070-2099 compared to current period 1976-2005 using ensemble mean of 34 CMIP5 models for annual, March to May (MAM), September to November (SON) and December to February (DJF)

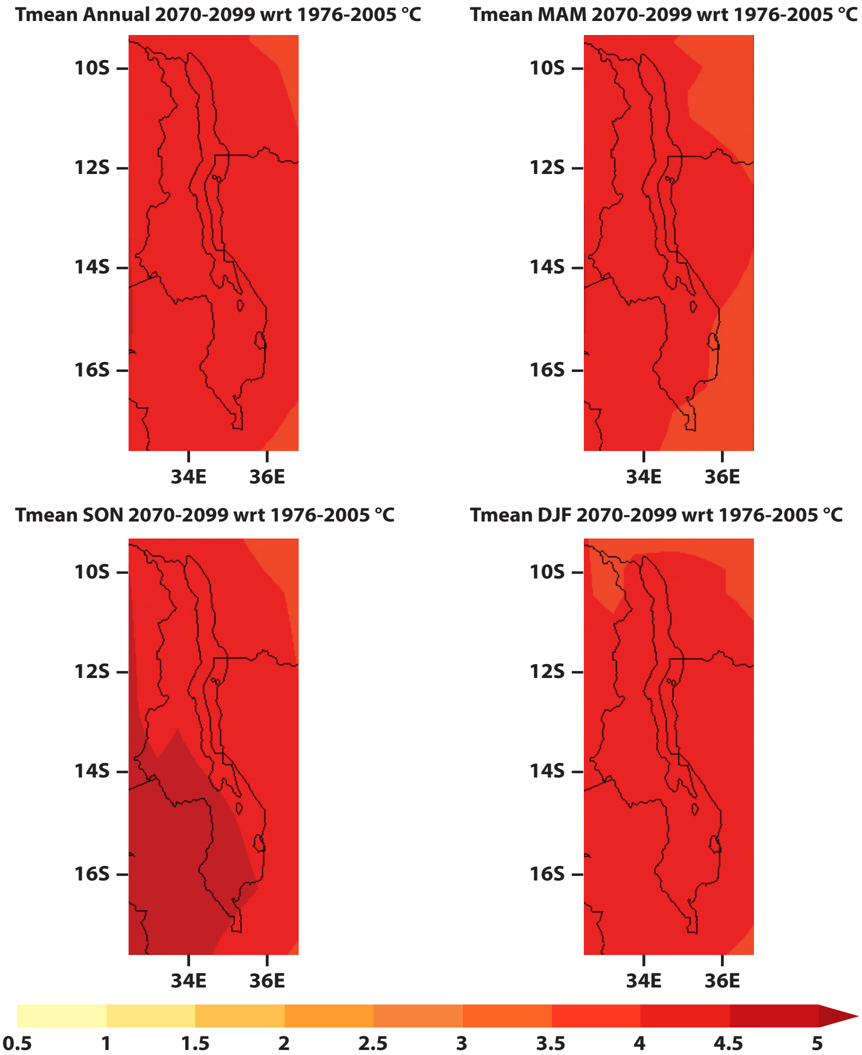
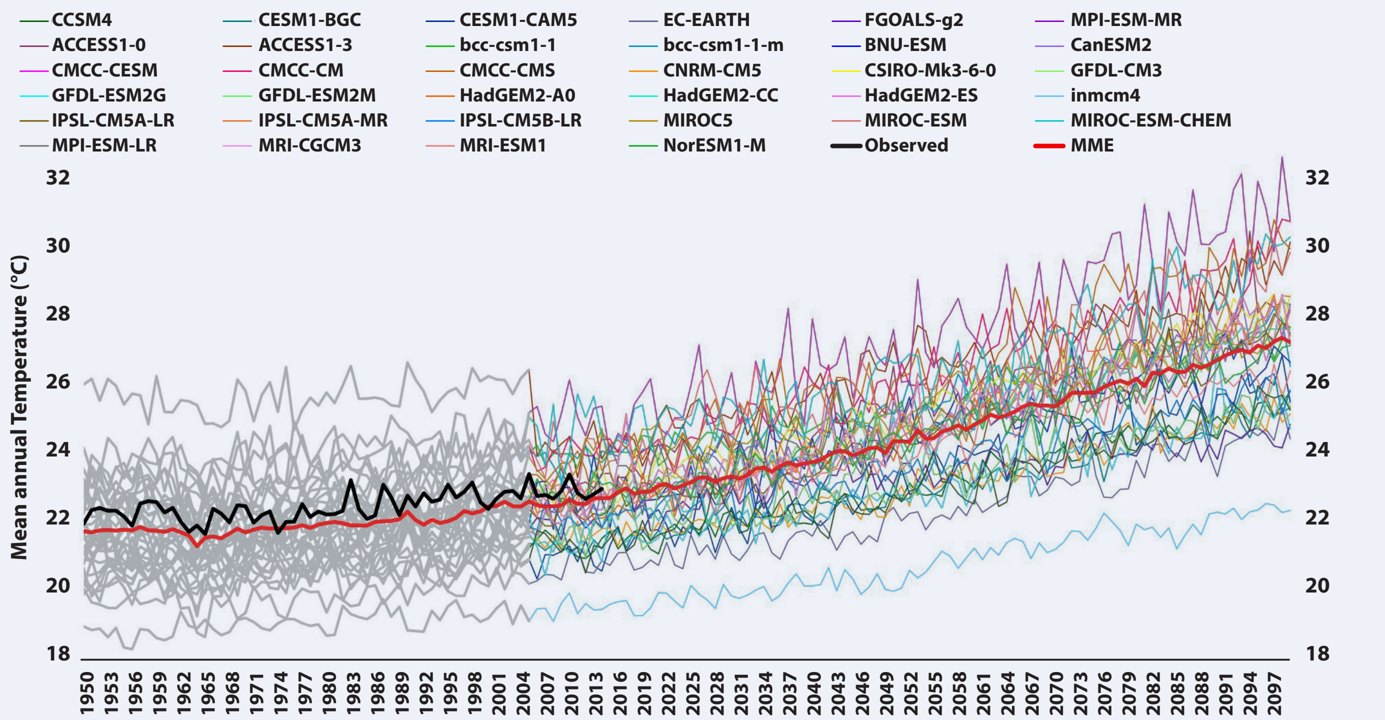


Figure 11: Time series of mean annual temperature (°C) for 34 CMIP5 models and their ensemble (bold red line) for the period 1950-2099 and CRU observations (bold black line) for the period 1950-2014



Endnotes

1 FCFA (2017a) Country climate brief. *Future climate projections for Malawi.* Cape Town: Future Climate for Africa. www.futureclimateafrica.org/resource/future-climate-projections-for-malawi

2 FCFA (2017b) Summary: *Future climate projections for Malawi.* Cape Town: Future Climate for Africa. www.futureclimateafrica.org/resource/future-climate-projections-for-malawi/

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26 DIVA GIS http://www.diva-gis.org/gdata

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. This brief was written by Neha Mittal of the UMFULA research team. You can find out more about their work under 'research teams' on www.futureclimateafrica.org.

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