24 AWARD Tech Report Series

Historical Trends & Climate Projections per Climate Region

Olifants River Catchment

Taryn Kong, Sharon Pollard & Ancois de Villiers
Based on data analysis by Climate System Analysis Group (CSAG)

2019

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Based on data analysis by Climate System Analysis Group (CSAG)

The Climate System Analysis Group (CSAG) is a research group at the University of Cape Town. CSAG seeks to apply core research to meet the knowledge needs of responding to climate variability and change. The climate data in this report comes from CSAG.

2019

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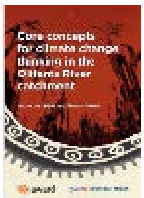
Acronyms

AWARD	Association for Water and Rural Development
CHIRPS	Climate Hazards Group InfraRed Precipitation with Stations
CRU	Climate Research Unit
CSAG	Climate System Analysis Group
GCMs	General Circulation Models
GHG	Greenhouse gas
GPCC	Global Precipitation Climatology Centre
IPCC	Intergovernmental Panel for Climate Change
RCP	Representative Concentration Pathways
SOMD	Self-Organizing Map based Downscaling
WFDEI	WATCH Forcing Data methodology applied to ERA-Interim

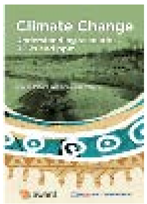
AWARD's Climate Change Adaptation series

Series 1: Understanding core concepts of climate change



Core Concepts for Climate Change Thinking in the Olifants River Catchment

A basic brochure describing the difference between climate and weather, and outlining climate change and its impacts. The brochure is available in English or Sepedi.



Climate Change: Understanding Scenarios, RCPS and PPM

A technical brochure that explores greenhouse gas scenarios and helps to understand Representative Concentration Pathways (RCPs) and parts of carbon dioxide per million parts of air – or parts per million (ppm). Find out what the 400 ppm figure is and why an increase of 2°C is so important.

Series 2: Understanding climate change projections in the Olifants Catchment

How is the climate changing in the Olifants River Catchment?

Within the Olifants River Catchment, the local climate has changed and is continuing to change. Importantly, these changes are not uniform across the catchment, partly because of the diversity and complexity of the landscape as well as weather patterns. This brochure describes the 5 distinct climate regions within the catchment. It can be used to inform planning and action to address climate change by reporting on the historical changes (from 1979 to 2013) and future projections (over a period including 2020, 2040 and 2080) in rainfall and temperature patterns for each climate region.

Technical brief series on historical trends and climate projections for local municipalities

A series of technical briefs which capture historical trends and projected changes in rainfall and temperature patterns for 5 local municipalities within the Olifants River Catchment:

1) Ba-Phalaborwa, Mopani District;
2) Maruleng, Mopani District;
3) Greater Tzaneen, Mopani District;
4) Elias Motsoaledi, Sekhukhune District Municipality; and
5) Lepelle-Nkumpi, Capricorn District Municipality.

Series 3: Dialogues for action - Supporting people to think about climate change & act

Guide to using a dialogical systemic approach for climate change literacy

A short guideline on how to facilitate meaning-making dialogues about climate change, potential impacts and adaptation to support climate literacy and action.

Series 4: Supporting adaptation plans

AWARD has developed several guides and tools to supporting identifying, developing and implementing potential adaptation plans for natural resource management.
See http://award.org.za/index.php/resources/

Summary

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

Climate regions

- The Olifants River Catchment (ORC) can be delineated into five climate regions: (a) Northern Highveld; (b) Southern Highveld; (c) Escarpment; (d) Lower Limpopo; and (e) Coastal.
- Historically, the Lower Limpopo and Coastal regions have the highest mean annual temperature, while the Escarpment and the Coastal regions have the highest mean annual rainfall.

Historical trends

- In all five climate regions except for the Coastal region, the mean daily maximum temperature has increased in the last three decades.
- The Lower Limpopo and Coastal regions have experienced a significant increase in the mean daily minimum temperature in the last three decades.
- Only the Northern Highveld has been experiencing an increasing number of extreme-heat days.
- The mean annual and daily rainfall, the number of days with heavy rainfall (amount exceeding 20 mm/day) and the duration of dry spells have not changed significantly in most of the ORC in the last three decades except for the Coastal region.

Downscaled projections

- Under both RCP4.5 and RCP8.5 scenarios, there was a consensus in the ensemble of GCMs[1] that the daily maximum temperature would increase in all five climate regions, with the projected increase being generally higher under RCP8.5.
- These projected increases in daily maximum temperature were similar across the climate regions.
- There was a consensus in the ensemble of GCMs that the number of days with a maximum temperature exceeding 36°C would increase in the future. Under the RCP4.5 scenario, the projected increases varied greatly across the climate regions, whereas the projected increases vary to a smaller degree under the RCP8.5 scenario.
- There was no clear consensus in the ensemble of GCMs with regard to the rainfall-related variables such as the total annual rainfall, the number of rain days, the number of heavy rain days and the duration of dry spells.
- Under the RCP4.5, most of the models projected no change for these variables except for one or two models.
- Under the RCP8.5, there were a few more models that projected a decrease in total annual rainfall, the number of rain days and the number of heavy rain days for the Escarpment, Lower Limpopo and Coastal regions. With regard to the duration of dry spell, there was a substantially higher number of models that projected a decrease in the Coastal region under RCP8.5.

[1] *General Circulation Models (GCMs) simulate the physical processes in the atmosphere, ocean, cryosphere and land surface*

Background

This brief summarises 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 five climate regions delineated based on historical rainfall and temperature data[2]. Each climate region represents an area with similar seasonality, inter-annual variability and combination of both that is distinct from another climate region. In the process, CSAG examined effects of temporal patterns alone and effects of temporal patterns with magnitude.

The CSAG exploration for distinct climate regions in the Olifants River Catchment (ORC) found that three to six regions or clusters could be delineated. This is probably because the climate in the Catchment has only one seasonal regime, and differences in seasonality of rainfall and temperature within it are minimal. The first level of delineation resulted in three regions: (a) upper Olifants or Highveld; (b) the Escarpment; and (c) the Limpopo or lower Olifants. In general, the Limpopo region is warmer than the other regions, and Escarpment region is wetter than the other regions. The second level of delineation further split the Limpopo region into a Coastal and an inland region called Lower Limpopo, and split the Highveld region into Northern Highveld and Southern Highveld. The additional delineation was done because the Coastal region has a slightly higher rainfall than the Lower Limpopo region, and because the Northern Highveld region is slightly hotter and drier than the Southern Highveld region. Therefore, the five distinct climate regions are: (a) Northern Highveld; (b) Southern Highveld; (c) Escarpment; (d) Lower Limpopo; and (e) Coastal (Figure 1).

