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Comparison of extreme bioclimatic episodes in Kolkata (India) and two neighbouring suburban stations

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Abstract: The objective of the present study is to estimate the duration of extreme thermal bioclimate conditions in and around Kolkata, one of the highly densely populated cities in India. The biometeorological conditions have been calculated by Physiologically Equivalent Temperature (PET) using RayMan model at 0530 h and 1430 h (IST) based on meteorological data for the stations Kolkata (Alipore), Dum Dum and Diamond Harbour for the period January, 2020 to December, 2021. Dum Dum is located to the north of Kolkata and Diamond Harbour is situated to the south of Kolkata. The meteorological data have been retrieved from the station data measured by Indian Meteorological Department (IMD). The atmospheric variables required to calculate the PET index are air temperature, relative humidity, cloud cover and wind speed. A recent study reported that stations outside Kolkata suffer warmer human thermal stress conditions. To account for the prolonged thermal stress periods, PET with greater than 40 ° C is categorized as an episode if it turns up consecutively between 1 to 5 days, 6 to 10 days, 11 to 15 days, 16 to 20 days, 21 to 25 days and 26 to 30 days. The number distribution of days not exceeding 40°C remains same for all the stations. The number of episodes occurring successively for 6-10 days 11-15 days, 16-20 days, 21-25 days is highest in/for Diamond Harbour relative to Kolkata and Dum Dum at 1430 hr. Episodes occurring successively for 26-30 days appears in Kolkata and Dum Dum whereas no episodes appear in Diamond Harbour.

Keywords: PET, Kolkata, Human Thermal Discomfort

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1. Introduction: A recent report by Intergovernmental Panel on Climate Change (IPCC) has described that impact of climate change will lead to more extreme temperatures and more hot days [1, 2]. Even include longer and more intense heat waves. Extreme heat events are days which exceeds local thresholds including single-day events or events of successive days of heat waves. It has now well understood through numerous studies based on several human thermal indices and investigated their past changes [3]. However, quantifying and assessing extreme heat episodes from a human biometeorological point of view have received little attention in West Bengal, which goes against a satisfactory understanding of extreme heat episodes and design of proper adaptive strategies. Therefore, this present research analysis aims to use Physiologically Equivalent Temperature (PET) using RayMan model [4, 5] to quantify biometeorological conditions and investigate the spatial changes of extreme heat episodes in Kolkata and its outskirts during 2020-2021.

2. Study regions: This study has been conducted over three stations of West Bengal (WB), i.e. Alipore (Kolkata), Dum Dum and Diamond Harbour. Kolkata is the capital city of WB. Diamond Harbour is located in South 24-Parganas and Dum Dum is located in North 24-Parganas. The geographical coordinates for each station with their altitudes are listed as follows: Alipore [KOL] (88.32°E, 22.52°N, 6m), Dum Dum [DMM] (88.45°E, 22.63°N, 6m) and Diamond Harbour [DHR] (88.20°E, 22.17°N, 4m). Both Kolkata and Dum Dum lie at an altitude of 6 m above mean sea level. Diamond Harbour at a height of 4 m above mean sea level. The climatology follows a similar pattern in all the three stations. The winter season starts from mid-November and continues till February. January is the coldest month of the year. The period of March to May is the summer season. The southwest monsoon is from June to September. October and the first half of November represent the post monsoon season. July is generally the rainiest month. With the progress of the summer season, evolution of both day and night time temperature increase in rapid pace until May, which is the hottest month, with the mean daily maximum temperature reaches until 32 °C and mean daily minimum temperature at 23 °C. Occasionally, the day temperatures cross 40 °C on some individual days. The monsoon withdraws early in October, and temperature begins to drop.

3. Data and Methodology: Meteorological data were obtained from Indian Meteorological Department (IMD) at 3-hour interval starting from 0530 hr to 2030 hr for all the three stations. The PET was calculated for the years 2020 and 2021 using air temperature, cloud cover, wind speed and relative humidity datasets. Apart from meteorological variables, personal data like clothing, gender and age were also considered. No major changes were not noticed/observed when the personal variables were varied. Thus, personal variables were fixed at 1.75 m (height), standing (position), 75 kg (weight), 35 years old (age) and male (gender). Consequently, PET was calculated for the three stations. The PET values were further used to identify events when it exceeds greater than 40 °C for each station and at each observation time. There are days with PET values not more than 40 °C described as no event days. Days with more than 40 °C is/has/have been classified into six categories namely with (a) with days between 1 to 5 (b) with days between 6 to 10 (c) with days between 11-15 (d) with days between 16 to 20 (e) with days 21 to 25 (f) with days between 26 to 30.

