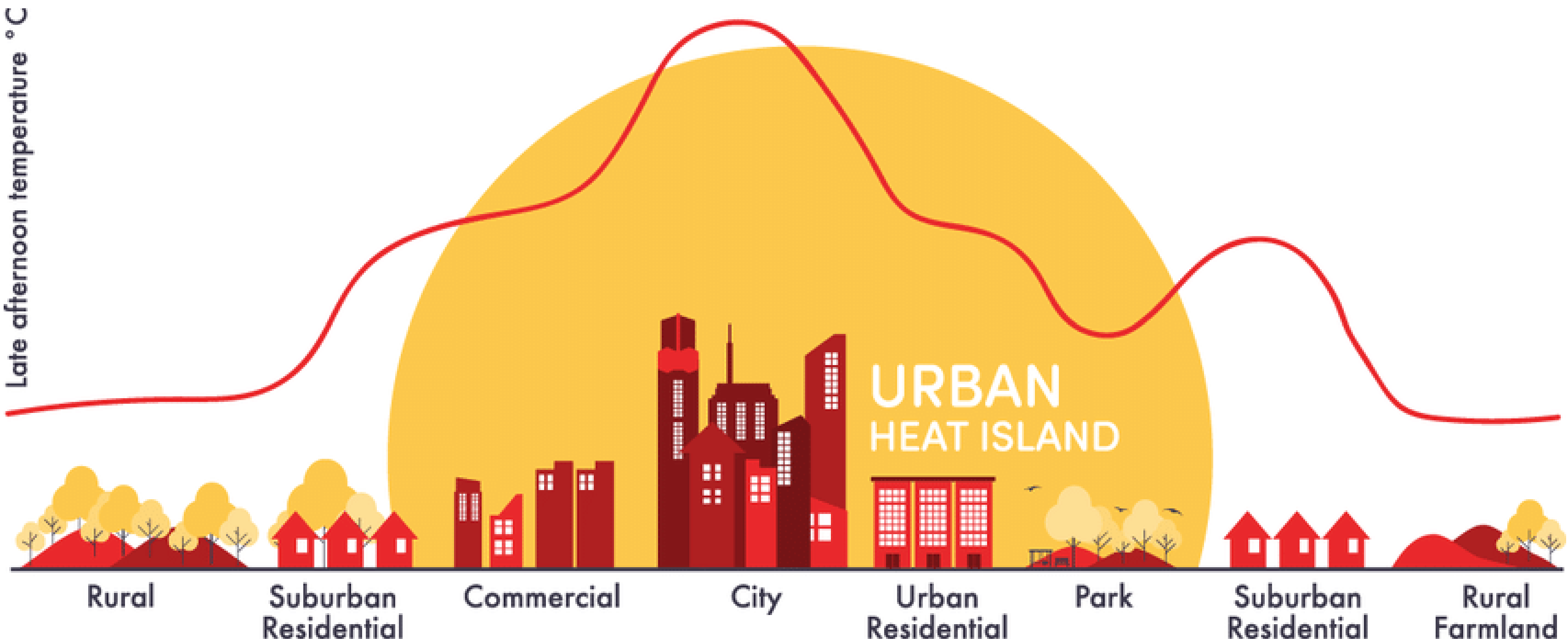
Mapping urban heat island

C.LAKSHUMANAN

urban heat island



Definition of Heat Islands

- A heat island is simply an area, volume, or region in which the temperature is higher than that of the surroundings.
- This very general definition can obviously apply to any scale and environment, from micrometers to thousands of kilometers.
- That is, a heat island can exist on a scale of a few millimeters, as a bubble of hot air surrounded by colder air, or on a scale of thousands of kilometers, such as a high-pressure weather system moving across a relatively cooler air mass. It can also be thought of as a more global or universal phenomenon.
- Thus, a UHI is the difference between the temperature in a certain urban location and that at a given reference point in a nonurban location (e.g., an upwind rural location).

