Understanding Temperature and humidity dynamics of Mumbai 2024

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Abstract:

The rate of urbanization and the climatic conditions in the coastal region have a great effect on the thermal environment of urban areas, and hence, the analysis of temperature variability is of utmost significance in understanding the climate of the region. Mumbai, a heavily populated coastal city, has extreme seasonal variations due to monsoon circulation, humidity, and cloud cover. This study investigates the monthly temperature variability and trends in Mumbai during January to December 2024 based on high-resolution half-hourly observational data. The analysis shows clear seasonal variations in the intensity and timing of daily temperature maxima. During the monsoon season, increased cloud cover and frequent rainfall lead to reduced solar. The results show that temperature patterns change noticeably with the seasons, both in how high the temperatures rise and in the time of day when the maximum is recorded. These differences become especially clear when comparing the monsoon and post-monsoon periods. In the monsoon season, thick cloud cover and frequent rainfall limit the amount of sunlight reaching the ground. Because surface heating is reduced, the highest temperature of the day is often reached earlier. After the monsoon withdraws, skies become clearer, and solar heating becomes more effective, allowing temperatures to continue rising into the late afternoon hours. Another important observation is the gradual drop in humidity during the post-monsoon months. Along with this, the variation between daytime and nighttime temperatures becomes smaller, indicating relatively steady atmospheric conditions. Overall, these seasonal changes strongly influence the daily temperature cycle and help in better understanding climate behavior in a coastal city like Mumbai.

Keywords: Temperature, Humidity, Inverse relation, Diurnal variation

Introduction:

Climate variability plays a crucial role in environmental and agricultural studies, as it directly affects weather patterns, crop yield, and overall ecosystem stability. Among various meteorological parameters, temperature and humidity are two of the most critical factors influencing local and global climate conditions. Their interaction determines atmospheric stability, precipitation patterns, and even human comfort levels.

Mumbai, a coastal metropolitan city in India, experiences a tropical climate with high humidity levels throughout the year due to its proximity to the Arabian Sea. The temperature and humidity levels in Mumbai are influenced by seasonal changes, monsoon patterns, urbanization, and global climatic phenomena such as solar activity.

According to Nwankwo et.al., in 2024, the Sun reached the peak of its solar cycle - a time when solar activity was at its strongest, with more sunspots appearing and greater variations in solar radiation. E. Friis-Christensen et.al. said that such solar variations are known to impact Earth's climate by affecting atmospheric circulation, temperature, and humidity patterns. Understanding these influences helps in predicting weather conditions and improving agricultural strategies.

Several studies have explored the relationship between temperature and humidity in urban environments. Diya Sundar et.al. has stated research indicates that temperature and humidity are inversely related in most cases - higher temperatures tend to lower humidity due to increased evaporation rates, while lower temperatures can result in higher humidity levels due to condensation. However, this relationship can vary depending on geographical location, altitude, and seasonal factors.

Previous studies on Mumbai's climate have shown that the city's temperature and humidity patterns exhibit significant variations due to monsoonal influence and urban heat island effects. Ilya G. Usoskin et.al. mentioned that studies on solar cycles suggested a correlation between increased solar activity and temperature fluctuations, potentially impacting humidity levels.

Materials and Methods:

RESEARCH DESIGN

This study follows a quantitative research design, focusing on numerical data analysis to establish the correlation between temperature and humidity in Mumbai throughout 2024. The research is observational and analytical, as it relies on recorded meteorological data rather than experimental interventions. The study is structured to analyse seasonal variations, identify peak shifts in temperature and humidity, and assess the potential influence of solar activity.

RESEARCH APPROACH

The approach taken in this study is data-driven and statistical, because of its effectiveness in dealing with large datasets and its ability to provide objective, measurable insights into climatic patterns. A quantitative method allows for the precise examination of numerical data and is ideal for trend analysis, statistical comparisons, and identifying correlations between variables such as temperature and humidity.

