ESIP Summer Meeting
July 16, 2015

Vulnerabilities and Resilience to Urban Heat Waves Associated with Climate Change

Erica Zell, Stephanie Weber, Natasha Sadoff
Battelle Memorial Institute

Alex de Sherbinin
CIESIN, Columbia University

Center for International Earth Science Information Network
EARTH INSTITUTE | COLUMBIA UNIVERSITY

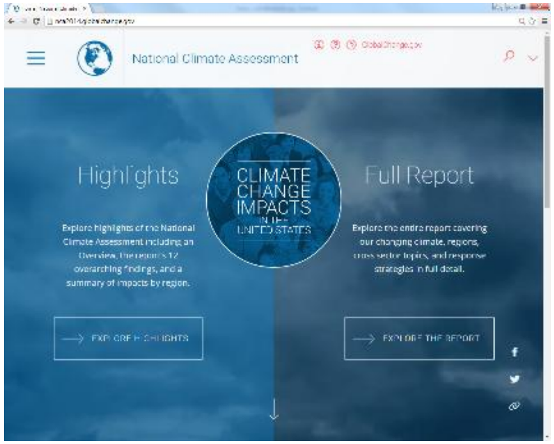
Battelle
The Business of Innovation

Project Context

- 18 months (Oct 2013-March 2015)
- Funded by NASA Applied Sciences Program
- Pilot project to test integration of satellite-based data to support potential National Climate Assessment indicators
- Prime: Battelle Memorial Institute
  - Sub: CIESIN/Earth Institute at Columbia University
- Leverages prior work on satellite-derived indicators and connections with Climate and Urban Systems Partnership (CUSP), Climate Change Research in the Urban Northeast (CCRUN), and NPCC2

Objective: *Engage urban stakeholders in a process to develop a set of vulnerability indicators that are focused on heat waves in urban areas, to elucidate for urban governments the degree to which heat waves are changing, differences in urban and rural temperatures, population vulnerability, and the effectiveness of adaptation actions to reduce urban temperatures.*

National Climate Assessment Context



- The US Global Change Research Program released 3rd National Climate Assessment Report- May 2014
  - Addresses Human Health, Infrastructure, Extreme Weather
  - For example, indicates that human influence on climate has already approximately doubled the probability of extreme heat events such as that experienced in 2011 in Texas and Oklahoma.
- Pilot indicators have been proposed for NCA (including Surface Temps, Cooling Degree Days, Heat-Related Morbidity)
- Our **indicators** will be considered for addition to pilot **indicators** and inclusion in Sustained Assessment Process

Conceptual Methodology

Identify and Engage Stakeholders
- *Urban health and planning departments*
- *City, county, state governments*

Refine Indicator Methodology

Calculate Indicators
- *Generate unique visualizations*
- *Vet results with stakeholders*

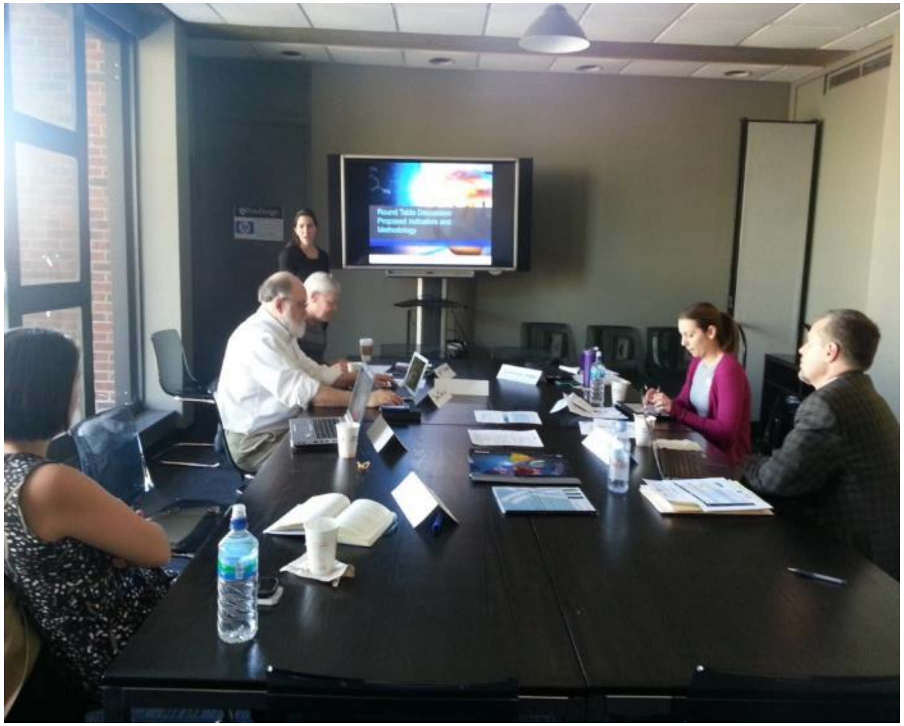
Assess National Scale-Up

- **Exposure indicators:**
  - *Urban Heat Wave Indicator:* An estimate of the intensity and total duration of heat waves for a city
  - *Urban Heat Island Indicator:* An estimate of the average Land Surface Temperature (LST) difference between urban areas and rural areas for periods of extreme heat
  - *Air Quality Indicator:* Ambient O_3 levels in metropolitan area during heat waves as a proxy for health impacts
- **Sensitivity indicator:**
  - *Urban Socioeconomic and Hotspot Indicator:* Classification of sensitivity of census units based on socioeconomic census and urban greenness data
- **Adaptive capacity indicator:**
  - *Urban Adaptation Effectiveness Indicator:* Measured reductions in LST or increases in Normalized Difference Vegetation Index (NDVI) in neighborhoods related to UHI reduction measures

Center for International Earth Science Information Network
Earth Institute | Columbia University
Battelle
The Business of Innovation

January 2014 - Advisory Group Meeting

PHILADELPHIA STAKEHOLDERS
Philadelphia Department of Public Health
Philadelphia City Planning Department
City of Philadelphia, Office of Sustainability
University of Pennsylvania
Philadelphia Electric Co. (PECO)
Azavea
Drexel University
The Franklin Institute
University of Pennsylvania School of Design
Others



- Presentation of the indicators, proposed methodology, Philadelphia-specific considerations, and communication strategies

Stakeholder Advisory Group Input

- Interest in **spatially disaggregated indicators** that can identify status and trends in localities
- Interest in **evaluating adaptation efforts**:
  - Using the spatial indicators to evaluate whether Philadelphia's efforts at tree planting and "cool roofs" are resulting in lower surface temperatures
- Interest in using the spatial indicators in a mapping tool for **public communication** at the Franklin Institute (through CUSP project)
- Interest in **heat impacts on health**, especially associated with **poor air quality**
- **Health impact mapping** not possible because data are restricted owing to confidentiality concerns
- Make the **indicators turn-key and user-friendly** → review options for mapping and visualizing

The Vulnerability Calculation

EXPOSURE	+	SENSITIVITY	=	VULNERABILITY	(ADAPTIVE CAPACITY)
•Physical exposure of urban populations to increasing heat waves associated with climate change		•Higher likelihood of health impacts for a given heat exposure, for certain population subsets such as elderly or low-income		•Overall susceptibility of urban populations to heat wave health impacts	•Ability to anticipate, cope with, or respond to climate stresses such as urban heat waves

