Refined Land Surface Temperature Modeling in Urban Environments: SOLWEIG vs. Traditional Remote Sensing

Sharmin Akter, Graduate Student, Department of Geography, Binghamton University

BACKGROUND

With the rise of global temperatures and impacts of urban heat islands on city residents, estimation and modeling of Land Surface Temperature (LST) is incredibly important. LST data are typically collected using spaceborne thermal infrared sensors from the Landsat series, ECOSTRESS, and ASTER. These data, though, lack spatial and temporal detail/resolution. Due to this, modeling efforts often fail to provide comprehensive understanding of microclimates and localized temperature variations. Also, these data cannot fully indicate human outdoor heat stress level as it does not consider surface features and is merely an emittance value from the Earth[1]. Hereby utilizing SOlar and LongWave Environmental Irradiance Geometry model (SOLWEIG) model, fine-scale microclimate modeling using high-resolution urban geometry and local meteorological data provides more accurate, detailed assessments of heat exposure, crucial for mitigating health risks in urban environments[1,2].

OBJECTIVES

1. Compare the SOLWEIG Model output with traditional satellite-based thermal data (Landsat).
2. Identify spatial heat patterns and variations on Binghamton University campus area.

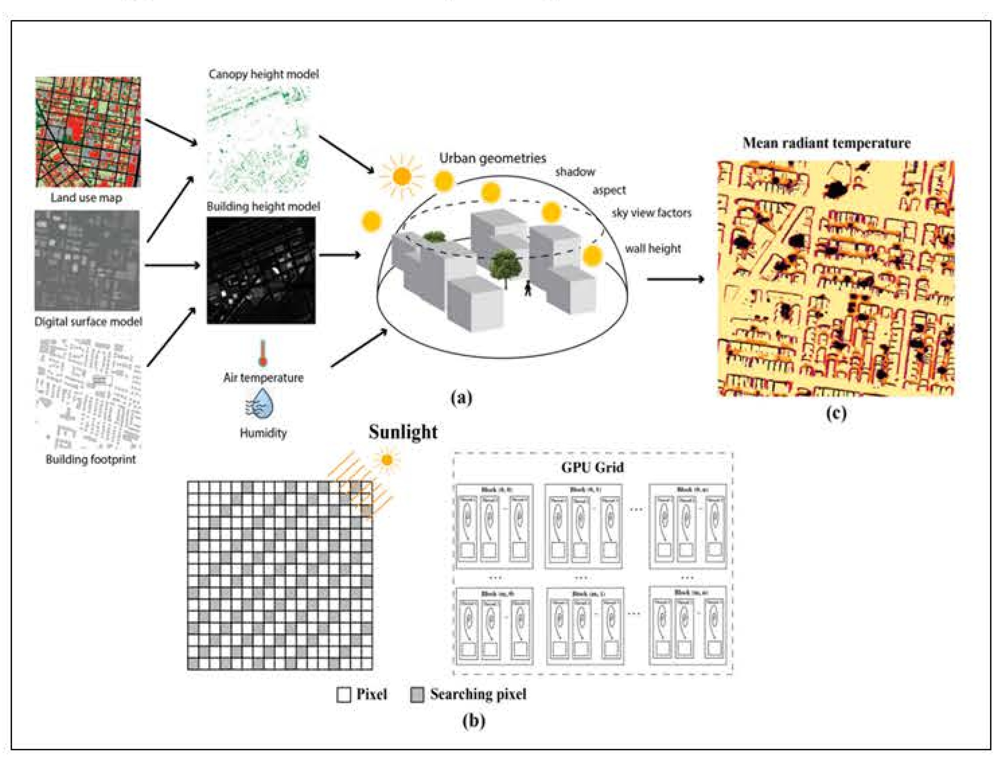


Figure 01: (a) the SOLWEIG model for computing Tmrt, (b) the GPU accelerated algorithm [1]

What's special about SOLWEIG Model?

This model simulates solar radiation and shading based on urban geometry, building heights, vegetation, and meteorological data providing detailed estimates of solar access and shade patterns for assessing pedestrian comfort and energy efficiency.