"Urban heat islands"

- "Urban heat islands" occur **when cities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat**.
- Heat islands form **as vegetation is replaced by asphalt and concrete for roads, buildings**, and other structures necessary to accommodate growing populations.
- These surfaces absorb—rather than reflect—the sun's heat, causing surface temperatures and overall ambient temperatures to rise.

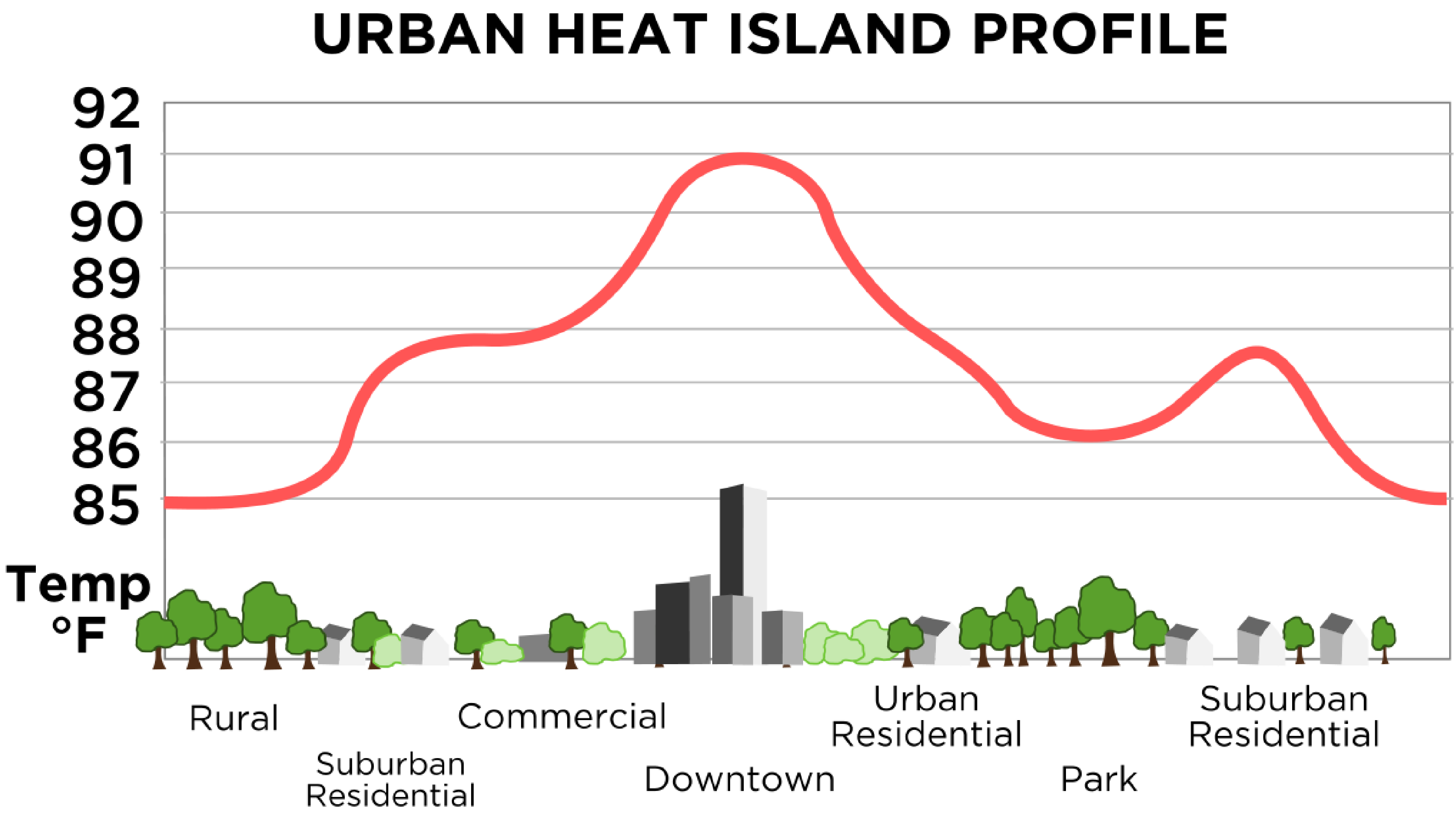
What is urban heat island Index?

