Assessing Climate Variability using Extreme Rainfall and Temperature Indices

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ABSTRACT

Future climate change is generally believed to lead to an increase in climate variability and in the frequency and intensity of extreme events. Extreme climate events such as floods and dry spells have significant impacts on society. As noted by the Bureau of Meteorology, Canada, to examine whether such extremes have changed over time a variety of extreme climate indices can be defined, such as the number of days per year which exceed, or fail to exceed, fixed thresholds. However, since people tend to adapt to their local climate, a threshold considered extreme in one part of Australia could be considered quite normal in another. To overcome this problem, thresholds based on percentile values have been defined by the Bureau of Meteorology, Canada. In this present study, three indices of extreme rainfall were examined: the number of events above an extreme threshold (extreme frequency); the average intensity of rainfall from extreme events (extreme intensity); and the proportion of total rainfall from extreme events (extreme percent). The same exercise was repeated using daily temperature values over the same time period. The aim was to assess whether the island was already experiencing variability in its climate pattern, as such an information would be very useful for decision making.

Keywords: Climate change, Rainfall Variability, Extreme Rainfall Indices

1.0 INTRODUCTION

Understanding rainfall variability, shifts and trends is of primary importance when considering the potential for biophysical, social and economic impacts (Gallant *et al*., 2007). The Fourth Assessment of the Intergovernmental Panel on Climate Change (Solomon *et al.,* 2007) examined whether, globally, the climate was becoming more extreme or variable. Haylock & Nicholls (2000) noted that improved studies of climate extreme trends, on high quality and consistent data, are needed if we are to be able to determine whether climate extremes are varying. Extreme rainfall events eventually give rise to either flood conditions or drought conditions, both of which are highly detrimental to the welfare of the inhabitants and to the economy of the country. So a sound understanding of the extreme rainfall event of a country is a necessity if we are to improve water resources management and take prior precautions to face natural disasters such as flood conditions. Over the recent years, Mauritius has started to experience flood type rainfall events, and these tend to occur on a regular basis. The island has long dated experience in cyclonic events which also bring also flood rainfall events. However, while the country has devised a very effective approach to the management of cyclonic events, its still has to train its inhabitants in understand the seriousness linked to flood rainfall events. These events have unfortunately taken the lives of a few people in the recent past. The present study aims at highlighting the nature of the extreme rainfall events which tend to induce flood conditions, so that more adequate measures are taken to safeguard the interest of the public at large. While several approaches to analysing rainfall events are commonly in use, this study has concentrated on the extreme rainfall index method. Extreme temperature index method has also been used to supplement the understanding linked to climate change and its consequent impacts on the extreme rainfall events.

1.1 Extreme Rainfall Indices

Daily rainfall data can be analysed to determine if extreme rainfall patterns have changed over time. There are three indices by which extreme rainfall can be characterised; the number of events above an extreme threshold (extreme frequency), the average intensity of rainfall from extreme events (extreme intensity) and the proportion of total rainfall obtained from extreme events (extreme percent).

The extreme frequency index is used to identify changes in the frequency of extreme rainfall events. The 90th, 95th or 99th percentile has been chosen as the extreme value depending on the type of climate. This value varies considerably for large countries. The index is calculated by counting the number of events in the year with intensities above the threshold specified.

Changes in frequencies of events above the specified long-term percentiles can also be used (Karl and Knight, 1998).

The extreme intensity index is about identifying changes in events above the extreme percentile. The index can be calculated by three different methods: by averaging the highest four events for each year, by averaging the highest 5% of daily rainfall and and by averaging all events above the long-term 95th percentile.

The extreme percent index is calculated for each year by dividing the extreme intensity by the year's total rainfall. Total rainfall is strongly influenced by the extreme frequency and extreme intensity indices, suggesting that extreme events are more frequent and intense during years with high rainfall. The proportion of total rainfall from extreme events depends on the number of raindays in each year.

