



ICLEI – Local Governments for Sustainability – Africa  
Climate Change Projections for Dar es Salaam: Adding value through downscaling



**\*Title:** Climate Change Projections for Dar es Salaam: Adding value through downscaling  
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**\*Report Type:** Research document  
**\*Date:** March 2012

**\*IDRC Project Number-Component Number:** 105868-001  
**\*IDRC Project Title:** Sub-Saharan African Cities: A Five-City Network to Pioneer Climate Adaptation through Participatory Research and Local Action.  
**\*Country/Region:** Namibia, South Africa, Mozambique, Tanzania, Mauritius

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**\*Abstract:**

This project addresses knowledge, resource, capacity and networking gaps on the theme: 'Strengthening urban governments in planning adaptation.'

The main objective of this project is to develop an adaptation framework for managing the increased risk to African local government and their communities due to climate change impact. The ultimate beneficiaries of this project will be African local governments and their communities. The guiding and well-tested ICLEI principle of locally designed and owned projects for the global common good, specifically in a developing world context, will be applied throughout project design, inception and delivery.

Additionally, the research will test the theory that the most vulnerable living and working in different geographical, climatic and ecosystem zones will be impacted differently and as such, will require a different set of actions to be taken. Potential commonalities will be sought towards regional participatory learning and wider applicability. The five urban centres chosen for this study, based on selection criteria, include: Cape Town, South Africa, Dar es Salaam, Tanzania; Maputo, Mozambique; Windhoek, Namibia; and Port St. Louis, Mauritius.

Through a participatory process, this project will carry out a desk-top study, long-term, multi-discipline, multi-sectoral stakeholder platforms in five Southern African cities comprising of academics, communities and the local government in order to facilitate knowledge-sharing, promote proactive climate adaptation and resource opportunities available for African cities, develop five tailor-made Adaptation Frameworks and explore regional applicability. A network of stakeholders within each urban centre will be established, feeding into a larger regional network of local authorities and partners in Sub-Saharan Africa, and globally through existing ICLEI global (e.g. the ICLEI Cities for Climate Protection programme), ICLEI Africa and UCLG-A members and networks, ensuring global best practice, roll-out, and long-term sustainability.

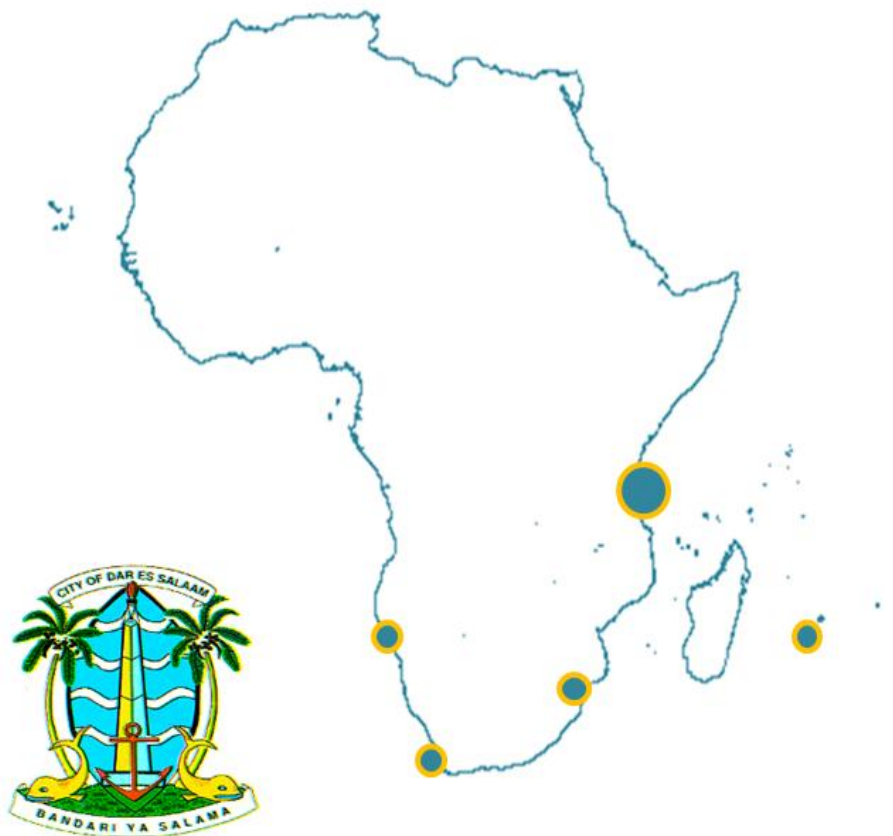
**Key words:** Adaptation, Africa, Climate Change, Local Governments, Participatory Action Research, Policy.

# Sub-Saharan African Cities:

## A Five-City Network to Pioneer Climate Adaptation through Participatory Research and Local Action



### Climate Change Projections for Dar es Salaam: Adding value through downscaling





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**Sub-Saharan African Cities: A five-City Network to Pioneer Climate  
Adaptation through Participatory Research & Local Action**

**Climate Change Projections for Dar es Salaam: Adding value through  
downscaling**

**March 2012**

**Authors: Mark Tadross and Peter Johnston**

**ISBN: 978-0-9921794-9-6**



## Contents

Preface.....	6
1 Historical observations and trends from Dar es Salaam .....	7
1.1 Climate of Dar es Salaam.....	7
1.2 Historical trends in climate at Dar es Salaam.....	8
2 GCM projections of future change (for 2050) .....	12
2.1 Rainfall.....	12
2.2 Temperature.....	14
2.3 Winds.....	15
3 Statistically downscaled projection of future changes in rainfall, temperature and evaporation .....	16
3.1 Rainfall.....	17
3.2 Temperature.....	18
3.3 Evaporation and effective rainfall .....	19
4 Changes in climate extremes.....	21
4.1 Changes in extreme temperatures.....	21
4.2 Changes in extreme rainfall.....	23
5 Dar es Salaam: impacts and vulnerabilities.....	23
5.1 Water and Sanitation.....	24
5.2 Transport .....	24
5.3 Health .....	25
5.4 Energy.....	25



## Preface

Climate change is expected to have severe physical, social, environmental and economic impacts on cities worldwide, both directly and indirectly. Although there are some uncertainties surrounding the understanding of earth's complex systems, there is strong evidence in current literature and climatic measurements to demonstrate that, as a result of increasing greenhouse gas emissions, atmospheric, land and sea surface temperatures are rising. Global model projections have demonstrated that temperature and rainfall changes throughout Africa, increased frequency of storms and sea-level rise in sub-tropical Oceans, will expose current vulnerabilities of coastal (and other) cities, whilst also potentially heightening risks associated with food security and water resources.

Global Climate Model (GCM) projections of change are presented and discussed in 'the baseline climate report for southern African countries including: Namibia, South Africa, Mozambique, Tanzania and Mauritius'.<sup>1</sup> This report shows the results from applying a downscaling methodology developed at the University of Cape Town to nine GCMs and the observed rainfall and temperature data from stations near Dar es Salaam. The downscaling relates daily weather systems to the observed rainfall and temperature at each location on each day (to a point-scale).

Projections are described as being manifested as certain impacts, depending on the region, amongst others;

- changes in rainfall and precipitation patterns (flooding and drought),
- increases in temperature and associated desiccation effects,
- increasing frequency and intensity of storm surges or extreme events,
- increasing average global sea levels due to melting glaciers and thermal expansion (permanent and non-permanent inundation) and,
- changes in wind speed.

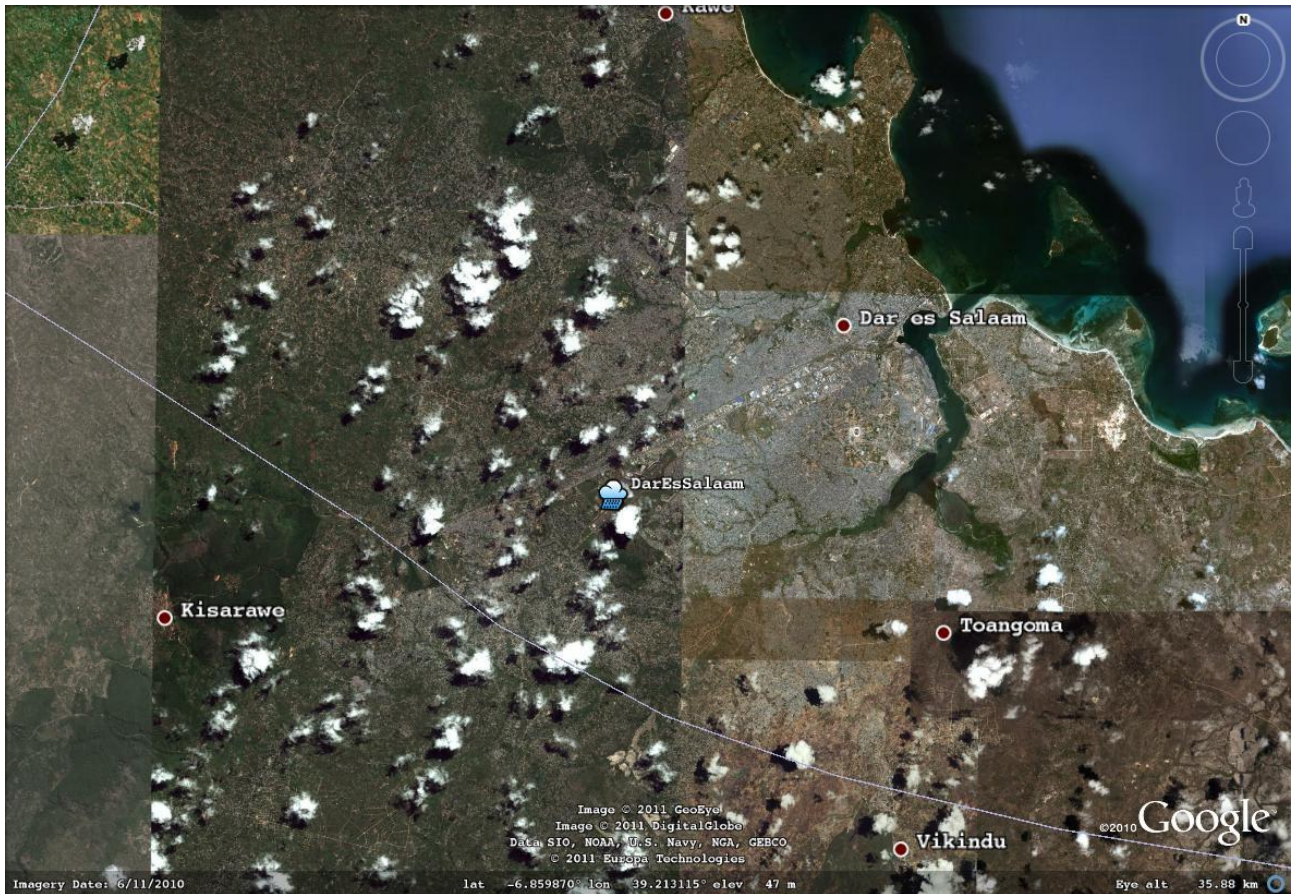
This report will outline impacts and vulnerabilities that the available model results typically imply for Dar es Salaam, as well as discuss constraints given the paucity of available climatological data and the limitations of the current methods. It must be noted that sea-level rise is NOT discussed or presented here, as it does not feature in downscaled projections and has been dealt with in more detail elsewhere.