- Urban Heat Island Index.
- The Index is **calculated as a positive temperature differential over time between an urban census tract and nearby upwind rural reference points at a height of two meters above ground level**, where people experience heat.

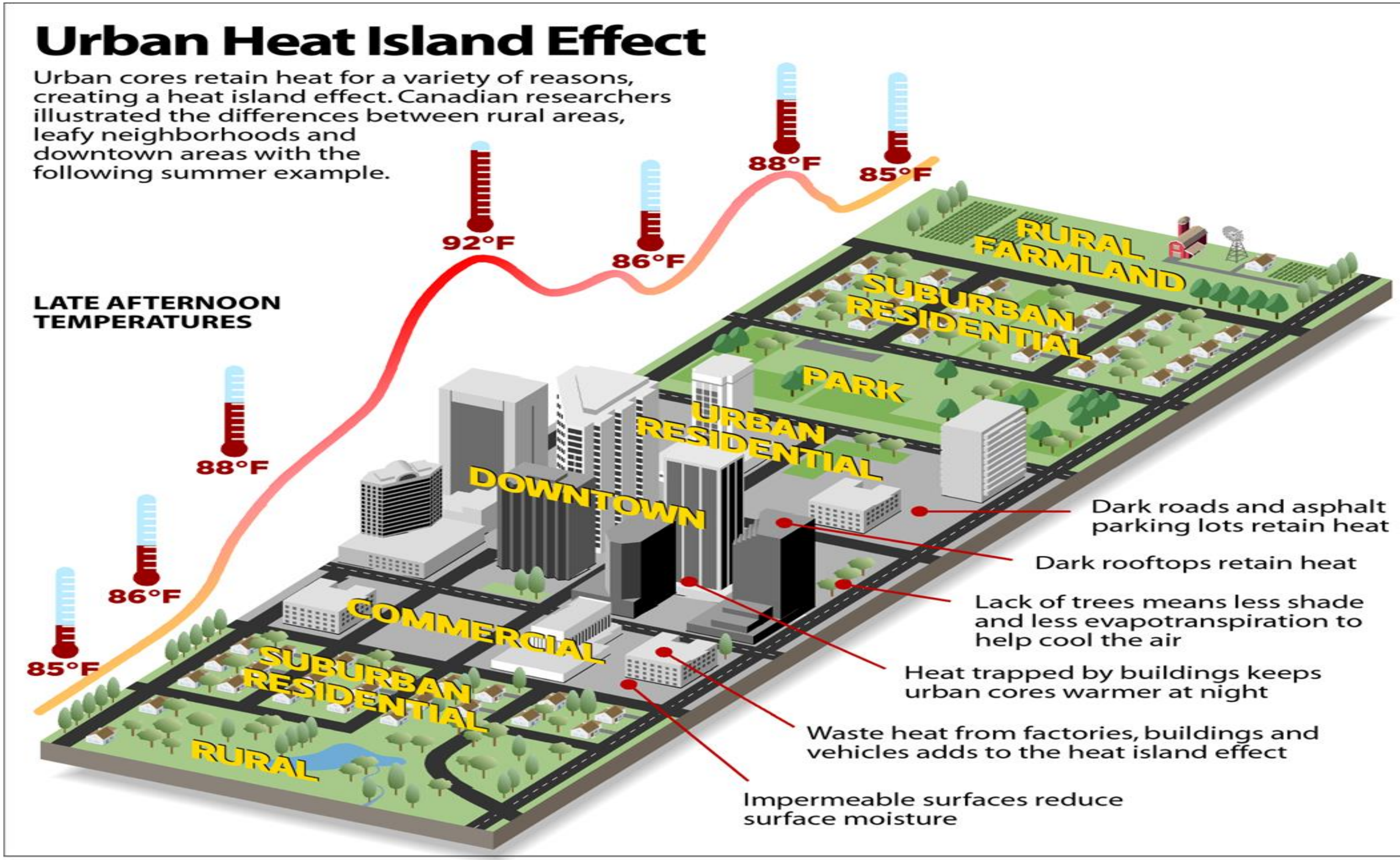
urban heat island

- An urban heat island occurs when **a city experiences much warmer temperatures than nearby rural areas**.
- The difference in temperature between urban and less-developed rural areas has to do with how well the surfaces in each environment absorb and hold heat.