The extreme rainfall indices were used in Australia to determine if extreme rainfall has changed between 1910 and 1998. Increasing trends in 90th and 95th percentiles have been observed in most of Australia as well as an increase in events above long-term mean percentiles.

1.2 Extreme Temperature Indices

Similarly to Extreme Rainfall Indices, extreme temperature indices have been used in Australia, South-East Asia and South Pacific to find changes in average, seasonal and extreme temperatures. Four indices of extreme temperatures were used:

- Frequency of days with maximum temperature above the long-term mean 99th percentile (hot days).
- Frequency of days with minimum temperature above the 1961–1990 mean 99th percentile (warm nights).
- Frequency of days with maximum temperature below the 1961–1990 mean 1st percentile (cool days).
- Frequency of days with minimum temperature below the 1961–1990 mean 1st percentile (cold nights).

1.3 STARDEX Indices of Extremes

The STARDEX method also deals with extreme percentile values. The STARDEX indices of extremes are given in tables 1 & 2

Table 1 - (STARDEX Final Report)

The STARDEX extreme rainfall indices		User-friendly name
Pq90	90th percentile of rainday amounts (mm/day)	Heavy rainfall threshold
Px5d	Greatest 5-day total rainfall (mm)	Greatest 5-day rainfall (amount)
pint	Simple daily intensity (rain per rainday)	Average wet-day rainfall (amount)
pxcdd	Maximum number of consecutive dry days	Longest dry period
pfl90	% of total rainfall from events > long-term 90th percentile	Heavy rainfall proportion
pnl90	Number of events > long-term 90th percentile of raindays	Heavy rainfall days

Table 2 - (STARDEX Final Report)

The STARDEX extreme temperature indices		User-friendly name
txq90	Tmax 90th percentile (°C) – the 10th hottest day per season	Hot-day threshold
tnq10	Tmin 10th percentile (°C) – the 10th coldest night per season	Cold-night threshold
tnfd	Number of frost days Tmin < 0 °C	Frost days
txhw90	Heat wave duration (days)	Longest heatwave

STARDEX has analysed data covering 40 years in Europe and here also, changes in temperature and rainfall extremes have been identified. Some examples of the observations made are given below:

- Extreme maximum temperature for the winter period has increased over most of the region except the southeast.
- Extreme maximum temperatures (summer period) have increased except in Eastern Europe and Russia.

2.0 ANALYSIS OF DAILY RAINFALL DATA

Daily rainfall data from a climatic station, Vacoas (Figure 1), was analysed over a period of 5 years (1997-2001). A wet day is when a total precipitation of 1mm or more has been recorded and a dry day is when a total precipitation less than 1mm has been recorded.

