Comparing Urban Heat Island Intensity across the United States for Summer 2023

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ABSTRACT

Urban Heat Islands (UHIs) drive up temperatures in densely built environments, affecting everything from energy consumption and public health to local ecosystems. This study uses data from multiple satellite platforms—including NOAA's Visible Infrared Imaging Radiometer Suite (VIIRS), NASA's Landsat 8 Surface Reflectance, and Google's Dynamic World Land Cover—to explore how 21 major U.S. cities (three in each region outlined by the Fifth National Climate Assessment) experienced summer heat from 2017 to 2023. UHI intensity is measured by comparing land surface temperatures in urban areas to those in nearby rural regions, while VIIRS nighttime radiance helps illustrate the extent of urban development. Our findings show a clear pattern: cities with brighter nighttime lights tend to have stronger UHIs, underscoring how factors like population density, building materials, and available green space can shape local heat conditions. By spotlighting the summer of 2023—one of the hottest on record just before 2024—we see how global warming may be intensifying these urban heat challenges. We also factor in extreme heat days (those in the top 5% of maximum temperatures), revealing a strong link between UHI intensity and the frequency of extreme hot days. These insights highlight the pressing need for measures such as planting more trees, using reflective surfaces, and adopting other cooling strategies to help cities cope with rising temperatures and bolster resilience.

RESEARCH QUESTION

1. How strongly do nighttime radiance measurements from VIIRS correlate with urban heat island intensity (UHI) during summer months?
2. Does UHI intensity vary across different regions in the lower continuous United States?
3. Do areas with higher nighttime radiance experience more pronounced effects during extreme heat events?

DATA AND METHODS

Data Acquistion: VIIRS Radiance (NOAA), Landsat 8 Surface Reflectance (NASA/USGS), Dynamic World Land Cover (Google), NOAA CPC, NCA5 Regional Definition.

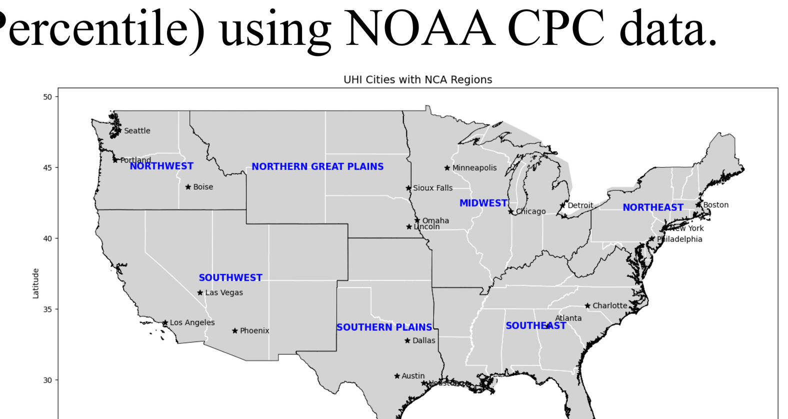
Preprocessing: Scaled reflectance & thermal bands, removing cloud pixels.

Metrics:

- $National\ Difference\ Vegetation\ Index\ (NDVI) = \frac{NIR-Red}{NIR+Red}$ (Landsat 8 to classify vegetation)
- $Emissivity = 0.004x\left(\frac{NDVI-NDVI_{min}}{NDVI_{max}-NDVI_{min}}\right)^2 + 0.986$ (Calculated to accurately assess Land Surface Temperature (LST))
- $LST = \frac{Thermal\ Band\ (TB)}{1+0.00115\ x\left(\frac{TB}{1.438}\right)x\ \log(Emissivity)} - 273.15$
- $UHI\ Intensity = |LST_{urban} - LST_{rural}|$