urban heat island



urban heat island EFFECTS



SOURCE: D.S. Lemmen and F.J. Warren, Climate Change Impacts and Adaptation

PAUL HORN / InsideClimate News

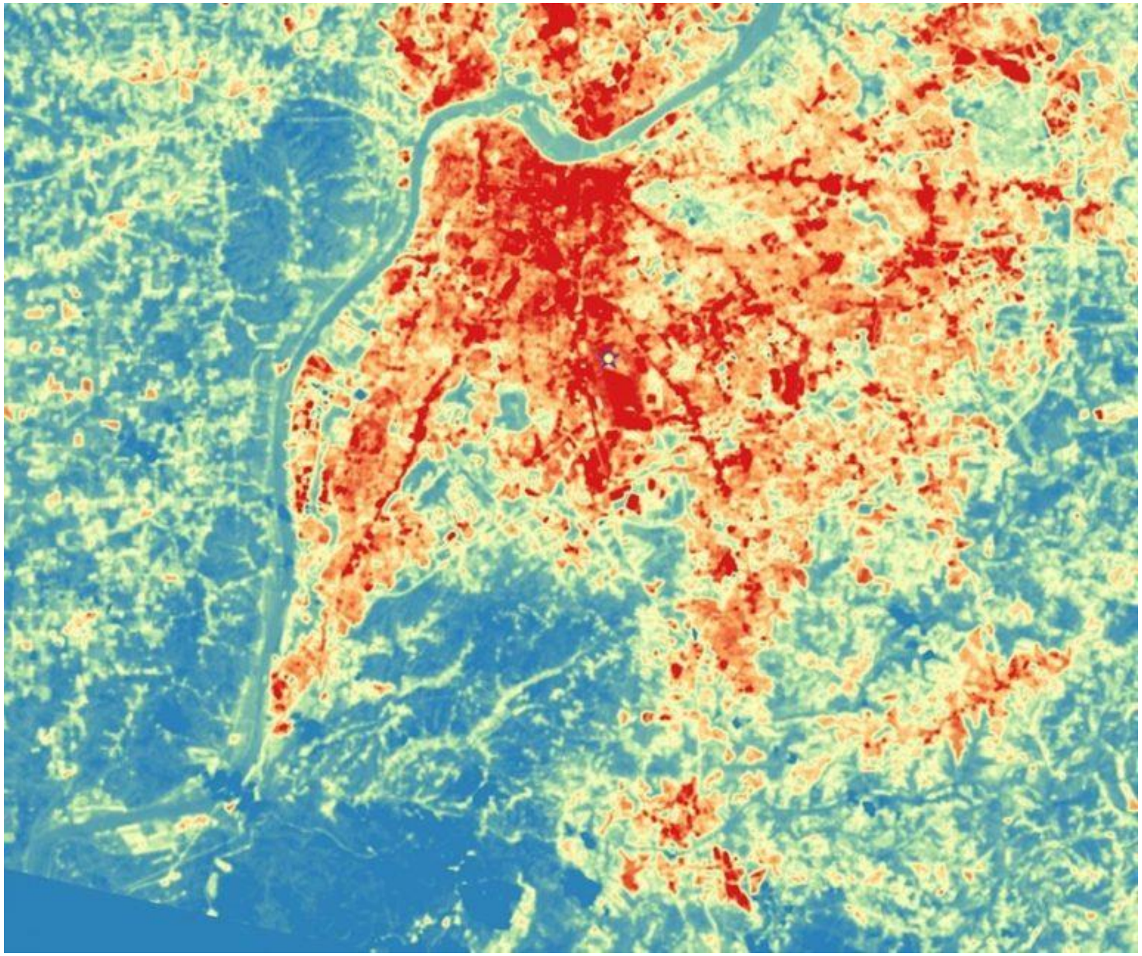
urban heat island (UHI) effects

- The urban heat island (UHI) effect is exacerbating the impact of climate change.
- Increased daytime temperatures, reduced night time cooling and higher air pollution are commonly experienced in high-density cities nowadays.
- Sensitive populations such as children and the elderly are particularly at risk.
- The abnormally hot and humid weather can lead to respiratory difficulties, heatstroke and exhaustion.

