Urban Heat Stress in major cities of India: Mumbai (Central India)

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The Urban Lab of Centre for Science and Environment (CSE) has analyzed the temperature trends for India from Jan 2015 till May 2022. This is an effort to understand the warming tread in a comprehensive way by covering all three dimensions of heat stress–Surface air temperature, Land surface temperature, and relative humidity (heat index). This city report is part of the larger study that has analyzed heat stress trends at global, national, regional, and local level. The city level analysis of this study covers metropolises of Mumbai, Mumbai, Kolkata and Hyderabad (each located in different IMD's homogenous region). Objective of the city analysis is to understand the combined effect of climate change induced unseasonal heatwaves and urbanisation induced heat Island effect on the thermal comfort and heat stress among these topographically and climatically diverse in cites.

This is part of the larger report on heat stress in India. For the main report please follow this *link (https://www.cseindia.org/heatwave-paper-National.pdf).*

Data and method

Freely accessible data is available on United States Geological survey (USGS) Earth Explorer website. Landsat 8 operational land imager/thermal infrared sensor (OLI/TIRS) satellite imagery were downloaded and used to analyze the land surface temperature.

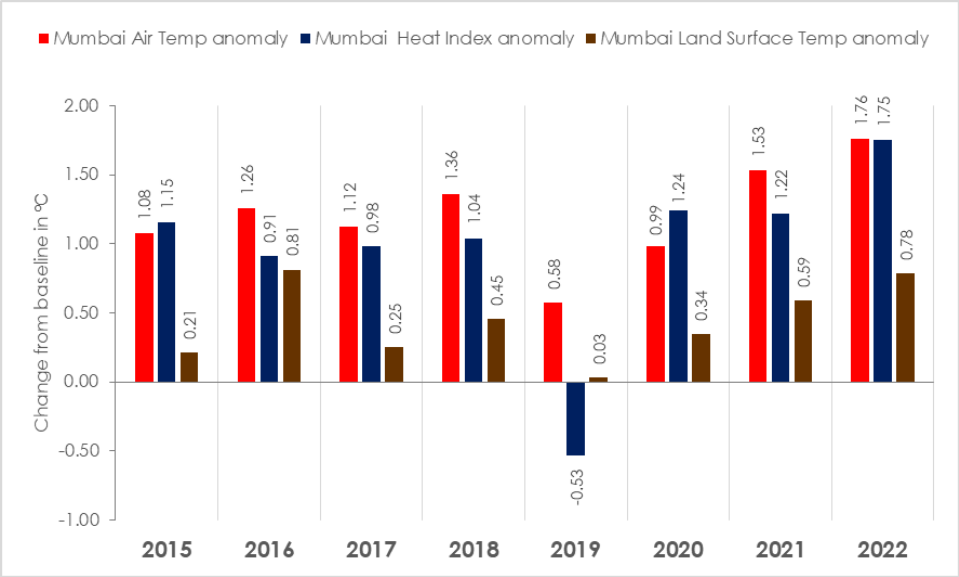
This city level assessment is focused on two things: Change in heat patterns over years for pre-monsoon season; and the land surface temperature variation on days with high air temperature during the pre-monsoon season of 2014, 2016, 2018, 2020 and 2022. For Mumbai the later analysis is based on 12 April 2014, 17 April 2016, 23 April 2018, 12 April 2020 and 2 April 2022.

Please refer the main report for further details on data and methodology employed in this study.

Findings-Heat patterns during pre-monsoon season

Air temperature and heat index in Mumbai highest since 2015, land surface temperature second hottest: Mumbai recorded significant positive anomaly on all three temperature parameters. Air temperature has been 1.76°C hotter than 1981-2010 baseline, while land surface temperature has been 0.78°C hotter. Heat Index is up by 1.75°C compared to 2010-19 baseline. Unlike the trend noted at the India level, 2016 was not the hottest Mumbai pre-monsoon before this year; 2018 and 2021 pre-monsoon season have been hotter (See *Graph 1: Pre-monsoon seasonal temperature anomalies in Mumbai (2015-22)*). In fact, the city has recorded consistently positive anomaly since 2015.

