Monthly and Annual Variation of Temperature in Urban Habitats of the Bengaluru Region, India

Somashekara Rajashekara

Centre for Applied Genetics, Department of Studies in Zoology, Bangalore University, Jnana Bharathi Campus, Off Mysuru Road, Bengaluru 560 056, Karnataka, INDIA.
E-Mail: rajachandra3908@yahoo.co.in; Tel: +91-99862 62344; +91-080-22961554; http://orcid.org/0000-0002-2512-6617

ABSTRACT An examination has been carried out to govern the daily, monthly and annual temperature variations in urban habitats of the Bengaluru region, India for the period 2007-2015. Spatial pattern of temperature showed the increase in monthly and annual variation in the Bengaluru region. Mean maximum temperature was found to be the highest in the month of April (32.65-35.34 °C), whereas mean minimum temperature was found to be the lowest in the month of January (15.27-17.11 °C). A linear relationship between the minimum (Y) and maximum temperatures (X) was established in the form of equation as $y = 0.6581x + 0.0674$; $R^2 = 0.2625$. The findings of the study are reliable with the results obtained by other parts of Indian subcontinent and the remaining parts of the world. Thus, climate change will rigorously influence the Indian monsoon in terms of generating more tolerances which may have impact on the biodiversity of flora and fauna.

KEYWORDS: Climate; Global warming; Temperature; Urban habitats.
Received 25 April 2020 **Revised** 9 May 2020 **Accepted** 26 May 2020 **Online** 12 July 2020

Original Article

INTRODUCTION

Temperature is a physical property of matter which quantitatively expresses hot and cold. It is the indicator of thermal energy present in all matter and is measured with a thermometer. The degree Celsius (°C) scale is commonly used for measurements of temperature in most of the world. Temperature is the main factor that determines the geographic distribution of organisms, both in the context of latitudinal and altitudinal gradients of thermal niches occupation (Hochachka & Somero 2002).

The variation in different meteorological parameters of a city has been a central point of research in urban climatology. The temperature of a city may vary spatially and temporally with different trends and periodicities (Mohapatra, 2002). The degree of impact of urbanization on weather parameters at Bengaluru city has also been studied by finding out the trend in the time series of difference of observations for a given parameter (Mohapatra, 2002).

The study of temperature is very important in the present scenario, since global temperatures are increasing in the one hand and the sea level is rising on the other hand. Urban centers have the unique characteristics that they attract populations from the rural areas due to the availability of employment, education and medical care, therefore increases in the population (Mahalingam *et al*., 2013). This increasing population converts open spaces and vegetation into built-up areas or urban concrete jungles. The effect of urbanization on climate has been studied in detailed account by many studies (Chandler, 1965; Bornstin, 1968; Bahl & Padmanabhamurthy, 1977; Krishnanand & Maske, 1981; Padmanabhamurty & Bahl, 1982; Mohapatra & Vijayraghvan, 1997; Mohapatra, 2002).

Local Climatic Zones (LCZs) are climate-based classification of the city fabric. It is defined as regions of uniform surface cover, structure, material, and human activity that span from hundreds of meters to several kilometers in horizontal scale (Stewart & Oke, 2012; Bechtel *et al*., 2015). Climate is changing at both the global (Dore, 2005) and the regional scales due to global warming (Kayano & Sansigolo, 2008) and enhanced greenhouse effect.

Keeping the above views in attention, an effort has been made to investigate the distribution of temperatures of both maximum and minimum which will be convenient for an essential survival of human beings and its existence in urban environment of the Bengaluru region, India.

METHODOLOGY

Study area

Bengaluru city is the fifth largest metropolitan city in India. This city is also known as the "Garden City" - means city full of parks (Udhyaana Nagara) since of its many beautiful parks, lakes, gardens and natural vegetation; and as well known as the "Silicon City" because this city is full of IT sectors, BT sectors and many small and big industrial hubs. Bengaluru is situated in the South Deccan plateau of the Peninsular region of India (located at 12°59′ North latitude and 77°57′ East longitude with an altitude of 920 m above mean sea level), occupying an area of 2,191 km2 of metropolitan area inhabiting 9 million population (24) (Figure 1). This city is composed of urban landscapes from dry deciduous forests scrub with open to closed canopy evergreen forests along the streams, urban to semi-urban regions. Three main seasons - winter (December to February), summer (March to May) and monsoon (June to November) are found in this region. An average maximum and minimum temperature are 36º and 14º C respectively. Generally, the Bengaluru region has humidity range is 35–80%. The flora plays a most important role with various kinds of extensively distributed trees in various urban habitats of the Bengaluru region. The flora with numerous species comprising bushes, shrubs and trees has generated an effective local unified and synergetic relationship with associated fauna of this region including mammals, birds, reptiles, amphibians and several species of invertebrate fauna.