Defining the Urban Heat Island Effects

- **Deforestation and rapid urbanization cause changes in the natural landscape.**
- **In high-density cities like Hong Kong, green open space is gradually replaced by skyscrapers, traffics and infrastructure.**
- **Permeable vegetation became impermeable concrete.**
- **Scientists have discovered that when compared to rural environments, the modified land surface (such as dark pavement and roofing) in the urban areas affects the storage and transfer of both radioactive and turbulent heat.**
- **This phenomenon is called the urban heat island (UHI) effect.**

NASA has mapped the temperature difference in an area containing Louisville and the suburban and rural areas in the vicinity.



Urban heat in Louisville (USA), measured by satellite. Source: Climate Central

negative effects

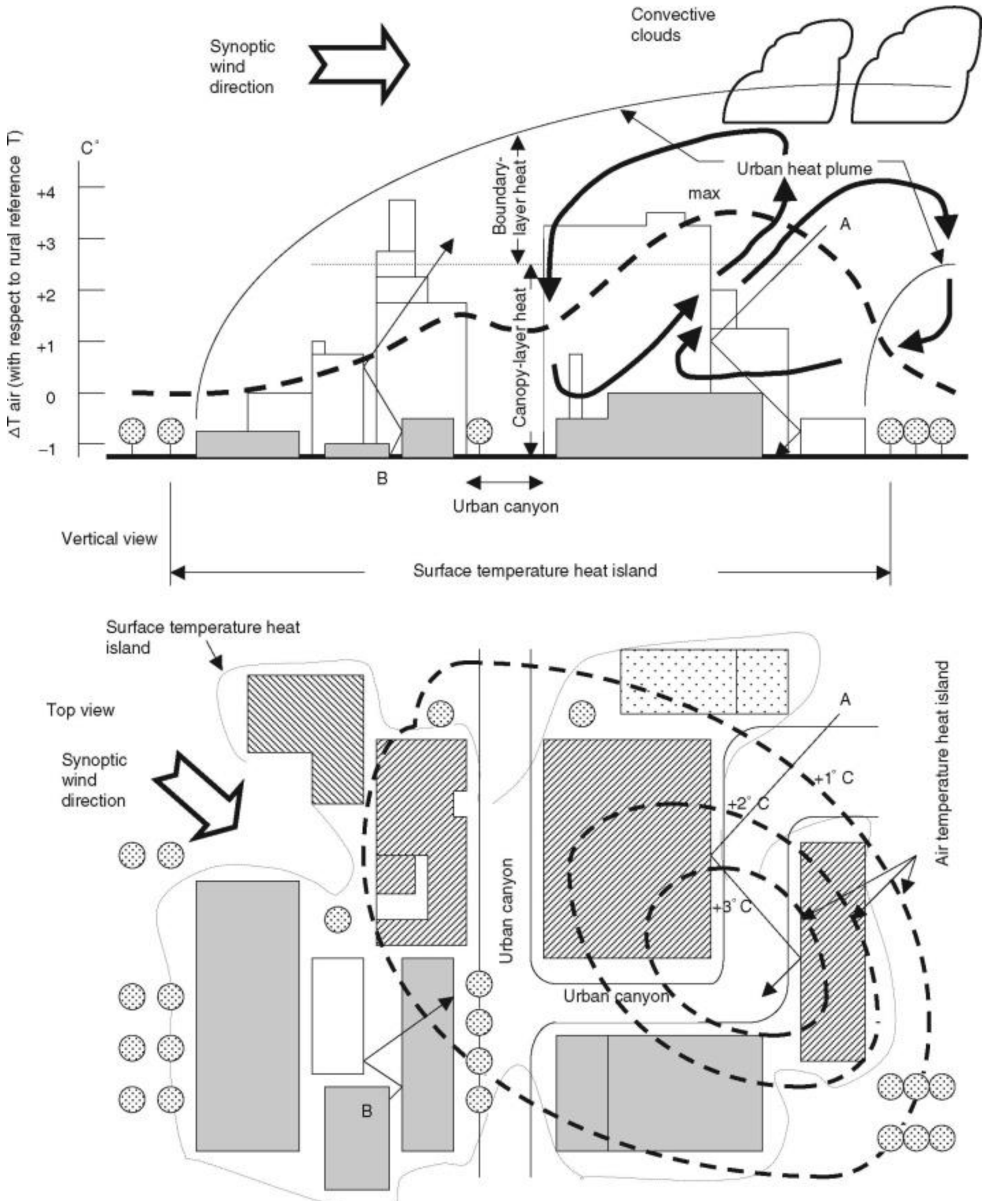
- Aside from the negative effect on quality of life and general activity levels in a city, excessive heat can put younger and older people at risks of dehydration, heat stroke and heat-related mortality.
- Urban heat islands also increase the demand for electrical energy in summer for air conditioning, increasing sulphur dioxide, nitrogen oxide, particulate matter and CO2 emissions.

