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Temperature as an Indicator of Climate Variation at a Local Weather Station

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Abstract: This study assessed temperature data from Chichiri weather station in Blantyre, Malawi for the possibility of warming and variation over a nine year (2000-2009) period. Blantyre was chosen because it is the industrial and commercial capital of Malawi whereas Chichiri is close to two industrial sites (Makata and Maselema). The data used was for mean monthly minimum temperature and mean monthly maximum temperature. The data was analyzed using Statistical Package for Social Scientists (SPSS) and Microsoft Excel. The results showed that there were no significant differences ($p > 0.05$) between yearly mean minimum temperatures which was also the case for the mean maximum temperature. However there were significant differences between mean monthly minimum and maximum temperatures ($p < 0.05$). Graphical presentation of the data showed increase in temperature over the years, especially between 2004 - 2005, which is in agreement with literature. This study has shown that temperatures over Chichiri are increasing which may be indicative of variation and sequential warming.

Key words: Global warming · Climate change · Industrial sites · weather station · Green house gases

INTRODUCTION

Malawi is a country located in Southern Africa and Blantyre is its industrial and commercial capital. The current government policy is to change Malawi from a predominantly consuming to a producing nation. This will involve increase in agricultural production and industrial development [1]. Industrial activities and agricultural production may lead to pollution which may include the release of greenhouse gases which cause global warming. Global warming over the next century is likely to be associated with a change in the extent to which atmospheric and soil temperatures fluctuate, on both a daily and seasonal basis. The average annual temperature of the Earth's surface is expected to increase, as is the frequency of hot days [2]. Data from ice cores indicate that major shifts in global climate regimes have occurred in as little as a decade and that for most of the span of human existence the climate has oscillated much more violently than it has over the last 10,000 years. This evidence presents enormous challenges for international climate change negotiation and regulation, which has thus far focused on gradual change [3].

Large, abrupt and widespread climate changes with major impacts have occurred repeatedly in the past, when the Earth system was forced across thresholds. Although abrupt climate changes can occur for many reasons, it is conceivable that human forcing of climate change is increasing the probability of large, abrupt events [4]. There is near unanimous scientific consensus that greenhouse gas emissions generated by human activity will change Earth's climate. The recent (globally averaged) warming by 0.5°C is partly attributable to such anthropogenic emissions [5]. It is strongly suggested that the earlier warming was natural internal climate-system variability, whereas the recent surface air temperature changes are a response to anthropogenic forcing [6]. Comparisons of observations with simulations from an energy balance climate model indicate that as much as 41 to 64% of preanthropogenic (pre-1850) decadal-scale temperature variations were due to changes in solar irradiance and volcanism. A 21st-century global warming projection far exceeds the natural variability of the past 1000 years and is greater than the best estimate of global temperature change for the last interglacial [7]. Carbon dioxide is an example of greenhouse gases. The continued increase in the atmospheric concentration of carbon

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dioxide due to anthropogenic emissions is predicted to lead to significant changes in climate. About half of the current emissions are being absorbed by the ocean and by land ecosystems, but this absorption is sensitive to climate, as well as to atmospheric carbon dioxide concentrations, creating a feedback loop [8].

The variation of temperature with depth and the amount of heat escaping from the interior of the earth’s crust through its surface are easily measured and give useful information on the ventilation requirements of deep mines, the deep structure of the earth's crust and on global warming [9]. In determining the best policies to deal with the climate of the future, a policy maker has to select an appropriate statistic to use to represent the changing climate. By convention, the statistic is the averaged global temperature as measured with thermometers at ground stations throughout the world, though in practice this is far from being satisfactory [10,11].

Climate change is a shift in the “average weather” that a given region experiences. This is measured by changes in all the features associated with weather, such as temperature, wind patterns, precipitation and storms. Global climate change does occur naturally, the ice age is an example. The earth's natural climate has always been and still is, constantly changing. The climate change we are seeing in recent times differs from previous climate change in both its rate and its magnitude. The need for valid climate forecasts has been underlined by the recognition that human activities are now modifying the climate [12]. For example anthropogenic activities have caused the tropical sea surface temperatures in Barbados corals to be 5°C warmer than the previous values [13].

