REPUBLIC OF MAURITIUS

METEOROLOGICAL SERVICES

Climate Change
Impacts on Mauritius

March 2009

FOREWORD

Since the early eighties, it has come to light that climate has been changing worldwide. Thousands of scientists, among whom some Mauritians, under the aegis of the Intergovernmental Panel on Climate Change (IPCC), have been conducting research and have, with each major report, referred to the danger of a business-as-usual attitude as far as climate is concerned.

The President of the 62nd Regular Session of the United Nations General Assembly (GA) while summing up the general debate in December 2007, stated that global warming had clearly become the "flagship issue" of the session. Subsequently, the UN compiled a report on all its activities in the area of climate change for its GA of February 2008, where 115 speakers addressed the issue, including the need for securing financing for mitigation and adaptation. Climate change is on the agenda of every major conference and meeting.

Although the Kyoto Protocol advocates' the acceptance of a greenhouse gas emission level which will tolerate global air temperature increase of two degrees, for many small island states this threshold is inconceivable. Already an increase of half this value is causing life-threatening calamities. Doubling the global warming extent will pause unimaginable threats to our livelihood.

So as to be proactive, the Mauritius Meteorological Services has lately increased its ability to systematically monitor climate parameters and have brought to light the negative trends over our region. Scientists from other Mauritian institutions have testified to undesirable changes in their own respective fields of purview. Several publications such as the Climate Change Action Plan, The Initial Communication to the UN Framework Convention on Climate Change, The Technology Needs Assessment, among others have been published.

We have thus started analysis of the issue and conducted some sectoral actions. Now a holistic approach with multi-sectoral contributions has become imperative. Only such an approach may yield tangible results. Developed countries may invest to help developing countries, especially those who are proactive, to mitigate and adapt to, the impacts of climate change.
This paper highlights the likely impacts on our socio-economic fields. At the same time it aims at sensitising further, our decision-makers, stakeholders and the public at large on the urgency for action so as to increase food security and ensure our wellbeing under a warmer climate.

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Climate Change – Impacts on Mauritius

1.0 Introduction

1.1 Despite extensive research on global climate change, this latter still remains a very complex issue which will require systematic monitoring of specific parameters and adjustments to be made in conclusions and findings for a long time to come. Barely six months after the Nobel-prize winning Intergovernmental Panel on Climate Change (IPCC) presented its Fourth Assessment Report (AR4) on the state of the global climate, there are fresh conclusions pointing towards even more dire consequences, than assumed in the report, for humans as a result of the impact of climate change.

1.2 Mauritius, similar to most Small Island Developing States, has every reason to worry about what may be in store for it. Its physical size and geographical isolation, its proneness to natural disasters and climate extremes, its reliance on imports and its low adaptive capacity, will increase its vulnerability and reduce its resilience to climate variability and change.

1.3 This report first analyses some findings of the AR4, with emphasis on facts pertinent to Mauritius. It then describes the changes in climate observed at Mauritius and its outer Islands and the projected changes and probable impacts according to various emission scenarios.

2.0 The Science of Climate Change

2.1 The Earth's climate is governed mainly by the amount of energy coming from the sun. Other factors such as the density of Greenhouse Gases (GHG) and aerosols in the atmosphere, and the properties of the Earth's surface determine how much of this solar energy is retained or reflected back into space. The GHG forming a layer, high up in the atmosphere, is essential to keep us warm and comfortable, the way we are presently living at the surface of the earth. An analogy of the function of this layer would be to consider the purpose of a blanket when we sleep. The blanket prevents the heat produced by the body to escape into the air thus keeping us warm. But when the room temperature is already elevated or if the blanket is too thick, then the body may feel hot and is no longer comfortable.

2.2 The GHG layer, which originally consisted mainly of water vapour, is now joined by other gases, which we humans, produce through our activities, by burning fossil fuels, land use change, etc. These gases, mainly carbon dioxide, nitrous oxide, methane,have increased the density and the heat-retention capacity of the GHG layer. However, at the same time they do not, because of their specificity, inhibit the energy from the sun to penetrate into the atmosphere. The incoming energy from the sun and the added heat from below cause the earth to warm up.

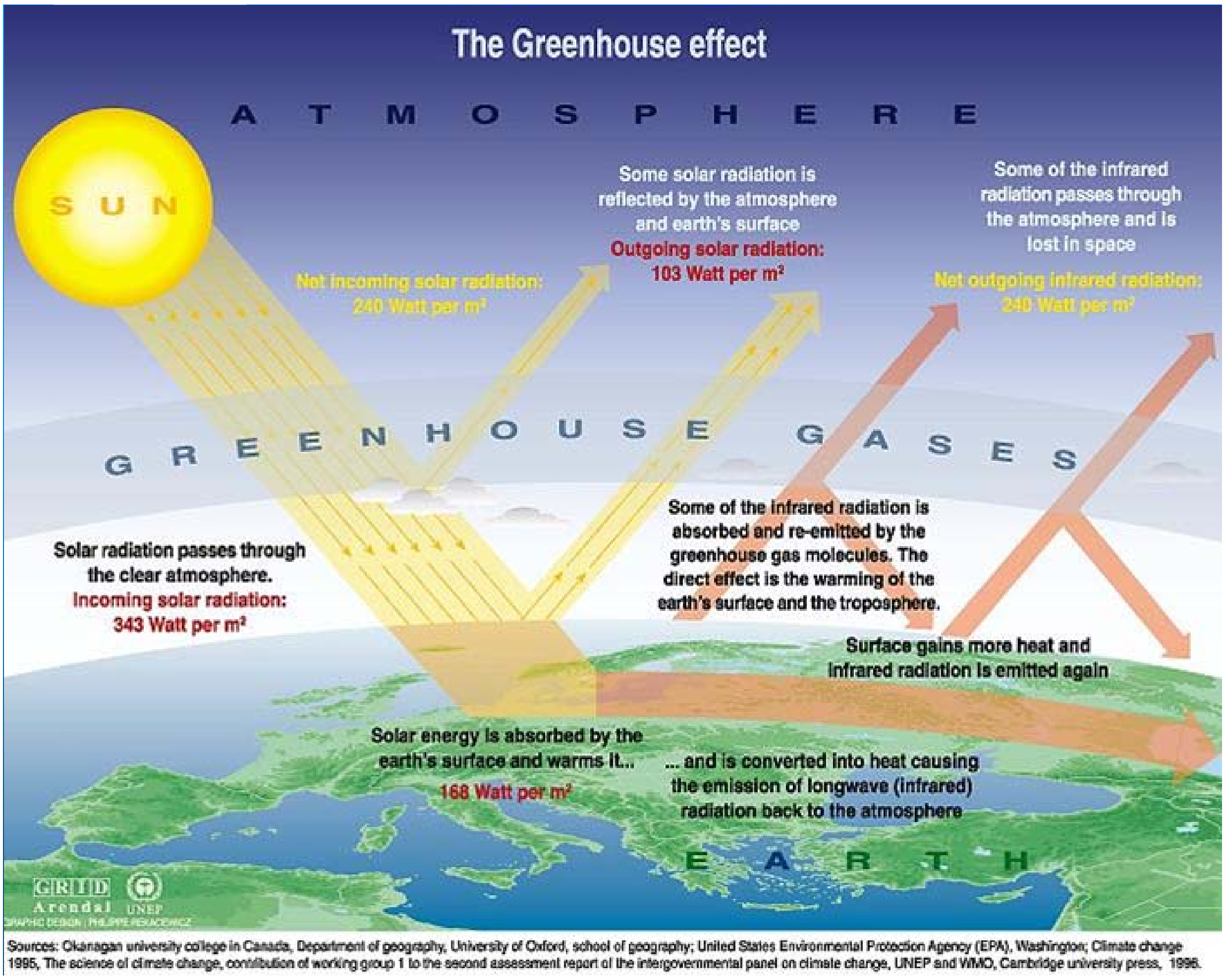


Fig.1 – Function of the Green House Gas layer in warming the earth

2.3 The concentration of carbon dioxide alone has increased markedly from 279 parts per million (ppm) since 1750, the beginning of the industrial revolution, to 381 ppm at present.

3.0 Observed changes in climate and their effects

3.1 There have been considerable improvements in the collection and analysis of climate data. The geographical coverage of monitoring stations, understanding of uncertainties, and variety of measurements have brought to light signs of increasing air and ocean temperatures which, coupled with evidence of widespread melting of snow and ice, and rising global average sea level, have led to the conclusion that **warming of global climate is unequivocal**.

