***Title:** Climate Change Projections for Maputo: Adding value through downscaling
***By:** Mark Tadross and Peter Johnston, Climate Systems Analysis Group, University of Cape Town
***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

***Full Name of Research Institution: ICLEI – Local Governments for Sustainability - Africa**
***Address of Research Institution:** P.O. Box 5319, Tygervalley, 7536, Cape Town, South Africa
***Name(s) of ICLEI Africa Core Project Team:** Lucinda Fairhurst and Priscilla Rowswell
***Contact Information of Researcher/Research Team members:** iclei-africa@iclei.org; +27 21 487 2312

***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 Maputo: Adding value through downscaling

ICLEI Local Governments for Sustainability

CITIES ADAPT

Adaptation IDRC CRDI DFID Department for International Development

CSAG CLIMATE SYSTEM ANALYSIS GROUP

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

Climate Change Projections for Maputo: Adding value through downscaling

March 2012

Authors: Mark Tadross and Peter Johnston

ISBN: 978-0-9921802-0-1

Contents

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 green house 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 projections of change are presented and discussed in 'the baseline climate report for southern African countries including: Namibia, South Africa, Mozambique, Tanzania and Mauritius. 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 Maputo. 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 recently available model results typically imply for Maputo, 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 the recent downscaled projections.

1 Historical observations and trends from Maputo

Historical observations of weather during the recent past from weather stations in the vicinity of Maputo are required in order to understand the current climate context of the city. They also assist in the determination and identification of any historical trends in climate that may be associated with anthropogenic climate change (usually trends in the short term (decades) are indicative of a changing climate, whereas changes over the longer (centuries) are part of a planetary/sun cycle). For this study local rainfall and temperature data from Maputo were made available from the Instituto Nacional de Meteorologia (INAM); 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 3 closest available stations (Maputo, Umbeluzi and Changalane).

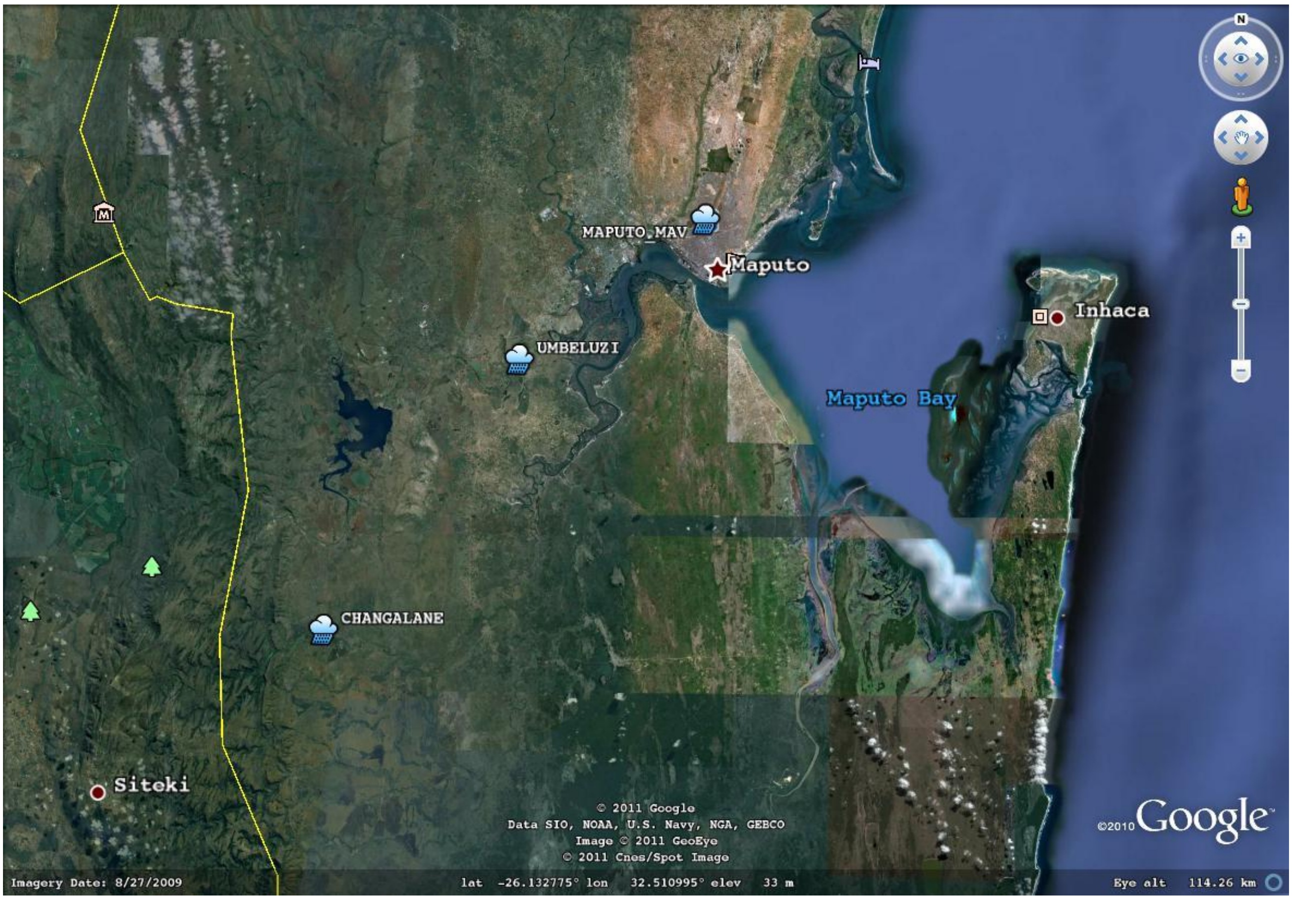


Figure 1: Available weather stations.

Unfortunately records available for Umbeluzi and Changalane have more missing data and shorter timeseries than available for Maputo, so the focus was on the Maputo data, using other station data where appropriate for the discussion.

1.1 Climatology of Maputo

The climate of Mozambique varies from tropical and sub-tropical in the north/central regions, to semi-arid and arid climates in the south. Rainfall varies widely from the coast (ave 800-1000 mm) decreasing inland to 400 mm at the border with SA and Zimbabwe. Rainfall also decreases from the north/central regions (1000-2000 mm, NE monsoon) towards the south, with having a total annual rainfall of approximately 778 mm.

From INAM, daily rainfall and temperature data were available for the Maputo and Umbeluzi stations between 1960 and 2006, though there were noticeably more missing data and non-reporting periods for the Umbeluzi station. Data for the Changalane station was available for the 1962-2006 period, again with more missing data and non-reporting periods than at Maputo. We use the Priestly-Taylor method to calculate reference evapotranspiration[1] (ET_0) based on simulated temperatures, solar radiation and altitude. Figures 2 and 3 show the daily climatology (average over all years) of rainfall, temperature and reference evapotranspiration at Maputo and Changalane (the furthest away from Maputo). It can be seen that the seasonal variation in climate is very similar at the two sites, though rainfall is slightly less and evapotranspiration slightly higher at Changalane compared to Maputo. This is because of Maputo's closer proximity to the sea, moisture, clouds and lower altitude, resulting in short periods when rainfall and evapotranspiration are similar values. Temperatures are similar at both locations and evapotranspiration is usually higher than rainfall.

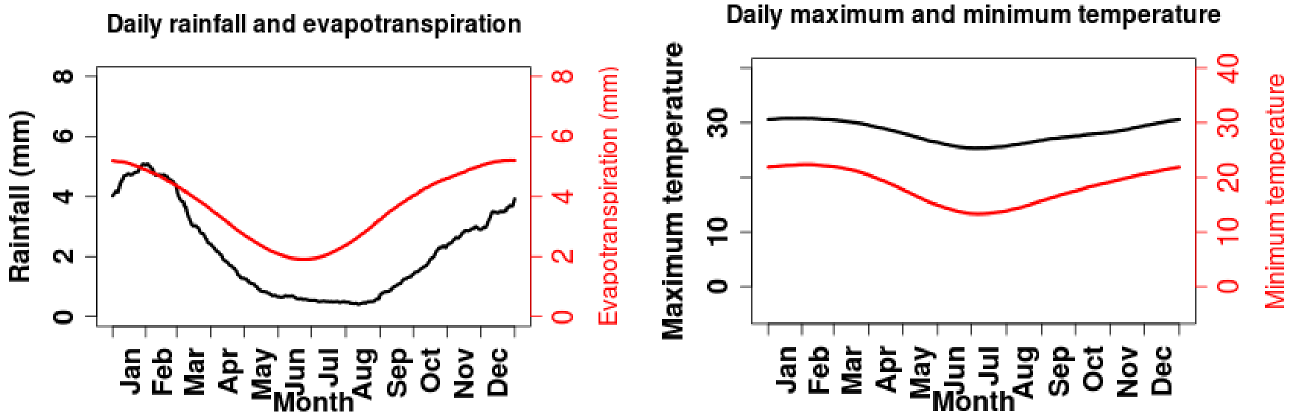


Figure 2: Daily climatology of rainfall (mm day^{-1}), minimum and maximum temperatures (°C) and reference evapotranspiration (mm day^{-1}) at Maputo.