Graph 1: Pre-monsoon seasonal temperature anomalies in Mumbai (2015-22)

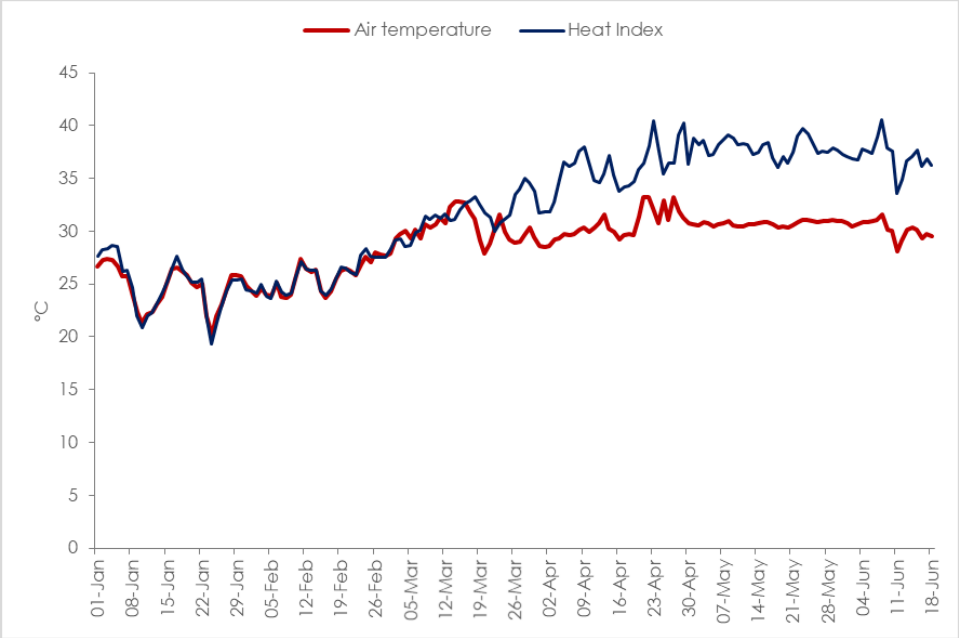


Note: Daily heat index was computed using the U.S. National Oceanic and Atmospheric Administration's (NOAA) formula. Air temperature and land surface temperature anomalies are computed with respect to 1981-2010 baseline. Heat Index anomaly is computed with respect to 2010-19 baseline.
Source: CSE analysis of IMD ground observation data and NASA satellite based remote sensing data

Heat Index is better measure of thermal discomfort in Mumbai, as it continues to climb up despite stabilization of air temperatures: Daily average air temperature in Mumbai tends to stabilize around 30°C from April onwards. But heat index continue to rise due to increase in humidity. Daily average heat index is usually 6-8°C higher than daily average air temperature. Since IMD doesn't account for humidity in its consideration for heatwaves, dangers of humid heat that is known to be more lethal to humans don't get reported. The daily average heat index crossed 40°C in June (See *Graph 2: Buildup of heat in Mumbai air temperature vs heat index (2022)*).