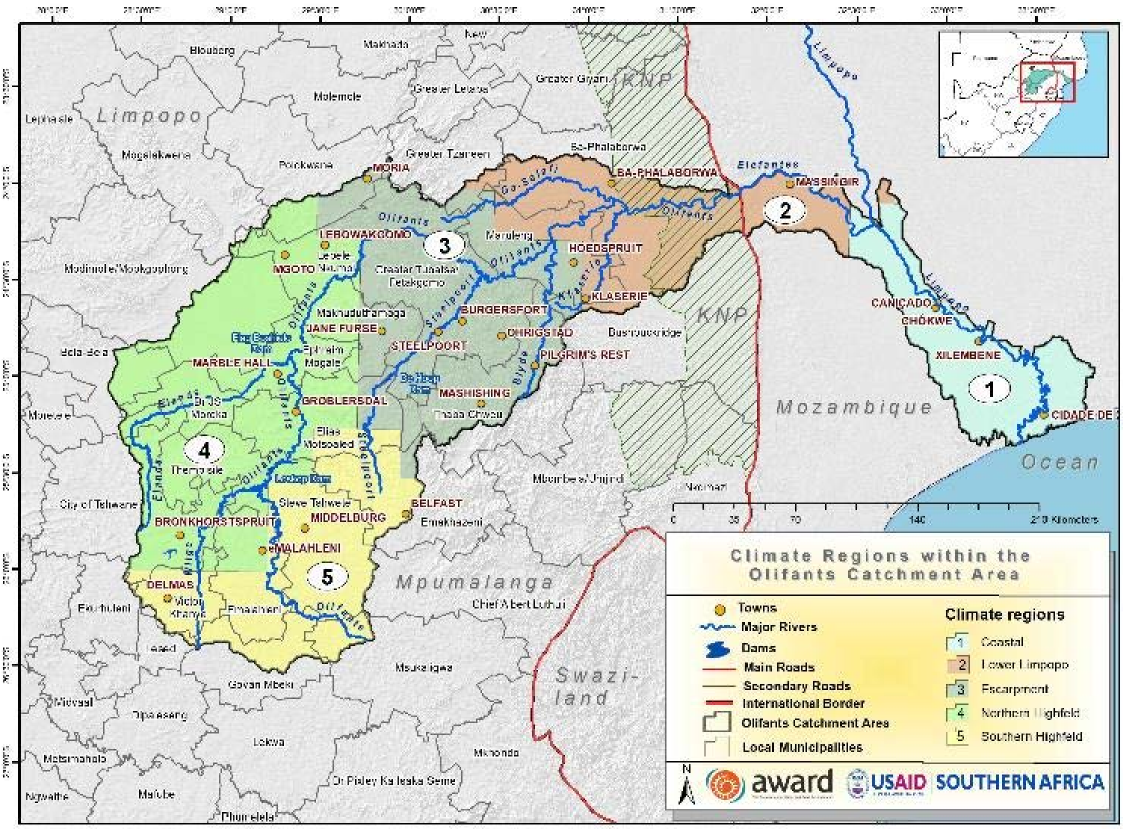


Figure 1. Five climate regions delineated by CSAG: (1) Northern Highveld; (2) Southern Highveld; (3) Escarpment; 4) Lower Limpopo; and (5) Coastal. (Source: CSAG 2018)

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[2] *Three gridded datasets were used. The first two contained observed data from the Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS) and the Climate Research Unit (CRU). The third one applied WATCH Forcing Data methodology to ERA-Interim data (WFDEI), which is a bias-corrected model data. Bias-correction is done with regard to Global Precipitation Climatology Centre (GPCC) station dataset. For the technical details of the three data sources, refer to Annex A.*

The mean annual temperature and rainfall for the five climate regions showed that the Lower Limpopo and Coastal regions have the hottest climate and the Escarpment and Coastal regions have the wettest climate in the Catchment (Table 1).

In analysing and visualising historical climate trends, CSAG used the WATCH WFDEI dataset to plot the averages of grid values in each climate region as a time series. Thirteen climatic variables were plotted. (See Box 1. Descriptions were provided for those that are not self-evident.)

TABLE 1. MEAN ANNUAL TEMPERATURE AND PRECIPITATION FOR THE FIVE CLIMATE REGIONS IN THE ORC
(adopted from CSAG, 2018)

Climate Region	Mean annual temp (˚C)	Mean annual rainfall (mm)
Northern Highveld	19	604
Southern Highveld	16	718
Escarpment	18	818
Lower Limpopo	23	558
Coastal	24	848

Box 1: Climate variables analysed

- Seasonal mean of daily maximum temperatures
- Seasonal mean of daily minimum temperatures
- Maximum duration of dry spell by year and by season: 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
- Seasonal total of daily rainfall
- Annual total of daily rainfall
- Mean daily rainfall on days with >1 mm/day for the year and by season: Mean daily rainfall on days with rain
- Number of rain day >20 mm/day: Number of days with rainfall greater than 20 mm per day

Overlaid on the time series, a Theil-Sen trend[3], a 95th-percent confidence interval and a Lowess smooth line[4] were added to illustrate multi-year to decadal trend and variability. (See Figure 2 as an example.) Additionally, CSAG applied the Mann-Kendall trend test in 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.

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[3] In non-parametric statistics, the Theil-Sen estimator is a method for robustly fitting a line to sample points in the plane and is insensitive to outliers. It has been called the most popular non-parametric technique for estimating a linear trend.
[4] LOWESS (locally weighted scatterplot smoothing) is a non-parametric regression method that fits simple models to localised subsets of the data to build up a function that describes the deterministic part of the variation in the data, point by point.

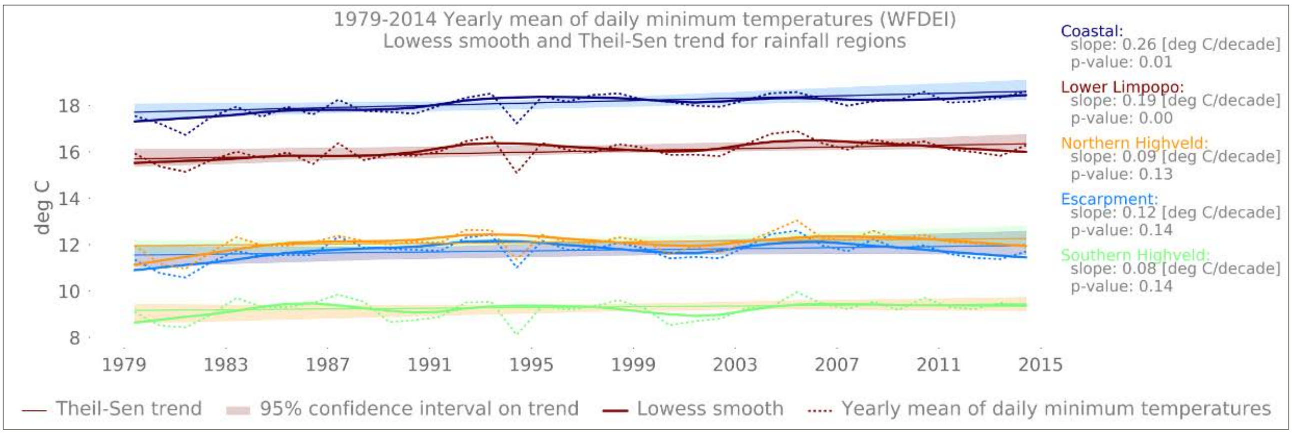

Figure 2. An example of the time series plotted from the WATCH WFDEI dataset. In this figure, the time series was for the annual mean of daily maximum temperature in Celsius. Theil-Sen trend, 95%-confidence interval and Lowess smooth line were overlaid on the time series. (Source: CSAG, 2018)

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. CSAG followed this approach in their analysis of the climate projections for the five climate regions. 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 covered by rectangular columns that stretch into the sky and dive into the ocean. The spatial scale of these grids is typically 250 and 600 km on each side horizontally[5]. Such a 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 involves 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[6]. 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.

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[5] 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.

[6] Van Vuuren, Detlef P., 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.

The climate scientists at CSAG have advised that the trajectory for RCP8.5 seems 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

Precipitation

Overall, there were very few statistically significant changes or trends in rainfall-related variables. For example, only the Coastal region had a statistically significant increase in the total annual rainfall, number of days with rainfall exceeding 20 mm and duration of dry spells per year (Table 2). These results mean that annual and mean daily rainfall, as well as number of days with heavy rainfall (amount exceeding 20 mm/day) and duration of dry spells have not changed significantly in most of the ORC in the last three decades.

Temperature

In all five climate regions except for the Coastal region, the mean daily maximum temperature has increased in the last three decades (Table 2), with the Northern Highveld having the biggest increase of 0.4 °C/decade. This means that the peak-temperatures in the day have been getting hotter in all of the ORC except in the Coastal region. Indeed, the number of days where the maximum temperature exceeds 36°C has been increasing by 1.2 day/decade in the Northern Highveld. In other words, the Northern Highveld has been experiencing an increasing number of extreme-heat days.