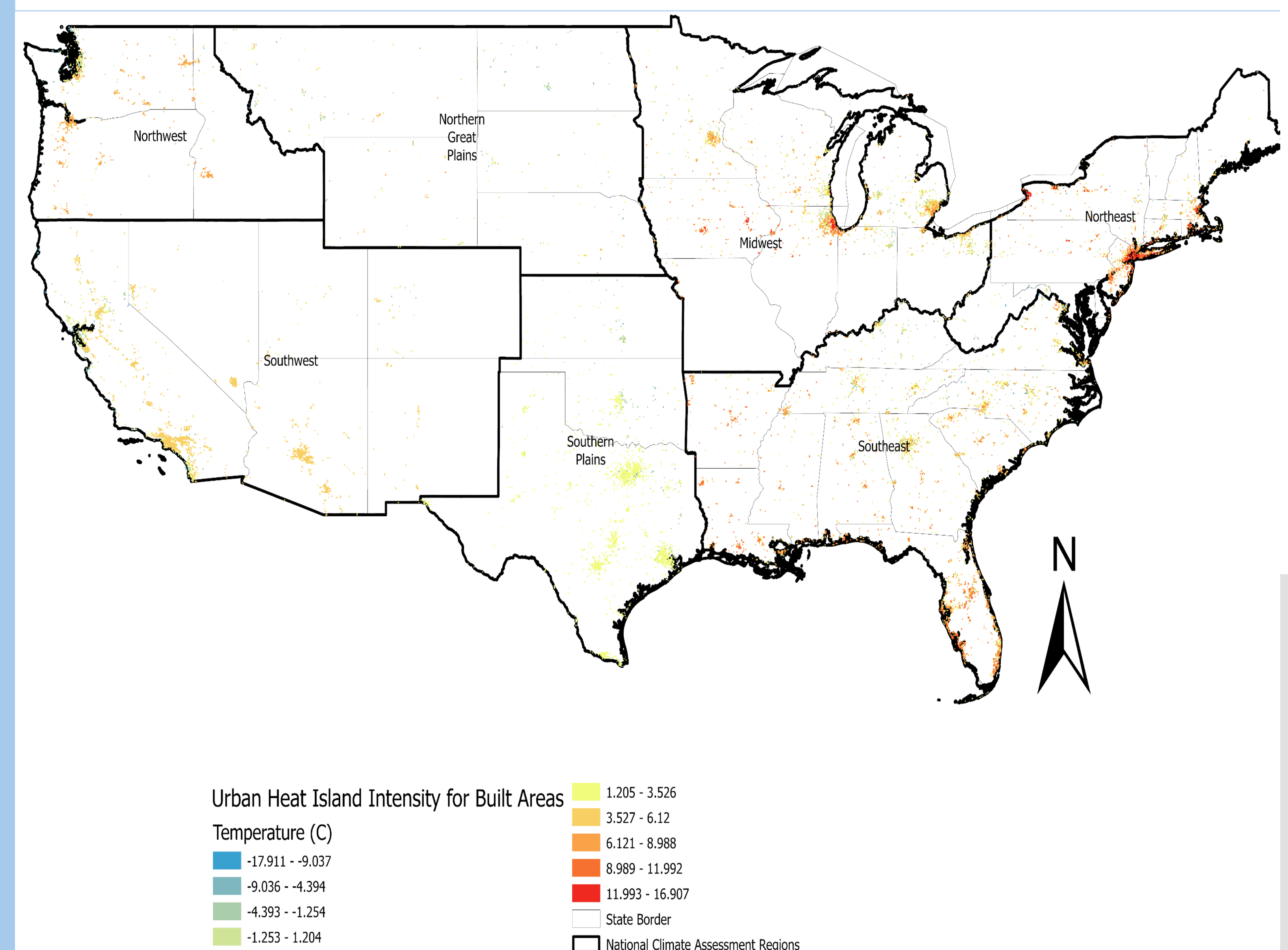
Analysis: Examined 18 major U.S. cities (2017-2023), calculated extreme heat days (>95th Percentile) using NOAA CPC data.

