Global warming and changing temperature patterns over Mauritius

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Abstract

The Earth's climate has been evolving since millions of years. Greenhouse gases, occurring in the atmosphere both naturally and mainly due to anthropogenic human activities, trap much heat from the Sun and heat the planet. By burning more and more fossil fuels, humans are accelerating the global warming. This paper discusses the changing temperature pattern over Mauritius. We observe an increase of 0.8\textdegree{}C in the temperature from 1976 to 2008. Compared to the mean 1951 to 1961 temperature, we find that there is shift in time (decadal) in the warming from northwest to other sectors. The temperature deviations are more marked in winter than in summer. Moreover, the number of hot days per year is increasing and the number of cold days is decreasing.

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1 Introduction

The temperature of the air around the earth has been changing since thousands of years. Fluctuations or changes in climate will almost always be reflected in variations in surface air temperature. Since the start of the 20th century the global average temperature has increased (Trenberth et al. 2007, Rosenzweig et al. 2007). Any changes in climate pattern that had been taken place must have been reflected through variations in surface air temperature.

Although systematic and continuous temperature measurements were started in 1874 by Mr Cere, the Director of the Botanical Gardens of Pamplemousses, it was not until 1876 that reliable recordings were made at the Royal Alfred Observatory (RAO) at Pamplemousses which could be used for computation of trends. A number of other stations measured temperature – such as the Port Louis Observatory and a number of agricultural establishments – but it has not been able to constitute a continuous long-term record for any of these stations. The records at RAO have been meticulously kept including details of the instruments used and their exposure. The RAO records therefore constitute a very important set of data of appreciable length for Mauritius from 1876 to 1952. Herchenroder was the first to analyse air temperature and humidity of the RAO from 1876 to 1935. His analysis revealed that the temperature at Pamplemousses decreased by a fraction of a degree between 1900 and 1935. By 1950, this temperature decrease appears to have been recovered. In this paper, long term data for Mauritius have been analysed in the context of global warming.

The warming of the global climate systems has changed the temperature patterns over the globe (IPCC 2007e). D. Wilkins and Wright (2004) from the Department for Environment Food and Rural Affairs (DEFRA) of UK have defined two parameters the hot day and the cold day. The increasing temperature must have changed the number of hot days and cold days not only during summer but also during winter. They defined a hot day to be a daily mean temperature at or above 20°C and a cold day to be a daily mean temperature at or below 0°C. But these criteria do not apply for Mauritius because the range of temperatures in the temperate area such as UK is different from that of the sub-tropics. For Mauritius, we have chosen to define a hot day to be a mean daily temperature of 3°C or more above the long term annual temperature of 1971-2000.
Annual temperature distribution over Mauritius is characterized by a mean maximum of 31°C along the northern and western coastal areas in December and January and a mean minimum temperature of about 14°C over the plateau in July and August. Absolute maximum and minimum temperatures recorded have been 37.5°C and 6.5°C respectively (NCC 1999). Although the average seasonal variation of temperature is relatively small, being of the order of 4°C, it is nevertheless sufficient to cause a well-marked difference in the season. Temperatures are generally higher in the coastal areas decreasing towards the Central Plateau (CP). Also, the northern and western regions of Mauritius, located on the leeward of the trade winds, are warmer than the southern and eastern regions. Diurnal air temperature variations varies from 6°C to 7.5°C in the CP, from 8.4 to 10 in the W, 6.5 to 8.5 in the N. Departures in daily temperature of more than 2°C from the normal is not uncommon and is usually caused by the passage of low-pressure systems in summer and high-pressure systems in winter.

![Figure 1: Distribution of Mean Minimum/Maximum Summer/Winter Temperatures – 1961-1990 normal (Source: NCC 1999)](image-url)
2 Source of data and method of study

To study the changes in the temperature patterns over Mauritius, the data over a long period of time has been studied. The monthly values of the air temperature have been collected from stations as shown in figure 2 by the Mauritius Meteorological Services where the data are quality controlled and updated accurately.

Figure 2: Stations over Mauritius (Source: Mauritius Meteorological Services)
We have used the regression technique to analyse the trends of the monthly mean data of the temperature recorded at the five reliable stations that satisfy the requirement. Pamplemousses represents the north, Fuel the east, Medine the west, Plaisance represents the south and Vacoas the Centre. The significance level has also been tested. INSAT™, SYSTAT™ and SPSS™ statistical packages have been used to make further analyses on the data. Our main objective here is to find any temporal fluctuations in the temperature patterns over Mauritius as far as climate change is concerned.