DATA COLLECTION METHODS

The data for this study was obtained from Wunderground.com, a weather monitoring website that collects real-time meteorological data from local weather stations. These stations are distributed across Mumbai, ensuring that the recorded temperature and humidity values are accurate and representative of the city's climate conditions.

For this research, half-hourly temperature and humidity data for the entire year of 2024 was extracted from Wunderground's historical data archives. The high frequency of data collection provided a detailed understanding of daily and seasonal variations.

DATA ANALYSIS TECHNIQUES

The collected temperature and humidity data were analysed using quantitative statistical methods to identify trends, correlations, and seasonal variations throughout 2024. The analysis was conducted using Microsoft Excel, where the data was processed, visualized, and interpreted.

First, the half-hourly data was categorized month-wise, allowing for a detailed examination of temperature and humidity fluctuations over time. Scatter graphs were plotted for each month to observe the trends. To understand the relationship between the two parameters, correlation analysis was performed to determine how changes in temperature influenced humidity levels and vice versa.

To track peak temperature variations, the highest recorded temperatures from each month were averaged to create a year-long trend analysis, helping to identify any shifting patterns in peak occurrences. Finally, the findings were interpreted in relation to their impact on agriculture, considering how variations in temperature and humidity affect crop growth, soil moisture, farming in Mumbai and similar regions.

JUSTIFICATION OF CHOSEN METHODS

The quantitative approach was selected for this study to provide an objective and data-driven analysis of temperature and humidity variations throughout 2024. Since the research aimed to establish correlations and observe trends, numerical data collected at half-hourly intervals offered a high level of precision and reliability.

Using Wunderground.com as a data source was justified due to its access to real-time and historical weather records from local weather stations in Mumbai. This ensured that the collected data was location-specific and reflective of actual climate conditions.

Microsoft Excel was chosen for data processing and visualization because of its efficiency in handling large datasets and generating clear, interpretable graphs. Scatter graphs were specifically used to track trends over time, making it easier to identify seasonal variations and peak shifts in temperature and humidity.

The use of correlation analysis was essential for understanding the relationship between temperature and humidity, while monthly averaging of peak temperatures helped in identifying long-term patterns. These methods allowed for a comprehensive analysis that could be directly applied to understanding climate impact on agriculture, urban meteorology, and broader environmental studies.

Result and Discussion:

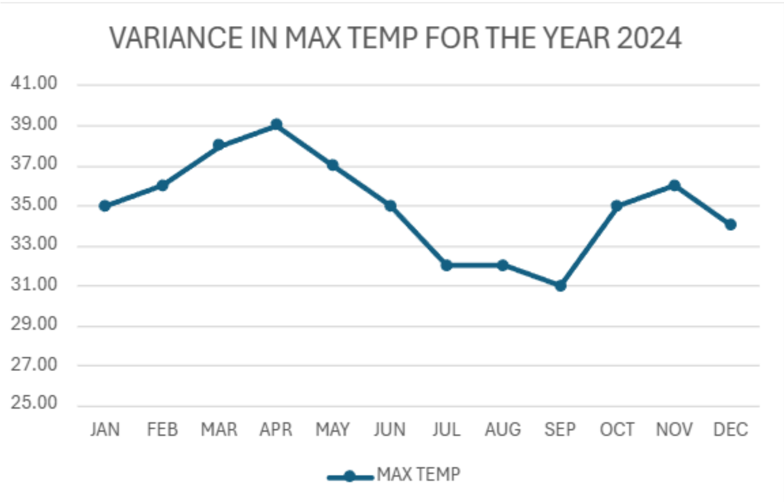
FIGURES AND TABLES

GRAPH 1:

Diurnal Variation of Temperature & Humidity

This graph shows the variation of temperature and humidity over the course of a day, from late night to late evening. Temperature generally starts lower during the night and early morning, gradually rises toward midday, and peaks around noon to early afternoon. After this peak, it slowly declines through the evening. Humidity shows an inverse pattern compared to temperature: it is relatively higher during the night and early morning, decreases sharply as temperature rises toward midday, and reaches its lowest values around noon. Later in the day, as temperature falls, humidity increases again. Overall, the graph highlights the typical daily (diurnal) relationship where higher temperatures correspond to lower humidity and vice versa.

