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Research Article

CHANGING TRENDS OF TEMPERATURE IN BHUBANESWAR: A CITY IN EASTERN INDIA

***Binodini Majhi[1] and Krishna Chandra Rath[2]**
[1]Department of Applied Geography,Ravenshaw University, Cuttack, Odisha
[2]P.G Department of Geography,Utkal University, Bhubaneswar, Odisha
**Author for Correspondence*: *binodini2007@gmail.com*

ABSTRACT

One of the most influencing factors of climate is temperature. Global warming is a consequence of temperature rise. The trend analysis of temperature has key role in urban areas since the urban areas are emerging as 'Heat Island'. The cities are recorded higher temperature than its rural surroundings. In this paper, an attempt is made to analyze the climate change in Bhubaneswar city with special emphasis on temperature trends. The study is based on the analysis of time series data obtained from Indian Metrological Department (IMD), Pune for 46 years *i.e.,* from 1970 - 2015. The findings of the study shows that temperatures remain most stable in the month of October and August where as it remain least stable in the month of December, January and November in the study period. The study also reveals that mean of monthly maximum temperature in Bhubaneswar city in the study period has increased at a faster rate than the average temperature and minimum temperature.

Keywords: *Urbanization, Climate Change, Temperature Change, Trend Analysis, Bhubaneswar*

INTRODUCTION

Urban centres all over the world are growing at an unprecedented rate. Today, nearly half of the world population lives in urban areas. Urbanization and industrialization is one of the major drivers of economic growth, but this trend is also associated many environmental issues and concerns. Urban centers generally have a climate which is different from the rural surroundings. The climate of urban areas is metamorphosed from its rural counterpart due to densely built-up area, paved surface, high rise buildings, vehicular traffic etc. Spatial growth becoming more vulnerable to weather related anomalies. One such problem is temperature variability and warming tendency, which is more produced in urban areas than its surroundings. The study of urban temperature trend is significant since global warming is a contemporary issue in climate change which is drawing attention of researchers, scientists, planners etc. Among climatic parameters, temperature is playing a major role in indicating climate change of urban areas. Climate change is increasingly accepted as a major issue facing human societies in the 21st century. Climate change is one of the most important global environmental challenges facing humanity with implications for food production, natural ecosystems, freshwater supply, health, etc.

Climate Change

Intergovernmental Panel on Climate Change (IPCC) defines "climate change" as - a change in the state of the climate that can be identified by changes in the mean or the variability of its properties, and that persists for an extended period, typically decades or longer. Whereas the United Nations Framework Convention on Climate Change (UNFCC) defines climate change as 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'.

New government figures for the global climate shows that 2010 was the wettest year in the historical record and it tied 2005 as the hottest year since record-keeping began in 1880. Two agencies, National Aeronautics Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA), reported on January 2012 that the global average surface temperature for 2010 had tied the record set in 2005. The phenomenon of climate change is more visible at regional scale.

According to Intergovernmental Panel on Climate Change (IPCC), 2007 report, the surface temperature of the earth is risen by $0.6 \pm 0.2\ ^0$C over the 20th century. Also in the last 50 years, the rise in temperature has been about 0.13 ± 0.07^0C per decade. As the warming depends on emissions of GHGs in the atmosphere, the IPCC has projected a warming of about 0.2^0C per decade. Further, surface air temperature could rise between 1.1^0C to 6.4^0C over 21th century.

In India, the climate change is expected to adversely cause changes in precipitation, temperature, monsoon timing and extreme events (Fulekar and Kale 2010). India, being a tropical region, is more susceptible to extreme events such as cyclones and floods. Such hazards are likely to increase in the future, as predicted by the IPCC fifth assessment report (IPCC,2013).In many Indian cities temperatures have rised over the years. Kumar and Hingane (1988) for instance, have noted a marked rise in temperatures in the three Indian cities of Kolkata,Mumbai and Bangalore; while Ramachandra and Kumar (2010) observed a temperature rise of 2^0C in Bangalore city due to an urban heat island effect. In 2005, Mumbai, one of India's most populated cities, was completely shut down due to extreme rainfall and flooding, with flood waters rising up to a 0.5 –1.5 m level in low-lying areas, causing severe economic losses and damage to infrastructure.