3.2 Over the last 100 years (1906-2005), global surface temperature has increased by 0.74 °C. This amount at first sight, may appear insignificant but it must be underlined that this is a globally averaged value and include measurements from the oceans where the increase is not high. **Over land and in some large cities temperatures have increased by 3-5 degrees**. Fig. 2 below shows the increase in global average temperature since 1850. Note the increase in the rate of rise in the latter decades (steeper, straight coloured lines).

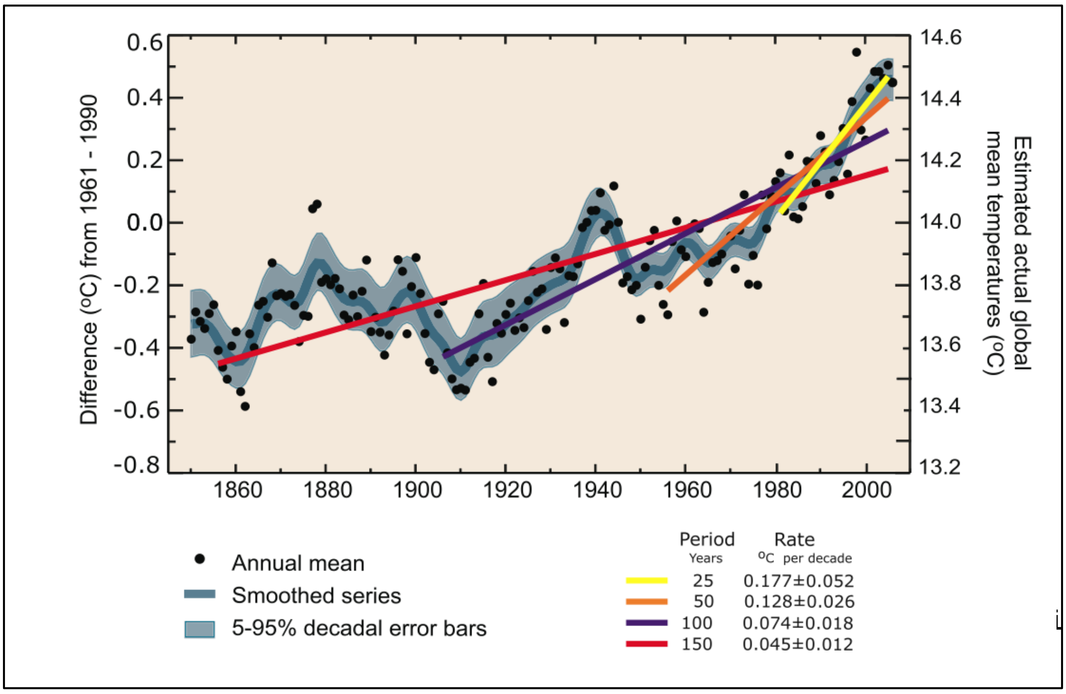


Fig.2 - Increase in global average temperature since 1850

3.2.1 It is significant that **eleven years of the period 1995 to 2006 rank among the warmest ever recorded** with 2005 and 1998 as the warmest two. **Temperatures in the higher atmosphere and in the oceans (to depths of at least 3000m) have**

also been rising, along with increase in the water vapor content of the atmosphere. This **temperature increase with depth is a build-up of ocean energy** contributing to faster intensification of cyclones.

3.3 Sea-level Rise

3.3.1 Analyses of available sea level records clearly show that the sea level is rising despite variations which are due to large scale oceanographic phenomena such as El Nino, coupled with volcanic and tectonic crustal motions. **Global sea level has risen by 17 cm during the 20th century**, in part because of the melting of snow and ice from many mountains and in the Polar Regions but mainly as a result of the thermal expansion of warmer waters. Over the 1961 to 2003 period, the average rate of global mean sea level rise is estimated from tide gauge data to be 1.8 ± 0.5 mm per year. Fig.3 below shows the global mean sea level based on partly reconstructed and partly observed data.

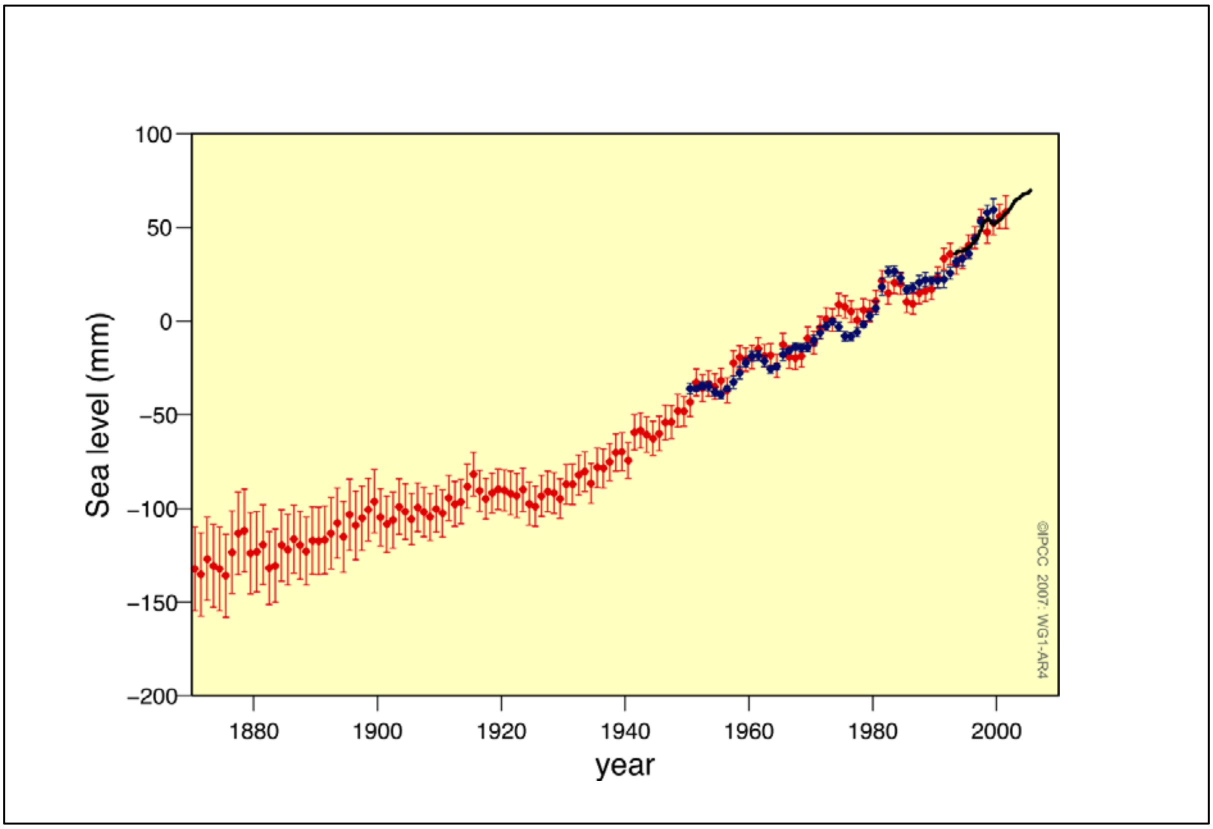


Fig.3 - Annual averages of the global mean sea level based on reconstructed sea level fields since 1870 (red), tide gauge measurements since 1950 (blue) and satellite altimetry since 1992 (black). Units are in mm.