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<sup>1</sup> Tadross and Johnston, 2011. **Projected Climate Change Over Southern Africa; Namibia, South Africa, Mozambique, Tanzania and Mauritius, Report for ICLEI, February 2011**

## 1 Historical observations and trends from Dar es Salaam

Historical observations of the recent past from weather stations in the vicinity of Dar es Salaam are required in order to understand the current climate context of the city, as well as to be able to identify any historical trends in climate that may be associated with anthropogenic climate change. For this study local rainfall and temperature data from Dar es Salaam were made available from the Tanzanian meteorological agency; these data were also used to produce downscaled estimates of changes in rainfall and temperature under anthropogenic climate change. Figure 1 shows the location of the available weather station in Dar es Salaam, at the international airport.



**Figure 1: The weather station for Dar es Salaam is shown by the cloud symbol.**

### 1.1 Climate of Dar es Salaam

The climate along the E Coast of Tanzania, including Dar es Salaam, is tropical with relatively high humidity. The average temperature, which is moderated by the sea breeze, ranges between 27 and 29°C. There are two rain seasons in most of the country: the long season from mid-March through to May and the short rain season during November, December and January.

Daily rainfall and temperature data were available for the Dar es Salaam station between 1981 and 2010 from the Tanzanian meteorological service. The Priestly-Taylor method was used to calculate reference

evapotranspiration<sup>2</sup> ( $ET_0$ ), based on simulated temperatures, solar radiation and altitude. Figure 2 shows the daily climatology (average over all years) of rainfall, temperature and reference evapotranspiration at Dar es Salaam. Seasonal variations in temperature are small with small differences between minimum and maximum temperatures, as is expected for a coastal location in the tropics. Rainfall illustrates the bimodal distribution with peak rainfall during April and May and a dry period during July to September on average.  $ET_0$  is higher than rainfall during most of the year, except during the peak of the main rainfall season.

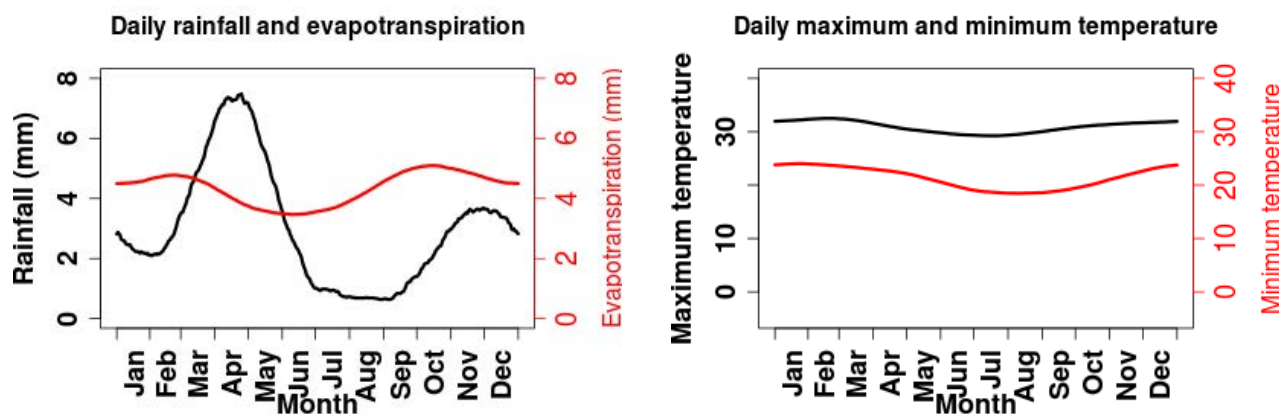


Figure 2: Daily climatology of rainfall ( $\text{mm day}^{-1}$ ), reference evapotranspiration ( $\text{mm day}^{-1}$ ) and minimum and maximum temperatures ( $^{\circ}\text{C}$ ) and at Dar es Salaam.

## 1.2 Historical trends in climate at Dar es Salaam

Any data collected at a weather station must undergo quality control procedures. Such quality control procedures are generally flexible and there are no hard and fast guidelines as to what should be implemented. For example, complex statistical techniques that detect discontinuities in time-series (usually indicating the relocation or deterioration of a sensor) can be used with historical data, though these do not work as well for rainfall data. In this analysis it was decided to use the following simple tests and data was removed if it failed any of them:

- check for duplicate or missing records;
- check for negative rainfall (an impossibility in reality);
- check for rainfall  $> 500$  mm in one day (also impossible);
- remove data more than 6 standard deviations from the mean (this would indicate an error in reading);
- remove data where minimum temperatures are greater than maximum temperatures (nonsensical).

The remaining data was then used to calculate extreme temperatures and rainfall indices, both on an annual and seasonal basis utilising software distributed by the ETCCDMI<sup>3</sup> and STARDEX<sup>4</sup> projects.

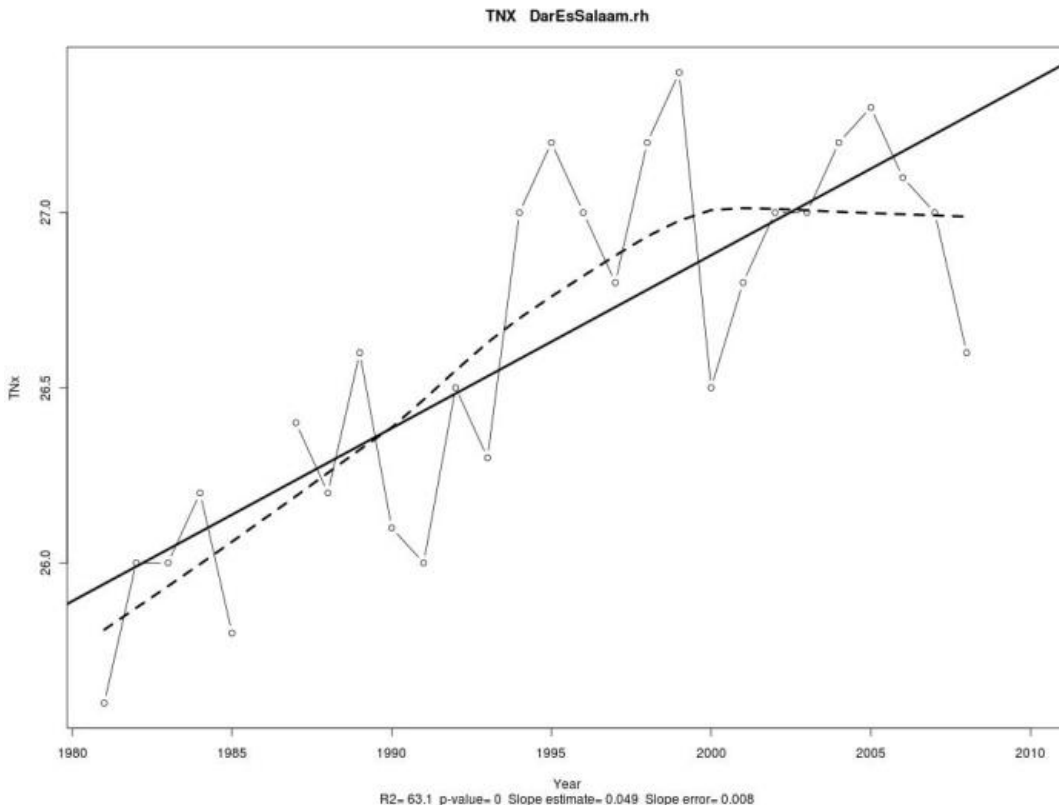
Increasing temperature trends are detectable in a number of temperature indices with the most significant (at the 90% confidence level<sup>5</sup>) for increasing monthly maximums of both minimum and maximum daily temperatures (figure 3).

<sup>2</sup> Reference evapotranspiration ( $ET_0$ ) indicates the amount of water that would be lost due to evaporation and transpiration if it were available. If  $ET$  is higher than rainfall it means that the soil and vegetation will dry out.

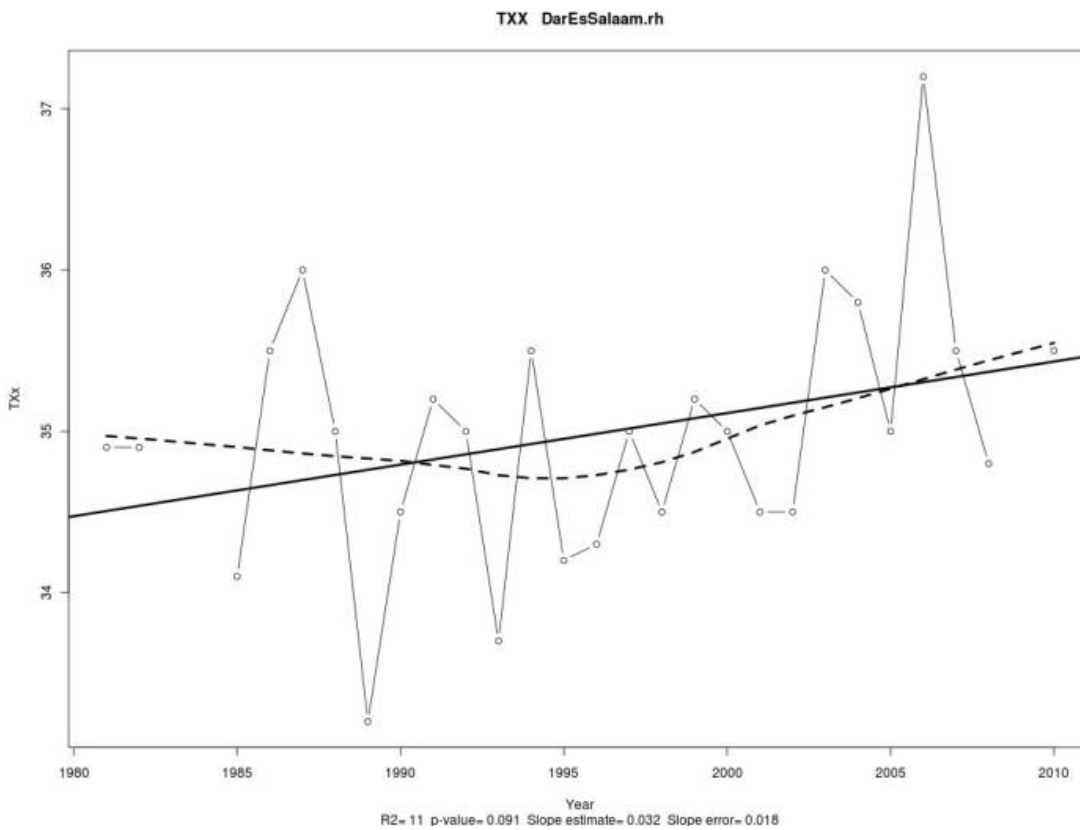
<sup>3</sup> <http://cccma.seos.uvic.ca/ETCCDMI/software.shtml>

