Historical climate trends & projections for the Olifants River Catchment
[Elias Motsoaledi]

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2017

USAID: RESILIENCE IN THE LIMPOPO BASIN PROGRAM (RESILIM) – OLIFANTS

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 Elias Motsoaledi Local Municipality (see 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.

Figure 1. Map of Greater Tzaneen Local Municipality. (NB: This is just a placeholder. We will replace this with a map made with ArcGIS later.)

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 Center (GPCC). For the technical details of the three data sources, refer to Annex A. Historical trends were analyzed for 11 climatic variables (See Box 1. Descriptions were provided for those that are not self-evident).

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 the Elias Motsoaledi 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. 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.

Box 1: Climate variables analysed

- 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.

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 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 understood as two separate sets of possible future, and thus should not be combined or averaged.

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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.*

Historical trends

Temperature

There was a statistically significant increase of 1.3°C in daily maximum temperatures on average in the last century. 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 three time higher than the increase in the last century.

There was a statistically significant increase of 1.6°C to 1.7°C in daily annual minimum temperatures on average in the last century. The increase was uniform in all seasons and throughout the century, but the increase in the recent three decades was statistically insignificant except for summer.
There was no statistically significant change in the annual number of days with maximum temperature over 36ºC in the last three decades.

Rainfall

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 4 and 5 rain days in winter and spring respectively over the last three decades.

Future projections

Temperature

All models projected that average daily maximum temperature will increase between 0.7°C and 2.0°C (under a good case scenario) and between 1°C and 2.3°C (under a bad case scenario) by 2040 (See Figure 2). Bad case scenario means RCP 8.5 and good case scenario means RCP 4.5 for the remainder of this document.

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 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.
The projected temperature increases are quite uniform in all seasons under both scenarios.

Regarding number of hot days (temperature over 35°C), all models agreed that it will increase, ranging from 5.5 to 19 more days (under a good case scenario) and ranging from 8 to 30 more days (under a bad case scenario) by 2040 (See Figure 3).

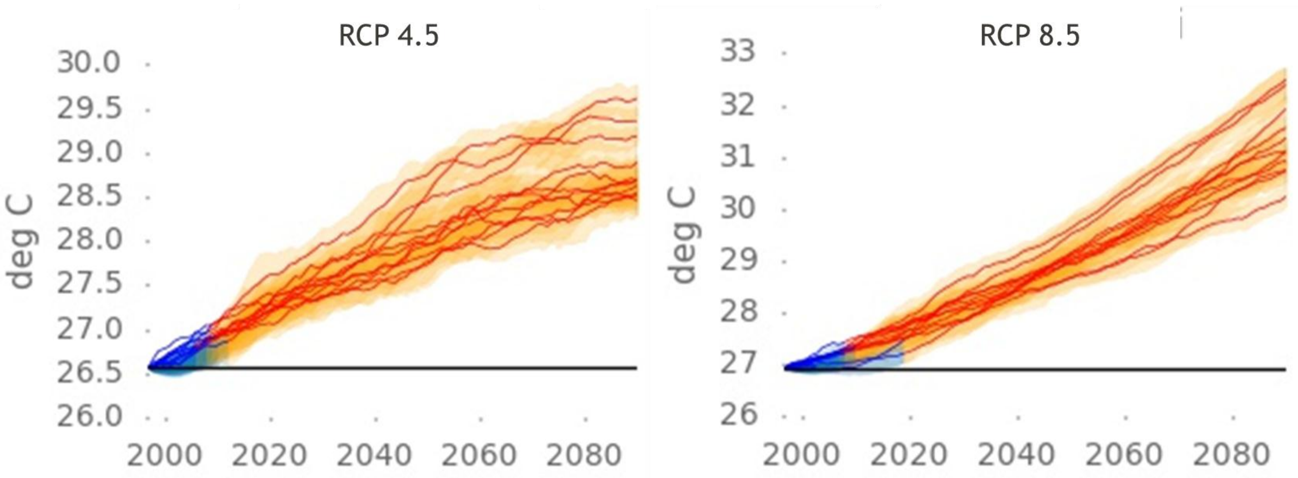

Figure 2. Downscaled projection of average daily maximum temperature under RCP 4.5 (left) and under RCP8.5 (right).