- Instead of focusing on each indicator as a stand-alone product, develop a set of related indicators aimed at identifying vulnerable populations
- The air quality indicator represents another aspect of exposure – to pollution in addition to heat

Data Gathering and Management

NASA MODIS: Land Surface Temp (LST), Normalized Difference Vegetation Index (NDVI), and Land Cover Data

- Gridded products downloaded from NASA Data Center (https://lpdaac.usgs.gov/data_access/data_pool)
  - 11 years of July data for 2 MODIS L3 tiles in HDF4 format (~ 2GB)
- HDF4 files mosaiced and converted to geotiff using automated batching of HEG tool (~20MB)
- Data processing conducted in R and data stored as an R object and exported to geotiffs

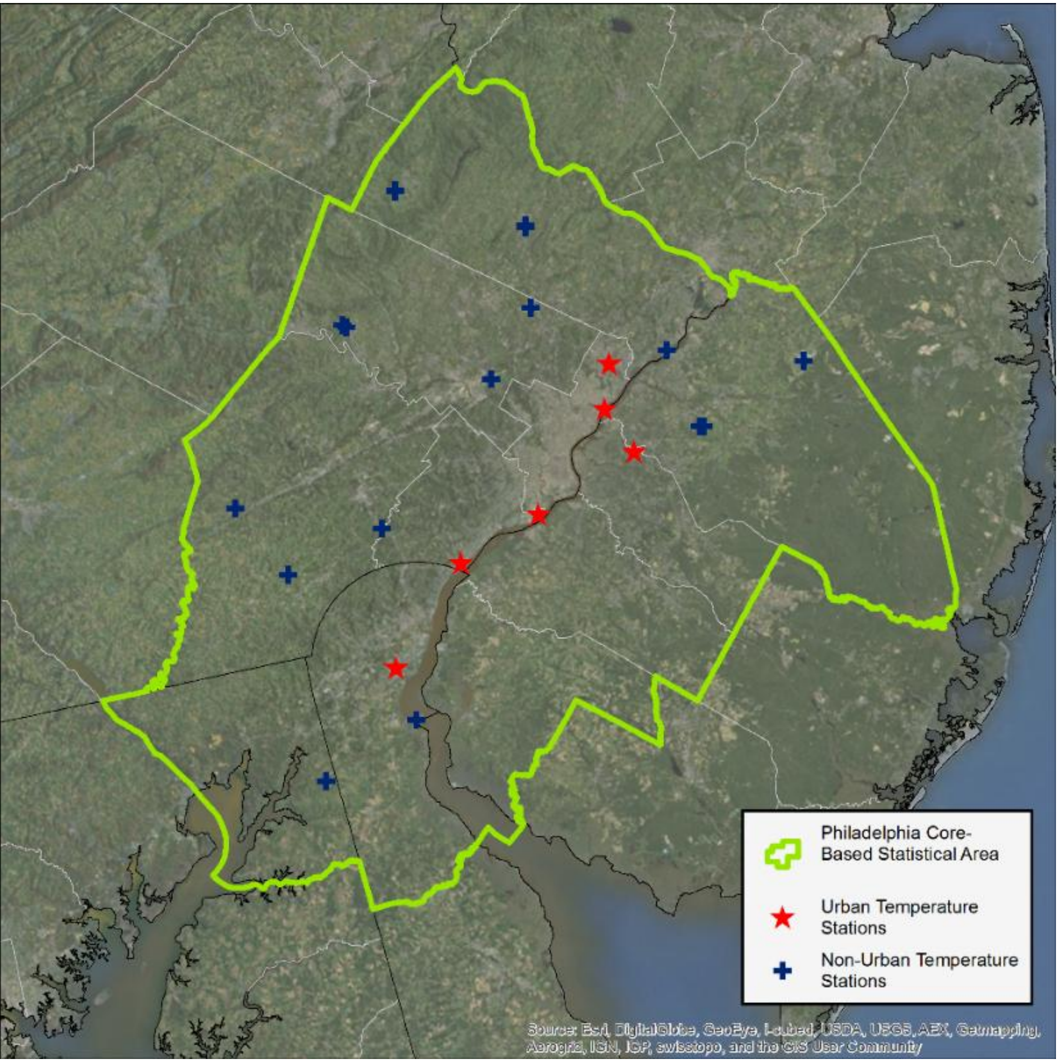
U.S. Census American Community Survey Demographic Data

- Data for states included downloaded Bureau (http://www2.census.gov/acs2012_5yr/summaryfile/)
  - All tables for all geography levels for 5 states (~3.5GB)
- Variable extraction and data processing conducted in R
- Data joined to census block group boundaries and stored in shapefiles

Ground-based Temperature Data

- Data from NOAA National Climatic Data Center (NCDC), as .csv files

Philadelphia: Urban Heat Wave Indicator



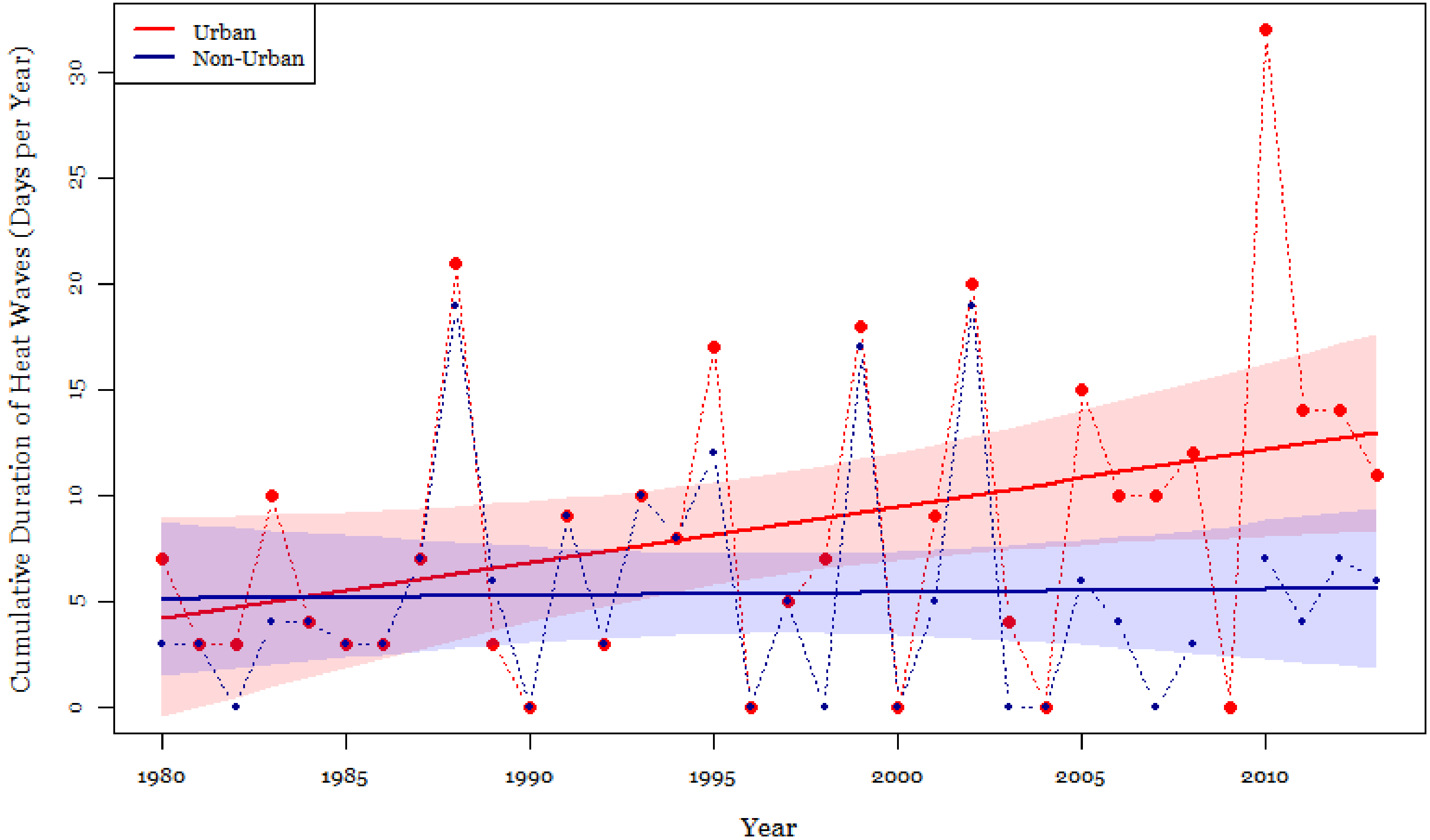
- ***Source:*** NCDC Global Summary of the Day
- Heat wave defined as exceeding the 85th percentile of daily average temperature based on 3-hourly July and August temperatures for 1961-1990 (NCDC) for three or more consecutive days.
  - Daily average temp of **81 F** for Philadelphia