[1] Reference evapotranspiration (ET_o) 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.

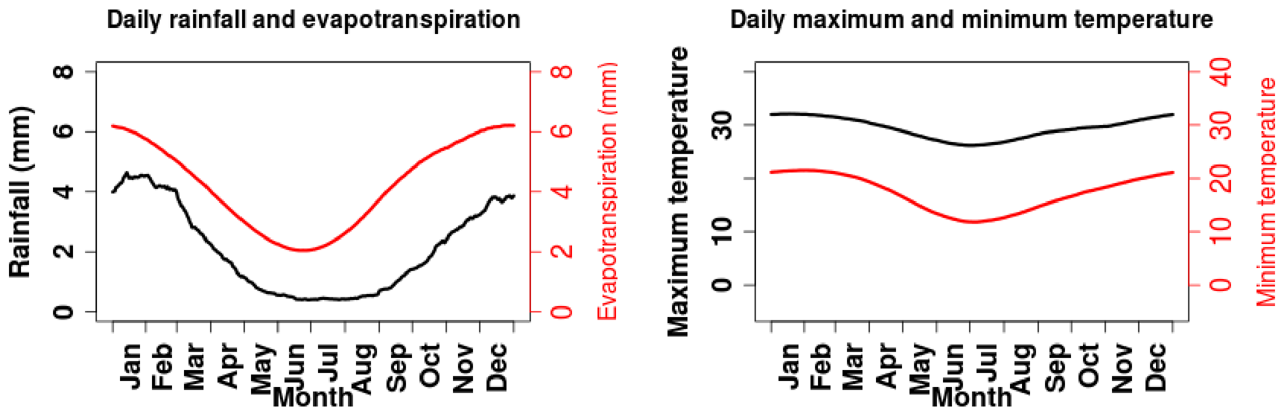


Figure 3: Daily climatology of rainfall (mm day^{-1}), minimum and maximum temperatures (°C) and reference evapotranspiration (mm day^{-1}) at Changalane.

Given these similarities in climate the focus remained on using the data for Maputo, specifically.

1.2 Historical trends in climate at Maputo

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:

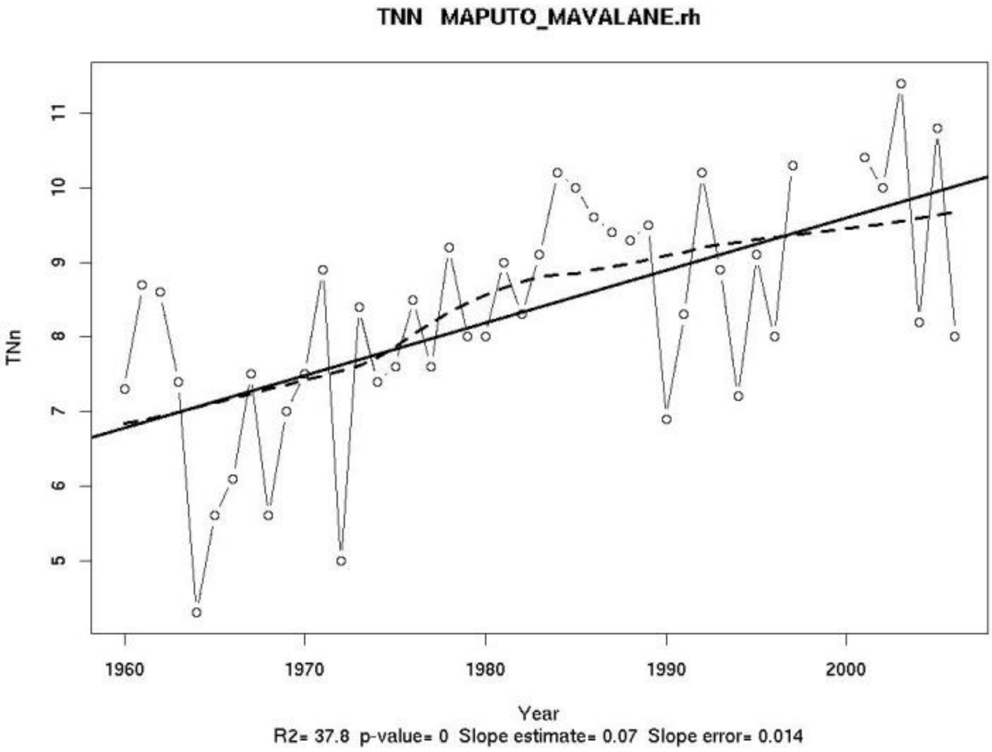
- check for duplicate or missing records;
- check for negative rainfall (an impossibility in reality);
- check for rainfall > 500 mm in one day (also impossible);
- remove data more than 6 standard deviations from the mean (this would indicate an error in reading);
- remove data where minimum temperatures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

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[2] and STARDEX[3] projects.

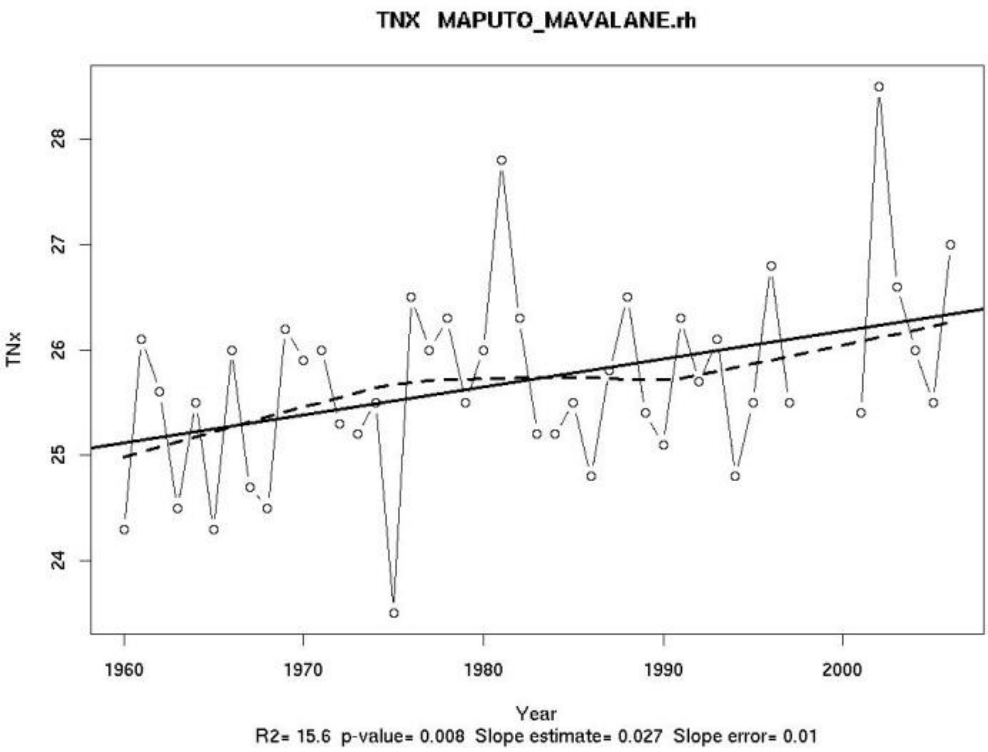
Increasing temperature trends are detectable in a number of temperature indices with the most significant (at the 90% confidence level[4]) for increasing minimum temperatures. Figure 4 shows the increasing trend in (maximum and minimum) daily minimum temperatures, which are consistent with those shown in the IPCC 4th assessment report [5].