<sup>4</sup> <http://www.cru.uea.ac.uk/projects/stardex/>





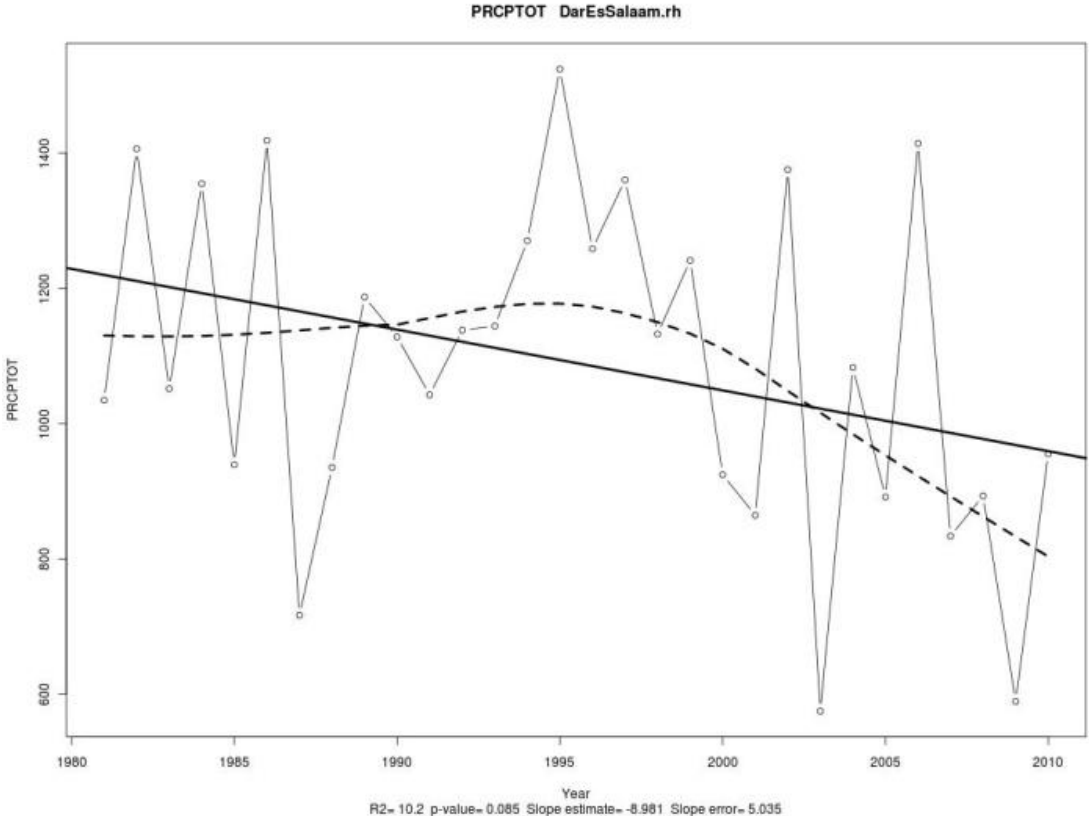
a)



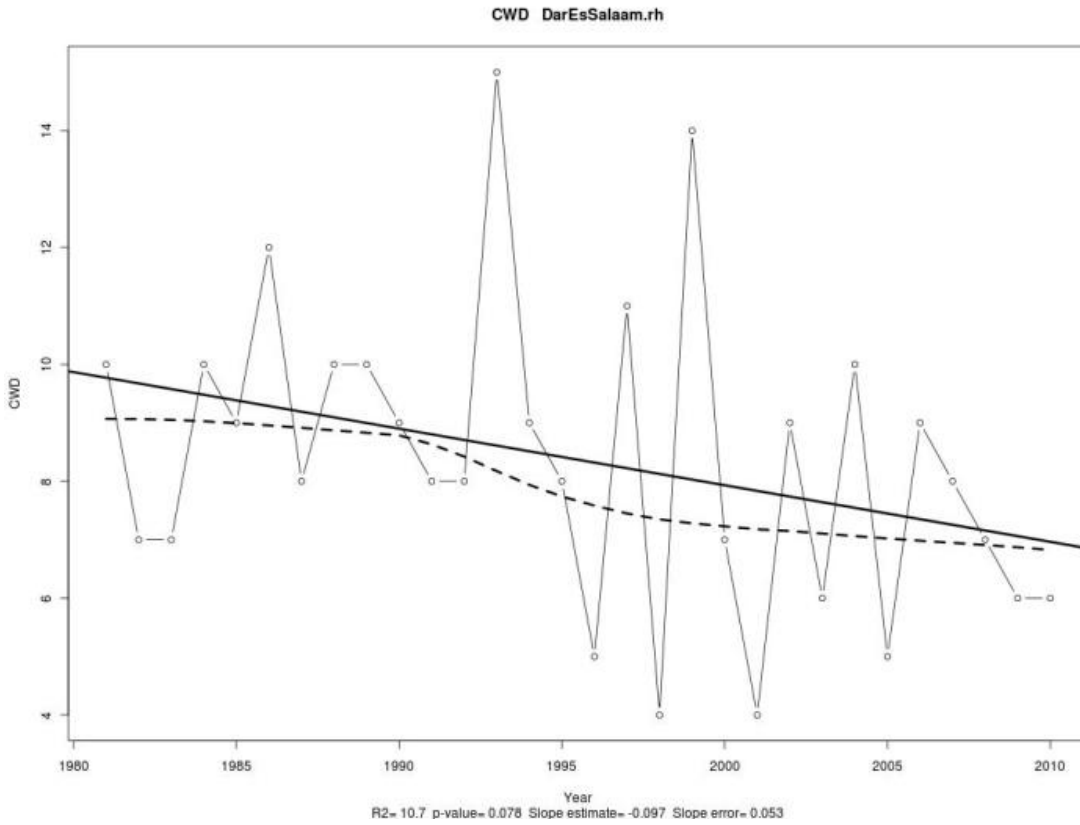
<sup>5</sup> The confidence level is a statistical term for how willing one is to be wrong. With a 90 percent confidence interval, there is a 10 percent chance of being wrong

b)  
**Figure 3: Trends in monthly maximums of (a) daily minimum temperatures and (b) daily maximum temperatures at Dar es Salaam.**

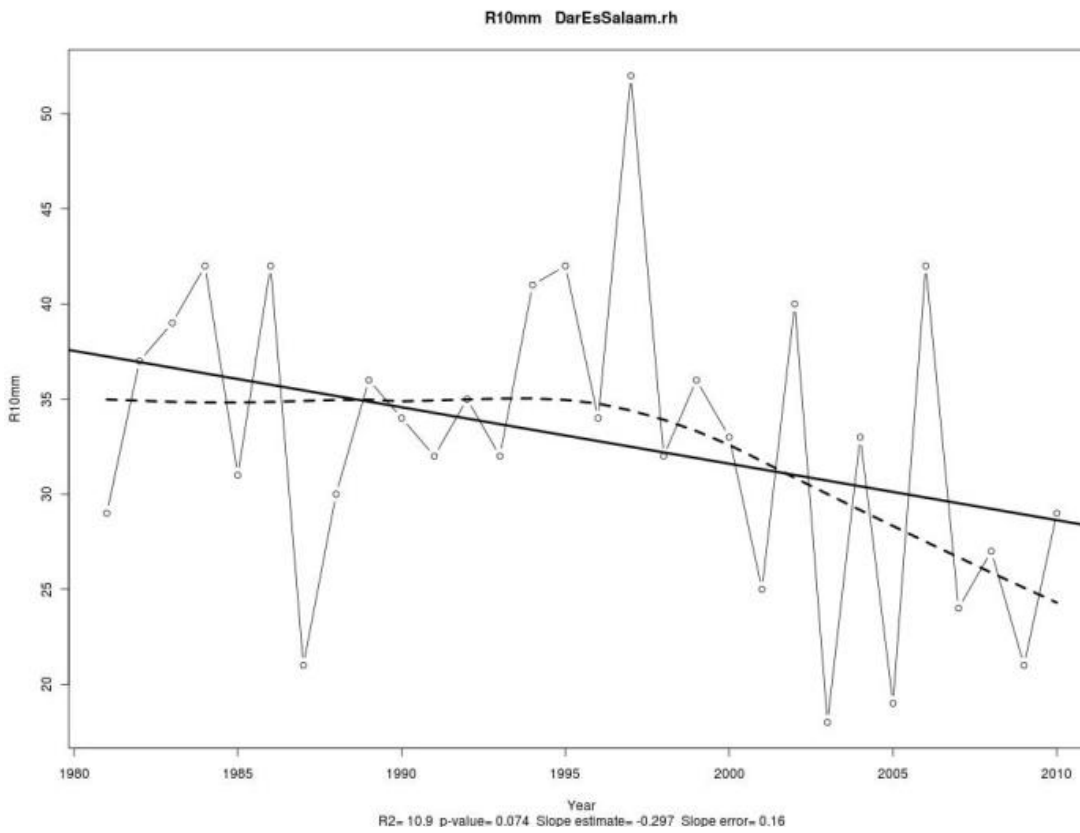
At the annual timescale there were also significant detectable trends in total rainfall decline, as well as the reduction in number of consecutive wet days, days > 10 mm rainfall and days > 20 mm rainfall, all of which are shown in figure 4.