3.4 Other Observed Changes

At regional, and ocean basin scales, numerous changes in climate have been observed, namely:

i) changes in Arctic temperatures and extent of ice-sheet cover

ii) widespread changes in temporal and spatial precipitation amounts

iii) increase in the number of hot days and hot nights; (heat waves have already become more frequent over land areas).

iv) the frequency of extreme weather events such as droughts, heavy precipitation have increased

v) an **increase in intense tropical cyclone activity in north Atlantic basin** since about 1970. This correlates well with the increase in sea surface temperature. There are suggestions of an increased number of intense tropical cyclones in some other regions as well.

vi) **faster rate of intensification of tropical cyclones observed in the South west Indian Ocean (Mauritius region)**

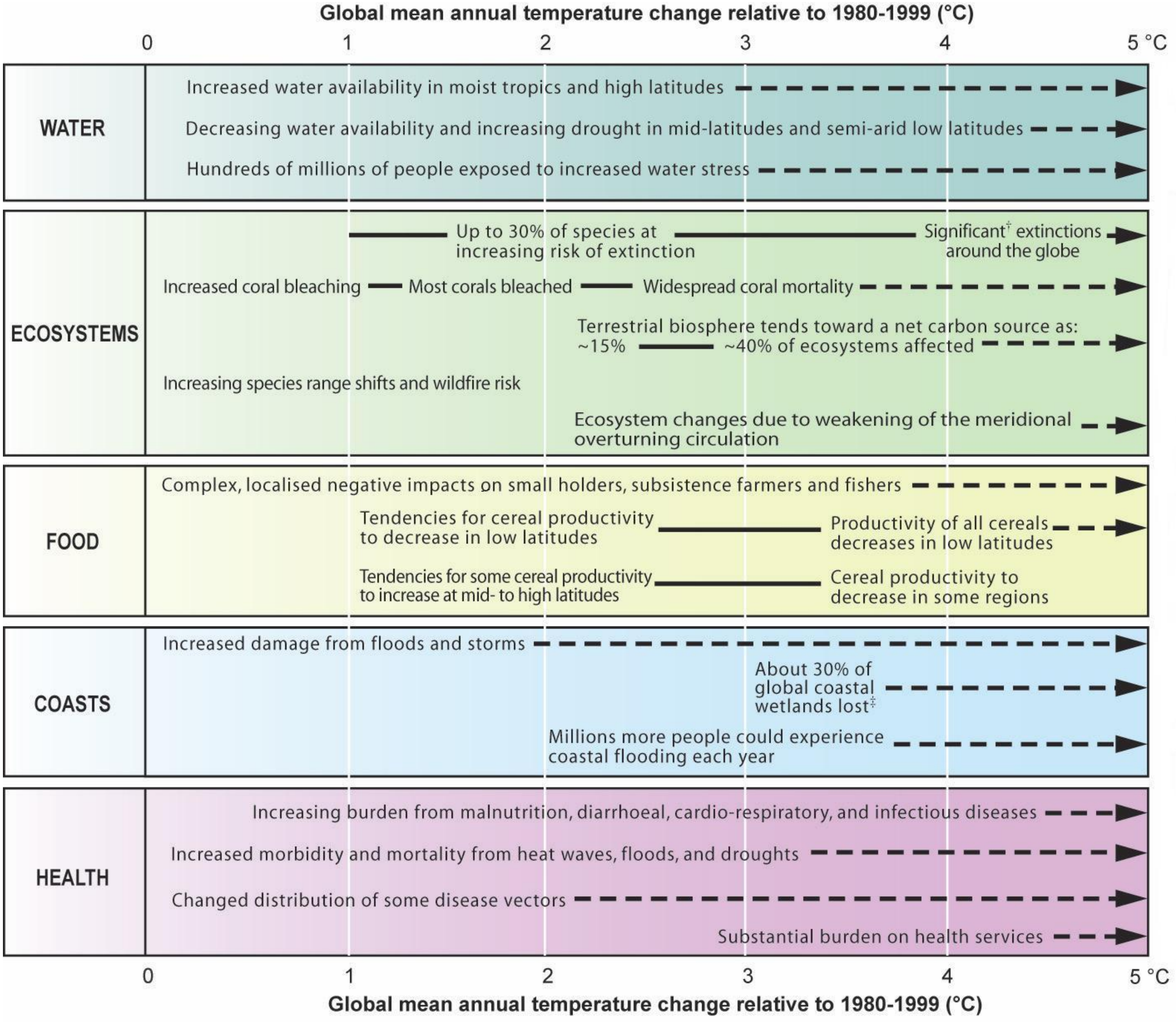
4.0 Projected Changes In The Climate For The 21st Century

4.1 Continuing GHG emissions at or above current rates would cause a further increase in global temperatures and provoke other climatic changes during the 21st century. The global average temperature is expected to increase by about **0.2°C per decade over the next two decades** that may result in a best estimate for **globally average surface air warming of between the 1990s and the 2090s range from 1.8°C to 4.0°C.** Global average sea level is **expected to rise by 18 to 59 cm by the end of the 21st century**.

Projected changes for Mauritius include:

- increased acidification of the oceans caused by increasing carbon dioxide concentrations in the atmosphere;
- **more frequent heat waves, and hotter summer months**
- **a rise in the number of heavy precipitation events**
- **increase in the number of intense tropical cyclones**

4.2 Warming and sea level rise caused by human activities will continue for centuries, even if GHG concentrations were to be stabilized. This is due to the long lifetime of the gases.Table 1 below summarizes key impacts of climate change in the various socio-economic sectors.



Source: AR4, Wk Group 2, IPCC 2007

Table 1- Key impacts of climate change

5.0 Observed Changes In Climate In The Republic Of Mauritius

5.1 Though the GHG emission of Mauritius is tiny, warming of our climate and its effects on our natural and ecological system are unavoidable and already palpable. However, some of this warming results directly from our own actions.

5.1.1 Analyses of temperature recorded at Mauritius and its outer islands show a definite warming trend. **Average temperature at Vacoas and Plaisance during the last ten years (1998-2008) was higher than that of the decade 1951- 60 by 0.74**

and 1.1 °C respectively. Most of the warming started as from the mid-seventies. The figures below show the temperature variation at different sites.