Concerning the mean daily minimum temperature, only the Lower Limpopo and Coastal regions have experienced a significant increase in the last three decades (Table 2). This means that the coolest part of the day is getting milder in the Lower ORC.

When looking at these temperature variables seasonally, the significant increase in mean daily maximum temperature occurred in winters and springs and the mean daily minimum temperature increased significantly in summer for all five climate regions (Table 2).

TABLE 2. SEVEN CLIMATIC VARIABLES ANALYSED FOR STATISTICALLY SIGNIFICANT CHANGE BETWEEN 1979 AND 2013 IN EACH OF THE FIVE CLIMATE REGIONS IN THE ORC BASED ON THE WFDEI DATASET. An "x" indicates that there was no significant change. A p-value and mean change (all increase) per decade were provided wherever there was a significant change. (source: CSAG)

Olifants Climate Region	Rainfall			Temperature			
	Total annual rainfall	Mean daily rainfall	Number of day rain>20 mm/day	Dry spell duration	Mean daily max temp	Mean daily min temp	Number of day with max temp > 36°C
Northern Highveld	no change	no change	no change	no change	↑0.4°C	no change	↑1.22 days
Southern Highveld	no change	no change	no change	no change	↑0.35°C	no change	*
Escarpment	no change	no change	no change	no change	↑0.33°C	no change	no change
Lower Limpopo	no change	no change	no change	no change	↑0.25°C	↑0.19°C	no change
Coastal	↑67.82 mm	no change	↑1.29 days	↑2.82 days	no change	↑0.26°C	no change

**The change was statistically significant, but less than 0.00 days per decade*

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) is 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.

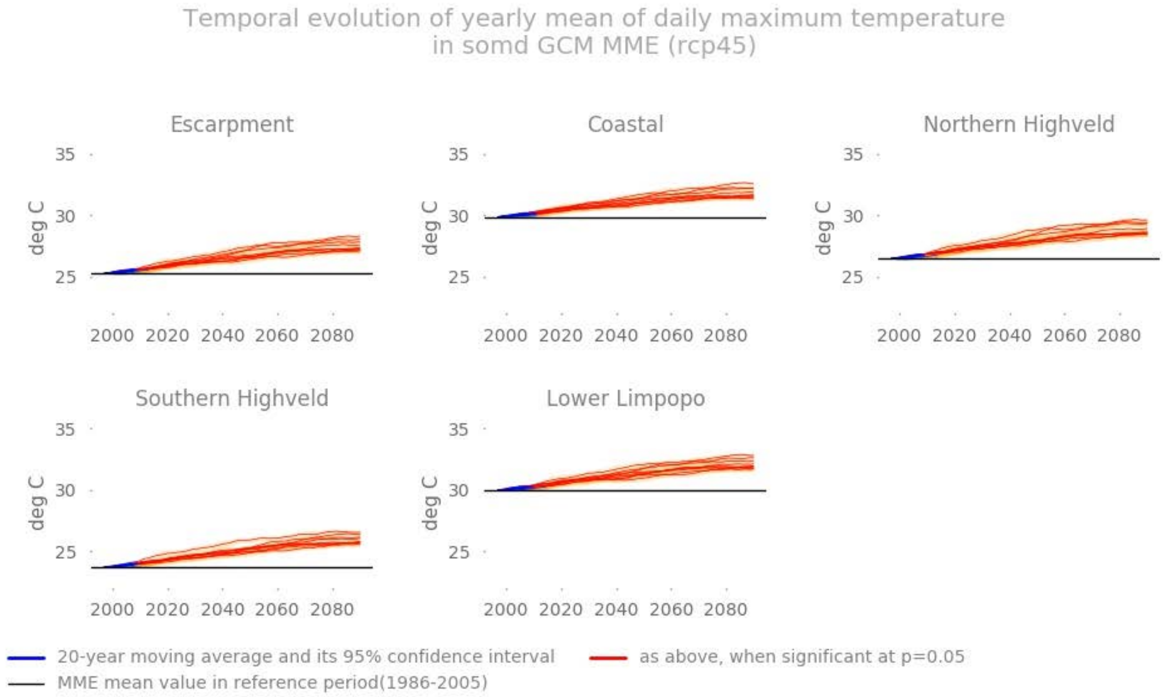
Note that for the remainder of this document, a bad case scenario refers to RCP 8.5 and a good case scenario refers to RCP 4.5.

Temperature

By examining all of the plume graphs on the projected evolution of temperature-related variables, a few highlights emerged.

- Under the RCP4.5 scenario, all five climate regions showed similarities in projected increases in daily maximum temperate, ranging about 1°C to 2°C by 2040 and about 2°C to 3°C by 2080.
- Under the RCP8.5 scenario, all five climate regions showed similar projected increases in daily maximum temperature, but generally greater increases were relative to those under RCP4.5. This ranged from 2°C to 3°C by 2040 and mostly from 4°C to 5°C by 2080.
- Under the RCP4.5 scenario, the projected increases in the number of days with maximum temperatures exceeding 36°C varied greatly across the five climate regions. Both Lower Limpopo and Coastal regions had the highest increase and the greatest range of increase in the number of days, followed by the Northern Highveld and Escarpment. The projected increase in the Southern Highveld appeared minimal.

- Under the RCP8.5 scenario, the projected increases in the number of days with maximum temperatures exceeding 36°C varied to a smaller degree across the five climate regions relative to those under RCP4.5. The ranking from the greatest to the smallest increase was the same under both RCPs, but the amount of increase was more pronounced under RCP8.5.



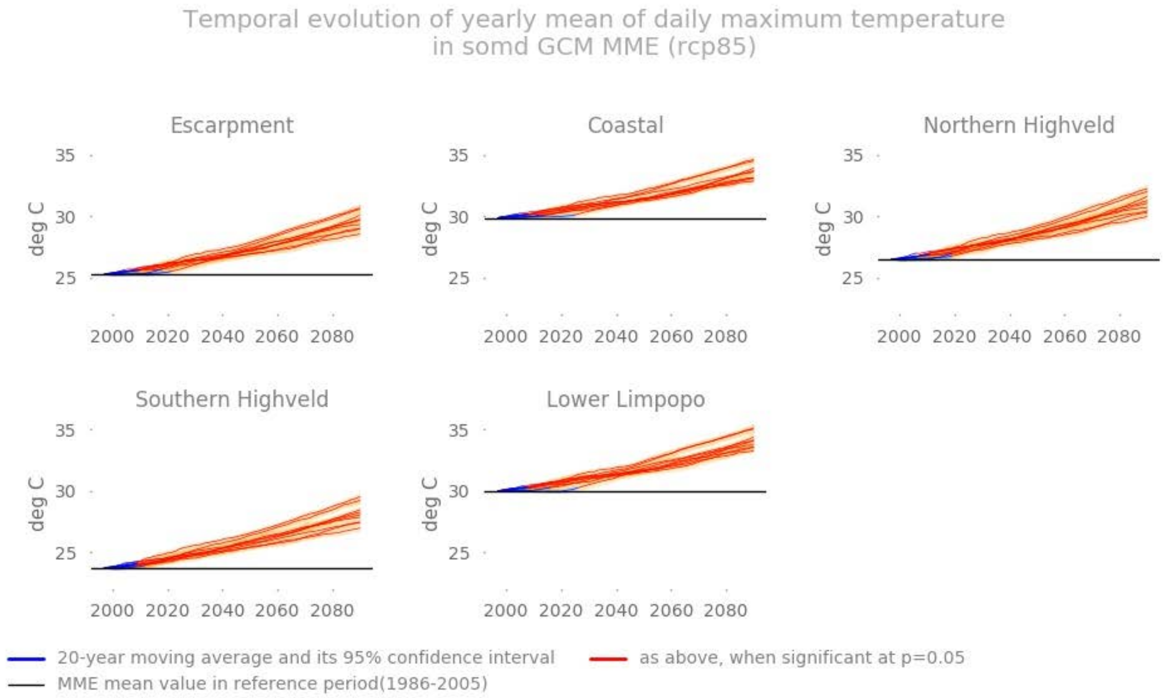
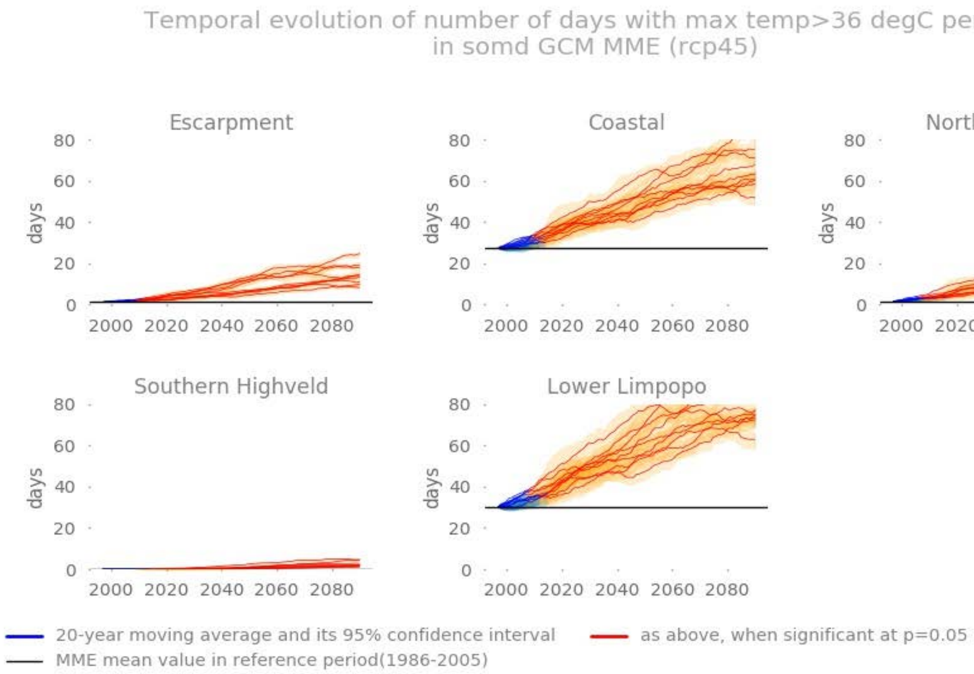