In relation to the foregoing discussion the present study focuses on Bhubaneswar-the state capital of Odisha. Over the years Bhubaneswar witnessed rapid urban development and land transformation due to demographic, spatial and economic growth. Today, with rapid phase of urbanization there is an increasing pressure on land. Bhubaneswar has emerged as an important hub for business and educational destination. Inadvertently, this situation is culminated into alarming growth in built up area, loss of agriculture land, vegetative cover along with increasing levels of air pollution, suspended particulate matter and emission of greenhouse gases. Climate change and global warming arising from anthropogenic driven emission of greenhouse gases and land use and land cover changes is one of the contemporary issues discussed and debated at various national and international forums. Among climatic variables, temperature plays key role in urban areas since urban areas emerging as 'Heat Island'. The study attempts to analyze long-term temporal variations in temperature over Bhubaneswar city in Odisha state in eastern India.

Objectives

The main objective of this paper is to analyze the variability and trend in temperature of Bhubaneswar city from1970-2015.

MATERIALS AND METHODS

This paper attempts to study temperature variability of Bhubaneswar city by analyzing the time series data. The temperature data pertains to a long term period extending from 1970 to 2015 has been collected for Bhubaneswar city from Indian Meteorological Department (IMD), Pune. The monthly and yearly averages were calculated from the daily readings which are analyzed. For better understanding of observed trends in temperature variability, mean values of annual temperature, maximum temperature and minimum temperature are computed. Linear regression method is used to analyze the trend and nature of annual minimum, annual maximum and annual average temperature as well for identifying variation in month wise temperature for 46 years.

Trend is defined as the general movement of a series over an extended period of time or it is the long term change in the dependent variable over a long period of time (Webber and Hawkins, 1980).Trend is determined by the relationship between the two variables as temperature and time. The statistical method such as regression analysis and coefficient of determination (R^2) are used for the significance of trend of temperature. The trend were using slope of the regression line. The mean, standard deviation (SD) and coefficient of variation (CV) of temperatures have been calculated for analysis.

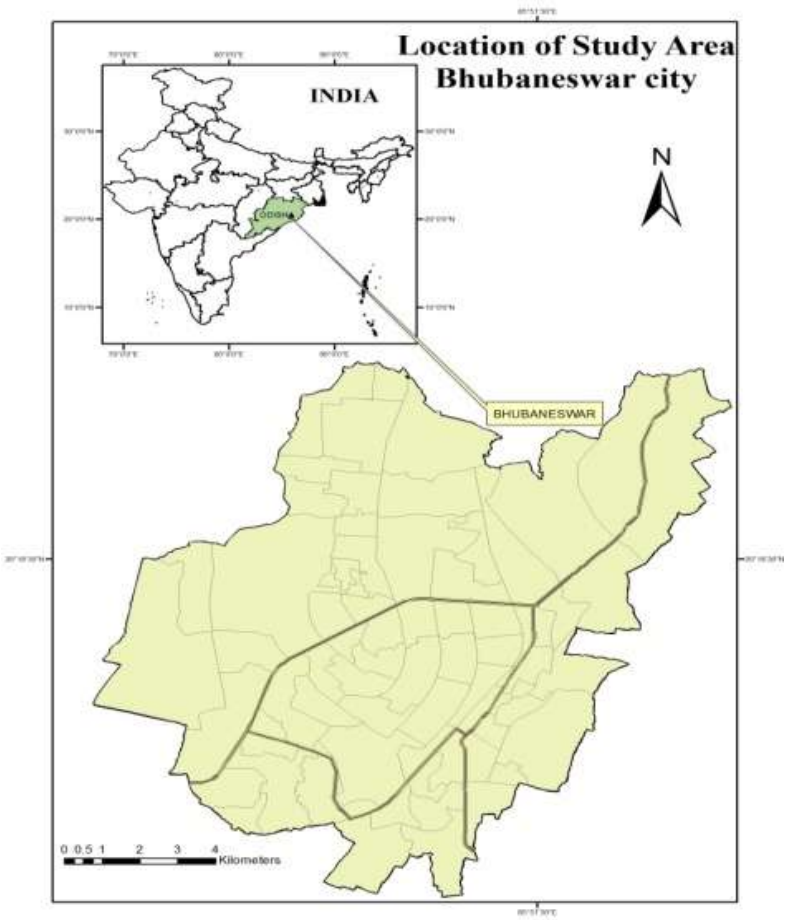


Figure1: Location of Study Area

Study Area The capital city of Odisha- Bhubaneswar is located between $20^0$25'N latitudes and $85^0$55'E longitude on the western fringe of coastal plain across the main axis of Eastern Ghats in Khurda district of Odisha in India. Geographically, the city forms part of the mid-coastal plain of Odisha with an average elevation of 45 meters above the mean sea level. More interestingly, the city is centrally located between the two metropolises *i.e.,* Kolkata and Chennai being connected by East coast Railway and National Highway No.16. In 1951 the total population of Bhubaneswar was only 16,512 and increased to 648032 in 2001 and 837737 in 2011.