3 Results and discussions

Mean Max, Mean Min Temperatures

The longest continuous record of measured surface air temperature over Mauritius is at Pamplemousses, a station located to the north of the island. The data on record date back to 1876 and are being continually up-dated by the Mauritius Meteorological Services. Figure 3 shows the time series for mean temperature that have been observed at Pamplemousses station from 1876 to 2008.

![Figure 3: Annual mean temperature recorded at Pamplemousses Station from 1876 to 2008 [Sources Herchen and Borgne, Central Statistics Office and Mauritius Meteorological Services]](image)

The thirty years running mean (solid line in red) in Figure 3 indicates that an increase in the annual mean temperature since 1876 has also been observed in Mauritius. The linear trend line in purple confirms the increase in temperature at an average rate of 0.009°C per year with a correlation coefficient of about 0.67. Figure 4 shows the mean maximum temperature
variation with the seasons in Mauritius where January, February, March and December are
the hottest and July and August are the coolest months. We also observe that there is an
increasing trend in the mean maximum temperature for all the months from 1950 to 2008.

Figure 4: Monthly variation of mean maximum temperature 1950 to 2008. The inset shows the trend for
March.

Figure 5 shows the trend in the mean temperature recorded at different regions all over the
island, north-east, south-west, north-west and south-east. An average of all these, that is, the
mean monthly temperature over the whole island has also been considered. All of them are
indicating an increase in the trend. The polynomial trend line in red bold solid line indicates
that the temperature was more or less stable before 1975. It is as from 1975 onwards that the
temperature is showing the increasing side. An increase of about 0.8°C on the average has
been noted from 1975 up to 2008. Even the monthly data from all the stations are showing
the increasing trend. We also notice that more warming has occurred since the 1990’s.
Figure 5: Regional temperature recorded from 1950 to 2008

Number of hot/cold days

For Mauritius, we have chosen to define a hot day to be a mean daily temperature of 3°C or more above the long term annual temperature of 1971-2000. For this purpose, we have chosen two stations only namely, Vacoas to represent the centre and Plaisance to represent the coastal region. Figure 6(a) and 6(b) show the variation in the number of hot days occurring at Plaisance and Vacoas respectively. We find a low temporal correlation of $r=0.4$ (see figure 4(a)) for a linear trend line suggesting an uncertainty in the linear trend. For a quadratic trend line we have a temporal correlation of $r=0.5$. Furthermore, we observe that as from 1976 onwards, the number of hot days increase quadratically for Plaisance. As far as Vacoas is concerned, we find that both the linear and the quadratic trend lines generate the same $r=0.3$, showing a low temporal correlation for the increasing number of hot days.
However, we obtain $r$ around 0.75 for the decreasing number of cold days with the linear and the quadratic trend lines. The number of cold days, on the other hand, shows a decreasing trend. As expected, figure 7(a) and 7(b) below indicate that the number of cold days is indeed decreasing. Note the drastic decrease in the number of cold days recorded at Vacoas as from 1976 onwards and at Plaisance as from 1989 onwards.
Decadal evolution of minimum/maximum temperatures

In particular, figure 8 shows krigged maps generated using SURFER® software of the decadal (1961-1970, 1971-1980, 1981-1990, 1990-2000) evolutions of minimum and maximum temperature for the month of April when compared to the 1951-1960 decade. The plots have been generated using 10 stations around the island which include Vacoas, Plaisance, Medine, Pamplemousses, Belle Rive, Beau Valon Cour, Labourdonais, Riche Lieu, Reduit and Union Park.
Figure 8: Evolution of minimum (top) and maximum (bottom) April temperature deviations relative to 1951-60
Table 1  Summary of decadal temperature variation (compared to 1951-1960)

