Historical climate trends & projections for the Olifants River Catchment

[Lepelle-Nkumpi Local Municipality]

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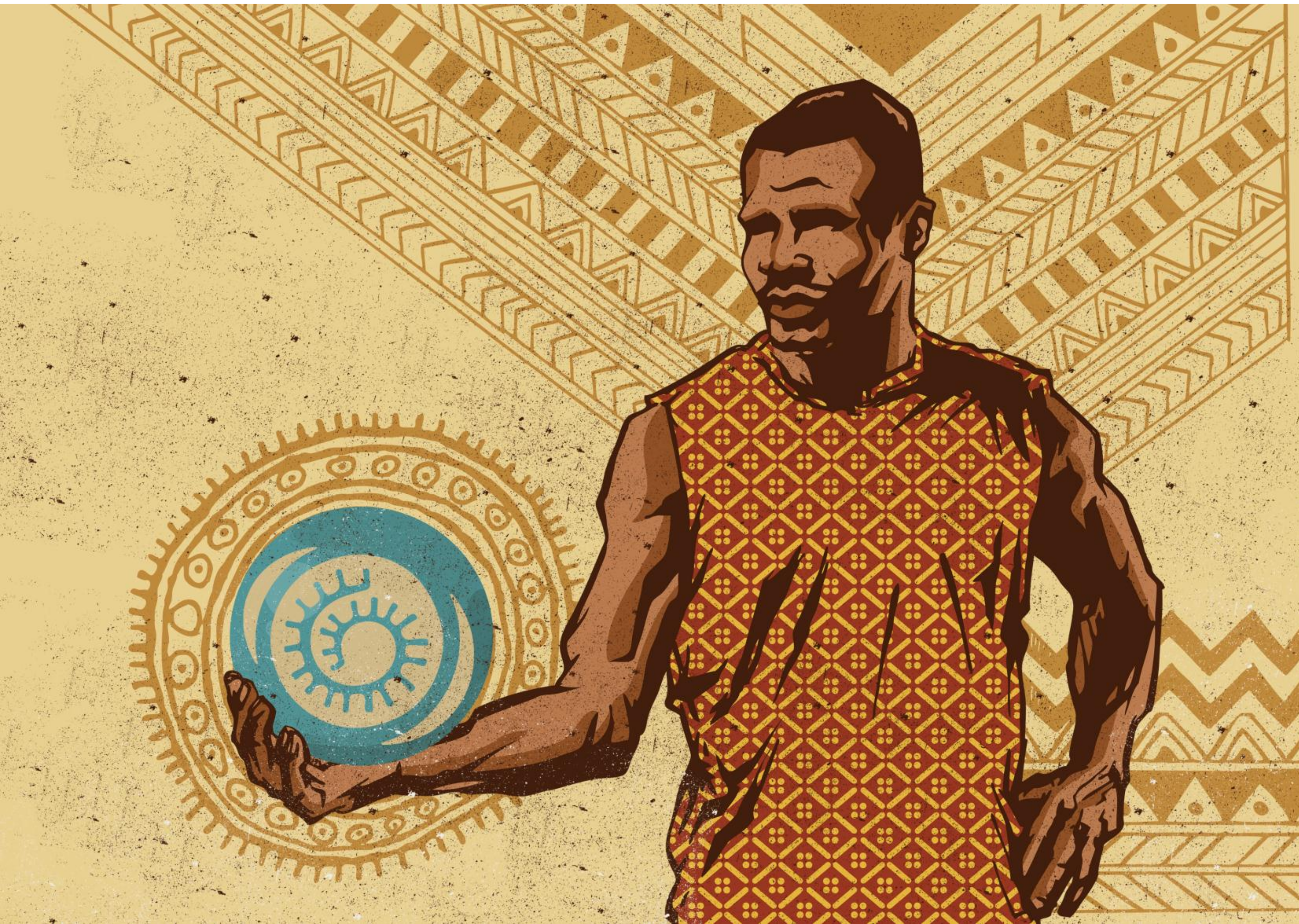

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Summary of projections

The following information is based on the data analysis by Climate System Analysis Group.

