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***By:** Mark Tadross and Peter Johnston, Climate Systems Analysis Group, University of Cape Town
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***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.

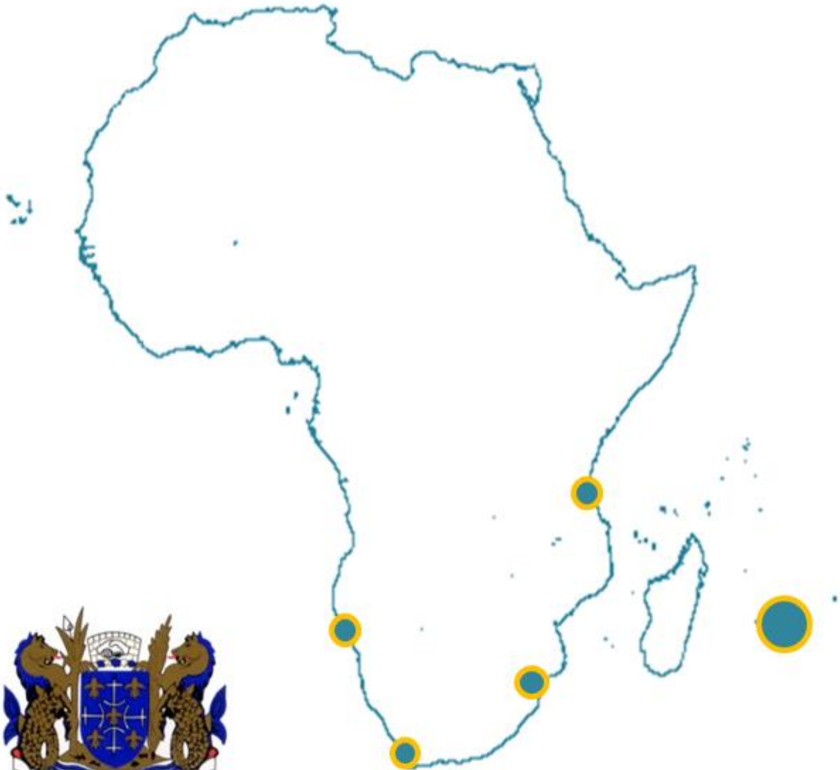
Through a participatory process, this project will carry out a desk-top study, long-term, multi-discipline, multi-sectoral stakeholder platforms in five Southern African cities comprising of academics, communities and the local government in order to facilitate knowledge-sharing, promote proactive climate 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 Port Louis:

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 Port Louis: Adding value through downscaling

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Authors: Mark Tadross and Peter Johnston

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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.[1] 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 Port Louis. 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;

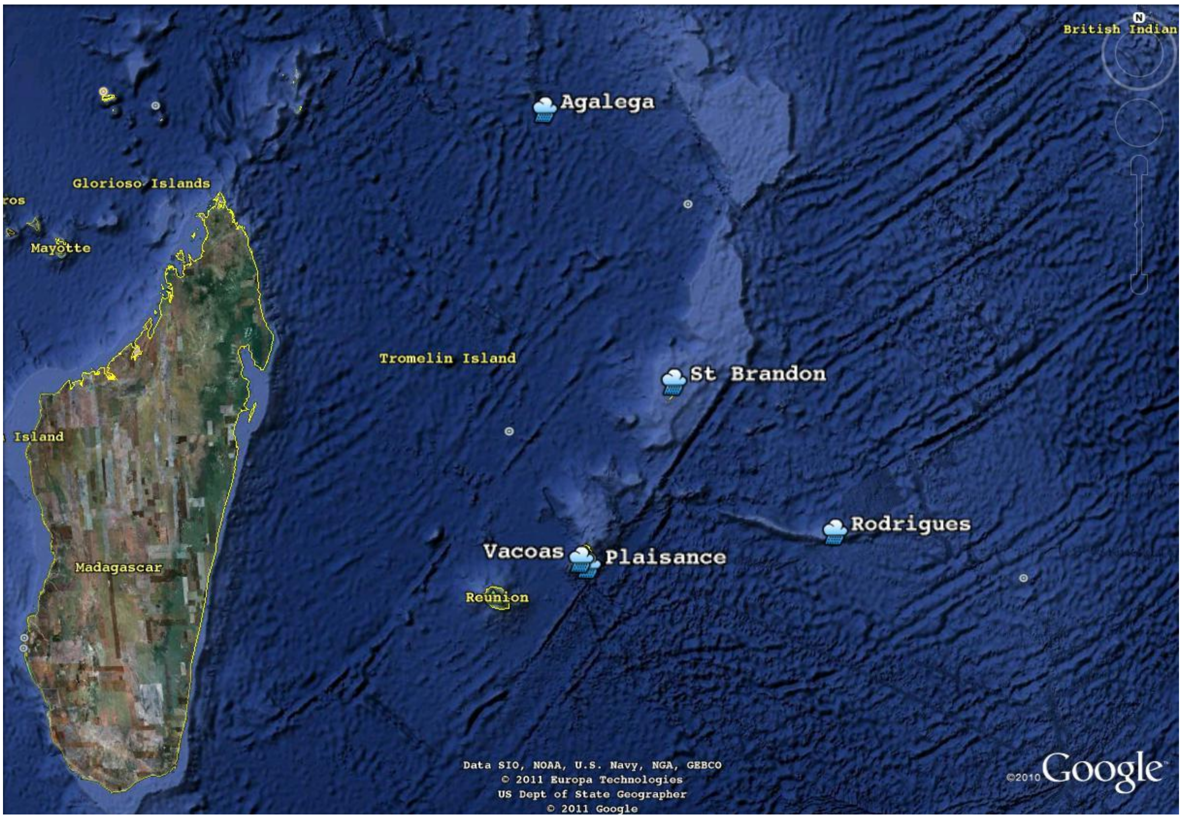
- changes in rainfall and precipitation patterns (flooding and drought),
- increases in temperature and associated desiccation effects,
- increasing frequency and intensity of storm surges or extreme events,
- increasing average global sea levels due to melting glaciers and thermal expansion (permanent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

This report will outline impacts and vulnerabilities that the recently results may imply for Port Louis, whilst also discussing constraints, given the paucity of available climatological data (there were only 5 stations form which data was available for the entire Republic of Mauritius) 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.