Around the world, climate change is projected to threaten the world's boreal forests with an increased fire risk because of the drying climate, cause water needs to outstrip supply, cause severe water loss due to changes in evaporation and precipitation patterns, cause flood damage to low-lying countries and island states, including loss of coastal land to rising sea levels, encourage the movement of tropical diseases such as malaria northward, where populations have little or no immunity and affect international trade patterns [14][15][16]. Recent evidence indicates that climate change can alter the geographical distribution of parasitic diseases, with potentially drastic consequences for their hosts. It is also possible that warmer conditions could promote the transmission of parasites and raise their local abundance [17]. There is mounting evidence that global climate change has extended growing seasons, changed distribution patterns and altered the phenology of flowering, breeding and migration. For migratory birds, the timing of arrival on breeding territories and over-wintering grounds is a key determinant of reproductive success, survivorship and fitness. This finding demonstrates that migratory phenology is quite likely to be affected by global climate change [18].

Climate change involves correlated increases in temperature and atmospheric carbon dioxide concentration. Global climate change is expected to have broad ecological consequences for species and communities [19]. Increasing evidence suggests that climate change has affected the breeding and distribution of wildlife [20]. A number of studies have clearly highlighted some of the specific problems that may arise due to global warming and climate change. Some of the examples are; Global warming has the potential to increase soil respiration, one of the major fluxes in the global carbon cycle [21], the annual-mean temperature has increased by about 2°C in Seoul over a period of 83 years. The temperature increase has been significant during the winter and early spring and becomes less significant during late spring [22], the buildup of greenhouse gases in the atmosphere has resulted in global climate change that is having a significant effect on many allergenic plants through increases in plant productivity and pollen allergenicity and shifts in plant phenology [23]. Jellyfish may bloom causing problems worldwide [24], glass eels migration will be affected since they tend to prefer cool water [25], increased incidences of enteric infections by Salmonella, pathogenic Escherichia coli and Campylobacter [26] and also global warming and the rise in atmospheric carbon dioxide concentration will increase the operating temperature of leaves in coming decades, often well above the thermal optimum for photosynthesis [27].

Temperature is identified as the dominant abiotic factor directly affecting herbivorous insects [28] therefore extremes of temperature may negatively affect insects. In the last decade it has become clear that the timing of many phenological processes, like the start of flowering and leaf unfolding in spring, have changed. The increase in temperature is believed to be the main cause. The earlier start of flowering will have consequences for the start of the pollen season and thus for the start of the hay fever season. Millions of people world-wide will therefore experience the impact of climate change in their daily lives during spring and summer [29]. Grain yield may decline by 10% for each 1°C increase in growing-season minimum temperature in the dry season. There is also decreased rice yield from increased night time temperature associated with global warming [30]. Climate change creates new challenges for biodiversity conservation. Species ranges and ecological dynamics are already responding to recent climate shifts and current reserves will not continue to support all species they were designed to protect [31].

There is scientific consensus that the global climate is changing, with rising surface temperatures, melting ice and snow, rising sea levels and increasing climate variability. These changes are expected to have substantial impacts on human health. There are known, effective public health responses for many of these impacts, but the scope, timeline and complexity of climate change are unprecedented [32]. Environmental problems and our perceptions of their current and future health effects, have changed over the decades. About 20-40 years back, public health was most concerned about localised environmental degradation, as exemplified by air and water pollution. We have since become aware, however, of the threats to human health which operate at a much larger geographical scale and which, because of their non-localized character, are even more difficult to investigate. All these global environmental changes are due to increased human pressure on the environment, of which the main drivers are population growth and an increase in per capita resource use and waste production. Climate change and other changes to the atmosphere, land use changes and soil degradation, freshwater depletion and contamination and biodiversity loss are four important categories of global environmental change, each of which form potential, although partly or largely unknown, threats to human health [33].