[2] http://cccma.seos.uvic.ca/ETCCDMI/software.shtml
[3] http://www.cru.uea.ac.uk/projects/stardex/
[4] 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
[5] IPCC, 2007. IPCC Fourth Assessment Report (AR4) [online]: Available: http://www.ipcc.ch/

Additionally there was a significant trend for decreasing daily temperature range and number of days greater than 25°C.



a)



(b)

Figure 4: Trends in daily minimum temperatures (a) minima and (b) maxima at Maputo.

All 4 seasons showed significant increasing trends in minimum and maximum temperatures (with the exception of maximum temperatures during June-August (winter), whereas there were few significant trends in rainfall. At the annual timescale there were no significant trends in rainfall, except for a decreasing trend in the maximum recorded 1 day total rainfall (indicating a reducing intensity of rainfall).

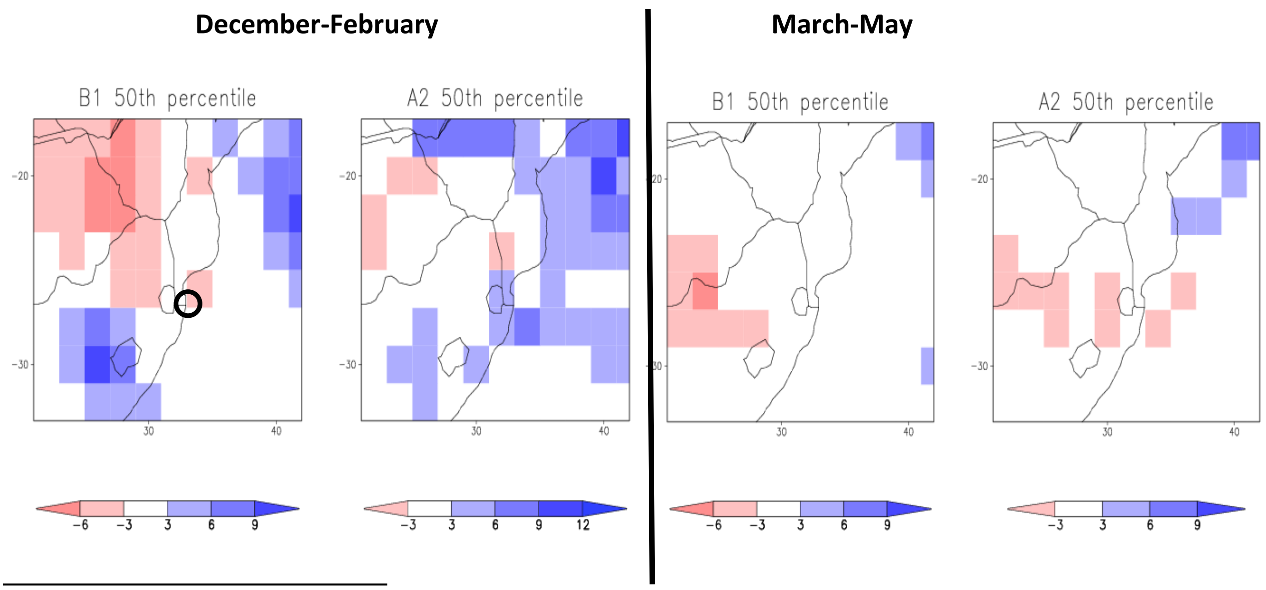
2 GCM projections of future change (for 2050)

GCM projections of change were presented in the baseline climate report for southern Africa[6] and are shown here with a focus on the region around Maputo.

2.1 Rainfall

Figure 5 demonstrates how rainfall is expected to change under both a B1 and A2 emissions scenario; for each season, both the median change (15/13 GCMs 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 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 (values less than 50% suggest most models are simulating a negative change, whereas greater than 50% suggest most models simulate a positive change).

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 scenario, then decreases in rainfall are suggested during June-November, with a suggestion of weaker decreases during March-May. During the December-February period the simulations are less consistent, with equal numbers of positive and negative changes simulated across the GCM models under an A2 emissions scenario.



[6] Tadross and Johnston 2011, Projected Climate Change Over Southern Africa; Namibia, South Africa, Mozambique, Tanzania and Mauritius, Report for ICLEI, February 2011

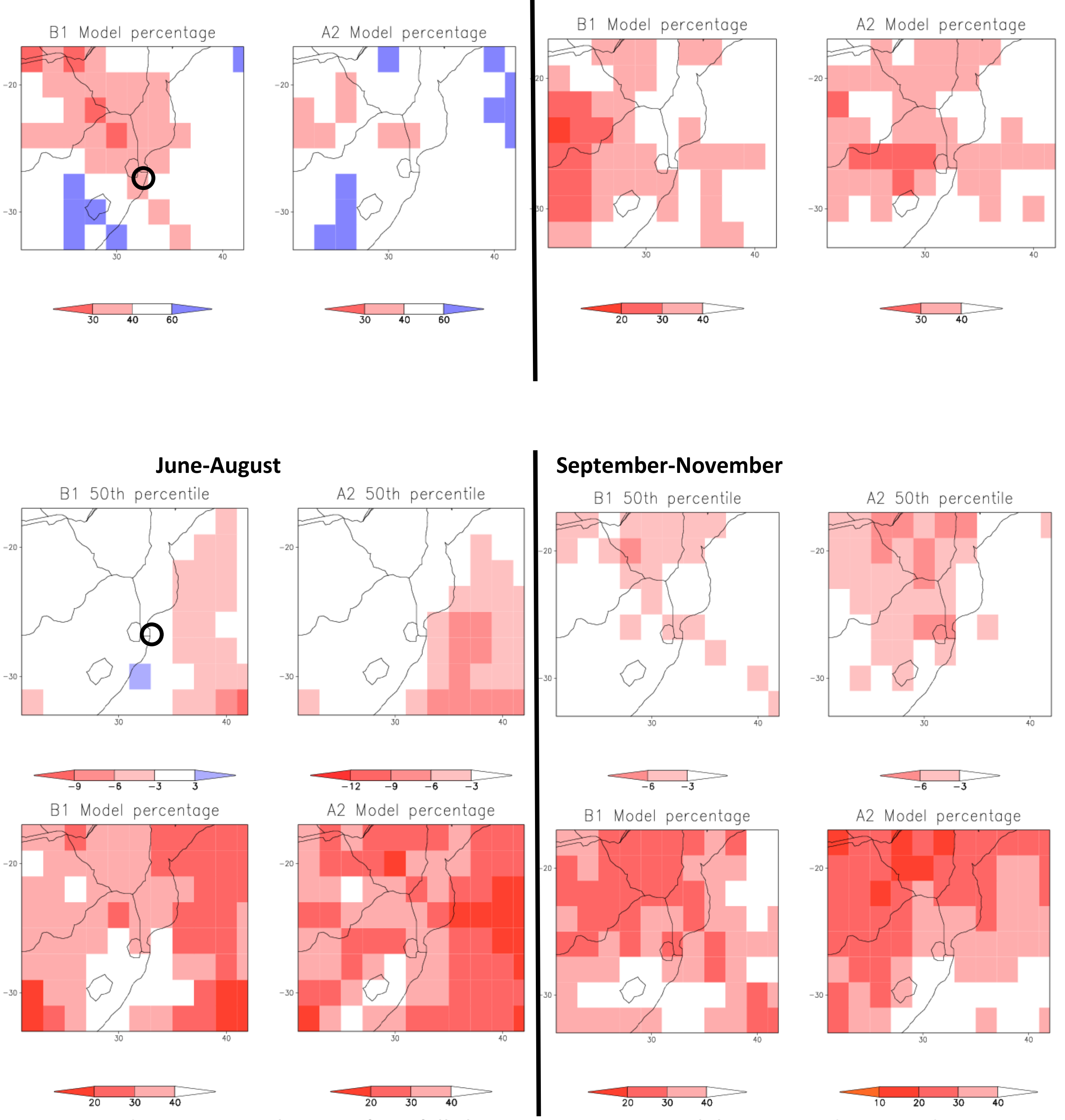


Figure 5: Median GCM simulations of rainfall change in mm per month by 2050 under A2 and B1 emissions scenarios for each season. The confidence of the model ensemble simulations is indicated by the percentage of models simulating a positive/negative change, indicated by the percentages where less than 40% (lower agreement) is in red shades and more than 60% (greater agreement) is in shades of blue.

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 used; 1.0-1.75°C for the B1 scenario and 1.5-2.25°C for the A2 scenario in the region of Maputo. Increases inland are significantly more than towards the coast, as the ocean has a moderating influence. These are median changes and incorporate a range of projected increases, all positive, in each case.