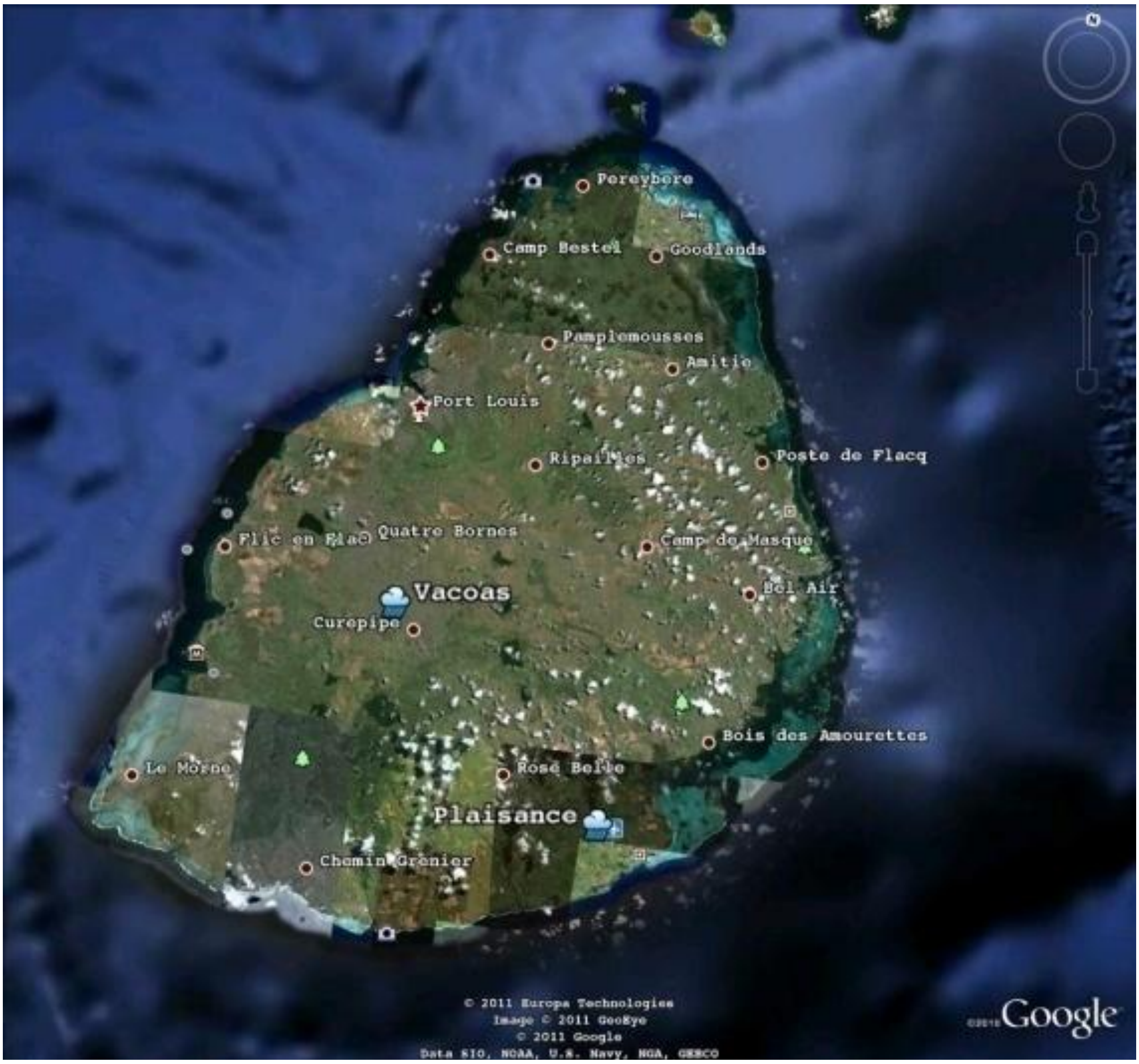
[1] Tadross and Johnston, 2011. **Projected Climate Change Over Southern Africa; Namibia, South Africa, Mozambique, Tanzania and Mauritius, Report for ICLEI, February 2011**

1 Historical observations and trends from Mauritius

Historical observations of weather during the recent past from weather stations in the vicinity of Port Louis 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). Unfortunately for this study records from local sources were not available so the baseline climate and trends (including the future downscaled climates) were taken from data available through the Global Historical Climatology Network (GHCN). Figure 1a depicts the geographical location of the 5 data stations available through this data source (Agalega, St Brandon, Rodrigues, Plaisance and Vacoas), whilst figure 1b is an aerial view of the island of Mauritius demonstrating the geographical location of the city of Port Louis in relation to the 2 nearest weather stations. (There were no suitable records available for Port Louis.)



(a)_



(b)

Figure 1: Available weather stations on Mauritius main island.

For the purposes of this report we will concentrate on the 2 Mauritian stations, Vacoas and Plaisance, of which Vacoas is the closer to Port Louis.

1.1 Climate of Port Louis, Vacoas and Plaisance

Port Louis features a tropical wet and dry climate with a longer wet season than dry season. Its wettest months are from December through April where, on average 100mm (or more) of, rain falls during each of these months. The months of September through November form the dry season, though technically July, with an average of just less than 60 mm of precipitation, could be considered a 'dry' month. The city also shows a large range of average temperatures; during the mid-year maximum temperatures average 24°C (MSM 2010[2]), while during the height of the wet season, maxima average around 30°C. The direction of

[2] MSM 2010 Meteorological Services Mauritius [online]: Available: http://metservice.intnet.mu/ [September 2010]

wind is generally from the east, although cyclones hit the island from the west. Mean monthly relative humidity[3] is generally high and varies from 86% in March to 80% in October in most places (Anon. 2010).

Through the GHCN network, daily data were available for the Vacoas station between 1960 and 1990, and for the Plaisance station between 1950 and 2010 (though at the latter, rainfall was only available until 1990). Figures 2 and 3 illustrate the daily climatology (averaged over all years) of rainfall, temperature and with reference evapotranspiration[4] at the two sites. The figures clearly indicate that the seasonal variation in climate is similar at the two stations with, on average, slightly higher rainfall and lower temperatures at Vacoas (which is topographically higher at 425m+MSL (above mean sea level), in comparison to 57m+MSL at Plaisance). This leads to slightly drier conditions at Plaisance which is away from the mountains, where rainfall is less than evapotranspiration for slightly longer periods than at Vacoas which is wetter due to the higher elevation.

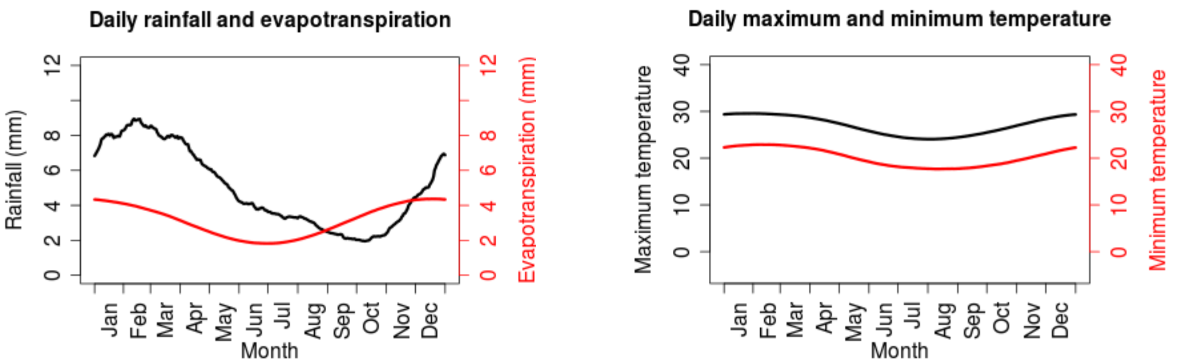


Figure 2: Daily climatology of rainfall (mm day^{-1}), minimum and maximum temperatures (°C) and reference evapotranspiration (mm day^{-1}) at Plaisance.

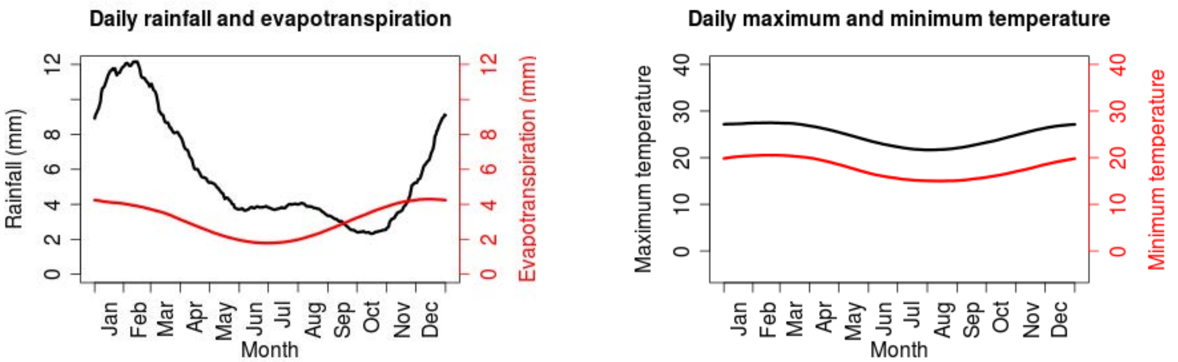


Figure 3: Daily climatology of rainfall (mm day^{-1}), minimum and maximum temperatures (°C) and reference evapotranspiration (mm day^{-1}) at Vacoas.