Effects of UHI

- Cool night air is allowed into the bottom of the building and starts the convective flow that vents the hot day time air through vents in the roof.
- Cool air is also stored in hollow floors and baseboard vents and then released into offices the next day

The model passive cooling system emulates ventilation designs found in termite mounds. Source: National Geographic

Schematic of an urban heat island: (top) vertical view (cross section); (bottom) corresponding projection top view. The thick broken lines show the air temperature UHI intensity read off the scale (°C) at left in the vertical view. The thick arrows show a UHI convective cell advected downwind of the urban center by the synoptic wind. The boundaries of an urban heat plume (also advected downwind) are shown. Other aspects shown are the boundaries of the surface temperature UHI, canopy and boundary layer UHI, convective clouds, incoming and outgoing radiative beams (A and B), and urban canyon.



major impacts of urban heat islands?

- Heat islands contribute to higher daytime temperatures, reduced night time cooling, and higher air-pollution levels.
- These, in turn, contribute to heat-related deaths and heat-related illnesses such as **general discomfort, respiratory difficulties, heat cramps, heat exhaustion, and non-fatal heat stroke**.

Urban heat island types

UHI may be classified into two main types:

i) surface urban heat islands, and
ii) atmospheric urban heat islands (Bhargava et al. 2017; Parlow et al. 2014).

•**Surface urban heat island, SUHI**, namely remotely sensed urban heat island, is usually visualized as a dome of hot air over urban areas with the help of far infrared data that allow to retrieve land surface temperature (LST).

• Using remote sensing, the urban land cover explains the SUHI intensities of many European cities (Zhou et al. 2013). Oke (1982) stated that surface urban heat islands occurred at night as same as at daytime but seemed to be stronger at night than they are at daytime.

•Dry exposed urban surfaces like roads and roofs can be heated to a temperature hotter than that for the air, while in moist surfaces the temperature of the air is usually close to the surface temperature (Berdahl and Bretz 1997).

• As it would be expected in most regions, the SUHI is usually greater in summer than they are in the other seasons as a result of changing in solar radiation and the drier weather Conditions (Oke 1987). The differences in nighttime, SUHI temperatures between urban and non-urban areas are typically 10 to 15 °C, considered higher than the daytime differences which is 5 to 10 °C (Voogt and Oke 2003).