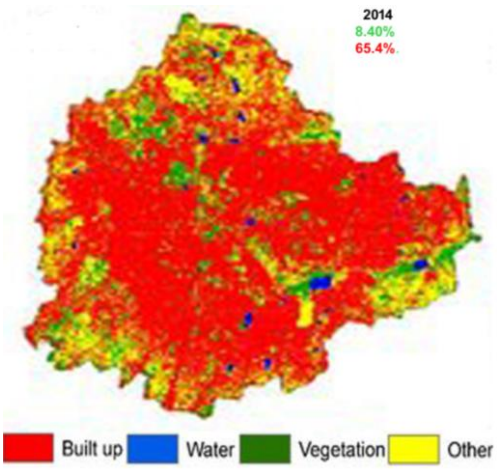


Figure 1. Map showing the land use and land cover patterns along the urban habitats of the Bengaluru region (Courtesy: Deccan Herald 8 February 2020).

Data analysis

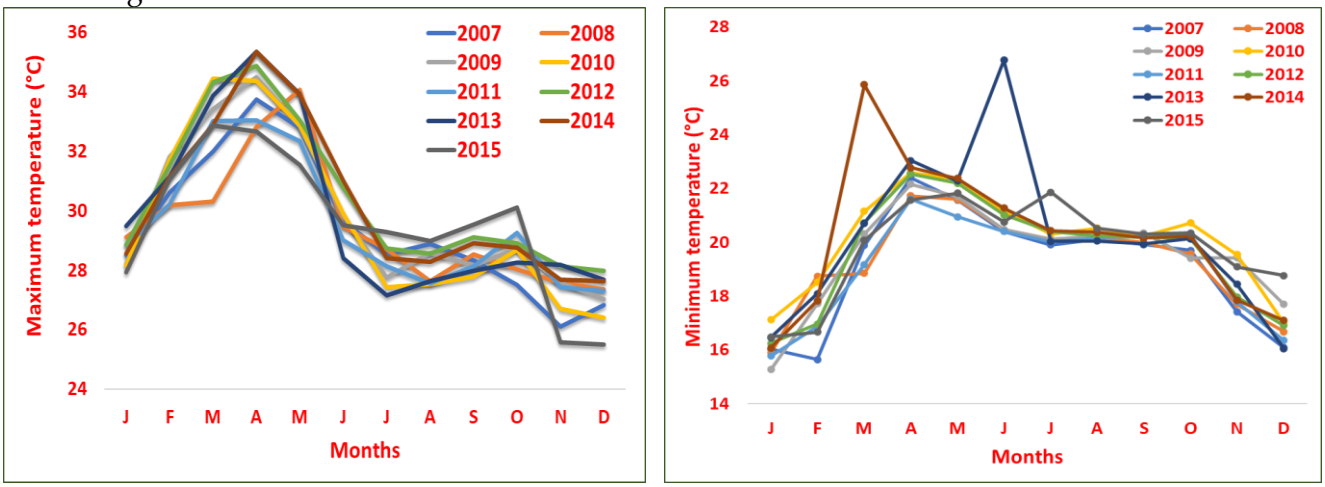
Data on the daily temperature for nine years (2007 to 2015) were collected from the mass communication media, mainly from the Deccan Herald (English) newspaper which was proudly announced by the authorities of the Indian Meteorological Department (IMD), Bengaluru. This daily temperature was averaged into monthly and annual temperature for further analysis. The Pearson's correlation analysis between the maximum and minimum temperatures was done by utilizing the annual data in the form of graph. Finally, data on the maximum and minimum temperatures (°C) in different years were represented in the form of mean ± standard deviation.