Study Site



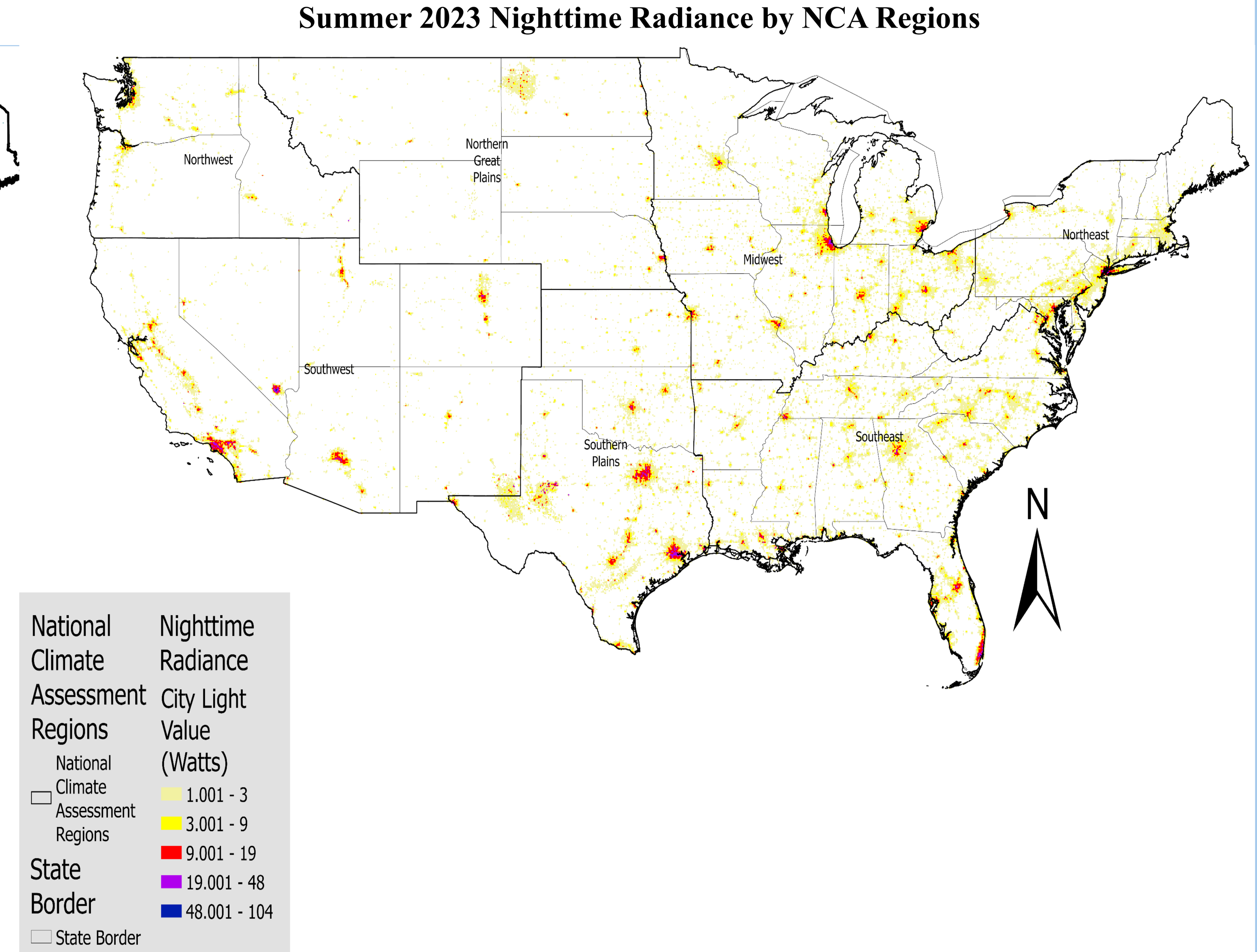
2023 SUMMER UHI INTENSITY

Summer 2023 Urban Heat Island Intensity in U.S. Build Environments by NCA Regions