Figure 3. Downscaled projected evolution of yearly mean of daily maximum temperature based on an ensemble of GCMs for (a) RCP4.5 and (b) RCP8.5 (Source: CSAG 2018)



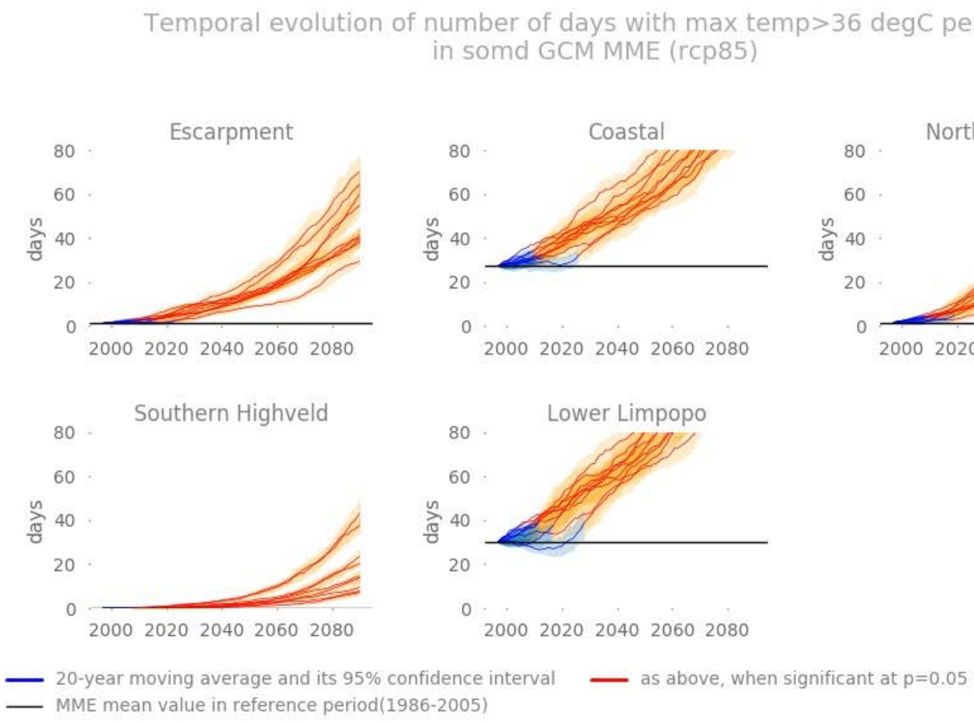


Figure 4. Downscaled projected evolution of number of days with maximum temperature exceeding 36°C based on an ensemble of GCMs for (a) RCP4.5 and (b) RCP8.5 (Source: CSAG 2018)

TABLE 3. THE PROJECTED CHANGE IN DAILY MAXIMUM TEMPERATURE AND NUMBER OF DAYS WITH MAXIMUM TEMPERATURE GREATER THAN 36°C FOR THE CLIMATE REGIONS BY 2020, 2040 AND 2080. The change is presented as a range from the 10th- to 90th-percentile*. Under all scenarios, an increase in these two variables were projected. (based on CSAG data)

Climate Region & year	RCP4.5		RCP8.5	
	Daily max temp	No. of days temp > 36 °C	Daily max temp	No. of days temp > 36 °C
Escarpment				
2020	↑ 1°C	↑ 3 to 6	↑ 1 to 2°C	↑ 3 to 10
2040	↑ 2°C	↑ 4 to 11	↑ 2°C	↑ 9 to 13
2080	↑ 2 to 3°C	↑ 11 to 21	↑ 4 to 5°C	↑ 29 to 27
Coastal				
2020	↑ 1°C	↑ 15 to 25	↑ 1°C	↑ 13 to 30
2040	↑ 1 to 2°C	↑ 22 to 27	↑ 2°C	↑ 28 to 39
2080	↑ 2 to 3°C	↑ 36 to 55	↑ 3 to 4°C	↑ 73 to 106
Northern Highveld				
2020	↑ 1°C	↑ 5 to 11	↑ 2°C	↑ 6 to 15
2040	↑ 1 to 2°C	↑ 7 to 22	↑ 2 to 3°C	↑ 19 to 26
2080	↑ 2 to 3°C	↑ 17 to 40	↑ 4 to 5°C	↑ 45 to 93
Southern Highveld				
2020	↑ 1°C	↑ 0 to 1	↑ 2°C	↑ 0 to 1
2040	↑ 1 to 2°C	↑ 0 to 1	↑ 2 to 3°C	↑ 1 to 3
2080	↑ 2 to 3°C	↑ 1 to 4	↑ 4 to 5°C	↑ 3 to 26
Lower Limpopo				
2020	↑ 1°C	↑ 21 to 28	↑ 1 to 2°C	↑ 18 to 42
2040	↑ 1 to 2°C	↑ 30 to 37	↑ 2°C	↑ 46 to 54
2080	↑ 3°C	↑ 51 to 60	↑ 4°C	↑ 97 to 132

*Note that these figures were rounded to ease interpretation

TABLE 4. THE PROJECTED DAILY MAXIMUM TEMPERATURE AND NUMBER OF DAYS WITH MAXIMUM TEMPERATURE GREATER THAN 36°C FOR THE CLIMATE REGIONS.