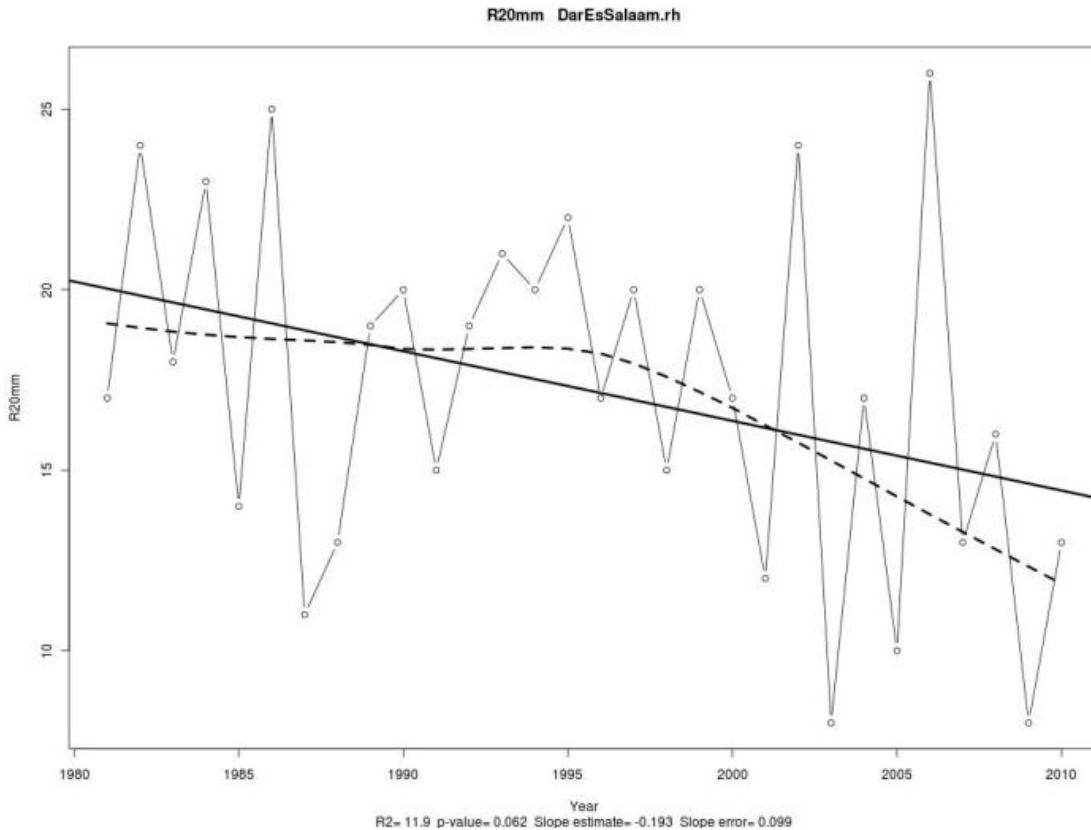
a)



b)



c)



d)

**Figure 4: Trends in (a) total annual rainfall, (b) maximum number of consecutive wet days, (c) number of days > 10 mm and (d) number of days > 20 mm at Dar es Salaam.**

All 4 seasons showed significant increasing trends in daily minimum temperatures, whereas daily maximum temperatures tended to increase most during DJF and JJA. Rainfall changes were significant across a larger range of indices during JJA, which indicated increases in the number of consecutive dry days and decreases in rainfall. There were also indications of decreases in wet spell duration and frequency of consecutive wet-day episodes during MAM.

## 2 GCM projections of future change (for 2050)

GCM projections of change are presented and discussed in the baseline climate report for southern Africa<sup>6</sup> and are shown here with a focus on the region around Dar es Salaam.

### 2.1 Rainfall

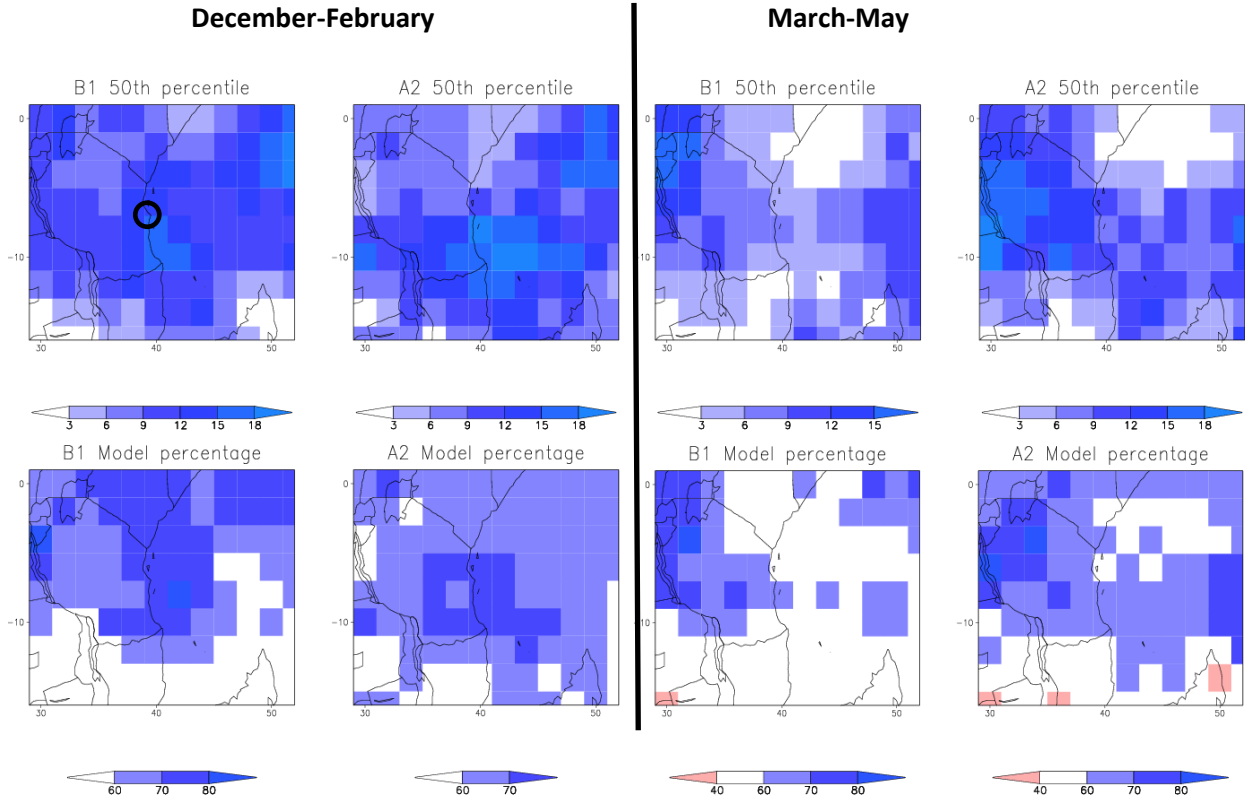
Figure 5 demonstrates how rainfall is expected to change under both a B1 and A2<sup>7</sup> emissions scenario; for each season both the median change (15/13 GCMs were used for the A2/B1 scenario) and percentage of models agreeing on the sign (i.e. increase or decrease) of the change is shown. The median of the models (i.e. the most common outcome) suggests the most likely change for each period, whereas the percentage

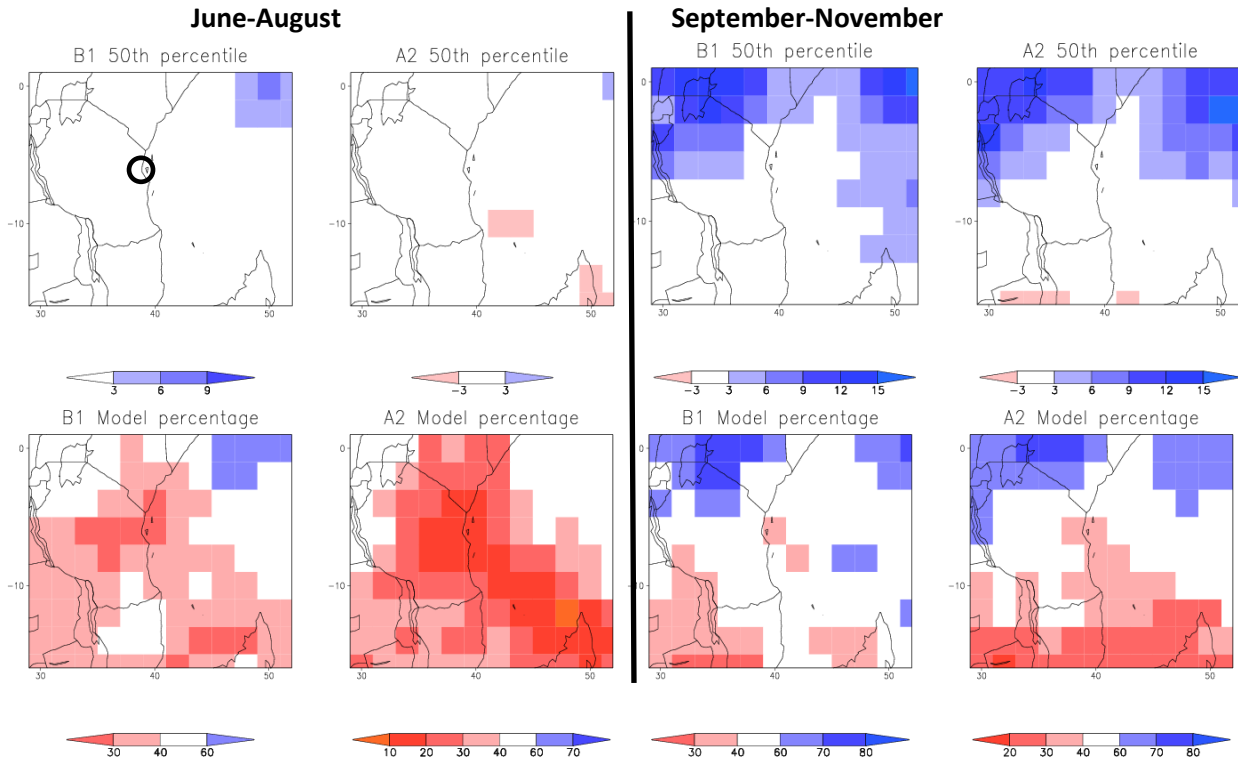
<sup>6</sup> Tadross and Johnston 2011, Projected Climate Change Over Southern Africa; Namibia, South Africa, Mozambique, Tanzania and Mauritius, Report for ICLEI, February 2011

<sup>7</sup> Emissions Scenarios were constructed to explore future developments in the global environment with special reference to the production of greenhouse gases and aerosol precursor emissions. The A2 scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. The B1 scenario family describes a convergent world with the emphasis on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

of models can be taken as an indication of the confidence in whether a positive or negative change is consistently simulated across the GCM models.

If one seeks consistency across GCM models (which could be defined as more than 60% of models agreeing on the sign of change) as well as consistency across both the A2 and B1 scenarios, then increases in rainfall are suggested during December-May, with decreases during June-August. During the September-November period the simulations are less consistent.