METHODOLOGY

- Landsat 8-9 LST data collected with <5% cloud cover from 2019 to the present within the summer months of June, July, and August.
- Computing Mean Radiant Temperature (Tmrt) using SOLWEIG Model.
- Comparing the outputs from Landsat and SOLWEIG.

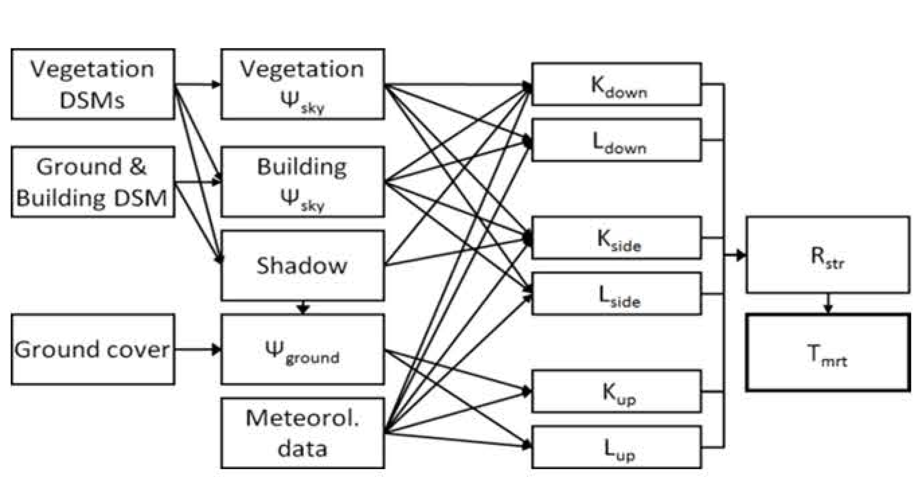


Figure 02: Overview of SOLWEIG [3]

DATA PREPARATION AND ANALYSIS

Identification and preparation of model inputs

Model Input	Process	Data Sources
DSM, DTM	Preparation of High Resolution (1m) DSM, DTM using Lidar Point Cloud Data.	NOAA, 2020
CDSM	Preparation of Canopy DSM (1m) from Lidar Point cloud	NOAA, 2020
Building Height and Aspect	Calculated from DSM using building footprint data	NYS GIS Clearinghouse (2024)
Meteorological data	Collecting hourly Air temperature (degC), Relative Humidity (%), Wind Speed (m/s), Direct radiation (W/m²), Diffused Radiation (W/m²), Rainfall (mm)	National Renewable Energy Laboratory (2020)
Other Parameters	Absorption of shortwave and longwave radiation, Walls Albedo & Emissivity, Ground Albedo & Emissivity	Model default

Calculation Process

$$T_{mrt} = \sqrt[4]{R/\varepsilon_p \sigma} - 273.15$$

εp is the emissivity of the human body (standard value 0.97), σ is the Stefan–Boltzmann constant, and R denotes total radiation exposure as the sum of short and long wave radiation from above, below, and the four cardinal directions.

The R can be calculated as,

$$R = \xi_k \sum_{1}^{6} K_i F_i + \varepsilon_p \sum_{1}^{6} L_i F_i$$

Ki is the shortwave radiation component from 6 directions (north, south, west, east, top and bottom), Li is the longwave radiation, Fi is the angular factor between a person and the surrounding environment, ξk is the absorption coefficient for shortwave radiation (standard value 0.7)

This study adopted the previously developed GPU-accelerated SOlar and LongWave Environmental Irradiance Geometry model (SOLWEIG) model to calculate the Tmrt based on the input urban 3D model and the meteorological data[1].