1.2 Historical trends in climate data at Vacoas and Plaisance

Whilst the records at the two stations are long enough to calculate trends (30-40 years), unfortunately they do not include recent years' data (which was not available), when the effects of climate change are likely to

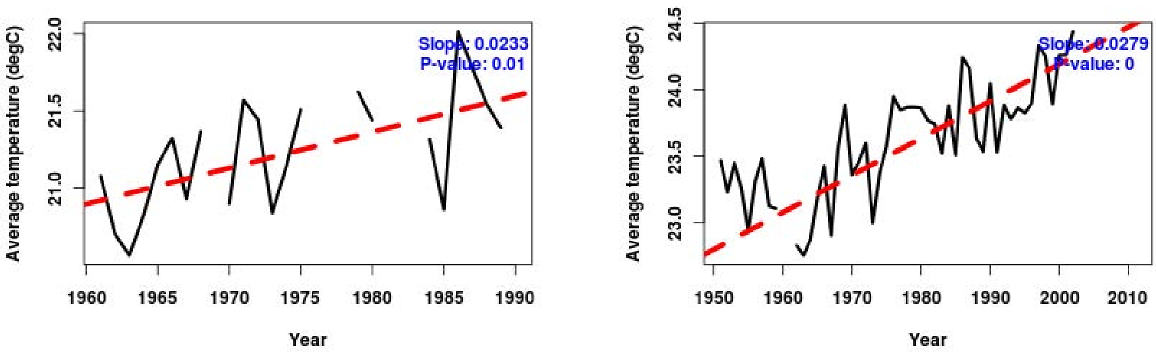
[3] Relative humidity is an indication of how much water the air contains relative to a maximum of 100%
[4] Reference evapotranspiration (ET_o) indicates the amount of water that would be lost due to evaporation and transpiration if it were available. If ET is higher than rainfall it means that the soil and vegetation will dry out.

be more observable - due to the acceleration of human activities and associated emissions on a global level. Nevertheless we investigated for any noticeable trends in the following climate parameters:

- start of the rainfall season based on criteria for planting a crop e.g. sugarcane (following standard criteria , assuming the season starts when 45mm of rain falls within a 10 day period and is followed by at least 60mm in the following 20 days consecutively);
- end of the rains (assuming the season ends when less than 60mm of rain falls in 20 days;
- duration of the rainfall season in days ;
- daily temperature, rainfall and evaporation data before, during and after the rainfall season;
- a potential moisture index (PMI[5]) which is taken as rainfall-evaporation;
- growing degree- days[6] associated with different stages of a sugarcane crop.

In each case, an examination was undertaken of the trends at both locations to see if there was consistency between the two locations - one would expect the impact of large-scale changes in the atmosphere due to climate change to be visible at both locations.

The only trends consistently detectable (significant at the 90% confidence level[7]) at both locations were those for increasing temperatures and associated indices e.g. growing degree days. Figure 4 illustrates increasing trends in average annual temperatures for both stations, which are consistent with those reported in the IPCC 4th assessment[8] and in the UNDP country profiles[9]. Trends depicted in figure 4 are of the order 0.25°C per decade. This would translate to 1 degree increase in average temperatures every 40 years.



(a) (b)

Figure 4: Trends in average annual temperatures for (a) Vacoas and (b) Plaisance

It is recommended that if climate data for a longer period, especially including later years (particularly rainfall data) becomes available in the future then this data should be further tested for trends in both extreme (e.g. using software from the ETCCDMI and STARDEX programmes) and mean climate

[5] PMI is an index of the effective moisture regime that is used in the classification of vegetation in southern Africa
[6] Growing degree days (GDD) are calculated by subtracting the plant's minimum threshold temperature from the average daily air temperature
[7] 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
[8] IPCC, 2007. IPCC Fourth Assessment Report (AR4) [online]: Available: http://www.ipcc.ch/
[9] http://country-profiles.geog.ox.ac.uk/

characteristics. This could give greater insight into the expected rainfall averages as well as frequency and nature of extreme rainfall.

2 GCM projections of future change (for 2050)

GCM projections of change are presented and discussed in the baseline climate report for southern Africa[10] and are shown here with a focus on the Mauritius region.

2.1 Rainfall

Figure 5 demonstrates how rainfall is projected to change under both a B1 and A2[11] emissions scenario; for each season, both the median[12] change (a total of 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 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 the most obvious changes are for simulated decreases in June-August and September-November rainfall; under the B1/A2 scenario the median decrease is less than 2 (JJA) and 4 (SON) mm day^{-1}. During the December-May period the simulations are less consistent, with equal numbers of models showing increases as decreases across the GCM models in the vicinity of Mauritius.

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

[11] 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.

[12] The median is the midpoint of a frequency distribution of observed values, sometimes reflected as the most common result.

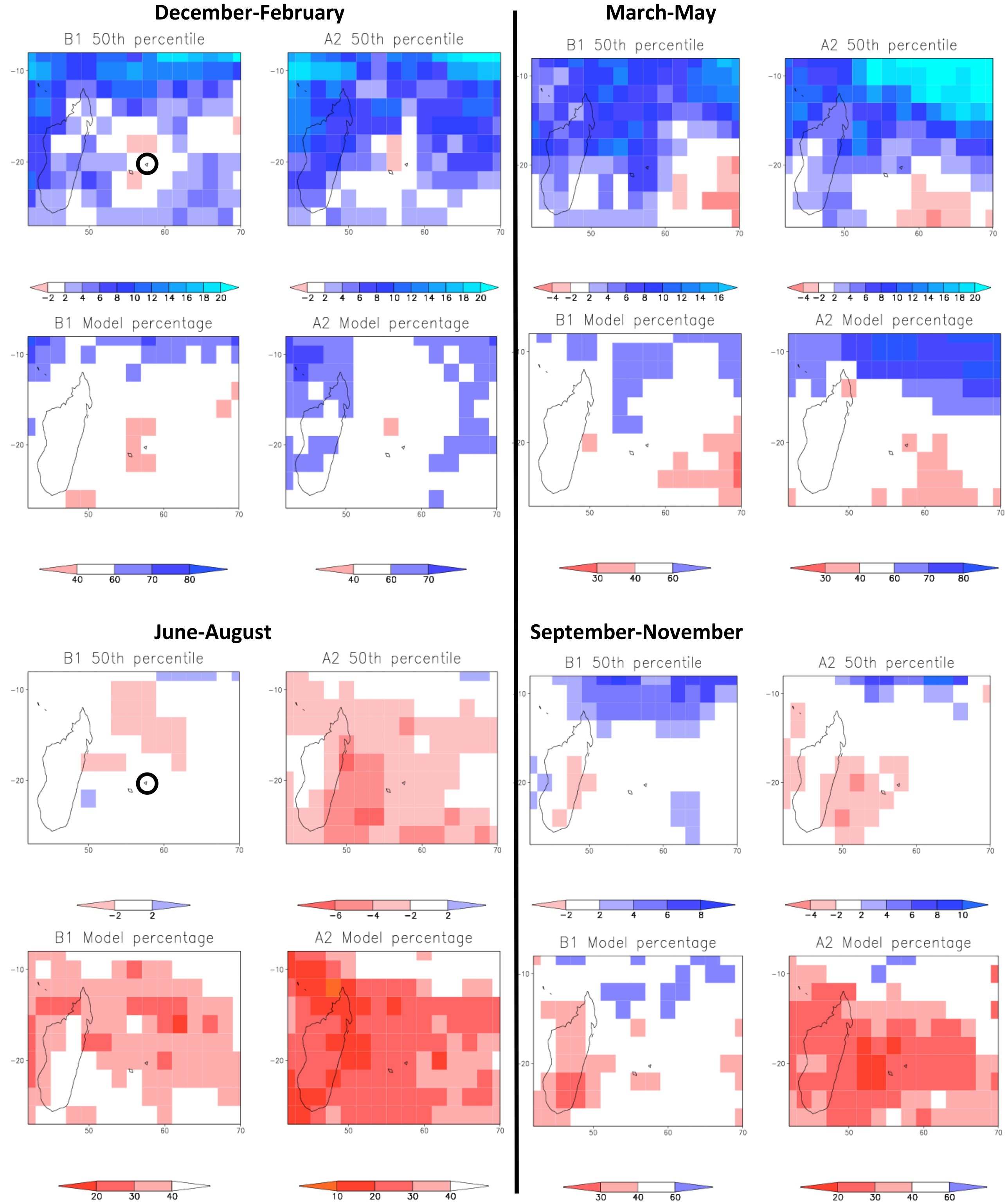


Figure 5: Median GCM simulations of rainfall change in mm per month by 2050 under A2 and B1 emissions scenarios for each season. The confidence of the model ensemble simulations is indicated by the percentage of models simulating a positive/negative change, indicated by the percentages where less than 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 B1 and A2 scenarios for each season. Increases are similar for each season with differences between the scenarios used; 1.0-1.25°C and 1.25-1.5°C for B1 and the A2 scenarios respectively.