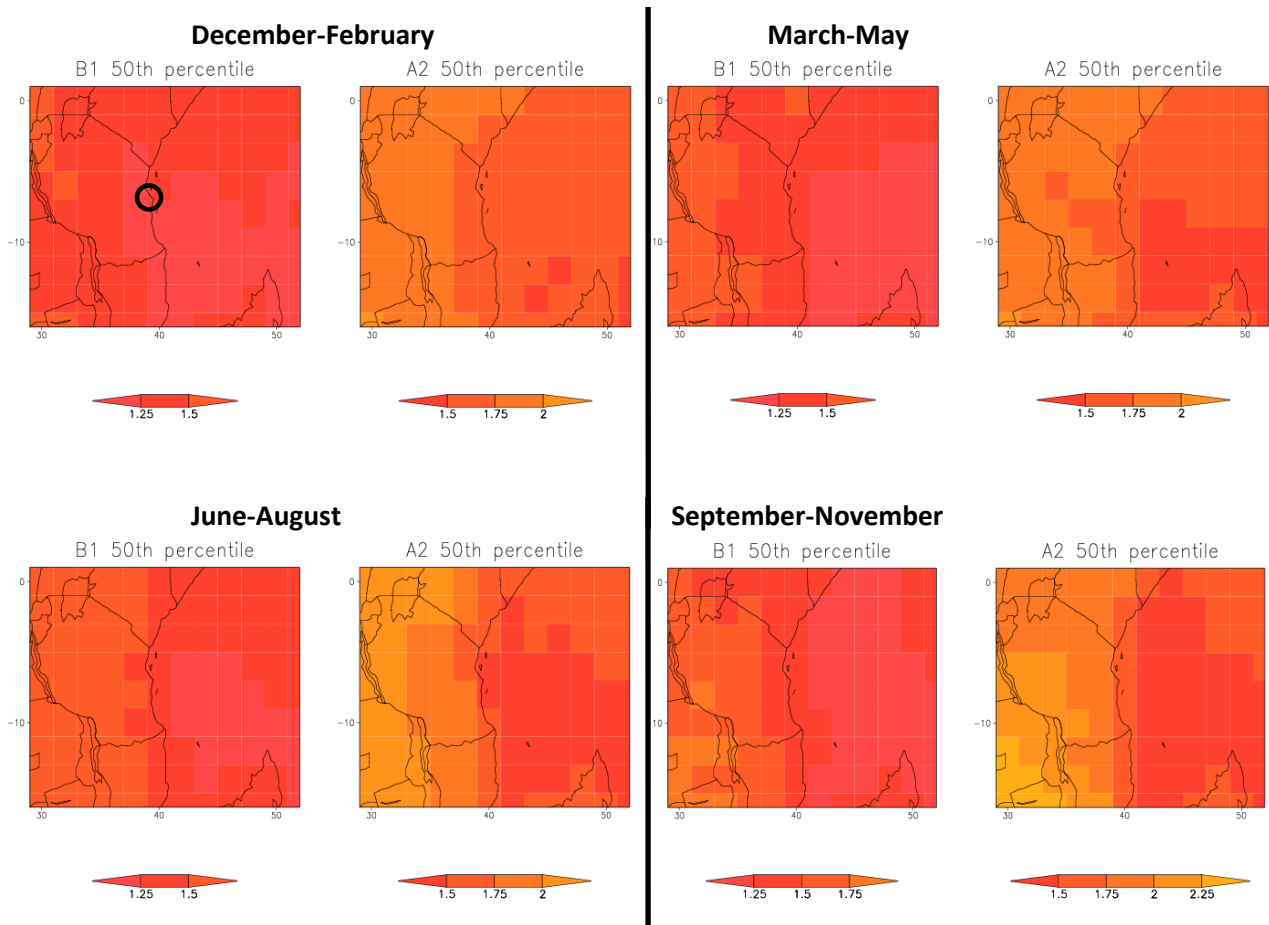




**Figure 5: Median GCM simulations of rainfall change in mm per month by 2050 under A2 and B1 emissions scenarios for each season. The confidence of the model ensemble simulations is indicated by the percentage of models simulating a positive/negative change, indicated by the percentages where less than 40% (lower agreement) is in red shades and more than 60% (greater agreement) is in shades of blue. e.g. if a rainfall increase of 5mm/month is shown but the confidence (model agreement) is only 30%, there is less likelihood of this being a reasonable assumption than if there was a higher confidence such as 60% model agreement.**

## 2.2 Temperature

All GCMs simulate an increase in temperature which results in the median changes shown in figure 6 for both scenarios and all four seasons. Increases are similar for each season depending on the scenario; 1.0-1.5°C for the B1 scenario and 1.5-2.0°C for the A2 scenario in the region of Dar es Salaam. Increases inland are generally more than towards the coast. These are median changes and incorporate a range of projected increases, all positive, in each case.



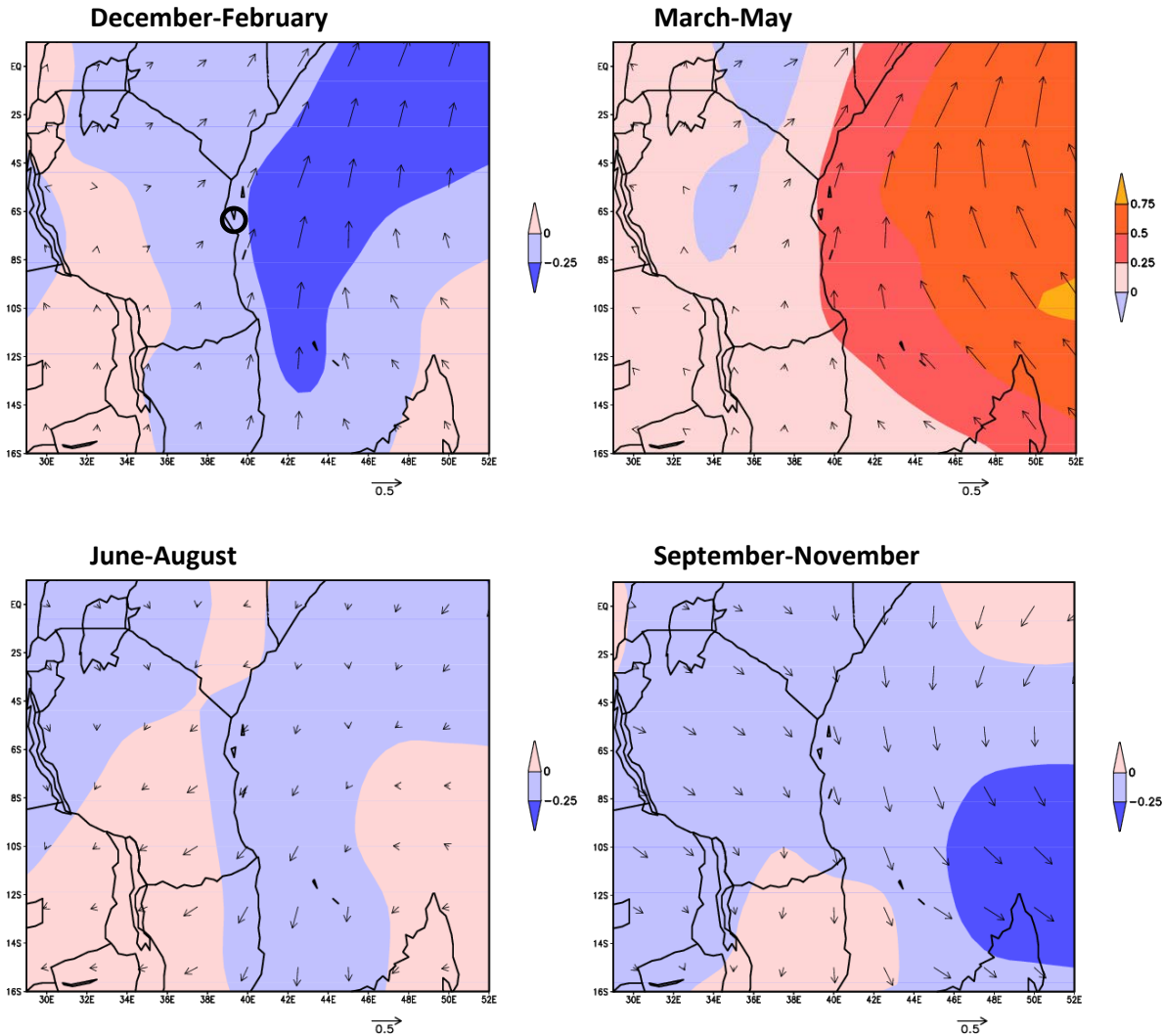
**Figure 6: Median GCM simulations of change by 2050 under A2 and B1 emissions scenarios for each season.**

### 2.3 Winds

Bearing in mind that there are only GCM wind projections available, Figure 7 shows the median changes in surface (actually 10m above the surface) winds simulated under an A2 scenario by 2050; the arrows indicate the changes in direction<sup>8</sup> and the magnitude of that change, while shading shows the changes in net speed of the wind - red shading indicates that median wind speed increases whereas dark blue shading indicates that wind speeds decrease. Wind speeds increase from the south during March-May, whereas they decrease and become more southerly during December-February. This represents a strengthening of the southeast monsoon during March-May and a weakening of the northwest monsoon during December-February.

Changes during June-November are weaker with the suggestion of weak northerly and offshore anomalies during September-November.

<sup>8</sup> Arrows indicate the movement of the wind – e.g. an arrow pointing south indicates a wind coming from the north.



**Figure 7: Median changes in 10m wind directions s simulated under an A2 emissions scenario; shading indicates changes in wind speed (in m/s).**

### 3 Statistically downscaled projection of future changes in rainfall, temperature and evaporation

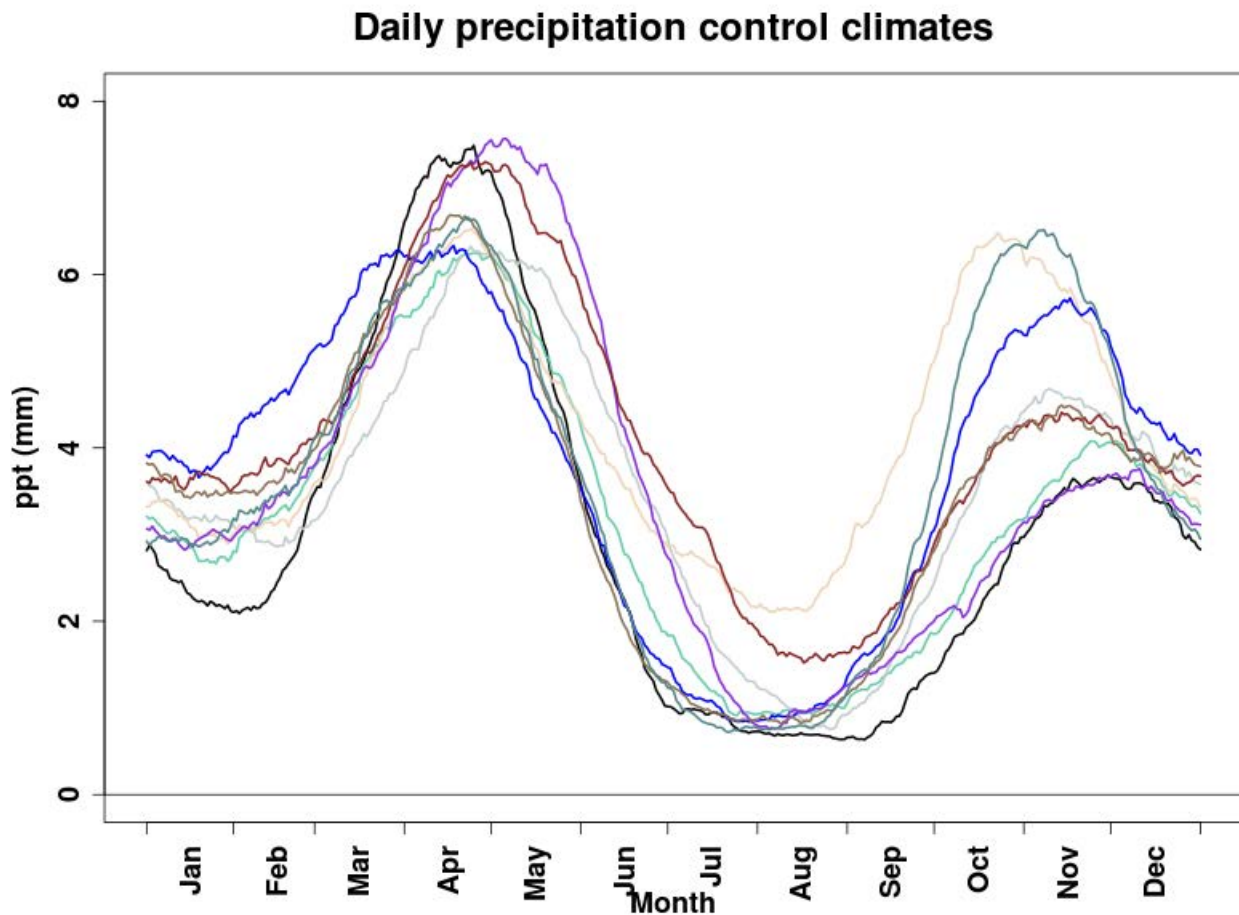
The following sections show the results from applying a downscaling methodology developed at the University of Cape Town to nine suitable GCMs<sup>9</sup> (forced with the A2 emissions scenario) and the observed rainfall and temperature data from the Dar es Salaam station. The downscaling relates daily weather systems to the observed rainfall and temperature at each location on each day. Taking the simulated changes in daily weather systems from each GCM the expected changes in daily rainfall and temperature are simulated for each location. The Priestly-Taylor method was used to calculate reference evapotranspiration ( $ET_0$ ) based on simulated temperatures, solar radiation and altitude.