Temperature

- Average daily maximum temperature. All models projected increases: 0.75°C and 2.1°C (good case scenario) and 1.1°C – 2.3°C (bad case scenario) by 2040.
- These projected increases are more pronounced in summer and autumn (good case scenario) and are relatively similar across all seasons (bad case scenario).
- The number of hot days (temperature > 36°C) per annum. All models projected increases: 6 to 25 more days (good case scenario) and 10 to 36 more days (bad case scenario) by 2040.

Rainfall

- Annual rainfall amount. Most models projected no change although there is some uncertainty because a few projected either an increase, or a decrease.
- Season total rainfall. Projected not to change by most models, although there is some uncertainty because a few projected either an increase, or a decrease.
- Number of days with heavy rain (over 20mm/day). Most models projected no change.
- For the above three variables, more models projected a decrease than those projected an increase under both scenarios.
- Maximum count of consecutive days with no rain. Most models projected no change.

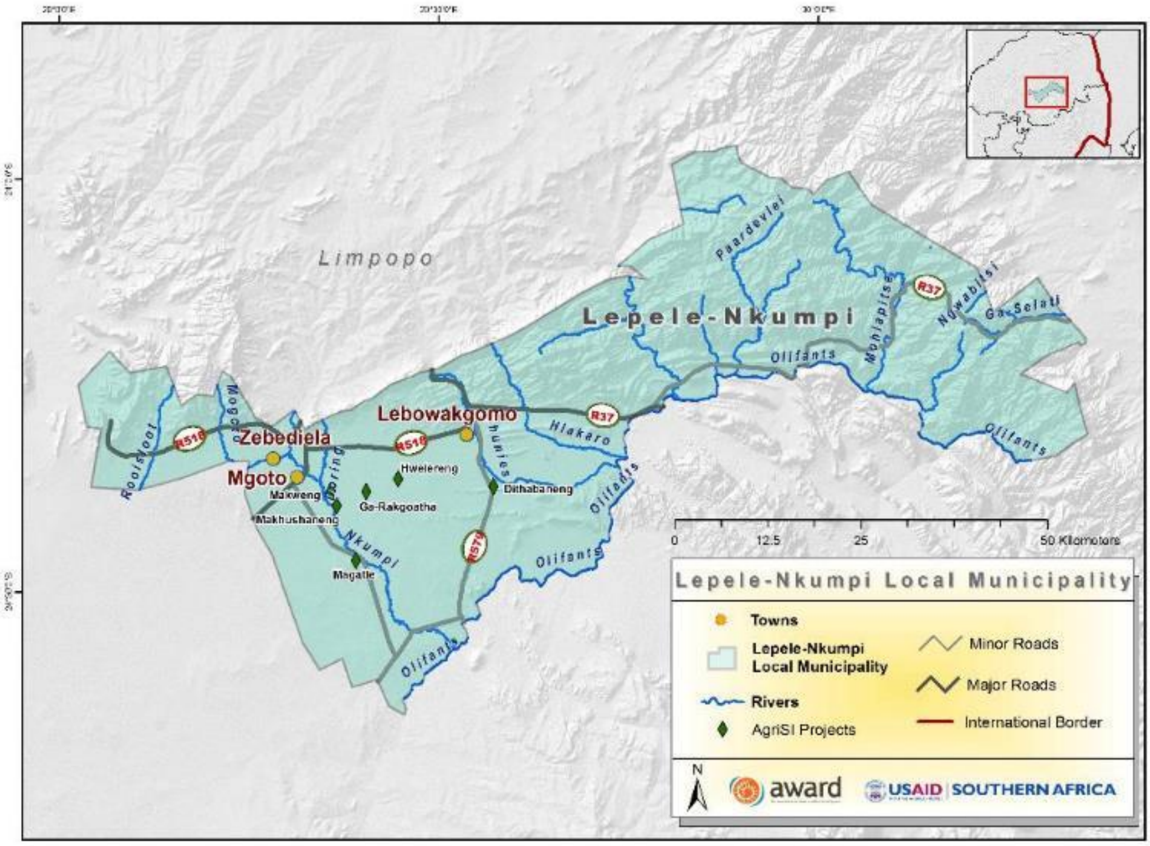

Figure 1. Map of the Lepelle-Nkumpi Local Municipality.