Center for International Earth Science Information Network
EARTH INSTITUTE | COLUMBIA UNIVERSITY

Battelle
The Business of Innovation

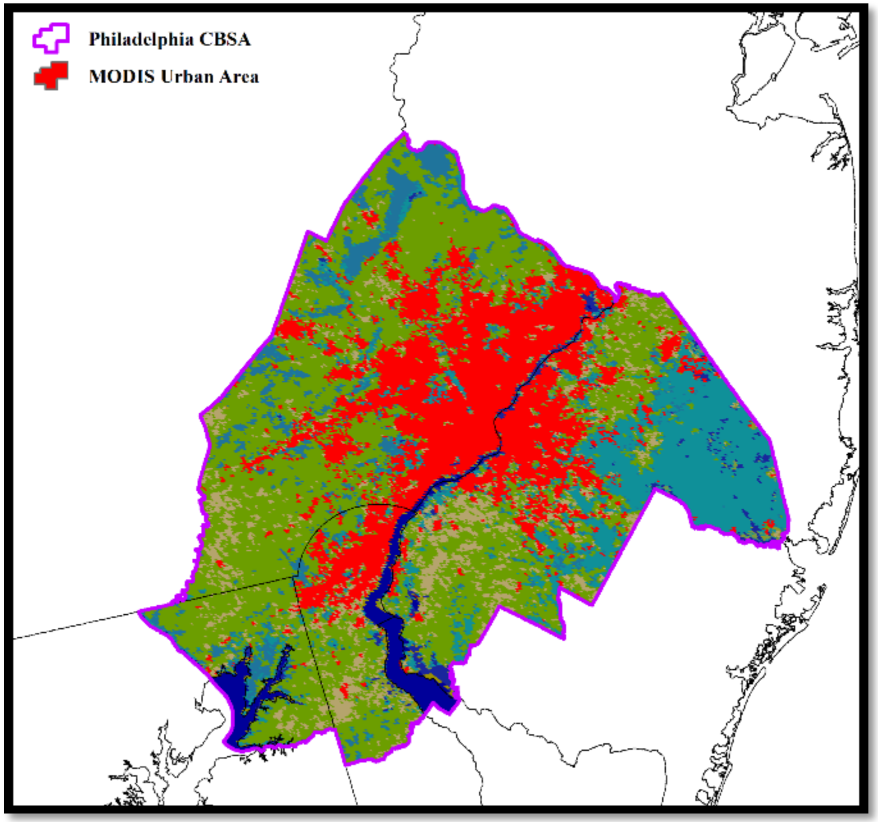
Philadelphia: Urban Heat Wave Indicator

Cumulative Duration (days per year) of Heat Waves

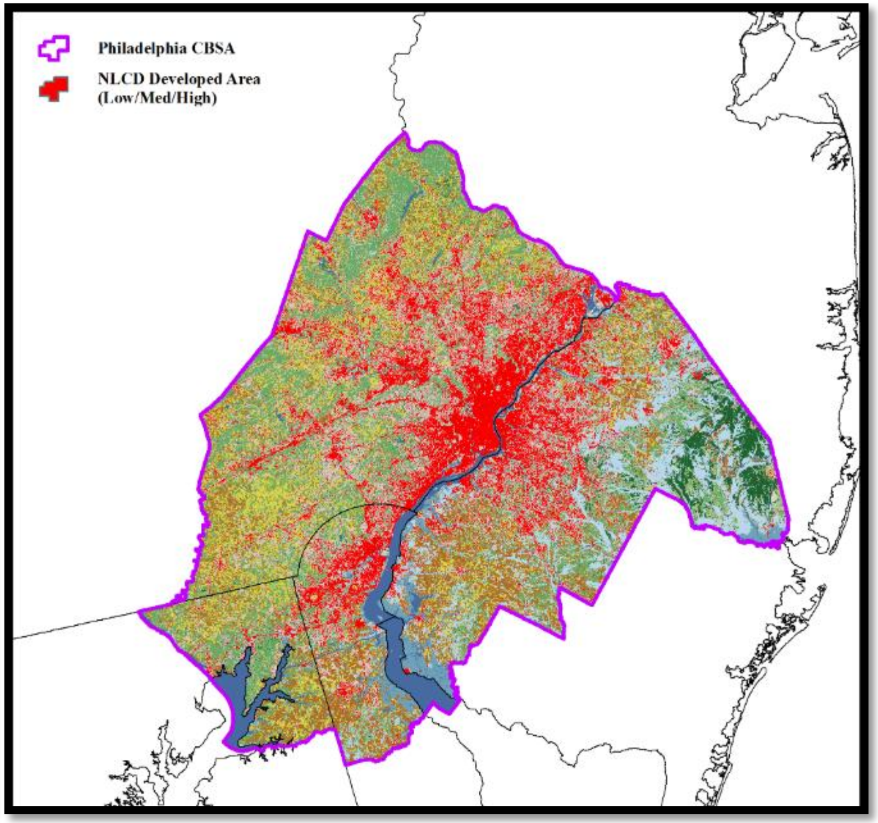


Urban Heat Island Indicator

NASA MODIS Urban Area



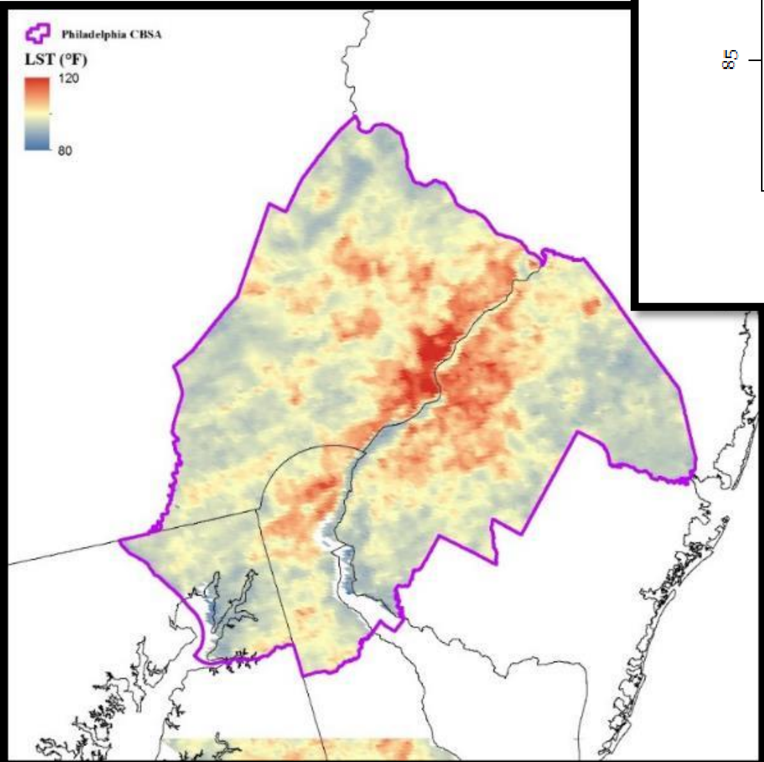
National Land Cover Database (NLCD) Urban Area