<sup>9</sup> The suitability of GCMs depends on the frequency of data and the type of variable



### 3.1 Rainfall

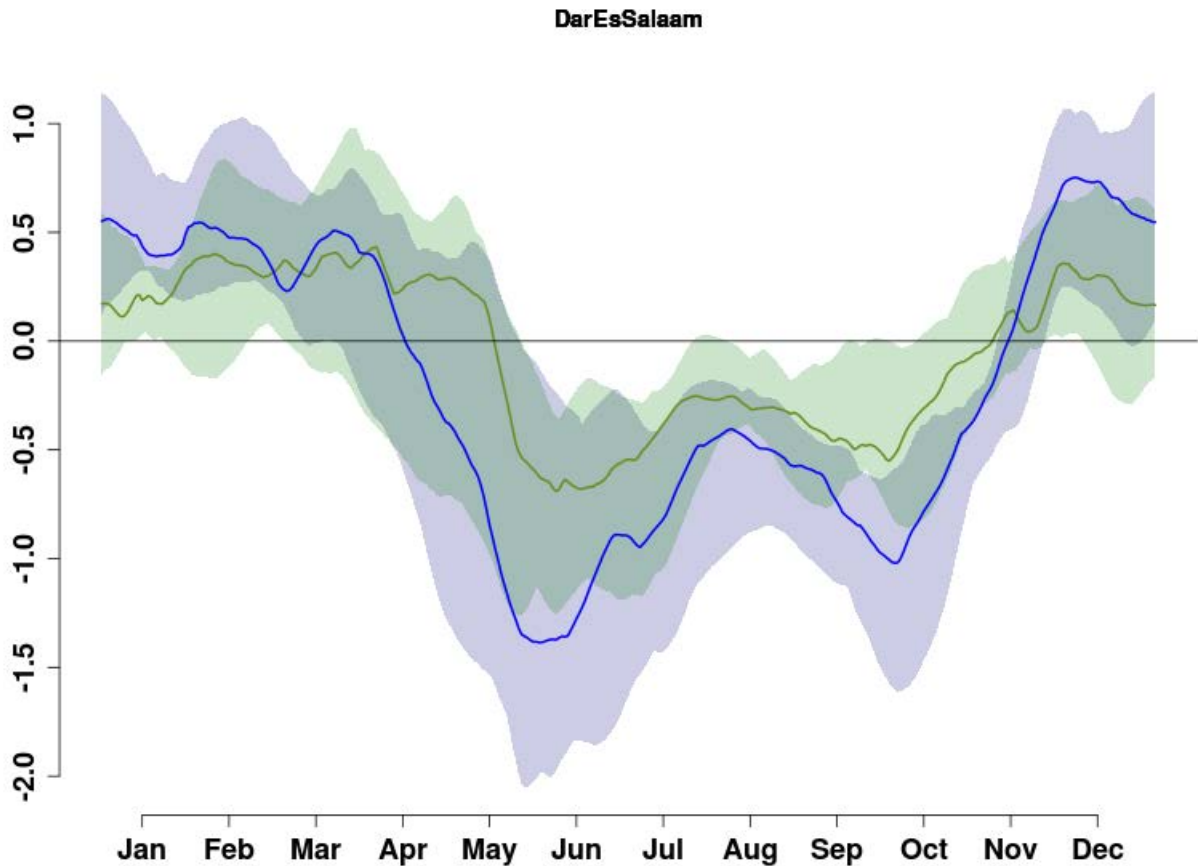
Figure 8 below compares the downscaled GCM control climates<sup>10</sup> (1961-2000) with the observed climate for Dar es Salaam. The GCM control climates are close to the observed (black line), replicating the observed bimodal seasonal cycle, peak rainfall during April/May and dry period during July-September. This gives one confidence that the downscaling methodology applied to these GCMs is simulating the local climates correctly, though it is noteworthy that the downscaled GCMs tend to overestimate rainfall during the drier periods and the short rains during September-November.



**Figure 8: GCM downscaled control rainfall climates (mm per day), for the period 1961-2000 at Dar es Salaam. Black line is observed climate and coloured lines are downscaled GCM climates.**

Figure 9 presents the simulated downscaled changes in rainfall for Dar es Salaam. The solid lines illustrate the median of the downscaled model response, while the shaded region indicates the spread between the different downscaled GCMs. Green colouring is for the change simulated for the 2046-2065 period and blue for the 2081-2100 period (all relative to the control period of 1961-2000). The median of the models suggests an increase in rainfall during November-April and a decrease from May to October. The spread of the models appears to be small in comparison to the median changes. They are also in line with the GCM changes, though the downscaled changes place more emphasis on the reductions (a total of up to 45mm less in the month of June) and less emphasis on the increases.

<sup>10</sup> A Control climate is the current climate as determined by the model – the degree of difference between the control and the observed climate gives an indication of the skill of the model



**Figure 9: Downscaled rainfall anomalies (mm day<sup>-1</sup>) for the 2046-2065 period (green) and 2081-2100 period (blue). Shading indicates the spread of results for the various models and solid lines the median model response.**

### 3.2 Temperature

The downscaled changes in temperature show similar increases to those from the GCMs presented earlier and are similar for both minimum and maximum temperatures. Maximum temperature changes are summarised in figure 10. The solid lines illustrate the median of the downscaled model response, while the shaded region indicates the spread between the different downscaled GCMs results. Green colouring is for the change simulated for the 2046-2065 period and blue for the 2081-2100 period (all relative to the control period of 1961-2000). Increases are similar during all months, with median changes for the 2081-2100 period as high as 3.5-4.0°C during SON. For the 2046-2065 period temperatures changes peak in the range 1.8-2.0°C.

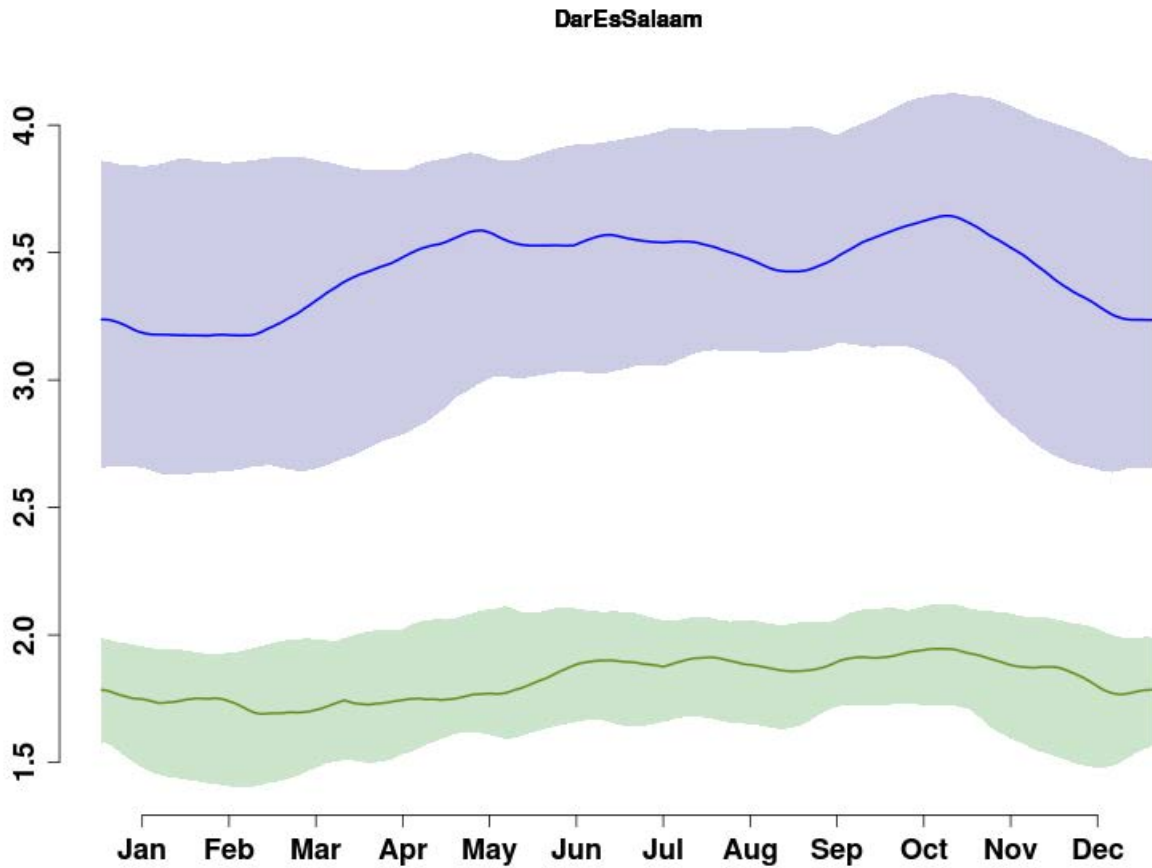
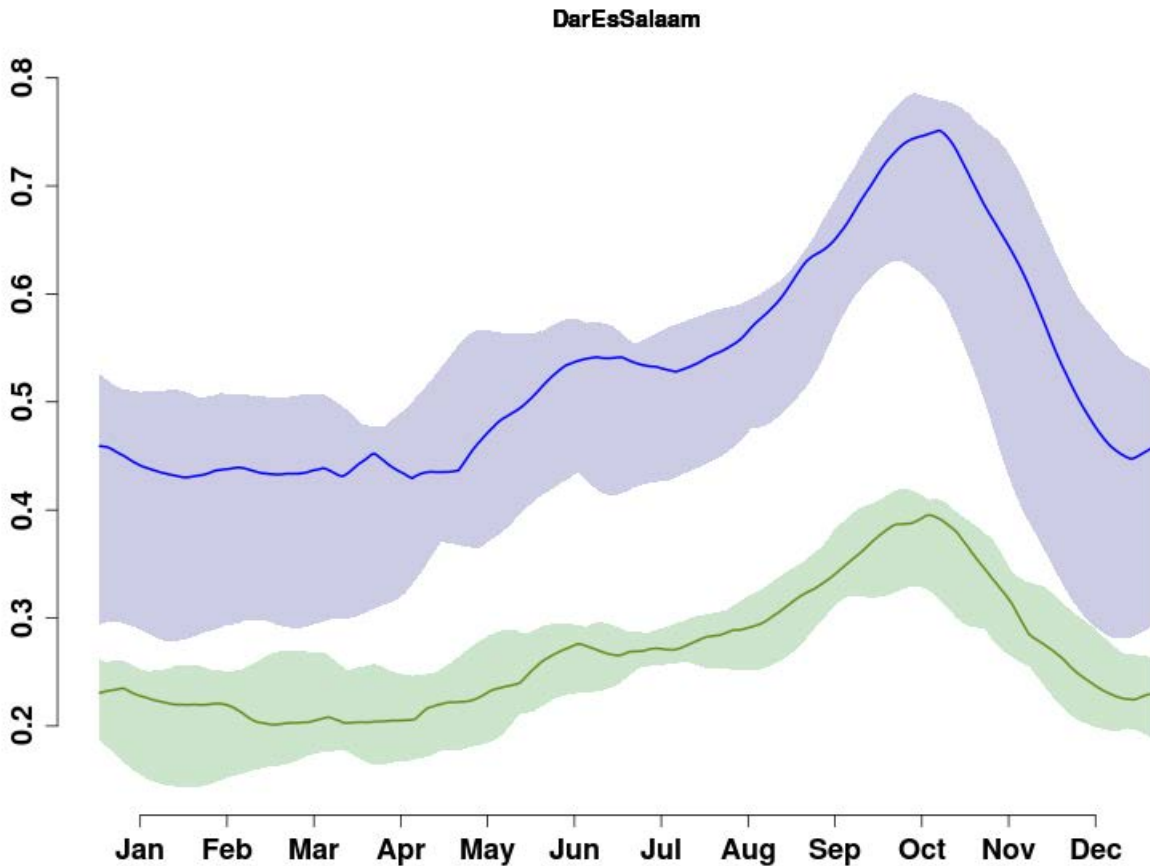