Over the past 100 years, the global average temperature has increased by approximately 0.6 °C and is projected to continue to rise at a rapid rate. Although species have responded to climatic changes throughout their evolutionary history, a primary concern for wild species and their ecosystems is this rapid rate of change. The synergism of rapid temperature rise and other stresses, in particular habitat destruction, could easily disrupt the connectedness among species and lead to a reformulation of species communities, reflecting differential changes in species and to numerous extirpations and possibly extinctions [34]. Monthly mean maximum and minimum temperatures for over 50% of the Northern (Southern) Hemisphere landmass, accounting for 37% of the global landmass, indicate that the rise of the minimum temperature has occurred at a rate three times that of the maximum temperature during the period 1951-90 (0.84°C versus 0.28°C) [35].

Temperature increase has not been steady, but from the 1980s warming has accelerated. Scientists are concerned that we are entering a period of unprecedented global warming caused by humans. Global surface temperature has increased by approximately 0.2°C per decade in the past 30 years, similar to the warming rate predicted in the 1980s in initial global climate model simulations with transient greenhouse gas changes [36]. A 100-year increase in global temperature by 0.3 to 0.6°C is reflected in atmospheric warming, glacier shrinkage and rising sea levels [37]. Many general circulation models (GCMs) predict that high latitude environments will experience substantial warming over the next 100 years, which will be particularly pronounced during the winter months [38]. The latest report by the Intergovernmental Panel on Climate Change (IPCC) predicts a 1.4-5.8°C average increase in the global surface temperature over the period 1990 to 2100 [39].

In Malawi some progress has been done on research related to climate change. For example studies have been done on contribution of greenhouse gases (especially methane) by waste treatment and disposal [40]. Also air temperature data from Chancellor College Meteorological Station was studied and between 1980-1993 the average annual temperature had increased by around 10°C [41]. It has also been suggested to use empirical methods for estimating the mean monthly daily diffuse radiation from the global radiation and extraterrestrial radiation on a horizontal plane [42]. However none of these studies has looked at temperature variations in an area close to industrial sites in Malawi hence the need for this study.

MATERIALS AND METHODS

The air temperature data was captured at the Malawi Department of Meteorological Services Chichiri weather station, which uses mercury thermometers. Chichiri was chosen because it is very close to three industrial sites (Chirimba, Makata and Maselema) and also data capture during the study period was not erratic. The thermometers used for capturing the data are shown in figure 1 and 2 below.

The data was analyzed using Statistical Package for Social Scientists (SPSS) (independent sample t-test) since it was assumed that the different yearly data was independent of each other. To clearly understand the temperature variations over the eight year period, the data was also presented graphically using Microsoft excel.

Fig. 1: The thermometer unit at Chichiri, weather station

Fig. 2: The thermometer housing unit

RESULTS AND DISCUSSION

Tables 1 and 2 below show the temperature data that was used in this study.

Comparing Mean Monthly Minimum Temperatures (2000-2009): The mean monthly minimum temperature over a period of two years was analyzed (for example year 2000 data was compared to year 2002 whilst year 2001 was compared to year 2003) (The data used is shown in table 1). Also the year 2000 data was compared to 2004 and 2009. This is because 2004 is taken worldwide as the warmest year while 2009 was the cutoff point for data used in this study. There were no significant differences ($p > 0.05$) in mean monthly minimum temperatures over the nine year period. It is however interesting to note that over the nine year period, minimum temperatures have been increasing over Chichiri up to 2005 when they started dropping (2005 - 2008) and then rising again (2008 - 2009) as shown by the graph below (Figure 3);

The graph above shows that though there are no significant differences over mean minimum temperature for the nine year period, warming cannot be ruled out. This is because the period between 2004 to 2005 is taken as the warmest time in history as indicated earlier.

Comparing Mean Monthly Maximum Temperatures (2000-2009): The data used is shown in table 2 and the procedure used was the same as that for the mean monthly minimum temperature. There were no significant differences ($p > 0.05$) in mean monthly maximum temperatures over the nine year period. However the graph below (Figure 4) shows that overall there has been an increase in mean maximum temperature over the years for Chichiri.

