Assessing the Effects of Local Cool Roof Policies on Urban Heat Islands

Project Status Update Meeting

Baltimore, Maryland

10/08/2019

EPDM Roofing
Association

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Study Overview

- Study research objectives
  - Conduct research on the effectiveness of local government cool roof mandates in reducing urban heat island effects
  - Assess empirical ambient temperatures in urban areas that have cool roof mandates compared to temperatures in localities without mandates
  - Develop data on the relative role of cool commercial roofs on heat island effects

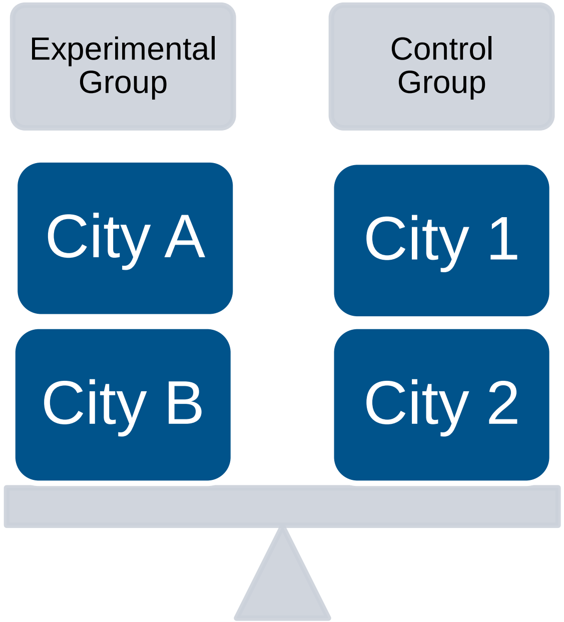
- Project Status, Design, and Methodology
  - Select experimental and control group cities
  - Develop consistent methods for measuring heat island effects
  - Select appropriate time-based weather data
  - Develop relative role of cool roofs in urban heat island

- Stage-gate approach
  - Phase 1 – preliminary analysis – select number of cities, understand availability of data and types of results
  - Phase 2 – additional analysis – option to improve level of rigor or expand analysis to additional cities

City Selection

- City pairs selected in consultation with ERA members
  - Control and Experimental cities for comparative analysis

- City selection considered
  - Year of mandate implementation
  - Availability of air temperature and GIS data
  - Resolution of GIS data
  - Climate conditions
  - Control of confounding factors such as local weather conditions



Control City	Baltimore			Indianapolis			Newark		
Experimental City	Washington			Chicago			New York		
Years	2008	2012	2016	2001	2005	2009	2012	2016	2019

Review of Relevant Research on Urban Heat Island (UHI)

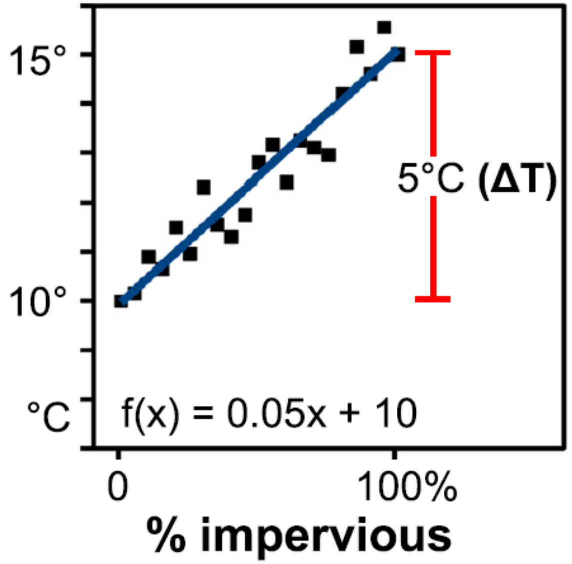
- Climate Central study (2014)
  - Current state of nationwide UHI estimates, impetus for concern over UHI in many cities
  - Used NOAA weather station air temperature data, justifying use of this dataset
  - Provided methodology for nighttime vs daytime UHI measurement
  - Gaps noted where this study could be improved, such as only 1 urban vs 1 rural station
  - https://www.epa.gov/heat-islands/measuring-heat-islands

- Environmental Research Letters paper (2015)
  - Provided methodology for measuring UHI as the slope of impervious surface area, rather than 2 data points
  - Developed % of variance in temperature explained by impervious surface area (R^2 value)

TOP 10:
Most intense urban heat islands (2004-2013)

- Las Vegas (7.3°F)
- Albuquerque (5.9°F)
- Denver (4.9°F)
- Portland (4.8°F)
- Louisville (4.8°F)
- Washington, DC (4.7°F)
- Kansas City (4.6°F)
- Columbus (4.4°F)
- Minneapolis (4.3°F)
- Seattle (4.1°F)