Figure 10: Downscaled maximum temperature anomalies (°C) for the 2046-2065 period (green) and 2081-2100 period (blue). Shading indicates the spread of results for the various models and solid lines the median model response.

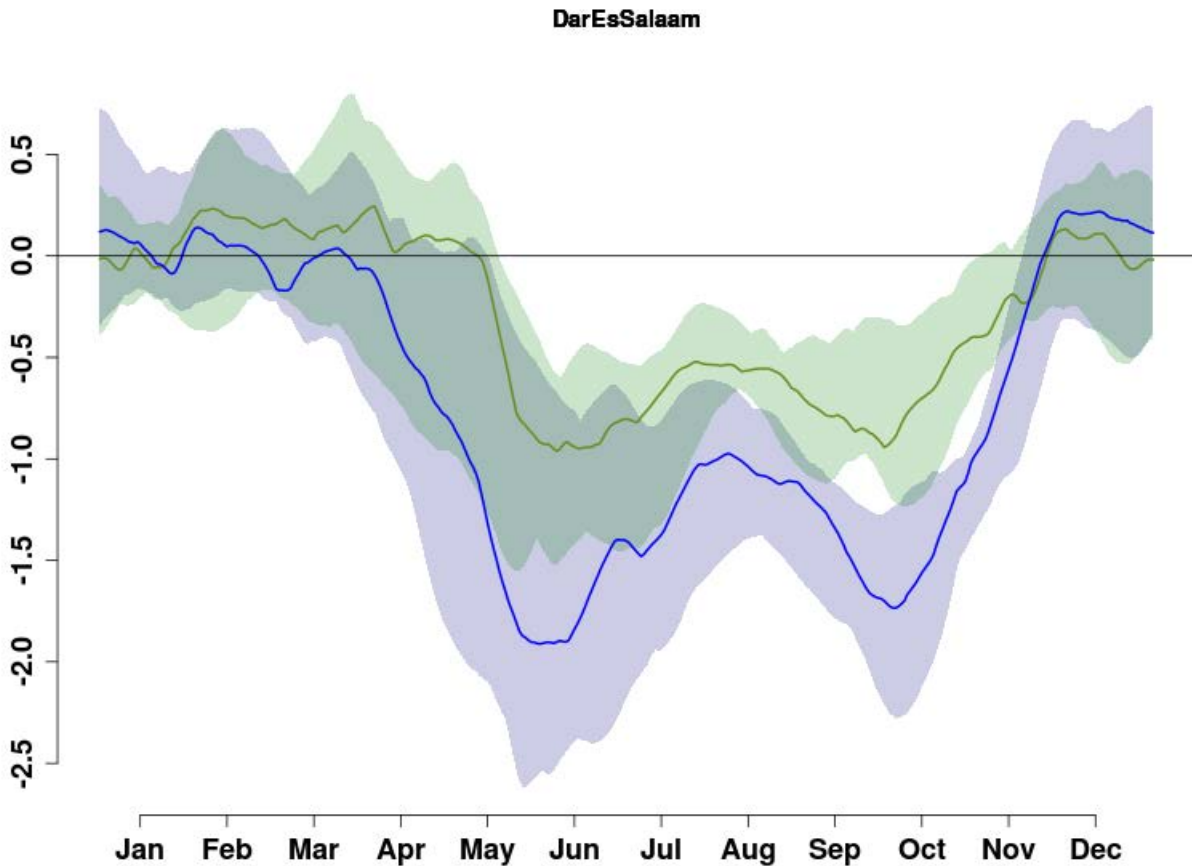
### 3.3 Evaporation and effective rainfall

One major consequence of the changes in temperature is to increase reference evapotranspiration ( $ET_0$ ) which is summarised in figure 11. Increases are highest during October, with highest increases of 0.7-0.8  $mm\ day^{-1}$  during the 2081-2100 period and 0.3-0.4  $mm$  per day during the 2046-2065 period.



**Figure 11: Downscaled reference evapotranspiration ( $ET_0$ ) anomalies ( $\text{mm day}^{-1}$ ) for the 2046-2065 period (green) and 2081-2100 period (blue). Shading indicates the spread of results for the various models and solid lines the median model response.**

One consequence of the increases in  $ET_0$  is that effective rainfall (rainfall less evaporation) becomes less, even without a decrease in rainfall. Assuming that evaporation occurs at the reference level (typical of a surface covered in short grass), figure 12 shows the change in effective rainfall. Comparing with figure 9 it can be seen that the change in evaporation reduces any increases in rainfall and accentuates the reductions. This implies less surface water available for dams, plants and agriculture than might be expected given the increases in rainfall and in particular suggests that the dry period will be hotter and drier in the future. For the urban areas such as Dar es Salaam, water storage and provision may be affected. This could also have important implications for agriculture, potentially affecting planting and irrigation scheduling later in the season.



**Figure 12: Downscaled effective rainfall (ppt -  $ET_0$ ) anomalies ( $mm\ day^{-1}$ ) for the 2046-2065 period (green) and 2081-2100 period (blue). Shading indicates the spread of results for the various models and solid lines the median model response.**

## 4 Changes in climate extremes

Climate extremes (or extreme events) are harder to simulate than changes in the mean climate, largely because GCMs are low resolution parameterised versions of the real climate and may fail to capture important mechanisms e.g. intense and localised convective rainfall. Whilst the downscaling here relates the large scale atmospheric GCM fields to observed rainfall and temperature, and is therefore good at projecting realistic climate on average, it still relies on the GCM simulations to model the change in atmospheric dynamics. This, and the infrequent nature of extreme events (poor sampling in the historical record,) means that it is difficult to project future changes in extremes.

Until there are fundamental improvements in the GCMs, better estimates of extreme climate events will be difficult; new simulations from the CORDEX programme will offer some high resolution dynamic simulations from multiple regional climate models (RCMs) for the first time, and these simulations may be able to better simulate the complex dynamics of extreme events leading to improved estimates of change.

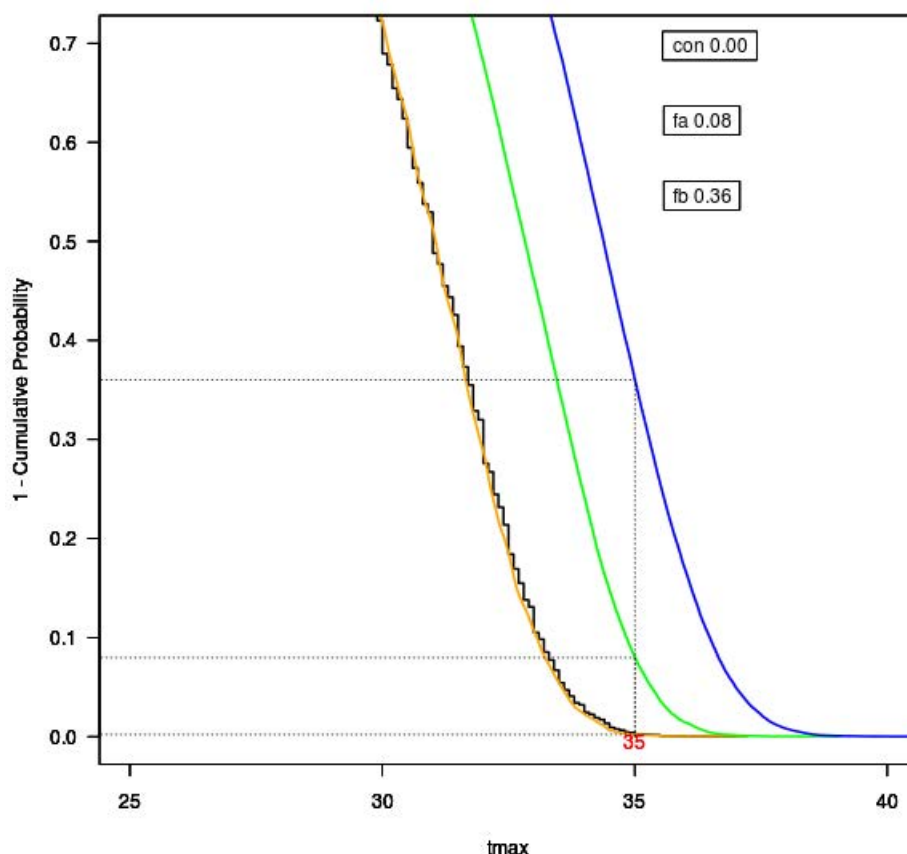
### 4.1 Changes in extreme temperatures

All the simulations from GCMs and the statistical downscaling used here indicate that extreme temperatures are likely to rise. Figure 13 indicates the cumulative probability of exceeding different

maximum daily temperatures for different periods at Dar es Salaam under an assumed A2 emissions scenario. The risk of exceeding high values (e.g. 35°C) is higher during future periods and the table below shows the probability of exceeding 35°C at Dar es Salaam for each period.