This is presented as range from the 10th- to 90th-percentile*. (based on CSAG data)

Climate Region and year	RCP4.5		RCP8.5	
	Daily max temp	No. of days temp > 36°C	Daily max temp	No. of days temp > 36°C
Escarpment				
2020	26 to 27°C	4 to 9	27 to 28°C	5 to 14
2040	27 to 28°C	5 to 14	28°C	11 to 17
2080	28 to 29°C	12 to 24	30 to 31°C	31 to 70
Coastal				
2020	31 to 32°C	44 to 63	30 to 32°C	44 to 68
2040	31 to 32°C	52 to 65	32°C	59 to 77
2080	32 to 33°C	66 to 93	33 to 35°C	104 to 144
Northern Highveld				
2020	27 to 28°C	8 to 17	28 to 29°C	9 to 22
2040	28 to 29°C	9 to 27	29 to 30°C	22 to 33
2080	29 to 30°C	20 to 45	31 to 33°C	48 to 100
Southern Highveld				
2020	24 to 25°C	0 to 1	25 to 26°C	0 to 1
2040	25 to 26°C	0 to 1	26 to 27°C	1 to 3
2080	26 to 27°C	1 to 4	28 to 29°C	3 to 26
Lower Limpopo				
2020	31 to 32°C	55 to 80	31 to 33°C	55 to 91
2040	32°C	65 to 89	32 to 33°C	83 to 103
2080	33 to 34°C	86 to 112	34 to 36°C	134 to 181

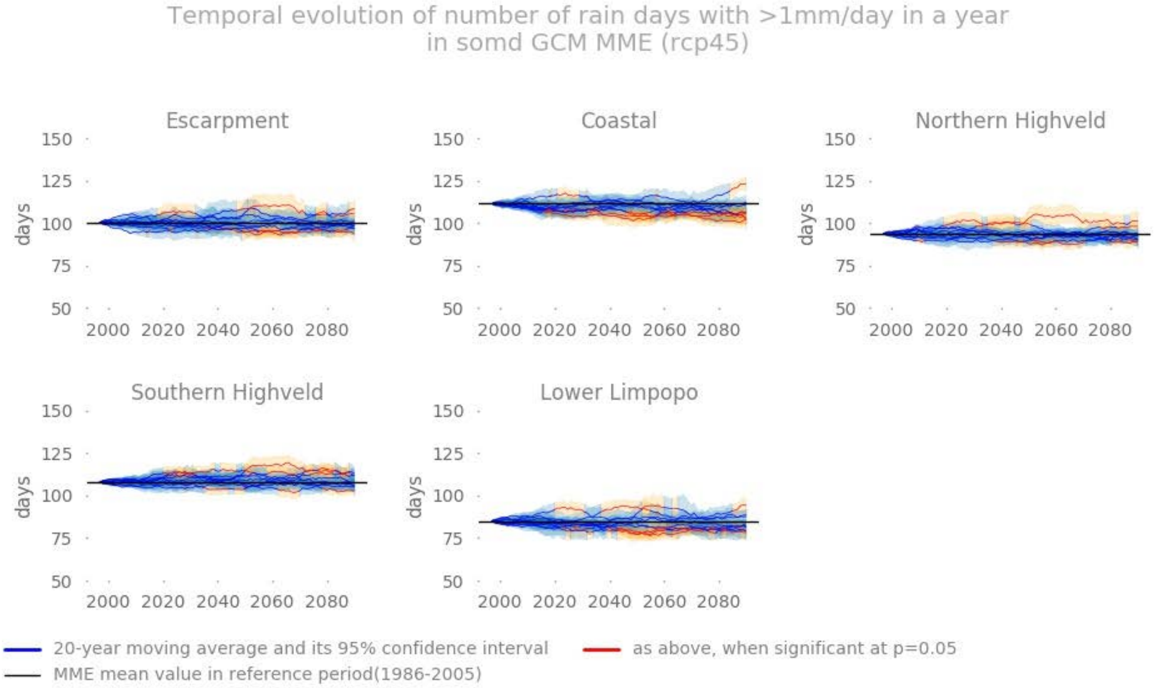
*Note that these figures were rounded to ease interpretation.

Rainfall

In general, there was no consensus in the projected trends of rainfall related variables under both RCP scenarios. The highlights of these projections are summarised as follows.

- With regard to the total annual rainfall, most GCMs projected no change except for one or two models that projected either an increase or decrease under the RCP4.5 scenario. Similarly, most models projected no change under RCP8.5, but four models projected a decrease for the Escarpment, Lower Limpopo and Coastal regions. (See
-
- Figure 5).
- With regard to the number of rain days and the number of heavy rain days (amount exceeding 95-percentile) in a year, most GCMs projected no change except for one or two models which projected either an increase or decrease for four of the five climate regions under the RCP4.5

scenario.