*see Appendix A for all 60 cities



Urban Heat Island Analysis – Weather Station Selection

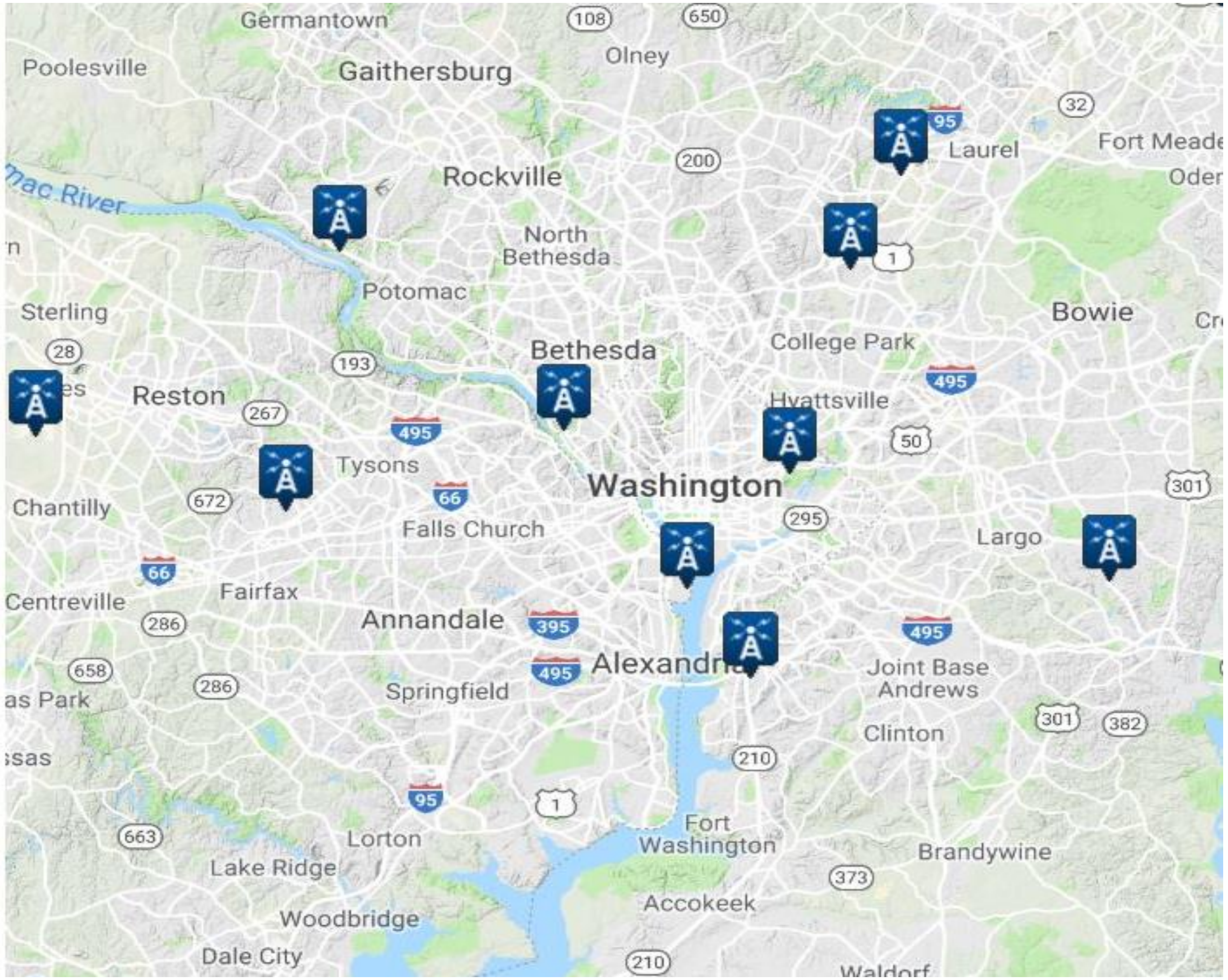
- Use air-temperature weather station data source that meets the following criteria:
  - Available at the national-level
  - Provides reasonable sample size at the city-level
  - Available for several years prior to and after mandate year
  - Consists of mostly complete datasets of hourly or daily air-temperature
  - Reliable format for development of scalable analysis framework

- NOAA Weather Station Data (https://www.ncdc.noaa.gov/cdo-web/datatools/findstation)
  - Consists of more than 2,500 US weather stations – fewer at the city-level with air-temperature data
  - Provides local daily minimum and maximum air-temperature data
  - Same data source used in the Climate Central study

