Project Summary – Fall 2020

Tempe Urban Development II
Establishing an Urban Heat Exposure Severity Score for Infrastructure Prioritization in Tempe, Arizona, Using NASA Earth Observations and LiDAR

Project Team

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Project Overview

Project Synopsis:
This project utilized NASA Earth observations to aid the City of Tempe in identifying areas that experience high heat severity for mitigation initiatives. Variables calculated include remotely sensed land surface temperature (LST), normalized difference vegetation index (NDVI), normalized difference built index (NDBI), normalized difference water index (NDWI), albedo, and a digital surface model of urban morphology from US Geological Survey (USGS) LiDAR data. These indices and environmental variables were combined with sociodemographic data to produce heat exposure, vulnerability, and priority maps through a principal component analysis (PCA) and a geodatabase to enable the City of Tempe to make data-driven decisions.

Abstract:
Located in the northern Sonoran Desert, Tempe, Arizona, features a semi-arid climate with summer daily maximum temperatures regularly exceeding 37.8° C (100.0° F). The area has experienced an increase in surface and air temperatures due to a steep expansion of impervious surfaces and rapid urban development. Urban heat is an increasingly pressing concern for Tempe with hundreds of heat-related deaths and thousands of heat-related hospitalizations over the past 15 years in Maricopa County. Furthermore, urban heat impacts residents' quality of life and the economic vitality of the city. Recognizing the impacts of extreme urban

heat, the City of Tempe collaborated with the Healthy Urban Environments initiative and the Fall 2020 Tempe Urban Development II NASA DEVELOP team to utilize NASA Earth observations to investigate the drivers of highest heat throughout the city. Data from Aqua Moderate Resolution Imaging Spectroradiometer (MODIS), Landsat 8 Operational Land Imager (OLI), and Landsat 8 Thermal Infrared Sensor (TIRS), American Community Survey, and LiDAR data were used to identify areas experiencing the worst heat effects that could be targeted for heat mitigation and adaptation. These areas included the Escalante neighborhood, Alegre Community, University Heights, and around Dwight Park. Additionally, according to our shading analysis, the Gilliland and Escalante neighborhood walksheds do not meet the "good" shading threshold set at 30% by the Maricopa Association of Government.

Key Terms:
outdoor thermal comfort, heat vulnerability, Healthy Urban Environments, remote sensing, urban heat modeling, LST, LiDAR

National Application Area Addressed: Urban Development
Study Location: Tempe, AZ
Study Period: April 2015 – October 2020

Community Concerns:
- Changing climatic conditions and rapid urbanization have contributed to an increase in the mean temperature for Tempe, diminishing quality of life, endangering economic stability, and exacerbating community health concerns related to urban heat.
- Local stakeholders and municipalities often represent various populations and interests. This can present challenges when coming to a consensus on heat mitigation efforts.
- Scientific reports and tools can be difficult to read and understand which can lead to an underutilization of data-driven research. Thus, the City of Tempe wants to present heat-related data and decision-making products in a usable format and platform for staff, developers, residents, and collaborators.

Project Objectives
- Integrate the capabilities of NASA's Earth observations and sociodemographic data to help address the pressing concern of urban heat in Tempe
- Provide the City of Tempe a sharable geodatabase to support future urban heat mitigation initiatives
- Produce a creative communication tool in the form of an ArcGIS StoryMap to assist Tempe's city staff, developers, and residents in understanding the concerns associated with urban heat
- Identify areas with the highest heat exposure and vulnerability using a PCA of sociodemographic and environmental variables to identify areas for public health awareness outreach and cooling initiatives
- Create static maps to display urban heat exposure, vulnerability, and priority across Tempe

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Previous Term:
2018 Fall (AZ) – Tempe Urban Development

Partner Overview

Partner Organizations:

Organization	POC (Name, Position/Title)	Partner Type	Boundary Org?
City of Tempe	Dr. Braden Kay, Project Lead City of Tempe, Sustainability Director	End User	Yes
Arizona State University, Urban Climate Research Center	Dr. David Sailor, Professor/Director; Dr. Paul Coseo, Healthy Urban Environments (HUE) Initiative Project Advisor	Collaborator	No
Arizona State University, School of Sustainability	Dr. Katja Brundiers, HUE Initiative Project Advisor; Grace Logan, Research Aide	Collaborator	No

Decision-Making Practices & Policies:
The Fall 2018 Tempe Urban Development NASA DEVELOP project and the City's 2017 Urban Forestry Master Plan demonstrated how crucial urban forests are to Tempe's public health infrastructure. The City of Tempe has yet to complete a macro-scale remote sensing analysis, but has used local point measurements of meteorological data to assist and inform decision-making and infrastructure investments. However, as of September 2020, the City of Tempe lacks an understanding of the exact locations to prioritize within the larger region for cooling infrastructure solutions. These solutions include repaving with low heat retention asphalt, high albedo roofing, adding shelters to bus stops, and urban green space expansion efforts.