Table 1. PET classification of Kolkata [6] has been used for all the sites in the present study.

Thermal sensation	PET range for Kolkata (°C)
Very cool/Cold	<3.31
Cool	3.31-11.42
Slightly cool	11.42-19.48
Neutral	19.48-27.59
Slightly warm	27.59-35.73
Warm	35.73-43.83
Hot	>43.83

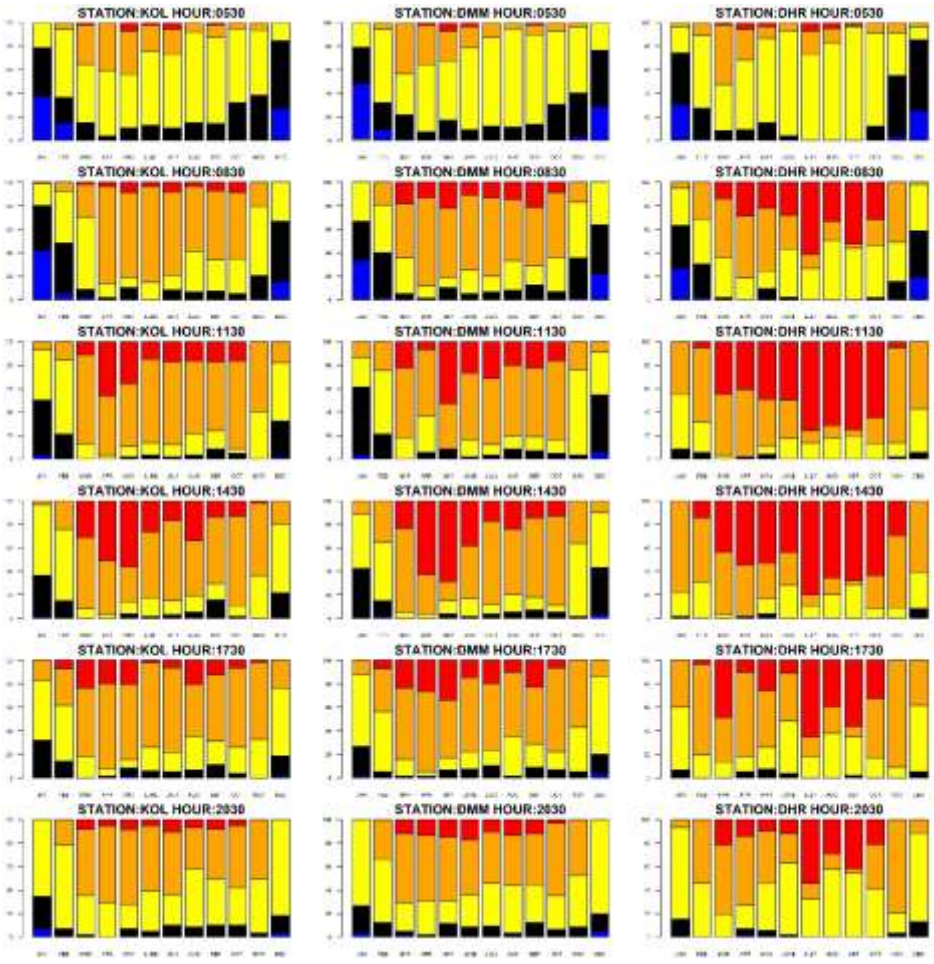

Figure 1. Monthly frequency diagram (in percentages) exhibiting the mean PET for Alipore (Kolkata) [KOL], Dum Dum {DMM], and Diamond Harbour {DHR] from the top at 0530 hr, 0830 hr, 1130 hr, 1430 hr, 1730 hr, 2030 hr during 2020 to 2021.