RESULT AND DISCUSSION

Temperature Change in Bhubaneswar City (1970-2015)

The statistical summary of mean temperature for all months is represented in Table-1. From the table it is clearly depicted and analysis of standard deviation value indicate that there was a high deviation of temperature from the mean value in the month of June(1.02) It means only in few years temperature found close to mean value. Similar conditions are observed for month of November (1.013) and December (1.011). Whereas opposite to that a very low deviation found for the month of October (0.52) and August (0.55) over the last 46 years (1970-2015) in Bhubaneswar city.

The coefficient of Variation for mean Annual Average temperature for Bhubaneswar is highest in the month of December (4.61%) which is followed by January (4.13%) and November (4.05%) where as it is lowest in the month of October (1.88%) and August (1.92%). From the analysis it can be concluded that temperature remained most stable in the month of October and August where as it remained least stable in the month of December, January and November in the study period (1970-2015).

Table 1: Statistical Summary of Monthly Average Temperature (1970-2015)

Months	Mean	Standard Deviation	Coefficient of Variation(C.V)%
Jan	22.26	0.92	4.13
Feb	25.27	0.89	3.52
Mar	28.98	0.88	3.03
April	31.20	0.96	3.07
May	31.98	0.93	2.90
June	30.79	1.02	3.31
July	28.88	0.66	2.31
August	38.57	0.55	1.92
September	28.67	0.68	2.37
October	27.58	0.52	1.88
November	24.96	1.013	4.05
December	21.91	1.011	4.61

Source: Calculated by authours based on IMD,Pune data.

Trends of Monthly Temperature (1970-2015)

The trends of monthly mean average temperature over different years were obtained using Linear Regression best fit Lines. The linear regression trends with their linear regression equations and Coefficient of determination (R^2) for all the months from January to December are represented in Fig-1 and summariesd in Table-2. It is evident from the figures that monthly mean temperature have positively increased for all months. The highest increase in temperature occurred in March at the rate of (0.032^0C) annually and has increased by 1.472^0C in the last 46 years (1970-2015). Similarly the month of April, May, June and August recorded an increase in temperature which is more than 1^0C in the same period. Whereas the lowest increase in temperature is observed for October month at the rate of (0.006^0C) and has increased by 0.276^0C and followed by July month at the rate of (0.008^0C) and increased by 0.368^0C in that period.

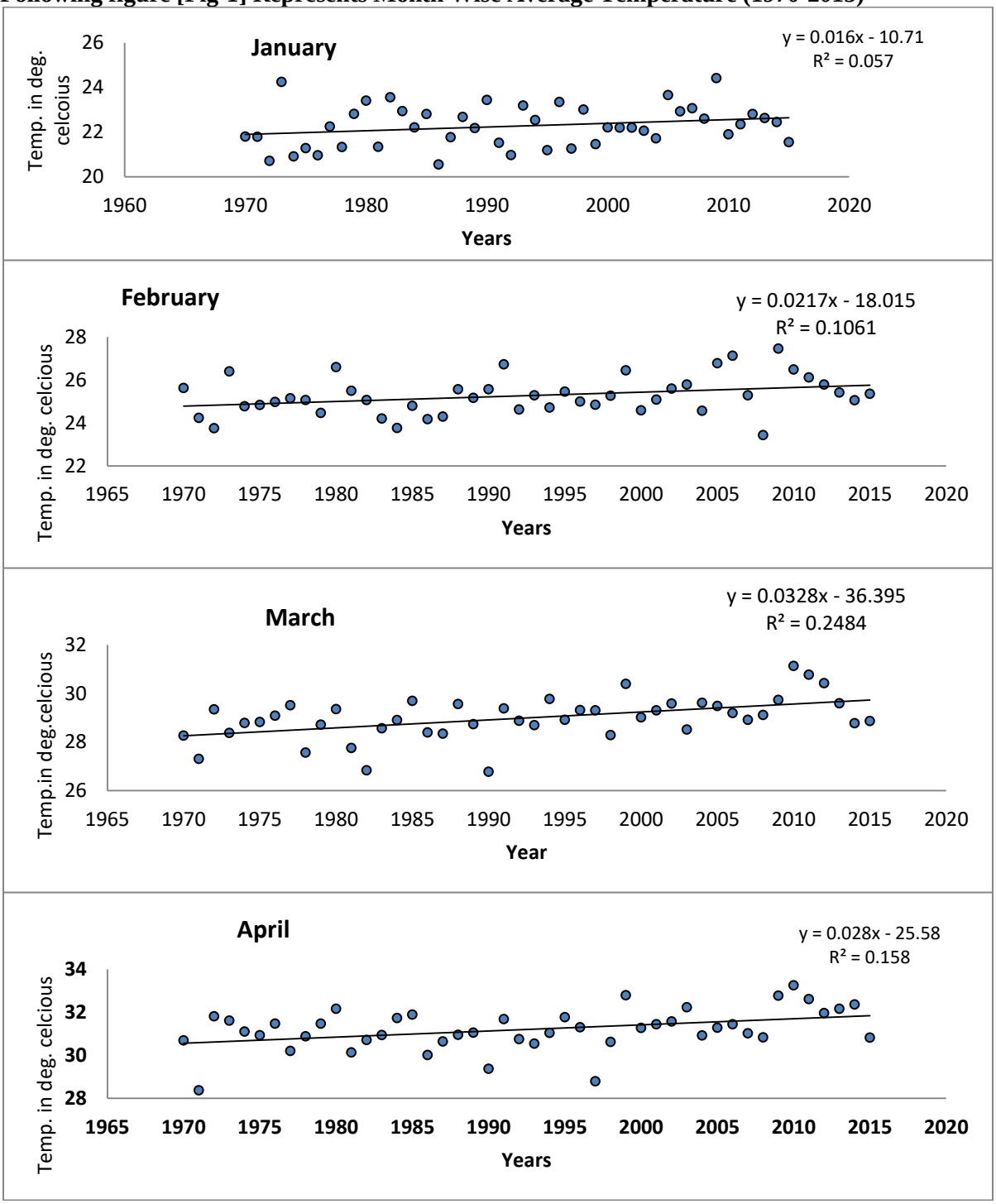
As the Coefficient of Correlation (R^2) value shows how close the data to the fitted regression line. The R^2 value shows good correlation but not significant in any cases throughout the data set because in the table (Table-2) all the R^2 values are less than (0.5), which are insignificant.