MODEL OUTPUT AND INTERPRETATION

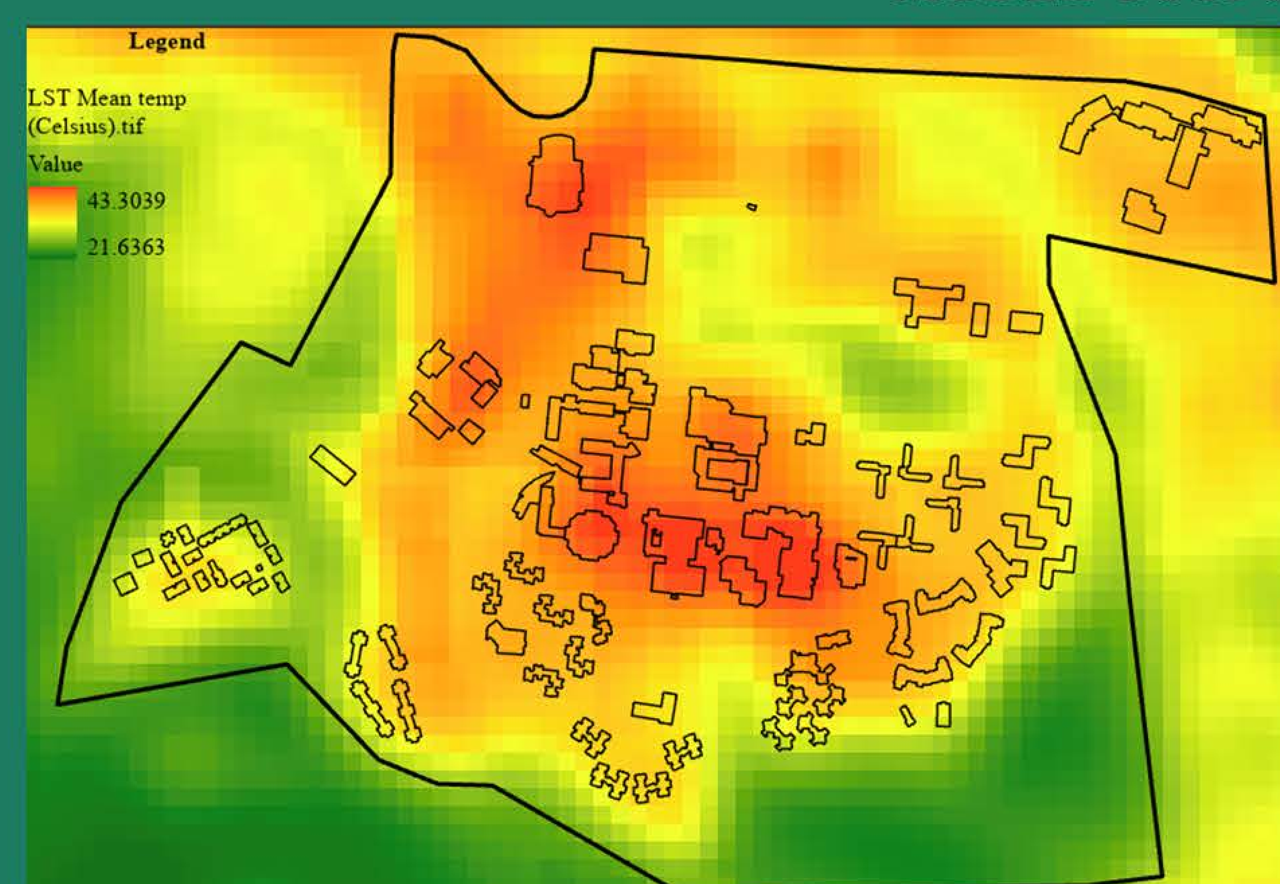


Figure 03: Land Surface Temperature (LST) from Landsat

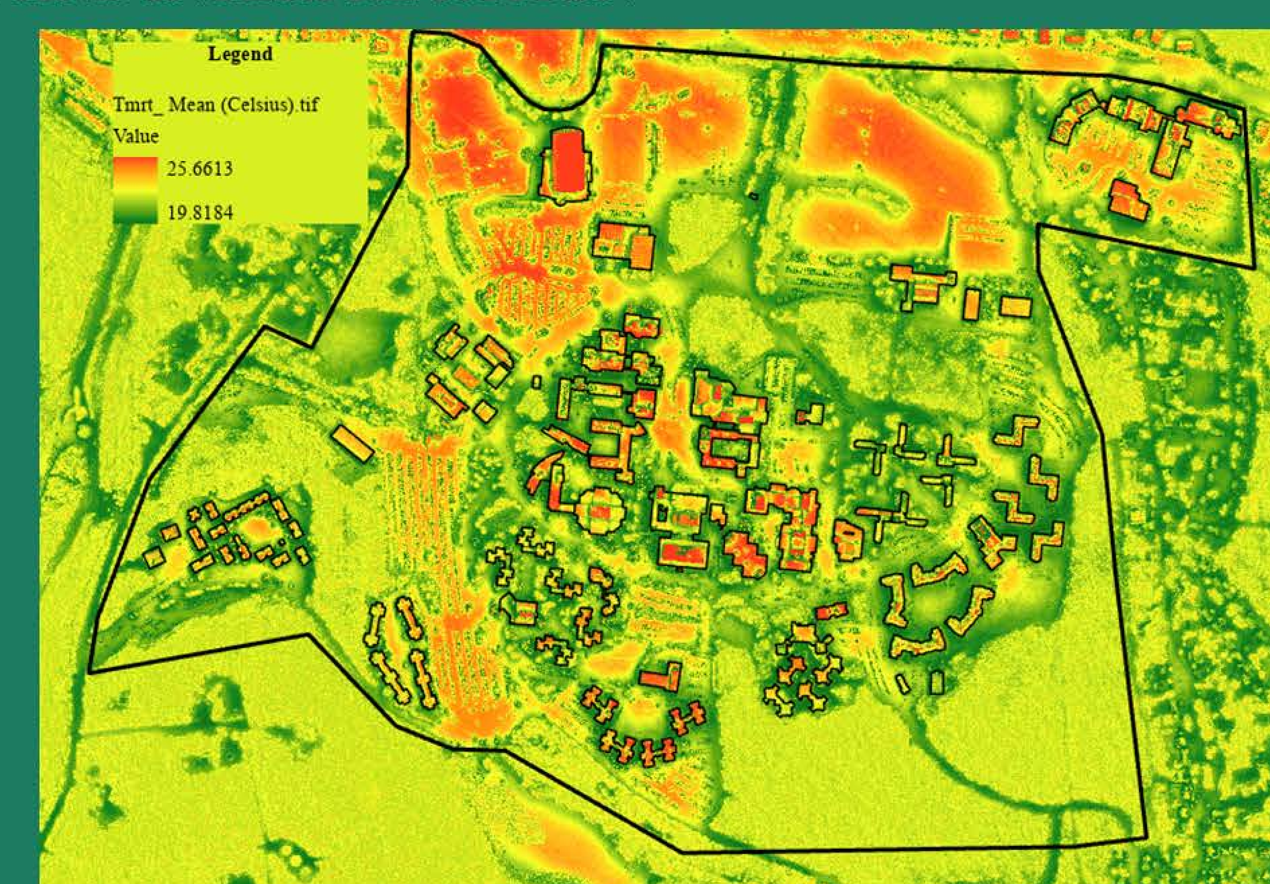


Figure 04: Mean Radiant temperature (Tmrt) from SOLWEIG Model

- Temperature data derived from the Landsat was compared to the Model Output. **SOLWEIG shows more precise spatial variation of heat** (Fig 04).
- We can get map of hourly heat variation, daytime and nighttime mean heat and areas having constantly higher heat over the day from the model.
- A single day of 2020 (July 1st) was considered to run the model and the outputs are here.
- **Nighttime mean temperature ranged in between 13°C to 22°C.** Campus built-up area is comparatively cooler than the surrounding forest area.
- **Daytime mean temperature ranged in between 22°C to 47 °C.** Parking lots and building roofs are the hottest place for the whole daytime.
- Large parking lots near the event center has constantly more than 32°C for around 20.8% time of the day and forested area never experienced this temp.