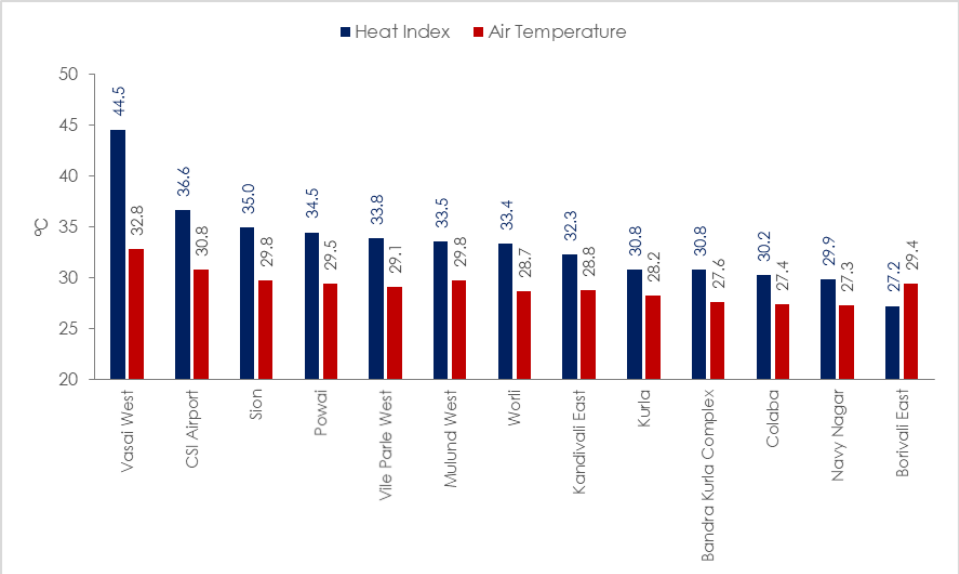
Vasai West and CSI Airport surroundings were on average hottest neighborhoods based on air temperature and heat index: There is variation of over 5.5°C in the observed seasonal air temperature among neighborhoods that have official air quality monitoring. Vasai West recorded highest seasonal air temperature average of 32.8°C in the city while Navy Nagar-Colaba with 27.3°C was the coolest. From heat index perspective as well Vasai West with an average seasonal heat index of 44.5°C has been the hottest part of the city. Borivali East had lowest average seasonal heat index in the city (See *Graph 3: Distribution of pre-monsoon heat within Mumbai air temperature vs heat index*)

Graph 2: Buildup of heat in Mumbai air temperature vs heat index (2022)



Note: Daily heat index was computed using the U.S. National Oceanic and Atmospheric Administration's (NOAA) formula.
Source: CSE analysis of IMD ground observation data

Graph 3: Distribution of pre-monsoon heat within Mumbai air temperature vs heat index



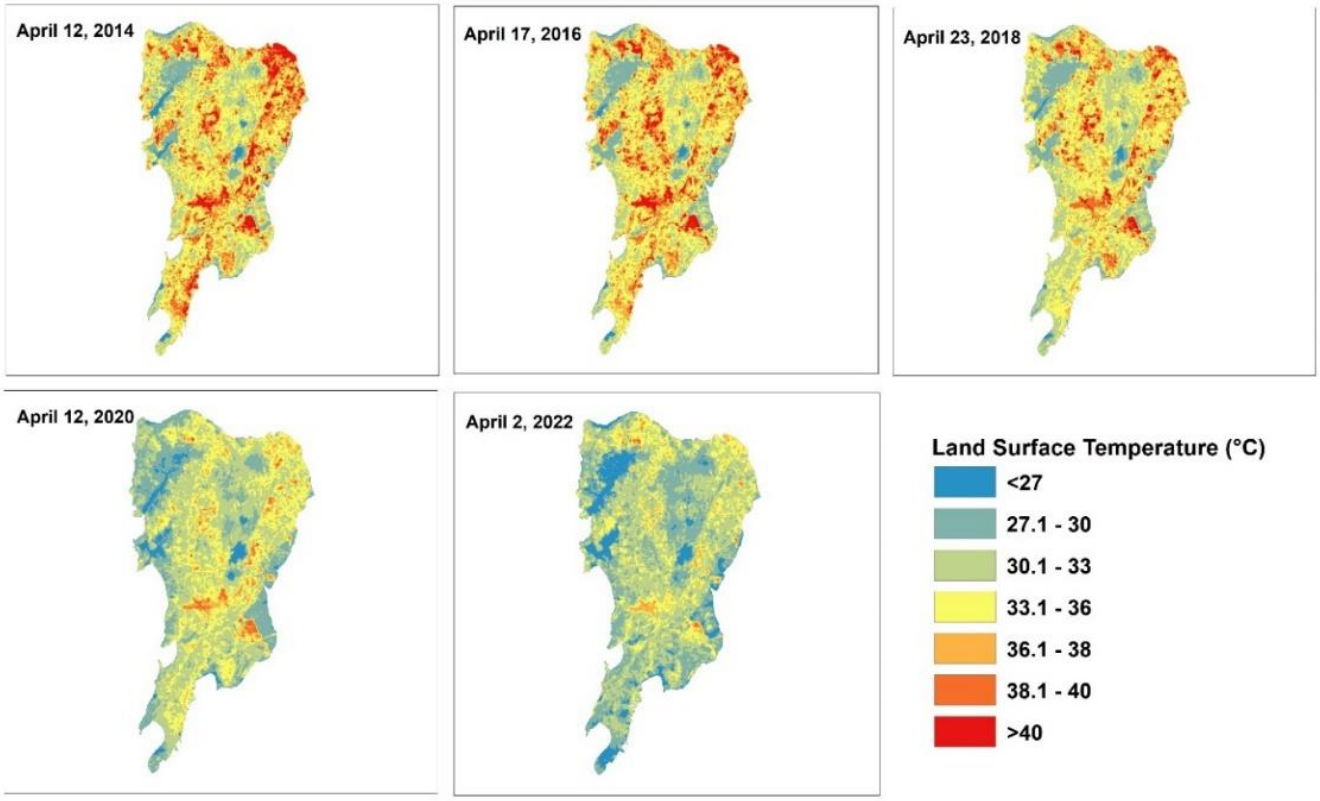
Note: Daily heat index was computed using the U.S. National Oceanic and Atmospheric Administration's (NOAA) formula.
Source: CSE analysis of temperature and humidity data from CAAQMS network of CPCB