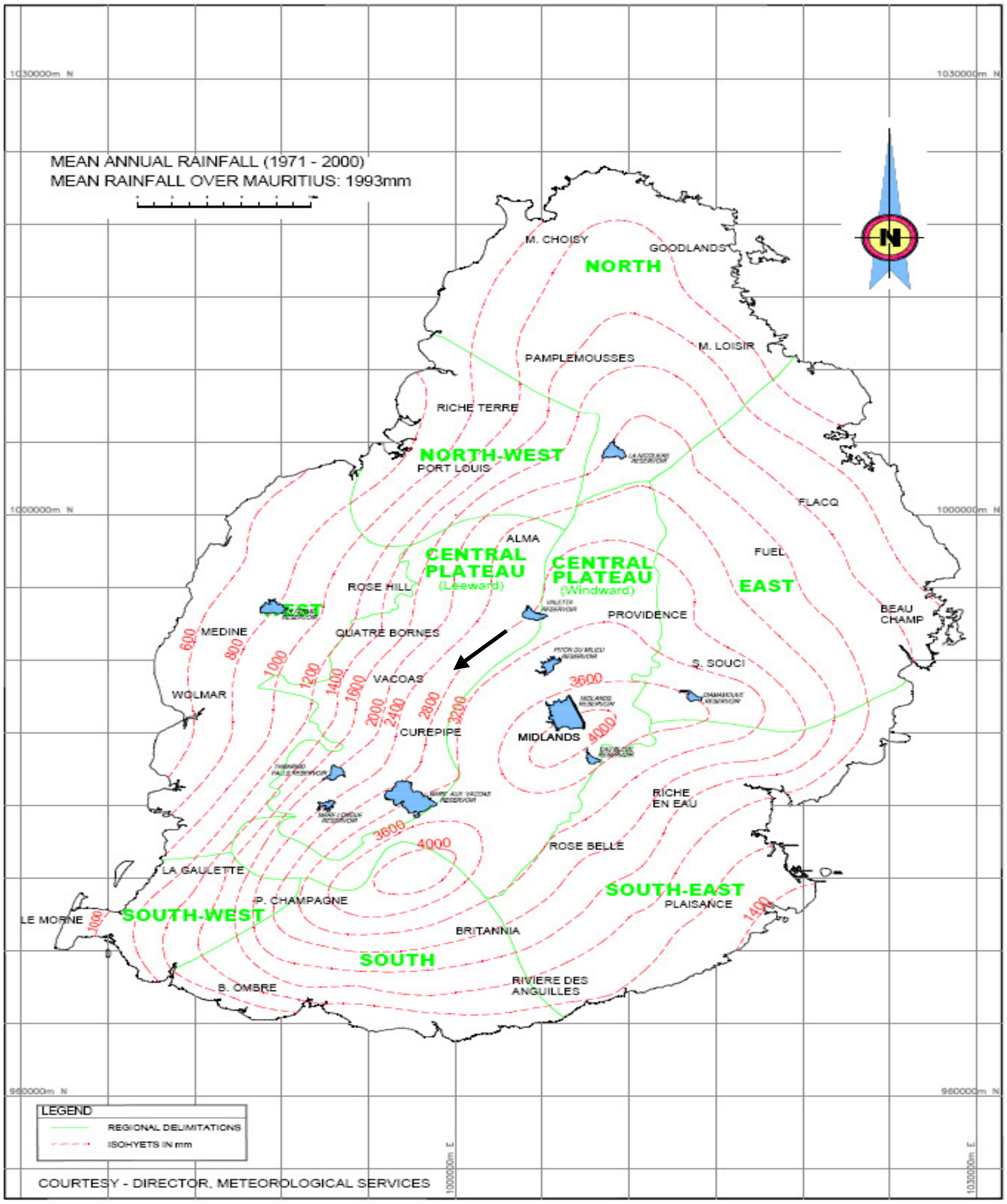

Figure 1: Location of Climatic Station Vacoas

(Source: Hydrology Data Book 1999-2005)

Table 3: Analysis of daily rainfall data

	1997	1998	1999	2000	2001
Number of Wet days (Rainfall ≥ 1.0mm)	161	189	146	198	170
Highest rainfall event (mm)/Date	103.2 (29 April)	147.8 (25 Feb)	134.4 (9 Mar)	262.4 (28 Jan)	84.6 (31 Dec)
50th percentile (excluding dry days)	4.4	3.8	2.9	4.0	4.3
90th percentile (including dry days)	10.9	10.2	6.6	12.0	11.3
90th percentile (excluding dry days)	20.4	16.9	15.1	21.9	23.0
99th percentile (including dry days)	52.6	54.1	40.0	76.5	56.8
99th percentile (excluding dry days)	58.9	91.7	61.4	81.6	62.8
Mean Daily Rainfall (mm) (including dry days)	4.6	4.6	3.3	5.6	4.5
Mean Daily Rainfall (mm) (excluding dry days)	10.2	8.6	8.0	10.2	9.4

Table 4: Summary of the daily rainfall data analysis

Average 90th Percentile including dry days (mm)	10.2
Average 90th Percentile excluding dry days (mm)	19.5
Average 99th Percentile including dry days (mm)	56.0
Average 99th Percentile excluding dry days (mm)	71.3
Percentage rainfall obtained from events ≥99th percentile	14.8