GRAPH 2:



Monthly variance in max temperature - 2024

The graph illustrates the monthly variation in maximum temperature in Mumbai during the year 2024, highlighting the influence of seasonal solar geometry, particularly the summer and winter solstices. From January to April, maximum temperatures show a steady increase as the region approaches the summer solstice in June, during which the Sun reaches its highest apparent position and day length increases, enhancing solar insolation. Although the summer solstice occurs in June, the highest maximum temperatures are observed slightly earlier, in April, reflecting the combined effects of increasing solar radiation and pre-monsoon atmospheric conditions.

Following the onset of the monsoon and after the summer solstice, maximum temperatures decline from June through September due to increased cloud cover, rainfall, and evaporative cooling, despite relatively high solar angles. The lowest maximum temperatures are recorded around September, as persistent monsoon conditions suppress daytime heating. As the year progresses toward the winter solstice in December, solar declination shifts southward, day length shortens, and incoming solar radiation decreases. This results in comparatively lower maximum temperatures during the late autumn and winter months, with a slight recovery in October and November under post-monsoon clear-sky conditions before temperatures decline again in December. Overall, the graph reflects the combined influence of solstitial solar forcing and regional monsoonal dynamics on

Mumbai's annual temperature cycle.

Key Findings :

1. Highest temperatures were recorded in March and April (38°C), confirming a strong pre monsoon heat buildup.
2. Monsoon months (June-September) displayed the lowest peak temperatures (29°C-32°C) with reduced fluctuations.
3. Post-monsoon months (October-December) showed gradual cooling with moderate fluctuations.
4. Peak temperature shifted towards later hours in summer months due to prolonged solar heating.
5. There is a noticeable trend of increasing peak temperatures compared to historical averages, suggesting possible climate change influences.
6. The pre-monsoon months exhibit the most variation in peak temperature timings, while monsoon months display greater stability.
7. The analysis indicates a generally negative correlation between temperature and humidity, meaning that as temperature increases, humidity tends to decrease, and vice versa.

Analysis of Results :

The temperature and humidity trends observed in 2024 in Mumbai clearly show the influence of seasonal atmospheric processes typical for a tropical coastal climate. The results show that variations in solar radiation, cloud cover, rainfall, and atmospheric moisture govern collectively over the city's temperature behaviour on daily and seasonal bases. During the pre-monsoon period, a progressive rise in the maximum temperatures is apparent, indicating a progressive accumulation of heat due to extended solar exposure and less cloud coverage. The enhanced absorption of solar radiation by the surfaces of the earth intensifies heating during the day, while the simultaneous reduction of humidity validates the contrariety of temperature and humidity since evaporation is encouraged by elevated temperatures and thus near-surface moisture is depleted. On the other hand, during the monsoon phase, there are stable variations of maximum temperatures of different days with low values. The constant cloud cover, rainfall and humidity limit incoming solar radiation and dampen maximum temperatures during the hours of sunshine. The reduced diurnal temperature range underscores the regulatory effects of humidity and precipitation and brings to light the monsoon's relevance as a natural cooling mechanism.

The post-monsoon phase provides a transition to more cool and stable atmospheric conditions. The post-monsoon skies are clearer, allowing for only moderate heating during the day, and reduced moisture enables more effective cooling during the night, causing the day–night temperature difference to be tighter. The exception to this can again be tied to transient atmospherics. All through the seasons, a negative correlation between temperature and humidity can be relied on indicative of the thermodynamic association between heat and moisture in coastal setups. Pre-monsoon warming can be explained by solar insolation and limited cloud coverage, which collectively increase surface heat retention. Urban surfaces further cause a heat lag by storing heat and releasing it slowly. During the monsoon months, solar input is curtailed by thick cloud cover, while rainfall and a high humidity foster evaporative cooling, resulting in a stabilization of temperature patterns and a reduction in diurnal variability. Post-monsoon cooling is the product of monsoonal withdrawal, clearing of skies and decrease moisture in the atmosphere, which allows for controlled heating during the day and good cooling at night. The minor temperature anomaly that might be experienced in this period can be explained in short-lived wind direction changes and the presence of leftover moisture. The delayed timing of the highest temperatures in summer points to a shift in the modalities of heat absorption and emission, with possible roles played by urban heat islands, the composition of the atmosphere, and overall climatic fluctuations. Pre-monsoon peak temperatures being relatively higher than historical averages points to probable influences of climate change effects and speaks to the need for long-term monitoring.