Urban Heat Island Analysis – Weather Station Selection

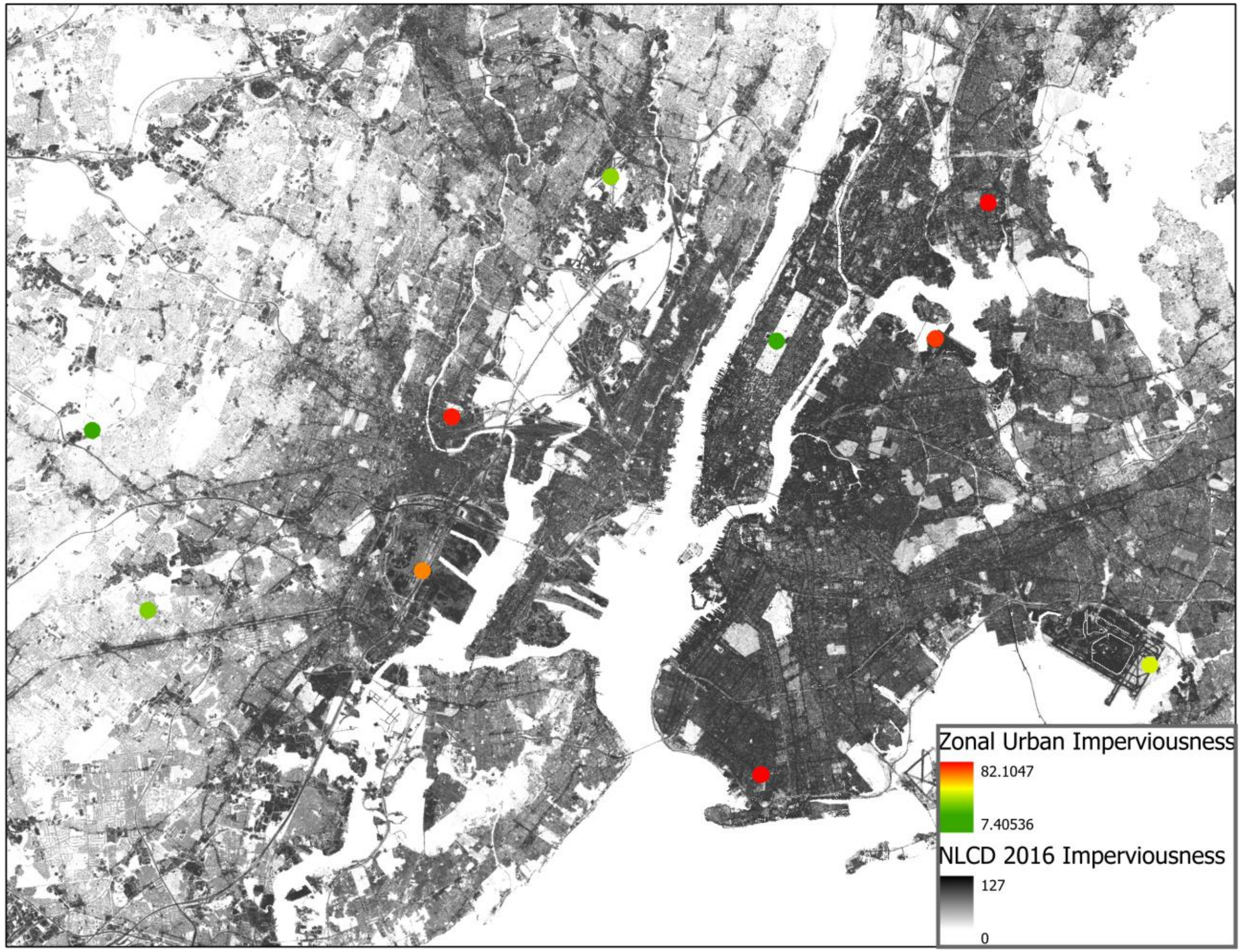
- For each city, all NOAA weather stations within a 20-mile radius of the city center were included in the study
  - Each weather station is assigned to a single city (i.e., no overlapping cities)
  - An average of 7 weather stations per city are used in the study
  - Air temperature data collected for 10 years prior to and after mandate year (depending on availability of data)

- Weather stations are location based rather than gridded
  - Air temperatures are influenced by local conditions



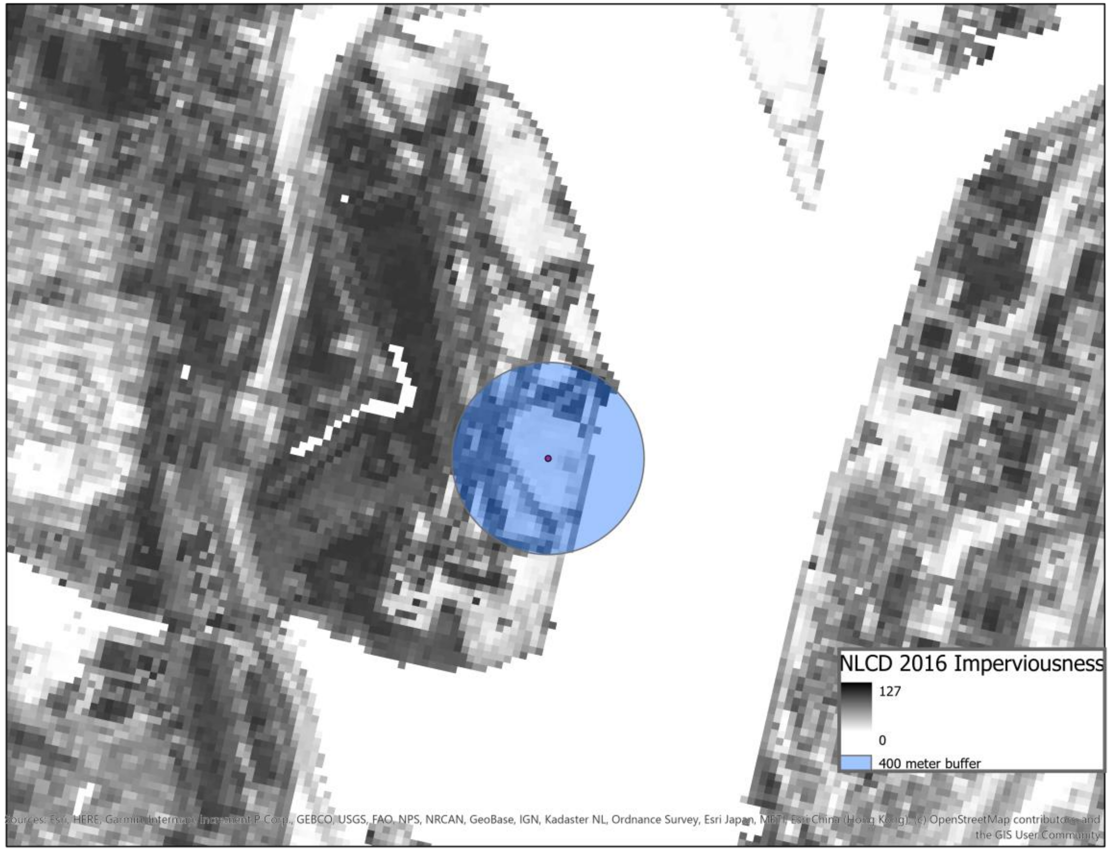
Urban Heat Island Analysis – Weather Station Classification

- Local weather stations conditions (i.e., makeup of land surface) are not well correlated with distance from city center
  - Necessary to classify weather stations based on urban density
  - Urban density calculated using National Land Cover Urban Imperviousness percentages surrounding weather stations



Urban Heat Island Analysis – Weather Station Classification

- For each weather station, data at 400m, 1600m, and 3200m were analyzed for urban density
  - 400-meter radius was selected because we looked at 400m, 1600m, 3200m, and found the best correlation between % impervious and temperature with the 400m radius.
  - This process and radius selection are consistent with Wisconsin (Environmental Letters) report which selected 600m.