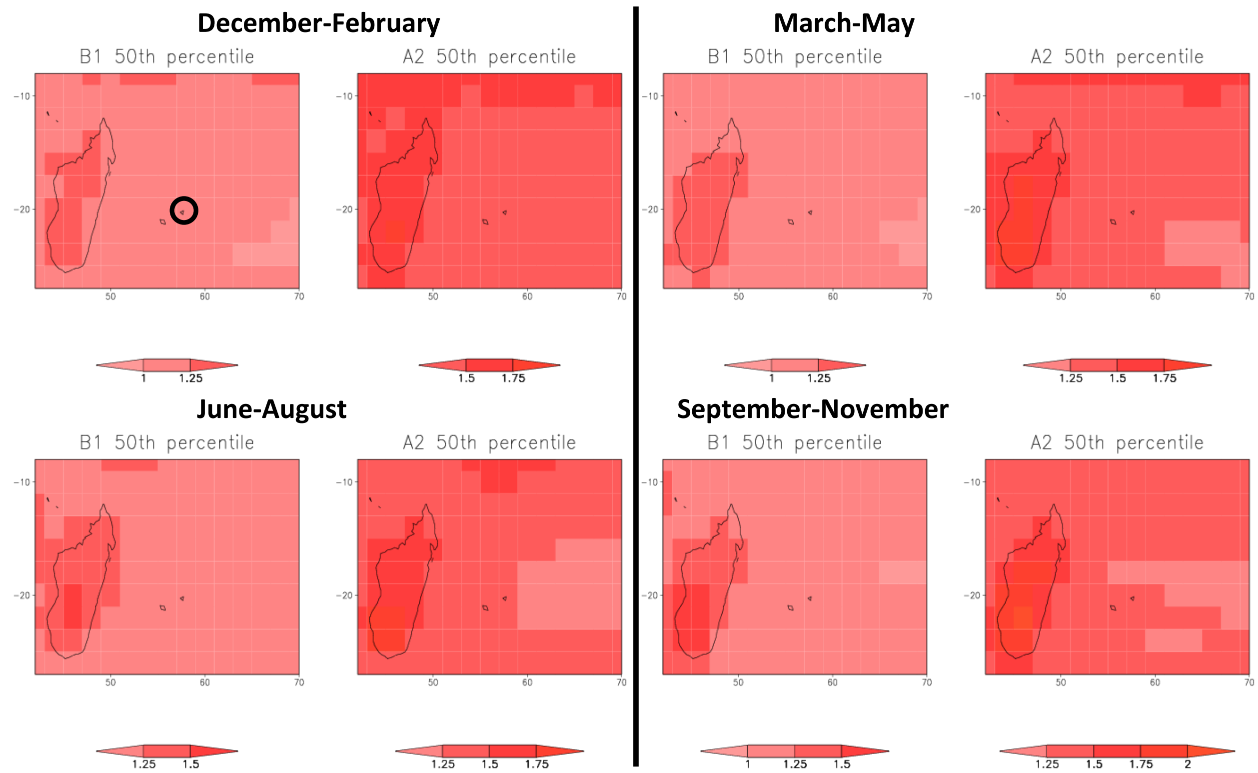


Figure 6: Median GCM simulations of change by 2050 under A2 and B1 emissions scenarios for each season.

The island of Mauritius is enclosed by just one grid cell, but the overall temperature increases in the region ensure that the expected temperature increases will be of the order shown, that is between 1 and 1.25 degrees for the B1 scenario and between 1.5 and 1.75 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 1.5 degrees warmer by 2050 than today. This is valid for All temperatures, minima, maxima and means.

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[13] 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 in all seasons except Spring (September-November). In this season they become slightly more northerly. Changes during June-November reflect a

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

strengthening of the anticyclonic (originating around a high pressure system) atmospheric circulation over the southern Indian Ocean during winter and early spring (June to September), as depicted in the IPCC 4th assessment report (IPCC, 2007). During December-May south easterly winds strengthen considerably, and are more common than today. This may have impacts on lodging of sugar cane in the Mauritian fields and an impact on tourism depending on the exposure of the location to these winds.

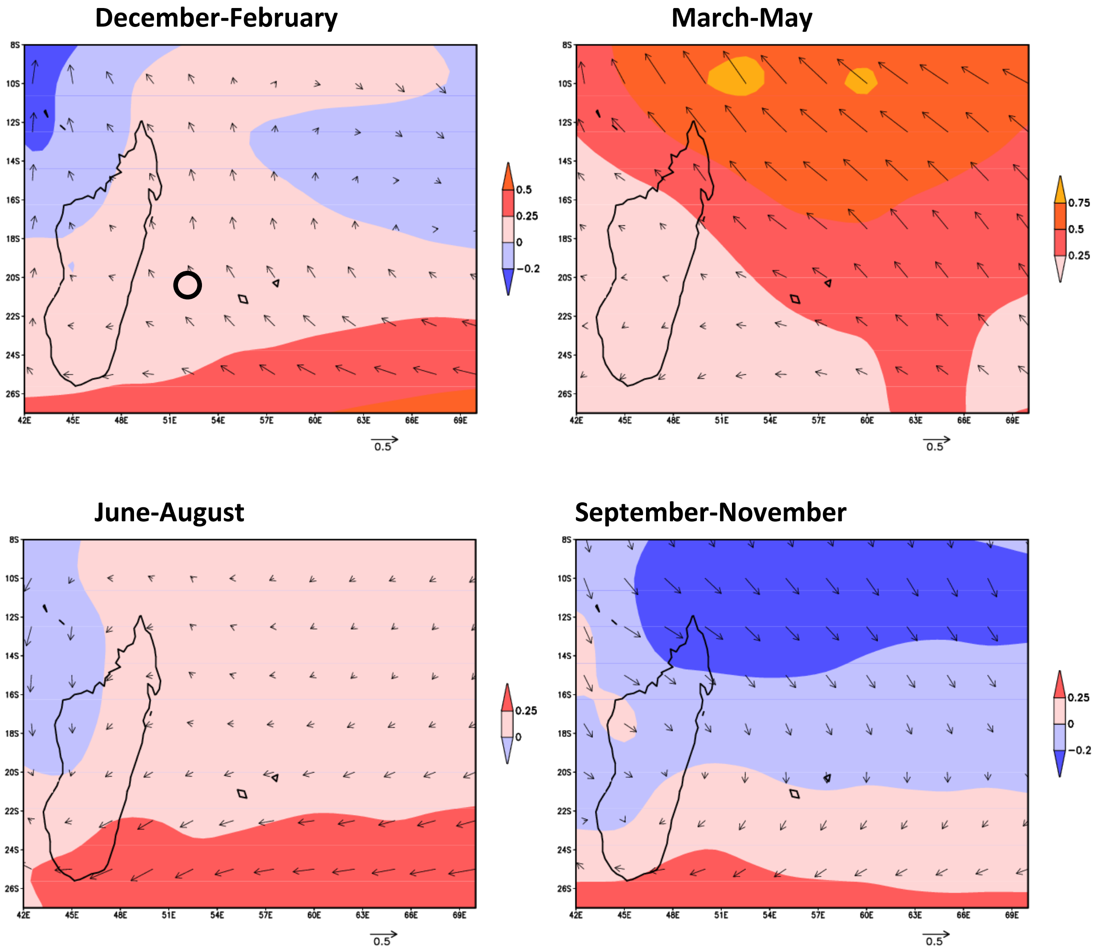


Figure 7: Median changes in 10m wind directions simulated under an A2 emissions scenario; shading indicates changes in wind speed (in m/s).