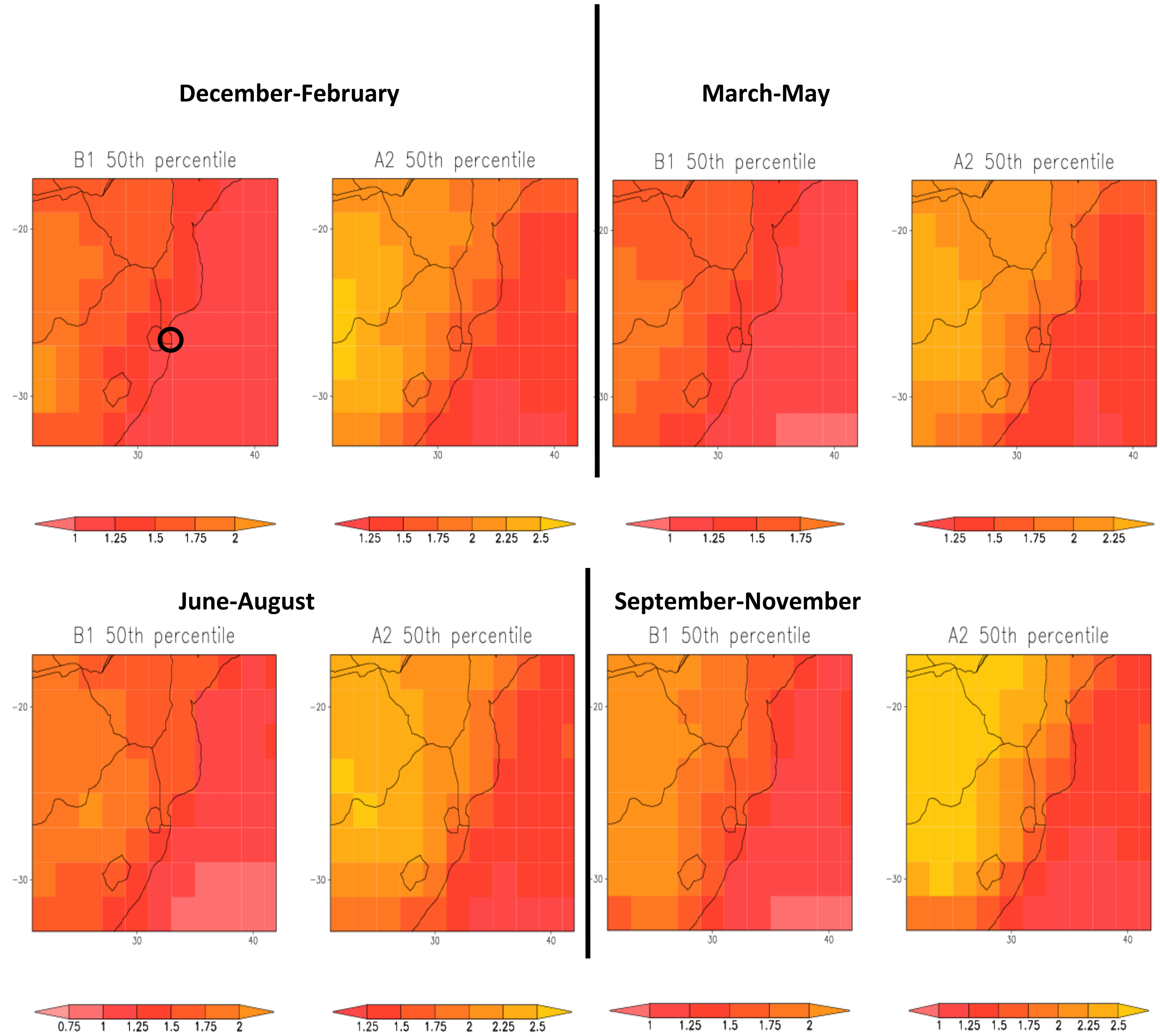


Figure 6: Median GCM simulations of change by 2050 under A2 and B1 emissions scenarios for each season.

The city of Maputo is bounded by a few different grid cells, but the overall temperature increases in the region ensure that the expected temperature increases will be of the order shown, that is between 1.00 and 1.75 degrees for the B1 scenario and between 1.5 and 2.5 degrees for the A2 scenario by 2050. Considering that the current trend of greenhouse gas emissions is closer to or exceeding those for the A2 scenario, it can confidently be expected to be around 2 degrees warmer by 2050 than today. This is valid for all temperatures, minima, maxima and means.

2.3 Winds

Figure 7 shows the median changes in surface (actually 10m above the surface) winds simulated under an A2 scenario; the arrows indicate the changes in direction[7] 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 east during June-February, whereas they decrease and become more northerly during March-May. Changes during

[7] Arrows indicate the movement of the wind – e.g.an arrow pointing south indicates a wind coming from the north.

June-November reflect a strengthening of the anticyclonic atmospheric circulation over the southern Indian Ocean during winter and early spring, which is clearly shown in the IPCC 4th assessment report and which is partly responsible for a southward retreat of the mid-latitude storm tracks which can bring winter rainfall. The changes during summer, particularly late summer, may indicate the potential for the advection of tropical air from the north, bringing in more moisture and indicating a possibility of more rain, though this would depend on winds at higher elevations (bearing in mind that his analysis was done on surface wind data).

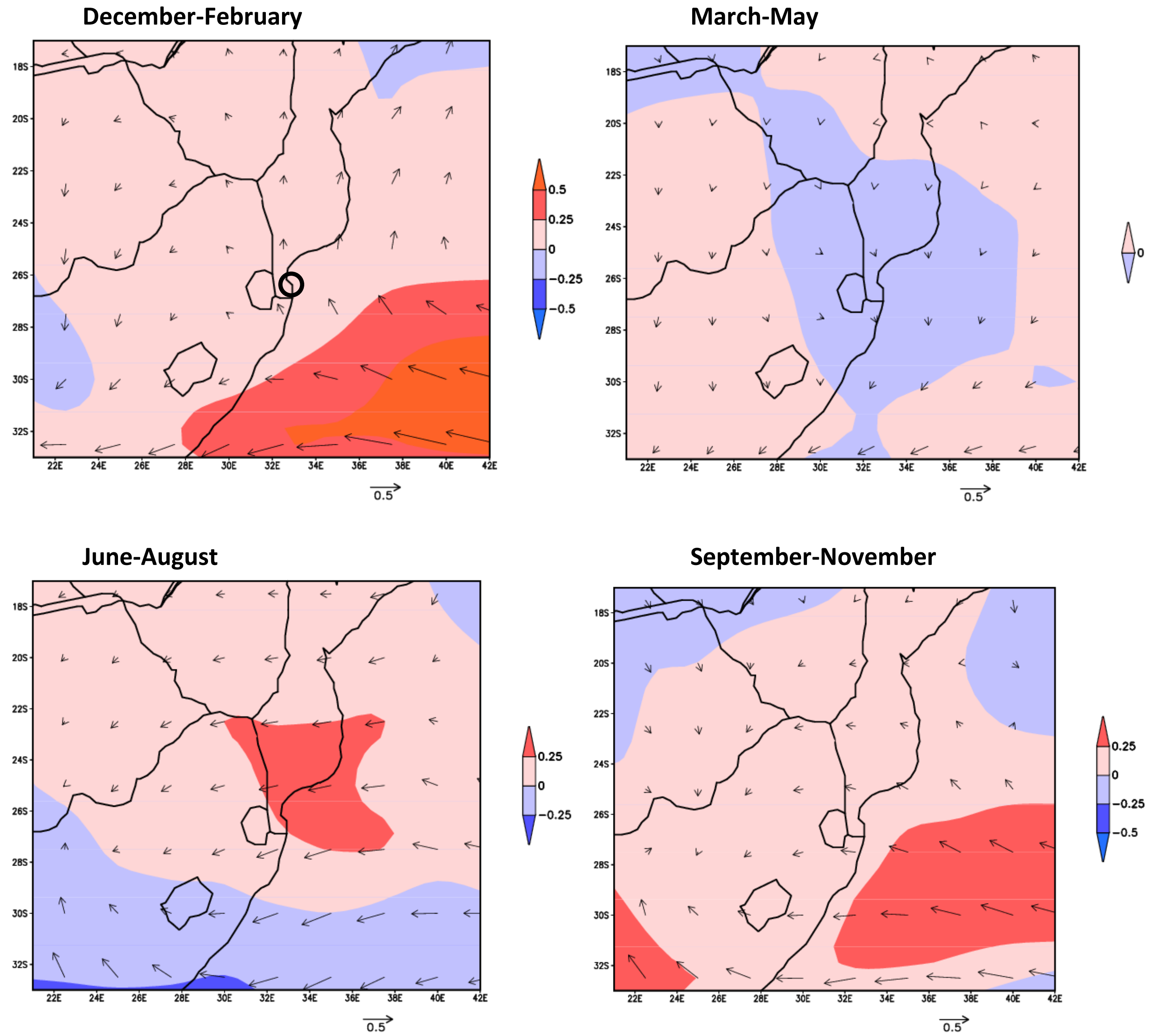


Figure 7: Median changes in 10m wind directions simulated under an A2 emissions scenario; shading indicates changes in wind speed (in m/s).

