Preliminary Evaluation of the Local Thermal Impacts of Data Centers Using Satellite Land Surface Temperature Products

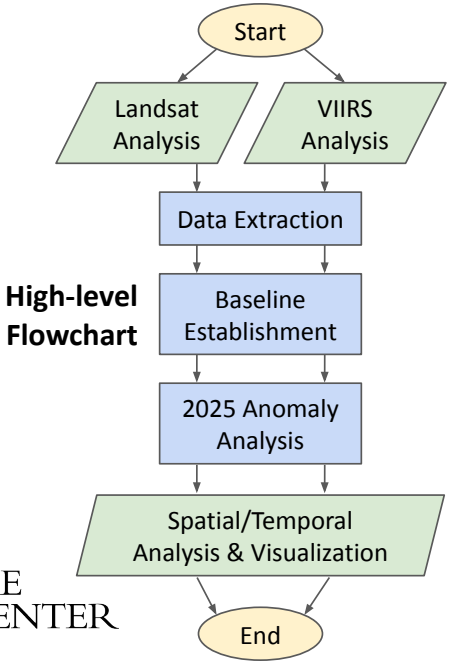
Claire Sun Mentor: Dr. Yuling Liu

Background

- Data centers are associated with an increased demand for electricity, fossil fuels, cooling, and infrastructure
- Land surface temperature (LST) is effective for measuring local thermal impacts
- LST products at different spatial resolutions are used: Landsat 8/9 and NOAA VIIRS LST

Objective: Evaluate the spatial extent and temporal characteristics of data center thermal effects using Landsat 8/9 and NOAA VIIRS LST products across stations in different climate zones.

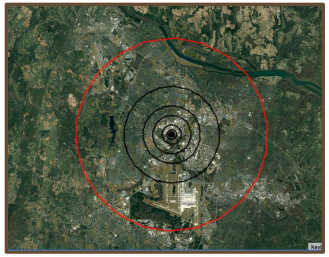
High-level Flowchart



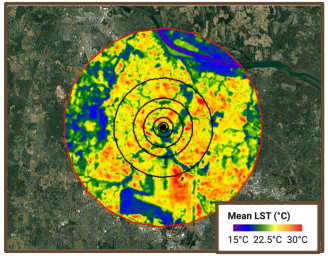
Methodology

- Three representative data center regions with varied land cover and climate conditions: Ashburn, VA (urban), Reno/Sparks, NV (desert), and Altoona, IA (agricultural)
- Multi-year monthly LST climatology for historical baseline
- Time series analysis for temporal variations
  - Anomaly analysis comparing 2025 conditions to baselines
- Multi-tier buffer ring analyses to characterize spatial variation and decay of LST
  - Distance scales appropriate for each satellite product

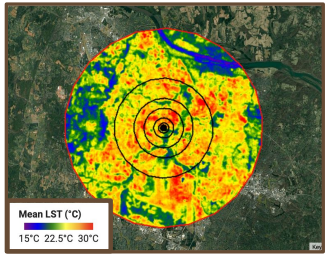
EARTH SYSTEM SCIENCE INTERDISCIPLINARY CENTER



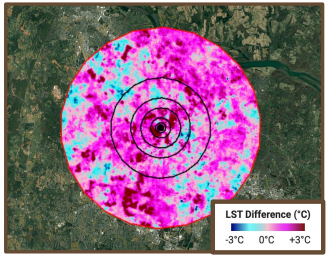
Background



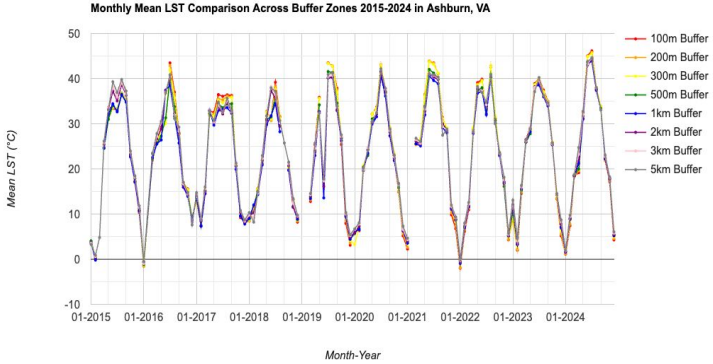
Historical (2015-2024) Mean LST (Landsat)



2025 Mean LST (Landsat)



LST Difference (Landsat)



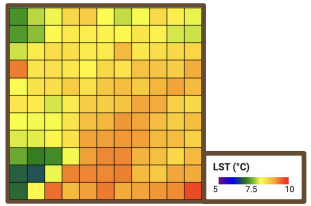
Spatial Analysis

- Clear thermal gradient (Landsat): higher LSTs in inner buffers than outer buffers
- Uniform spatial footprint across all buffer zones (VIIRS)
- Higher mean LST in 2025 across all buffer sizes compared to baseline in both Landsat and VIIRS (nighttime)

