**Providence & Elizabeth Urban Development**

*Utilizing NASA Earth Observations to Explore Heat and Flood-Related Vulnerability in Urban Settings*

**VPS Title:** Cities & Vulnerabilities: Assessing Heat and Flooding in Providence, RI, and Elizabeth, NJ

**Project Team**

***Project Team:***

Holly Gould (Project Lead)

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***Advisors & Mentors:***

Dr. Kenton Ross (NASA Langley Research Center)

Lance Watkins (Arizona State University)

**Project Overview**

***Project Synopsis:*** Groundwork USA is an environmental non-profit focused on enhancing the well-being of marginalized communities. One of Groundwork’s initiatives is to address and reduce urban heat and flood risk in these areas. This project utilized NASA Earth observations to assess heat distribution throughout two of Groundwork USA’s partner cities, Providence, RI, and Elizabeth, NJ. The team also derived flood extent indices from land cover products to map flood distributions. The primary goal was to show areas within the study areas that experience high vulnerability to heat and flooding and develop a reproducible methodology for Groundwork to utilize in other cities.

***Abstract:***

Coastal cities like Providence, RI, and Elizabeth, NJ, are directly affected by extreme heat and flooding events, which impacts the lives of community members. Groundwork USA is a community-based non-profit organization dedicated to increasing environmental resilience in urban communities. One of its initiatives, the Climate Safe Neighborhoods project, is aimed at assessing climate resiliency through the implementation of urban heat and flood mapping methodologies**.** This project used the Landsat Level-2 Provisional Surface Temperature product (STP), provided by the United States Geological Survey (USGS), to analyze land surface temperatures. The team cross-referenced the STP with both Terra Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Spaceborne Thermal Emission and Reflection (ASTER) land surface temperature data for validation purposes. Similarities in the land surface temperature values from the three products proved that STP is a viable alternative to other previously established heat methodologies. The results of this analysis showed significantly higher temperatures in the highest urbanized areas. The flood distribution map analysis utilized surface reflectance data from Landsat 5, Landsat 7, and Landsat 8 over a 30-year time series. Normalized Difference Water Index (NDWI) and Modified Normalized Difference Water Index (MNDWI) were applied to the Landsat images to calculate and visualize annual and decadal flood frequency. This allowed for a robust methodology to analyze flood frequency over a 30-year time period and the analysis showed areas within both cities that had higher flooding frequency rates. The heat and flood assessment maps generated from this project will aid Groundwork USA in its resilience planning efforts and urban planning advocacy.

**Keywords:**

urban heat island effect, flood vulnerability, Landsat, land surface temperature, heat distribution, remote sensing, coastal cities, Normalized Difference Water Index, Modified Normalized Difference Water Index

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

***Study Location:*** Elizabeth, NJ, and Providence, RI

***Study Period:*** January 1988 to December 2018

***Community Concern:***

* Providence, RI, and Elizabeth, NJ, are both heavily urbanized and situated in low-lying coastal areas. As a result, these communities are highly vulnerable to intense heat and severe flooding.
* Groundwork USA, alongside its RI and NJ local trusts, seeks to enhance the aforementioned cities’ climate resiliency planning initiatives. The organization does not have a current method for assessing the heat and flood vulnerabilities but would like to so that they can fulfill this objective.
* As part of its Climate Safe Neighborhood Initiative, Groundwork USA hopes to enhance its mission by utilizing Earth observations to create a vulnerability assessment methodology. This can eventually be applied across the Groundwork network and be used to create reproducible and consistent map products.

***Project Objectives:***

* Assess the accuracy of the Landsat Level-2 Provisional Surface Temperature product, provided by the United States Geological Survey (USGS), by cross-referencing it with other surface temperature datasets
* Develop an efficient methodology for assessing urban heat and flood in various locations
* Identify areas of Providence, RI, and Elizabeth, NJ, that are vulnerable to urban heat and/or flooding events
* Produce data and maps to allow Groundwork USA to inform the public and make data-driven decisions for its communities

**Partner Overview**

***Partner Organization:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Groundwork USA** | Lawrence Hoffman, GIS Program Manager, Groundwork USA;  Cate Mingoya, Director of Capacity Building, Groundwork USA;  Steve Burrington, Executive Director, Groundwork USA;  Amelia Rose, Executive Director, Groundwork Rhode Island;  Jonathan Phillips, Executive Director, Groundwork Elizabeth | End User | Yes |

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

Groundwork USA is a non-profit organization that specializes in community-based environmental work. The organization has twenty local trusts across the nation that work to enhance the environment within marginalized communities. One of Groundwork’s current projects is the Climate Safe Neighborhoods project which is aimed at reducing the risks associated with increased heat and flooding. The project utilizes data and maps to visualize historic heat and flooding events, create solutions, and enhance community involvement. The data will be used to inform the public, stakeholders, and government officials about the risks associated with these vulnerabilities to further support the decision-making that keeps these communities safe. Groundwork is enacting this project in five of its locations across the nation; two of those locations are Providence, RI, and Elizabeth, NJ. Earth observations have been incorporated into some of the local Groundwork trusts by past partnerships with DEVELOP teams, but have not been incorporated across all Groundwork cities. Currently, Groundwork USA has no consistent mapping methodology for analyzing urban heat and flood risks throughout its various locations.