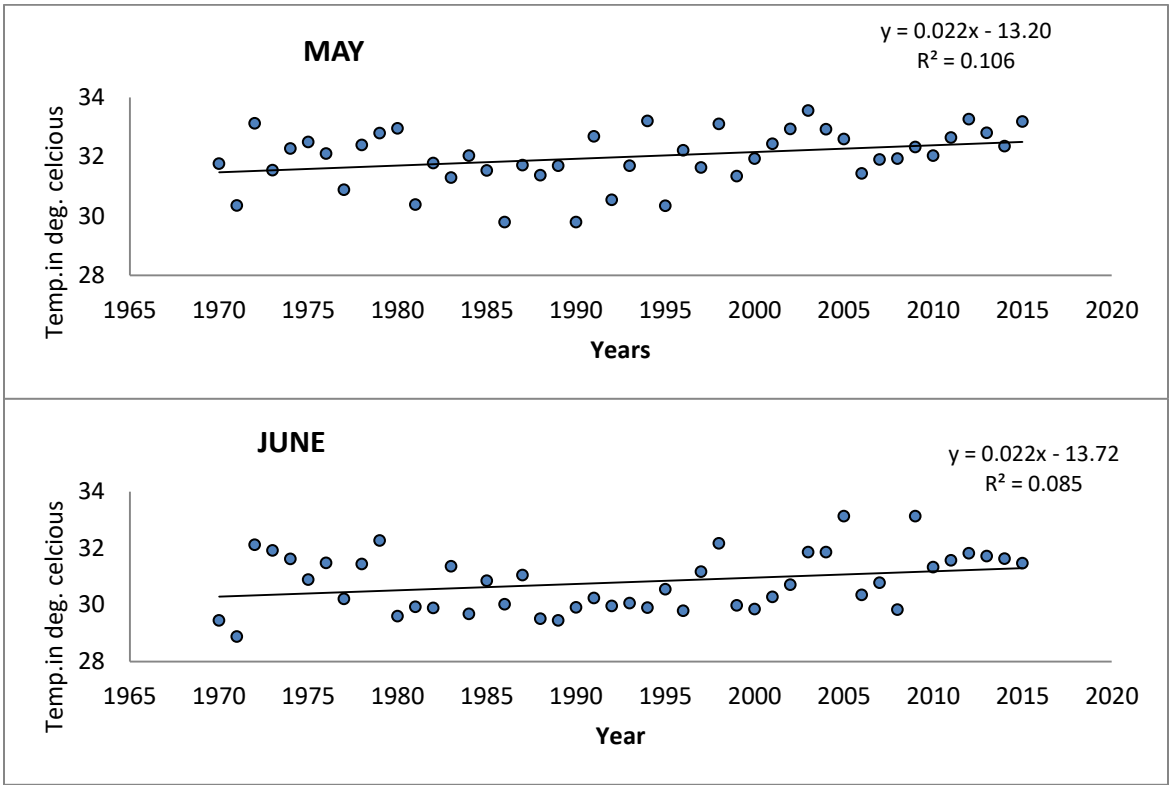
Table-2: Linear regression equations of monthly mean temperatures for all months (1970-2015)

