



Distinguishing between Global Warming and Urban Warming for Bangalore with the aid of Statistical Analysis

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Abstract: The present research presents a statistical framework for distinguishing between Urban Warming and Global Warming, as an outcome of urbanisation. While global warming is the increase in the average temperature of earth's near-surface air, Urban Warming in the form of Urban Heat Islands (U.H.I.), signifies an urban area warmer than its rural surroundings brought about by man-made alterations of the urban surface. This research presents a local climatological investigation so as to distinguish between both forms of warming for Bangalore. To achieve this, ambient air temperature was monitored and recorded simultaneously at 12 stationary observatories in adherence to meteorological guidelines. Industrial belt across Bangalore West had mercury touching 30°C, while residential layouts near water-bodies on the same day and time were found to be coolest with maximum temperature not exceeding 24°C. Rural fringes of Bangalore North owing to relatively undisturbed natural terrain had a minimum temperature of 11.4°C, while dense urban sprawls of Bangalore Central basked with nocturnal Urban Heat Islands at 18°C. On certain occasions, relative intensity was found to be higher than 7°C. This research confirms the distinct presence and dominant trend of urban warming over global warming at the intra-urban locations, thereby warranting control at regional level.

Keywords: Bangalore; global; warming; heat island; urban

I. Introduction

Urban Warming and Global Warming are the most discussed and debated issues of urban climatological studies. Unlike Global Warming, which entails a worldwide rise in temperature, Urban Warming occurs at the local level [1]. Separate studies on Urban Warming and Global Warming, as an outcome of urbanisation; have been documented by several experts widely across the globe. However, only a few among them attempted to distinguish these. Bangalore is currently the 5th largest metropolitan city of India [2]. As capital of Karnataka, the city underwent rapid and tremendous urbanisation thereby introducing drastic transformation severely influencing its salubrious climate [3]. Hence it's befitting to conduct the study for Bangalore city.

II. Research Methodology

Thermal structure of a city can be conveniently studied by using long-term and real time temperature data. As Bangalore had an ideal topography and city morphology, the study facilitated 12 stationary multiple points representing considerable variation in terms of layout, thermal properties and vegetation cover. This further involved collection of air temperature values at these locations, by conducting simultaneous field measurements for over an year covering all the 4 seasons, with the aid of strategically placed calibrated watchdog D.T. 1000 Sensor, with data logger programmed to record data unhindered for 6 months at half an hour intervals. The sensors were housed in Radiation shield at an elevation of 1.5m above ground level as per World Meteorological Standards [4]. The collected climatic data was then subjected for analysis of the warming and cooling trend, wherein the 'maximum' and 'minimum' temperatures of daily recordings, registered at the weather stations were grouped into 'weekly' and 'monthly' averages. To determine which type of warming was predominant, the 'mean' and 'total' change for the dataset was computed simultaneously across all the stations for T_{max} , T_{min} and T_{avg} . While 'total change' (Equation 1) refers to the sum of changes found, 'mean change' (Equation 2) is a term, used to describe the average change over an entire dataset. Herein 'X' is the climatic variable, 'n' is the total number of observations and 'i' is the respective range at which 'Xi' represents the respective value.

$$\text{Total Change} = \sum_{i=2}^n (X_i - X_{i-1}) + \dots + (X_n - X_{n-1}) \quad \dots \text{Eqn. 1}$$

$$\text{Mean Change} = \frac{\text{Total Change}}{n} = \frac{\sum_{i=2}^n (X_i - X_{i-1}) + \dots + (X_n - X_{n-1})}{n} \quad \dots \text{Eqn. 2}$$

III. Results and Discussion

The statistical results for analysis of real-time data unveil that while certain stations cooled, some other warmed during the period of testing; with the intensity found to be varying across each station. The same can be clearly observed from the charts 1 and 2. Hence, it may be affirmed that across all the stations, the rate of temperature variation was distinct and different. While Chart 1 indicates month-wise, the 'total' change; Chart 2 indicates the 'mean' change, year-wise. As can also be generally observed from the plots, there is an obvious differential variation in the rate of warming and cooling, both month-wise and annually, across all the stations. Hence, this hints at the probability of the existence of urban warming as an indirect measure of urbanisation. While determination of change only provides a numerical outlook, it falters as far as pictorial representation is considered. Hence, for a better understanding, Trend Analysis results have been presented herewith for seasonal statistics involving weekly variation.

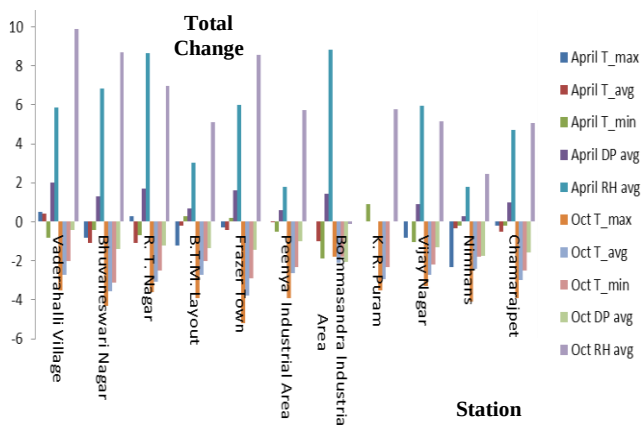


Chart 3: Total change, month-wise across stations.