***Project Benefit to End User:***

The team will aid in Groundwork USA’s Climate Safe Neighborhoods project in standardizing a mapping methodology that can be used to examine urban heat and flood risks within Providence, RI, and Elizabeth, NJ. The maps created by this methodology will be used to research impacts, determine strategies, identify solutions, engage local stakeholders, and influence local policy and practice within communities. The end products from this project will allow Groundwork to visualize areas within both cities that have high heat and flood distributions. As this project is specifically for Providence and Elizabeth, the team will provide the partner with a useful methodology that enables them to apply this analysis to the other participating cities in the Climate Safe Neighborhoods project.

**Earth Observations & End Products Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Surface Reflectance Surface Temperature\* | Landsat 8 Operational Land Imager (OLI) surface reflectance was used to generate Normalized Difference Water Index (NDWI) and Modified Normalized Difference Water Index (MNDWI) values to assess flood risk.  Landsat 8 OLI surface temperature was used to generate land surface temperature maps. |
| **Landsat 8 TIRS** | Surface Temperature\* | Landsat 8 Thermal Infrared Sensor (TIRS) surface temperature was used to generate land surface temperature maps. |
| **Landsat 7 ETM+** | Surface Reflectance  Surface Temperature\* | Landsat 7 Enhanced Thematic Mapper Plus (ETM+) surface reflectance was used to generate NDWI and MNDWI values to assess flood risk.  Landsat 7 ETM+ surface temperature was used to generate land surface temperature maps. |
| **Landsat 5 TM** | Surface Reflectance | Landsat 5 Thematic Mapper (TM) was used to generate NDWI and MNDWI values to assess flood risk. |
| **Terra MODIS** | Land Surface Temperature | Terra Moderate Resolution Imaging Spectroradiometer (MODIS) MOD11A1 and MOD11A2 data were an additional reference and validation data source and were used as a point of comparison to Landsat derived temperature and emissivity products. |
| **Terra ASTER** | Land Surface Temperature | Terra Advanced Spaceborne Thermal Emission and Reflection (ASTER) data were an additional reference and validation data source and were used as a point of comparison for monitored land surface temperatures and emissivity with calculated land surface temperature from Landsat data. |

\* These parameters were combined to create the Landsat Level-2 Provisional Surface Temperature product, provided by the United States Geological Survey (USGS).

***Ancillary Datasets:***

* Multi-Resolution Land Characteristics Consortium National Land Cover Database (NLCD), 2011 – Define land cover classifications across the study areas to allow for reference when viewing flood maps, also used for levels of urbanization classification

***Software & Scripting:***

* ESRI ArcGIS Pro – Raster manipulation, land cover classification of all Landsat imagery, map product generation
* ESRI ArcMap – Perform map algebra and data processing of all Landsat Imagery, Terra MODIS, and Terra ASTER
* Python – Applying a cloud mask and calculating water indices for all Landsat Imagery

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Annual Urban Heat Maps for 2014 and 2018** | Landsat 8 OLI/TIRS  Landsat 7 ETM+  Terra ASTER  Terra MODIS | These maps can be used to visualize the change in annual land surface temperature distributions across the study areas. | N/A |
| **5-Year Urban Heat Map from 2014 to 2018** | Landsat 8 OLI/TIRS  Landsat 7 ETM+  Terra ASTER  Terra MODIS | The partners can use this map to identify vulnerable areas with consistently high land surface temperatures. | N/A |
| **Annual Flood Distribution Maps for 1988 to 2018** | Landsat 8 OLI  Landsat 7 ETM+  Landsat 5 TM | These maps can be used to visualize the annual change in flood distributions across the study areas. | III |
| **Decadal Flood Distribution Maps for 1988 to 1998, 1998 to 2008, and 2008 to 2018** | Landsat 8 OLI  Landsat 7 ETM+  Landsat 5 TM | The partners can use these decadal maps to identify vulnerable areas with consistently high flood frequency. | III |
| **Project Methodology Standard Operating Procedure Document** | N/A | This detailed document outlines the project procedure and methodology so that Groundwork USA can replicate this analysis in other cities. | N/A |

**Project Handoff Package**

*Transition Plan:* During the final week of the term, the team conducted a conference call with Groundwork USA for the project handoff. In this meeting, the team presented Groundwork with methodologies, map products, and a Standard Operating Procedure document. All end products were delivered to the end user through NASA’s Large File Transfer system.

*Software Release Plan:* There was a software release for the Python code created by the team for data processing. Groundwork USA was notified about the software release process and the length of time needed for it to go through export control when the team decided on this methodology. The partners received the end products that incorporated the code at the end of the term so they could access map results and analysis to review before they received the code.

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**Handoff Package:**

* Annual Urban Heat Maps for 2014 and 2018
* 5-year Urban Heat Map from 2014 to 2018
* Annual Flood Distribution Maps for 1988 to 2018
* Decadal Flood Distribution Maps for 1988 to 1998, 1998 to 2008, and 2008 to 2018
* Project Methodology Standard Operating Procedure Document
* Technical Paper
* Project Video

**References:**

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