Weather Station Name	Urban Density @ 400m	Urban Density @ 1600m	Urban Density @ 3200m
Washington Regan, VA	33.94	32.19	35.11
National Arboretum, DC	23.26	39.60	44.40
Oxon Hill, MD	36.70	30.14	22.49

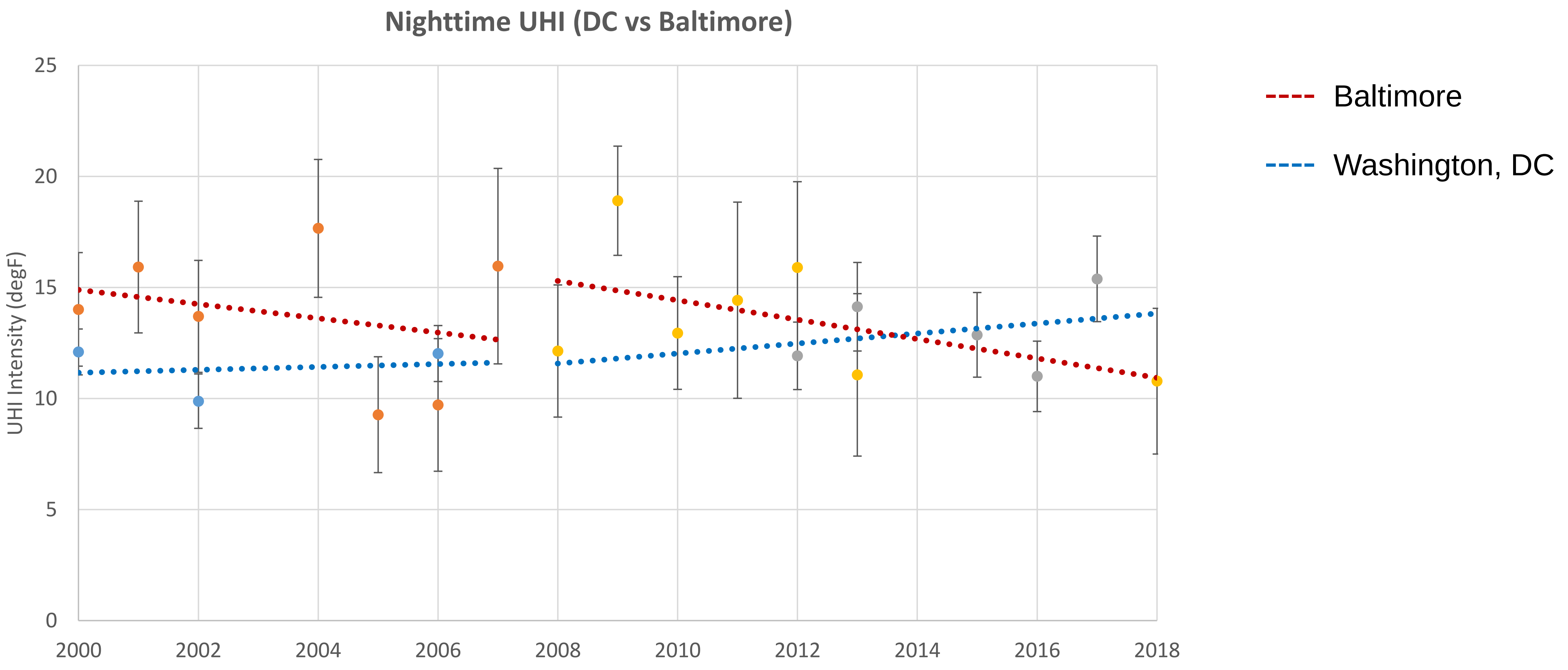
Urban Heat Island Analysis – Urban Heat Island (UHI) Effect

- Developed UHI for nighttime and daytime periods
  - Average daily summer minimum temperature used for nighttime UHI
  - Average daily summer maximum temperature used for daytime UHI

- UHI for a given year measured as slope of the average summer temperature plotted against the urban density (% impervious area at 400m radius) for the weather stations in and around the city
  - Weather station urban density assumed not to have any significant relative change over analysis period

- UHI with R2 value greater than 0.48 (from Environmental Research Letters paper) plotted over time for mandate and control cities
  - Relative decrease in the UHI over time in the experimental city after the start of the mandate could potentially be attributed to the cool roof mandate

