

# Web GIS-Based Temporal Analysis of Climatic Factors Impacting Heat Stroke in Karachi

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## Abstract

This study focuses on the impact of climate change, specifically the increasing threat of heatwaves, in Pakistan, with a particular emphasis on the city of Karachi. The Pakistan Meteorological Department (PMD) analysed a century of climatic data to reveal warming trends, attributing them to human-induced factors. The vulnerability of Pakistan to climate change is highlighted, given its warm climate and location in a region where temperature increases are expected to surpass global averages. The study examines the past three decades, noting a significant rise in the frequency of hot days, especially in Karachi, where heatwaves have become more prevalent. The aims and objectives of the study involve identifying temporal changes in temperature, rainfall, humidity, and wind speed from 1984 to 2014 in Karachi. The literature review emphasizes the health implications of heatwaves, citing increased mortality during such events globally. The study incorporates a comprehensive temporal analysis, addressing gaps in previous research by considering multiple climate indicators responsible for heatwaves. The methodology involves statistical analyses, including linear regression and Pearson correlation, applied to temperature data and urbanization parameters. Results indicate an increasing trend in heat index temperature, with heatwave vulnerability peaking in the last three decades. Heat Index Temperature Anomalies show a clear surge, emphasizing the need for new indices to control critical heat stress conditions. The study concludes that tropical climate variability, particularly heat index, is linked to extreme hot days, urging measures to reduce population vulnerability. The findings underscore the importance of policy strategies, such

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as integrated coastal zone management, to mitigate the adverse health effects of heatwaves in Karachi's vulnerable population.

## Keywords

IPCC, Heat Wave, Heat Index, PMD

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## 1. Introduction

The threat of climate change can be coped with by identifying its effects on different socio-economic stores of a country. Pakistan Meteorological Department carried out an analysis on past hundred year's data to detect the changes in different climatic parameters happened in the last century and trends of recent climate events. The analysis presented illustrate that the climate in Pakistan is also changing. Over the last 100 years and especially the last 30 years, the climate change indicators show warming trends in the region. This is now well known fact that this warning is human induced.

Pakistan can be quite vulnerable to climate change because it generally has a warm climate; it lies in a world region where the temperature increases are expected to be higher than the global averages. Its land area is mostly arid and semi-arid (about 60 per cent of the area receives less than 250 mm of rainfall per year and 24 per cent receives between 250 - 500 mm). During the last century, average annual temperature over Pakistan increased by 0.6°C, in agreement with the global trend, with the temperature increase over northern Pakistan being higher than over southern Pakistan (0.8°C versus 0.5°C). Precipitation over Pakistan also increased on the average by about 25%. Studies based on the ensemble outputs of several Global Circulation Models (GCMs) project that the average temperature over Pakistan will increase in the range 1.3°C - 1.5°C by the 2020s, 2.5°C - 2.8°C by the 2050s, and 3.9°C - 4.4°C by the 2080s, corresponding to an increase in average global surface temperature by 2.8°C - 3.4°C by the turn of the 21st century. Precipitation is projected to increase slightly in the summer and decrease in winter with no significant change in annual precipitation. Furthermore, it is projected that climate change will increase the variability of monsoon rains and enhance the frequency and severity of extreme events such as floods and droughts.

Over the past one decade, the frequency of hot days has been noted three times higher than the frequency of recorded cold days at the global scale. According to a study conducted by the Pakistan Meteorological Department (PMD), in recent decade the number of heat-waves days has sharply increased in country [1]. Hot weather is a pre-requisite for heat waves, but it is important to understand that heat waves are more than just stand-alone hot days [2].

This study will investigate the last three decades to assess the possible cause of Heat wave in Karachi because to be on safe side this span is enough to get a

glimpse of adverse effects hit by it.

## 2. Aims and Objectives

To identify the temporal changes 1984-2014 in the months of May, June, July and August in the following parameters:

- To identify Temperature variation during this specific span in Karachi;
- To carve out monthly or annually Rainfall in mm to assess variation;
- To support the result of Humidity in this area are critical;
- To gauge Wind speed to consolidate the outcomes;
- To perceive the magnitude of correlation statistically.

## 3. Literature Review

Heatwaves were characterized as intervals during which two thresholds, derived from an adapted version of the Excess Heat Factor index (EHF) and the 95th percentile of the maximum daily temperature, were surpassed continuously for a minimum of three consecutive days [3]. Heatwaves were characterized as intervals during which two thresholds, derived from an adapted version of the Excess Heat Factor index (EHF) and the 95th percentile of the maximum daily temperature, were surpassed continuously for a minimum of three consecutive days [4]. Moreover, heatwaves have been linked to significant consequences, leading to economic losses in agriculture [5]. Heatstroke occurs in epidemic form during heat waves [6]. Over the past one decade, the frequency of hot days has been noted three times higher than the frequency of recorded cold days at the global scale. In recent decade the number of heat-waves days has sharply increased in the country [1].