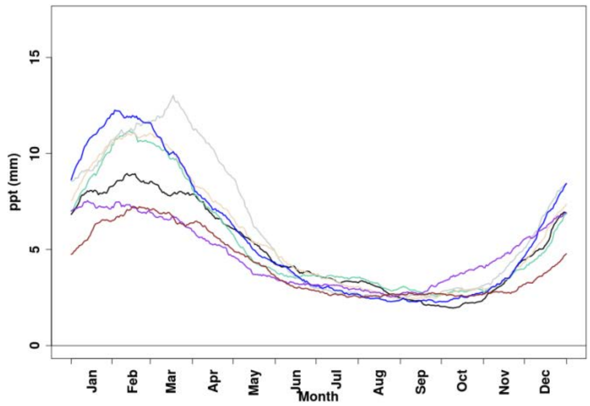
The impacts on Port Louis itself cannot be inferred from the results alone. Some activities may benefit from the wind changes, while for others it may be detrimental but apart from the seasonal changes reflected here it would be required to identify specific sectors that are already vulnerable to wind to determine what the effects would be in the future.

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

The following sections show the results from applying a statistical downscaling methodology developed at the University of Cape Town to nine suitable GCMs[14] (forced with the A2 emissions scenario) and the observed rainfall and temperature data from the Plaisance and Vacoas stations. The downscaling relates daily weather systems that lead 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. As there is no wind data for each location we use the Priestly-Taylor method to calculate reference evapotranspiration (ET_0) based on simulated wind-induced temperatures.

3.1 Rainfall

Figure 8 below compares the downscaled GCM control climates[15] (1961-2000) with the observed climates for the two stations. In both cases the GCM control climates are close to the observed, replicating the observed seasonal cycle and peak rainfall during February as well as tending to capture the higher rainfall at Vacoas. This gives us confidence that the downscaling methodology applied to these GCMs is simulating the local climates correctly.



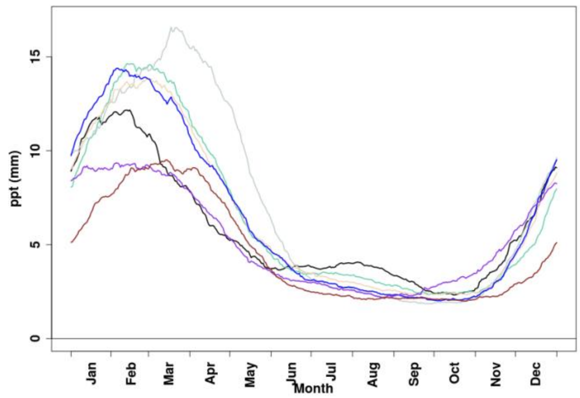


Figure 8: GCM downscaled control rainfall climates (mm per day), for the period 1961-2000; Plaisance (left) and Vacoas (right). Black line is observed climate and coloured lines are downscaled GCM climates.

Figure 9 shows the average anomalies[16] for the nine GCMs at each location. There is generally a large spread between the models, more so during the rainy season and more so at Vacoas. The spread covers the zero anomaly line, meaning some show increases and some decreases, but more models tend to be simulating a decrease in rainfall during the main part of the rainy season. It can be assumed that Port Louis data would yield a similar result.

[14] The suitability of GCMs depends on the frequency of data and the type of variable
[15] 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
[16] An anomaly is the difference between the current climate and a future climate as projected by a model.

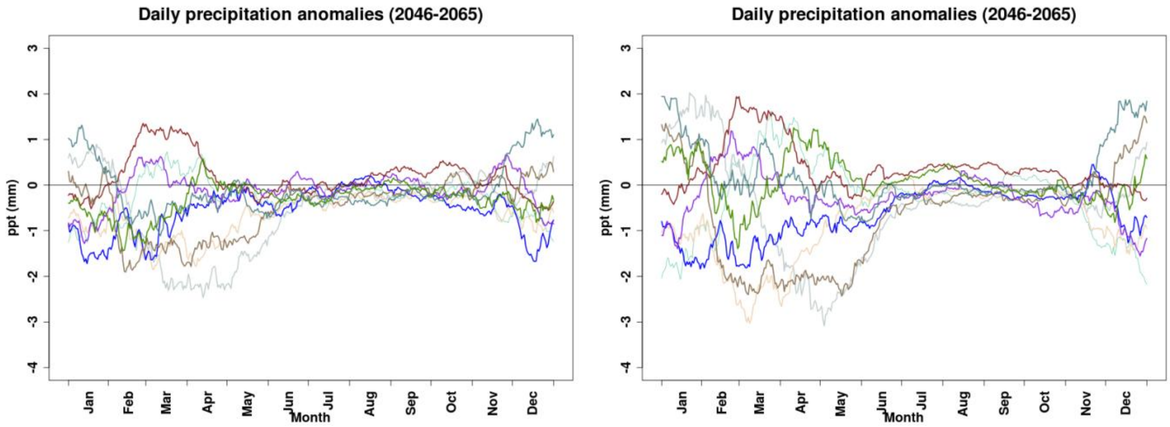


Figure 9: GCM downscaled changes in rainfall (mm per day), for the period 2046-2065 relative to the control climate of the period 1961-2000 (black zero line); Plaisance (left) and Vacoas (right).

Summarising the rainfall changes, figure 10 presents the data for both Plaisance and Vacoas. 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 change is negative for all months and both periods (more so for the later period), meaning an average decrease in rainfall of between 0 and 1 mm per day. During the rainy season this could therefore have implications of up to 30 mm less rainfall per month (based upon the median). There is no indication that the type/intensity of rainfall may or may not change.

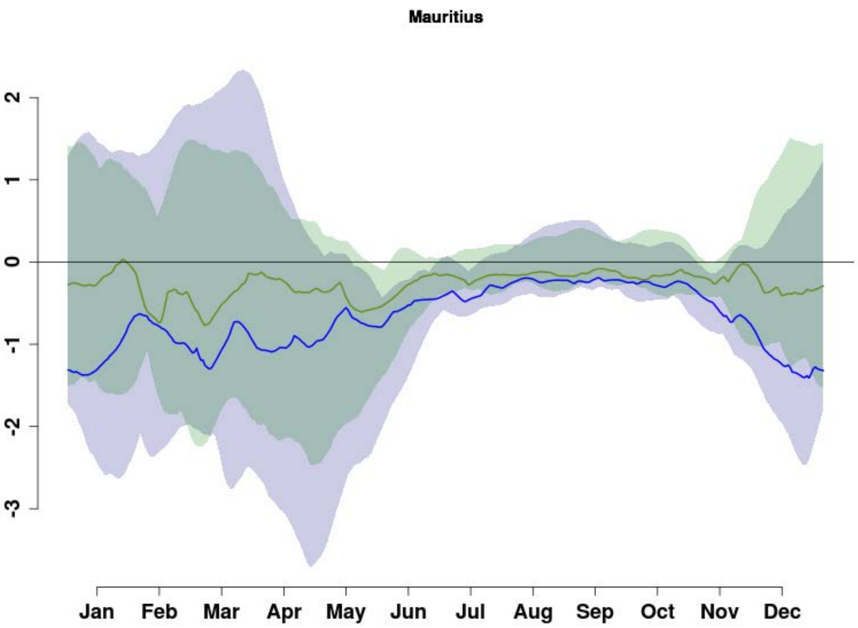


Figure 10: Downscaled rainfall anomalies (mm day^{-1}) for the 2046-2065 period (green) and 2081-2100 period (blue). Shading indicates the spread of results for the various models and solid lines the median model response.

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. Minimum temperature changes are summarised for both stations together in figure 11. 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)Highest increases are during the drier winter period, with median changes for the 2081-2100 period as high as 3°C warmer than current averages.