Background

This brief summarizes the interpretation of the climate analysis provided by the Climate System Analysis Group (CSAG) from the University of Cape Town (UCT). The analysis herein pertains to the Lepelle-Nkumpi Local Municipality (Figure 1) and should not be construed to be representative of the other areas in the Olifants Catchment because of high heterogeneity in the catchment's climate system.

Box 1: Climate variables analyzed

- Seasonal mean of daily maximum temperatures
- Seasonal mean of daily minimum temperatures
- Maximum dry spell per year: A dry spell is a period of at least 15 consecutive days with less than 1 mm of rainfall/day.
- Annual number of days with maximum temperatures over 36°C
- Annual mean of daily maximum temperatures
- Annual mean of daily minimum temperatures
- Number of rain days per season
- Mean daily rainfall in a season
- Mean daily rainfall in a year
- Total seasonal rainfall
- Total annual rainfall
- Number of rain day >20 mm: Number of day with rainfall greater than 20 mm per day.
- Maximum duration of period with rainfall < 1 mm/day: Maximum count of consecutive dry days in a year.

Analysis for the historical trends was based on observed data from Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS) and Climate Research Unit (CRU), and simulated data that have been adjusted to observations from Global Precipitation Climatology Centre (GPCC). For the technical details of the three data sources, refer to Annex A. Historical trends were analysed for 11 climatic variables (See Box 1. Descriptions were provided for those that are not self-evident).

In analysing the historical trends, CSAG applied Mann-Kendall trend test, of which the *p-value* is used to determine statistical significance. The *p-value* indicates the probability that the trend observed could have been the result of random variability rather than some underlying process such as global warming. In this brief, a *p-value* of 0.05 is used as a threshold for statistical significance. It is important to note that a lack of significance does not imply that a change has not occurred but rather that we cannot ascribe the change to some underlying process such as global warming. In terms of impacts, even non-significant trends can still be experienced as an impact and this is often corroborated by the experiences of members of society who experience real change.

Future climate projections are a product of modelling of global climate response to increasing greenhouse gas (GHG) concentrations. These models are called General Circulation Models (GCMs), which simulate the physical processes in the atmosphere, ocean, cryosphere and land surface. There are many GCMs developed by different climate research institutes around the world. Each GCM may simulate a different climate response for the same inputs because of the way certain processes and feedbacks are modelled. Among the scientific community, one way to manage this uncertainty is to use an ensemble of GCMs instead of an individual model. This is the approach that CSAG followed in their analysis of the climate projections for Lepelle-Nkumpi Local Municipality. With an ensemble, climate projections should be read as a range instead of a single number or an average.

Each unit of analysis in a GCM is a three-dimensional grid over the globe; imagine the globe covers by rectangular columns that stretch into the sky and dive into the ocean. The spatial scale of these grids are typically 250 and 600 km on each side horizontally[1]. Such spatial scale is too coarse for use at a local level, where factors contributing to the climate are at a much finer spatial scale. Therefore, these GCMs need to be downscaled, which is a process of adding spatial resolution to projections. Typically, downscaled projections have a spatial resolution of 25 km by 25 km. There are two main types of downscaling techniques: dynamical and empirical/statistical. CSAG used an empirical downscaling technique called Self-Organizing Map based Downscaling (SOMD), which is a statistic approximation of regional scale response based on global scale circulation and historical observed data. See Annex B for the list of downscaled GCMs used in their analysis.