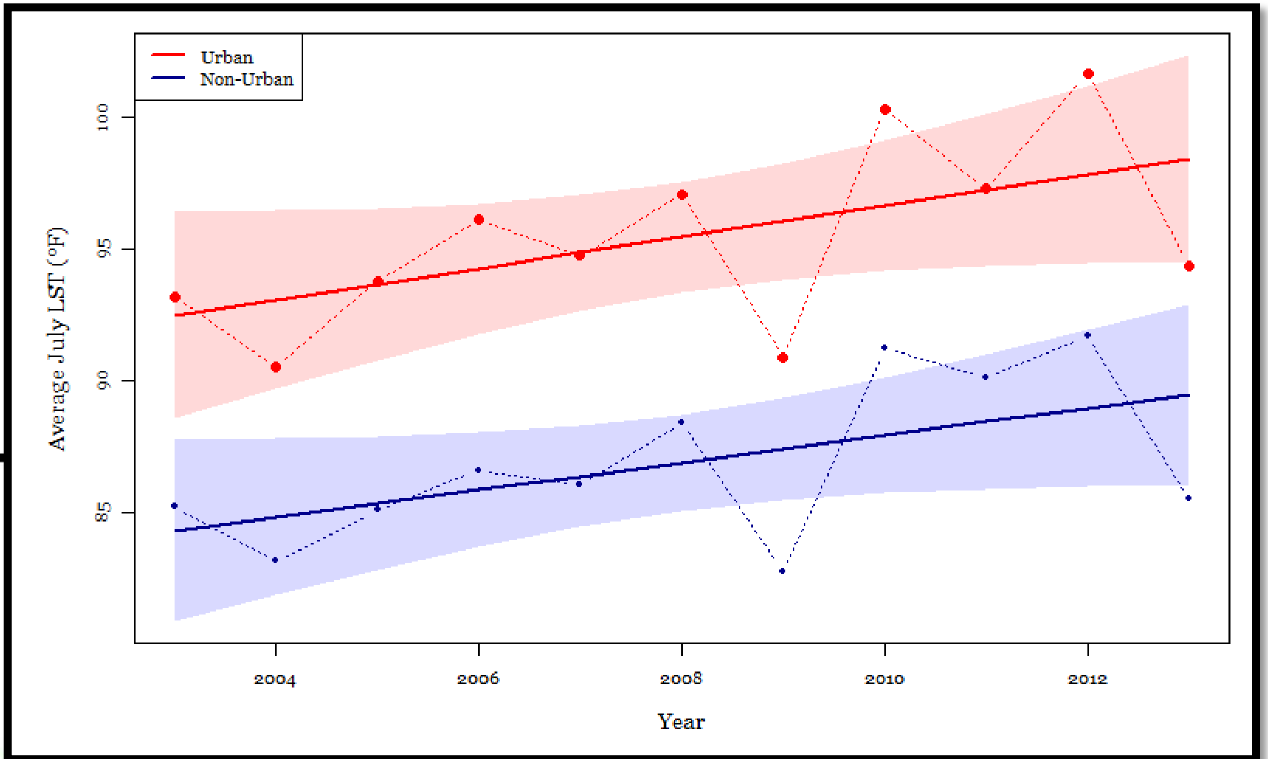


Urban Heat Island Indicator

LST

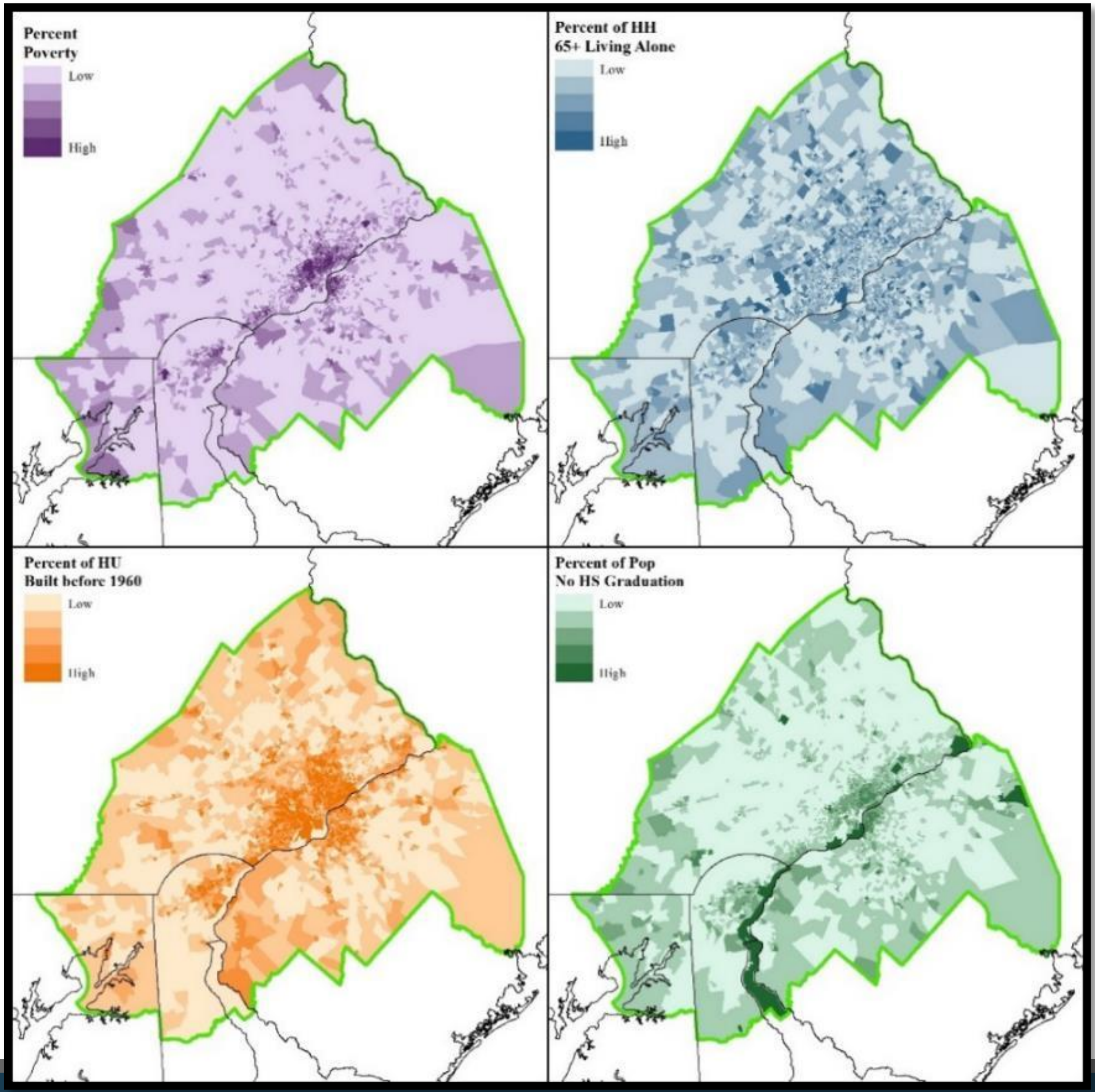
July 2012





Urban Socioeconomic Indicator

- ACS 5-year Estimates (2008-2012)
  - Percent of population living below the poverty line
  - Percent of households where there is a person age 65 or older living alone
  - Percent of housing units built prior to 1960
  - Percent of population that achieved an education level less than high school graduation

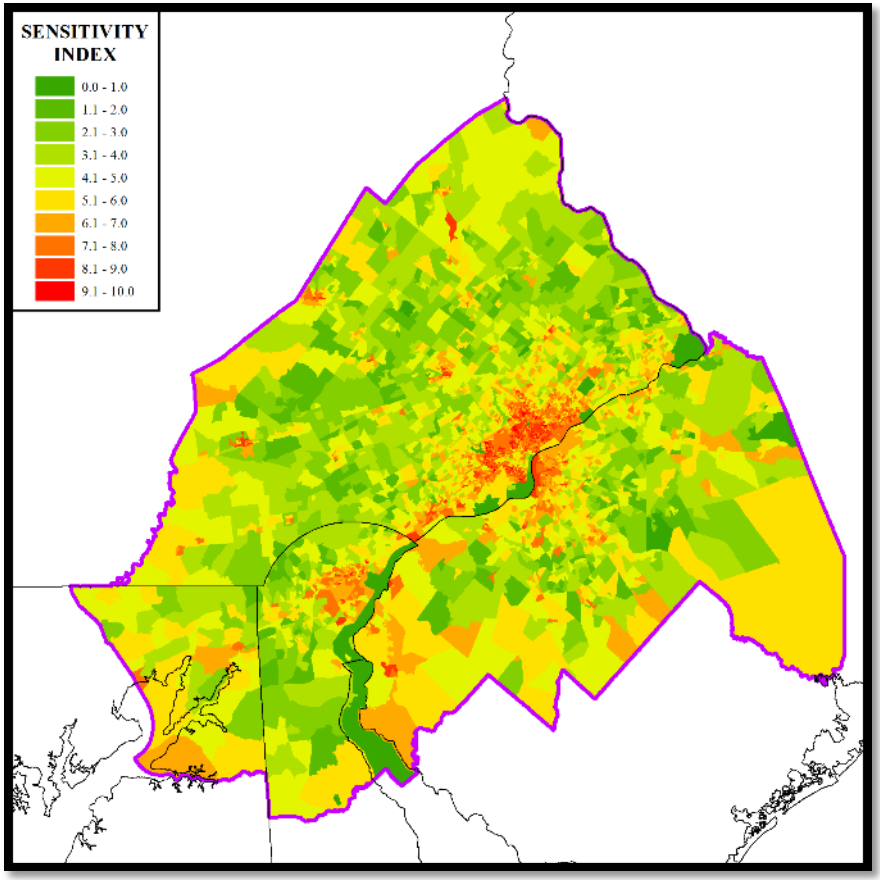


Center for International Earth Science Information Network
EARTH INSTITUTE | COLUMBIA UNIVERSITY

Battelle
The Business of Innovation

Social Sensitivity Index

- Combine socioeconomic factors into single sensitivity indicator:
  - Break census block group values for each individual factor into deciles *(i.e. lowest 10%, 10-20%, etc.)* and assign a rank from 1-10 with 10 being the "worst case" relative to heat sensitivity (*i.e. high percent poverty, high percent of population 65+ living alone, high percent of housing units built before 1960 and low percent HS graduate*)
  - Average individual factor rankings to get a total sensitivity index
  - Equal weighting was applied to all factors, but could be changed based on stakeholder requirements