Findings-Heat patterns on hot days

Land surface temperature (LST) variation on hot days over years: Bright red tone in the map represents region with high temperature and as the tone shifts towards blue, the temperature reduces. Highest LST was observed on April 17, 2016 when 47.1°C was recorded within city limits. It is followed by April 12, 2014 and April 23, 2018 with both reporting maximum LST of 45.9°C. This year, maximum LST was observed to be just 41.1°C (See *Figure 1: Variation in land surface temperature over Mumbai for 2014, 2016, 2018, 2020 and 2022*).

Maximum LST is recorded around Deonar dumping ground (above 40°C). Apart from Deonar, fragmented forest and barren land near Radha Soami Satsang Beas in the city's northwest outskirts has consistently recorded high LST crossing 40 °C. Areas around Chhatrapati Shivaji International Airport recorded highest LST inside main city with values in 37 - 38°C range. In general, minimum LST is observed along water bodies such as Tulsi Lake, Vihar Lake and Powai Lake and regions in the vicinity of the sea. LST in these areas has been observed to be in 25°C – 26°C range.

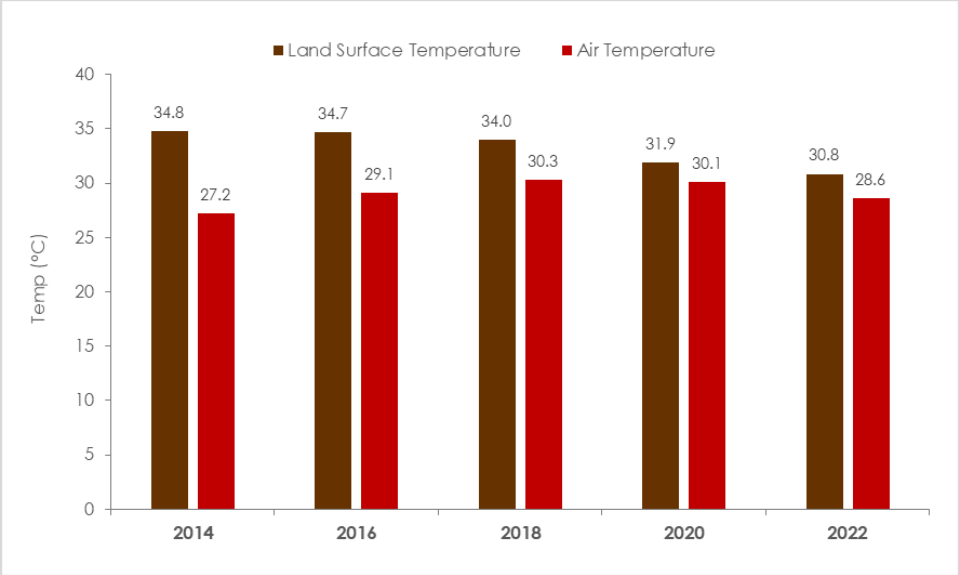
Figure 1: Variation in land surface temperature over Mumbai for 2014, 2016, 2018, 2020 and 2022