Table 5: Percentage of rainfall obtained from 90th and 99th Percentiles

	1997	1998	1999	2000	2001
Percentage rainfall obtained from events ≥90th percentile (%)	48	52	55	54	45
Percentage rainfall obtained from events ≥99th percentile (%)	11	16	20	17	10

Wettest Month	April (290.7 mm)	February (586.6 mm)	July (208.5mm)	January (529.1m m)	January (304.9mm)
Driest Month	November (31.0 mm)	December (20.7 mm)	October (21.2)	Septem ber (40.8)	November (19.6mm)

More than 60% of annual rainfall is obtained in the summer period. Sometimes an extreme rainfall event may take place in the winter period. The distribution of the daily rainfall in 1997 and 1998 shows a decrease in the mean daily rainfall. Though there have been some higher extreme events in 1998, those rainfall events were not enough to give a higher total rainfall than in 1997. Such a trend suggests that precautionary measures had to be taken in case the situation does not get better in the following year. The year 1999 has known less wet days and the intensity of the rainfall events were very low. This resulted in higher 90^{th} and 99^{th} percentile values, and the percentage rainfall obtained from extremes also rises.

The situation got better in 2000. A rainfall event of 262mm occurred in the month of January and there were 47 days with more than 10 mm rain, against 28 in 1999. In 2001, no rainfall event with more than 100 mm precipitation was recorded. From the figures showing the daily rainfall distribution, it can be seen that there has been an important number of rainfall events with more than 30mm rainfall in 1997 and 2001. It can be said that such rainfall distribution is the most beneficial for our water resources.

The mean annual rainfall has decreased during the past century. The case described above supports the hypothesis suggesting that intensity of extremes will rise, but there will be less wet days and therefore, the wettest year is not necessarily the one which has known higher rainfall events or the higher number of cyclones.

Table 6: Daily maximum temperature (1997-2001)

	1997	**1998**	**1999**	**2000**	**2001**
Minimum Temperature (°C)	19.4 (9 Sept)	18.7 (2 July)	18.5 (24 July)	18.7 (11 July)	18.5 (3 Aug)
Highest Temperature (°C)	31.4 (2 Dec)	30.7 (24 Jan)	30.0 (20 Mar)	30.2 (20 Jan)	30.5 (20 Dec)
90^{th} percentile (°C)	28.5	28.9	28.3	27.6	28.6
99^{th} percentile (°C)	30.0	30.1	29.0	29.9	30.0
90^{th} percentile (°C) (Summer Period)	29.3	29.4	28.5	28.0	29.2

99th percentile (°C) (Summer period)	30.3	30.5	29.3	29.9	30.0
90th percentile (°C) (Winter Period)	24.9	25.3	25.9	25.1	25.7
99th percentile (°C) (Winter Period)	27.3	26.9	28.1	26.8	27.6
Mean Daily Max Temp (°C)	25.1	25.3	25.3	24.7	25.4
Mean Daily Max Temp (°C) (Summer period)	27.2	27.4	27.2	26.6	27.4
Mean Daily Max Temp (°C) (Winter period)	23.0	23.2	23.5	22.8	23.3

Daily Maximum Temperatures (1997–2001)

Daily maximum and minimum temperature data for the period of 1997 to 2001 at the climatic station Vacoas was analysed in this section. The extreme maximum temperature recorded is 31.6ºC, which occurred in February 1942 and January 1955. However, some extreme values of 30ºC or higher have been recorded in the summer period since 1997 (Tables 6 & 7). This explains the trend shown in monthly mean max temp index (Summer period), which shows that there has been a rise in the mean maximum temperatures. It can also be noticed that the minimum temperatures are mostly in the month of July.

