**San Diego Urban Development**

*Utilizing NASA Earth Observations to Identify Drivers of Extreme Urban Heat and Generate a High-Resolution Vulnerability Index for Urban Planning and Climate Resiliency in San Diego, California*

**Project Team**

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**Project Overview**

***Project Synopsis:***

This project utilized NASA Earth observations to quantify and visualize urban heat risk, exposure, vulnerability, and effects of proposed mitigation measures for the City of San Diego, California. These tools will inform the development of the city’s Climate Adaptation and Resiliency Plan by identifying communities subject to the greatest amount of urban heat and most vulnerable. Vulnerability is defined as an aggregate of social and health indicators that have known correlations to increased heat morbidity. The city strives to find which social and environmental factors are associated with heat vulnerability throughout San Diego. Additionally, we utilized the InVEST urban cooling model to understand the cooling capacity of the landscape and predict the cooling effects of increased tree canopy, further supporting the city’s climate resiliency plans. Our work will assist the city in prioritizing means of cooling interventions.

***Abstract:***

Exposure to heat exacerbated by an increase in urbanization as well as increasing global temperatures has become a growing concern for cities and their residents. Excess heat can cause increased heat-related morbidity, mortality, and energy costs. Vulnerability to heat-related illnesses is oftentimes correlated to demographics, socioeconomic status, and pre-existing health conditions. The City of San Diego, California boasts 1.4 million residents and, like many other major cities, has experienced increases in heat-related hospitalizations and mortality. The burden of urban heat is also not equal amongst communities; areas with lower income and communities of color bear a disproportionate burden. In partnership with the City of San Diego, and American Geophysical Union’s (AGU) Thriving Earth Exchange, the DEVELOP team used Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), and ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) imagery to identify areas of highest heat based on land surface temperature from 2015-2020. Our analyses showed that health demographics such as obesity and cardiovascular health were the strongest indicators for heat vulnerability. In addition, various inputs (land use/land cover, tree canopy, and building intensity derived from the City of San Diego data along with albedo from Landsat 8) were used in the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) urban cooling model to investigate changes in cooling rates in current and future scenarios for the city. The model results showed cooling has occurred due to a 5% increase in tree canopy. The City of San Diego can use these results to inform the development of the Climate Resilient SD plan and prioritize at-risk communities for cooling interventions.

***Key Terms:***

urban heat island, InVEST urban cooling model, ECOSTRESS, exposure, vulnerability, climate justice, heat risk

***National Application Area Addressed:*** Urban Development

***Study Location:*** San Diego, California

***Study Period:*** 2015 to 2020 (May – September)

***Community Concerns:***

* Vulnerable populations including those who are 65+ and/or living alone, with pre-existing conditions, and socioeconomic factors such as income level and race/ethnicity are disproportionately impacted by environmental hazards such as excess heat.
* Increasing temperatures result in increasing energy use from air conditioning, further exacerbating greenhouse gas emissions and excess heat-related sickness and mortality particularly in communities of concern in San Diego.
* Increasing temperatures decreases work productivity especially for outdoor laborers.

***Project Objectives:***

* Provide the City of San Diego with data that can be used to support Climate Resilient SD, the city’s climate adaptation and resiliency plan
* Create a set of thematic maps showing median daytime and nighttime land surface temperature (LST) for the summer months of 2015-2020
* Provide the city with InVEST model output that shows existing landscape cooling capacity and models the implications of increasing tree canopy in targeted areas
* Identify what communities are the most vulnerable by creating a vulnerability index composed of scores from a Principal Components Analysis (PCA) that used social and health indicators
* Merge LST and vulnerability index to create a map of heat risk in community planning areas

**Partner Overview**

***Partner Organizations:***

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| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **City of San Diego, Planning Department** | Julia Chase, Senior Planner, Project Manager for Climate Resilient San Diego; Heidi Vonblum, Deputy Director of Environmental Policy and Public Spaces | End User | Yes |
| **American Geophysical Union, Thriving Earth Exchange** | Kristen O’Shea, Community Science Fellow | Collaborator | No |

***Decision-Making Practices & Policies:***

In 2015, the City of San Diego instituted a Climate Action Plan entitled “Our Climate Our Future” that planned efforts in climate change mitigation. Now the city is focusing on making San Diego more resilient and adaptable to the consequences of climate change with their Climate Resilient SD plan. Currently the City of San Diego is using a climate equity index to inform their decision making on where to prioritize their resilient and adaptation. However, the scale of these products is too coarse, and only take into account very limited vulnerability indicators. There may also be additional available datasets that would be beneficial to planners in evaluating heat vulnerability. As of January 2021, while the city has conducted a vulnerability assessment, they do not have a comprehensive vulnerability index of what communities are most vulnerable to urban heat throughout San Diego.