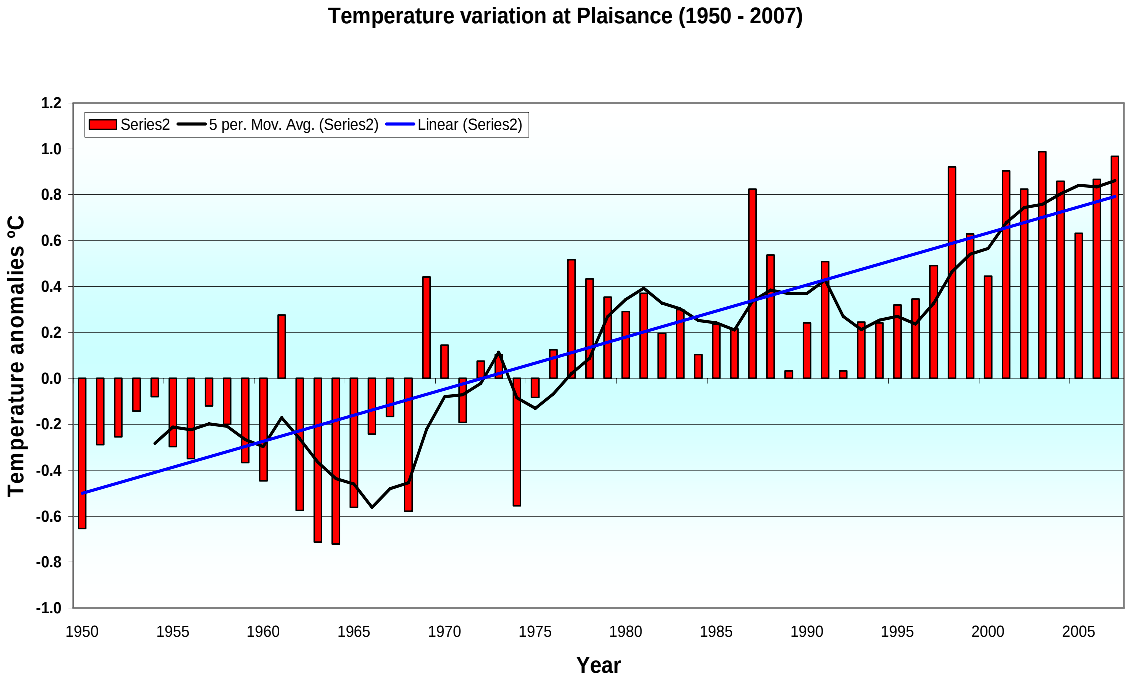


Fig. 4 - Mean annual temperature variation at Plaisance

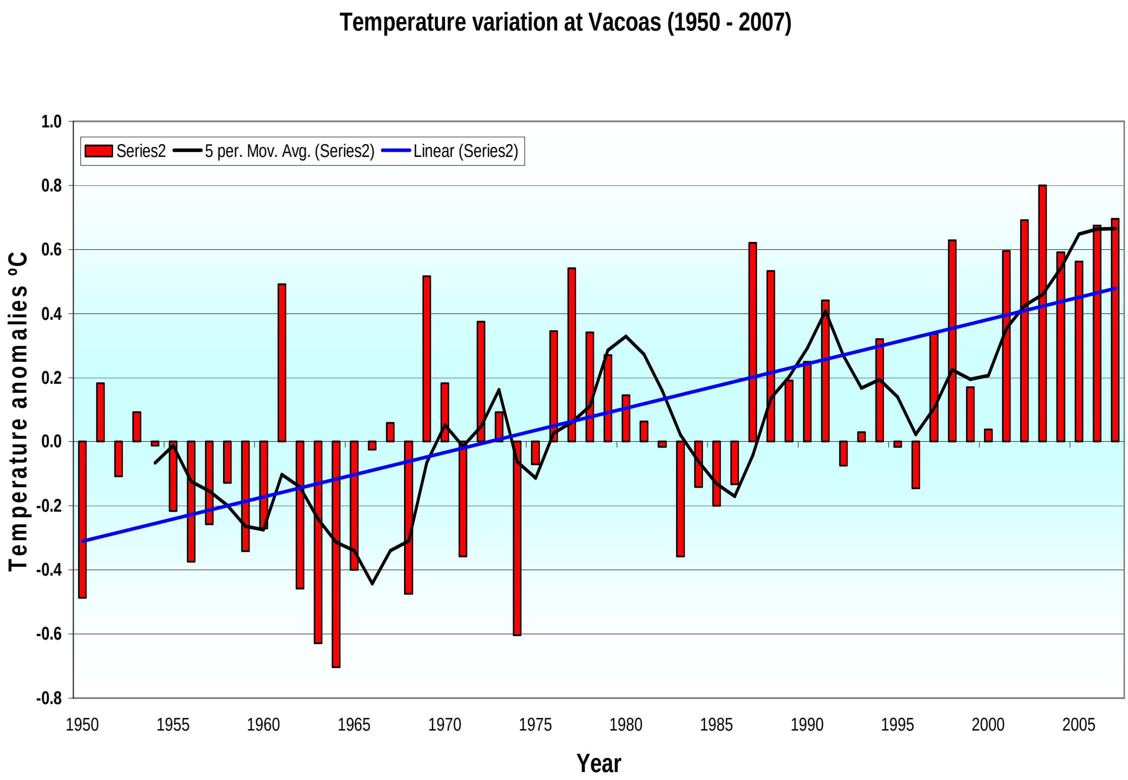


Fig.5 – Mean annual temperature variation at Vacoas.

5.2 Similar warming trends were also observed at Rodrigues, St Brandon and Agalega, (Fig. 6, Fig. 7 and Fig. 8) where **the temperature rise is in the range of 0.5 to 1.0 ˚C**.

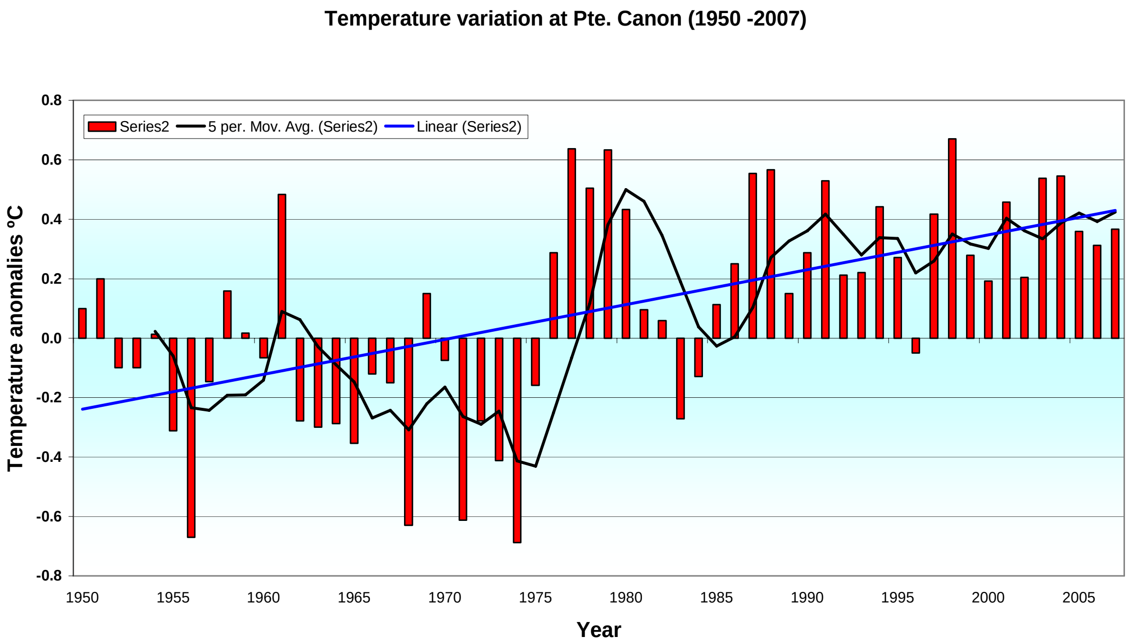


Fig. 6 - Mean annual temperature variation at Rodrigues

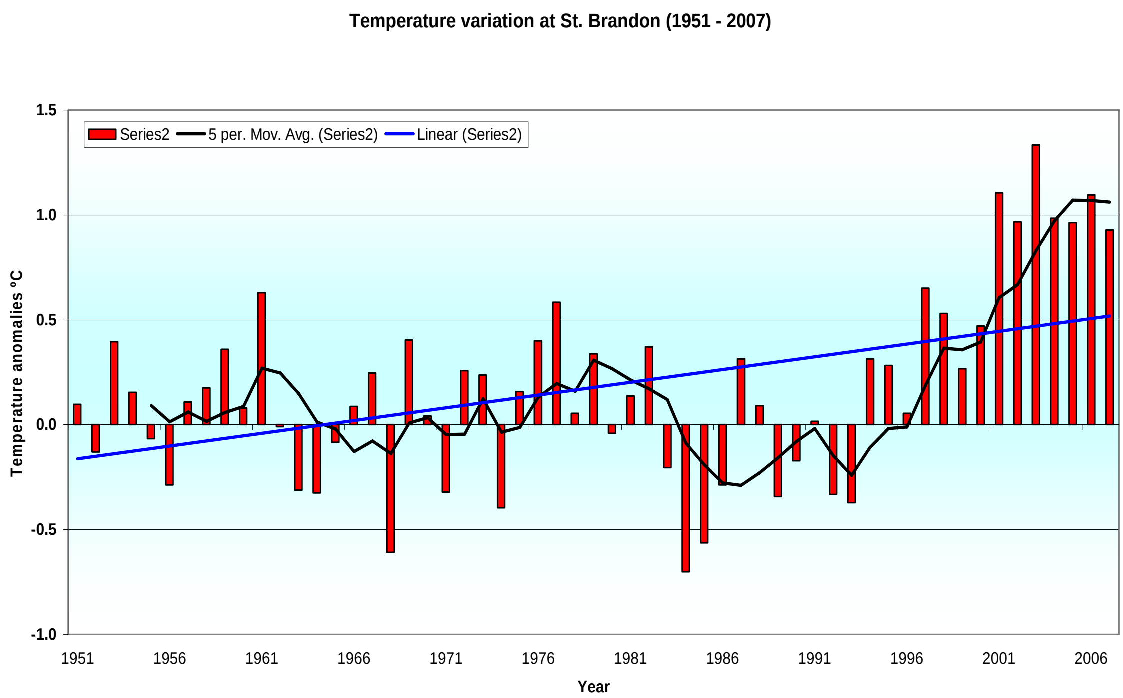


Fig. 7 - Mean annual temperature variation at St Brandon

Temperature variation at Agalega (1951 - 2007)

