**NASA DEVELOP National Program**

**2020 Fall Project Proposal**

**Arizona – Tempe**

**Tempe Urban Development II**

*Establishing an Urban Heat Exposure Severity Index for Infrastructure Prioritization using NASA Earth Observations and LiDAR*

**Project Overview**

***Project Synopsis*:** This project will address the severe urban heat issues in Tempe, Arizona, by determining which regions are experiencing the worst heat effects and should be targeted for mitigation initiatives. DEVELOP is partnering the City of Tempe and Arizona State University’s Urban Climate Research Center to complete a macro-scale analysis of urban heat using NASA Earth observations of land surface temperature from Landsat 8 TIRS/OLI and Aqua MODIS, greenness from Landsat 8 OLI, and urban surface material analysis from Sentinel-2 MSI and Terra ASTER. The DEVELOP team will make a sharable geodatabase containing areas of heat exposure severity using a four-tiered system, determined through a weighted analysis of the heat-related observations. The analyses will be combined with the partners’ microclimate measurements as well as location information of future capital improvement projects to make informed and collaborative infrastructure improvement plans in targeted areas.

***Community Concern:*** Urban heat is an important issue for Tempe, Arizona, with hundreds of heat deaths and thousands of heat-related hospitalizations reported in the last fifteen years. Municipalities around the city have competing interests and infrastructure priorities, which has made heat mitigation efforts challenging. The City is hoping to compile a heat intervention mapping toolbox using both micro-scale and macro-scale heat and infrastructure datasets. The City also needs all its heat-related data and decision products in a usable format and platform for its City staff, developers, residents, and members of the Healthy Urban Environments (HUE) team.

***Source of Project Idea:*** This project idea was initialized by Dr. David Hondula, the DEVELOP Arizona – Tempe science advisor, from discussions with the urban heat research and management community of Arizona State University and Tempe. The Arizona – Tempe node partnered with the City of Tempe on a project in 2018, investigating the impact of green parks on urban heat. This project will expand on related work to identify factors that impact experienced urban heat and its severity across the whole city.

***National Application Area Addressed:*** Urban Development, Health & Air Quality

***Study Location:*** Tempe, AZ

***Study Period:*** August 2015 – August 2020

***Advisor:*** Dr. David Hondula (Arizona State University)

**Partner Overview**

***Partner Organizations:***

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

***End User Overview***

***End User’s Current Decision-Making Process:***The City of Tempe's Climate Action Plan promotes green infrastructure and resiliency proposals for reducing extreme heat. The City of Tempe is currently working with ASU researchers to implement a HUE Initiative proposal that would require the city to use data-driven research to make heat mitigation decisions. The HUE Initiative proposal has been partially approved by the city and aims to help the city make data-driven decisions regarding heat mitigation that can be accomplished in tandem with existing capital improvement project plans. The city has started to collect and use local point measurements of weather and climate data to inform decision-making and infrastructure investment. However, it currently lacks understanding of the location prioritization within the larger city design for these cooling infrastructure solutions, such as repaving with low heat retention asphalt, white roofing, or urban green space expansion.

***End User’s Capacity to Use NASA Earth Observations:***

*City of Tempe* – The City has a GIS department that has used data from NASA Earth observations before, but these were provided by ASU. The groups working on urban heat for the city have not implemented Earth observation derived datasets into any of their decision making, and mainly use ground-based heat and climate measurements.

***Collaborator & Boundary Organization Overview***

***Collaborator Support:***

*Arizona State University, Urban Climate Research Center* – The Center will provide local knowledge of urban heat issues and *in situ* meteorological measurements of air temperature, relative humidity, wind, and surface temperature to better inform the weighted analysis of Earth observation datasets that measure potential urban heat contributing factors.

***Dissemination by Boundary Organizations*:**

*City of Tempe* –The City wants to provide geospatial data of the heat severity zones in an easy to use format, such as an ArcGIS Online platform and explanatory StoryMap for City staff, developers, and residents to use for city improvement planning. The created geodatabase will be shared and utilized by multiple members of the HUE project in later analyses.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** The NASA DEVELOP project team will meet with the partners weekly over video chat. There will also be ongoing communication via email. The main POC will be the Project Lead once the Fellow has introduced the team to the partners. All communication and final presentations will be done virtually.