<table>
<thead>
<tr>
<th>Decades</th>
<th>Minimum temperature</th>
<th>Maximum temperature</th>
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<tbody>
<tr>
<td>1961 to 1970</td>
<td>Warming of +1 to +2.2°C in the minimum throughout the year for the decade to the NW of the island. The area widens during the months April, June and July. The warming is spreading to N as we move from 1960’s to 1990’s. A significant warming in June and July.</td>
<td>Warming of +1 to +2.2°C in the maximum throughout the year for the decade to the NW of the island. The area widens during the months April, to September. Significant warming in June and July. Warming shifts towards the Centre and the N as we move from 1960’s to 1990’s.</td>
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<tr>
<td>1971 to 1980</td>
<td>Relatively cool decade, we note practically no warming in January, February, March and September. For the rest of the year, we note warming occurring in the centre, to the S and the N.</td>
<td>Relatively cool decade, little warming in Centre for January, extending towards N and S from February&amp; March, decreasing towards December</td>
</tr>
<tr>
<td>1981 to 1990</td>
<td>Warming of up to +1.5°C in the month of April, July, October and November. For the rest of the year, we note no significant warming except to the NW.</td>
<td>Little warming in Centre for January, picking up as from April, highest occurring in May to September to +2.0°C and extending towards N and S.</td>
</tr>
<tr>
<td>1991 to 2000</td>
<td>Warming up to 1.5°C to the NW, SE and N in February, more significant in April, gradually decreasing up to December. But NW remains warm.</td>
<td>Warming in the Centre and the N for the whole year, less significant in January and December, peaking to +2.0°C April, May and June.</td>
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Table 1 summaries the findings in the decadal monthly anomalies. Interestingly we note that there is a warming of 1.0 to 2.2°C in the minimum throughout the year for the decade to the NW of the island. The area widens during the months April, June and July. The warming spreads to northern and the southern areas as we move from 1960’s to 1990’s. The coastal zones are also becoming warmer.

Figure 9: Evolution of minimum (top) and maximum (bottom) April temperature deviations relative to previous decade.
Table 2  Summary of decadal temperature variation with previous decades

<table>
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<tbody>
<tr>
<td>1961 to 1970</td>
<td>NW is again warmer by +1 to +2.2°C throughout the year. The area widens during the months April, May, June and July; including September, October and November. The warming confines itself to the NW and the N. A significant warming in April, June and July.</td>
<td>NW warmer by +1 to +2.2°C in the maximum Wide areas during the months April, June July and August. Significant warming in June. The warming is shifting towards the Centre and the other sectors as we move from 1960’s.</td>
</tr>
<tr>
<td>1971 to 1980</td>
<td>SE warming by +2.2°C in April, May, July, August and October. Relatively less warming in January and December.</td>
<td>Warming in the S and the SE, gradually extending to the N. Highest of the order of +1.5°C in May. No noticeable warming in February is observed.</td>
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<tr>
<td>1981 to 1990</td>
<td>Warming noted all sectors, except the centre. Highest +1.2°C to the NW and SE in October. No noticeable warming is observed in July.</td>
<td>Warming SE throughout year, extending to other sectors except in May and December. Highest +1.0°C in February.</td>
</tr>
<tr>
<td>1991 to 2000</td>
<td>NW and SE +1°C. Centre warming in February, March,April, May, June and July. Again from September to December no noticeable warming is observed.</td>
<td>Warming all sectors in January to June except April, August, November and December no warming in SE. September warming of +2.0°C in NW</td>
</tr>
</tbody>
</table>

We observe a variation in the warming and cooling in for the whole year as we go from the 1960’s to the 1990’s. Only the maximum temperature for January shows a continuous warming and a shift from the northwest to the other sectors. The minimum temperature for September to December in the 1990’s indicate a cooling compared to the previous decade.

4 Conclusions

We note a gradual increase in the mean temperature from 23.5°C in 1976 to 24.3°C in 2008, that is, an increase of about 0.8°C. Linear and quadratic increasing trends in the mean minimum/maximum temperature for summer/winter with time over the island occur for almost all the stations. The observations of the hot/cold days further support the notion of global warming with the increasing trend in the number of hot-days and the decreasing trend in the number of cold-days. In addition, we find that the number of hot and cold days along the coastal regions respectively increase and decrease quadratically. Furthermore, almost a linear increase and decrease in the number of hot and cold days have been observed at the centre. Decadal trends reveal a warming towards the south and the upland areas as we move from the 50’s to the 90’s. Decade to decade deviations do not show a definite pattern in the tendency of temperature.
References


Wilkins D. and Wright K (2004), ‘Review of UK Climate Change Indicators’, Contract EPG 1/1/158, Department for Environment Food and Rural Affairs (DEFRA), UK