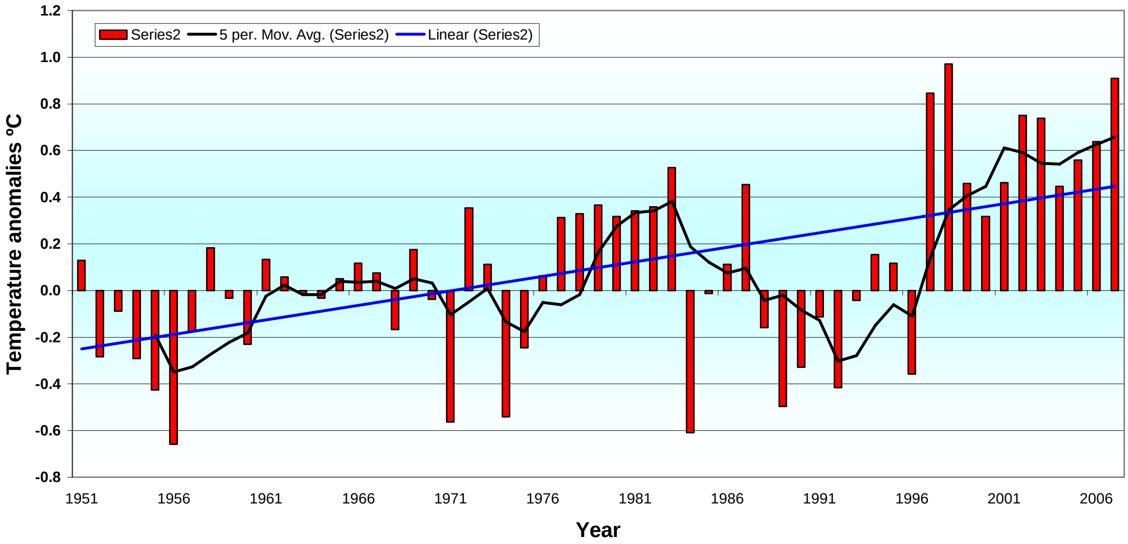


Fig. 8 - Mean annual temperature variation at Agalega

5.3 Analysis of temperatures at Vacoas for the period 1950-2008 shows an increase in the annual number of hot days and warm nights. During the last ten years **summer maximum temperatures (therefore daytime temperatures) became warmer by an average of 1.0 ˚C**. By all comparisons of temperatures the summer of 2008 – 2009 has been a unique one: day time maxima have stayed between 33 – 34 ºC almost continuously for weeks. **This indisputably leads to conditions which are beyond human endurance**. The likelihood of such temperatures in the future is not to be excluded. Fig.9 below shows the trend in maximum temperature at Vacoas and Fig.10 the trend in minimum temperature at the same location.

Maximum Temperature During Summer Months(Dec-Jan-Feb) at Vacoas
Period 1951-2008

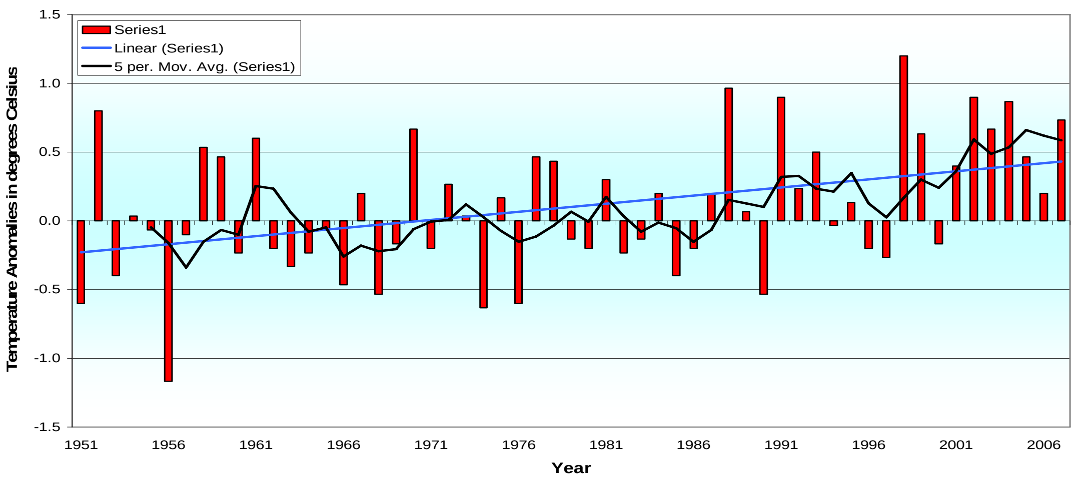


Fig. 9 - Trend in maximum temperature at Vacoas. Summer days are getting hotter.

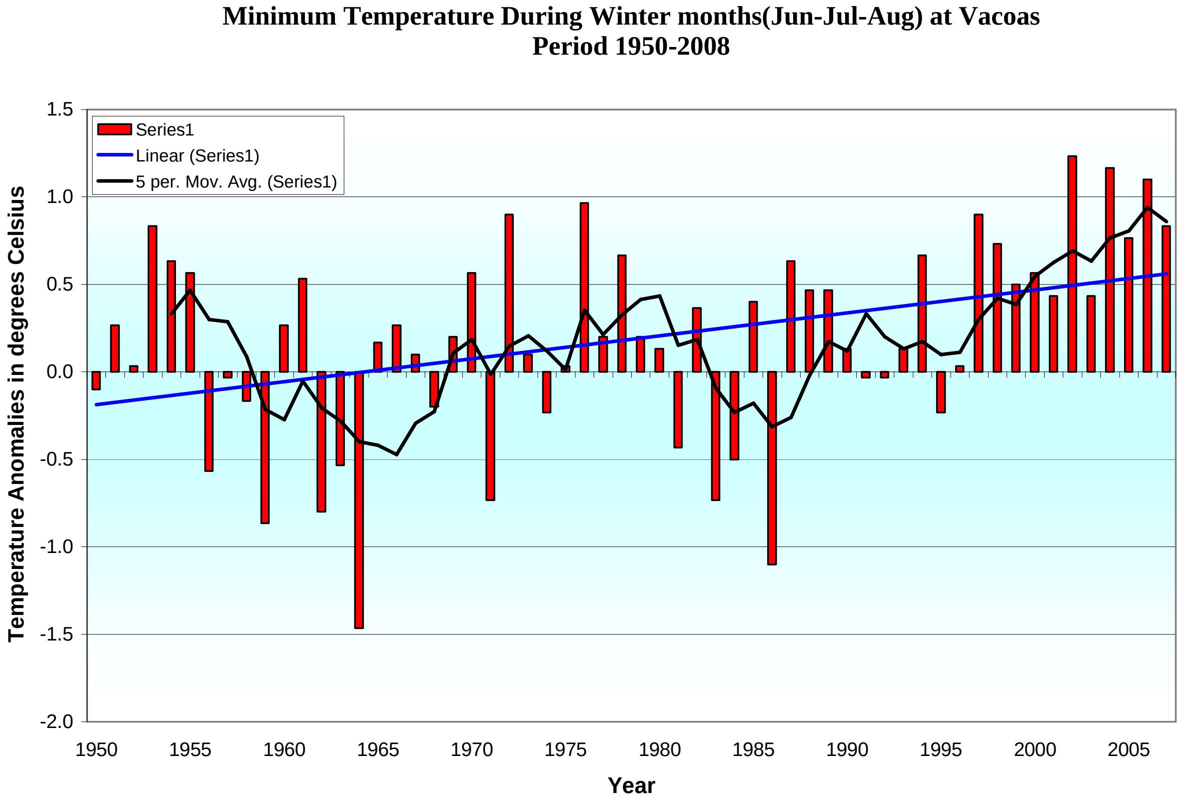


Fig. 10 - Trend in minimum temperature during winter months at Vacoas. Winter is getting milder!

5.4 Monitoring Of Sea Level

5.4.1 A tide gauge installed at Trou Fanfaron, Port Louis since 1987 is used to monitor sea-level in Mauritius. The mean sea level rise during the past decade (1998-2007) was 2.1 mm/yr at Port Louis. Tide gauge data from Rodrigues gives values of the same order of magnitude. Although these findings are consistent with IPCC conclusions, longer period of measurements are necessary for reliable conclusions.

5.5 Precipitation

5.5.1 Long-term time series of rainfall amount over the past century (1905 to 2008) **show a decreasing trend in annual rainfall over Mauritius**. Fig. 11 depicts the time series of rainfall amount over Mauritius; and the regression line clearly indicates the decreasing rainfall trend, which is about 8% when compared to the 1950s.