Months	**Regression Line**	**R^2**
Jan	Y=0.016x -10.71	0.057
Feb	Y=0.021x -18.01	0.106
Mar	Y=0.032x-36.39	0.248
April	Y=0.028x-25.58	0.158
May	Y=0.022x-13.20	0.106
June	Y=0.022x-13.72	0.085
July	Y=0.008x+12.81	0.026
August	Y=0.023x-18.06	0.322
September	Y=0.011x +6.550	0.047
October	Y=0.006x +14.69	0.027
November	Y=0.020x +15.12	0.071
December	Y=0.021x -21.33	0.083

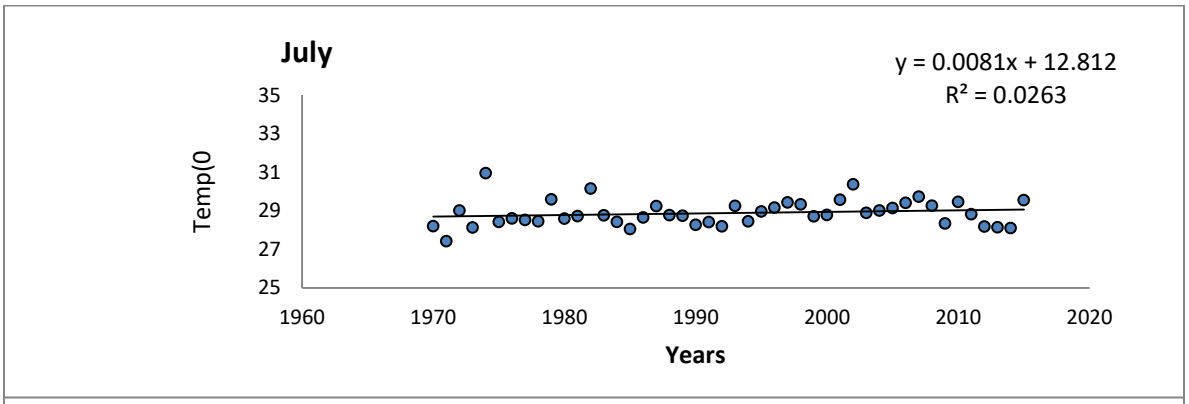
Source: Calculated by Authors

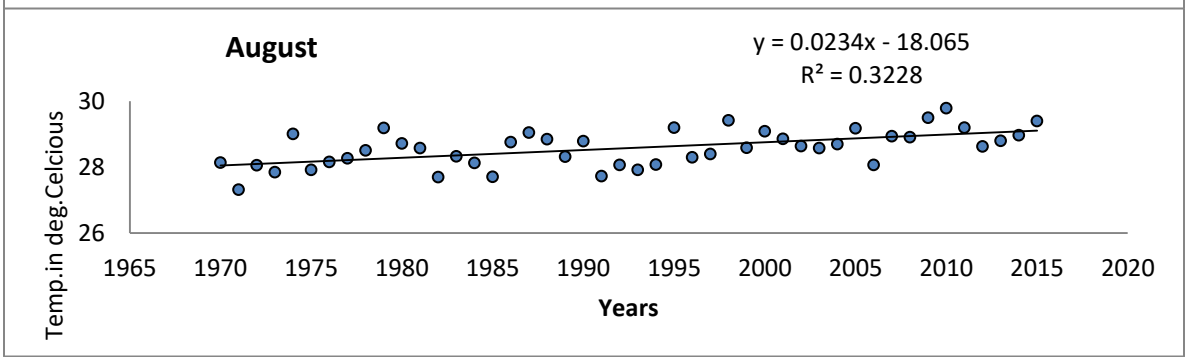
Following figure [Fig-1] Represents Month Wise Average Temperature (1970-2015)