One key input for the GCM is GHG concentrations. The Intergovernmental Panel for Climate Change (IPCC) adopted four GHG concentration trajectories, or Representative Concentration Pathways (RCPs), for its more recent (fifth) assessment report. The four RCPs are RCP2.6, RCP4.6, RCP6 and RCP8.5[2]. One could think of these RCPs as different scenarios, ranging from optimistic (RCP2.6) to pessimistic (RCP8.5) about global efforts to change the future of GHG concentration in the atmosphere. The climate scientists at CSAG have advised me that the trajectory for RCP8.5 is looking to be the most likely scenario given the current upward trend of GHG concentration in the atmosphere. In this brief, CSAG performed analysis on climate projections for RCP4.5 and RCP8.5. The ensemble projections for the two RCPs should be understood as two separate sets of possible futures, and thus should not be combined or averaged.

Historical trends

There was a statistically significant increase of 1.3°C in daily maximum and minimum temperatures on average in the last century. However, there was no statistically significant increase in the daily minimum temperatures when we only consider the three most recent decades.

The increase in daily maximum temperature was greater in autumn, winter and spring than in summer. Looking at the three recent decades as a period, the increase in daily maximum temperatures was only significant in winters and springs and was about 3 to 5 times higher than the increase in the last century. Annually, the increase in daily maximum temperature in the last three decades was 3 times higher the increase in the last century. This means that the warming of daily maximum temperature has accelerated in the recent decades relative to the earlier part of the last century. The increase in the daily minimum temperatures was similar across all seasons.

There was an increase of 2 days with maximum temperature over 36ºC per year in the last three decades.

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[1] IPCC. "What Is a GCM?". Content last modified: 18 June 2013. Accessed 6 April 2017 at http://www.ipcc-data.org/guidelines/pages/gcm_guide.html.

[2] Vuuren, Detlef P. van, Jae Edmonds, Mikiko Kainuma, Keywan Riahi, Allison Thomson, Kathy Hibbard, George C. Hurtt, et al. 2011. "The Representative Concentration Pathways: An Overview." Climatic Change 109 (1-2): 5. doi:10.1007/s10584-011-0148-z. Available online at http://link.springer.com/article/10.1007%2Fs10584-011-0148-z.
The dataset for the four RCPs can be accessed at http://www.iiasa.ac.at/web-apps/tnt/RcpDb.

There was no statistically significant change in mean daily rainfall in a season and in a year in the last three decades. Similarly, there was no statistically significant change in total amount of seasonal and annual rainfall in the last century and last three decades. Furthermore, there was no statistically significant change in the maximum duration of dry spell per year in the last three decades. Duration of dry spell is usually used in determining meteorological drought. However, one dataset (WFDEI) showed that there was a decrease of 3 rain days in winter over the last three decades. This change is interesting considering that rain is very uncommon in Ba-Phalaborwa during the winter months anyway.

Future projections

In the figures that follow, each line represents the downscaled projection by a GCM. The shaded areas surrounding the projected values (i.e. the plume shape in the figure) are estimates of uncertainty resulting from natural variability. The significance of the projected changes (i.e. when the changes exceed the bounds of what we have experienced in the past) are highlighted by a change in colour from blue to reddish orange. This allows for some estimation of when in the future we are likely to be operating under a climate that is distinctly different from the climate we currently experience.

Note: A bad case scenario refers to RCP 8.5 and a good case scenario refers to RCP 4.5 for the remainder of this document.

Temperature

All models projected that average daily maximum temperature will increase between 0.75˚C and 2.1˚C (good case scenario) and between 1.1˚C and 2.3˚C (bad case scenario) by 2040 (Figure 2). Under a good case scenario, the increase spreads over a bigger range in summers and autumns than in winters and springs. The increase is relatively uniform across all seasons under a bad case scenario.