Mean Annual Rainfall over Mauritius, 1905 - 2008

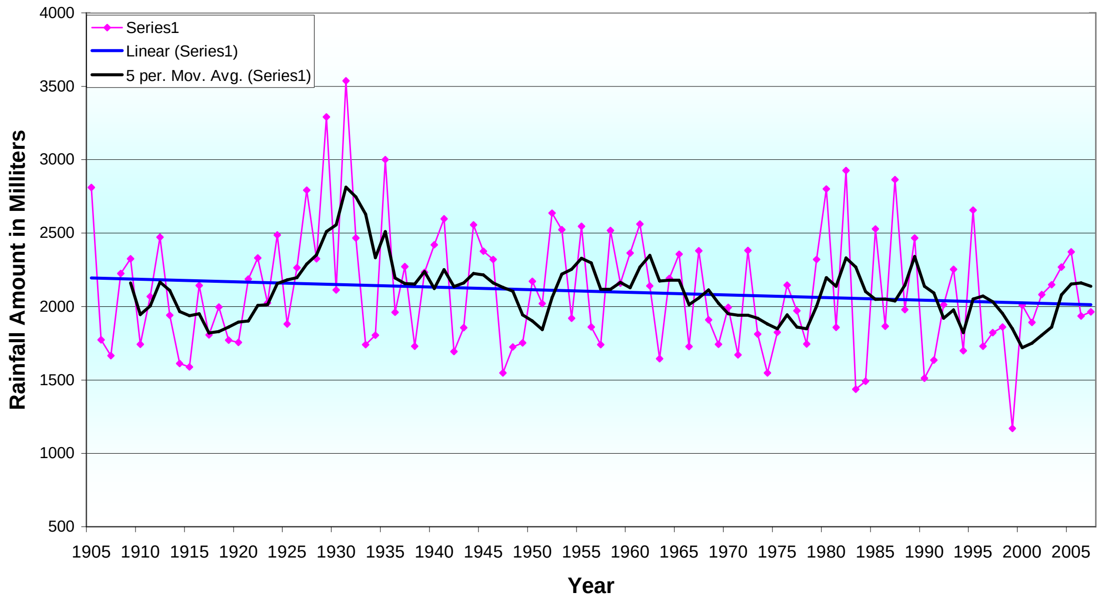


Fig. 11 - Mean annual rainfall over Mauritius, (1905-2008)

5.5.2 The graphs (fig. 12 to fig. 14) for Rodrigues, St Brandon and Agalega indicate significant variation from year to year but long-term and decadal analysis do show decreasing rainfall trend.

Annual Rainfall at Rodrigues (Pte. Canon), 1955 - 2008

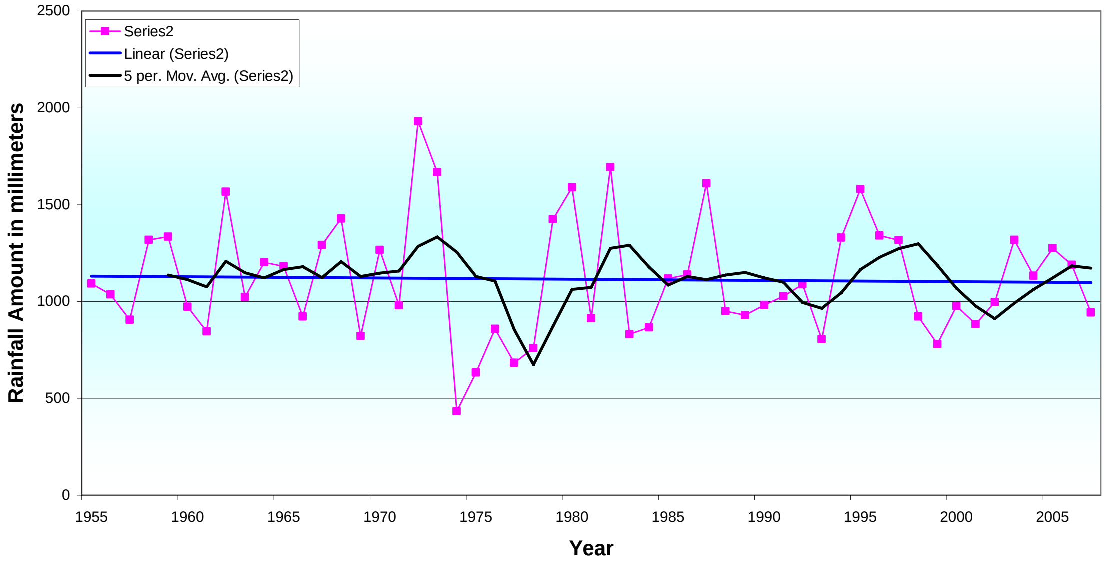


Fig. 12 – Mean annual rainfall at Pte Canon, Rodrigues (1955-2008)

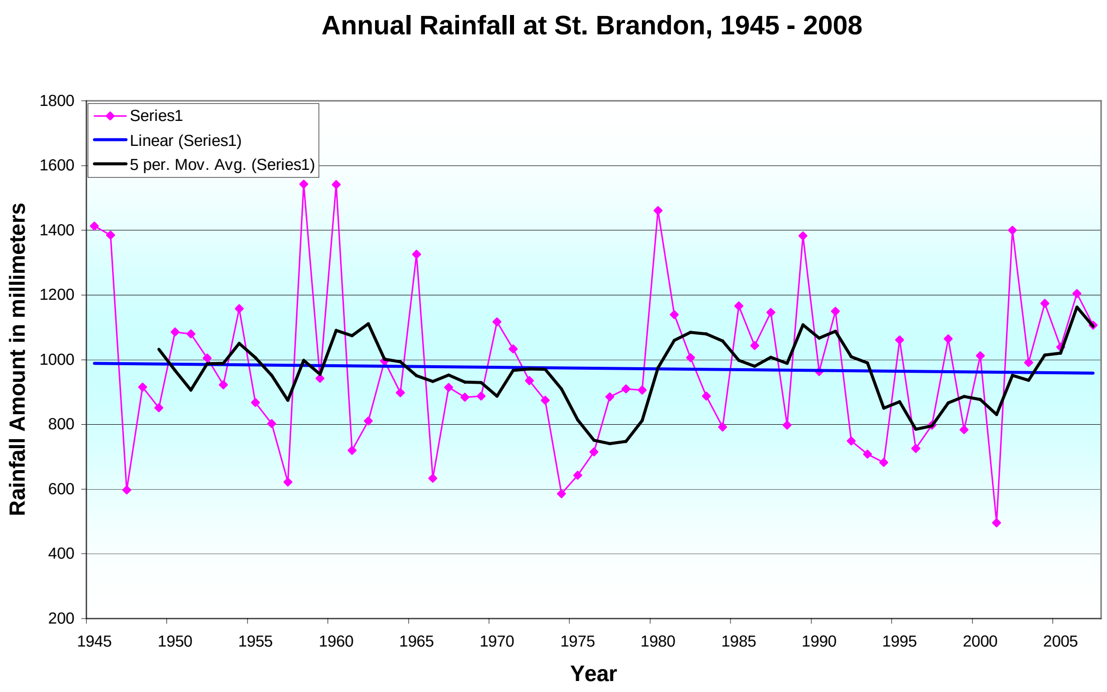


Fig. 13- Mean annual rainfall at St Brandon, (1945-2008)