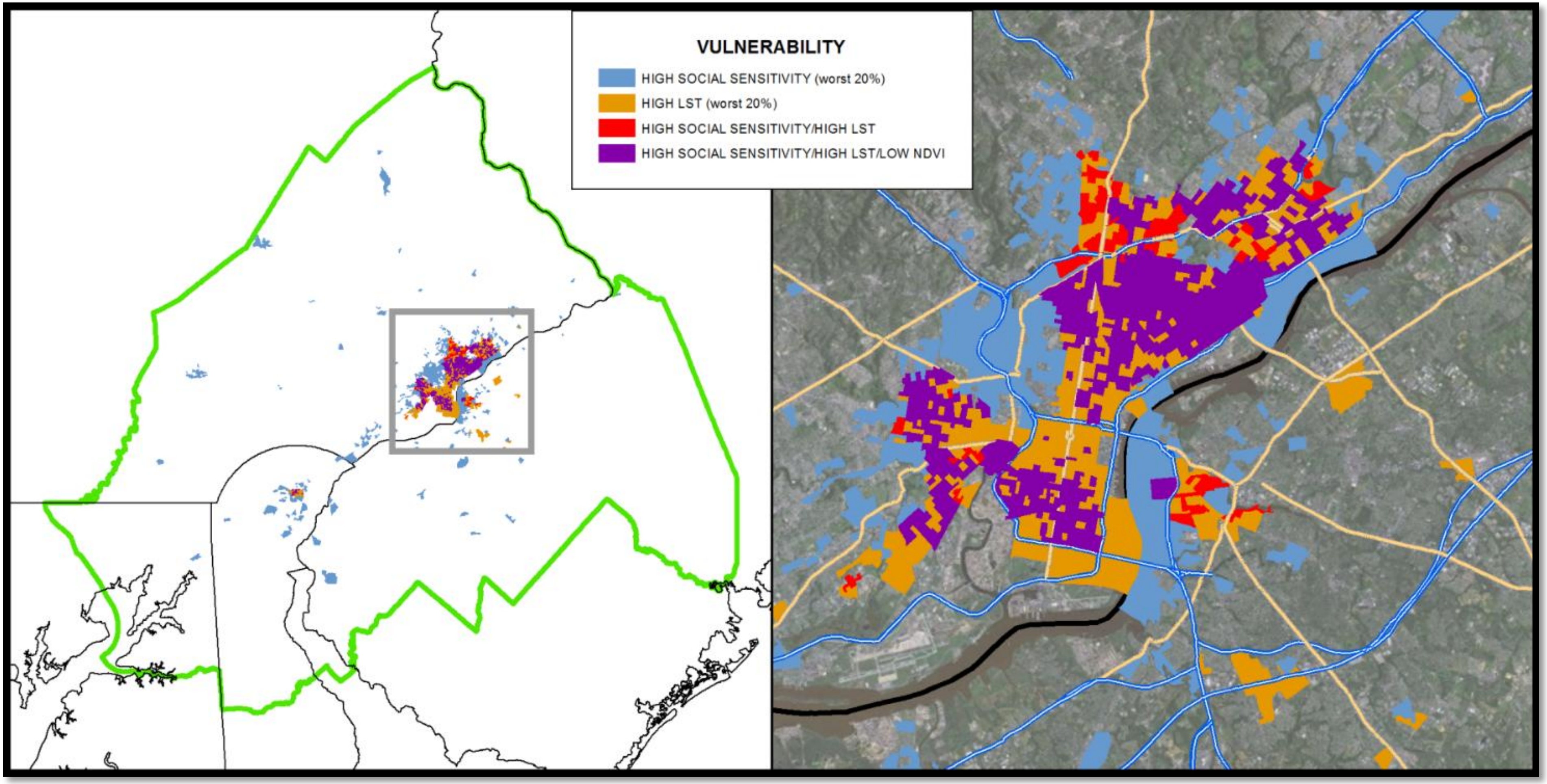


Center for International Earth Science Information Network
EARTH INSTITUTE | COLUMBIA UNIVERSITY

Battelle
The Business of Innovation

Vulnerability

- Intersection of areas of high exposure and high sensitivity

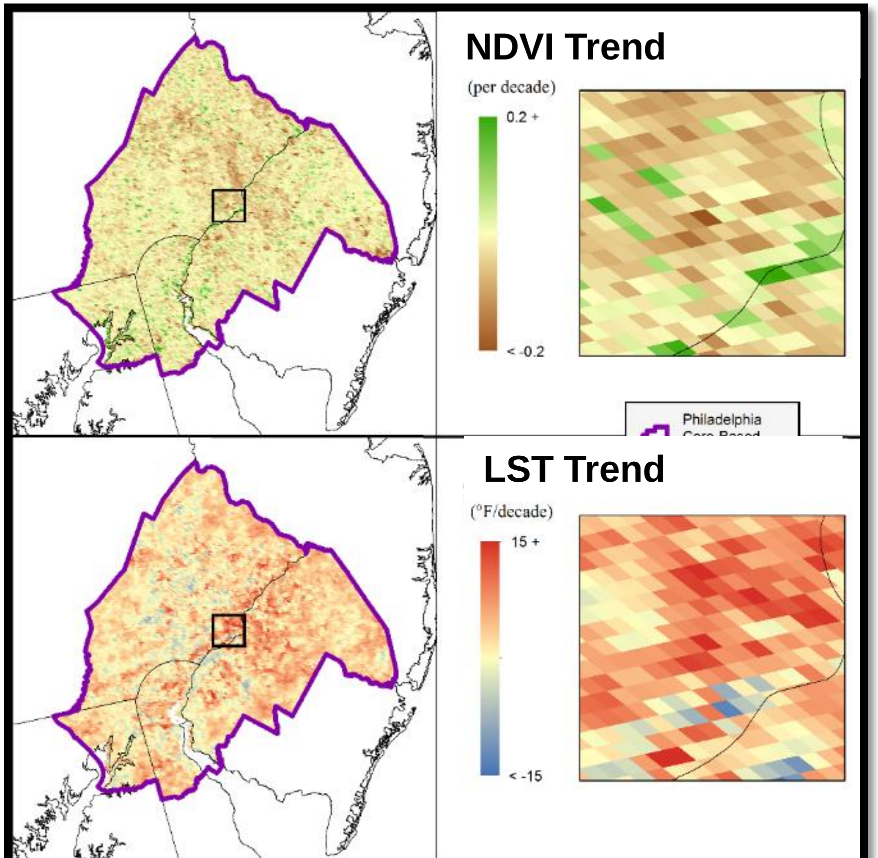


Center for International Earth Science Information Network
EARTH INSTITUTE | COLUMBIA UNIVERSITY

Battelle
The Business of Innovation

Adaptive Capacity

Assessing program effectiveness



Wholesale Produce Market – Opened in 2008

Though this is a ‘reverse’ example, it demonstrates how these products could be used to observe and quantify physical changes associated with specific programs

Center for International Earth Science Information Network
EARTH INSTITUTE | COLUMBIA UNIVERSITY

Battelle
The Business of Innovation

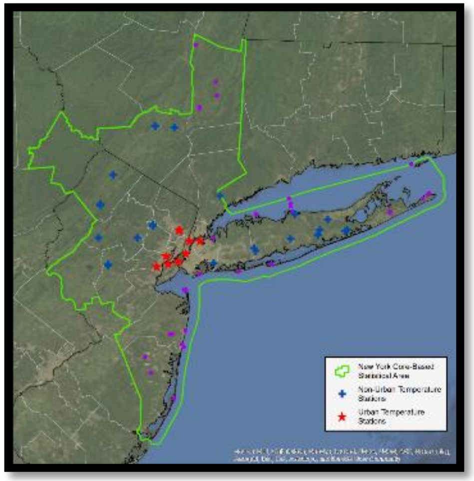
Philadelphia Results Summary

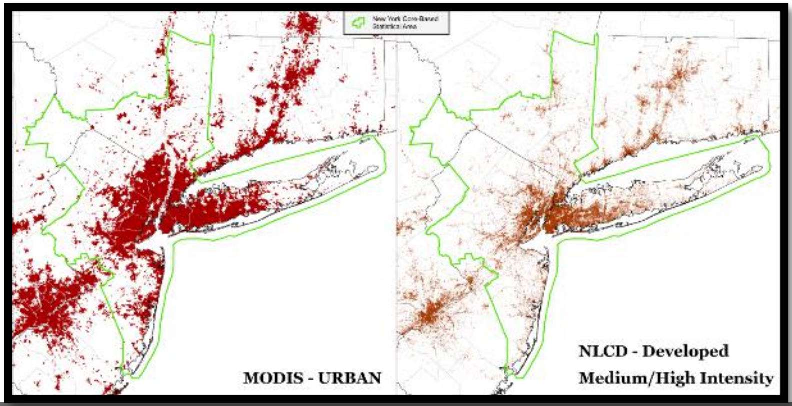
- From 1980-2013, the number of “heat wave” days per year in Philadelphia increased from 4 to 12 in urban areas, and stayed relatively constant at 5 in non-urban areas.
- Approx. 10% of the population in the Philadelphia core based statistical area (CBSA) lives within the most vulnerable areas to heat wave health impacts, as mapped in red and purple on the Vulnerability map, facilitating targeting of cooling adaptation measures.
- Isolated examples of adaptation (urban cooling) measures were provided by local officials, but none are yet at the scale or concentration to be measured by decreased LST or increased NDVI at the scale of the satellite data used (1 km).