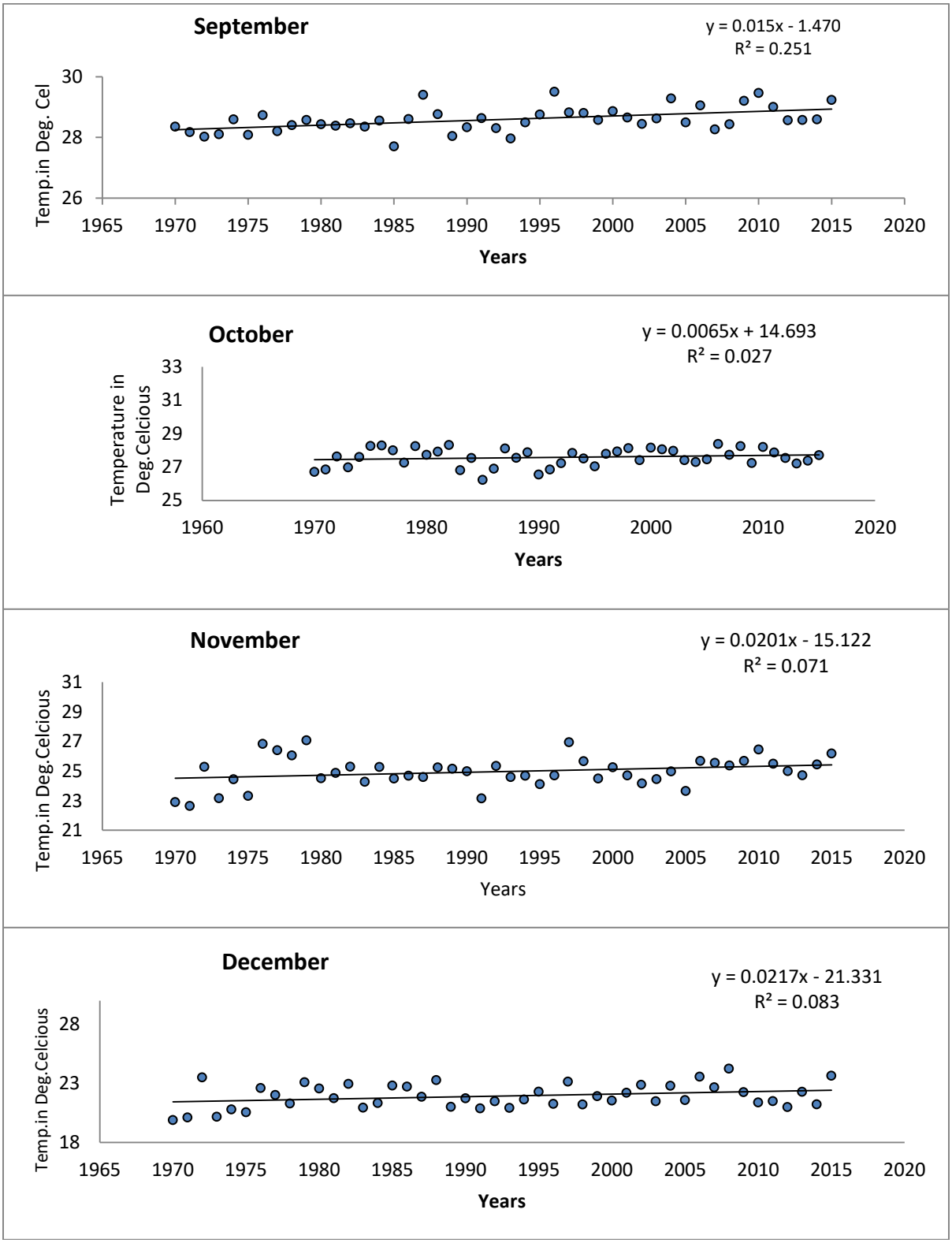



MAY
y = 0.022x - 13.20
R² = 0.106
Temp.in deg. celcious
34
32
30
28
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Years

JUNE
y = 0.022x - 13.72
R² = 0.085
Temp.in deg. celcious
34
32
30
28
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


July
y = 0.0081x + 12.812
R² = 0.0263
Templ0
35
33
31
29
27
25
1960
1970
1980
1990
2000
2010
2020
Years


August
y = 0.0234x - 18.065
R² = 0.3228
Temp.in deg.Celcious
30
28
26
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Years


September
y = 0.015x - 1.470
R² = 0.251
Temp.in Deg. Cel
30
28
26
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Years
October
y = 0.0065x + 14.693
R² = 0.027
Temperature in Deg.Celcious
33
31
29
27
25
1960
1970
1980
1990
2000
2010
2020
Years
November
y = 0.0201x - 15.122
R² = 0.071
Temp.in Deg.Celcious
31
29
27
25
23
21
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Years
December
y = 0.0217x - 21.331
R² = 0.083
Temp.in Deg.Celcious
28
23
18
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Years