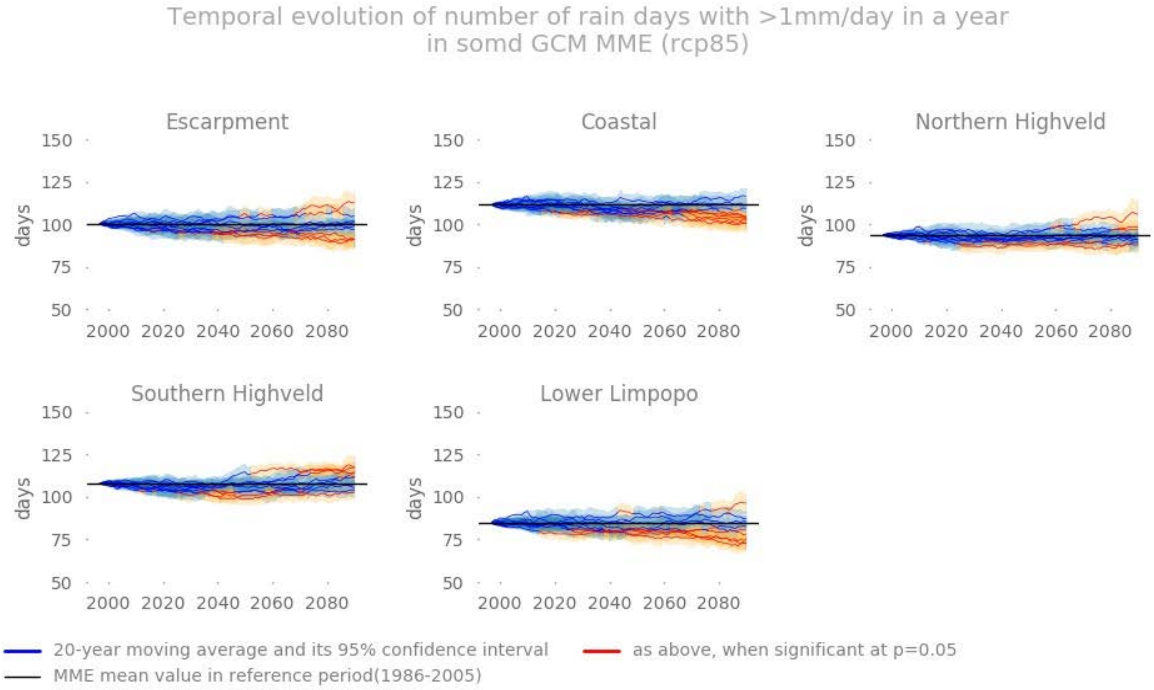


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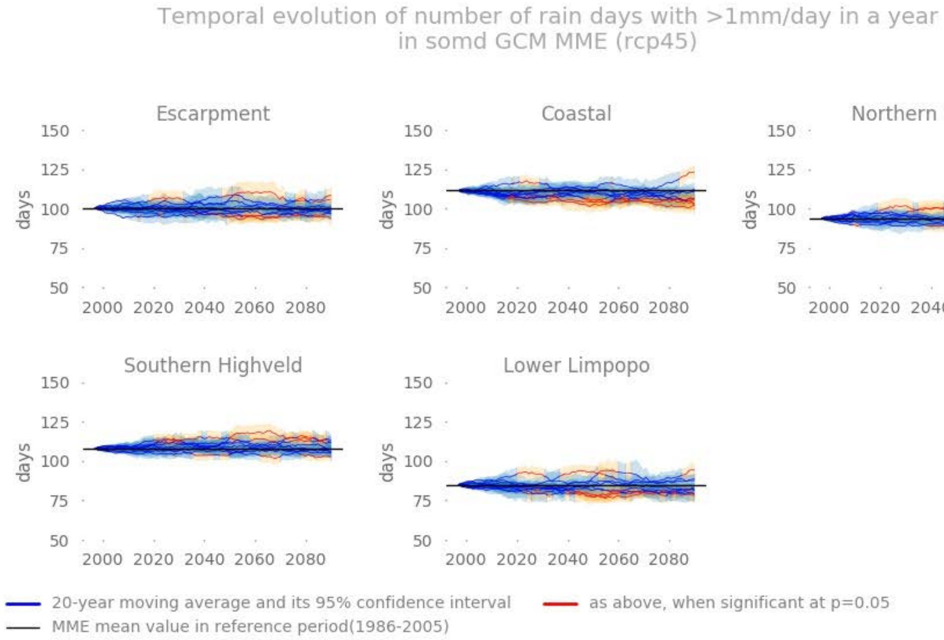
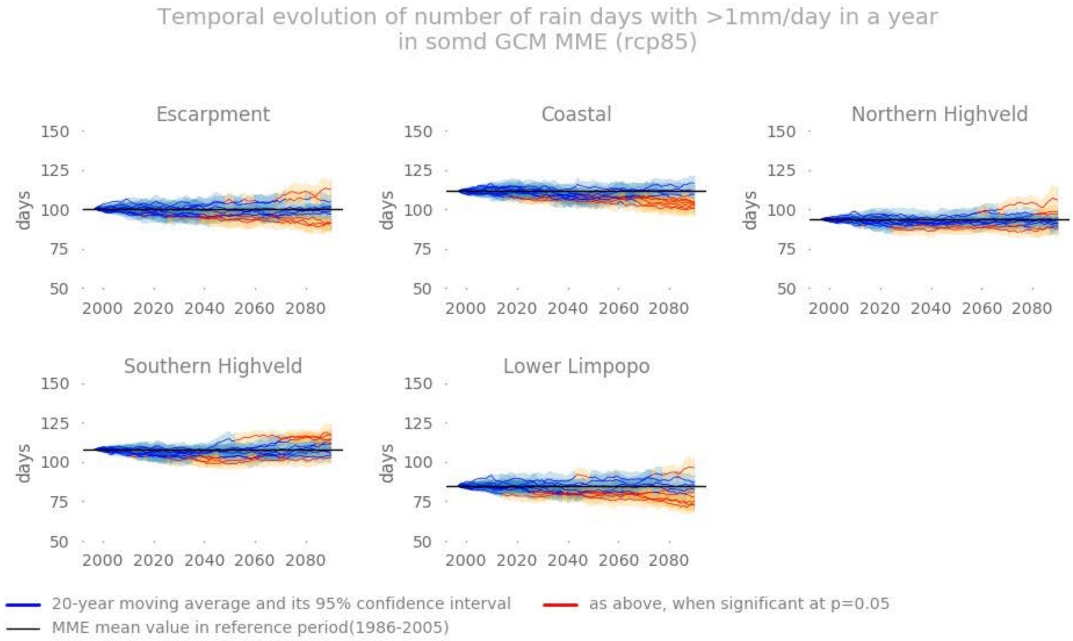
Figure 6 and Figure 7).





- Similarly, most models projected no change in the number of rain days and the number of heavy rain days (amount exceeding 95-percentile) in a year under RCP8.5, but more models projected a decrease for the Escarpment, Lower Limpopo and Coastal regions relative to RCP4.5. (See Figure 6 and Figure 7).
- With regard to the duration of dry spells, most of the models projected no change under both RCP4.5 and RCP8.5 across all climate regions except for the Coastal region, where there was a substantially higher number of models that projected a decrease under RCP8.5. (See Figure 8).

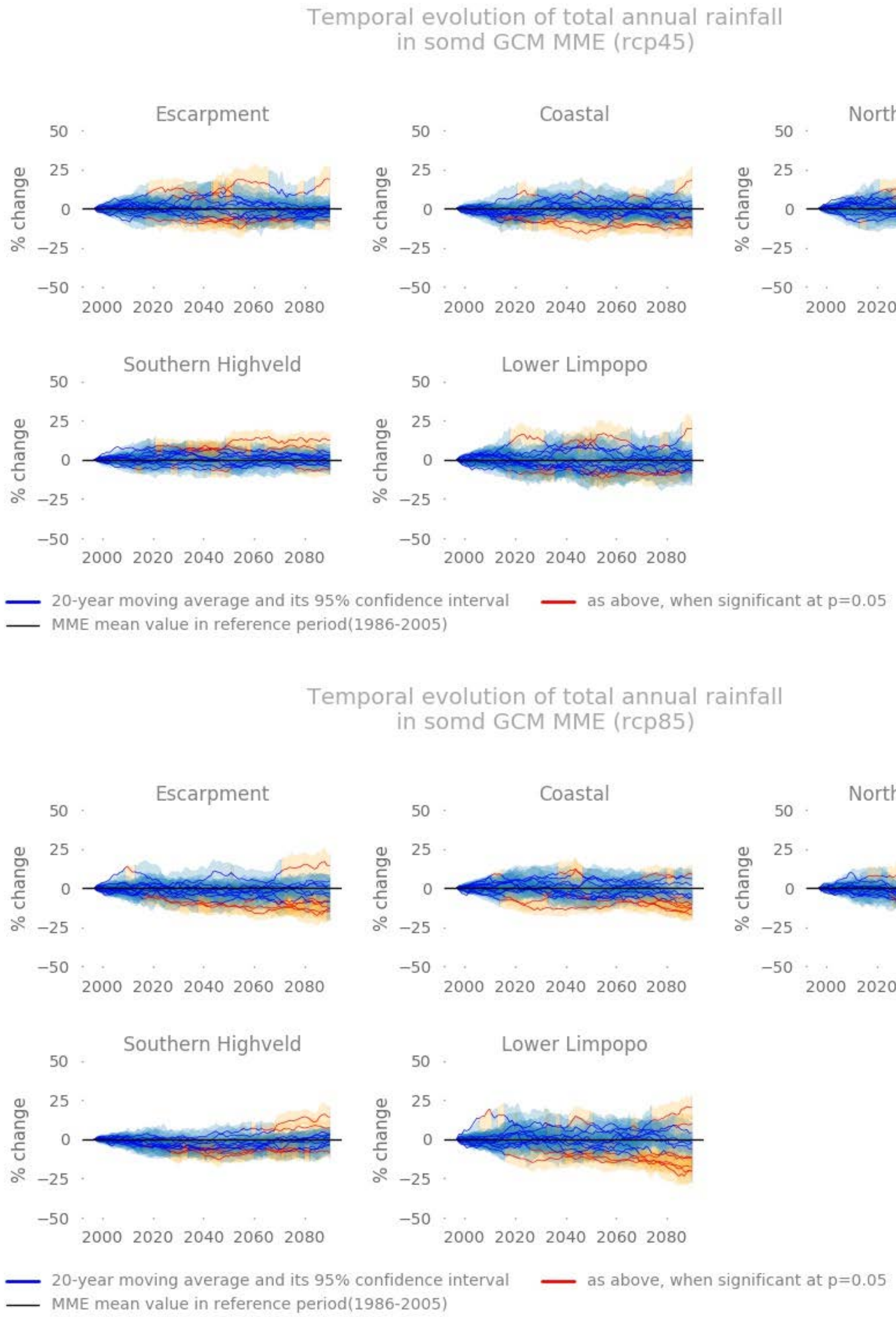


Figure 5. Downscaled projected evolution of total annual rainfall as a percentage of change from a reference period based on an ensemble of GCMs for (a) RCP4.5 and (b) RCP8.5 (Source: CSAG 2018)