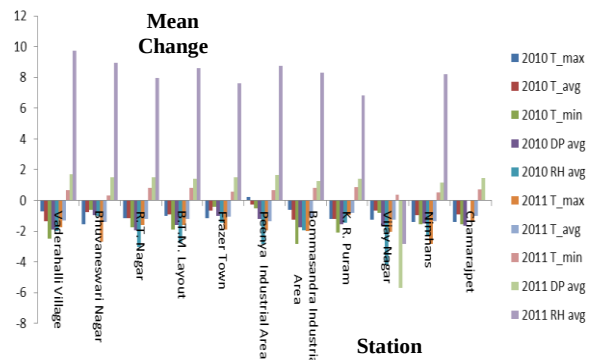


Chart 4: Mean change, year-wise across each stations

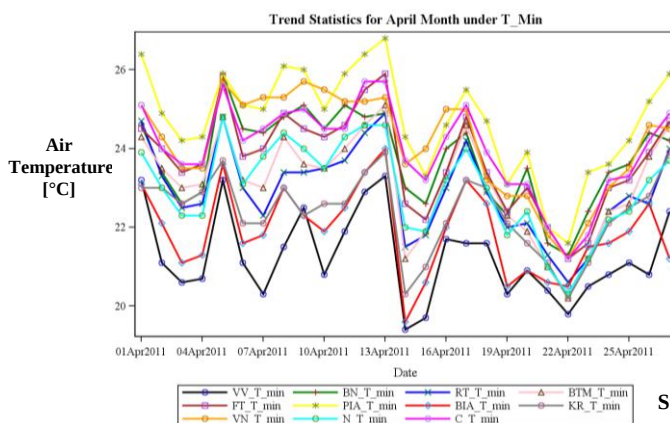


Chart 3: Time series for Minimum Air Temperature.

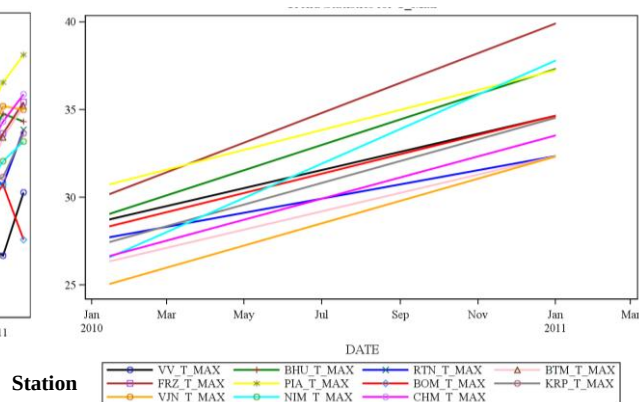


Chart 4: Trend-lines for Maximum Air Temperature.

As can be observed from the Charts 3 and 4, the Time series plots of air temperature variation are conclusive of the fact that all the stations do not follow the same trend. There is a distinct variation from one station to another. It can easily visualized from the trend series plots that, while at few of the stations there was peaking of rise and falls, the rest had no sharp turns. For instance, for $T_{\min}$, it can be realised that Vaderahalli Village always had the coolest temperature, while Peenya Industrial area was the warmest. On the outset, it is also most vital to realise

that few stations such as Vaderahalli Village and Bommasandra Industrial Area depicted a rapid increase in minimum temperatures (5°C) than the urban stations whose minimum temperature rose only by 2.5°C from 2010 to 2011. This is due to the rising man-made operations and activities, rapidly gaining strides at these undeveloped terrains. Interestingly more sharp turns can be visualized in this graph, highlighting the presence of 'Nocturnal' U.H.I. This is because the construction materials exhibit a high thermal inertia, and consequently they continue releasing heat slowly after sunset and even near dawn, when most of the natural surfaces have cooled down.

All these aforementioned evidence clearly proves that the variation in climatic parameters is due to the varying intra-urban micro-climatic changes, occurring at each station. In case of T_{max} , it was found that during most of the study period, though all the stations have witnessed similar rise and fall on the same days. On an average scale, it may be affirmed that stations with more urban features and surfaces tend to be hotter than the underdeveloped suburbs and rural surroundings. Stations such as Peenya industrial area and Frazer Town were always found to be hotter than the other stations, unlike the stations found on the outskirts such as Bommasandra and Vaderahalli Village. Interestingly the latter station had smooth trend compared to the former. This may be attributed to the scattered industrial operations of Bommasandra Industrial Area. On an whole, it may be summarized that at the highly urbanised stations (e.g. Peenya Industrial Area and Frazer Town) the minimum and maximum air temperatures of locations always showed an increasing trend, while the stations outside the city (Vaderahalli Village, Bommasandra Industrial Area etc.), and those with distinct green cover (NIMHANS) depicted a reverse trend.