Source: CSE analysis of Landsat 8 satellite image from USGS Earth Explorer website

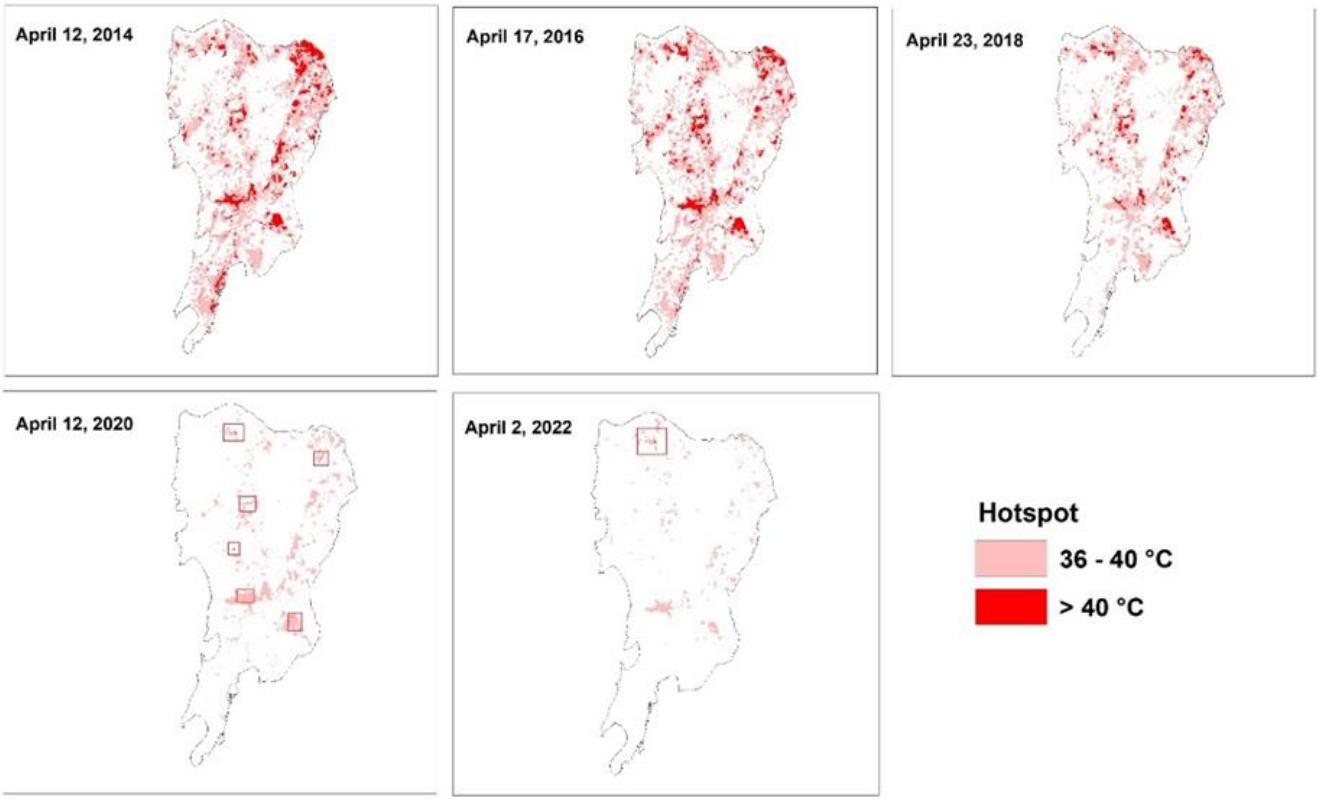
Decreasing Land Surface Temperature on hot days over years: The average LST in Mumbai on April 2, 2022 was 30.8°C. Compared to April 12, 2014 the average LST has decreased by 8°C (see *Graph 4: LST Trend over Mumbai on hot days in 2014, 2016, 2018, 2020 and 2022*). The daily average air temperature has also been lower on April 2, 2022 compared to April 12, 2014. The average LST is getting level with the daily average air temperature recorded at city's primary weather station at Santa Cruz. It used to be relatively higher in 2014 and 2016.