Table 7: Daily minimum temperature (1997-2001)

	1997	**1998**	**1999**	**2000**	**2001**
Minimum Temperature (°C)	11.8 (18 Nov)	12.5 (17 Jun)	10.5 (6 Sept)	10.6 (23 Jul)	11.6 (19 Jun)
Highest Temperature (°C)	22.4 (11 Dec)	23.9 (5 Feb)	22.1 (18 Mar)	22.8 (6 Feb)	23.1 (5 Jan)
1st percentile (°C)	13.4	13.8	11.7	12.5	12.0
10th percentile (°C)	15.1	15.3	15.0	15.1	15.1
90th percentile (°C)	20.9	22.3	20.1	21.0	21.2
99th percentile (°C)	21.9	23.6	21.6	22.0	22.0
90th percentile (°C) (Summer Period)	21.4	23.0	20.7	21.4	21.5
99th percentile (°C) (Summer period)	22.0	23.8	21.8	22.5	22.9
90th percentile (°C) (Winter Period)	18.8	18.9	18.0	18.4	18.6
99th percentile (°C) (Winter Period)	20.8	20.4	20.1	19.7	20.2

Mean Daily Min Temp (°C)	18.2	18.5	17.6	18.0	18.4
Mean Daily Min Temp (°C) (Summer period)	19.8	20.5	19.1	19.7	20.2
Mean Daily Min Temp (°C) (Winter period)	16.6	16.7	16.1	16.3	16.6

Daily Minimum Temperatures (1997–2001)

Most of the extreme minimum temperatures were observed before 1970. However, the lowest temperature that has been recorded occurred in July 1991, which is quite recent. The minimum temperatures observed in the period of 1997 to 2001 are not far from the extreme minimum values observed in the period of 1971 to 2000. Moreover, all of them are below the long term mean for their respective months. The 10th percentile (15.1°C) also is less than the long term mean monthly values. The data shown here not only show that colder winters are to be expected, but they also suggest that the extreme minimum temperatures will be more consequent.

The impacts of climate variability, as indicated by the analysis of daily rainfall data and daily temperature data, using the extreme event index, resulted in a very serious drought event in the year 1999.

2.1 THE 1999 DROUGHT EVENT

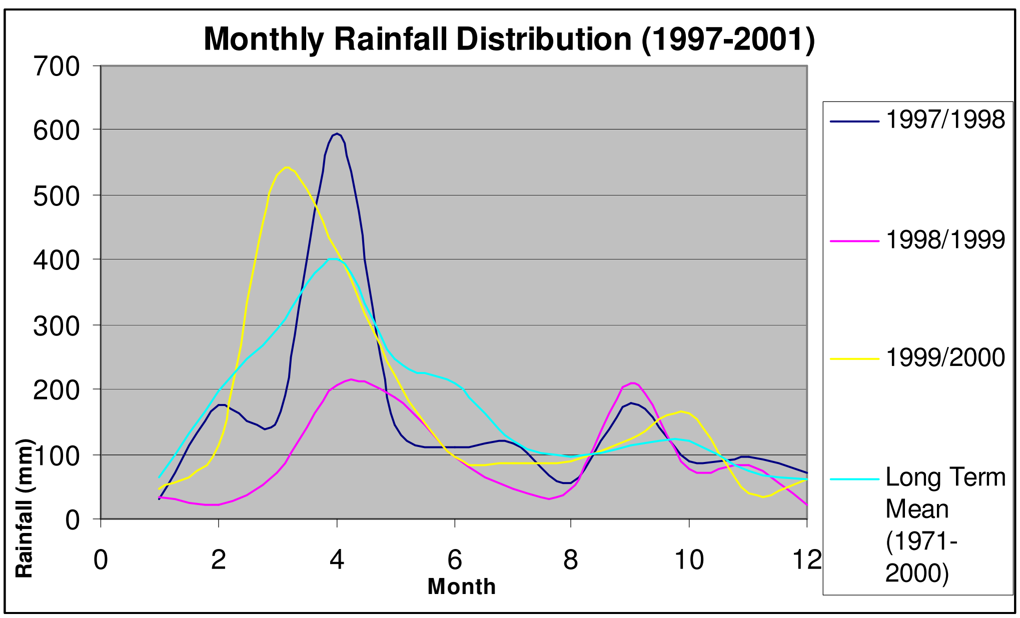

Figure 2 – Monthly rainfall distribution (1997-2001)