Trends of Annual Mean of Monthly Temperature

Trend analysis of annual mean of Monthly average temperature, mean of monthly Maximum temperature and mean of monthly minimum temperature and its R^2 values for last 46 years (1970-2015) are depicted from Fig-2,Fig-3 and Fig-4 and its Statistical summary is presented in Table-3. It is clearly visible from Fig-2 that the annual mean of monthly average temperature shows an increasing trend having an annual increase of 0.025^0C per year and has increased by

Table 3: Statistical Summary of Annual Temperature of Bhubaneswar City, 1970-2015

Temperature	Mean	Standard Dev.	C.V (%)	Regression Line	Coefficient of Variation(R^2)
Average Temperature	27.83	1.61275	5.794	Y=0.025x-23.02	0.464
Maximum Temperature	32.88	0.585633	1.781022	Y=0.030x-28.44	0.497
Minimum Temperature	22.38	0.487477	2.17	Y=0.020x-17.59	0.305

Source: Calculated by Authors

1.15^0C. Similarly Fig-2 shows the trend of monthly maximum temperature depicting an increasing trend having an annual increase of 0.030^0C per year and which has increased by 1.38^0C.The monthly minimum temperature also shows an increasing trends with an annual increase of 0.020^0C and which has increase by 0.92^0C in the said period.

From the analysis it is clear that mean of monthly maximum temperature in Bhubaneswar city in the study period has increased at a faster rate than the average temperature and minimum temperature. It is also revealed from table-3 that the coefficient of variation is found to be high in case of annual average temperature which is 5.79 percent and lowest in maximum temperature which is 1.78 percent.

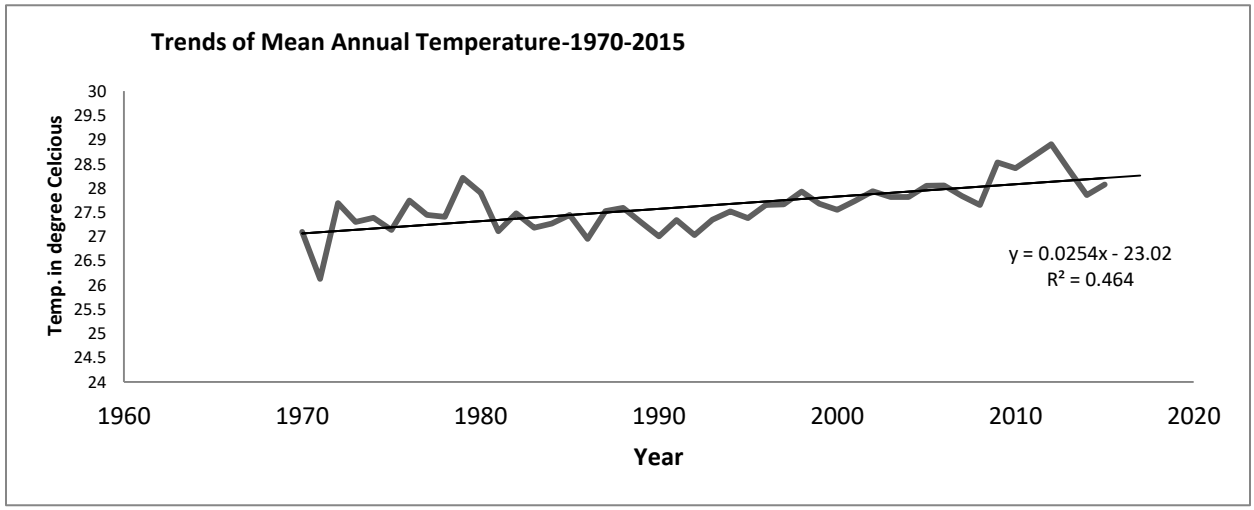
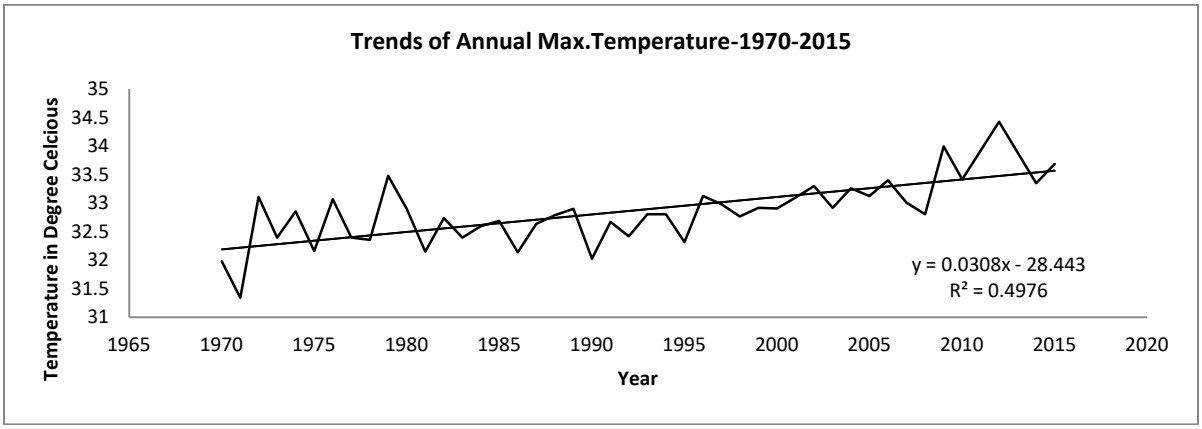
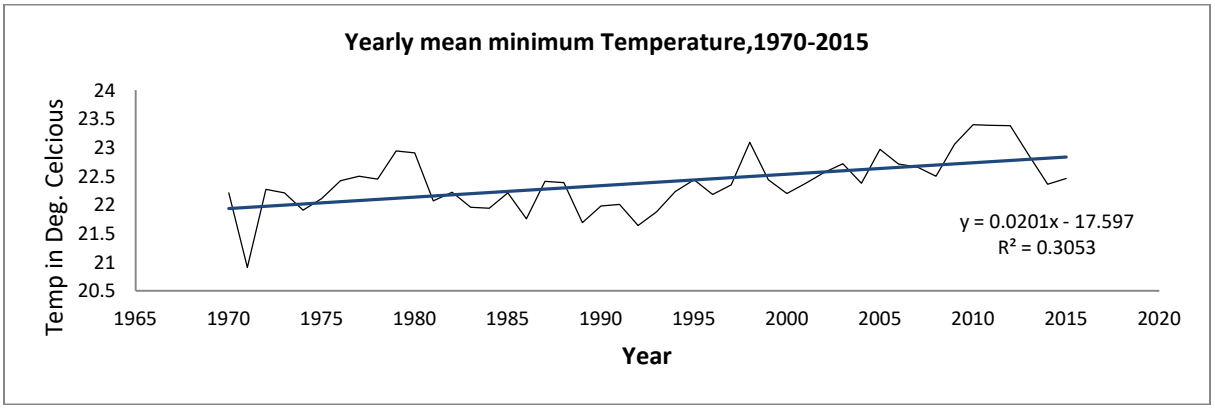