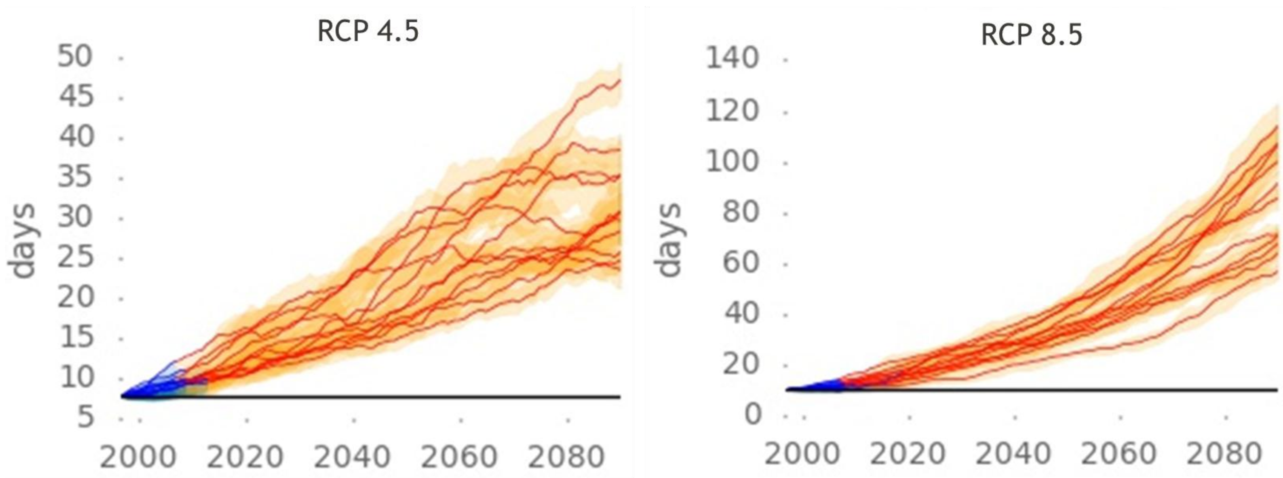

Figure 2. Downscaled projection of number of days with temperature over 35°C under RCP 4.5 (left) and under RCP8.5 (right).

Rainfall

Most climate models projected no change in annual rainfall amount. However, there are two models that projected an increase post-2020 and one model that projected a decrease between 2030 and 2050 under a good case scenario. There are three models that projected a decrease post-2040 and one model that projected an increase toward end of the century under a good case scenario (See Figure 4).

Season total rainfall is projected not to change by most climate models, but two models projected an increase in spring and autumn post-2020, and two models projected an increase in summer and winter post-2040 under a good case scenario.

There is one model that projected a decrease in all four seasons in the next century. In a bad case scenario, one or two models have projected either an increase or a decrease in winter and spring post-2020, while one to two models projected a decrease in summer and autumn post-2020.

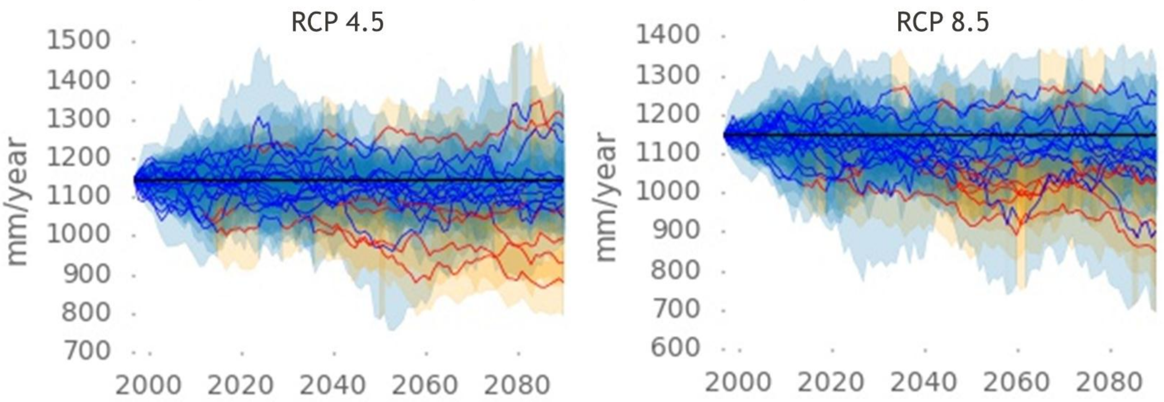

Figure 3. Downscaled projection of total annual rainfall under RCP 4.5 (left) and under RCP8.5 (right).

