**Cambridge Urban Development**

*Quantifying Changes in Urban Albedo with NASA Earth Observations to Reduce Urban Heat Island Effect in Cambridge, Massachusetts*

**Project Team**

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**Project Overview**

***Project Synopsis:***

Elevated temperatures resulting from the urban heat island effect have widespread impacts on human health, infrastructure, and ecosystems. Historically, Cambridge, Massachusetts has not been affected by extreme heat, but rising temperatures have prompted community leaders to develop preventative measures that mitigate the effects of urban heat. To contribute to these efforts, the Summer 2020 DEVELOP Massachusetts – Boston team mapped changes in rooftop albedo, generated a nighttime temperature record, and produced temperature anomaly maps that identify ‘hot spots’ across the city. These results are displayed in the Cambridge Urban Heat Dashboard, a tool that allows users to explore spatial and temporal trends in albedo over time.

***Abstract:***

The urban heat island (UHI) effect occurs when urban areas have temperatures that are warmer on average than the surrounding suburban and rural regions. Low albedo surfaces traditionally found in urban landscapes, such as dark asphalt and rooftops, absorb solar irradiance and reemit heat, which contributes to the UHI effect. Cambridge, Massachusetts, part of the Boston metropolitan area, expects severe impacts on human health, infrastructure, and local environmental features due to increasing urban heat. The Massachusetts – Boston NASA DEVELOP team partnered with the City of Cambridge Community Development Department and the American Geophysical Union’s Thriving Earth Exchange to inform ongoing planning and heat mitigation efforts. High Resolution Orthoimagery (HRO) and National Agriculture Imagery Program (NAIP) scenes were analyzed in conjunction with ancillary datasets to assess changes in rooftop albedo between 2008 and 2018. Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) data were used to determine nighttime land surface temperature (LST) between 2003 and 2019. Lastly, temperature anomalies were calculated using seasonally averaged nighttime LST values obtained from Aqua MODIS to display ‘hot spots’ for summers between 2004 and 2019. On average, albedo increased by 0.12 across the city, with the majority of positive change in commercial areas. Analysis of mean summer nighttime LST between 2003 and 2019 revealed a non-significant increase in temperature, although temperature anomaly maps demonstrated that Cambridge was warmer on average than rural areas. These results were incorporated in the interactive Cambridge Urban Heat Dashboard, which allows users to explore temporal trends in albedo.

***Key Terms:***

urban heat island, albedo, land surface temperature, climate preparedness, remote sensing, ArcGIS Dashboard

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

***Study Location:*** Cambridge, MA

***Study Period:*** 2003 to 2019 (April through October)

***Community Concerns:***

* Impervious surfaces, which contribute to the UHI effect, cover over 60% of Cambridge, home to over 100,000 residents in the Boston metropolitan area.
* By 2030, experts expect that Cambridge will experience warmer than average temperatures, more heat waves, and as many as triple the number of abnormally warm days above 90°F per year, further exacerbating the impacts of the UHI effect.
* Impacts of the UHI effect include increases in heat-related mortality, increased air pollution, impacts to biodiversity in local ecosystems, and increased energy consumption as community members attempt to cool buildings.

***Project Objectives:***

* Calculate changes in rooftop albedo for the period of 2008 to 2018
* Generate a nighttime land surface temperature record for Cambridge using NASA Earth observations for the period of 2003 to 2019
* Map temperature ‘hot spots’ in Cambridge compared to an area of eastern Massachusetts from 2004 to 2019
* Create an interactive ArcGIS Online ‘Cambridge Urban Heat Dashboard’ that allows partners to explore spatial and temporal patterns in albedo, visualize temperature anomalies, and assess impacts of urban infrastructure changes

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **City of Cambridge, Community Development Department** | John R. Bolduc, Environmental Planner; Drew Kane, Land Use Planner | End User | No |
| **American Geophysical Union, Thriving Earth Exchange** | Julia Jeanty, Community Science Fellow | Collaborator | Yes |