Location	Probability exceeding 35°C under present climate (1960-2000)	Probability exceeding 35°C under future climate (2046-2065)	Probability exceeding 35°C under future climate (2081-2100)
Dar es Salaam	0%	8%	36%

Under current climate conditions simulated by the GCMs the chance of exceeding 35°C is less than 1%, whereas for the 2046-2065 period 8% of days are expected to be higher than 35°C, and this rises to 36% of days for the 2081-2100 period.



**Figure 13: Cumulative probability of exceeding maximum temperatures under current (black), downscaled control (orange), downscaled 2046-2065 (green) and downscaled 2081-2100 (blue) periods. Dar es Salaam (left) and Dar es Salaam, Umbeluzi and Chagalane together (right).**

Given that temperatures are already increasing (as per the localised observed data discussed above in section 1.2) sectors (such as roads, stormwater, water and sanitation etc.) that are vulnerable to high temperatures should be prioritised and considered in terms of both maintenance plans and future development plans to ensure resilience and adaptability. One improvement on these estimates of temperature change for the future would be to downscale using a higher resolution RCM, and preferably using several RCMs to sample the uncertainty in downscaling (this was beyond the scope of the current

study and no such data were readily available). This would be better able to resolve gradual temperature changes in regions of steep topography, something that the GCMs and statistical downscaling used here is not able to do. The multiple RCM simulations generated as part of the CORDEX programme could be used in this regard, but were not available at this time

## 4.2 Changes in extreme rainfall

Changes in extreme rainfall will be at least partly difficult to estimate due to the problems in simulating extreme atmospheric conditions mentioned earlier. Additionally the statistical downscaling technique used here can only simulate daily rainfall values seen in the historical record. This means that it may underestimate increases in rainfall due to increases in intensity, especially at the extreme tail of the distribution. Given that increases in intensity are possible in a hotter climate with more moisture for rainfall, this is a shortcoming of the downscaling methodology employed here. Using RCMs (which are not restricted by such limits) is currently not an option as there are not enough RCM simulations for multiple GCMs available for the region (in order to construct envelopes of change and assess the probability/risk of particular changes). Again this may change when the CORDEX data becomes available.

Given these limitations Generalised Extreme Value (GEV) distributions were fitted to the annual maximum 1, 3 and 5 day total rainfall simulated by the downscaled GCMs for both the control and future climate simulations. From these GEV distributions we calculated the 10, 20 and 50 year return levels of extreme rainfall, as well as their 95% confidence intervals. *Nearly all the calculated return levels were the same (within 95% confidence limits) for the present and future simulations, though this is not surprising given the limitations mentioned above.* This does however illustrate one important point: potential decreases in average rainfall do not necessarily translate into expected decreases in extreme rainfall events – given the expected increases in moisture and temperature in these tropical regions *it is reasonable to expect increases in maximum daily rainfall amounts.* However this will only be possible to simulate in the future, using other models.

## 5 Dar es Salaam: impacts and vulnerabilities

The City of Dar es Salaam is the largest city in Tanzania and hosts a major port located along the Indian Ocean coast and is the centre of the permanent central government. It serves as the capital for the surrounding Dar es Salaam Region.

Climate change has resulted in the migration of affected people from rural areas to urban centres such as Dar es Salaam, threatening to overwhelm the carrying capacity of the city's infrastructure and services. This exacerbates Tanzania's vulnerability to a changing climate.

The population of Dar es Salaam is currently 3.2 million<sup>11</sup> and is projected to be 6 million by 2020. This will raise the water demand to 970 000 m<sup>3</sup>/day, a worrying prospect for a city already unable to meet its water demands. Seventy percent of the city's inhabitants live in unplanned settlements that cause major challenges to urban infrastructure. In an effort to improve their situation, urban poor use any available space to grow food. In backyards and vacant lots people grow crops and raise livestock to feed their families.<sup>12</sup>

<sup>11</sup> <https://www.cia.gov/library/publications/the-world-factbook/geos/tz.html>

<sup>12</sup> Priscilla Rowswell and Lucinda Fairhurst (2011) Sub-Saharan African Cities: A five-City Network to Pioneer Climate Adaptation through Participatory Research & Local Action Draft Baseline Study (February 2011)

These impacts may increase or decrease specific threats and vulnerabilities to specific local government sectors which were identified in the baseline report. Any assessment on threats associated with climate change in Dar es Salaam must include vulnerabilities to the following impacts:

- Increased number of extreme weather events;
- Increasing mean sea level rise;
- Contaminated and decreased water resources;
- Loss of biodiversity, ecosystems, natural and marine resources;
- Damage to residential, key industrial and municipal infrastructure;
- Change in local temperature and precipitation, and
- Increased health problems due to heat stress

The risks and impacts upon sectors such as water and sanitation, energy, transport and health ultimately and inherently affect livelihoods. Thus risks and impacts associated with sea level rise (both storm-driven intermittent and permanent inundation) will also embody impacts upon livelihoods.

Both current and future risks are summarised in the tables below. Increased risks in the future are highlighted in yellow.

## 5.1 Water and Sanitation

Impacts upon Water and Sanitation	Impact on livelihoods
<ul style="list-style-type: none"> <li>• Decreased water supply and availability</li> <li>• Reduced quality due to siltation and stagnant water</li> <li>• Increased demand on water resources for human consumption</li> <li>• Increased demand on water resources for agricultural irrigation</li> <li>• Increased demand on water resources for livestock watering</li> <li>• Increased temperatures cause increased surface water evaporation and evapotranspiration</li> <li>• Damage to fish habitat, loss from fishery production</li> <li>• Higher costs, levels of competition and potential conflict for water</li> <li>• resources between users including industrial facilities, power generators</li> <li>• (for cooling and hydropower), public water suppliers and the agricultural community.</li> </ul>	<ul style="list-style-type: none"> <li>• Increased casualties from dehydration</li> <li>• Increased geographical dispersal of water borne diseases</li> <li>• Decreased availability of fresh water supply (drinking water and for cooking purposes)</li> <li>• High livestock mortality rates</li> <li>• Decreased water supply reduces sanitation and hygiene</li> <li>• Decreased food production (food shortages)</li> <li>• Loss of human life from food shortages, heat, suicides, violence</li> </ul>

## 5.2 Transport

Type	Impacts upon Transport	Impact on livelihoods
<b>Road</b>	<ul style="list-style-type: none"> <li>• Damage of infrastructure</li> <li>• Blockage of roads (fallen trees, debris)</li> <li>• Coastal Flooding causes diversions</li> <li>• Accidents</li> <li>• Inundation of roads</li> <li>• Mudslides</li> </ul>	<ul style="list-style-type: none"> <li>• Limits access routes</li> <li>• Work hours lost– reducing income</li> <li>• Risk to public safety</li> <li>• Inability to travel to work and market places and seek health assistance</li> <li>• Increased food and fuel prices</li> </ul>
<b>Port</b>	<ul style="list-style-type: none"> <li>• Damage of infrastructure</li> <li>• Erosion to coastal infrastructure and equipment</li> <li>• Damage of boats</li> <li>• Erosion to harbour wall</li> </ul>	<ul style="list-style-type: none"> <li>• Days at sea lost</li> <li>• Work hours lost – reducing income, if the port is rendered unworkable then there is no income stream until the damage has been cleared.</li> </ul>



	<ul style="list-style-type: none"> <li>• Delay in exports/imports</li> <li>• Increased insurance premiums</li> </ul>
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### 5.3 Health

Impacts upon Health (see also water above)	Impact on livelihoods
<ul style="list-style-type: none"> <li>• Increased casualties suffering from dehydration</li> <li>• Inequity in the distribution of drought relief</li> <li>• Increase in heat-related illnesses such as dizziness, heat stress and illnesses</li> <li>• Increased infection and distribution of disease vectors</li> <li>• Loss of human life, wildlife and stock</li> <li>• Dehydration and other heat related ailments</li> <li>• Decreased sanitation from less available water leads to water-borne diseases such as cholera as risk of contamination increases as more people use limited water sources.</li> </ul>	<ul style="list-style-type: none"> <li>• Lower productivity in the work place due to dehydration or heat stroke and loss of man hours</li> <li>• In drought people may choose to prioritise their time to getting water and food supplies rather than conventional work and so productivity may decrease</li> <li>• Increased mental and physical stress</li> <li>• Increased human mortality from food and water shortages, disease and heat stress.</li> <li>• Hunger and famine</li> <li>• Threat to public safety as conflict will arise as resources become scarcer.</li> </ul>

### 5.4 Energy

Impacts upon Energy	Impact on livelihoods
<ul style="list-style-type: none"> <li>• Limited water reduces hydro-electric energy supply</li> <li>• Increased demand for electricity during prolonged droughts and high temperatures as cooling demands for domestic and commercial use rises.</li> <li>• Increased episodes of power outages (black outs)</li> <li>• Hydroelectric power companies will need to look into other fuel sources or alternative renewable technologies</li> <li>• Knock on effects on other sectors such as increased demand for health services; problems in the transport sector; damage to fresh produce as a result of limited cooling.</li> <li>• Increased water demands by sewerage treatment plants.</li> <li>• Increased demand for air conditioning</li> </ul>	<ul style="list-style-type: none"> <li>• Increased costs resulting from higher energy demand, particularly increased peak demand in the summer for cooling</li> <li>• Spoilage of food</li> <li>• Increased costs associated with increased power usage</li> <li>• Power cuts lead to knock on effects such as reduced working hours which limits income</li> <li>• Reduced power limits transportation options</li> <li>• Environmental degradation from other thermal energy sources</li> </ul>

The risks and impacts upon water and sanitation, transport, health, and energy as shown and highlighted above, ultimately affect human livelihoods. Local authorities need to analyse associated and projected impacts and adapt and plan accordingly to strategically build resilience. There is a need for ongoing vulnerability assessment and the development of adaptation strategies and preparedness in protecting local communities and the environment on which they depend upon for their livelihoods and well-being. It is increasingly important to gauge the value of pre-emptive adaptation strategies that increase resilience and decrease vulnerability, against the cost of damages if these measures are not put in place.