Urban Heat Island Analysis – Washington, DC vs Baltimore



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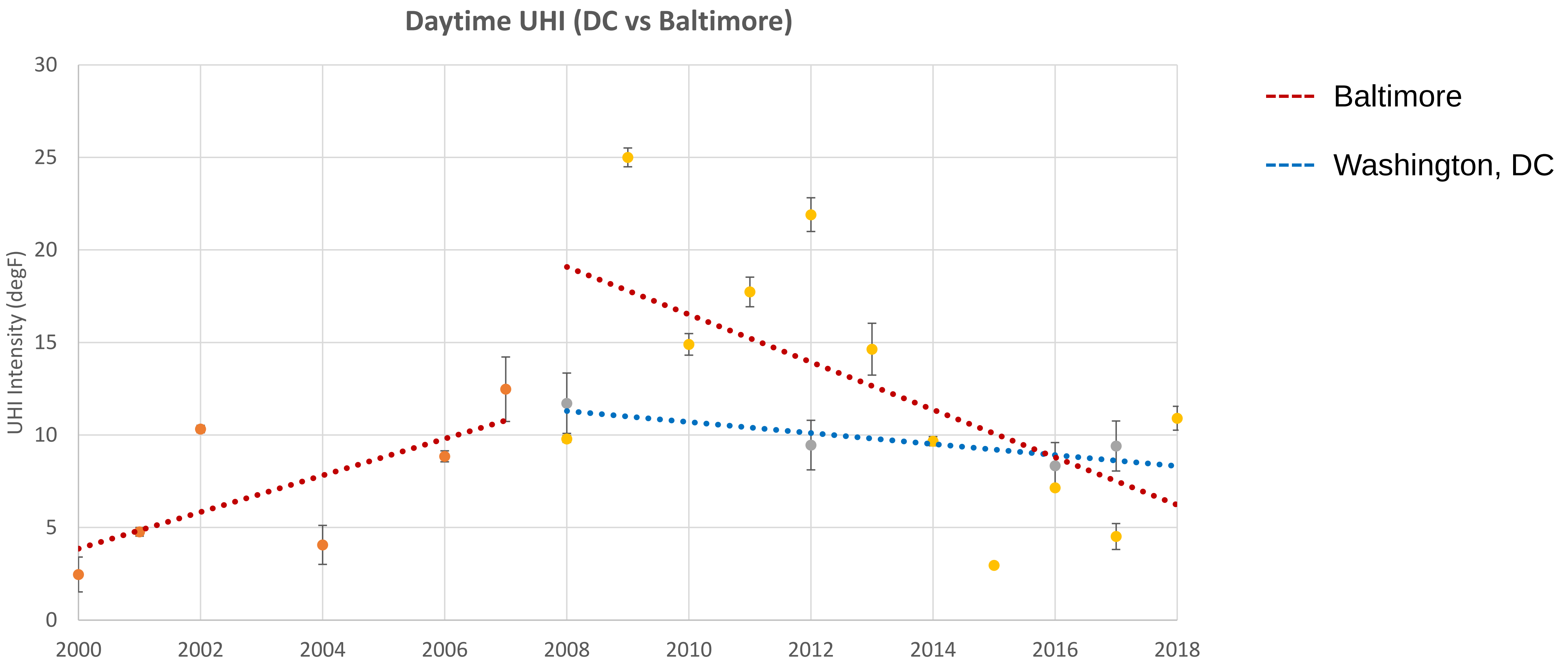
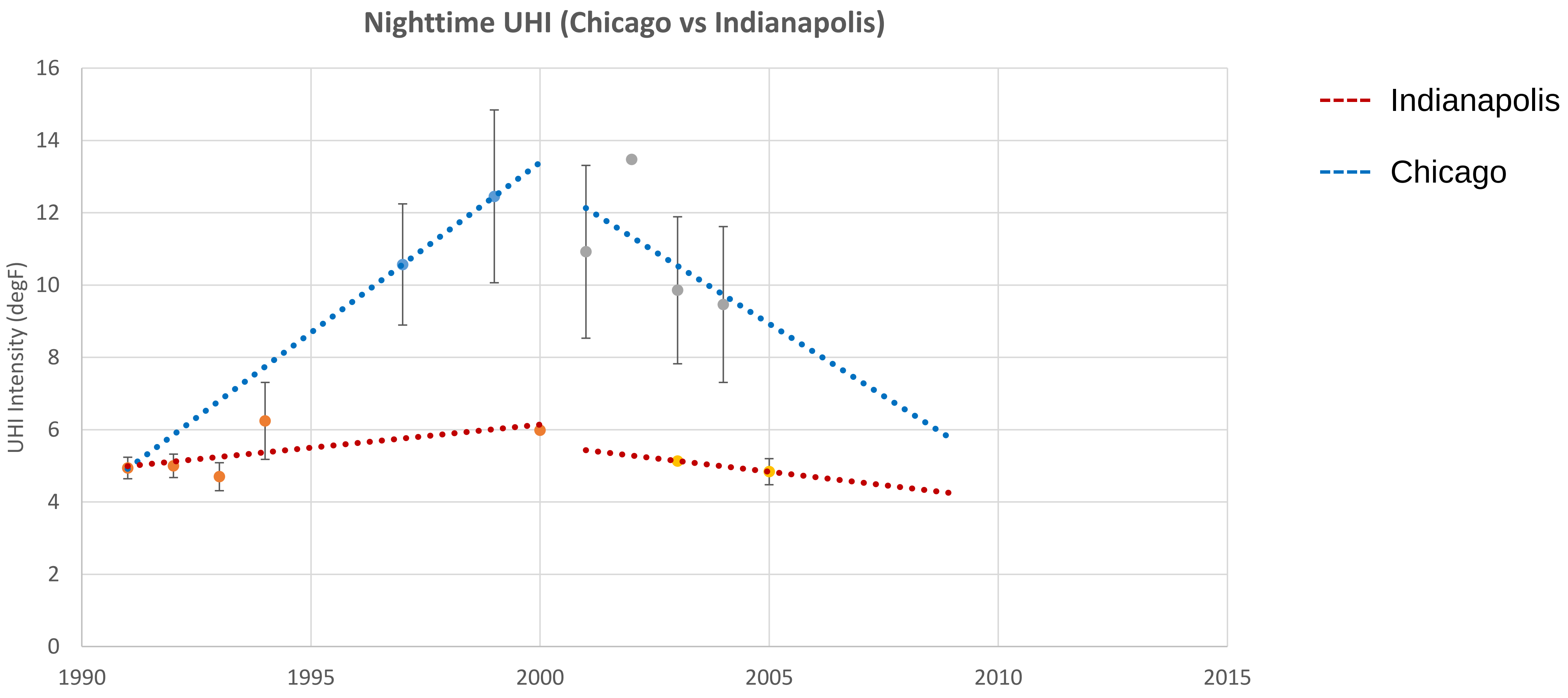


