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Monitoring Urban Heat Islands Using Thermal Remote Sensing Data

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Abstract

Urban Heat Islands (UHIs) represent a significant environmental concern in modern cities, where anthropogenic activities and reduced vegetation contribute to elevated surface and atmospheric temperatures compared to surrounding rural areas. Thermal remote sensing provides an efficient, large-scale, and repeatable approach to monitor, quantify, and analyze UHI effects using satellite-derived land surface temperature (LST) data. This paper examines the application of thermal remote sensing in detecting and mapping UHIs, highlights methodologies for data acquisition and processing, and discusses case studies demonstrating the relationship between LST patterns, urban morphology, and land use changes. Key thermal sensors, such as Landsat Thermal Infrared Sensor (TIRS), MODIS, and ECOSTRESS, are reviewed for their suitability in UHI monitoring. Additionally, the integration of remote sensing data with geographic information systems (GIS) is explored to provide spatially explicit insights for urban climate adaptation strategies.

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Keywords: *Urban Heat Island, Thermal Remote Sensing, Land Surface Temperature, Satellite Data, Urban Climate, MODIS, Landsat, GIS.*

INTRODUCTION

Urban Heat Islands (UHIs) occur when metropolitan areas experience higher temperatures than their surrounding rural regions. This phenomenon results from changes in land cover, excessive energy consumption, and reduced vegetation cover. The elevated temperatures can exacerbate energy demands, increase air pollution levels, and intensify health risks, especially during heatwaves.

Monitoring UHIs is critical for sustainable urban planning, climate adaptation, and mitigation strategies. Conventional ground-based monitoring is accurate but limited in spatial coverage. Thermal remote sensing, however, allows for large-scale, consistent, and cost-effective monitoring by capturing land surface temperature (LST) over wide areas at regular intervals.

THERMAL REMOTE SENSING PRINCIPLES FOR UHI MONITORING

Thermal remote sensing involves detecting emitted thermal infrared (TIR) radiation from the Earth's surface, which correlates with surface temperature. The key principles include:

1. **Thermal Radiation Measurement** – All objects emit radiation proportional to their temperature; satellites measure this in the TIR region (8–14 μm).
2. **Emissivity Correction** – Urban materials like asphalt and concrete have high emissivity, which influences LST calculations.
3. **Atmospheric Correction** – Removing atmospheric effects ensures accurate temperature estimation.

KEY SATELLITE DATA SOURCES

Satellite/Sensor	Spatial Resolution	Temporal Resolution	Key Applications in UHI
Landsat TIRS	100 m	16 days	Detailed city-scale UHI mapping
MODIS	1 km	Daily	Regional and seasonal UHI trends

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Satellite/Sensor	Spatial Resolution	Temporal Resolution	Key Applications in UHI
ECOSTRESS	70 m	Variable (3–5 days)	Heat stress analysis at neighborhood scale

Table 1: Common thermal remote sensing platforms for UHI monitoring, highlighting their resolution and application suitability.

DATA PROCESSING WORKFLOW

The thermal remote sensing workflow for UHI monitoring involves:

1. **Data Acquisition** – Downloading TIR data from USGS Earth Explorer, NASA LAADS, or ESA Copernicus portals.
2. **Radiometric Calibration** – Converting raw digital numbers to radiance values.
3. **Atmospheric Correction** – Using algorithms like Radiative Transfer Model (RTM) to adjust for atmospheric effects.
4. **Emissivity Assignment** – Applying NDVI-based or land cover-based emissivity models.
5. **LST Retrieval** – Converting corrected radiance into temperature values using the Planck function.
6. **UHI Mapping** – Classifying LST values to highlight UHI zones using GIS tools.

CASE STUDY: DELHI, INDIA

Thermal remote sensing was applied to monitor UHIs in Delhi using Landsat 8 TIRS data for May 2023. The results revealed a temperature gradient of up to 6°C between dense urban cores and surrounding rural areas. High LST zones were correlated with industrial districts and high-density residential areas, while lower LST values corresponded to parks, lakes, and forested regions.

ADVANTAGES AND LIMITATIONS

Advantages:

- Large-scale spatial coverage
- Multi-temporal analysis capability

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- Non-invasive and repeatable measurements

Limitations:

- Cloud cover interference
- Limited temporal resolution for certain satellites
- Requires atmospheric correction for accurate results

INTEGRATING REMOTE SENSING WITH GIS

GIS enables integration of LST maps with other spatial datasets such as land use, vegetation cover, and population density. This integration supports decision-making for urban planners, allowing targeted interventions such as increasing green spaces or optimizing building materials.

STRATEGIES FOR UHI MITIGATION

Based on thermal remote sensing findings, several strategies can be recommended:

- **Urban Greening** – Expanding parks, green roofs, and urban forestry.
- **Cool Roofs and Pavements** – Using reflective materials to reduce heat absorption.
- **Water Bodies** – Incorporating artificial lakes and fountains to enhance cooling.

CONCLUSION

Thermal remote sensing has revolutionized the way UHIs are monitored and understood. It provides accurate, consistent, and spatially detailed temperature data that can inform sustainable urban design and climate adaptation measures. While limitations like cloud cover remain, advancements in sensor technology and data processing are expanding the potential of thermal imagery for urban climate studies. Future developments in high-resolution thermal sensors and machine learning-based analysis promise even more precise and actionable insights for UHI mitigation.

REFERENCES

1. Voogt, J.A., & Oke, T.R., “Thermal Remote Sensing of Urban Climates,” Remote Sensing of Environment, vol. 86, no. 3, pp. 370–384, 2003.

Page 48-51 © MANTECH PUBLIATIONS 2016. All Rights Reserved

2. Weng, Q., Lu, D., & Schubring, J., "Estimation of Land Surface Temperature–Vegetation Abundance Relationship for Urban Heat Island Studies," Remote Sensing of Environment, vol. 89, no. 4, pp. 467–483, 2004.

3. NASA, "ECOSTRESS Science Overview," [Online]. Available: https://ecostress.jpl.nasa.gov

4. USGS, "Landsat Thermal Data Products," [Online]. Available: https://landsat.usgs.gov

5. Li, X., Zhou, Y., "Urban Heat Island Mapping Using MODIS Land Surface Temperature Data," Remote Sensing, vol. 9, no. 6, pp. 1–18, 2017.

6. Oke, T.R., "The Energetic Basis of the Urban Heat Island," Quarterly Journal of the Royal Meteorological Society, vol. 108, pp. 1–24, 1982.

7. Chudnovsky, A., Ben-Dor, E., & Saaroni, H., "Diurnal Thermal Behavior of Selected Urban Objects," International Journal of Remote Sensing, vol. 25, no. 15, pp. 3117–3138, 2004.

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