Table 1: Chichiri mean monthly minimum temperature (°C)

Year/Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Jan	18.4	17.9	17.8	18.5	19.3	18.7	19.2	18.7	18.8	18.9
Feb	18.2	18.2	17.1	18.4	17.8	18.4	18.7	18.4	17.0	17.9
March	17.9	17.9	17.4	17.0	18.1	18.0	18.9	18.1	17.0	17.5
April	16.2	15.0	16.0	15.4	17.1	15.9	16.4	17.9	14.8	15.1
May	14.1	13.8	14.0	14.9	14.5	14.0	14.7	14.9	14.1	14.9
June	13.1	11.8	12.3	12.6	10.5	17.6	12.7	13.1	11.9	14.5
July	11.2	11.6	13.6	11.4	10.0	12.5	12.7	12.2	12.9	12.1
Aug	12.0	13.7	13.9	12.7	14.5	14.8	14.1	13.7	12.9	13.1
Sept	15.8	15.8	15.2	15.2	15.6	15.0	15.6	15.2	16.1	15.5
Oct	16.7	16.0	17.0	17.3	18.2	17.4	17.8	17.7	18.5	18.0
Nov	18.1	19.1	16.8	18.9	17.5	19.2	18.4	19.3	19.0	18.2
Dec	18.3	19.2	18.0	19.9	18.7	19.5	19.2	19.3	19.5	19.1
Mean	15.8	15.8	15.8	16.0	16.0	16.7	16.6	16.5	16.0	16.2

Table 2: Chichiri mean monthly maximum temperature (°C)

Year/Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Jan	26.4	25.0	25.9	25.5	28.8	27.3	27.7	26.0	26.6	27.3
Feb	27.0	25.5	25.8	26.5	26.0	27.4	27.1	26.1	26.2	26.4
March	26.8	26.2	26.7	25.1	26.8	28.3	26.7	26.7	25.9	25.9
April	24.1	24.4	24.6	24.9	25.2	26.4	24.6	26.7	25.5	23.9
May	23.1	23.3	23.3	24.5	21.7	24.9	24.8	24.3	25.1	25.0
June	22.3	21.9	20.9	20.9	20.0	23.5	22.0	22.7	21.8	24.2
July	21.0	21.4	24.2	19.8	19.5	22.1	22.3	21.0	22.5	21.1
Aug	23.5	24.5	23.9	23.5	24.8	26.1	25.7	26.2	23.8	23.6
Sept	27.0	27.2	25.8	26.6	26.2	27.1	25.8	27.6	28.3	28.0
Oct	28.3	26.6	28.0	28.9	29.1	29.4	29.7	29.2	29.5	29.4
Nov	26.0	29.4	27.5	29.4	27.2	30.3	28.2	29.5	30.3	29.3
Dec	25.4	27.4	26.5	28.4	26.6	28.3	27.7	27.4	27.5	28.7
Mean	25.1	25.2	25.3	25.3	25.2	26.8	26.0	26.1	26.1	26.1