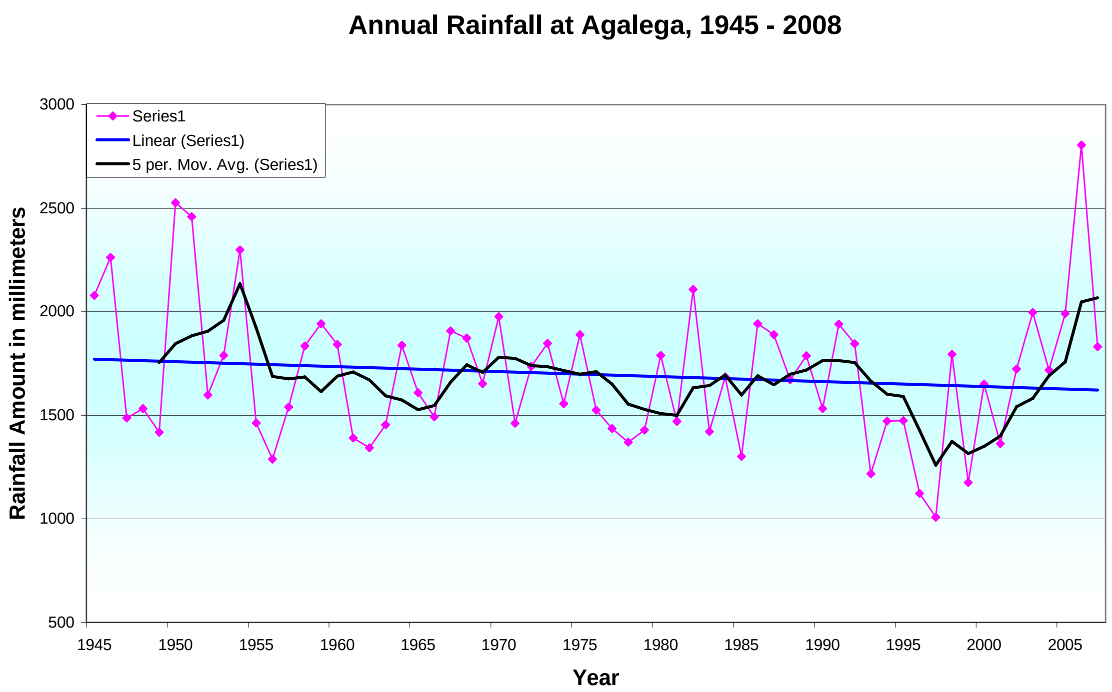


Fig. 14 - Mean annual rainfall at Agalega, (1945-2008)

5.6 Duration of Dry Spell

5.6.1 The duration of the intermediate dry months, the transition period between winter and summer, is becoming longer. While in the 60s and 70s summer rains used to start by November, they now occur only in late December. Since the past four summer seasons, the rains started only in January of the following year. Furthermore, and as if to catch up with the delay, when it starts to rain it really pours with recurrent flash floods in February and March. This shift in the onset of summer rain is highly significant as it translates into increasing pressure on the water sector to increase storage capacity to cater for longer periods of dry spells and to meet equally increasing demands of the agricultural, tourism, industrial and domestic sectors.

5.6.2 On the other hand the temporal distribution of rain is no longer what it used to be. The number of rainy days has decreased but the frequency of heavy rainfall events has increased. This means that **we have to increase our rain harvesting capacity**.

5.6.3 While in the old days, most of the summer rains resulted from cyclones, since the past five or so years **summer rains have been harvested outside cyclones**. Fig.15 shows the summer rainfall in pentads recorded during summer 2005-2006. Records show that only five storms were observed in the south Indian Ocean and none came to within 100 km of Mauritius. Yet, only five heavy rainfall events, unrelated to storms, replenished the country's reservoirs.

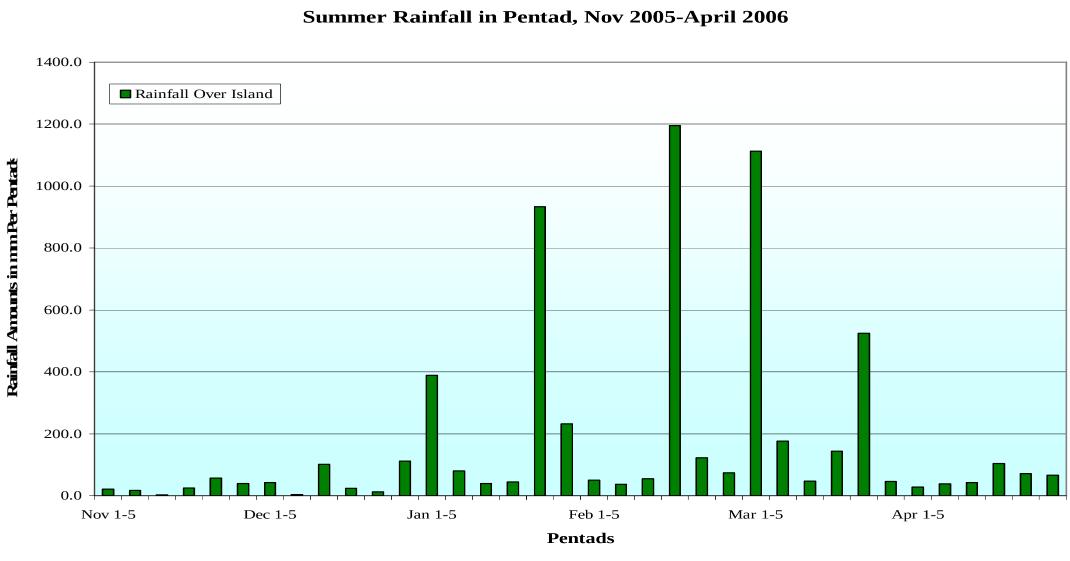


Fig.15 - Heavy rainfall events of 2005-06

5.7 Cyclones

5.7.1 Analysis of data from Mauritius Meteorological Services does not show any increase in the number of storms in the South West Indian Ocean basin (SWIO). However, decadal plot of the number of storm formations over the last 32 years (1975- 2008) clearly shows **the increasing trend in the number of intense cyclone (winds above 165 km/hr)**. Fig.17 shows the trend in the number of tropical cyclones in the South Indian Ocean. Cyclone season 2001-02 was exceptional in that nine out of eleven named storms reached tropical cyclone strength. In season 2006-07, seven out of ten named storms reached the tropical cyclone stage or higher. Furthermore, since the last decade observation **indicates rapid or even explosive intensification** of tropical storms.

Two basic factors drive the intensification of tropical cyclones, namely the sea surface temperature (SST) and the moisture content of the environment of the storm. **Both of these factors have been observed to increase with climate change and global warming.**

The summer 2008-2009 experienced abnormally high sea surface temperatures in the South West Indian Ocean (SWIO). Figures 16a and 16b show the SST during the month of January 2009. Ship observations and high – tech drifting buoys confirmed that on certain days SST between Mauritius and Madagascar reached 31 degrees Celsius, which is greater by 3 degrees above the long term mean for the region around Mauritius.

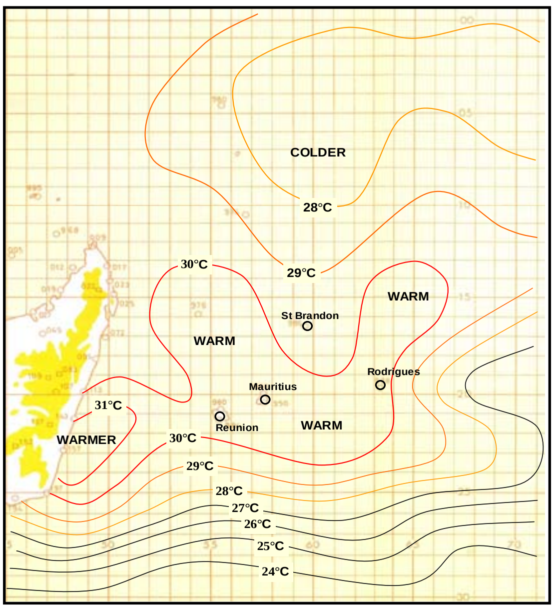


Fig 16a - Sea Surface Temperature
01 - 15 January 2009

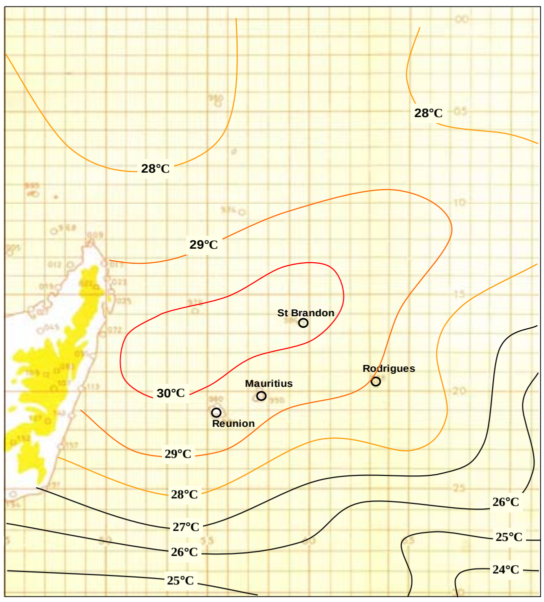


Fig 16b - Sea Surface Temperature
16 - 31 January 2009

The table below gives the list of storms/cyclones that experienced above normal or even explosive intensification rate. In fact, these intensified twice faster.