Regarding number of days with heavy rain (over 20mm/day), most climate models projected no change, but in a good case scenario, one model projected an increase and one model projected a decrease post-2020, while two models projected a decrease from 2040 onward in a bad case scenario (See Figure 5)

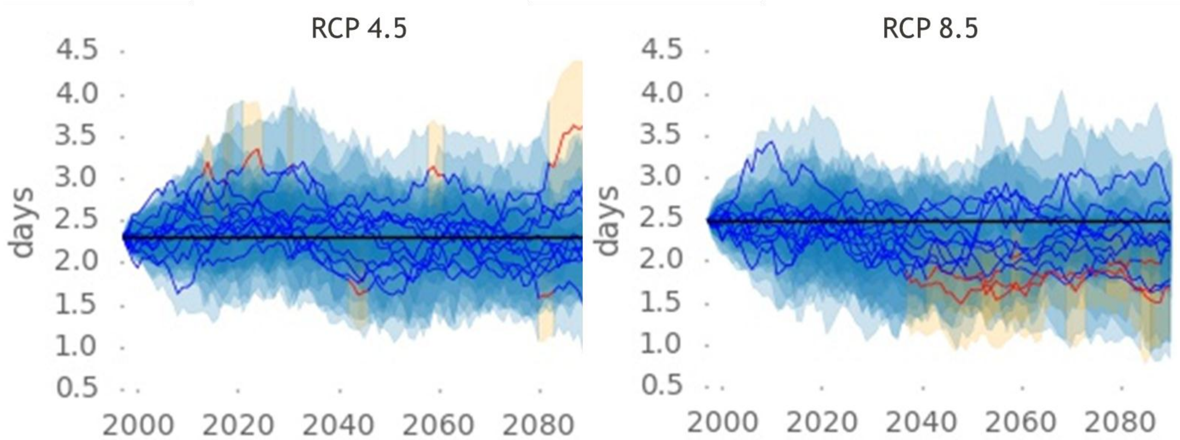

Figure 4. Downscaled projection of maximum count of consecutive dry days (i.e. less than 1mm of rainfall per day) in a year under RCP 4.5 (left) and under RCP8.5 (right).

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. However, a few models (one in a good case scenario and three in a bad case scenario) are projecting an increase of 10 days in dry spell between 2020 and 2040 (See Figure 6).

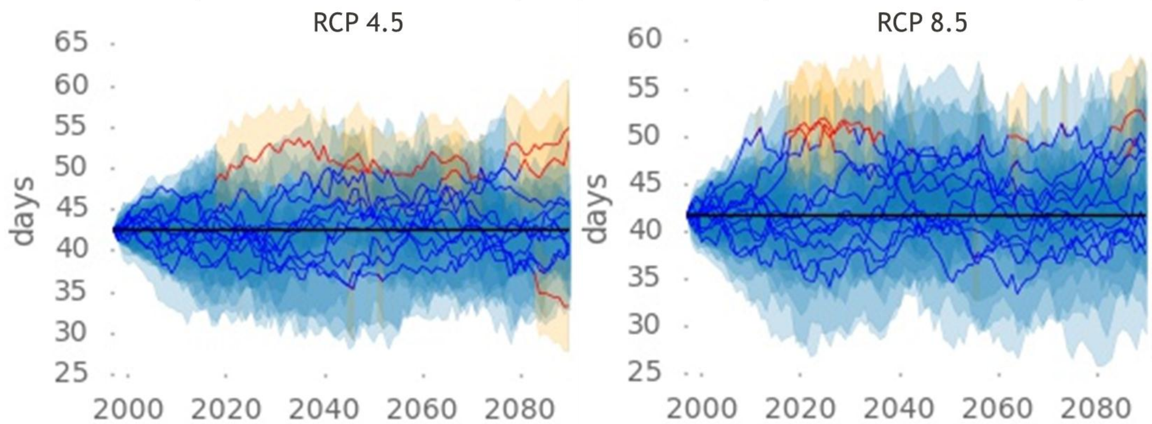

Figure 5. Downscaled projection of maximum count of consecutive dry days (i.e. less than 1mm of rainfall per day) in a year under RCP 4.5 (left) and under RCP8.5 (right).

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 Center (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. ANALYZED 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*

Annexure 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 Center, 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.

Acknowledgements: Project funding and support

The USAID: RESILIM-O project is funded by the U.S. Agency for International Development under USAID/ Southern Africa RESILIENCE IN THE LIMPOPO BASIN PROGRAM (RESILIM). The RESILIM-O project is implemented by the Association for Water and Rural Development (AWARD), in collaboration with partners. Cooperative Agreement nr AID-674-A-13-00008

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