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

The City of Cambridge is preparing for the impacts of climate change by creating a Climate Change Preparedness & Resilience (CCPR) Plan. Partners at the City of Cambridge Community Development Department have introductory knowledge of NASA Earth observations and in-house GIS resources. The department has previously outsourced remote sensing analyses of the city’s impervious surfaces, tree canopy cover, and Normalized Difference Vegetation Index. Currently, staff are looking for ways to track changes in rooftop albedo to better understand the UHI effect. The partners do not currently incorporate remote sensing or NASA Earth observations in their decision-making process.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Aqua MODIS** | Land surface temperature and emissivity | MODIS data were used to determine nighttime LST. |

***Ancillary Datasets:***

* USDA National Agriculture Imagery Program (NAIP) (2010, 2014, 2018) – Aerial Imagery containing four bands: Red, Green, Blue, and Near-infrared, used for calculating rooftop albedo
* USGS High Resolution Orthoimagery (HRO) (2008, 2013, 2018) – Aerial Imagery containing four bands: Red, Green, Blue, and Near-infrared, used for calculating rooftop albedo
* City of Cambridge Buildings (2010, 2018) – Cambridge building footprints used for isolating rooftop NAIP and HRO pixels while calculating albedo
* MassGIS Building Structure (2D) (2013) – Building footprints for Massachusetts used for isolating rooftop NAIP and HRO pixels while calculating albedo of Cambridge rooftops for 2013
* City of Cambridge Neighborhood Boundaries (2020) – Shapefile containing neighborhood boundary information, included in albedo calculation as well as the dashboard for comparison of albedo values at a neighborhood scale
* City of Cambridge Tree Canopy (2014) – High-resolution tree canopy change-detection layer for Cambridge, included in the dashboard for visual comparison of vegetation in relation to albedo values
* City of Cambridge Impervious Surface (2010) – Compilation imagery estimating impervious surface in Cambridge, included in the dashboard to allow visual comparison of areas of high percentages of impervious surface with albedo values
* Metropolitan Area Planning Council Municipal Boundaries (2017) – Shapefile containing 101 municipality boundaries surrounding Boston, Massachusetts, included in the dashboard to provide visual comparison of nighttime temperature anomalies at the municipality level

***Software & Scripting:***

* Esri ArcGIS Pro – Data visualization and map generation
* Esri ArcGIS Online – Data visualization and dashboard creation
* Google Earth Engine – Data acquisition, processing, and analysis
* Python 3.7.4 – Data processing and analysis
* R 3.4.4 – Data and statistical analysis

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Rooftop Albedo Maps** | NAIP, HRO | Enables partners to track changes in albedo from 2008 to 2018 at the scale of an individual building or through the entire city. This will help evaluate the effectiveness of initiatives aimed at reducing the impacts of urban heat in the City of Cambridge. | N/A |
| **Nighttime LST Maps** | Aqua MODIS | Enables partners to assess spatial and temporal patterns in nighttime LST within the City of Cambridge from 2003 to 2019. | N/A |
| **Temperature Anomaly Maps** | Aqua MODIS | Enables partners to assess spatial and temporal patterns in nighttime LST temperature anomalies within the City of Cambridge from 2004 to 2019. | N/A |
| **Cambridge Urban Heat Dashboard** | Aqua MODIS | Allows partners or community users to interact with and examine spatial patterns between changes in albedo over time and environmental factors, such as temperature and tree canopy cover, that increase the potential for the UHI effect to occur. Created in ArcGIS Online. | N/A |

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

Cambridge is actively taking steps to reduce the impact of the UHI effect within the community. This includes creating a CCPR Plan to prepare for the impacts of a changing climate on Cambridge. The end products from this project will provide the City of Cambridge with a way to visualize changes in rooftop albedo during the study period of 2008 to 2018 and assess the effectiveness of urban heat reduction strategies implemented during this time. Ultimately, these tools will help the city adapt and mitigate how the UHI effect could affect communities in Cambridge.

**References**

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