The issue of climate change has affected very strongly during the last two decades. According to IPCC [7] The most recent report (2001) from the United Nations' Intergovernmental Panel on Climate Change IPCC 3rd report [8] states that the global average land and sea surface temperature has increased by  $0.6^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$  since the mid-19th century, with most change occurring since 1976. Recent scientific assessments indicate that, as global temperatures continue to increase because of climate change, the number and intensity of extreme events are likely to increase [9]. According to [1] in recent decade the number of heat-waves days has sharply increased in the country. Global warming is causing heat waves in temperate climate [10]. The World Meteorological Organization estimates that the number of heat-related fatalities could double in less than 20 years. Studies of recent heat waves across Greece in 2007 [11]. Australia in 2009 [12], Russia in 2010 [13] and India in 2012 [14] were all associated with increased mortality.

A widely used metric is HI [15]. This metric enjoys wide use in the health and meteorological communities because it can be computed from the variables humidity and temperature [16] [17].

Current study will incorporate above results in mind and give a comprehen-

sive temporal analysis which will figure out the variation in climate. It will be an insightful research that cover the all the indicator like humidity, rainfall, temperature etc. which lacks in previous studies. Hence, a web based temporal analysis of climate based on various indicators which are responsible for Heat wave.

#### 4. Methodology

Three different data time series of MMxT, MMiT, MAT, as well as selected urbanization parameters i-e number of vehicles, population, for the specified study area was analysed by some statistical methods. A statistical test gives scholarly fundamental insight for formulating decisions quantitatively for a process or processes subsequently [18].

To observe the significant change in temperature trend with respect to the passage of time and for finding out its causes, linear regression and Pearson correlation were applied respectively.

The present study is aimed mainly at to find out the causes but before considering how intense this relationship may exist between natural and anthropogenic factors, it is determined if trends exists and in what magnitude.

For this purpose, firstly data is compiled and MAT, MMxT, MMiT were calculated by monthly averages on seasonal and yearly basis. Then, data is compiled and scatter plots in graphing feature of SPSS 19.0, are used to understand the structures and distributions of variables in order to select what types of test is opting either linear, Spearman or Kendal tau to analyses data series.

After plotting, the graph of these variables observed data positions in the direction from the lower left-hand corner of the graph to the upper right. So, the linear regression test was applied to understand relationships between temperature and MAT. Linear regression analysis is a statistical test for the inquiry of relationships between variables when data is parametric. Usually, the researchers seek to determine the causal effect of one variable upon another. It determines and defines the relationship between variables in a very clear manner. In addition, it tells the value of strengthening between independent variables and values of the dependent variable.

According to this linear regression analysis, the null hypothesis H0 assumes that there is no trend in opposition to the alternative hypothesis H1, which supposed that there is a trend either increasing or decreasing. The null hypothesis for temperature data for LMA is calculated at 95% confidence level with rule of thumb that p-value less than the significance level  $\alpha$  (alpha) = 0.05, will reject H0. Here, Rejection of H0 shows that there is the presence of some trend in the data time series. On contrary, with the rejection of the null hypothesis, the result will be considered with no change in time series at all.

Implication of another statistical test named Pearson correlation, on the other hand, used for investigating the causal relationship between variables for finding out the causes.

In statistical rules, values between  $\pm 1$  and  $+1$  of Pearson correlation shows

positive correlation and indicates that both variables increase together. However, a negative correlation indicates that one variable increases when the other decreases in its values.

In this section, our hypothesis is that “due to multifarious causes the temperature trend of the Lahore metropolitan area is observed in the change”. To execute a linear regression and person correlation on three series of data, arranged data is used and denote variables in the regression in SPSS as given below in **Table 1**.

## 5. Results

The results obtained in this study suggest that vulnerability of heatstroke increases due to the heat index depicts an increasing trend. Climate variability plays a reasonable role in human health. Significant increasing trend of temperature and heat index leads towards extreme caution or danger to human health. There is an increase in heat stroke related mortality when temperature crossed 40°C. As there is a direct relationship between mortality and HI. Mean daily mortality shows a significant association with daily maximum temperature and HI.

Another interesting finding in this study is that the vulnerability of heat stroke due to heat stress shows a decade shift from 1984 to 2014, when the risk of heat

**Table 1.** Datasets information and procedure of applied statistical test.

	Datasets	Analysis	Statistical Test	Procedure
A	MAT, MMiT and MMxT	Trend for 5 decades	Linear regression	Analyze ↓ Regression
B	Seasonal mean Temperature DJF, MAM, JJAS, and ON	Trends at seasonal basis for 5 decades	Linear regression	↓ Linear
C	Indicators of Urbanization Population explosion Built-up area increases Reduction in vegetation cover Increase in motor vehicles Industrialization Greenhouse gases	Causes	Pearson's Correlation	Analyze ↓ Correlation ↓ Bivariate
	MAT - Mean Annual Temperature	MMiT - Mean Monthly Temperature	MMxT - Mean Maximum Temperature	
	DJF stands for December, January, and February	MAM stands for March, April, and May	JJAS stands for June, July, August, and Septembe	ON stands for October, Novembe