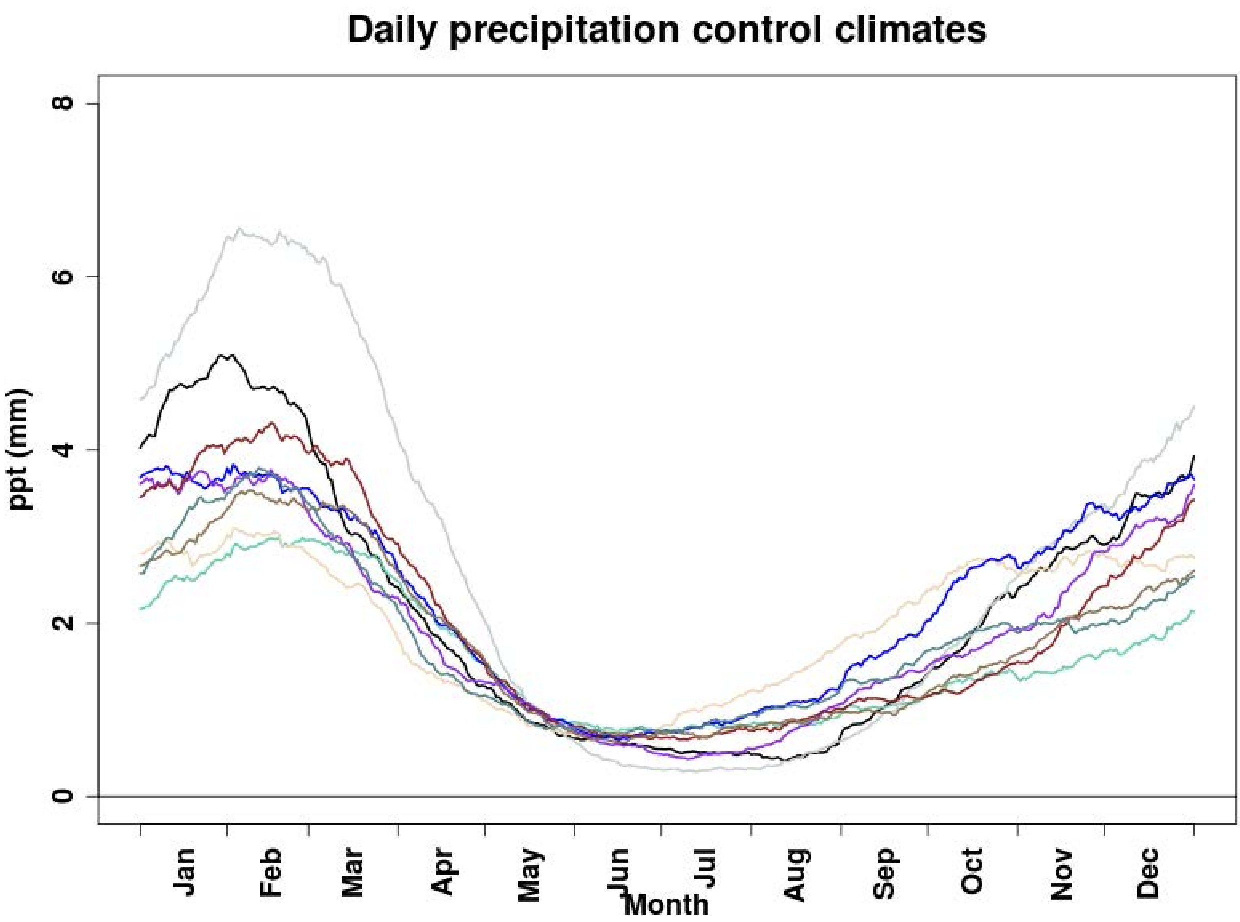
The implications of increased wind strength during June-February must be considered in terms of any existing vulnerabilities that Maputo may face.

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[8] (forced with the A2 emissions scenario) and the observed rainfall and temperature data from the Walvis Bay and Windhoek stations. 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 were then simulated at each location. The Priestly-Taylor method was used to calculate reference evapotranspiration (ET_0) based on simulated temperatures, solar radiation and altitude.

3.1 Rainfall

Figure 8 below compares the downscaled GCM control climates[9] (1961-2000) with the observed climate for Maputo. In both cases the GCM control climates are close to the observed, replicating the observed seasonal cycle and peak rainfall during February. This gives us confidence that the downscaling methodology applied to these GCMs is simulating the local climates correctly.



[8] The suitability of GCMs depends on the frequency of data and the type of variable

[9] 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 8: GCM downscaled control rainfall climates (mm per day), for the period 1961-2000 at Maputo. Black line is observed climate and coloured lines are downscaled GCM climates.

Figure 9 presents the simulated changes (or anomalies[10]) in rainfall for Maputo. The shaded regions indicate the spread between the different downscaled GCMs (between 10th and 90th percentiles) and the solid lines the median downscaled response. 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 models suggest an increase in rainfall during September and October, whereas there is significant spread between the 10th and 90th percentile models during the rest of the year. This tends to be different to the GCM simulated changes which suggested a decrease in rainfall during SON, hence these simulated increases should be treated with caution.
The implications of this are discussed in 3.3.