***Transition Plan*:** A handoff will be conducted virtually in the last week of the term via Google Meet. This meeting will be open to all members of the HUE project and other parties working with Tempe on heat resiliency infrastructure. All processed data products and end products will be sent to the partners by Google Drive sharing or NASA Large File Transfer.

**Earth Observations Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Landsat 8 TIRS** | Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI) | LST data will serve as a proxy for urban heat. NDVI will be used to map tree coverage in the study area. |
| **Landsat 8 OLI** | NDVI, Albedo | NDVI will be used to map tree coverage in the study area. Albedo measurements will identify surface areas that absorb or reflect light. |
| **Sentinel-2 MSI** | Normalized Difference Impervious Surface Index (NDISI) | NDISI will be used to create impervious surface maps. |
| **Aqua MODIS** | Nighttime LST | Nighttime LST data will show urban heat exposure at night. |
| **Terra ASTER** | Emissivity | Direct measurement of material emissivity will be used to better estimate LST in the urban environment in the absence of an NDVI modeled emissivity value. This could be used in conjunction with the Landsat provisional LST dataset. |

***Ancillary Datasets:***

* USGS Phoenix Metro LiDAR – LiDAR point data, with derived 3D building polygons and tree point data, for performing shadow analysis of walking paths and roads in Tempe
* City of Tempe Pavement Quality Index Segments – Tempe roadway quality measurement rated from 0 to 100, to improve prioritization recommendations for cooling initiative prioritization, targeting infrastructure issues that overlap with areas of high urban heat so these goals can be coordinated and accomplished in tandem
* City of Tempe Pavement Quality Index Segments (Planned City Improvements Program Repairs) (data.tempe.gov) – Tempe roadways that have been selected for capital improvement projects for road resurfacing, for targeting planned infrastructure projects that overlap with areas of high urban heat so these goals can be coordinated and accomplished in tandem
* ASU Urban Climate Research Center *In situ* Meteorological Measurements – Air temperature, relative humidity, and surface temperature for use in comparison to macro-scale measurements of temperature

***Software & Scripting:***

* Google Earth Engine API – Generate raster layers for urban heat contribution variables derived from NASA Earth observations
* Esri ArcGIS Pro – Overlay analysis of urban heat contributing factor rasters and infrastructure layers for determination of prioritization zoning boundaries
* Python – Shadowing analysis from LiDAR data
* R – Statistical weighting determination of urban heat contributing factors
* Esri ArcGIS Online – Development of a reusable geodatabase for the Tempe partners on an easy to use platform

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **ArcGIS Online Geodatabase of Data Layers, Ranked Heat Severity Regions & Proposed Locations** | This online geodatabase will serve as a usable source of data for many decision makers across different divisions of the City of Tempe. The data must be openly accessible for all portions of the project to wither visualize or download easily so it can be used in later analyses with additional local measurements of experienced temperature. | This will include data from Landsat 8 OLI/TIRS, Aqua MODIS, Sentinel-2 MSI, and Terra ASTER; a shadowing raster from LiDAR; and provided city infrastructure projects location datasets. Statistical analysis to weight the contribution of the observed datasets in the determination of the simplified ranked severity regions. | N/A |
| **Tempe Urban Development II Project Video** | Partners want to combine the DEVELOP video with a series of other short videos produced by HUE. This video will give an understandable explanation of how the severity regions were determined and examples of how the urban heat can be decreased with targeted infrastructure projects. These videos will be used for public outreach. | This video will include Earth observation data from Landsat 8 OLI/TIRS, Aqua MODIS, Sentinel-2 MSI, and Terra ASTER along with USGS LiDAR data. | N/A |

***End User Benefit*:** This work will help the City of Tempe identify a plan toward their heat mitigation goals, allowing the City to target its first efforts in the quantifiably hottest parts of the Tempe. By simplifying the factors that contribute to urban heat into a four-tiered system of heat exposure severity, staff will be able to more easily communicate prioritization needs across city departments. Through previous collaboration with the ASU Urban Climate Research Center, the City of Tempe has an understanding of the complexity of urban heat but this project would give them the large-scale analysis it needs for knowing where to prioritize their efforts.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 2 Terms: Fall 2018 and Fall 2020