RESULT AND DISCUSSION

Maximum, Minimum and Annual temperatures

The mean maximum temperature was found in almost highest in the month of April (32.65-35.34 °C) during the period of years 2007-2015 (Figure 2a). However, the variations in the maximum temperature are negligible. The maximum temperatures of study region appear as a bell-shaped distribution and follows the same polynomial patterns in all years. It confirms that the April month showed highest maximum temperature in the summer season (March to May) and was also throughout the year. The mean maximum temperature of Bengaluru region shows the rising trend for all the months. It also shows the rising trend for all the seasons and year as a whole. Hence it may be concluded that the Bengaluru region is becoming warmer in terms of maximum temperature being significantly so during the period and furthermore years also.

The mean minimum temperature was found in almost lowest in the month of January (15.27-17.11 °C) during the period of years 2007-2015 (Figure 2b). Again, the variations in the minimum temperature are negligible. Here also, the minimum temperatures of study region appear as a bell-shaped distribution and follows the same polynomial patterns in all years. It confirms that the January month showed lowest minimum temperature in the winter season (December to February) and was also throughout the year. The difference of annual mean minimum temperatures shows the decreasing trend.



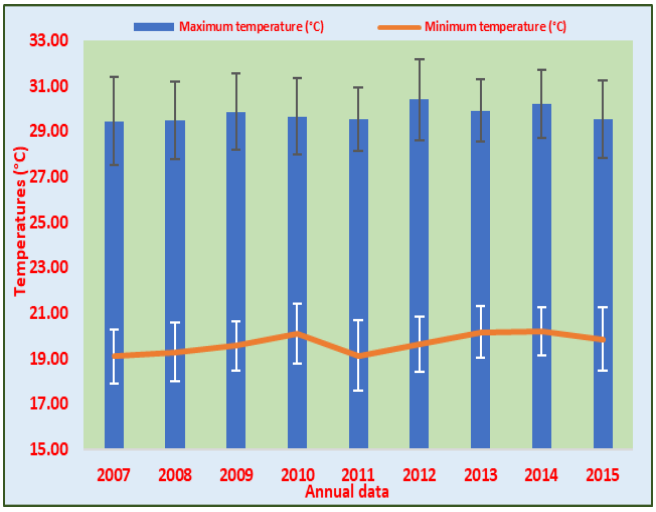
(a) Mean monthly maximum temperature (°C) (b) Mean monthly minimum temperature (°C)

Figure 2. Mean monthly maximum and minimum temperature for the period of 2007-2015

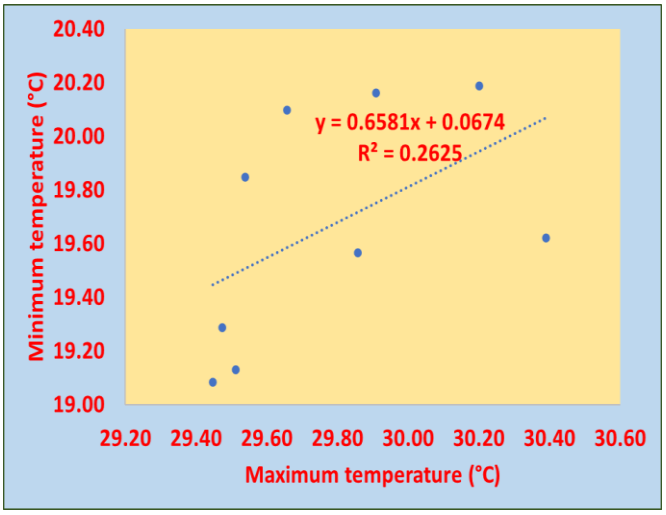
The mean yearly maximum temperature was ranged from 29.45 ± 1.96 °C to 30.39 ± 1.77 °C during the period of years 2007-2015, while the mean yearly minimum temperature was ranged from 19.08 ± 1.21 °C to 20.19 ± 1.06 °C during the period of years 2007-2015 (Figure 3a). Furthermore, this diurnal temperature ranges (DTR) including maximum and minimum temperatures are more useful in the study region. The range of diurnal temperature variation is very important for the best and net photosynthesis which in turn helpful for the food manufacturing process of plants and trees.

Relationship between maximum and minimum temperatures

A linear relationship between the maximum and minimum temperatures of the Bengaluru region was existed when subjected to the Pearson's correlation coefficient analysis. The regression equation such as $y = 0.6581x + 0.0674$; $R^2 = 0.2625$ was developed between the variables minimum (Y) and maximum temperatures (X), in which 26.25 % of the variables will follow this positive relationship (Figure 3b).