Implications of Findings :

Urban Planning: Rising pre-monsoon temperatures necessitate improved cooling infrastructure, such as green spaces, heat-reflective materials, and energy-efficient city planning.

Agriculture: Farmers must prepare for water shortages and heat stress in pre-monsoon months and adapt sowing cycles to match peak temperature trends for optimal crop growth.

Public Health: Increasing peak temperatures during summer months could lead to higher heatstroke incidents, dehydration risks, and energy demand surges for cooling.

Climate Monitoring: The temperature trends can aid in forecasting extreme weather events, monsoon onset predictions, and climate resilience planning.

Comparison With Existing Research :

The observed trends align with Indian Meteorological Department (IMD) records of seasonal variations in Mumbai, confirming the cyclic nature of temperature changes. Global studies on urban heat islands confirm similar trends in peak temperature shifts, emphasizing the role of solar radiation, urbanization, and deforestation. Comparisons with historical data suggest an increasing trend in pre-monsoon temperature peaks, potentially linked to climate change and rising greenhouse gas emissions. Research on solar cycle influences indicates that Mumbai's warming trend might be linked to increased solar activity during the 11th solar cycle.

Discussion :

The analysis confirms that Mumbai's climate follows predictable seasonal changes, but peak temperature shifts are not uniform across all months. External factors such as solar activity, atmospheric pressure variations, urban heat effects, may contribute to fluctuations.

Findings are consistent with known climate trends in tropical coastal regions, but further verification with long-term datasets and satellite observations is required. The presence of heat islands in urban areas could be intensifying temperature peaks, especially in summer months. The higher variability in peak times during March-May suggests increasing heat stress before the monsoon, affecting energy consumption and public health. The study reinforces the importance of considering local climatic conditions when analyzing temperature-humidity interactions, as multiple meteorological factors contribute to observed patterns.

Limitations of the Study :

Short-term study period (one year) may not capture long-term climatic trends and anomalies. External factors such as wind patterns, oceanic influences, and human-induced land modifications were not fully examined in this study. The analysis does not account for microclimatic variations within Mumbai, which may affect localized temperature readings.

Recommendation for Future Work :

Extend the study period to track multi-year trends and confirm long-term climate patterns and anomalies. Integrate satellite-based solar radiation and wind speed data to examine the direct impact of solar cycles, atmospheric circulation, and global climate influences. Investigate urbanization effects on temperature variations, particularly in high-density areas, to assess the impact of construction materials, vehicular emissions, and deforestation. Study energy consumption patterns in response to temperature peaks, particularly during extreme heat months, to aid in power grid planning and sustainability efforts. Compare Mumbai's data with other coastal cities experiencing similar climatic conditions to determine broader regional trends and climate adaptation strategies. This study contributes valuable insights into temperature trends in Mumbai, aiding climate monitoring, urban meteorology, agricultural planning, and climate adaptation strategies.

Conclusion :

Mumbai's temperature trends follow a seasonal pattern, with pre-monsoon heating, monsoon stabilization, and post-monsoon cooling. Peak temperature shifts are influenced by solar activity, humidity levels, urbanization, and climatic variations. The findings are valuable for climate resilience planning, agricultural management, public health strategies, and future weather prediction models. The rising trend of peak temperatures in pre-monsoon months suggests the need for climate adaptation measures to mitigate heat-related risks. This study serves as a foundation for further research into climate change impacts and urban heat effects in Mumbai.One needs to do large data observation to identify the exact reason for the trendline

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