Baltimore Energy and Infrastructure
Assessing Urban Heat Vulnerability in Baltimore Neighborhoods to Inform Transportation Resiliency Planning Efforts

Project Team

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Project Overview

Project Synopsis:
The purpose of the project is to provide The Maryland Transit Administration (MTA) with Urban Heat Island (UHI) data to incorporate into their Adaptation and Resiliency Toolbox and ultimately inform mitigation and management efforts surrounding bus infrastructure in an equity framework.

Abstract:
Across the world, climate change is altering cities and their local climate systems. Following global trends of rising mean temperatures, Baltimore, Maryland is projected to experience more frequent extreme heat events. Exacerbated by Urban Heat Island (UHI) effects, residents of the city face high temperatures from limited tree canopy, highly paved and impervious surfaces, limited air flow, and high concentrations of localized emissions. Urban heat is dispersed asymmetrically, with historically marginalized populations experiencing disproportionately severe heat. Recognizing the impacts of extreme urban heat, the Maryland Transit Administration (MTA) collaborated with us, the Spring 2024 Goddard Energy and Infrastructure NASA DEVELOP team to assess urban impacts of MTA users and assets and explore opportunities to enhance resiliency planning. We evaluated the feasibility of NASA Earth observations (EOs) in visualizing heat vulnerability in Baltimore City and County. We mapped UHI and extreme heat using remote sensing observations, tailored a Heat Priority Score (HPS) to analyze heat data in tandem with socioeconomic data from American Community Survey (ACS), and utilized SOLWEIG to model MTA riders' thermal comfort. NASA EOs served to quantify the distribution and severity of extreme heat at the block group level, which was found to correlate with a lack of vegetation and presence of densely built-up surroundings. The HPS revealed that extreme heat events most negatively impact communities that exhibit social vulnerability through indicators such as age, race, and income. These findings will inform neighborhood resiliency plans for the MTA that can be incorporated into their Adaptation Resiliency Toolbox (ART).

Key Terms:

Baltimore, Transportation, Human Vulnerability Index, Maryland Transit Administration, PCA, SOLWEIG, Urban Heat Island Effect, UHEAT

Application Area: Urban Heat Islands, Climate Change
Study Location: Baltimore, Maryland (MD)
Study Period: 2013 to 2023 (June – October)

Community Concerns:

- Baltimore is experiencing extreme heat. The number of danger days, or days with a heat index above 105°F, are expected to increase from 8 in 2000 to 47 by 2050.
- Historically marginalized and disinvested communities continue to experience increased heat exposure, and a relatively limited ability to adapt to extreme heat events.
- The MTA needs to build out their ART to include specific data on extreme heat to help them target their mitigation strategies towards people that are more at risk of experiencing extreme heat at Baltimore bus stops.

Project Objectives:

- Utilize NASA Earth Observations to measure and visualize urban heat in relation to transportation corridors in Baltimore City and Baltimore County.
- Pinpoint neighborhoods with high heat vulnerability, using demographic variables tailored to Baltimore.
- Identify areas of overlap between hotspots and high heat vulnerability neighborhoods to inform bus cooling strategies.

Partner Overview

Partner Organizations:

Organizations	Contact (Name, Position/Title)	Partner Type	Sector
Maryland Transit Administration (MTA)	Jennifer Martin, MTA Consultant	End User	State Government

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Decision-Making Practices & Policies:

The MTA and its fellow subagencies engage in resiliency planning across a large scale, balancing their different assets, expertise, budgets, streamlining data, and collaboration. Within this group, MTA focuses on multiple types of transit across the state, including buses, light rail, and trains. MTA's resiliency planning process centers on the collection and analysis of data to determine the type and extent of need, as well as if the asset is up for investment or rehabilitation. MTA also assigns priority to their assets, influenced by their equity matrix. After these stages with data, MTA does community outreach to identify what mitigation infrastructure or strategies could look like. The ART currently encompasses water-based disasters like flooding events, with ongoing efforts by MTA to broaden their scope to include urban heat. Additionally, MTA engages their personnel in educational trainings rooted in vulnerability and environmental justice concepts to ensure a holistic approach to solutions. In MTA's environmental planning division, they have Geographic Information System (GIS) professionals on staff and routinely use GIS software for their dashboards and analyses.

Earth Observations & End Products Overview

Platform & Sensor	Parameter(s)	Use
Landsat 8 OLI	Normalized Difference Vegetation Index (NDVI),	Data was used to calculate various indices in relation to land-cover and surface reflexivity.

	Normalized Difference Building Index (NDBI), Albedo	
Landsat 8 TIRS	Land Surface Temperature (LST) and Albedo	Data was used to access maximum LST, mean LST, and surface reflexivity.
Terra MODIS	Nighttime LST	Data was used to calculate mean nighttime LST over the study period.
Aqua MODIS	Normalized Difference Water Index (NDWI)	Data was used to calculate reflexivity of various water bodies in the study area.

Ancillary Datasets:

- US Census Bureau American Community Survey (ACS) Data, 2020 5-Year Survey – to create vulnerability index and exposure maps
- MTA shapefiles – contains bus stop locations and routes to be used as input for vulnerability assessment package
- MD Environmental Justice (EJ) Data – used for scaling to neighborhoods and includes equity framework indicators, as well as other census information

Models

- SOlar and LongWave Environmental Irradiance Geometry model (SOLWEIG) (Contact: Mehdi Heris, Hunter College) – Produce an outdoor thermal comfort model for specific bus stop locations

Software & Coding Languages:

- Google Earth Engine – Access, filter, and analyze satellite earth observations from Landsat 8, Aqua MODIS, and Terra MODIS
- R Studio 4.3.3 – Access U.S. Census Bureau data at the block-group level through the Tidycensus package, conduct a Principal Component Analysis (PCA) of sociodemographic and environmental variables, and produce a Heat Vulnerability Index
- ArcGIS Pro 3.2.0 – Visualize urban heat, environmental exposure, and social vulnerability
- QGIS 3.36.0 – Used to run SOLWEIG model

End Products:

End Products	Earth Observations/Data Used	Partner Benefit & Use
Heat Assessment Package	Landsat 8 OLI/TIRS Aqua MODIS Terra MODIS	Map visualizations of Urban Heat Island data to aid in the development of MTA's Adaptation and Resilience Toolbox (ART)
Heat Vulnerability Assessment Package	U.S. Census Bureau (ACS) 5- year Estimates	Map visualizations of social vulnerability used to identify census block groups with less adaptive capacity
Outdoor Thermal Comfort Model	Virtual Crossing Meteorological Data LiDAR Point Cloud USGS | National Map 1- Meter NAIP Imagery	Map visualizations of daylong outdoor ambient temperature for McElderry Park in Baltimore, MD through the SOLEWIG model
Video	EO's & Census Data	This creative communication deliverable with impactful visuals and storytelling about urban heat and public transportation

		will support the partners in their community engagement and education efforts internally throughout the MTA.

Product Benefit to End User:

Urban Heat Island visualizations and data will be provided to MTA which will ultimately inform future decision-making regarding transit-related heat mitigation strategies throughout Maryland. Additionally, social vulnerability visualizations and data will be provided to illustrate how urban heat is felt disproportionately throughout the city, largely impacting marginalized and disinvested communities. This will aid MTA in targeting their mitigation strategies towards communities that are more at risk of experiencing increased chronic and extreme heat at bus stops within Baltimore city and county Additionally, the informative video will be distributed internally throughout MTA to educate personnel about the urban heat island effect in Baltimore City.

References

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