**NASA DEVELOP National Program**

**2020 Summer Project Proposal**

**Massachusetts – Boston**

**Cambridge Urban Development**

*Quantifying Changes in Urban Albedo with NASA Earth Observations to Reduce the Urban Heat Island Effect*

**Project Overview**

***Project Synopsis*:** As impacts from changes in environmental conditions become more widespread, cities like Cambridge, Massachusetts, that have not historically been affected by extreme heat, now anticipate urban heat will impact human health, infrastructure, and local ecosystems. In order to combat these extreme heat impacts, community leaders in Cambridge are planning ahead and looking for ways to track changes in urban albedo over time. This project will map surface and rooftop albedo in Cambridge as well as create an interactive ArcGIS Dashboard, allowing partners to explore spatial and temporal albedo trends and assess the impacts of previous urban infrastructural changes. Products will be created using Terra MODIS, Landsat 5 TM, Landsat 8 OLI and TIRS, Sentinel-2 MSI, and ancillary datasets. Overall, the methodology and results from this project will help partners at the City of Cambridge, Community Development Department and the American Geophysical Union, Thriving Earth Exchange (TEX) transform the city with sustainable urban planning to be better equipped for threats from increased heat.

***Community Concern:*** The Urban Heat Island (UHI) effect is a phenomenon that makes urban areas significantly warmer than surrounding suburban or rural regions. Part of Boston’s metropolitan area, Cambridge, MA is home to over 100,000 people, with ~60% land area being some form of impervious surface. As climate change advances, cities like Cambridge expect to see serious impacts on residents’ health, local environmental features, and infrastructure due to the UHI. The city is currently monitoring impervious surface area and canopy cover within the city limits, but has no way of tracking changes in urban surface and rooftop albedo. Observing changes in urban albedo through time would enable evaluation of whether Cambridge is successfully reducing the UHI effect and reducing future threats to the city’s public health and economic well-being.

***Source of Project Idea:*** This is a TEX project and DEVELOP joined once initial planning began. Nancy Searby, the Program Manager of NASA’s Capacity Building Program, expressed interest in a collaboration between DEVELOP and TEX. This will be one of the first collaborative projects between the two organizations. Dr. Mehdi Heris is acting as the main TEX scientific advisor and provided ideas for the project’s methodology.

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

***Study Location:*** Cambridge, Massachusetts

***Study Period:*** April 2010 – April 2020

***Advisors:*** Dr. Cedric Fichot (Boston University), Dr. Mehdi P. Heris (University of Colorado Denver)

**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 |

***End User Overview***

***End User’s Current Decision-Making Process:***The City of Cambridge is currently creating a Climate Change Preparedness & Resilience (CCPR) Plan to prepare Cambridge for impacts from climate change. Partners are looking for ways to evaluate progress on reducing the UHI effect. They currently have methods for measuring and tracking impervious surface and canopy cover, but have no methods for tracking changes in surface albedo. At this time, partners do not use remote sensing in their decision-making process.

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

*City of Cambridge, Community Development Department* – The main partner contacts, John R. Bolduc and Drew Kane, have introductory knowledge of NASA Earth observations and in-house GIS resources. However, they do not currently have working knowledge of how to use NASA Earth observations in their work or decision-making. The end user mentioned that they are excited to integrate new cost efficient and user-friendly ways of informing their future decision-making.

***Collaborator & Boundary Organization Overview***

***Collaborator Support:***

*American Geophysical Union, Thriving Earth Exchange* – TEX connected DEVELOP to the lead principal investigator for the project, Dr. Mehdi P. Heris. Fellow and point of contact, Julia Jeanty, will act as the TEX liaison for introducing the team to resources and tailoring the project to TEX standard practices.

***Dissemination by Boundary Organizations*:**

*American Geophysical Union, Thriving Earth Exchange* – TEX’s mission is to encourage collaboration between scientists, partner organizations, and communities around the world. As such, they have built a network of researchers and community leaders across a diverse range of organizations. All completed TEX projects are shared on their website where access to methodologies and results is available for anyone in their network.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** The partners will meet virtually with the Boston DEVELOP team on a bi-weekly basis during the summer term. The main POC for all communications will be the Project Lead, with support from the Fellow, if necessary.

***Transition Plan*:** The partner hand-off will take place in week 10 of the term. The event will take place remotely over Google Meet. The project team will present the term’s methods and findings as well as answer questions. Maps will be immediately delivered to partners for policy and research integration. Deliverables and end products will be delivered to partners after completing export control.