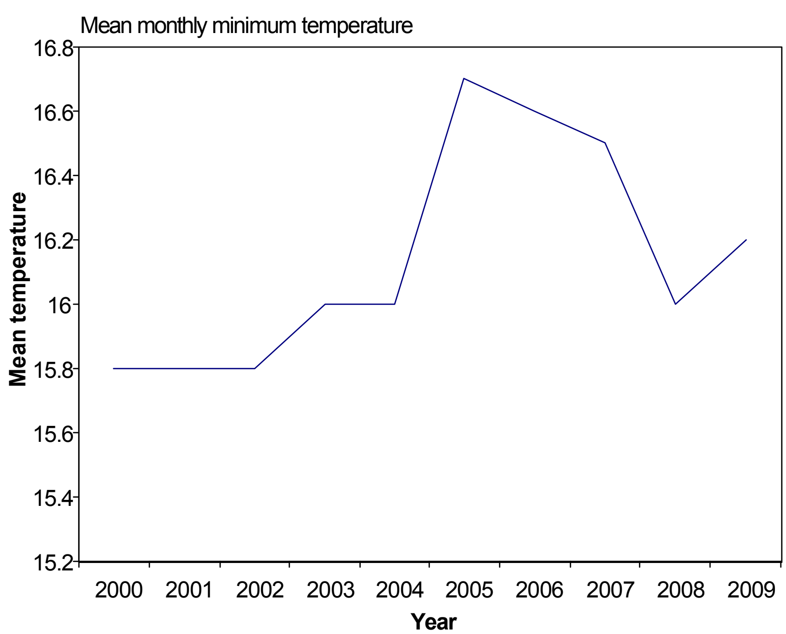

Fig. 3: Mean minimum temperature for Chichiri

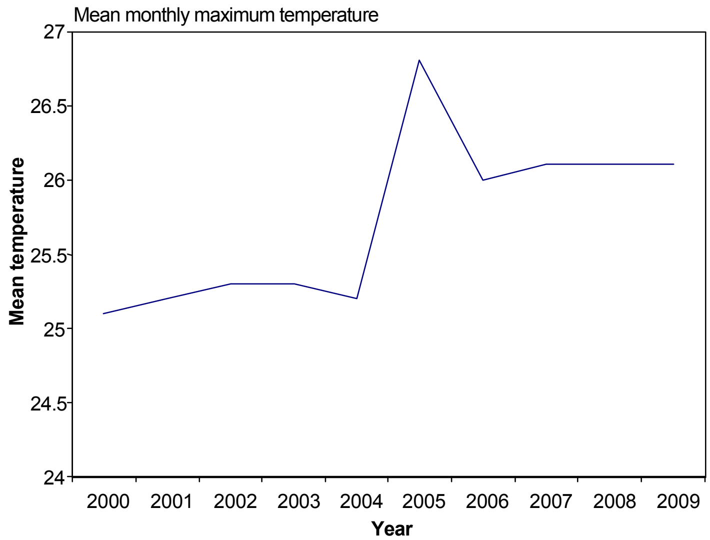

Fig. 4: Mean maximum temperature for Chichiri

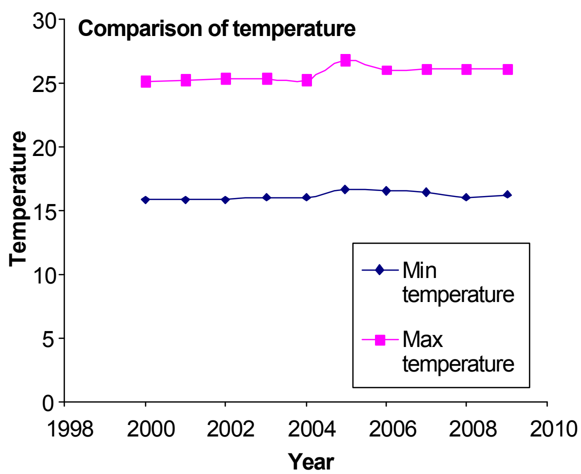

Fig. 5: Comparison of mean yearly minimum and maximum temperature

Figure 4 shows that the mean maximum temperature has been increasing and this is clearly shown between 2004 and 2005 as stated by literature. The graph also shows that though there was a drop in temperature between 2005 and 2006, the trend changed between 2006 - 2009, when it has almost remained constant. The mean maximum temperature data over Chichiri shows that there has been an increase of temperature by approximately 1°C during the study period which is higher than the global temperature rise in a decade (0.2°C) as indicated above.

Comparing Mean Yearly Maximum to Minimum Temperatures (2000-2009): The mean yearly maximum temperature was also compared to the mean yearly minimum temperature over the nine year period (Figure 5).

In this scenario for example the data for 2000 mean monthly minimum temperature was compared to the data for 2000 mean monthly maximum temperature. It was found that there were significant differences ($p < 0.05$) for all the years. This shows that there is a very huge difference between the minimum and maximum temperatures.

CONCLUSIONS

The study generally found that there are no statistically significant temperature differences at Chichiri for the ten year (2000 - 2009) period except comparison of minimum and maximum temperatures. However it can be concluded that temperatures over Chichiri are increasing which may be indicative of variation and sequential warming as shown by graphical presentation of the data.

Recommendations: It is recommended that further data analysis should be done over a very long period of time so that conclusive results can be obtained. It is also recommended that solar radiation measurements and carbon dioxide concentration should be measured at Chichiri so that the data can compliment the temperature data. The data from Chichiri should also be compared with other areas so that conclusions on global warming can be drawn for Malawi.

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