(a) Mean annual temperatures (maximum and minimum in °C) for the period of 2007-2015.



(b) Pearson's Correlation analysis between the mean annual temperatures of maximum and minimum (°C).

Figure 3. Mean annual temperature and the corresponding Pearson's Correlation analysis

A number of studies have been considered for the recent trends of temperature records in the world. Alexander *et al*. (2006) found that widespread significant changes in temperature extremes associated with warming with a positive shift in the distribution of daily minimum temperature throughout the globe. The difference between maximum and minimum temperatures is decreasing, indicating that the minimum temperature is increasing faster than the maximum temperature. This is similar to that of study reported in Sri Lanka by Jayawardena *et al*. (2018).

The change in maximum and minimum temperatures pattern may be attributed to the change in annual and seasonal variation of rainfall patterns in the Bengaluru region (Rajashekara, 2019). Vegetation and the urban setting were also observed as an important factor affecting well-being (Kotharkar *et al*., 2019). Several climatic, geographic, built-up and anthropogenic factors form an additional contributes to the development of positive temperature variance in urban areas (Oke, 1982).

Organisms can be classified into three categories based on the ability to occupy thermal niches. They are (i) psychrophiles, which live and reproduce at temperatures below +15 °C, some of which maintain metabolic activities at temperatures up to -20 °C; (ii) mesophiles, which live comfortably between +15 and +40 °C; and (iii) thermophiles, which have their best performance from +50 to +60 °C (moderate thermophiles). The term hyperthermophiles (or extreme thermophiles) has been used for organisms with optimal growth rates above +80 °C (Counts *et al*., 2017).

Temperature is one of the main environmental factors that affect plant metabolism (Nievola *et al*., 2017). The importance of temperature as a physical factor on the distribution of organisms is a consequence of its direct influence on molecular (RNA, DNA and proteins) or supramolecular (cell membranes, cell organelles and chromosomes) structures, that results from merely a thermodynamic effect. These changes are usually fast; therefore, changes in the ambient temperature can be quickly detected by cell organelles, triggering specific pathways of biochemical and molecular responses in each of these cell compartments and making up an integrated cell response to temperature changes (Ruelland & Zachowski, 2010).

The present study has focused on the aspects to find out the temporal changes of temperature and to compare the spatial extension of temperature in the urban habitats of the Bengaluru region. Bengaluru region is becoming warmer in terms of mean maximum and mean minimum temperatures for all the months and season. The increase in temperatures is significantly may be higher over Bengaluru region than the other metropolitan cities. The result of the first aspect of temporal changes showed that the minimum and maximum temperature of Bengaluru city has increased in the gradual years. The overall study of temporal changes shows that, Bengaluru's temperature has increased similar to the other cities such as Delhi, Mumbai, Kolkatta, Chennai and Hyderabad. The second aspect of the spatial extension of temperature shows that the areal unit of higher temperature has increased while the lower temperatures have decreased in all the cities of India. Bengaluru city had already witnessed high in the areal extension of temperature over period than the other cities. The third aspect seems to realize the temperature variation in different urban habitats shows that built-up and barren lands may be higher temperatures than other rural habitats while vegetation and water bodies have the lowest temperatures, which clearly demonstrates that increasing cultivation of vegetation and protection of water bodies in city area can reduce the surface temperature.

CONCLUSION

This study was concentrated for analyzing the pattern of temperatures in the urban habitats of the Bengaluru region, Karnataka, India. For this persistence, daily maximum and minimum temperatures data of nine years (2007 to 2015) was used to assess the daily, monthly and annual pattern of temperatures. This study also appraised to reveal the relationship between the maximum and minimum temperatures. The classification of local climate zone provides a scientific framework to understand the interaction between the built-up environment and urban climate. This study contributes to the understanding of local climate zones and its potential to evaluate outdoor thermal ease.

It is expected that the climate trend maps and the study will help to describe climate change policy planning in Indian cities along with to understand the regional climate changes in order to understand the broad features of the Asian countries. Thus, climate change will rigorously influence the Indian monsoon in terms of generating more extravagances and this also form impact on the biodiversity of flora and fauna. Given that no city in India has yet framed climate change adaptation strategies, this analysis can help for enhancing the current state of knowledge.