Earth Observations & End Products Overview

Earth Observations:

Platform & Sensor	Parameters	Use
Aqua MODIS	Nighttime Land Surface Temperature (LST); Normalized Difference Water Index (NDWI)	MODIS data were used for NDWI and nighttime LST calculations included in the PCA.
Landsat 8 OLI	Normalized Difference Vegetation Index (NDVI); Normalized Difference Built	NDVI was used to map tree coverage in the study area and green space. NDBI was used to map impervious surfaces in the area. Albedo indicated which areas are reflecting light versus absorbing it.

	Index (NDBI); Albedo	
Landsat 8 TIRS	Daytime LST	LST products were used as a proxy for urban heat measured at a city-wide scale of 100 m and resampled to 30 m resolution.

Ancillary Datasets:
- Open Street Maps – Street layer in line format was used to assist the shading analysis to create community walksheds for important community features such as schools, parks, and community centers.
- US Census Bureau, Five-Year American Community Survey by Census Tract 2014 to 2018 – Sociodemographic variables from the survey were included for the
- US Geological Survey LiDAR dataset Phoenix Metro (ASU Map and Geospatial Hub) – LiDAR point cloud data, alongside derived 3D building, building footprints, and tree point data were used to perform shadow analysis of walking paths, roads, and buildings.
- Valley Metro Geo-Center – Feature layer including all bus stops in the Phoenix metropolitan area.

Software & Scripting:
- Esri ArcMap 10.7.1– Development of a shareable geodatabase and StoryMap for the City of Tempe.
- Esri ArcGIS Pro 2.6.2 – Overlay analysis of urban heat factors, sociodemographic data, and infrastructure layers to determine which areas could be prioritized for heat mitigation.
- Google Earth Engine – Image processing and calculations for urban heat contribution variables derived from NASA Earth observations to be used in the heat exposure score maps.
- RStudio 4.0.3 – Statistical weighting determination of urban heat contributing factors and PCA.

End Products:

End Products	Earth Observations Used	Partner Benefit & Use	Software Release Category
Esri ArcMap Geodatabase of Data – Regions Ranked by Heat Severity & Locations of	Landsat 8 OLI Landsat 8 TIRS Aqua MODIS	This geodatabase will allow the City of Tempe to easily visualize regions ranked by heat severity and identify areas for mitigation	N/A

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Proposed Mitigation Projects		projects.	
LiDAR Derivatives	N/A	These data will allow the City of Tempe to examine the percent shade in the Gililland and Escalante neighborhoods. Additionally, the sidewalks that fell within these neighborhoods were analyzed for percent shade throughout the day and in a walkshed analysis which incorporated schools, parks, and community centers.	N/A
Map of Heat Exposure Scores by Census Tract	Landsat 8 OLI Landsat 8 TIRS Aqua MODIS	Partners will use this map to identify areas within Tempe that experience the highest heat exposure by census tract.	N/A
Map of Social Vulnerability Scores by Census Tract	N/A	Partners will use this map to identify areas within Tempe that experience the highest social vulnerability by census tract.	N/A
Map of Heat Priority Score by Census Tract	Landsat 8 OLI Landsat 8 TIRS Aqua MODIS	Partners will use this map to identify areas within Tempe that experience the highest heat vulnerability by census tract, bringing together heat exposure and social vulnerability.	N/A
Map of High LST Tempe Bus Stops	Landsat 8 OLI Landsat 8 TIRS	Partners will use this map to identify Valley Metro bus stops within Tempe that have no shade or shelter and experience the highest LST temperatures.	N/A

Esri ArcGIS StoryMap	Landsat 8 OLI Landsat 8 TIRS Aqua MODIS	The StoryMap will be used by the City of Tempe and community stakeholders to quickly conceptualize urban heat throughout Tempe.	N/A
Data Training Tutorial	N/A	The City of Tempe will use this tutorial to aid in the reproduction of the heat score maps and datasets as new satellite images and US Census data becomes available.	N/A
Code Training Tutorial	N/A	The City of Tempe will use this code tutorial, following software release to learn how to use the R and JavaScript code to reproduce the heat maps and datasets as new satellite images and US Census data become available.	III
Code – R & JavaScript	N/A	The city of Tempe will use this code, following software release to reproduce the heat maps and datasets as new satellite images and US Census data become available.	III

Product Benefit to End User:
The City of Tempe may use these results to identify areas of concern and implement strategies to improve the thermal environment in an evidence-based approach. The macro-level analyses and end products will complement the City of Tempe's microclimate measurements and location information for future capital improvement projects. This can enable city staff to make informed and collaborative infrastructure improvement decisions in targeted areas. The StoryMap will provide a conduit for the City of Tempe for outreach and education programs to the public.

References

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