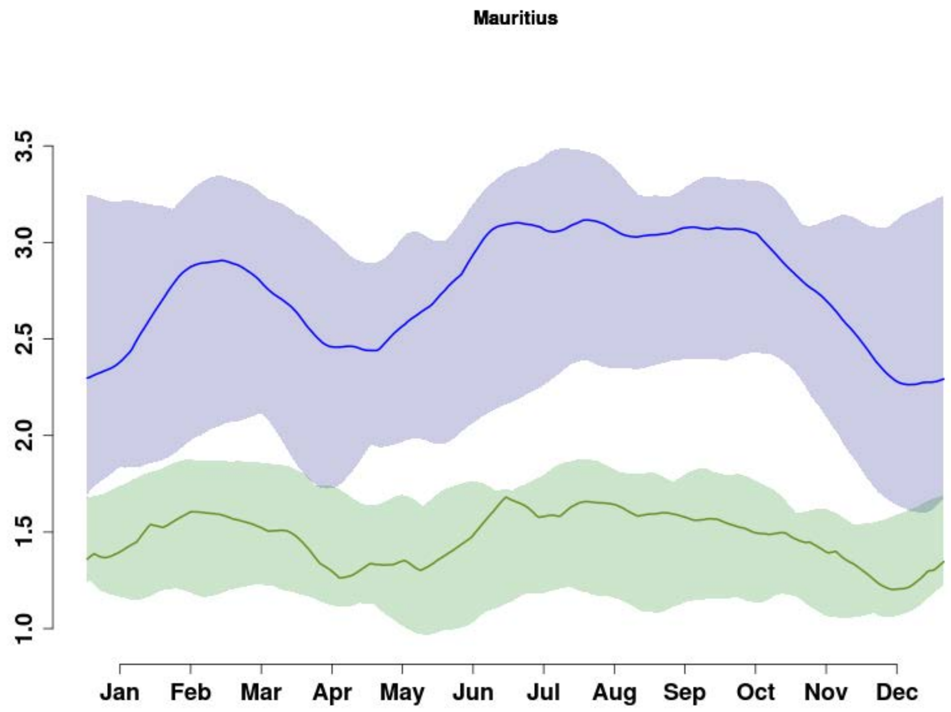


Figure 11: Downscaled minimum temperature anomalies (°C) for the 2046-2065 period (green) and 2081-2100 period (blue). Shading indicates the spread of results for the various models and solid lines the median model response.

3.3 Evaporation and effective rainfall

One major consequence of the projected increases in temperature is the resultant increase in reference evapotranspiration (ET_0) which is summarised for both stations in figure 12. Increases in ET are highest during the start and middle of the rainy season with highest increases of 0.3 mm day^{-1} during the 2081-2100 period.

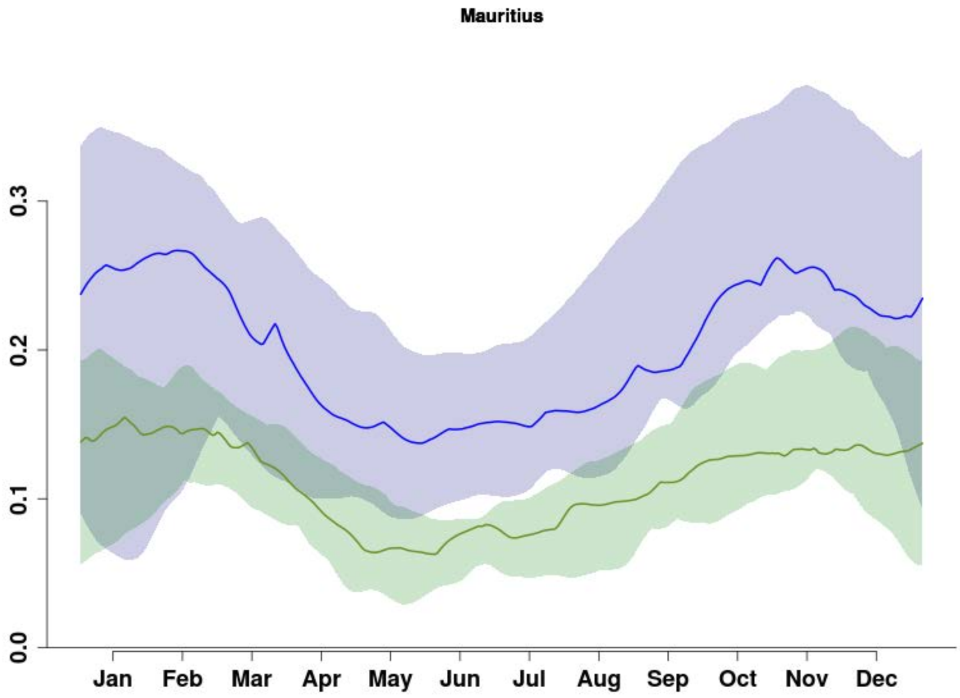


Figure 12: Downscaled reference evapotranspiration (ET_0) anomalies (mm day^{-1}) for the 2046-2065 period (green) and 2081-2100 period (blue). Shading indicates the spread of results for the various models and solid lines the median model response.

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 13 shows the change in effective rainfall. Comparing with figure 10 it can be seen that the changes are slightly more negative and that more of the downscaled GCMs are simulating a negative change, meaning lower rainfall. The implication is that there will likely be less effective rainfall, especially during the April to August period and around November at the beginning of the rainy season. For the urban areas such as Port Louis, 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.

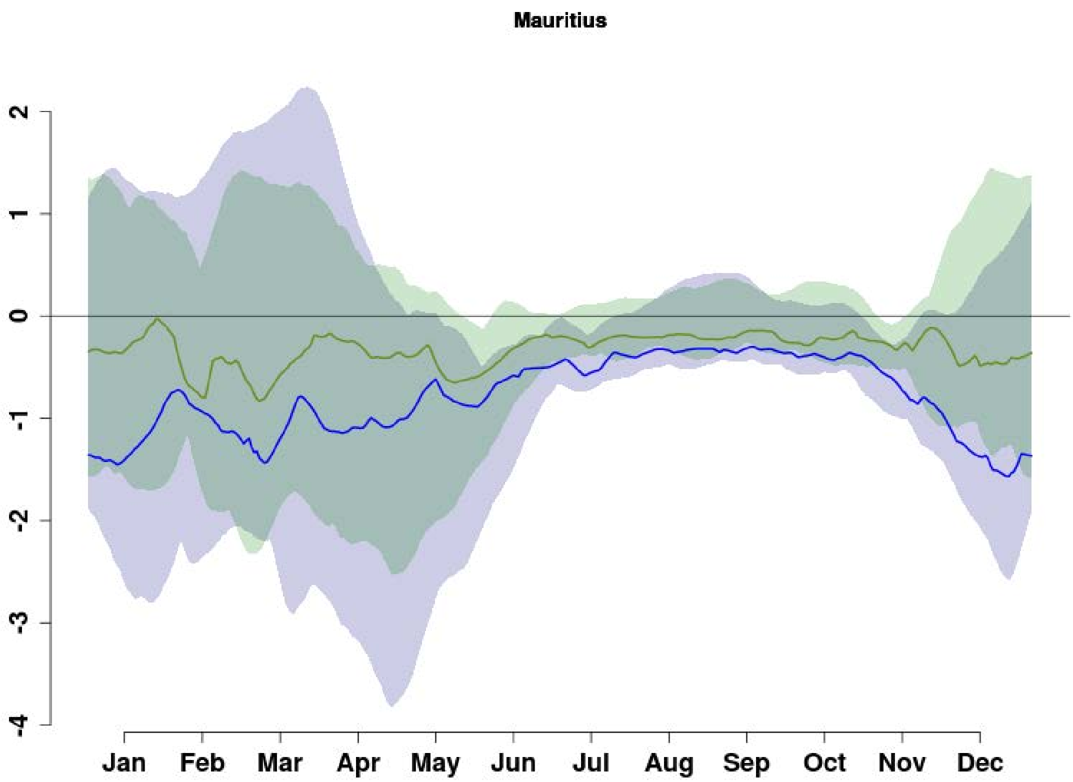
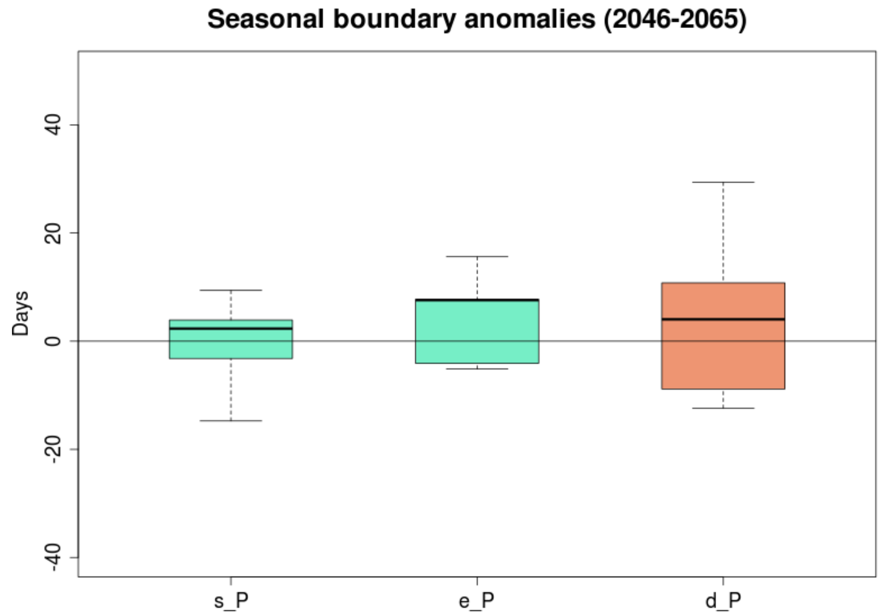