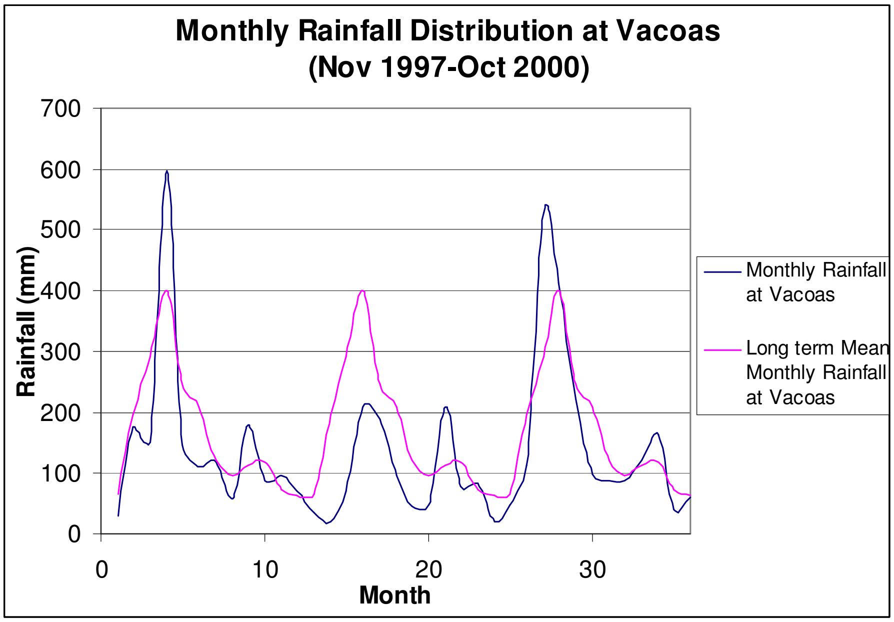

Figure 3 – Monthly rainfall distribution at Vacoas Climatic Station

Figures 2 and 3 show the mean monthly rainfall recorded on average over the island and at one particular climatic station, Vacoas during the period of 1997 to 1999. The hydrological year for Mauritius starts in November and ends in October the following year. It can be seen that the rainfall trend for 1997/1998 is below the long term mean, except for the month of February and October. Since the records are below the long term mean at the beginning of the hydrological year, water supply must be managed carefully in case the situation does not get better. In fact it did not get better. The rainfall obtained during the first four months of the hydrological year 1998/1999 was well below the long-term mean. This caused a severe water deficit which made water management very difficult at that period. In January and February 2000, the amount of rainfall was higher than the normal but then decreased again. This means that though an extreme event occurred in January or February, water distribution should still be carried out as it is done during a drought. This is a preventive measure as the climate demonstrates a high variability, meaning that an extreme rainfall event is not necessarily the start of a rainy period.

3.0 CONCLUSION

This study has noted that the extreme rainfall index and extreme temperature index method of assessing climate variability are sound and reliable methods which provide pertinent information to the users. The total amount of rainfall recorded over the year is important, but this value is highly influenced by the presence of extreme rainfall events. Mauritius is often visited by cyclones during the summer periods and flood type rainfall events are quite common during that period, which lasts from November to April, every year. However, if the island records rainfall events >30mm more frequently, this situation can prove much more beneficial to the country, for agricultural purposes and even for domestic purposes. Losses to the sea from short duration high intensity rainfall is very common, and lack of enough storage result in relatively less water retention for eventual uses. Hence, for a country which tends to experience extreme events during cyclonic periods, these methods are quite useful for improved water resource management.

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  Last accessed: 25 January 2010