Figure 05: Nighttime Temperature Variation from Model

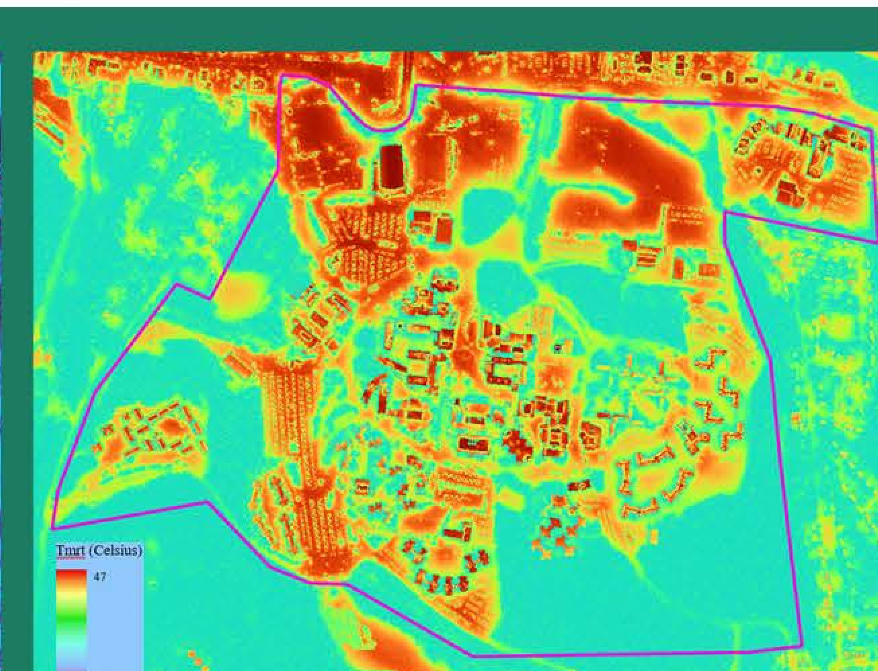


Figure 06: Daytime Temperature Variation from Model

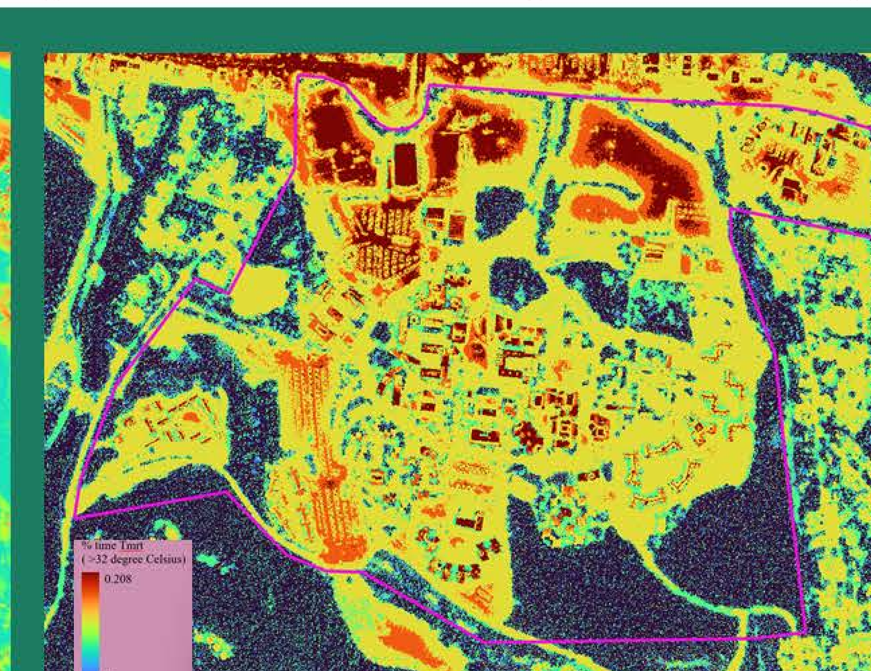
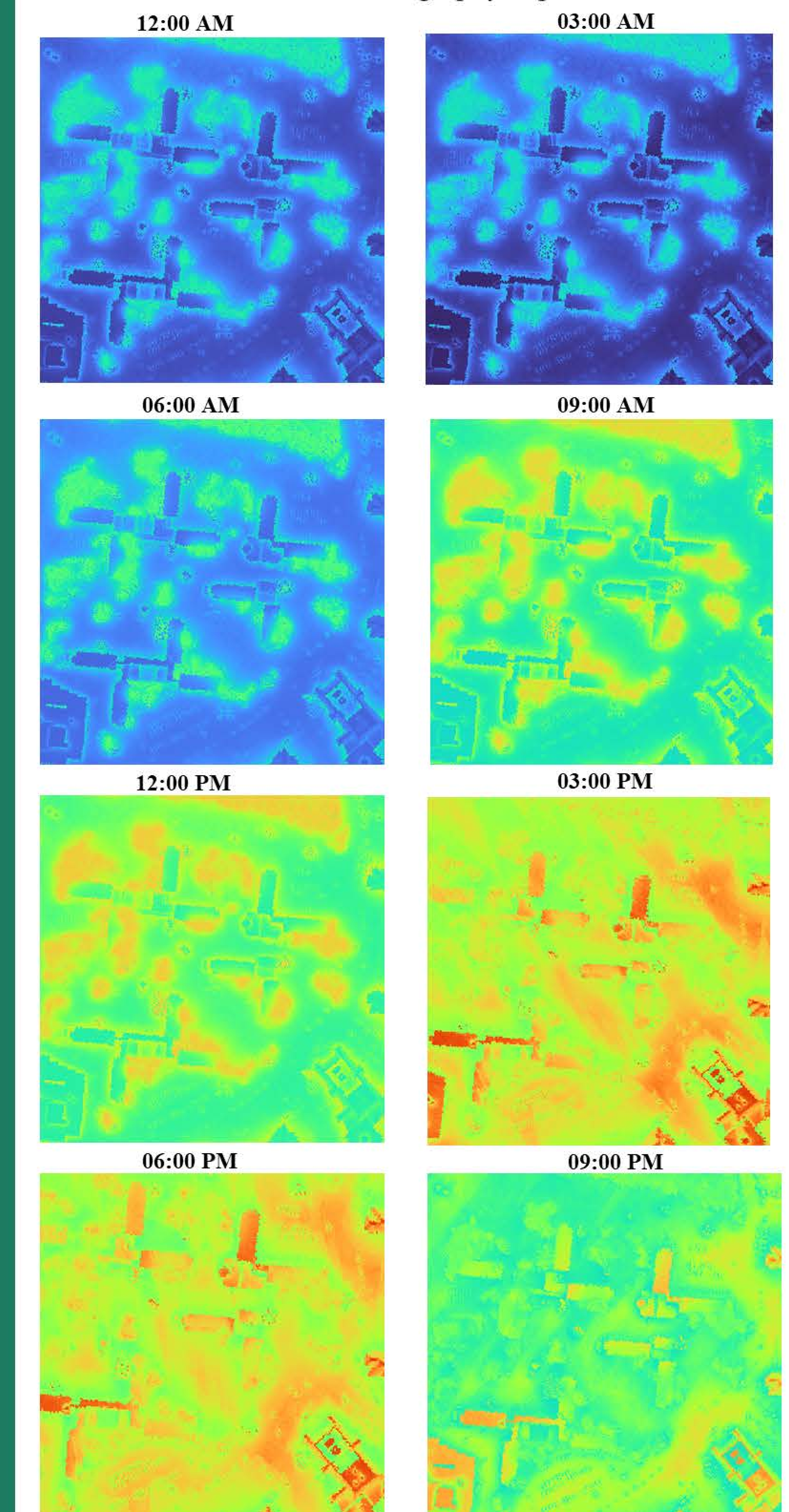


Figure 07: Temperature Vulnerable Area

FINDINGS

24 hours heat variation at Geography department area.



DISCUSSION

- Use of SOLWEIG Model is best for urban microclimate analysis, particularly in studying heat islands, thermal comfort, and urban planning at a much finer spatial resolution (ideal for specific neighborhoods or cities).
- This model is computationally intensive, complex and requires large number of variables input.
- Preparation of variables is time consuming and for larger study area, it requires much time to run the model.
- Model is not best for large-scale, long-term, and multi-temporal land surface change analysis

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REFERENCES

1. Li X 2021 Investigating the spatial distribution of resident's outdoor heat exposure across neighborhoods of Philadelphia, Pennsylvania using urban microclimate modeling Sustain. Cities Soc. 72 103066
2. Li X, Chakraborty T C and Wang G 2023 Comparing land surface temperature and mean radiant temperature for urban heat mapping in Philadelphia Urban Clim.51 101615
3. https://umepdocs.readthedocs.io/projects/tutorial/en/latest/Tutorials/IntroductionToSolweig.html