

Urban Heat Stress in major cities of India: Delhi (Northwest India)

Sharanjeet Kaur and Avikal Somvanshi

Centre for Science and Environment, New Delhi, 4 July, 2022

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 Delhi, 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 Delhi the later analysis is based on 16 May 2014, 21 May 2016, 11 May 2018, 16 May 2020 and 14 May 2022

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



Findings-Heat patterns during pre-monsoon season

Land surface temperature in Delhi highest since 2010, air temperature third hottest: Delhi recorded significant positive anomaly on all three temperature parameters. Air temperature has been 1.77oC hotter than 1981-2010 baseline, while land surface temperature has been 1.95oC hotter. Heat Index is up by 1.64oC compared to 2010-19 baseline. As noted in the India trend, Delhi also shows peaking of premonsoon temperatures in 2016 and had been cooling down until this year (See *Graph 1: Pre-monsoon seasonal temperature anomalies in Delhi (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 continues to climb up despite stabilization of air and land temperatures: March and April have been unusually dry in Delhi but humidity started to rise in May with some scattered rain spells which brought relief from heatwaves. But this spike in humidity has led to increase in heat index in the city indicating increased thermal discomfort among the population. 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 40oC in June (See *Graph 2: Buildup of heat in Delhi air temperature vs heat index (2022)*).

Sirfort and Chandni Chowk were on average hottest neighborhoods based on air temperature and heat index: There is variation of over 6oC in the observed seasonal air temperature among neighborhoods that have official air quality monitoring. Chandni Chowk recorded highest seasonal air temperature average of 34.2oC in the city while Sir Aurobindo Marg with 28.1oC was the coolest. From heat index perspective Sirfort with an average seasonal heat index of 38.2oC edges out Chandni Chowk which had an average seasonal heat index of 36.8oC. Sadipur (29.1oC) and Sir Aurobindo Marg (29.6oC) had lowest average seasonal heat index in the city (See *Graph 3: Distribution of pre-monsoon heat within Delhi air temperature vs heat index*)





Graph 2: Buildup of heat in Delhi 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 Delhi 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 May 16, 2020 when 53.9°C was recorded within city limits. It is followed by May 14, 2022 with maximum LST of 51.8°C. In the previous years, maximum LST was observed to be in mid-40s range (See *Figure 1: Variation in land surface temperature over Delhi for 2014, 2016, 2018, 2020 and 2022*).

Maximum LST is recorded in the south-west part of the city, area around Najafgarh, across all the time periods examined in this study. Apart from Najafgarh, Badarpur and Jaitpur are other neighborhoods that show consistently high LST with levels above 40°C. This year during the heatwave in the month of May, LST across Delhi shot above 38°C that was unusual as the green pockets within the city have not heated up to this magnitude in the previous years. In general, minimum LST is observed along Yamuna River and Okhla bird sanctuary.





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

Increasing Land Surface Temperature on hot days over years: The average LST in Delhi on May 14, 2022 was 41.2°C. Compared to May 16, 2014 the average LST has increased by 9.8°C (see *Graph 4: LST Trend over Delhi during heatwave spells in 2014, 2016, 2018, 2020 and 2022*). The average LST is also getting higher than daily average air temperature recorded at city primary weather station at Safdarjung Airport. It used to be relatively identical on hot days in 2014 and 2016.





Graph 4: LST Trend over Delhi during heatwave spells 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 Safdarjung Meteorological Station



Figure 2: Hotspots identification over Delhi 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 Delhi: May 14, 2022 showed the most number of hotspot with LST exceeding 40°C followed by May 16, 2020; May 11, 2018; and May 21, 2016 (see *Figure 2: Hotspots identified over Delhi on hot days in 2014, 2016, 2018, 2020 and 2022*). The least number of hotspot were observed during 2014, showing only small patch of pixel with temperature above 40°C near Bawana. Maximum LST was higher in 2020 compared to 2022 despite milder heat conditions probably due to massive reduction in PM pollution in the city due to Covid lockdowns. PM pollution partly blocks solar radiation from reaching the ground. In absence of it land is exposed to higher load of solar radiation which leads to high LST.