Figure 11: Downscaled effective rainfall (ppt - ET_0) anomalies (mm day^{-1}) for the 2046-2065 period (green) and 2081-2100 period (blue). Shading indicates the spread of results for the various models and solid lines the median model response.

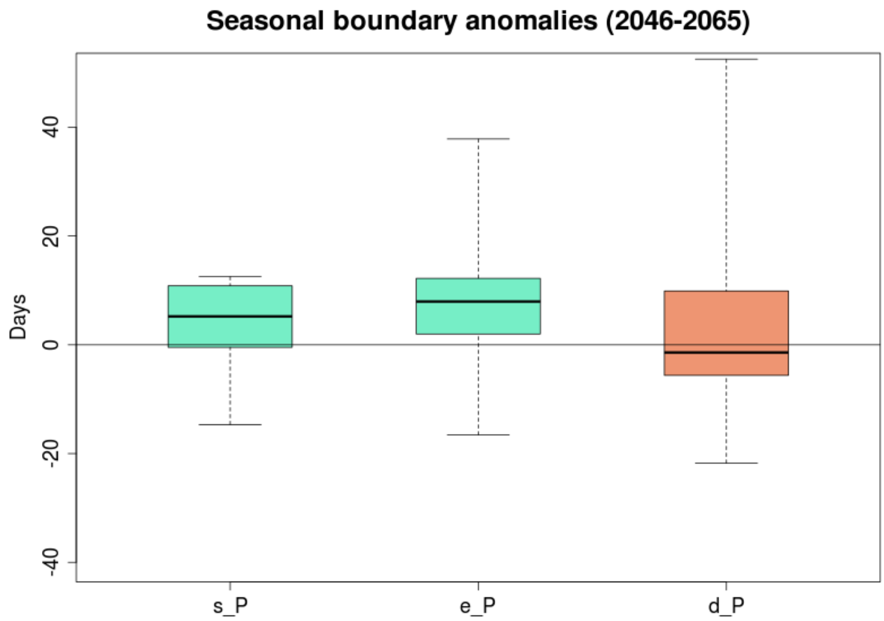
3.4 Changes in seasonality and potential moisture

The changes in rainfall and ET_0 simulated above may lead to changes in the start, end and duration of the rainy season, as well as the moisture available for plant and crop growth. We The start, end and duration of the rainy season were calculated based on the criteria given in section 1.2 and these defined times were then used to calculate what the average Potential Moisture Index (PMI) would be before, during and after the rainfall season. The PMI was calculated as (rainfall-ET_0) during the season and (rainfall-0.15*ET_0) out of season – assuming a short grass cover out of season and a maturing crop during the season. This PMI relates to soil moisture and thus cannot be applied to the hard surfaces in an urban context, but increased PMI could be translated into more runoff off hard surfaces.

Figure 12 illustrates the mean *changes* in the start, end and duration of the season for all GCMs at both Plaisance and Vacoas in days (the boxplots indicate the range of values from the 9 GCMs around the current season, given as the zero line, where positive numbers mean a *later* start or end and negative numbers *earlier*). In both cases the rainy season is simulated to start and end slightly later than at present (though, as the spread indicates, it should be noted that not all GCMs simulate this). This results in median changes in **seasonal duration** that are slightly (the median value is 4 days) longer at Plaisance and slightly shorter (the median value is -1 days) at Vacoas. The changes are relatively small.



a) Plaisance

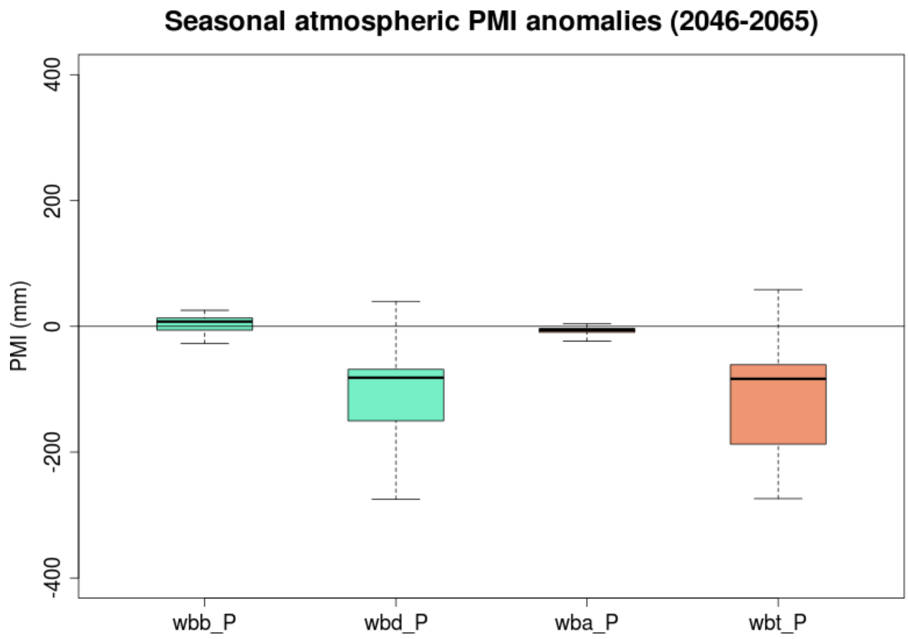


b) Vacoas

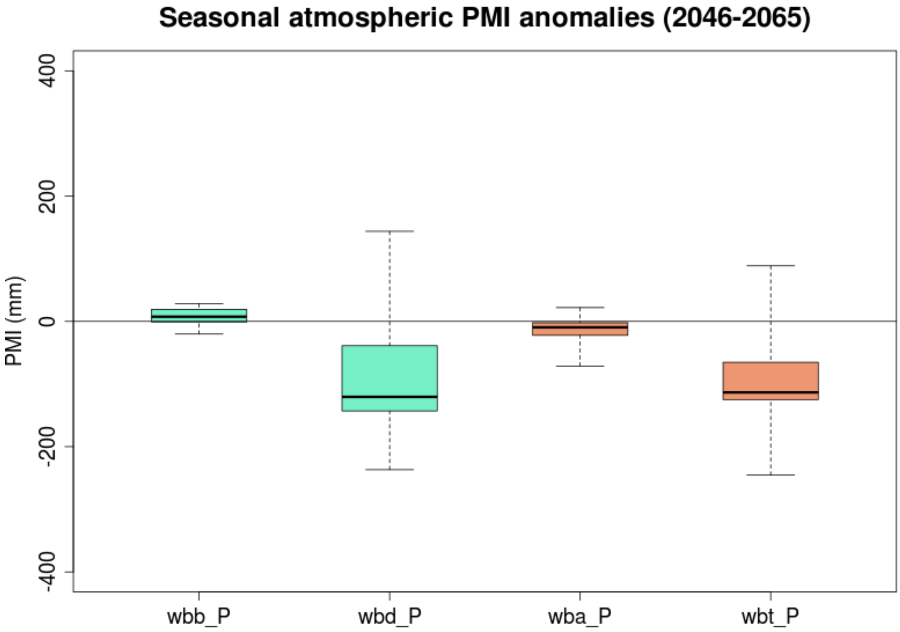
Figure 12: Simulated changes in the start (s_P), end (e_P) and duration (d_P) of the rainy season for Plaisance (a) and Vacoas (b). Boxplots show the range from the different GCMs (coloured sections include 50% of the models) with the median change given as a black line.