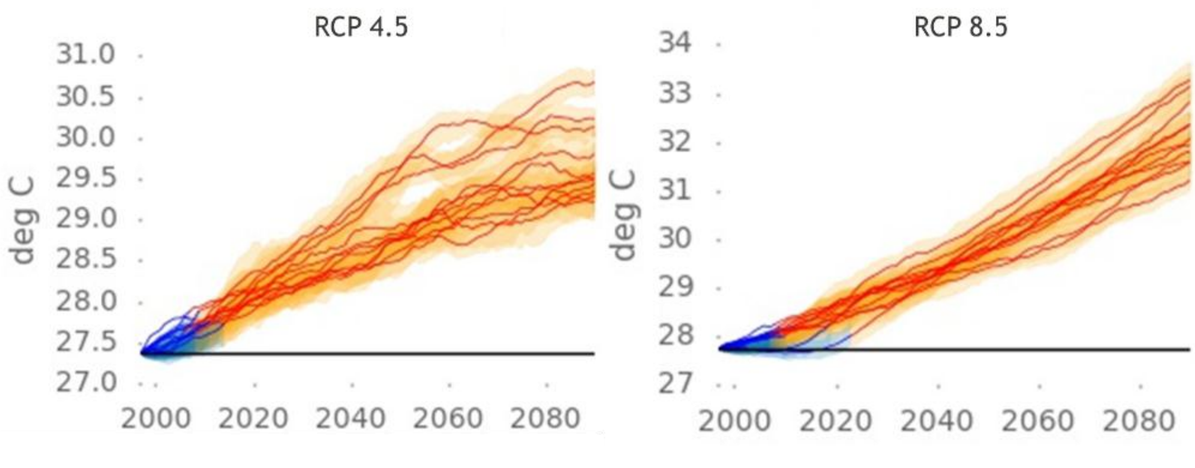

Figure 2. Downscaled projection of average daily maximum temperature under RCP 4.5 (left) and under RCP8.5 (right).

All models agreed that there would be more hot days, where maximum temperature exceeds 36˚C. This ranges from 6 to 25 more days under a good case scenario, 10 to 36 more days under a bad case scenario by 2040 (Figure 3).

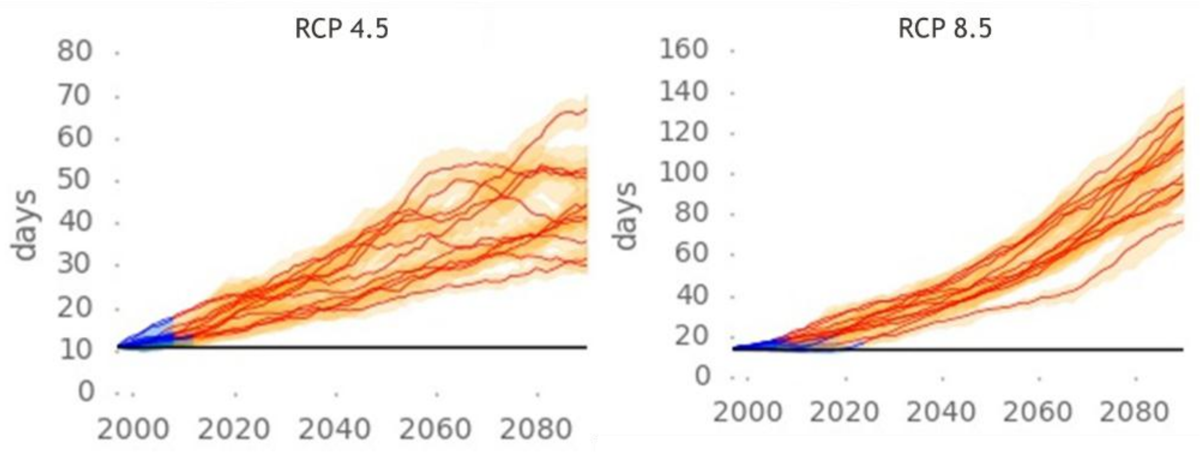

Figure 3. Downscaled projection of number of days with temperature over 36°C under RCP 4.5 (left) and under RCP8.5 (right).

Rainfall

Most climate models projected no change in annual rainfall amount, but some models projected changes in the near, medium and distant future (Figure 4).

- One model projected an increase in the near future and one model projected an increase in the medium to distant future under a good case scenario.
- Two models projected a sustained decrease post-2040, while three additional models projected a sporadic decrease in the medium future under a good case scenario.
- Under a bad case scenario, one model projected an intermittent increase throughout the century.
- One model, then another followed, projected a sustained decrease until the end of the century from 2020 and 2040, respectively under a bad case scenario. By the end of the century, five models projected a decrease.