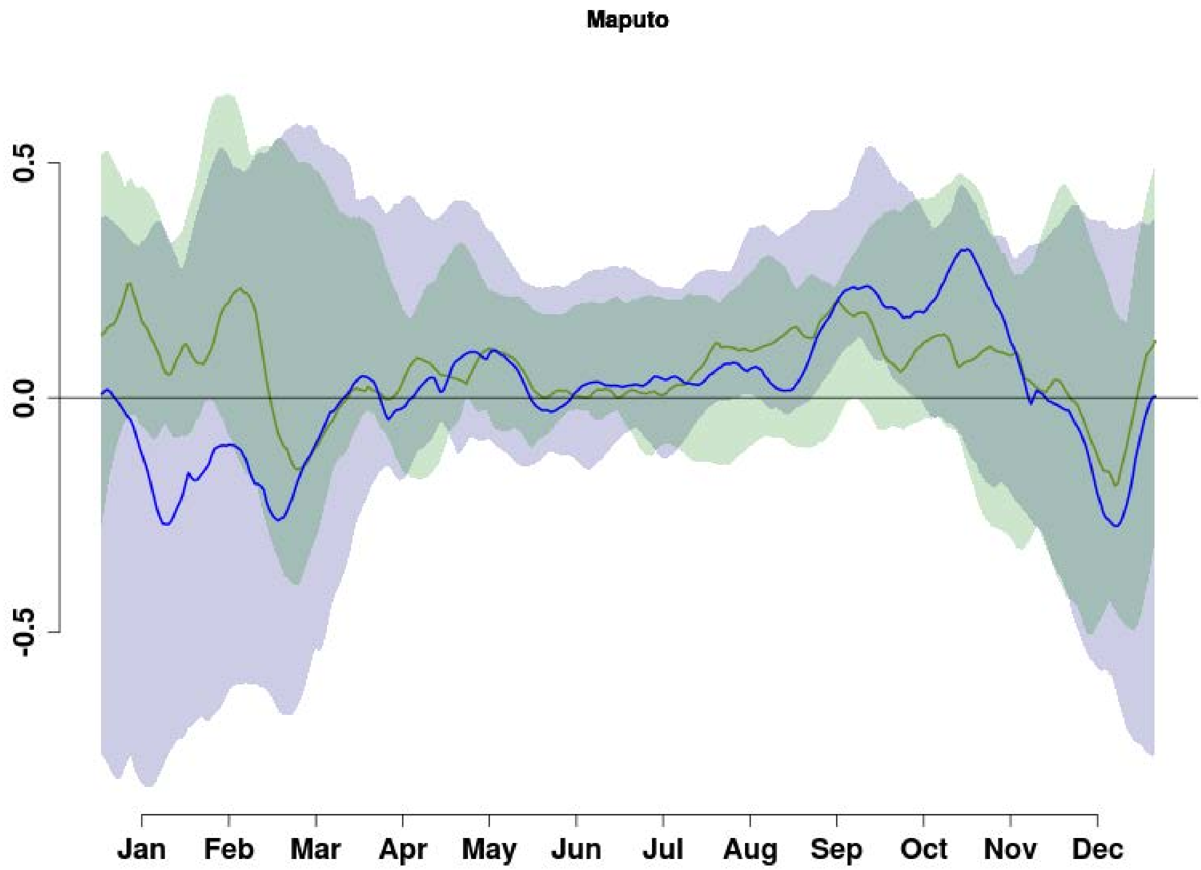


Figure 9: Downscaled rainfall anomalies (mm day^{-1}) for the 2046-2065 period (green) and 2081-2100 period (blue). Shading indicates model spread (10th to 90th percentile change) and solid lines the median model response.

[10] An anomaly is the difference between the current climate and a future climate as projected by a model.

3.2 Temperature

The downscaled changes in temperature are similar to those from the GCMs presented earlier and are similar for both minimum and maximum temperatures. Maximum temperature changes are summarised in figure 10. Increases are similar during all months, with median changes for the 2081-2100 period as high as 3.7°C during SON.

The implications of this are discussed in 3.3.

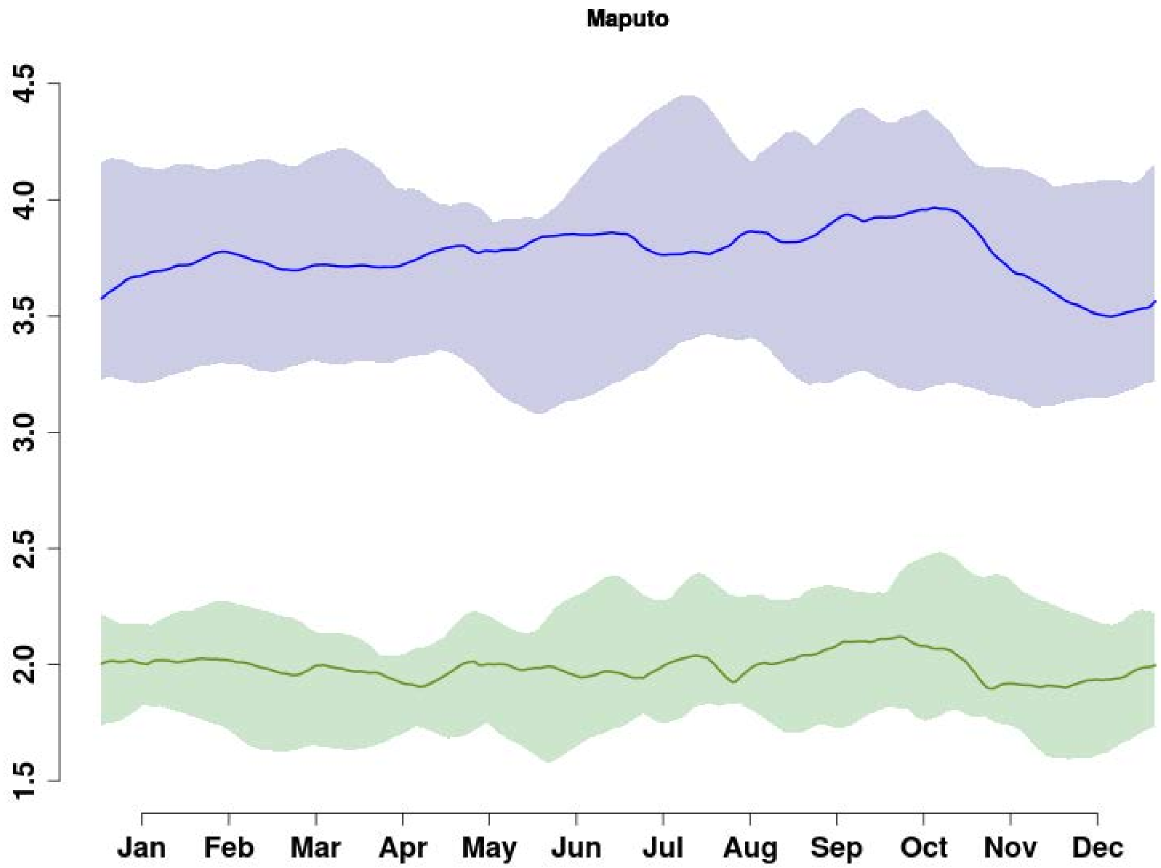


Figure 10: Downscaled maximum temperature anomalies (°C) for the 2046-2065 period (green) and 2081-2100 period (blue). Shading indicates the spread of results for the various models and solid lines the median model response.

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 0.5-0.6 mm day^{-1} during the 2081-2100 period and 0.2-0.3 mm day^{-1} during the 2046-2065 period.

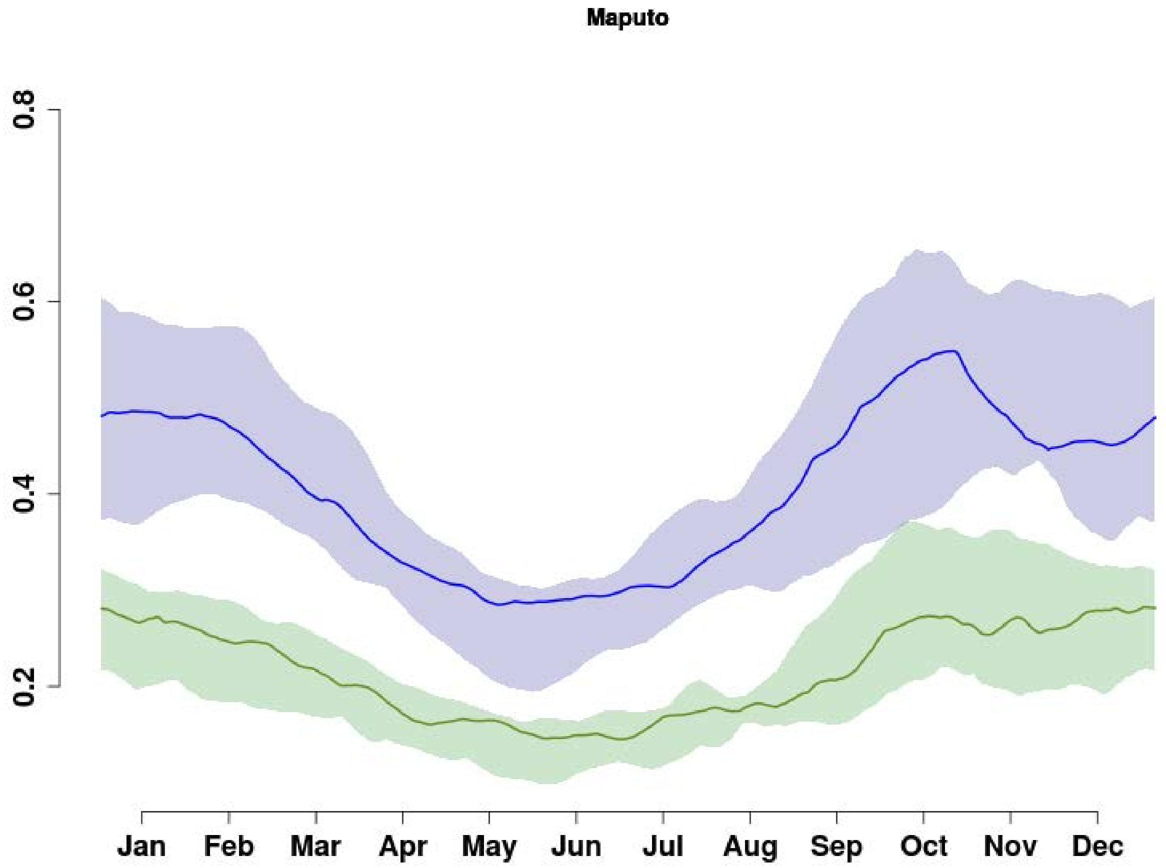


Figure 11: Downscaled reference evapotranspiration (ET_0) anomalies (mm day^{-1}) for the 2046-2065 period (green) and 2081-2100 period (blue). Shading indicates the spread of results for the various models and solid lines the median model response.