**Earth Observations Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Landsat 5 TM** | Top-of-atmosphere reflectance and radiance  | Landsat 5 will be used to calculate surface and rooftop albedo.  |
| **Landsat 8 OLI**  | Top-of-atmosphere reflectance and radiance  | Landsat 8 will be used to calculate surface and rooftop albedo. |
| **Landsat 8 TIRS** | Temperature | Landsat 8 TIRS data will be retrieved as Analysis Ready Data and used to calculate daytime land surface temperature.  |
| **Sentinel-2 MSI**  | Surface reflectance | Sentinel-2 will be used to estimate albedo and calculate the broadband albedo spectrum from the narrowband data.  |
| **Terra MODIS**  | Land surface temperature and emissivity | Terra MODIS will be used to determine nighttime land surface temperature.  |

***Ancillary Datasets:***

* City of Cambridge Buildings – the building footprints for Cambridge for isolating rooftop imagery
* City of Cambridge Impervious Surface – 2010 compilation imagery estimating impervious surface in Cambridge
* City of Cambridge Orthophotos – provides a longitudinal study of albedo changes
* City of Cambridge Tree Canopy – high-resolution tree canopy change-detection layer for Cambridge, for identifying any rooftop-covering tree canopies
* United States Geological Survey National Land Cover Database – 2016 land cover and impervious surface data
* US Census American Community Survey (ACS) – estimates of Cambridge demographic, housing, and socioeconomic community
* USDA National Agriculture Imagery Program (NAIP) – high-resolution imagery for more accurate estimates past albedo

***Software & Scripting:***

* Esri ArcGIS – data visualization and map generation
* Esri ArcGIS Online – data visualization and Dashboard creation
* Google Earth Engine – data downloading, processing, and analyses
* Python – data processing and analysis
* R – data and principal component analysis

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **2010 – 2020 Surface and Rooftop Albedo Maps** | Partners will be able to examine how changes in surface and rooftop albedo influence the UHI of the city as well as track changes in albedo through time. This will assist the partners’ goal of evaluating if they are successfully reducing the UHI effect and the effectiveness of their white roofing policy.  | Landsat and Sentinel data will be used in conjunction with Cambridge Building Footprints to calculate surface albedo and isolated rooftop albedo for two methodologies intended to validate the results. For verification, the analysis will be completed using both NAIP data and Orthoimagery.  | III |
| **ArcGIS Dashboard** | Partners will be able to explore the spatial patterns of UHI effect and albedo variations throughout the city of Cambridge, as well as assess the impact of previous urban infrastructural changes.  | Albedo calculations will be visualized and merged with MODIS and Landsat land surface temperature data, as well as other previously analyzed environmental factors contributing to the UHI effect in an interactive, online dashboard for partner use.  | N/A |

***End User Benefit*:** Currently, Cambridge is creating a CCPR Plan to prepare for likely impacts from climate change. Community leaders are looking for ways to evaluate progress on reducing the UHI effect, but presently have no methods for tracking changes in surface or rooftop albedo. The end products will provide partners with a replicable methodology and affordable results to assess urban albedo in Cambridge. Overall, remote sensing and NASA Earth observations will allow the partners to assess changes in albedo through time, albedo’s impact on the UHI effect, and help the city adapt for the effects of climate change.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 1 Term: 2020 Summer

***Related DEVELOP Work:***

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

2019 Fall (NC) – Asheville Urban Development: Using NASA Earth Observations to Quantify the Impact of Urban Tree Canopy Cover on Urban heat Island Community Vulnerability in Asheville, North Carolina

2019 Summer (AL) – Mobile Urban Development: Evaluating Urban Heat Islands and Flooding to Enhance Green Infrastructure Initiatives in Coastal Communities in Mobile, Alabama

2018 Fall (AL) – New Orleans Health & Air Quality: Monitoring the Urban Heat Island Effects on the Health of residents of New Orleans, Louisiana Metropolitan Area with Landsat and Land Surface Temperature Products

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

**Notes & References:**

***Notes*:** If the team has additional time, they will also look into incorporating ECOSTRESS land surface temperature data for validating the Terra MODIS nighttime land surface temperature record.

***References:***

Ban-Weiss, G. A., Woods, J., & Levinson, R. (2015). Using remote sensing to quantify albedo of roofs in seven California cities, Part 1: Methods. *Solar Energy*, *115*, 777-790. <https://doi.org/10.1016/j.solener.2014.10.022>

Bonafoni, S., Baldinelli, G., & Verducci, P. (2017). Sustainable strategies for smart cities: Analysis of the town development effect on surface urban heat island through remote sensing methodologies. *Sustainable Cities and Society*, *29*, 211-218. <https://doi.org/10.1016/j.scs.2016.11.005>

Goward, S. N. (1981). Thermal behavior of urban landscapes and the urban heat island. *Physical Geography*, *2*(1), 19-33. <https://doi.org/10.1080/02723646.1981.10642202>

Kato, S., & Yamaguchi, Y. (2005). Analysis of urban heat-island effect using ASTER and ETM+ Data: Separation of anthropogenic heat discharge and natural heat radiation from sensible heat flux. *Remote Sensing of Environment*, *99*(1-2), 44-54. <https://doi.org/10.1016/j.rse.2005.04.026>

Mackey, C. W., Lee, X., & Smith, R. B. (2012). Remotely sensing the cooling effects of city scale efforts to reduce urban heat island. *Building and Environment*, *49*, 348-358. [https://doi.org/10.1016/j.buildenv.2011.08.00](https://doi.org/10.1016/j.buildenv.2011.08.004)4