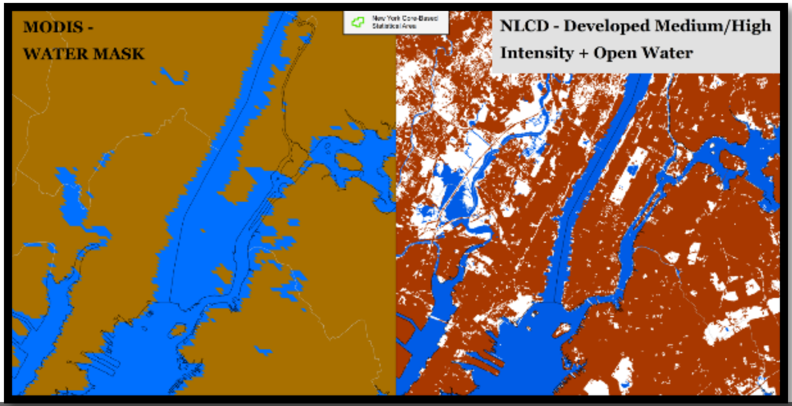
Assessing National Scale-Up

New York City

- Calculated indicators for NYC using same methodology as for Philadelphia
- *Issues/Resolutions*:
  - New York CBSA is much larger and encompasses many different geography types – e.g. coastal plains, barrier islands, mountains – *Eliminate monitors that don't seem consistent with providing a non-urban/urban comparison for NYC*
  - MODIS land use classifies a lot of the coastal NJ area as urban – *Use NLCD*
  - MODIS water mask (used to remove water from NDVI calculations) has much of lower Manhattan defined as 'water' – *Use NLCD*





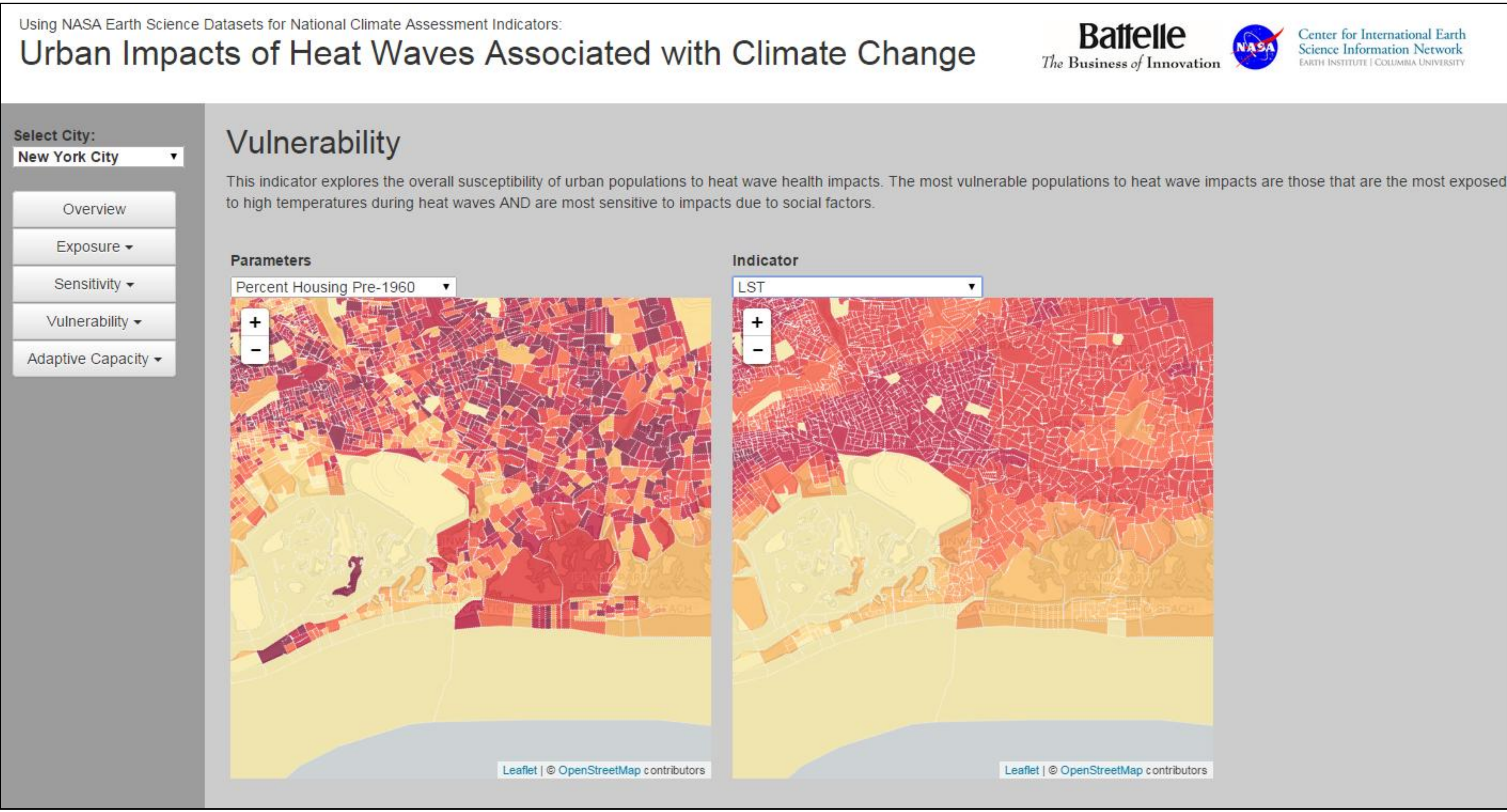


Information Management and Dissemination

- Conducted call with Stakeholders in Feb 2015 to share results and gather feedback
  - Included representatives from NYC Dept of Health
- Variety of methods discussed:
  - Final Report and journal article with figures
  - Demo of pilot HTML delivery tool
  - Shapefile and/or KML of sensitivity/vulnerability
  - KML and/or raster of LST and NDVI trends

Center for International Earth Science Information Network
Earth Institute | Columbia University
Battelle
The Business of Innovation