Urban Heat Island Analysis – Chicago vs Indianapolis



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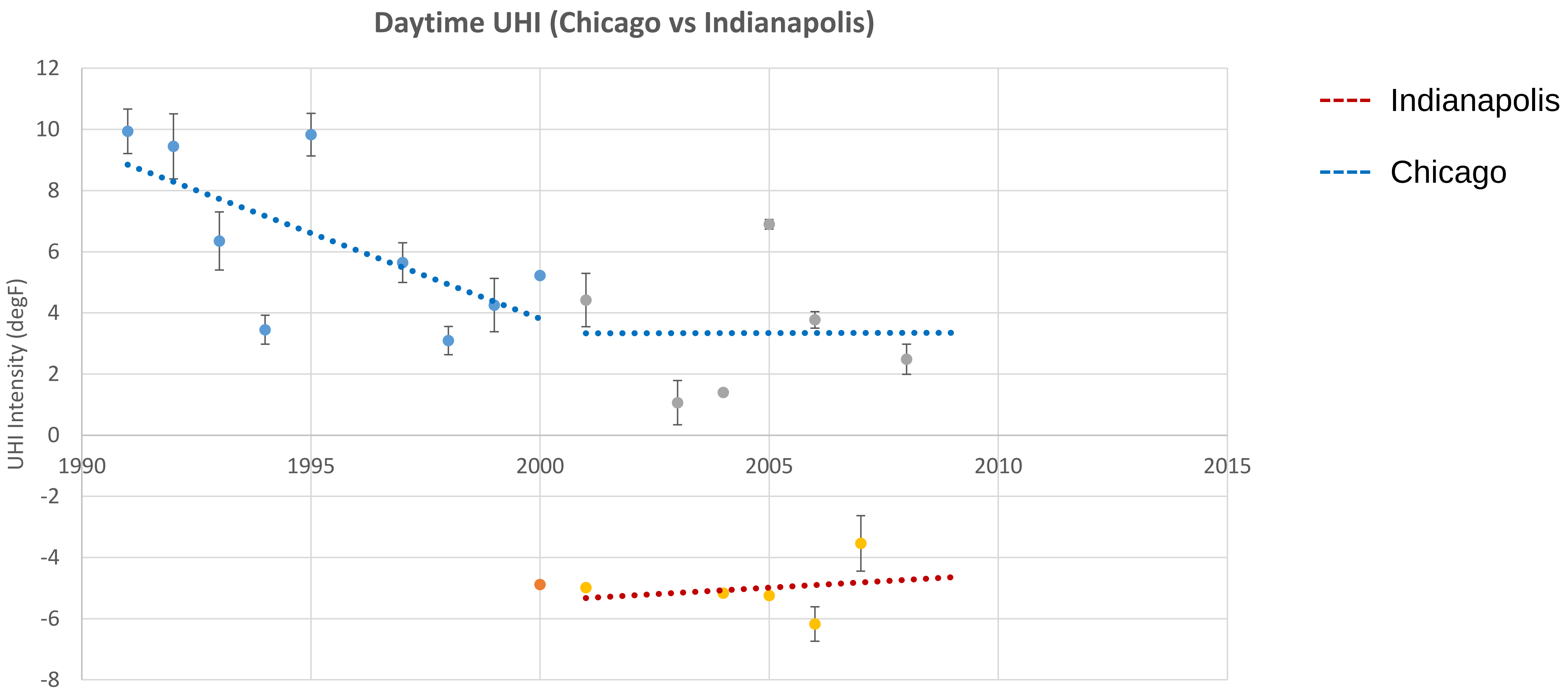
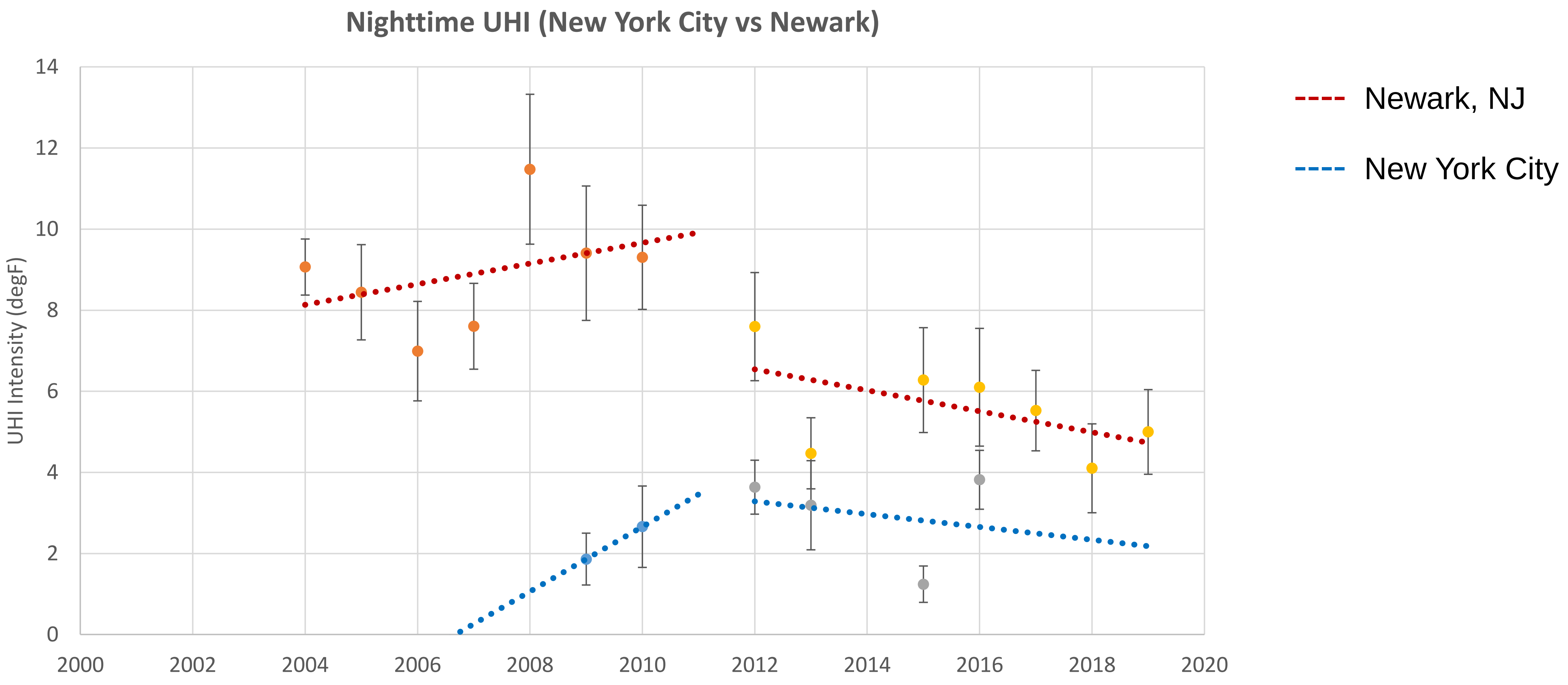