Table 2: List of cyclones that experience rapid intensification, period 2007-2009.

Date	Cyclone Name
21 Feb – 02 Mar 2007	*ITC Gamede
12 – 18 Mar 2007	ITC Indlala
29 Mar – 04 Apr 2007	ITC Jaya
05 – 29 Feb 2008	ITC Hondo
07 – 21 Feb 2008	ITC Ivan
05 –12 Mar 2008	ITC Jokwe
04-13 Mar 2008	ITC Kamba
30 Jan – 09 Feb 2009	ITC Gael
18 – 23 Jan 2009	ITC Fanele
* ITC – Intense Tropical Cyclone	

It will be recalled that the above normal intensification rate of Gael and Fanele earlier this year is both due to the above normal SST in the west Indian Ocean.

The explosive intensification rate of tropical cyclone calls for a revisit of our existing cyclone warning system. With the current global warming trend, **it is likely that tropical cyclone will continue to intensify at above climatological rate**, in which case the lead-time to warn the population may be inadequate. In such a situation, it is likely that there will not be sufficient time to go through all the phases of warning rigidly before the advent of cyclonic conditions. As the climate continues to change, lead-time to warn the population will obviously decrease.

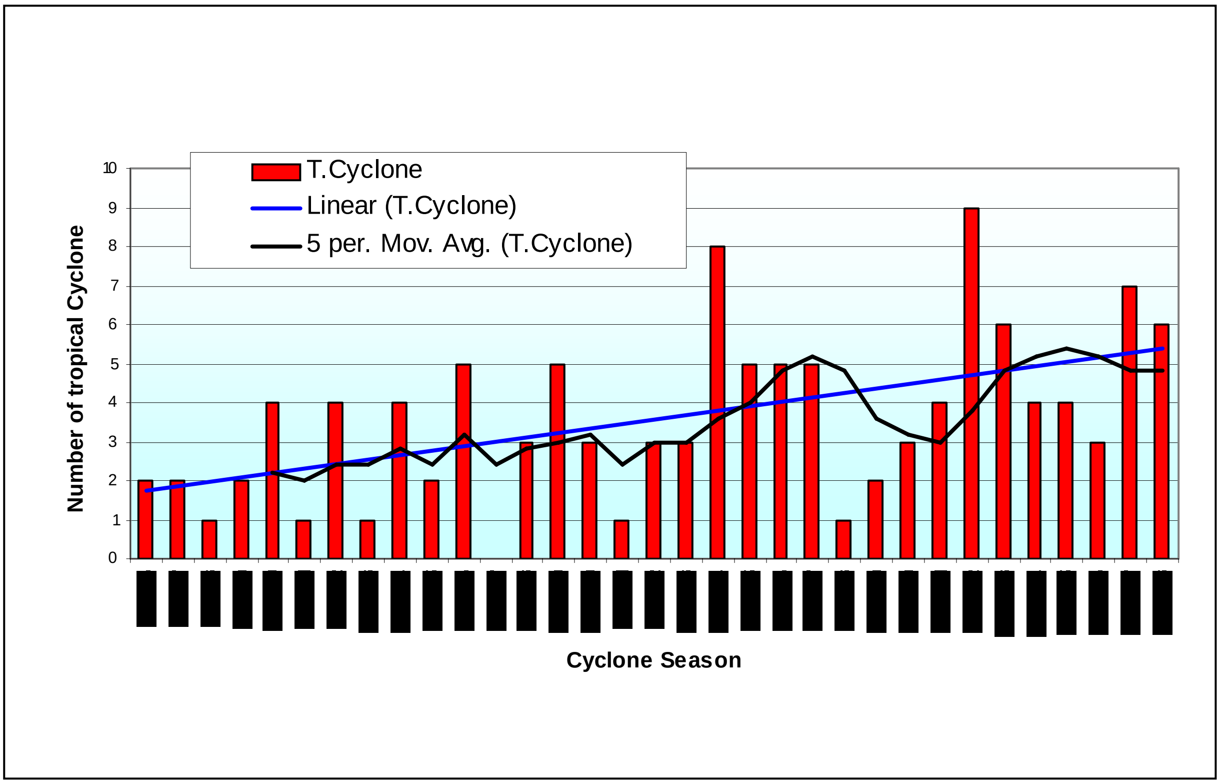


Fig. 17 -Trend in the number of intense tropical cyclone

6.0 Projected Climatic Changes In Mauritius

6.1 Model simulation for the Indian Ocean gives a temperature increase in the range of 0.51 to 3.77 °C and sea level rise between 18 and 59 cm by 2100. Mauritius will experience the same effect.

6.2 These projected changes will result in:

- Decreasing trend of 8% in annual rainfall
- Increase in heavy precipitation events with increased risk of flash flood
- More frequent heat waves in summer
- Milder winters
- Increase in the number of intense tropical cyclones
- Increase in duration of dry spell, and therefore higher demands of water
- Increase events of high energy waves (tidal surge) impacting the shores of Mauritius
- Exacerbating food security

6.2.1 Frequent extreme climate events such as tornadoes is not excluded. While this element has been only very rarely observed over land in Mauritius, it is not excluded that with the increase in available energy in the atmosphere they start to manifest themselves more often. Up to now even with the most sophisticated equipments it has been almost impossible to predict tornado formation well in advance to warn populations.

6.3 Consequences of the Impacts of Climate Change in the Republic of Mauritius

6.3.1 Impacts on the primary parameters, temperature and rainfall will result in secondary but no less important consequences:

- The capacity of ecosystems to adapt will be exceeded, with negative consequences such as an increased risk of extinction of species
- Fisheries and aquaculture will be adversely affected as our marine ecosystem fall prey to rising temperatures
- Coastal areas will be exposed to increasing risks of coastal erosion, due to sea-level rise. An increase in 5 cm in the sea level may translate into the effect of an increase of one meter during cyclones or tidal surges. Coastal ecosystems such as coral reefs, wetlands, and mangroves will be negatively affected.
- Extent of flooding of coastal zones will increase. This extent will be exacerbated by cyclones, tidal surges
- Traditional and present crop varieties will suffer, impacting severely on food security.
- Human health and well-being will be negatively affected by rising temperatures, bearing in mind that human endurance to heat has limits.
- Increased incidence of diseases is very likely together with more extensive proliferation of infectious diseases

6.3.2 The 1999 severe drought, known as the drought of the century, led to the activation of bugs which have destroyed even what is known as the evergreen trees, the cypress. This is a stark example of consequences if temperatures are to rise consistently and water availability to decrease.

Fig. 18 – Cypress trees dying as a result of the prolonged 1999 drought - a likely event with other plant species in a warmer climate.

7.0 Adaptation To Climate Change

Some of the impacts described above are unavoidable in the coming 5 decades. However, a significant number of them will only occur if we adopt a business-as-usual attitude. To combat the effect of climate change we have embarked on a number of activities already. Some of these are:

- A more rational management of our water resources and revision of related policies
- Reduction of our fuel consumption
- Making our buildings more energy efficient
- Use of renewable energy
- Research into new crop varieties
- Our approach to mitigation and adaptation efforts should be holistic rather than a sectoral one. Only this will enhance the resilience of whole island socio-ecological systems.

7.1 *Adaptation: Constraints and opportunities*

The following constraints need to be highlighted:

- lack of financial resources
- lack of information and skills
- absence of inadequate infrastructure
- insufficient human resources
- absence of legal framework (climate change issues are not included in sustainable development policies)

8 Conclusions

Given the number of variables that govern the climate system, the degree of uncertainties that prevail in the world political arena, the see-saw and often unpredictable evolution of the world economy, the turmoil in numerous locations of the globe which may lead to wars, control over the climate is still a very remote probability. Therefore predictions will stay predictions. This leads to conclude that uncertainties will persist in the evolution of global climate. This further means that even if one wants to go back to the university bench to study the future climate there won't be any teacher to teach the science.

Therefore preparedness, self-efficacy, strong local, national and international support networks, together with a willingness to act collectively and to learn from mistakes, are factors which can increase the resilience of the Republic to climate-related risks. Such resiliency can also contribute to opportunities of development in the various sectors. A revision of our strategic goals and developmental plans which must invariably make adjustments to include change in climatic factors and their impacts on the socio-economic fields has become a necessity.

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