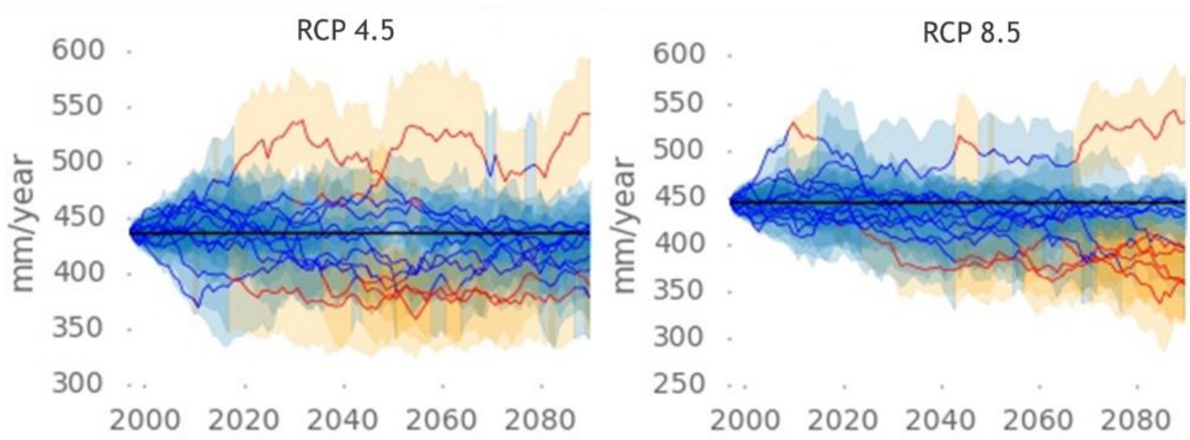

Figure 4. Downscaled projection of total annual rainfall under RCP 4.5 (left) and under RCP8.5 (right).

Similarly, the seasonal total rainfall is projected not to change by most climate models, but some models projected changes.

- One model projected an increase in summer post-2040, two models projected an increase in autumn post-2020, and two models projected a decrease in some parts of the century across all seasons post-2040 under a good case scenario.
- One model projected an increase in summer and autumn, three models projected a decrease in every season except for winter post-2020, and three models projected a decrease post-2040 in winter under a bad case scenario.

Regarding number of days with heavy rain (over 20mm/day), most climate models projected no change, but some projected changes (Figure 5). For examples, two models projected an increase at various points in the coming century under a good case scenario, and three models projected a decrease post-2040 in both case scenarios.

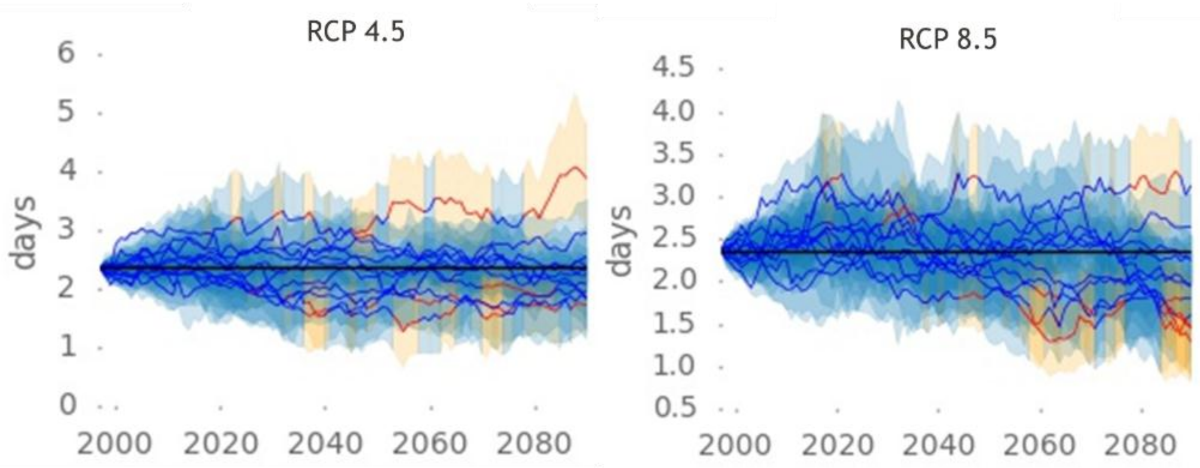

Figure 5. Downscaled projection of number of days in a year with over 20mm rain/day under RCP 4.5 (left) and under RCP8.5 (right).