Graph 4: LST Trend over Mumbai on hot days in 2014, 2016, 2018, 2020 and 2022



Note: Average land surface temperature is based on mean of all values recoded over the city and ambient temperature is based on mean of daily values recorded at 2 stations in the city.
Source: CSE analysis of Landsat 8 land surface temperature and IMD weather data from Santa Cruz Meteorological Station

Figure 2: Hotspots identification over Mumbai on hot days in 2014, 2016, 2018, 2020 and 2022

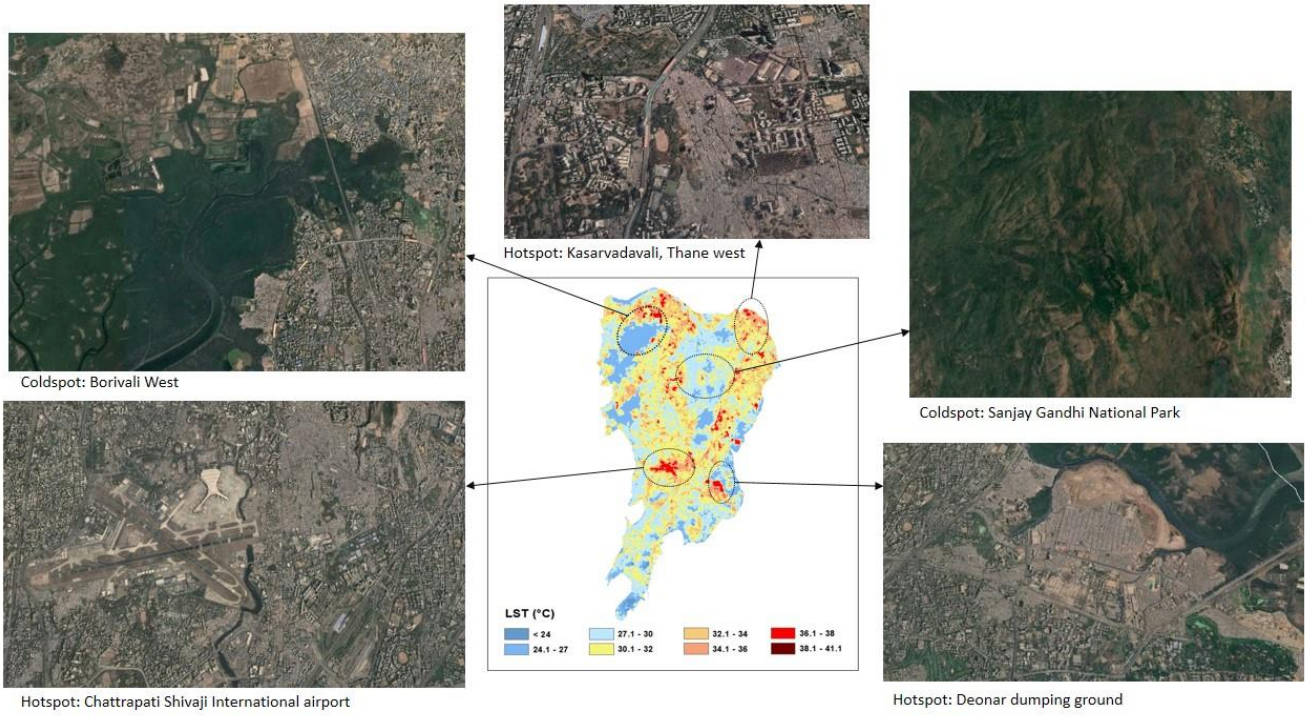


Source: CSE analysis of Landsat 8 satellite image from USGS Earth Explorer website