Tool Mock-Up Demonstration



Urban Heat Wave Vulnerability and Adaptation Tool

Welcome
Simple Explanatory Text on what this tool can do, etc and Tutorial Video

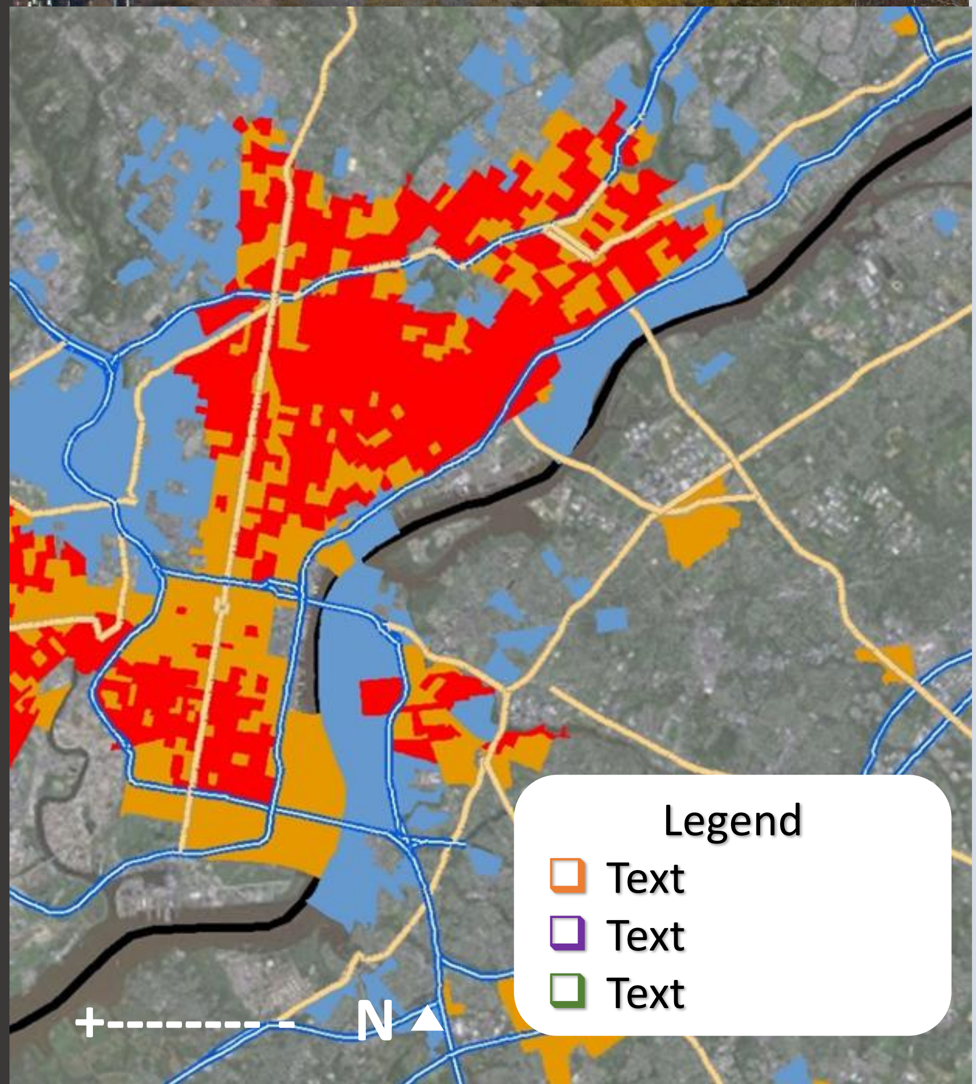
View Indicators

- [X] Heat Exposure
- [ ] Vegetation Cover
- [ ] Elderly Populations
- [X] Green Roof Projects
- [ ] Cooling Centers

More

Older 2000 — Current 2015

Animate



Advanced Users

Graph
Climate Projections
Download Data
Energy Tools
Metadata

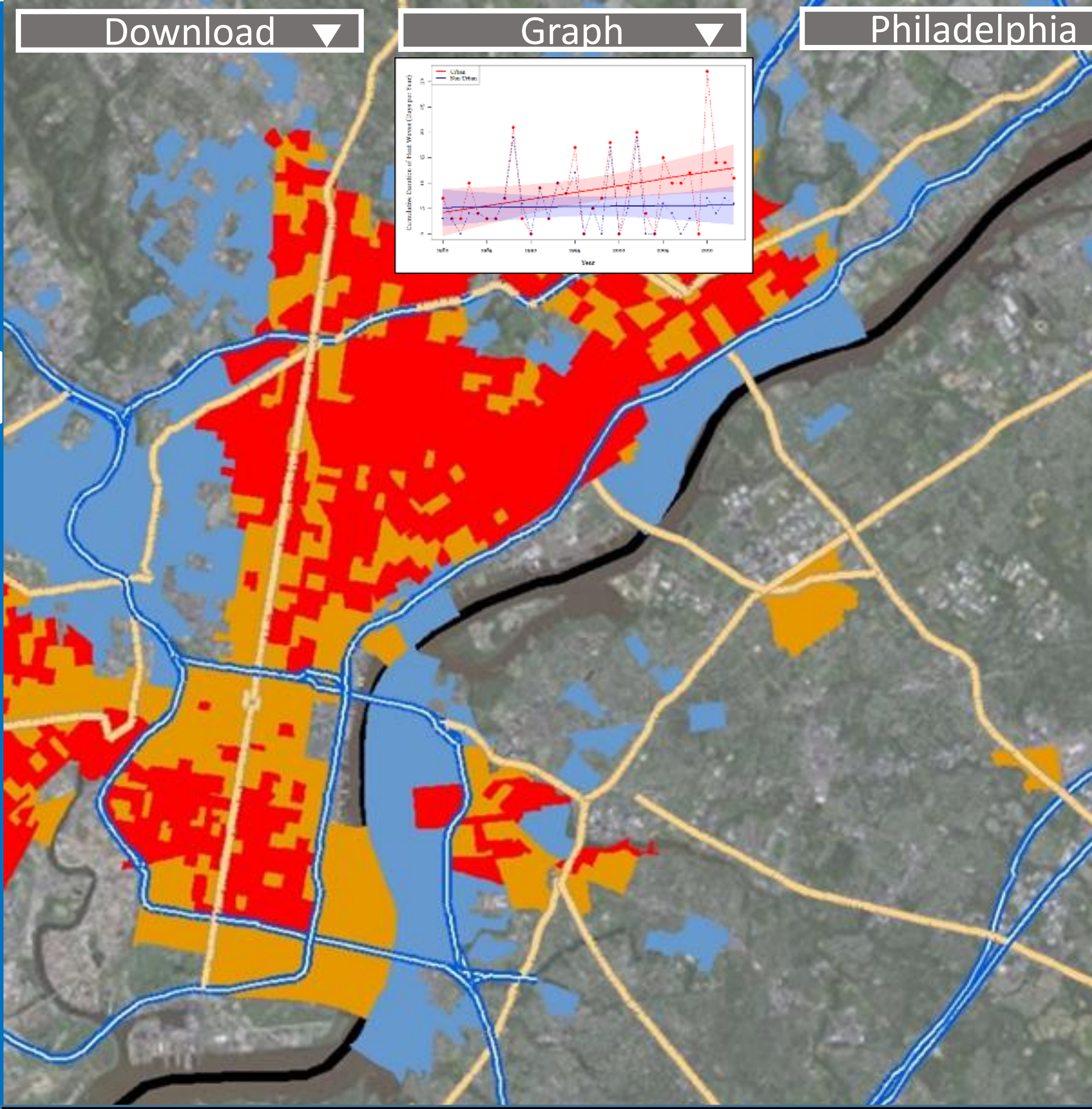
Urban Heat Wave Vulnerability and Adaptation Tool: Advanced Users

Indicators | Legend | Metadata

- Exposure
+ Sensitivity

Weightings	Factor
25%	Elderly
25%	Low-Income
25%	Old Housing Units
25%	Low Education

- Vulnerability
- Adaptive Capacity
- Climate Zones (Current)
- Climate Zones (2020s)
- Solar GHI Resources



Energy Tools: Draw Polygon Calculate Potential Adjust Defa

+--------

Conclusions

- Integrating the physical and social aspects of vulnerability is useful to city level decision-makers
- City officials want tools to help them analyze (and justify, from a cost/benefit perspective) various adaptation options
- Climate adaptation and mitigation can go hand-in-hand in the energy sector
- Finer scale (<250 m) satellite data is needed for urban areas
    - Highly downscaled spatial patterns of climate projections were NOT requested by city decision-makers

Center for International Earth Science Information Network
EARTH INSTITUTE | COLUMBIA UNIVERSITY

Thank you!

Erica Zell
Senior Research Scientist
Battelle
zelle@battelle.org
512-659-2523