The implication of these 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 dominates the change in rainfall resulting in negative changes in effective rainfall in nearly all simulations and all months. This implies less surface water available for dams, plants and agriculture. The reduction in effective rainfall has no bearing on flood frequency as the intensity of rainfall is not reflected here.

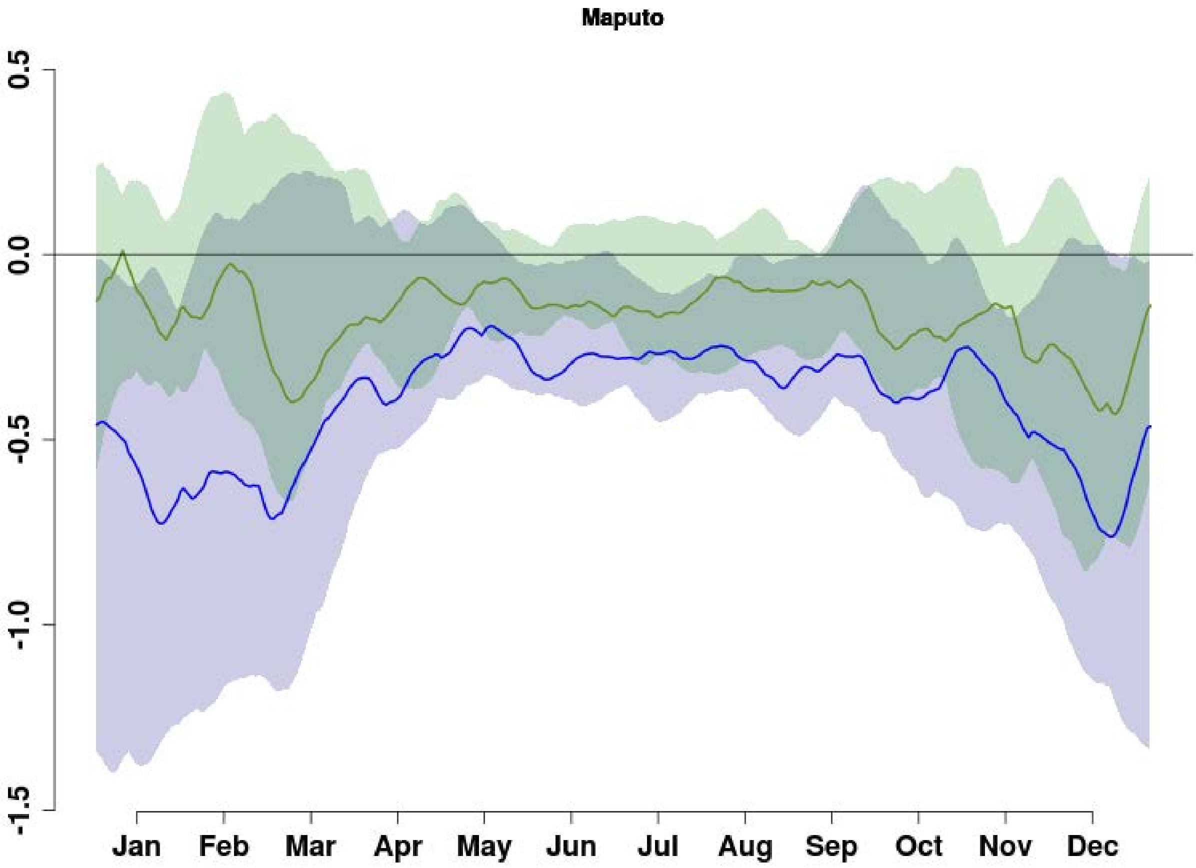


Figure 12: Downscaled effective rainfall (ppt - ET_0) anomalies (mm day^{-1}) for the 2046-2065 period (green) and 2081-2100 period (blue). Shading indicates the spread of results for the various models and solid lines the median model response.

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.

GCMs also fail to capture important mechanisms for the generation of cyclones e.g. simulating the dynamics of a cyclone's eye wall. Whilst there have been attempts by international teams to use combined statistical and dynamical approaches to generate synthetic cyclone tracks, these have yielded no consistent messages with regard to changes in the *frequency* and likely *tracks* of future cyclones in the Mozambique channel. There are however, clearer indications that cyclones will become more *intense and the proportion* *of more intense cyclones relative to the least intense cyclones will increase*[11], and it is this aspect of cyclone activity that should be considered when making long-term choices for adaptation and disaster risk managements and response. Damages from any particular cyclone may therefore be greater in the future.

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, but these simulations are unlikely to include important interactions for cyclones, such as feedbacks with the underlying ocean etc.

4.1 Changes in extreme temperatures

Changes in extreme temperatures are positive (meaning increases in maximum temperatures and the frequency of days with extremely high temperatures) in all simulations from GCMs and the statistical downscaling used here. Figure 13 indicates the cumulative probability of exceeding different maximum daily temperatures for different periods at Maputo and for Maputo, Umbeluzi and Changalane together under an assumed A2 emissions scenario. The risk of exceeding high values (e.g. 35°C) is higher during future periods at each location, with the change in probability higher at inland than at Maputo; this reflects the higher increases in temperature simulated for inland locations in the GCM data noted previously. The table below shows the probability of exceeding 35°C for Maputo and the 3 stations together, as well as 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)
Maputo, Umbeluzi and Changalane	7%	16%	30%
Maputo	4%	10%	23%

Table 1. Probability of the occurrence of very hot days.

The chance of exceeding 35°C is higher under present conditions at the inland stations than at Maputo, and the increase in probability is also greater at these stations. Even so we can expect the frequency of days exceeding 35°C to more than double by 2055 at Maputo (from 4% to 10%).

[11] Tropical cyclones and climate change. Nature Geoscience 3, 157 - 163 (2010) Published online: 21 February 2010 | doi:10.1038/ngeo779.

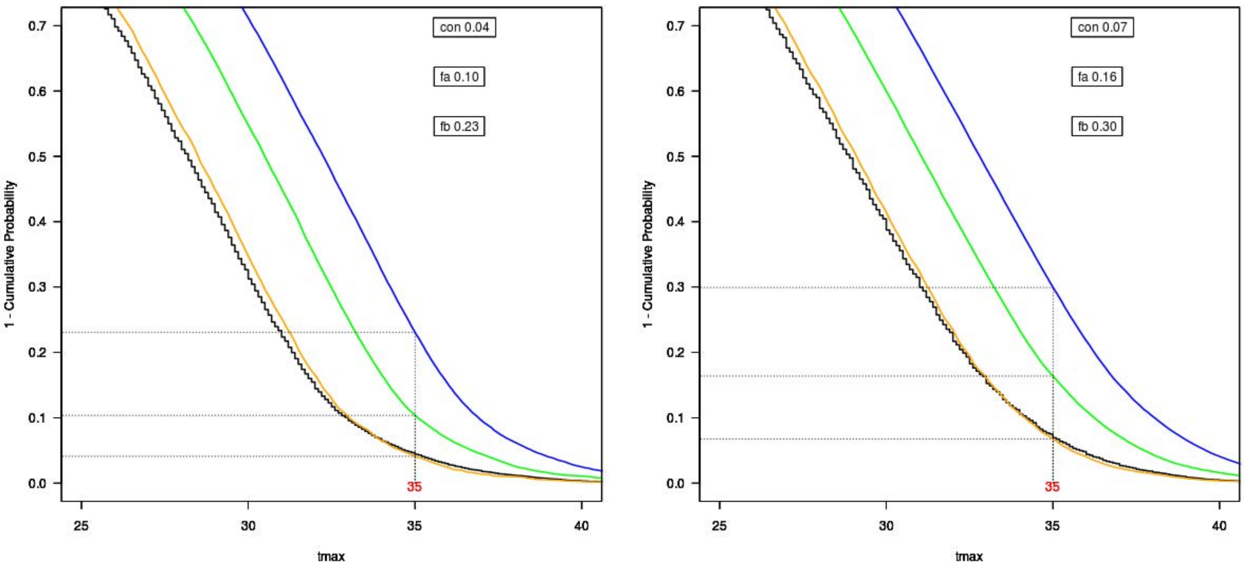


Figure 13: Cumulative probability of exceeding maximum temperatures under current (black), downscaled control (orange), downscaled 2046-2065 (green) and downscaled 2081-2100 (blue) periods. Maputo (left) and Maputo, Umbeluzi and Changalane together (right).