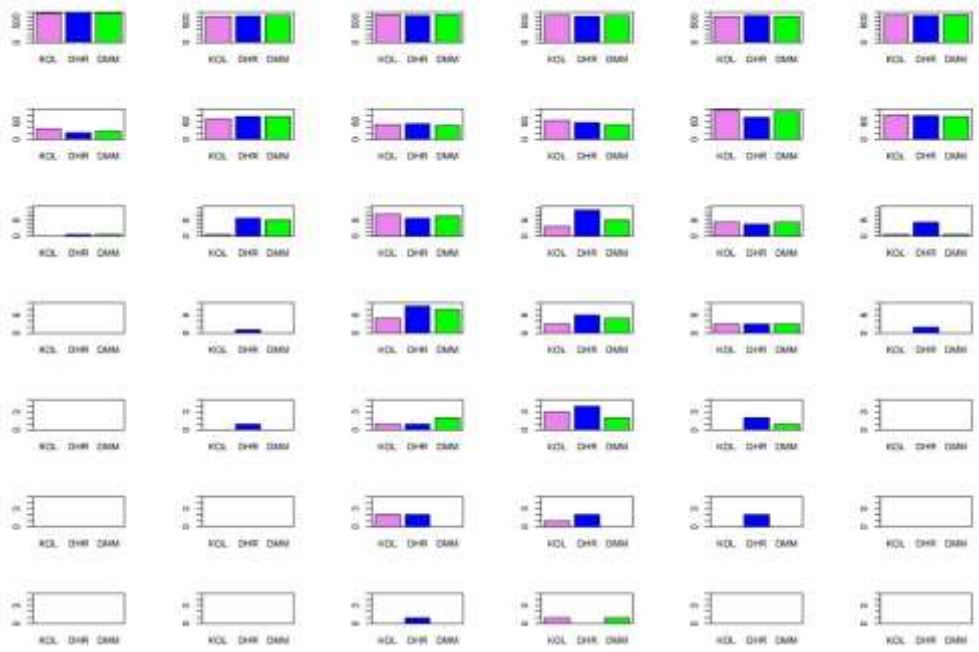

Figure 2. From the top first row depicts number of days with PET less than 40°C. Depicts number of episodes which represent PET value greater than 40°C and sustains between 1 to 5 days (second row), 6 to 10 days (third row), 11 to 15 days (fourth row), 16 to 20

days (fifth row), 21 to 25 days (sixth row), 26 to 30 days (seventh row). Each column from the left represents at 0530 hr, 0830 hr, 1130 hr, 1430 hr, 1730 hr, 2030 hr respectively.

4. Results: The bioclimate diagram of PET for Alipore (Kolkata), Dum Dum and Diamond Harbour during the period (2020–2021) at every 3h interval starting from 0530 hr (IST) till 2030 hr (IST) extracted from IMD respectively has been presented in Fig. 1. For all the time of observations, PET values suggest that none of the stations experience cool or very cool thermal stresses. Monthly thermal classes of PET vary from slightly cool stress (more than 11.4 °C) to hot stress (more than 43.8 °C) for all the three stations. At 1430 hr, significant percentage of hot stress condition is observed for Kolkata and Dum Dum during April to May with relatively less percentage of hot stress condition in Diamond Harbour in these months. Out of all the considered stations, largest share of hot stress condition (more than 80%) is observed in Diamond Harbour during July to October.

The frequency distribution of PET having more than 40°C at different hours of a day occurring successively for (i) 1-5 days (ii) 6-10 days (iii) 11-15 days (iv) 16-20 days (v) 21-25 days (vi) 26-30 days have been presented in Fig. 2 along with number days not exceeding 40°C. The number distribution of days not exceeding 40°C remains same for all the stations. The number of episodes occurring successively for 6-10 days 11-15 days, 16-20 days, 21-25 days is highest in/for Diamond Harbour relative to Kolkata and Dum Dum at 1430 hr. Episodes occurring successively for 26-30 days appears in Kolkata and Dum Dum whereas no episodes appear in Diamond Harbour.

6. Discussion: Future research should consider data sources which should have climate projection of improved resolution over the study sites. Furthermore, hourly data of each day is essential to express the diurnal variation of health-related thermal conditions. Future intense heat episodes which critically influence human health, might occur often, more acutely in these sites. With respect to these expectations, clearly there is a need to extend this research taking into account the short-term acclimatization, impact of different age groups, living status of individual, indoor environment, building design and materials they are made of. These criteria will assist in future assessment and improvement to reduce thermal stress. At present, major part of this region is experiencing a rapid urbanization process, so, environment planning at small-scale level of towns should be upgraded to reduce the significant benefaction to extreme human bio-climate conditions. The potential steps could be the use of cool-roofing, green terrace, paving materials, planting trees and vegetables, more water bodies in open spaces etc.

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Ethics approval: Meteorological datasets used in this study can all be obtained from publicly accessible archives.

Consent to Participate: This research did not involve human subjects.

Code and Material availability: The codes and visualizations required for the study were made in R software. The data and code are available from the corresponding author upon reasonable request.

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Authors' contributions: Sourabh Bal (SB), as the corresponding author, pursued the idea and analyzed all datasets, results and prepared the draft; Adwitia Bal (AB) was involved and helped in interpreting and improving both results and the manuscript. All authors read and approved the final manuscript.

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