With regards to the maximum count of consecutive days that are effectively dry, i.e. when rainfall is less than 1mm/day, most models projected no significant change (Figure 6). However, two models (good case scenario) and three models (bad case scenario) projected 8-10 more days without rain post-2020 and -2040, respectively. There is one model that projected a sporadic dip in the maximum duration of dry period under both case scenarios.

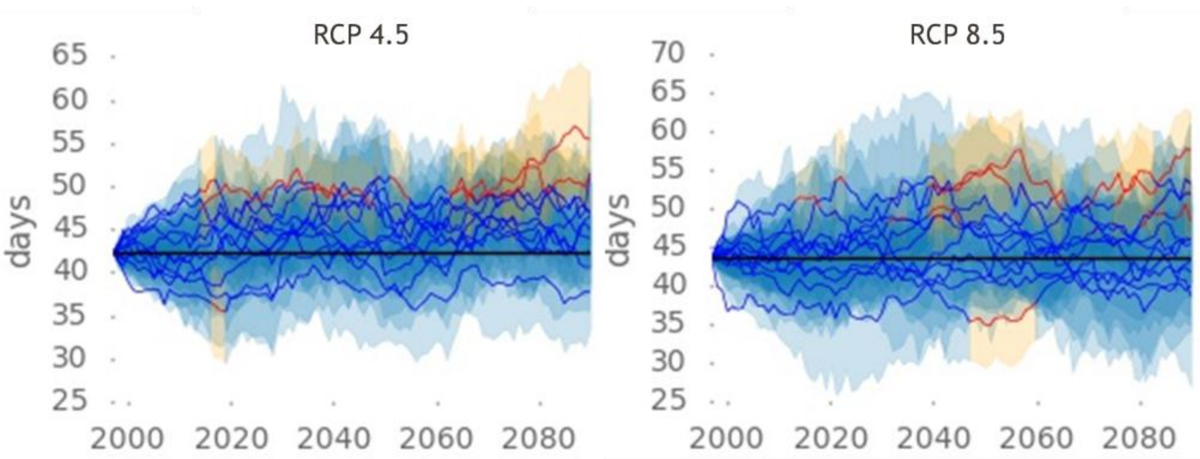

Figure 6. Downscaled projection of maximum count of consecutive dry days (i.e. less than 1mm of rainfall per day) in a year under RCP 4.5 (left) and under RCP8.5 (right).

Annex A: CHIRPS, CRU & WATCH WFDEI datasets

Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS)

The CHIRPS data comprises daily rainfall data only. It is a combination of satellite and weather station rainfall data, and is available for the period 1981-2014, gridded to 0.25 x 0.25 degree spatial resolution.

Climate Research Unit (CRU)

The CRU time-series data is made up of monthly time series of various climate variables, which include maximum and minimum temperature and rainfall. The data is based on over 4000 global weather stations, is available for the period 1901 – 2012, and is gridded to 0.5 x 0.5 degree spatial resolution.

WATCH Forcing Data methodology applied to ERA-Interim data (WFDEI)

WATCH is a European-Commission funded project to simulate the global terrestrial water cycle in the twentieth century via a suite of hydrological models. To allow direct comparison of model outputs, the WATCH Forcing Data (WFD) were created. The WFDEI was produced using WFD methodology applied to ERA-Interim data.[3] It is a meteorological forcing dataset extending into early 21st century (1979 – 2014). Eight meteorological variables are available at 3-hourly time steps, and as daily averages. Simulated rainfall is adjusted to observations from Global Precipitation Climatology Centre (GPCC).