Urban Heat Island Analysis – New York City vs Newark, NJ



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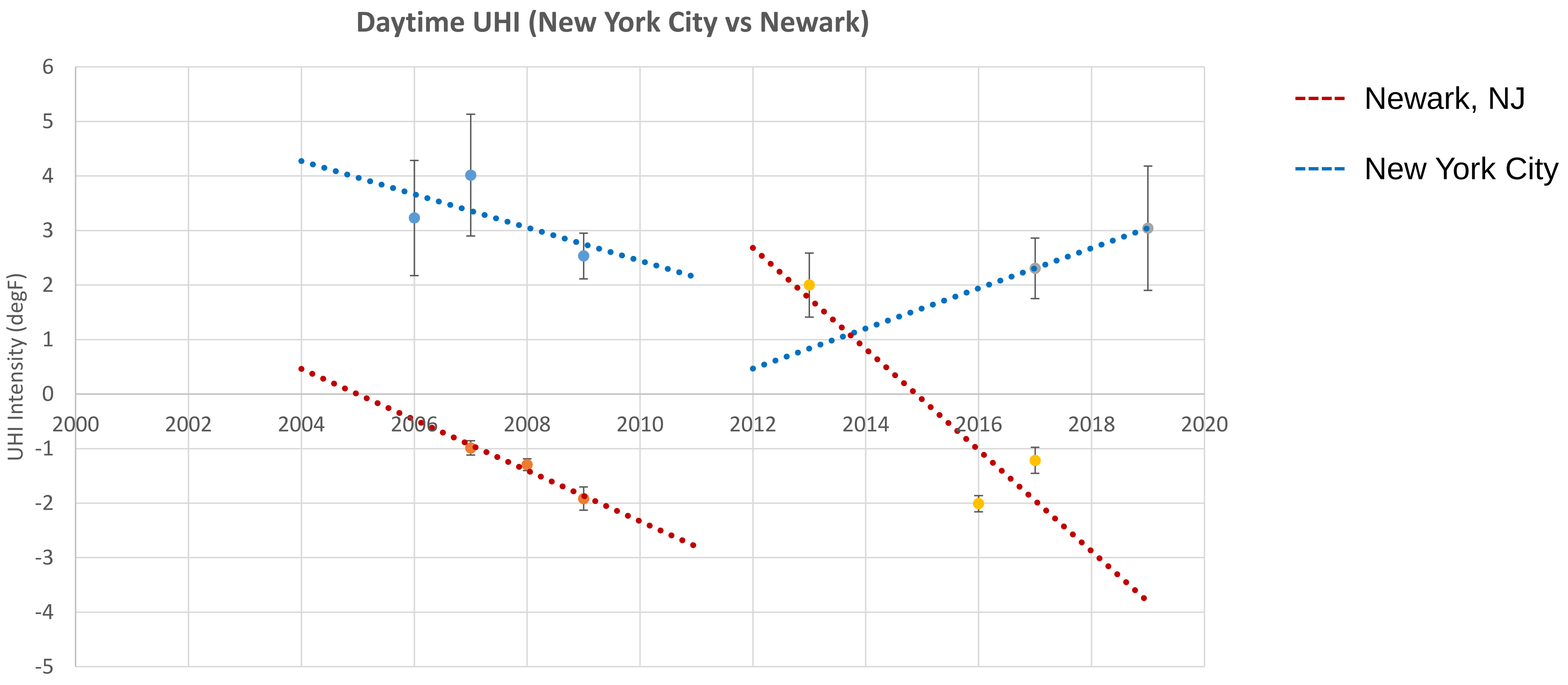


GIS Change Detection - Tools and Inputs

- Imagery:
  - LANDSAT 7 ETM Satellite Imagery
  - Bands 1/2/3/5 (Blue/Green/Red/Short-wave Infrared)