One improvement on these estimates of change for the future would be to downscale using a higher resolution RCM which would be better able to resolve graded 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.

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 available 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 bound) 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

4.3 Changes in extreme winds

Extreme wind speeds are often associated with cyclones and the fundamental problems associated with simulating changes in cyclones will thus have a bearing on simulating extreme winds. Therefore, a statistical downscaling of extreme winds was not attempted due to a lack of availability of wind data. It is worth noting however, that a statistical downscaling of wind would suffer similar restrictions as noted for extreme rainfall (4.2). It is the opinion of the authors that a better representation of extreme winds might be found in RCM simulations e.g. CORDEX, especially in regions of topographical differences. Given the general increase in wind speed suggested in the GCM simulations for most seasons, it is possible that extremes associated with south easterly winds may increase during summer. Assuming that extreme winds are associated with intense cyclones, the potential for cyclones increasing in intensity would suggest potential increases in associated wind damage to crops and infrastructure, not least harbour activity. It must be noted that Maputo is probably less exposed to the extreme winds due to its location. It is also unclear what sectors are most vulnerable in the city and whether that vulnerability would be increased by increased frequency of extreme winds.

5 Maputo: impacts and vulnerabilities

According to the ICLEI baseline study[12] Maputo is vulnerable to flooding and droughts and also lies in the path of tropical cyclones. A preliminary assessment of climate change impacts in the urban areas of Maputo[13] identified the following vulnerable areas:

- Coastal zones and their associated ecosystems
- Human settlements and infrastructure
- Health, food security and waste management (see Section 5)
- Transportation system (see Section 5)
- Wetlands and urban agriculture

The downscaled modelling projections produced for this report imply impacts on Maputo. These impacts may increase or decrease specific threats and vulnerabilities to specific local government sectors which were identified in the regional report[14] . In *this* report, agriculture has been included as one of the sectors as there are potential implications for the food security of Maputo through local production and also exports and imports through the port. Both current and future risks are summarised in the tables below. Increased risks in the future are highlighted in yellow.

[12] Kemp, Lucy V., Lucinda Fairhurst, Priscilla Rowswell, Tarryn Quayle 2011 Local Governments for Sustainability – Africa Baseline Study – Maputo, ICLEI.
[13] INGC 2009. Synthesis report. INGC Climate Change Report: Study on the impact of climate change on disaster risk in Mozambique. [van Logchem B and Brito R (ed.)]. INGC, Mozambique
University Press
[14] Tadross and Johnston, 2011. **Projected Climate Change Over Southern Africa; Namibia, South Africa, Mozambique, Tanzania and Mauritius, Report for ICLEI, February 2011**

5.1 Water and Sanitation

Impacts upon Water and Sanitation	Impact on livelihoods
Water supply • Risk of aquifer over-exploitation • Risk of erosion around the wells caused by water flowage • Increased risk of developing disease-transmitting vectors (mosquitoes) in the puddles created around the springs/ wells • Risk of developing diseases related to water due to poor maintenance of wells and the surrounding area • Salt water intrusion into freshwater systems in coastal zones is anticipated to increase. • Flooding causing strong water flows in aquifers thus increasing capacity for water • Decreased availability in freshwater for domestic and industrial use • Sedimentation of aquifers • Sea water intrusion into underground aquifers • Reducing quality of water in aquifers • Salt water intrusions into fresh water • Water treatment capacity will have to increase if insufficient fresh water is available • Poor and limited water supply to residents • Changing flood plains and greater damage to properties and infrastructure **Sanitation** • Contamination of water supply sources due to latrines overflow. • Increased risk of vectors that transmit diseases (mosquitoes, flies, small rodents) development • Lack of maintenance and unhygienic conditions can lead people to avoid the use of latrines • Changes in land use (i.e., potential flood areas could begin to be targeted for residential occupation) • Solid waste disposal in drainage channels, causing blockage and water contamination • Indiscriminate waste water discharge in the channel, causing water contamination • Increased public health risk due to the use of discharged water for human consumption by the surrounding population • Increased risk of developing disease-transmitting vectors (mosquitoes) along the ditches • Increased flooding and erosion in the channel's discharge area, affecting land use and structures and facilities existent there • Water pollution downstream, bringing impacts on public health and potential impacts on ecologically sensitive areas (e.g. mangroves, wetlands) • Sewerage water seeping into fresh water supply if flooding becomes more prevalent as storm water drainage is lacking	• Increased pressure and stress on fresh water supply. • Impacting water sanitation in the poorer, vulnerable areas • Cascade effect on health as a result of increased likelihood of contamination of fresh water sources. • Poor water access and poor water quality • Any business that uses water will suffer reduced productivity, leading to reduced income, employment decreases.

5.2 Transport

Type	Impacts upon Transport	Impact on livelihoods
Road	• Blockage of roads causing delays • Flooding causes diversions, often onto roads not capable of carrying the higher loads • Traffic congestions and accidents • Inundation of roads by water or sand, causing structural damage • Erosion of bridges, pavements and roads adjacent to the coast needing rebuilding and fortifying against future events	• Limits access routes for both emergency personnel during an event and normal business movements during and after. • Delays to the work place and markets, with consequences of raised prices in the event of constant demand • Work hours lost reducing productivity and income • Risk to public safety
Rail	• Erosion of railway infrastructure • Inundation of railways by water • Reduced use of rail to transport goods to Ressano Garcia	• Causes delays and cancellations of trains • Unable to reach destination • Work hours lost– reducing income
Air	• Reduction in business transacted through Maputo if goods and capacity lose this vital link to local and global economies.	• Reduces accessibility to airports • Delay in exports/imports
Port	• Erosion to coastal infrastructure and equipment • Damage to boats at sea if storms are more intense as expected • Erosion to harbour wall • Damage to boats anchored at port, both private yachts and commercial vessels. • Any proposed extensions to the port should carefully consider vulnerabilities to climate change impacts.	• Days at sea lost • Work hours lost – reducing income, if the port is rendered unworkable then there is no income stream until the damage has been cleared. • Delay in exports/imports • Increased insurance premiums

5.3 Health

Impacts upon Health	Impact on livelihoods
Flooding • Damage to clinics, hospitals and other infrastructure and services • Increased pressure on emergency services. • Service delivery backlogs in clinics and hospitals • Chemical Hazards: contamination of flood water with oil, diesel, pesticides, fertilisers etc. **Increased temperature** • Spread of infectious diseases: skin and respiratory diseases and stomach ailments. • Worsening of existing chronic illnesses • Long-lasting psychological impacts • Increased health threats through heat stress • Disruption of solid waste management • Loss of hygiene and sanitation – increased pests and vectors **Increased wind** • Higher wind speeds and changes in air pressure cause people to feel unwell (i.e. headaches) • Increased drying effect	• increased deaths from: – Drowning – Electrocution • Loss of work by a breadwinner due to cholera or any other waterborne disease will have serious ramifications for vulnerable families. • Poor and limited water supply to residents • Dehydration • Loss of shelter • Likely to affect vulnerable communities (young, woman and elderly) most at risk to infection and heal risks and impacts associated with severe extreme events. • Food scarcity

5.4 Energy

Impacts upon Energy	Impact on livelihoods
• Erosion of coastal power lines • Damage and losses to energy production facilities and infrastructure (power stations, high voltage lines etc). • Extreme temperatures increase the demand of energy as cooling facilities are employed • Power outages due to floods destroying power lines • Energy supply cut for bore hole water pumping • Loss of economic activity unless alternate energy supplies are in position	• Limited fresh produce for consumption • Limited water supply if water sector does not have backup generators causing dehydration • Inability to boil water to ensure water is potable and to prevent the spread of cholera and other water-borne diseases.

5.5 Agriculture

Impacts upon Agriculture	Impact on livelihoods
• Decreased effective rainfall • Higher temperatures • Increased evaporation - drying of soils • Seasonal shifts • Flooding • Strong winds during cyclones	• Decrease in crop yields • Increased irrigation requirements • Limited fresh produce for consumption • Access to markets reduced by flooding • Crop damage

The risks and impacts upon water and sanitation, transport, health, energy and agriculture 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.