**Earth Observations & End Products Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Albedo | Albedo was used as input into the InVEST model for reflection of urban surfaces. |
| **Landsat 8 TIRS** | Daytime LST | LST was used as a proxy for air temperature or urban heat experienced by people throughout the City of San Diego. It will also enhance partners’ understanding of urban heat dissipation and consequent neighborhood-level helth concerns. |
| **ISS ECOSTRESS** | Nighttime LST | Nighttime measurements of land surface temperature (NLST) were gathered from ECOSTRESS to enhance the partners’ understanding of urban heat dissipation and consequent neighborhood-level health concerns.  NLST was also used as a proxy for air temperature for the InVEST model. Evapotranspiration was used as input as well. |

***Ancillary Datasets:***

* CDC 500 Cities Project – census-tract level estimates of chronic disease risk factors, health outcomes, and clinical preventive service use; these were incorporated into the heat vulnerability analysis
* City of San Diego Urban Tree Canopy Data – Tree canopy layer was used as an input for the InVEST cooling model
* City of San Diego Land Cover Land Use Data – Raster of landcover was used as inputs for the InVEST cooling model
* City of San Diego Building Outlines – shapefile Building foot print throughout the city.
* US Census Bureau American Community Survey (ACS) by tract and census block group 2014 to 2018 – Socioeconomic variables of race, education, age, and English language proficiency from the survey were included with additional variables at the census tract level to help evaluate heat vulnerability

***Modeling:***

* Natural Capitol Project InVEST urban cooling model (POC: Jesse Goldstein, Stanford University) – used for modeling heat mitigation and urban cooling.

***Software & Scripting:***

* Google Earth Engine (GEE) – used to create raster layers for LST, NDVI, and albedo, derived from NASA Earth observations ArcGIS Pro 2.6.2 – Overlay analysis of urban heat contributing factor rasters and infrastructure layers for determination of prioritization zoning boundaries, process InVEST inputs and analyze InVEST output
* R 4.0.3 – used for statistical weighting and spatial regression determination of urban heat contributing factors

***End Products:***

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| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Geodatabase of Heat Risk, Heat Exposure Variables, and PCA Outputs** | Landsat 8 OLI  Landsat 8 TIRS  ISS ECOSTRESS | The geodatabase includes all raster and vector files used in the creation of our end products. The partners can use this geodatabase to create alternative maps using the raw data or PCA outputs, as well as to update their online map with new data from this database. | III |
| **ArcGIS StoryMap** | Landsat 8 OLI  Landsat 8 TIRS  ISS ECOSTRESS | The StoryMap will provide interactive maps and a narrative for the city to share with the public. The content will detail which areas face the most heat risk by examining the environmental and socioeconomic variables in those regions. | N/A |
| **InVEST Scenario Model Outputs Geodatabase** | Landsat 8 OLI  Landsat 8 TIRS  ISS ECOSTRESS | The City of San Diego will use InVEST outputs to understand the inequalities in cooling capacity and the impact of increasing tree canopy s. | N/A |
| **AppEEARS Tutorial** | N/A | The City of San Diego will use satellite data accessed from AppEEARS online portal to download and process data for InVEST model outputs in the future. | N/A |
| **InVEST Tutorial** | N/A | The City of San Diego will use this tutorial toe run and update inputs to the InVEST urban cooling model based on new urban cooling and heat mitigation scenarios | N/A |
| **R Code** | N/A | The City of San Diego will use this code, following software release to reproduce the heat maps and datasets as new US Census data becomes available | III |
| **Code Training Tutorial** | N/A | The City of San Diego will use this code tutorial, following software release to learn how to use the R code to reproduce the heat maps and datasets as new US Census data becomes available. | III |

***Product Benefit to End User:***

Resulting maps of heat risk will be used by the City of San Diego to prioritize areas for natural cooling interventions such as increasing the city’s tree canopy. The results of the InVEST model will be used to assess the cooling impact of desired and predicted tree canopy scenarios. Overall, these outputs will inform mitigation efforts and the development of the City of San Diego’s Climate Resilient SD Plan. They will also build a foundation for the development of a future app that would allow residents to see if they live in an area vulnerable to extreme heat.

**References**

Guirguis, K., (2018). Heat, disparities, and health outcomes in San Diego County’s diverse climate zones. *GeoHealth, 2*(7), 212-223. https://doi.org/10.1029/2017GH000127

Hulley, G., Shivers, S., Wetherley, E., & Cudd, R. (2019). New ECOSTRESS and MODIS land surface temperature data reveal fine-scale heat vulnerability in cities: A case study for Los Angeles County, California. *Remote Sensing, 11*(18), 2136. https://doi.org/10.3390/rs11182136

Sabrin, S., Karimi, M., Fahad, M. G. R., & Nazari, R. (2020). Quantifying environmental and social vulnerability: Role of urban Heat Island and air quality, a case study of Camden, NJ. *Urban Climate*, 34, 100699. https://doi.org/10.1016/j.uclim.2020.100699

Zhou, D., Zhao, S., Zhang, L., & Liu, S. (2016). Remotely sensed assessment of urbanization effects on vegetation phenology in China's 32 major cities. *Remote Sensing of Environment,* 176, 272-281. https://doi.org/10.1016/j.rse.2016.02.010