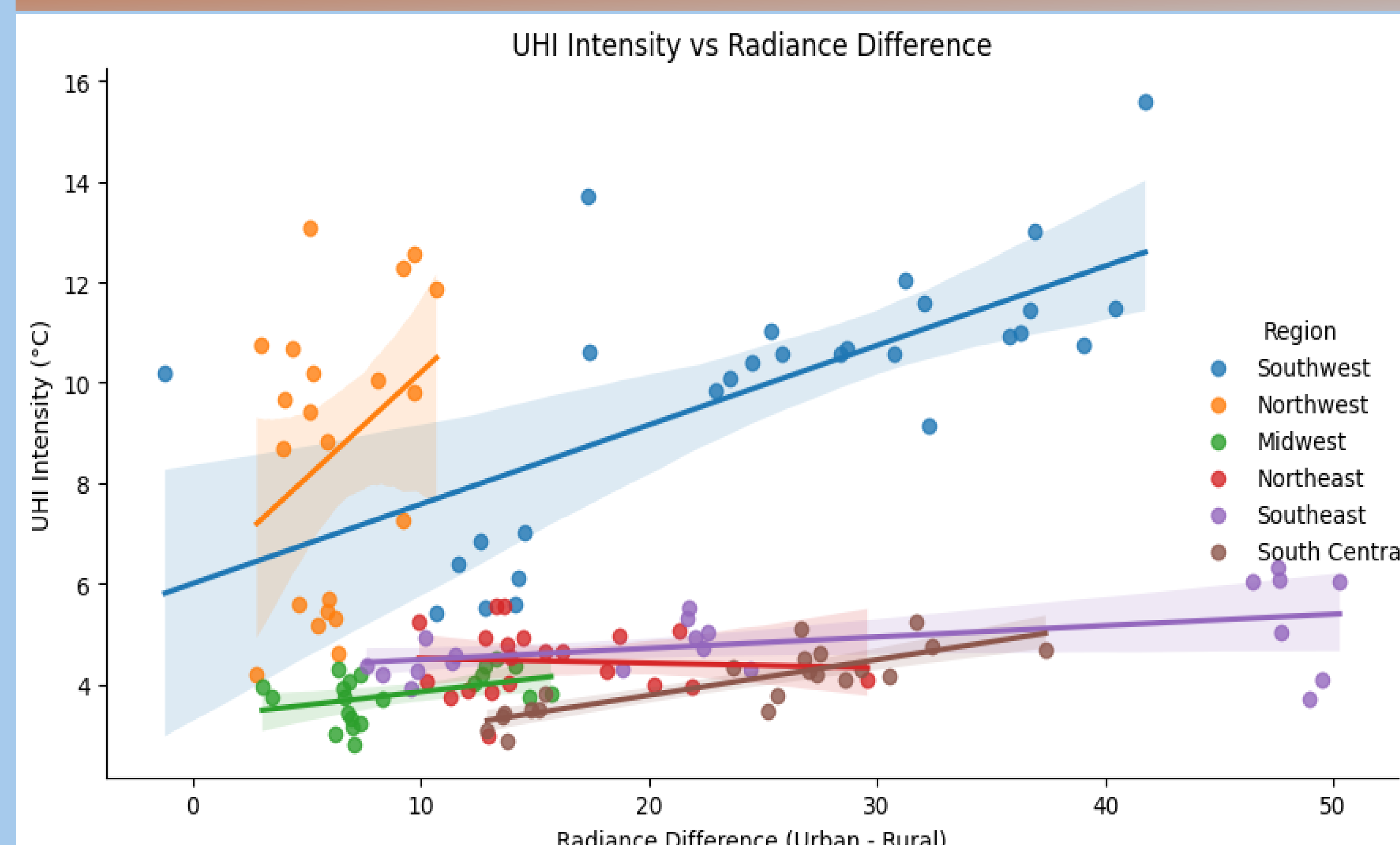


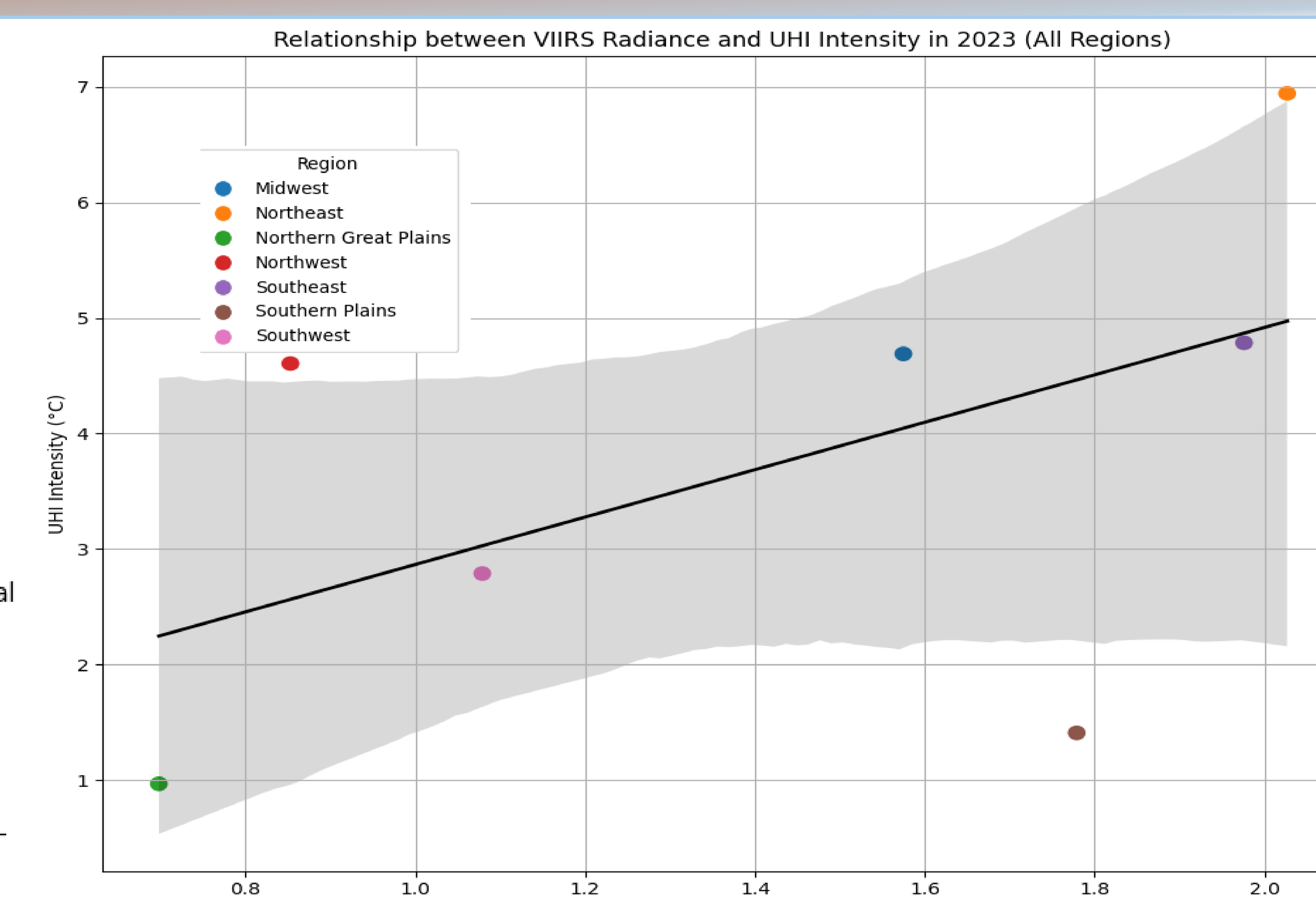
2023 SUMMER NIGHTTIME RADIANCE

Summer 2023 Nighttime Radiance by NCA Regions

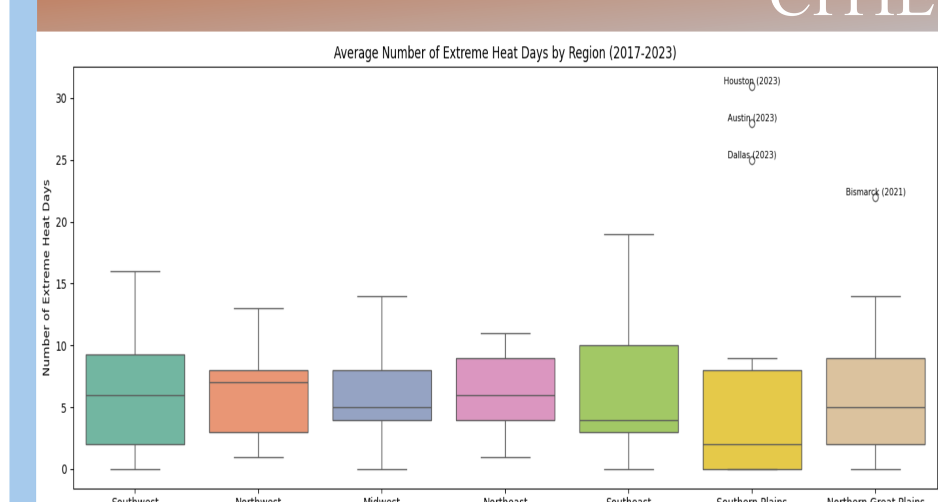


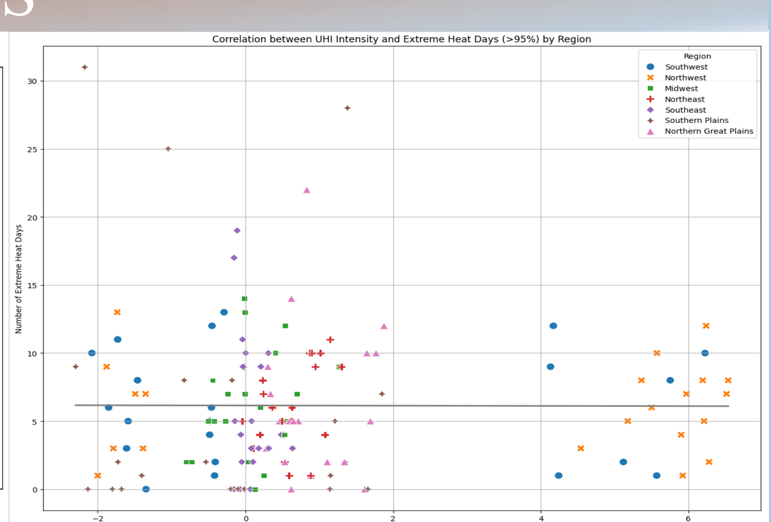
UHI INTENSITY vs. RADIANCE DIFFERENCE/MEAN VIIRS RADIANCE



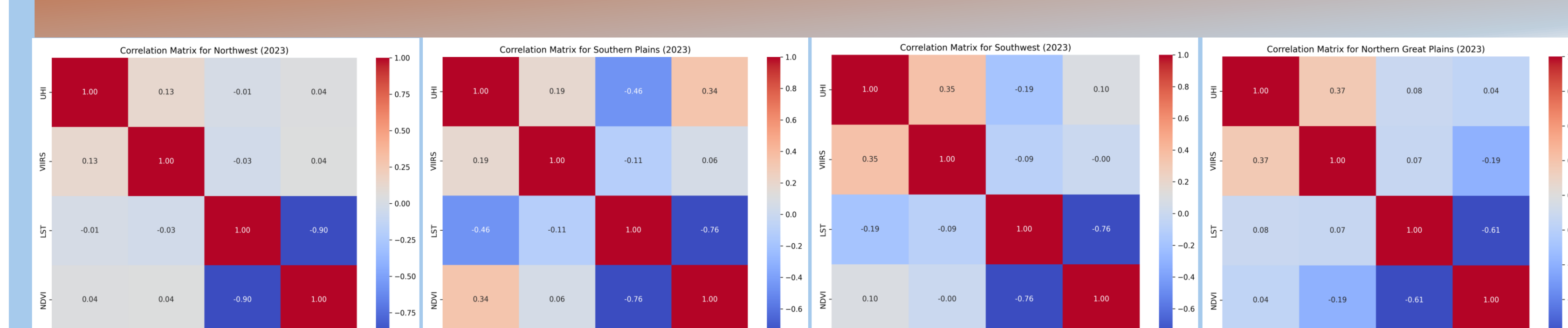


2017-2023 URBAN HEAT ISLAND FOR POPULATED CITIES





CORRELATION MATRIX



CONCLUSIONS

- **UHI & City Wattage:** Areas with higher nighttime radiance generally show stronger Urban Heat Island (UHI) effects, reflecting intensified heat retention due to dense infrastructure, materials, and human activities.
  Industrial Outliers: Bright but rural industrial sites (e.g., oilfields) stand out as exceptions, highlighting that lighting alone doesn't guarantee increased UHI. Identifying and accounting for such outliers is crucial to avoid skewed interpretations.
- **Regional Variations:** The observed UHI–NDVI relationship in the Southern Plains, absent in other regions, suggests that specific land cover, climate, or urban planning factors can enhance or diminish vegetation's influence on UHI intensity.
- **Data Considerations:** Dataset limitations (e.g., VIIRS spatial resolution) and measurement biases must be acknowledged. Improving data quality and resolution can refine UHI assessments and better isolate urban signals.
- **Implications:** Stronger correlations in certain regions (e.g., Southwest, Northwest) may indicate evolving urban forms and higher anthropogenic influence. In contrast, weaker associations elsewhere could stem from more mature infrastructures, mitigation strategies, or differing climate and landscape characteristics.