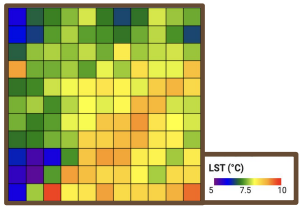
Temporal Analysis

- Daytime summer warming (Landsat): increasing trend in mean LST 2015-2024
- Relatively stable historical thermal conditions, but 2025 VIIRS LST notably higher than the historical mean

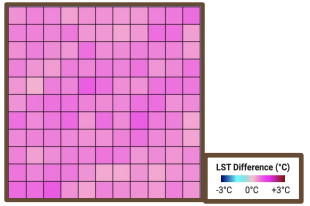
Ashburn, VA



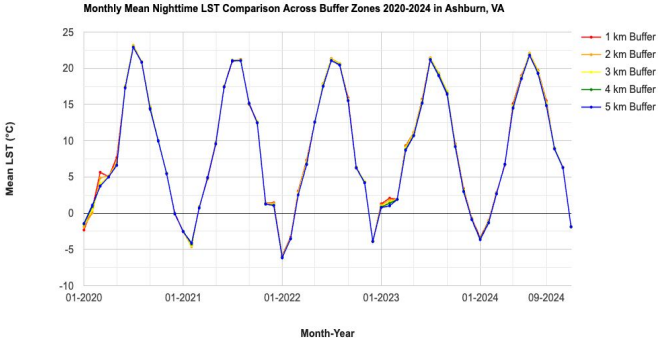
Historical (2020- 2024) Monthly Mean LST (VIIRS)



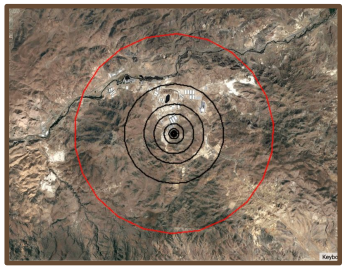
2025 Mean LST (VIIRS)



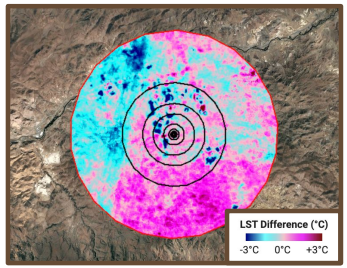
LST Difference (VIIRS)



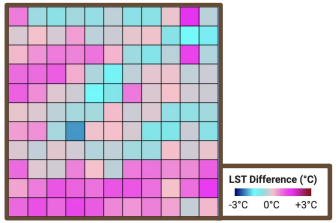
Top Left: Landsat daytime plots **Top Right:** VIIRS nighttime plots **Bottom Left:** Landsat daytime monthly mean LST time series across buffer zones (2015-2024) **Bottom Right:** VIIRS nighttime monthly mean time series across buffer zones (2020-2024)



Background



LST Difference (Landsat)

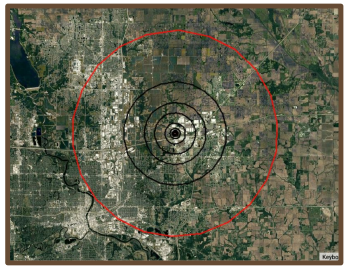


LST Difference (VIIRS)

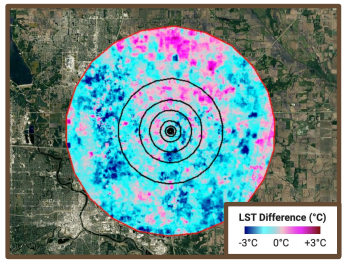
Reno/ Sparks, NV

Landsat v.s. VIIRS

- Spatial consistency: daytime difference maps from both sensors align in magnitude and spatial patterns
- Regional variations: Reno/Sparks and Altoona exhibit different thermal difference trends

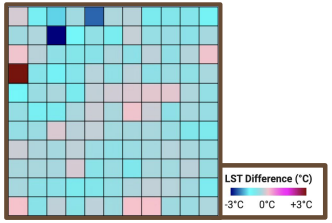


Background



LST Difference (Landsat)

Altoona, IA



LST Difference (VIIRS)

Conclusions

Long term time series

- Landsat: Clear, gradual increasing trend in mean LST over historical period (2015-2024), particularly summer
- VIIRS (Nighttime): Relatively stable historical thermal conditions over time across all buffer zones

Station-specific 2025 anomalies varied significantly by location, influenced by local climate and land cover

- Ashburn: Consistently higher LST across all buffer sizes
- Reno/Sparks: Mixed spatial patterns (localized warming and cooling)
- Altoona: Consistently lower LST across all buffer sizes