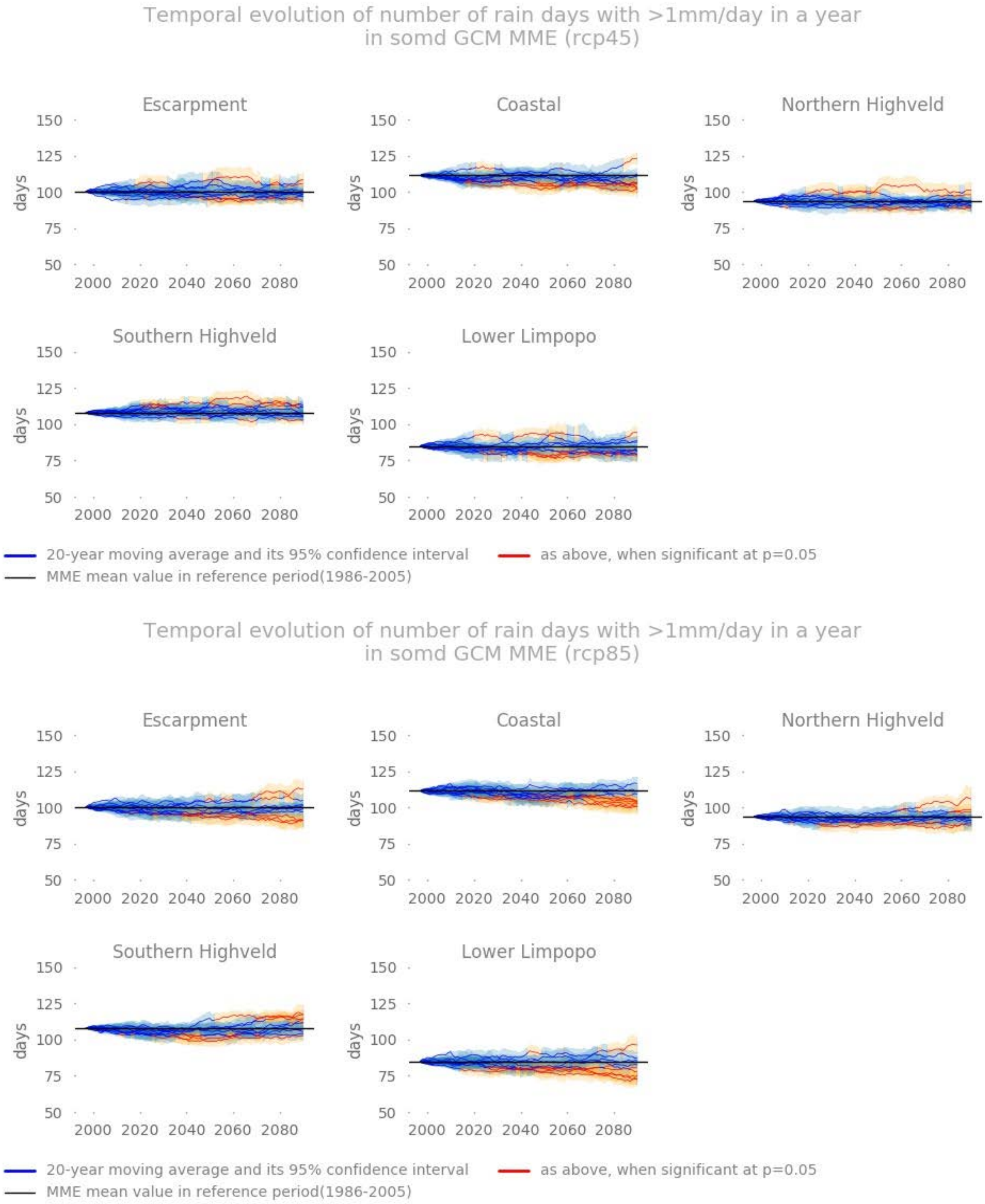
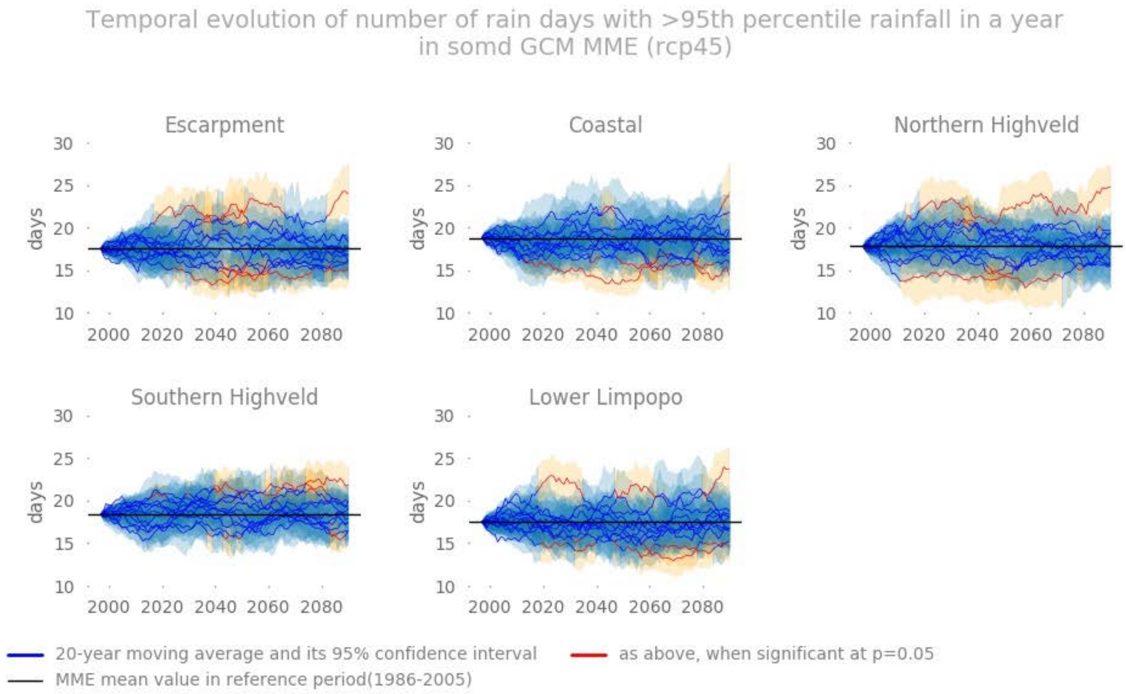


Figure 6. Downscaled projected evolution of number of rain days based on an ensemble of GCMs for (a) RCP4.5 and (b) RCP8.5(Source: CSAG 2018)