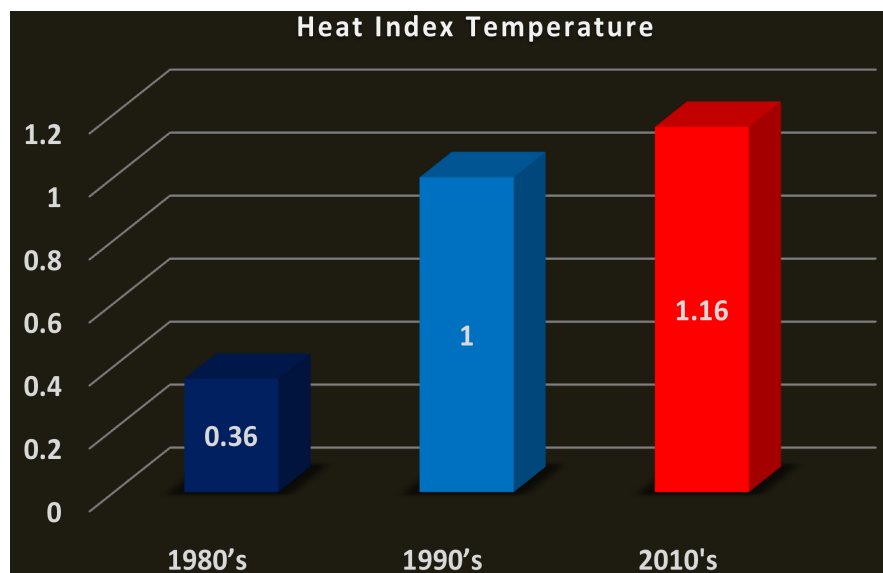
stroke related death increases dramatically. Heat Index Temperature anomaly shows a positive increase during the 1990's to 2010's and 1980's to 2010's is 0.36°C, 1°C, 1.16°C respectively.

It is evident from **Table 2** that last three decades clearly witness the upsurge in temperature column which results in heat wave in patches of season.

**Figure 1** depicts the graphical view of heat index temperature which clearly suggest a surge in temperatures in last three decades in Karachi. Its adverse impact cast on denizen in form of heatstroke that claims casualties in this span.

We strongly believe that new and significant indices are needed to control critical heat stress conditions that consider more predictors of the effect of climate variability on human health, such as temperature, heat index, the number of days of stress (NDS).

Based on our results it is concluded that the tropical climate variability such as heat discomfort or heat index have a link with the extremely hot days in Karachi through the atmospheric teleconnection. Given the trends associated with climate change, dangerous periods of extreme heat are likely to occur more frequently, suggesting the need for measures to reduce population vulnerability. To improve the correlations and achieve the best linear relationship, a study of the mixed effect of climate indices is strongly suggested.



**Figure 1.** Heat index temperature in decades in graphical view.

**Table 2.** Heat index temperature anomalies.

Sr #	Decades	Temperature (°C)
1	1980's	0.36°C
2	1990's	1°C
3	2010	1.16°C

In the future warming climate, even a small temperature perturbation related to the Karachi climate variability may lead to the occurrence of the heat stroke due to increase in heat index. Karachi from the geographical and environmental point of view is a land of natural calamities. Multiple studies have shown that the maximum & minimum temperature of the country is rising alarmingly. Severe heat waves are expected in the country in future. As heat waves are the silent killers. Government should consider heat wave as a national emergency and develop proper remedial measures for the future. Analysis may fulfil the needs of policy makers and apply strategies like integrated coastal zone management. Extreme heat related mortality merits further analysis in order to reduce the harmful health effects among Karachi's most vulnerable population.

## 6. Conclusions

Climate indicators in Karachi have been analysed in this report. This descriptive study investigates the most influential climate parameters or bioclimatic index on human health and presents a relationship between physiologically relevant climate indices for human health (heat discomfort, vulnerability of heatstroke due to heat index) observations to examine the associations among the set of inter-related parameters, and facilitate a deeper understanding of the relationship of climate and vulnerability of heat stroke. Long term data has been the main focus to calculate the indicators. By using the observational data during boreal summer of 1984-2014, we investigated inter annual variability of climatic factors affecting heatstroke in Karachi, Pakistan. The results show that over the analysis period, though the climatic trend is abrupt in Karachi but still we are leading towards extremes mean annual temperature is increasing sharply and as well as mean maximum and mean minimum temperature is also shows the increasing trend on the other hand rainfall pattern shows the decreasing trend which leads towards severity in the climate as the Temperature and Precipitation have been the key parameters for climate analysis. Wind speed increases with the passage of time and humidity is decreasing, especially in the recent twentieth century.

It also shows that the local (Karachi) maximum and minimum (May to August) mean monthly temperature trends have much similar increasing trend as depicted in mean annual maximum, minimum and annual temperature since 1984 to 2014. The trend models and the time plots rainfall (May-August) since 1984 to 2014 is decreased due to which risk of heat stroke has enhanced. During this time period humidity is sharply decreased. These climatic factors correlate with heat stroke.

Mean Annual Heat index of Karachi has increased by 1.6°C from 1984 to 2014 and it has risen by 0.36°C from the period from 2010 to 2014 and 1. C 1980's to 2010's Rise in heat index is even faster in the last decade of the data period.

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### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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