As also can be observed from the Trend-lines depicted in Chart 4, the pattern though slightly is similar, all of them had still certain directional change. When compared across all stations, the study revealed that the maximum temperatures have increased at a greater rate in the congested urban centres (Frazer Town, R. T. Nagar), than the stations (Vaderahalli Village, Bommasandra Industrial Area) with more natural features. This was so because the stations located on the outskirts were cooling at a faster rate than the urban canyons of stations in core areas of the city. This was due to the fact that these stations had more surfaces of concrete and asphalt. These surfaces have a significant heat capacity and thermal conductivity, which introduces variation in the energy balance, eventually raising the temperature when compared to the rural areas. Simultaneously, minimum temperatures reached the warmest values in the urban areas.

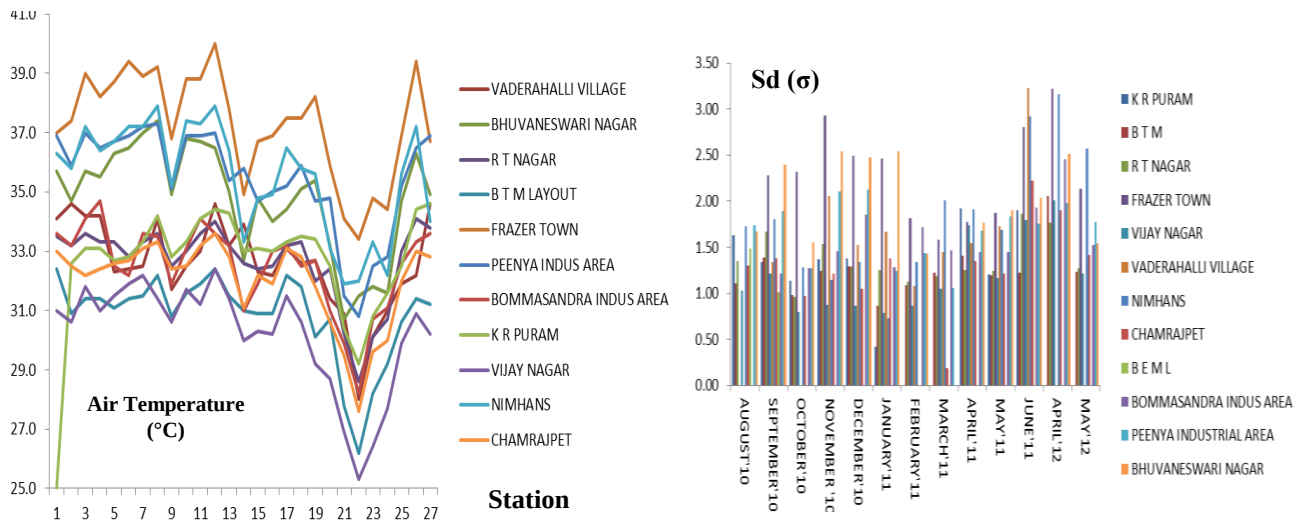


Chart 5: Diurnal variation of 'Average' air temperature. **Chart 6:** Standard deviation of 'mean' air temperature.

As can also be observed from the diurnal plot (Chart 5), the effect of urbanization was usually reflected with the sharp drop in night-time temperatures being observed in rural and suburbs only. The urban centers continued to show warming signs at all locations. This may be attributed to the continuous heat contamination, as derived from human activities such as central heating systems and night traffic. For instance, Industrial belt across Bangalore West had a diurnal U.H.I. with mercury touching a maximum of 30°C due to the release of hot plumes via stacks. Contrastingly, on the same day and time, residential layout under the influence of evaporation due to proximity to water-body was found to be coolest with maximum temperature not exceeding 24°C. Also, rural fringes of Bangalore North, owing to relatively 'undisturbed natural terrain' and 'pollution free environment' enjoyed a minimum temperature of 11.4°C, while around the same time, dense urban sprawls of Bangalore Central basked with nocturnal U.H.I. at 18°C.

The present study also computed standard deviation (Chart 6) of the 'Average' air temperature. After analysis of the detailed dynamic changes of climatic parameters at the twelve stations, one can observe a general trend in the temporal series, such as high 'standard deviation' for minimum temperatures at rural stations, and for maximum temperatures at urban stations respectively.

IV. Conclusion

The demarcation between urbanisation and global climate change is quite complex. The basic argument that both rural and urban areas are equally warming fails. Though the temperatures in both urban and rural stations show an increasing tendency, it is at urban stations where there is a sharp rise and non-uniform dips. Under this circumstance Global Warming will exacerbate the incidence of heat waves and add an additional thermal burden to urban areas, accentuating its impacts.

VI. References

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