The three datasets used in the analysis have different origin, and this may cause discrepancies between them. CRU is based on interpolation of station data, WFDEI uses station data to bias-correct results of climate model simulations, while CHIRPS integrates satellite-derived product with observations.

TABLE 1. ANALYSED RAINFALL (P) AND AIR TEMPERATURE (T) DATASETS.

Dataset	Time period	Data	Temporal resolution	Spatial resolution
CHIRPS v2.0	1981- to date	P	Daily	0.25
CRU v3.23	1901-2012	P	Monthly	0.5
WFDEI	1979-2009	P,T	Daily	0.5

[3] *Weedon, Graham P., Gianpaolo Balsamo, Nicolas Bellouin, Sandra Gomes, Martin J. Best, and Pedro Viterbo. 2014. "The WFDEI Meteorological Forcing Data Set: WATCH Forcing Data Methodology Applied to ERA-Interim Reanalysis Data." Water Resources Research 50 (9): 7505-14. doi:10.1002/2014WR015638. Accessed 8 April 2017 at http://onlinelibrary.wiley.com/doi/10.1002/2014WR015638/full*

Annex B: GCMs downscaled in the analysis for this brief

The Coupled Model Intercomparision Project (CMIP) was established under the World Climate Research Program (WRCP) by the Working Group on Coupled Modelling (WGCM). The goal was to provide a standard experimental protocol for studying the output of coupled Atmosphere-Ocean GCMs in order to facilitate model improvement through better model quality control and a better understanding of model behaviour (Meehl et al., 2000). The fifth phase of the CMIP (CMIP5) is the latest set of coordinated climate model experiments. The table below lists the GCMs from the CMIP5 that were downscaled by CSAG for the analysis interpreted in this brief.

For a complete list of available GCMs in CMIP5, see http://cmip-pcmdi.llnl.gov/cmip5/availability.html

TABLE 2. GCMS FROM THE CMIP5 THAT WERE DOWNSCALED BY CSAG.

GCM code	Institutions	Country
BCC-CSM1.1	Beijing Climate Centre, China Meteorological Administration	China
BNU-ESM	College of Global Change and Earth System Science, Beijing Normal University	China
CNRM-CM5	Météo-France / Centre National de Recherches Météorologiques	France
GFDL-ESM2G	US Department of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory	U.S.A.
HadGEM2-CC	Met Office Hadley Centre	U.K.
IPSL-CM5B-LR	Institut Pierre-Simon Laplace	France
MIROC-ESM	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies	Japan
MPI-ESM-LR	Max Planck Institute for Meteorology (MPI-M)	Germany
CMCC-CESM	Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
CanESM2	Canadian Centre for Climate Modelling and Analysis	Canada
GFDL-ESM2M	US Department of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory	U.S.A.
IPSL-CM5A-MR	Institut Pierre-Simon Laplace	France
MIROC-ESM-CHEM	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies	Japan
MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	Japan
MRI-CGCM3	Meteorological Research Institute	Japan

award

The Association for Water and Rural Development

AWARD is a non-profit organisation specialising in participatory, research-based project implementation. Their work addresses issues of sustainability, inequity and poverty by building natural-resource management competence and supporting sustainable livelihoods. One of their current projects, supported by USAID, focuses on the Olifants River and the way in which people living in South Africa and Mozambique depend on the Olifants and its contributing waterways. It aims to improve water security and resource management in support of the healthy ecosystems to sustain livelihoods and resilient economic development in the catchment.

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About USAID: RESILIM-O

USAID: RESILIM-O focuses on the Olifants River Basin and the way in which people living in South Africa and Mozambique depend on the Olifants and its contributing waterways. It aims to improve water security and resource management in support of the healthy ecosystems that support livelihoods and resilient economic development in the catchment. The 5-year programme, involving the South African and Mozambican portions of the Olifants catchment, is being implemented by the Association for Water and Rural Development (AWARD) and is funded by USAID Southern Africa.

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