The seasonal shift does not infer an increase of rainfall (that is discussed above) but an increase in the number of raindays, and would not have a significant impact on the city of Port Louis unless it is evident that a change in the number of raindays affects a particular sector.

Figure 13 shows the simulated **changes** in PMI for the different times of the year. In both locations it can be seen that there is little change in PMI before, and after, the rainy season (this is perhaps not surprising as the rainy season is long and these periods, before and after, are short). However, during the season (and the change for the total annual value) changes in PMI are negative at both locations, indicating that increases in ET_0 and decreases in rainfall result in less moisture being potentially available to a crop or plant. This suggests that an increase in water for irrigation purposes will be required to make up the shortfall if rainfall does not currently provide enough moisture for a purely rainfed crop. It also suggests that less water will be available for general consumption unless there are improvements in efficiency at both collecting, use and distribution of water, especially in concentrated urban areas such as Port Louis.



a) Plaisance



b) Vacoas

Figure 13: Simulated changes in the Potential Moisture Index (PMI) at Plaisance (a) and Vacoas (b):

- **before the rainy season (wbb_P),**
- **during the rainy season (wbd_P),**
- **after the rainy season (wba_P) and**
- **total during the year (wbt_P);**

. Boxplots show the range from the different GCMs (coloured sections include 50% of the models) with the median change given as a black line.

4 Changes in cyclones and 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 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 Indian Ocean. 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*[17], 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 skill and resolution of GCMs it is unlikely that improved estimates of cyclone tracks and frequencies will be forthcoming; new simulations from the CORDEX programme could offer some high resolution dynamic simulations of cyclone genesis and movement from

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

multiple regional climate models (RCMs) for the first time but these simulations are unlikely to include important interactions for cyclones, such as feedbacks with the underlying ocean etc.
Thus to generalise for Port Louis, taking account that it is a small city on a small island, in the context of tropical cyclones that are hundreds of km in diameter, one could say that there is no indication of more cyclones affecting the city, but that cyclones that do will be more intense with stronger wind and heavier rainfall.

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. These changes are similar to those noted in the UNDP country study i.e. very hot days and nights in the current climate (currently 5% of all days) will occur on 29-48% of days by 2060. 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 are, at least partly, difficult to estimate due to the problems in simulating cyclones mentioned earlier (section XX). Additionally, the statistical downscaling technique used here can only simulate daily rainfall values seen in the historical record (which in this case was only from 1960-1990). This means that there may be an underestimation in projected increases in rainfall due to increases in intensity. Given that increasing intensities of rainfall are likely in a hotter climate with more moisture for rainfall, especially in tropical regions such as Mauritius, 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 currently not enough RCM simulations for multiple GCMs available for the region in order to construct envelopes of change and for assessing the probability/risk of particular changes. Again, this may change when the CORDEX data becomes available. Overall it must be acknowledged that it is quite possible that extreme rainfall occurrences will increase in the future, given the increase in temperature and available moisture and the likely increase in cyclone intensities.

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 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 Port Louis is probably least exposed to the SE 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 Port Louis: impacts and vulnerabilities

Port Louis is home to around 170 000 inhabitants, a large proportion of the Mauritius urban population; practically the entire urban population of this island is found within the two neighbouring districts of Port Louis and Plaines Wilhems (NAR 2010). The city is located five metres above sea level and Port Louis hosts the only port on the island for import and export trade for Mauritius.

As a coastal town, Port Louis is exposed to risks and impacts associated with storms, storm-surges, flooding, coastal erosion and direct damage to infrastructure, services and property. Port Louis has already experienced such impacts, often associated with cyclones. In the past, there have been several destructive cyclones, for example, Hollanda (1994) and Dina (2002), which have had impacts on city infrastructure and services. Hollanda destroyed 290 houses and severely damaged another 160, leaving at least 1,500 people homeless. High winds downed 30% of the island's trees. Many fell onto power lines, and all external communications were cut to the country during the cyclone. Nearly half of the sugar plantations were destroyed, although the primary industry of tourism was not significantly affected. In total, the cyclone killed two people, and caused $135 million in damage (1994 USD).[18] Dina caused severe damage to infrastructure especially the electrical power and telecommunications network. Heavy damage was also reported in the agricultural sector, especially sugar, one of the main economic sources in Mauritius. 3 deaths and 50 injuries were reported. [19]

The downscaled modelling projections produced for this report, whilst not directly for Port Louis, imply impacts on Port Louis (as the two meteorological stations for which there were sufficient records considered representative for the island of Mauritius). These impacts may increase or decrease specific threats and vulnerabilities to specific local government sectors which were identified in the regional report[20] . In this report, agriculture has been included as one of the sectors as there are potential implications for the food security of Port Louis 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.

5.1 Water and Sanitation

Impacts upon Water and Sanitation	Impact on livelihoods
• Damage to water supply infrastructure • Deposition of mud and contaminants in urban freshwater supply and dams • Increased wave action and flooding along the coast	• Increased pressure and need for water supplies for irrigation • Blockages and silting of storm water ways • Increased need for maintenance, upgrades or replacement

[18] *Indian Ocean Newsletter* (611). 1994-02-19.
[19] Mauritius - Tropical Cyclone Dina OCHA Situation Report No. 3, 23-01-2002
[20] Tadross and Johnston, 2011. **Projected Climate Change Over Southern Africa; Namibia, South Africa, Mozambique, Tanzania and Mauritius, Report for ICLEI, February 2011**

• Flooding causing strong water flows in aquifers • Flooding of storm water pipes • Damage to properties and infrastructure • Increased sand depositions • Erosion and landslides which may damage (storm water) infrastructure and assets even more • Increase in storm water pollution • Wind may cause a greater drying effect	of infrastructure (e.g. storm water facilities) • Some water supplies / dams offline and thus increasing pressure on remaining water sources and potential water restrictions • Knock on effect on health as a result of increased changes of contamination of fresh water sources. • Cases of Dehydration • Poor water access • Poor water quality

5.2 Transport

Type	Impacts upon Transport	Impact on livelihoods
Road	• Damage of infrastructure • Blockage of roads (fallen trees, debris) • Flooding causes diversions • Accidents • Inundation of roads • Road closures on bridges and mountain passes • Damage to signage and overhead cables • Erosion of bridges	• Traffic jam and increased waiting time • Limits access routes • Delays to the work place and markets • Work hours lost– reducing income • Risk to public safety
Rail	• Damage of infrastructure • Blockage of railway tracks (fallen trees, debris) • Erosion of railway infrastructure • Inundation of railways • Disruption of electronic transport infrastructure (e.g. train signals) • Expense of maintenance	• Causes delays and cancellations of trains • Unable to reach destination • Work hours lost– reducing income
Air	• Damage of infrastructure • Accidents and air crashes • Reduction in GDP • Airport closes for safety during cyclones • Increased insurance required by operators	• Reduces accessibility to airports • Delay in exports/imports • Decreased safety
Port	• Damage of infrastructure • Erosion to coastal infrastructure and equipment • Damage of boats • Erosion to harbour wall • Damage to anchored boats	• 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
• 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. • Spread of infectious diseases: skin and respiratory diseases and stomach ailments. • Worsening of existing chronic illnesses • Long-lasting psychological impacts • Higher wind speeds and changes in air pressure cause people to feel unwell (i.e. headaches) • Increased drying effect • Increased health threats through heat stress • Disruption of solid waste management	• increased deaths from: – Drowning – Electrocution – Injuries cause by trees and other debris flying around • Increased casualties • Hours of work lost • Medical bills to pay • 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

• Loss of hygiene and sanitation – increased pests and vectors	

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). • May cause an increased demand for energy • 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	• Chances of electrocution by livewires being submerged in floodwater • 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 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.