Fig.-2 Trends of Annual Temperature (Average, Maximum and Minimum), 1970-2015





CONCLUSION

From the analysis it is clear that mean of monthly maximum temperature in Bhubaneswar city in the study period has increased at a faster rate than the average temperature and minimum temperature. Monthly maximum temperature depicting an increasing trend having an annual increase of 0.030^0C per year and which has increased by 1.38^0C.The monthly minimum temperature also shows increasing trends with an annual increase of 0.020^0C and which has increase by 0.92^0C in the period. It is also revealed that the coefficient of variation is found to be high in case of annual average temperature which is 5.79 percent and lowest in maximum temperature which is 1.78 percent. It is evident from the analysis that monthly mean temperature have positively increased for all months. The highest increase in temperature occurred in March at the rate of (0.032^0C) annually and has increased by 1.472^0C in the last 46 years. Whereas the lowest increase in temperature is observed for October month at the rate of (0.006^0C) and has increased by 0.276^0C and followed by July month at the rate of (0.008^0C) and increased by 0.368^0C in that period.

Urbanization, climate change and cities are intricately related as change in any one will affect the others. Cities contribute to climate change via burning of fossil fuels, generating urban heat islands, deforestation and other activities, and are subject to climate change and its ill effects. Cities, however, can help to control climate change via reducing greenhouse gases, renewable energy, green designs, sustainable communities, eco-cities and other measures. There are countless innovative means of addressing sustainability issues in cities. Cities must control their ecological, water and carbon footprints, especially when climate change is now impacting the entire planet. As a solution or mitigation for the aforesaid problem is increasing urban green space in cities which can provide mitigation of urban heat island effects, microclimate regulation, and carbon sequestration. Therefore integrating vegetation, green spaces and permeable surfaces into our cities and towns, communities can adapt urban environments to minimize local temperatures, now and into the future. Increasing urban green cover provides effective and relatively

low cost resilience to heat impacts while improving community amenity and providing multiple benefits. So, increasing green cover is not only done by government but citizens' awareness and involvement is very much important in this context.

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