Denuded and densely built areas are the heat hotspots: Hotspots are observed near Najafgarh, Jafarpur Kalan, Indira Gandhi International airport in the south-west Delhi; Badarpur, Jaitpur, Sangam Vihar and Fatehpur Beri in the south Delhi; Narela and Bawana in the north Delhi; and Shahdara near the Yamuna river bank. The hotspot region in Delhi have significantly increased over years. The south central parts of the city, where LST tends to hover in 36-40°C range, is the only persistent coldspot in the city. (See *Figure 3: Hotspots and Coldspots over Delhi*)

Figure 3: Hotspots and Coldspots over Delhi



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



Air temperature variation among city's stations: Chandni Chowk recorded the highest average air temperature on May 14, 2022 with 40.39°C. It was followed by Punjabi Bagh at 40.29°C, Mundka at 39.5°C, and Paharganj at 39.1°C (See *Graph 5: Daily average air temperature variation within Delhi on May 14, 2022*). The daily average air temperature in Narela was the lowest, although it was still hot at 34.44°C.





Source: CSE analysis of CPCB's real time air temperature data of 14 May 2022

Comparsion of heat conditions between heatwave spells in March and May in Delhi: On March 19, 2022, maximum LST value recorded was 37.2°C with a city average of 29.2°C. However, on May 14, 2022, the maximum LST rose to 51.7 °C with the city average of 41.2°C. The lowest ground temperature rises from 23.3 to 27.2 °C (See Figure 4: Comparison of land surface temperature over Delhi on March 19, 2022 and May 14, 2022). The average and maximum surface temperature increases 11.94°C and 14.51°C from March 19 to May 14, 2022.

In March, the maximum surface temperature was recorded in the south-east and the south-western areas. The neighboring areas in the southwest are Najafgarh, Daulatpur, and Daryapur Khurd; Indira Gandhi International Airport in New Delhi; Badarpur, Ali Vihar and Tigri in the south east; and Jahangirpuri and Bawana in the north, records the temperature above 33°C. The Yamuna River, Okhla bird sanctuary, agricultural areas in the southwest, northwest, and north, and leisure parks in the city's central and south zones had relatively low LST falling below 27°C.

In May, the LST of 44°C or higher was recorded over Southwest, Northwest and North Delhi along with the small stretch over Badarpur and Tigri in the Southeast Delhi and Indira Gandhi International Airport. The recreational parks in the Central and New Delhi recorded LST in 34 – 38°C range. Even the temperature of the water bodies rose to 29-30°C, which were well below 27°C in March.

< 27

27.1 - 29





Figure 4: Comparison of land surface temperature over Delhi on March 19, 2022 and May 14, 2022

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

34.1 - 36

36.1 - 38

29.1 - 32

32.1 - 34

Industrial and agricultural zone record most increase in land surface temperature between March to May: The regions at the city periphery in the North, Southwest, and Northwest Delhi have seen the extremely high surface temperature rise from March 19 to May 14, 2022 (See Figure 5: Change in land surface temperature between March 19, 2022 and May 14, 2022).

44.1 - 47

> 47

38.1 - 40

40.4 - 44

The surface temperature in Narela records the highest increase of 26.5°C, followed by 25.3°C in Bawana, 24°C in Matiala, 23.9°C in Mundka, 22.9°C in Najafgarh, 22.8°C in Burari, and 20.7°C in Karawal Nagar. The temperature greatly increases in agricultural and rural areas varies from 13.6°C to 26°C.

Rajinder Nagar, Ghonda along the banks of Yamuna River, Laxmi Nagar, Badarpur, Okhla, Rohini, Tughlakabad, Sangam Vihar, Deoli, Mehrauli, and the southern region of Chattarpur all recorded temperature rises between 13.6°C and 19°C. LST in the Central and New Delhi rose by 7.6-10.5°C.

Usually high land surface temperatures correspond to areas with low vegetation and desolate terrain. In March the green cover in the city stretched across the rural and agricultural areas in northern and southwestern Delhi as well as along the Yamuna river bank, which kept the land surface temperature as low as 23°C over these land parcels even when the air had begun to blow hot. But, due to agricultural harvesting, the green cover over this region was lost in May, and the land surface temperature in these areas shot up to 47-51°C.

34.1 - 36

36.1 - 38

38.1 - 40

40.4 - 44

29.1 - 32

32.1 - 34

27.1 - 29





Figure 5: Change in land surface temperature between March 19, 2022 and May 14, 2022

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