REFERENCES

[1] Alexander, L. V., Zhang, X., Peterson, T. C., Caesar, J., Gleason, B.., Klein Tank, A. M. G., Haylock, M., Collins, D., Trewin, B., Rahimzadeh, F. & Tagipour, A. 2006. Global Observed Changes in Daily Climate Extremes of Temperature and Precipitation. *Journal of Geophysical Research: Atmospheres*, 111(D5).

[2] Bahl, H. D. & Padmanabhamurthy, B. 1977. *Heat island studies at Delhi*. Indian Meterological Department: Pre-Publication Science Report No-0077/6.

[3] Bechtel, B., Alexander, P., Böhner, J., Ching, J., Conrad, O., Feddema, J., Mills, G., See, L. & Stewart, I. 2015. Mapping local climate zones for a worldwide database of the form and function of cities. *ISPRS International Journal of Geo-Information*, 4(1), 199-219.

[4] Bornstin, R. D. 1968. Observations of the urban heat island effect in New York city. *Journal of Applied Meteorology*, 7, 575-582.

[5] Chandler, T. J. 1965. *The climate of London*. Hutchinson and Company Publishers: London University Library, pp 292.

[6] Counts, J. A., Zeldes, B. M., Lee, L. L., Straub, C. T., Adams, M. W. W. & Kelly, R. M. 2017. Physiological, metabolic and biotechnological features of extremely thermophilic microorganisms. *Wiley Interdisciplinary Reviews: Systems Biology and Medicine*, 9(3), e1377. doi:10.1002/wsbm.1377.

[7] Dore, M. H. I. 2005. Climate change and changes in global precipitation patterns: What do we know. *Environment International*, 31(8), 1167-1181.

[8] Hochachka, P. W. & Somero, G. N. 2002. *Biochemical adaptation: mechanism and process in physiological evolution*. New York: Oxford University Press.

[9] Jayawardena, I. M. S. P., Darshika, D. W. T. T. & Herath, H. M. R. C. 2018. Recent Trends in Climate Extreme Indices over Sri Lanka. *American Journal of Climate Change*, 7, 586-599.

[10] Kayano, M. T. & Sansígolo, C. 2008. Interannual to decadal variations of precipitation and daily maximum and daily minimum temperatures in southern Brazil. *Theoretical and Applied Climatology*, 97, 81–90.

[11] Kotharkar, R., Bagade, A. & Agrawal, A. A. 2019. Investigating Local Climate Zones for Outdoor Thermal Comfort Assessment in an Indian City. *Geographica Pannonica*, 23(4), 318–328.

[12] Krishnanand & Maske, S. T. 1981. Mean heat island intensities at Delhi-Assessed from urban climatological data. *Mausam*, 32(3), 269-272.

[13] Mahalingam, B., Ramu & Vinay, M. 2013. A comparative temperature study of south Indian metropolitan cities in India using remote sensing and GIS technique. *International Journal of Engineering Technology and Computer Research*, 2(5), 27-39.

[14] Mohapatra, M. 2002. Recent trends in climate of Bangalore. *Mausam*, 53(4), 425-438.

[15] Mohapatra, M. & Vijayraghavan, G. S. 1997. Interannual variation of Temperature of Bangalore city. *Proceedings of IGBP National Symposium*. Bhubaneswar, India, 40-43.

[16] Nievola, C. C., Carvalho, C. P., Carvalho, V. & Rodrigues, E. 2017. Rapid responses of plants to temperature changes. *Temperature*, 4(4), 371-405.

[17] Oke, T. R. 1982. The energetic basis of the urban heat island. *Quarterly Journal of the Royal Meteorological Society*, 108, 1-24.

[18] Padmanabhamurty, B. & Bahl, H. D. 1982. Some physical features of heat and humidity islands at Delhi. *Mausam*, 33(2), 211-218.

[19] Rajashekara, S. 2019. Annual and Seasonal Variation of Rainfall in Urban Landscapes of the Bengaluru Region, India. *Environment Analysis and Ecological Studies*, 5(3), EAES.000615.2019.

[20] Ruelland, E. & Zachowski, A. 2010. How plants sense temperature. *Environmental and Experimental Botany*, 69(3), 225–232.

[21] Stewart, I. D. & Oke, T. R. 2012. Local Climate Zones for Urban Temperature Studies. *Bulletin of the American Meteorological Society*, 93(12), 1879-1900.