Identification of heat hotspots over Mumbai: April 12, 2014 showed the most number of hotspot with LST exceeding 40°C followed by April 17, 2016 and April 23, 2018 (see *Figure 2: Hotspots identified over Mumbai on hot days in 2014, 2016, 2018, 2020 and 2022*). The least number of hotspot were observed this year (April 2, 2022), showing only small patch of pixel with temperature above 40°C near the Radha Soami Satsang Beas. Chhatrapati Shivaji International Airport and Deonar dumping ground are other regions within the city that have consistently recorded high LST.

Denuded and densely built areas are the heat hotspots: Hotspot areas were observed in and around the city center, the suburbs surrounding the Chhatrapati Shivaji International Airport and northern outskirts of the city. Coldspots, areas with minimum LST, are observed along water bodies such as Tulsi Lake, Vihar Lake and Powai Lake, and regions in the vicinity of the sea like Colaba. Borivali East is another coldspot in the city (See *Figure 3: Hotspots and Coldspots over Mumbai*).

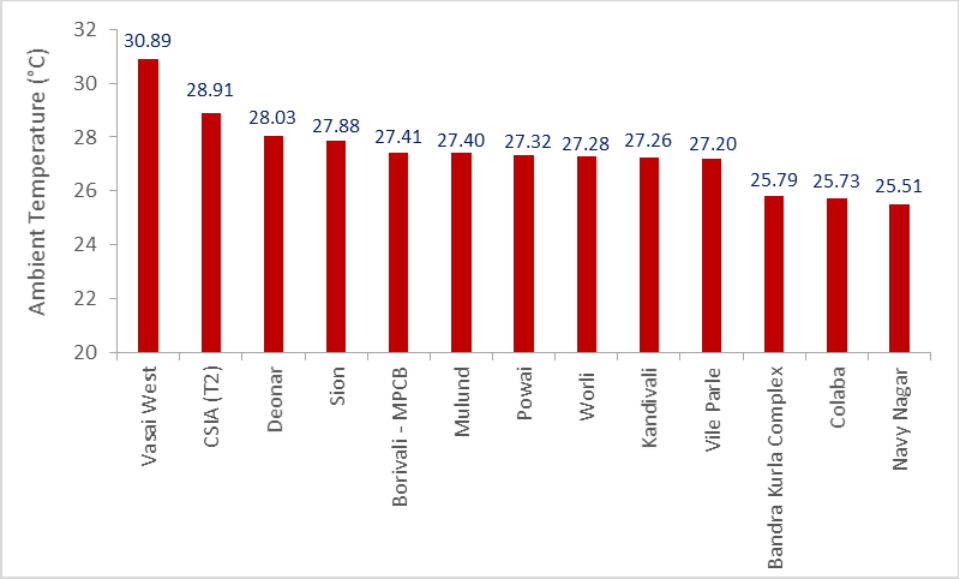
Figure 3: Hotspots and Coldspots over Mumbai



Source: CSE analysis of Landsat 8 satellite image from USGS Earth Explorer website

Air temperature variation among city's stations: Vasai West recorded the highest average air temperature on April 2, 2022 with 30.89°C. It was followed by CSI Airport at 28.91°C (See *Graph 5: Daily average air temperature variation within Mumbai on April 2, 2022*). The daily average air temperature in Navy Nagar was the lowest, although it was still warm at 25.51°C.

Graph 5: Daily average air temperature variation within Mumbai on April 2, 2022



Source: CSE analysis of CPCB's real time air temperature data of 2 April 2022