Atmospheric urban heat islands

- The atmospheric urban heat islands may be described as the comparison between warmer air and cooler air in nearby rural areas, which can be divided into two main types:
- 1) Canopy layer urban heat islands and 2) Boundary layer urban heat islands.
- Canopy layer urban heat island exists in the lowest air layer, where people live, and extends from the ground surface to below the tops of urban roofs and vegetation.
- Boundary layer urban heat island begins from the urban roofs and extends up to the point where there is no urban effect of the atmosphere, usually 1.5 km from the surface (Li et al. 2012).
- The effect of atmospheric UHI during the daytime is absent and after sunset shows features similar to the night time SUHI (Bonafoni et al. 2015).
- Atmospheric urban heat island mainly relies on ground-based in-situ measurements of air temperature and can be considered the classical way of assessing the urban heat islands (Parlow et al. 2014).
- It is absolutely necessary that technical terms of urban heat islands are clearly separated because UHI and SUHI are mostly decoupled during daytime (Oke et al. 2017).

Factors influencing affecting urban heat islands

- The formation of UHI is determined by several factors, such as geographical location, size and function of the city, building material properties, synoptic weather, and time.
- Changing the land use and reducing vegetation is one of the most important factors leading to the growth and development of thermal islands, which are formed mainly in cities (He et al. 2007).
- The thermal island generated over the city depends mainly on the total area covered by materials with high capacity to absorb and storage the heat such as asphalt, brick, concrete, and stone. Most of these materials do not have a good reflectivity, that is, the proportion of reflected radiation is relatively low (Abutaleb et al. 2015).
- In addition, the compaction of soils under roads not only increases their carrying capacity, but also increases their heat storage capacity (Abu-Hamdeh 2003).
- In fact, most modern cities are famous for multi-story buildings surrounded by tiled areas, these high buildings tend to catch the sun, so that the heat generated from these buildings increase in the spaces between them, and this helps in a session on the city’s temperature rise.

Land surface temperature and emissivity retrieval methods

- The emissivity of a material can be defined as the ratio of the radiance emitted from this material to that radiance emitted by a black body at the same temperature and wavelength (Li et al. 2013).
- However, the emissivity of land, unlike that of oceans, can differ significantly from the emissivity of the black body which equals one and vary with vegetation, surface moisture, roughness, and viewing angles (Salisbury and D'Aria 1992).
- Satellite sensors can measure radiance covering a wide range of the spectral. Land surface emissivity (LSE) can be estimated with the help of the collecting radiance which contains the combined effects of surface and atmosphere.

Retrieval of temperature(ie)

- The approach to the retrieval of temperature was described in the Landsat 8 User's Handbook. It is also simplified to two separate steps as follows: first, the DN values were converted to radiance by the following formula:
- Lλ=ML∗Qcal+ALLλ=ML∗Qcal+AL

- Where:
- L_λ:spectral radiance (W/(m^2 * sr * µm))
- M_L:radiance multiplicative scaling factor obtained from the metadata
- A_L:radiance additive scaling factor obtained from the metadata
- Q_{cal}:the image pixel value
- Then, the effective at-satellite temperature of the viewed earth-atmosphere system under the assumption of a uniform emissivity could be obtained, from the above spectral radiance by following formula:
- Tc=K2ln(K1Lλ+1)−273.15Tc=K2ln(K1Lλ+1)−273.15

- Where:
- T_C:TOA brightness temperature, in Celsius
- L_λ:spectral radiance (Watts/ (m2 * sr * µm))
- *K1:*thermal conversion constant for the band (K1_CONSTANT_BAND_n from the metadata)
- *K2:*thermal conversion constant for the band (K2_CONSTANT_BAND_n from the metadata)
- In fact, the radiation emitted from a surface is mainly a function of both the surface temperature and emissivity of that surface material. So, the temperature, T calculated with the assumption listed previously, needs to be modified related to the nature of the surface. For this purpose, information regarding surface emissivity for land cover particularly each class appeared in the scene can be defined after spot image classification and NDVI calculation. Consequently, the true surface temperature can be estimated and SUHI identified.

Conclusions

- Satellite-based mapping for SUHIs
- The ground emissivity can be estimated through the land cover pattern from satellite data.
- The study of SUHIs over the city may be appeared as small boundaries- configuration is due to the land use patterns.
- The differences in night time surface temperatures between urban and non-urban areas study of surface urban heat island phenomena through satellite data is more accurate than its study through traditional ground observation data.
- In fact, unlike traditional terrestrial observation methods, satellite images collect data for different regions simultaneously.