***Multi-Term Objectives:***

* **Term 1:** 2018 Fall (AZ) – Tempe Urban Development
  + The City of Tempe had a goal of becoming a walkable city by supporting urban green space so that residents could comfortably walk or bike to major amenities within 20 minutes of their homes. The team examined the correlation between tree clustering, land cover, and LST in city parks. They also examined changes in LST and NDVI during 1998-2018. The City could use these results to inform residents and developers about how investment in deliberate urban forestry improves the city’s thermal environment and helps mitigate extreme heat. This term visualized changes Tempe’s LST and NDVI over time and the impact on the UHI effect.
* **Term 2 (Proposed Term):** 2020 Fall (AZ) – Tempe Urban Development II
  + DEVELOP will continue to work with the City of Tempe and the Urban Climate Research Center to conduct a macro-scale analysis of current urban heat conditions that will coordinate with the partner’s micro-scale analysis of experienced temperature. The team will create a weighted severity map of urban heat that partners can use to target further on-the-ground analysis and promote infrastructure decisions for cooling initiative. They will combine the factors of LST, NDVI, albedo, NDISI, emissivity, and shadowing to create the severity maps the partners will share with all persons combatting urban heat in Tempe.

***Previous Terms:***

2018 Fall (AZ) – Tempe Urban Development: Utilizing NASA Earth Observations to Assess Thermal

Landscapes and Prioritize Greening Initiatives in Tempe, Arizona

***Related DEVELOP Work:***

2020 Summer (MA) – Cambridge Urban Development: Quantifying Changes in Urban Albedo with NASA Earth Observations to Reduce Urban Heat Island Effect in Cambridge, Massachusetts

2020 Spring (AZ) – Philadelphia Health & Air Quality: Assessing Land Surface Temperature, Vegetation Cover, and Compounding Vulnerability Factors to Identify High Priority Areas for Cooling Initiatives in Philadelphia, Pennsylvania

2018 Summer (AZ) – Washoe County Urban Development: Utilizing NASA Earth Observations to Assess Urban Heat Island Reductions Strategies in Washoe County, Nevada

2017 Summer (AZ) – Las Cruces Health & Air Quality: Assessing Urban Heat as it Relates to Social Vulnerability and Land Use Changes in Las Cruces, New Mexico

**Notes & References:**

***Notes*:**

* The team can explore alternative options for deriving the environmental parameters described above. Terra MISR or NAIP data could alternatives for albedo. Planet RapidEye data also has strong possibilities for determination of NDVI and other parameters derived with visible light, red edge, and near-infrared bands at a much higher resolution. This data source is not often used in DEVELOP projects but may offer many opportunities for the higher resolution analysis needed in highly variable urban environments and is interoperable with Sentinel-2 bands.
* Tempe open GIS data: <https://data-tempegov.opendata.arcgis.com/search?collection=Dataset>
* Arizona existing LiDAR datasets map: <http://gis.azgeo.az.gov/lidarcoverage/>
* USGS LiDAR Data for Metro Phoenix: <https://lib.asu.edu/geo/news/robust-usgs-lidar-data-now-available>
* Shade studies in Tempe led by Ariane Middel from ASU: <https://sustainability.asu.edu/hue/research/project/the-right-shade-in-the-right-place-thermal-assessment-of-natural-and-engineered-shade-in-tempe-hue/>
* Maricopa County-ASU HUE Iniatative: <https://sustainability.asu.edu/hue/about/>

***References:***

Corburn, J. (2009). Cities, climate change and urban heat island mitigation: Localising global environmental science. *Urban Studies*, *46*(2), 413-427.

Golden, J. S., & Kaloush, K. E. (2006). Mesoscale and microscale evaluation of surface pavement impacts on the urban heat island effects. *The International Journal of Pavement Engineering*, *7*(1), 37-52.

Harlan, S. L., Chakalian, P., Declet-Barreto, J., Hondula, D. M., & Jenerette, G. D. (2019). Pathways to climate justice in a desert metropolis. *People and Climate Change: Vulnerability, Adaptation, and Social Justice*, 23.

Harlan, S. L., Declet-Barreto, J. H., Stefanov, W. L., & Petitti, D. B. (2013). Neighborhood effects on heat deaths: Social and environmental predictors of vulnerability in Maricopa County, Arizona. *Environmental Health Perspectives, 121*(2), 197-204. doi:10.1289/ehp.110465

Middel, A., Selover, N., Hagen, B., & Chhetri, N. (2016). Impact of shade on outdoor thermal comfort—A

seasonal field study in Tempe, Arizona. *International Journal of Biometeorology, 60*(12), 1849-1861. doi:10.1007/s00484-016-1172-5