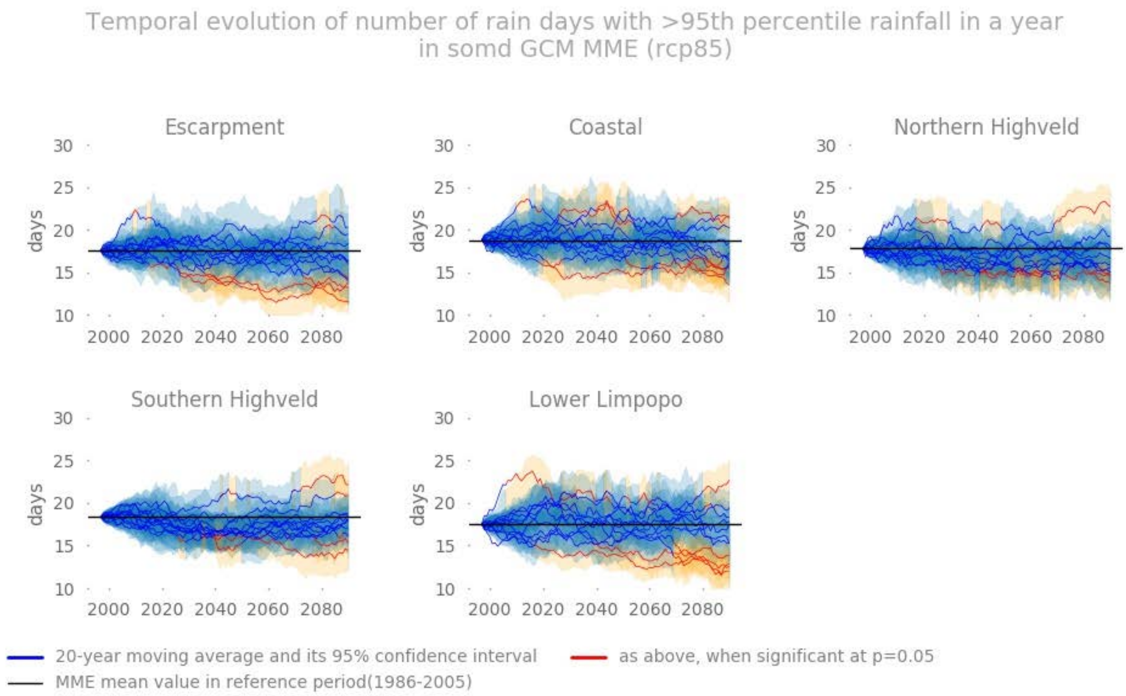


Figure 7. Downscaled projected evolution of number of days with heavy rainfall where amount exceeds 95-percentile based on an ensemble of GCMs for (a) RCP4.5 and (b) RCP8.5 (Source: CSAG 2018)

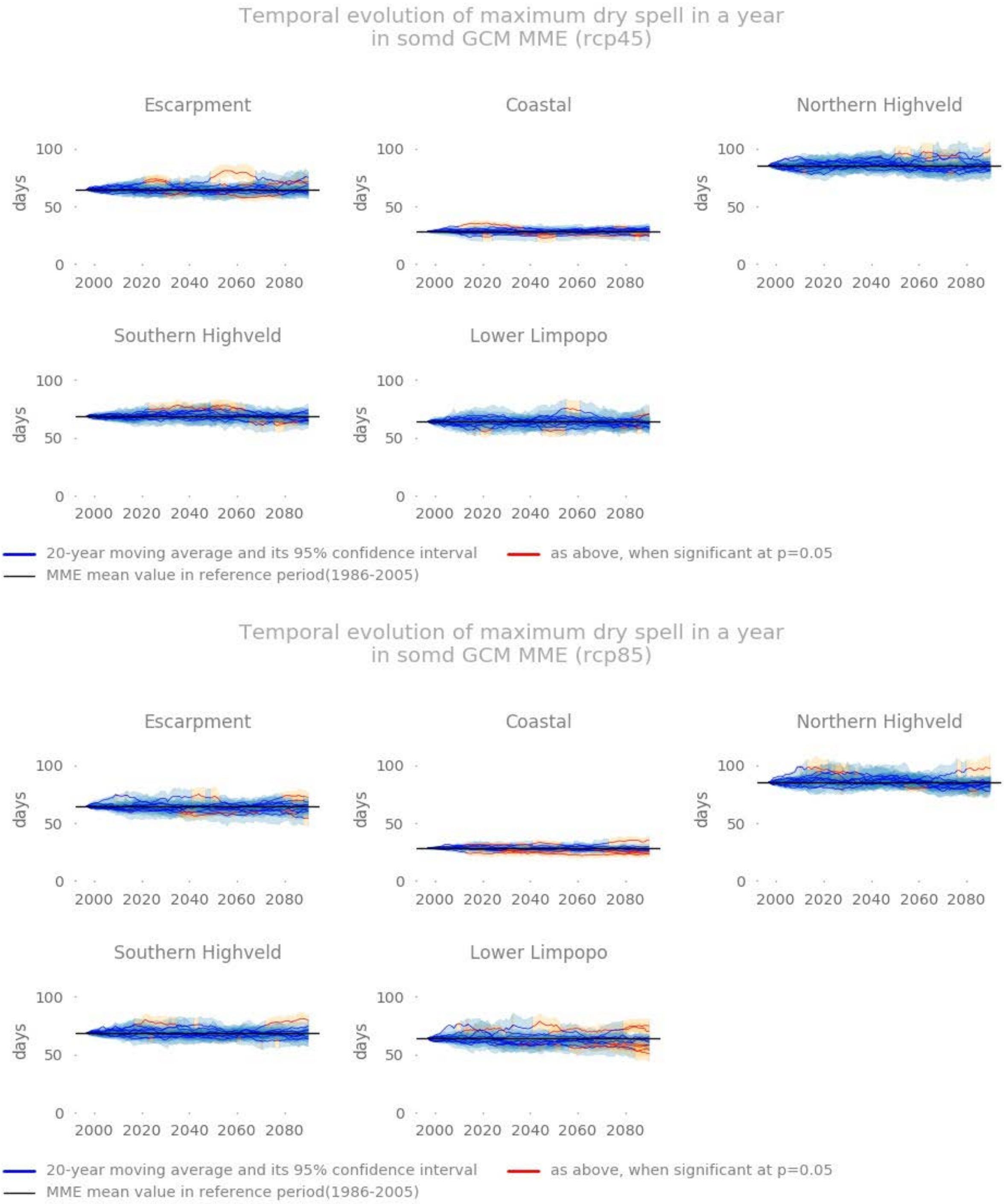


Figure 8. Downscaled projected evolution of maximum duration of dry spell in a year based on an ensemble of GCMs for (a) RCP4.5 and (b) RCP8.5 (Source: CSAG 2018)

TABLE 5. PROJECTED CHANGES IN THE TOTAL ANNUAL RAINFALL AND NUMBER OF HEAVY RAINFALL DAYS (EXCEEDING 20 MM) (BASED ON CSAG DATA)

Climate Regions	RCP4.5		RCP8.5	
	Total annual rainfall	No. of heavy rain days (>20 mm)	Total annual rainfall	No. of heavy rain days (>20 mm)
Northern Highveld	Mostly no change 1 model ↑ post-2020 1 model intermittently ↑ post-2040	Mostly no change 2 models ↑ post-2020 2 models intermittently ↓ post-2040	Mostly no change 1 model briefly ↑ post-2060 4 models ↓ post-2020	Mostly no change 1 model intermittently ↑ and 1 model ↓ post-2040
Southern Highveld	Mostly no change 2 models ↑ post-2040 1 model intermittently ↓ post-2020	Mostly no change 1 model intermittently ↑ and 1 intermittently ↓ post-2040	Mostly no change 2 models ↑ post-2060 3 models ↓ post-2020	Mostly no change 1 model ↑ post-2080 2 models intermittently ↓ post-2040
Escarpment	Mostly no change 1 model ↑ and 2 models intermittently ↓ post-2020	Mostly no change 1 model ↑ and 2 models ↓ post-2020	Mostly no change 1 model ↑ post-2060 4 models ↓ post-2020	Mostly no change 2 models ↓ post-2020 1 model intermittently ↓ post-2040
Lower Limpopo	Mostly no change 1 model intermittently ↑ 1 model intermittently ↓ post-2020	Mostly no change 1 model ↑ near future 2 models ↓ post-2020	Mostly no change 1 model intermittently ↑ post-2020 4 models ↓ post-2020	Mostly no change 1 model intermittently ↑ post-2020 1 model ↓ post-2020 2 models ↓ post-2040
Coastal	Mostly no change 1 model intermittently ↑ and 2 models ↓ post-2020	Mostly no change 2 models ↓ post-2020	Mostly no change 1 model intermittently ↑ post-2020 5 models ↓ post-2020	Mostly no change 1 model intermittently ↑ 2 models ↓ post-2040 2 models ↓ post-2080

Annex A: CHIRPS, CRU and 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[7]. It is a meteorological forcing dataset extending into early 21st century (1979 – 2014). Eight meteorological variables are available at three-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 origins, 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 6. 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

[7] *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 from 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://cmippcmdi.llnl.gov/cmip5/availability. html*

TABLE 7. 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	USA
HadGEM2-CC	Met Office Hadley Centre	UK
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	USA
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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