- Tools Used:
  - ESRI ArcPro

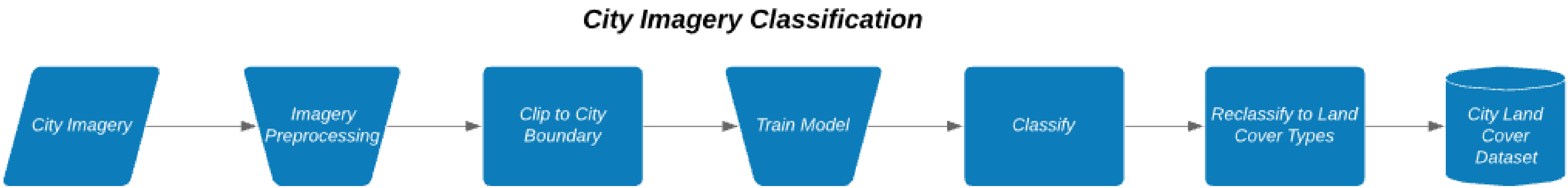
- Time Periods:
  - Cool Roof Mandate Year
  - 4 years post-mandate
  - 8 years post-mandate

Control City	Baltimore			Indianapolis			Newark		
Experimental City	Washington			Chicago			New York		
Years	2008	2012	2016	2001	2005	2009	2012	2016	2019

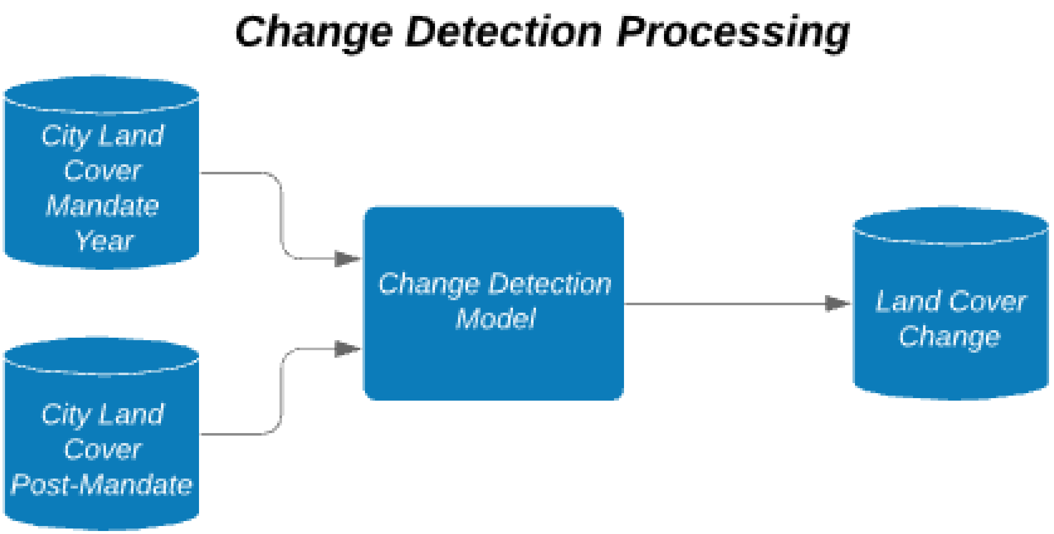
GIS Change Detection - Classification

- Using imagery of the city for 3 time periods, classified imagery and identified areas with high surface reflectance and lighter color impervious areas to locate potential cool roofing.

- Performed change detection across 3 time periods
  - Approximated increase in cool roof as a percent of urban environment
  - Changes from dark-urban to light-urban used as proxies for changes in commercial roofing

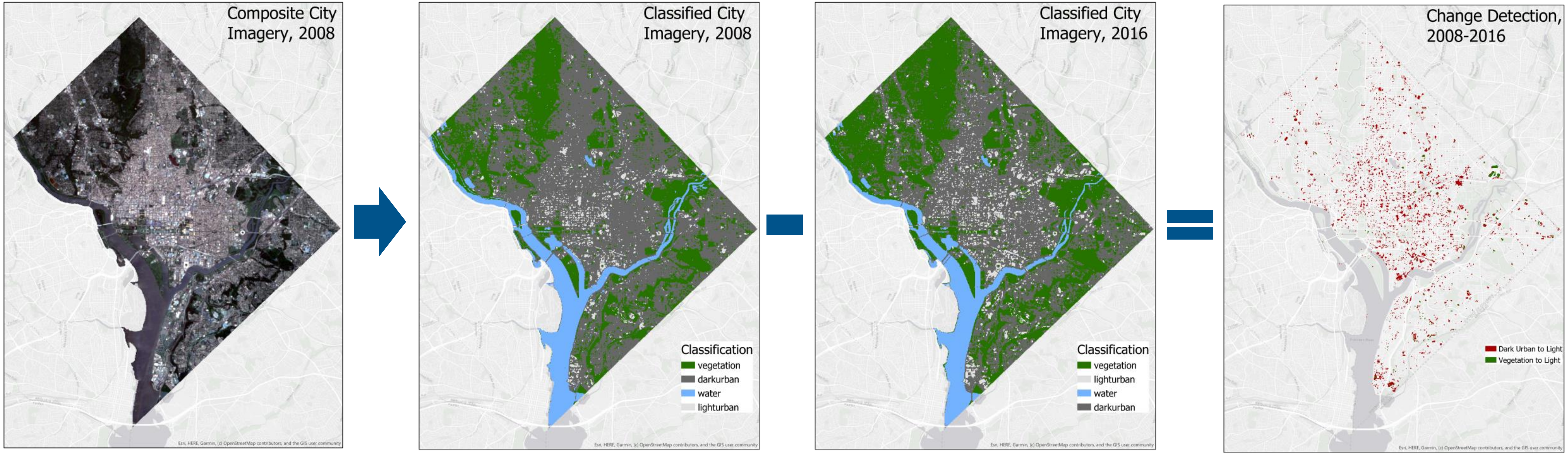


GIS Change Detection - Methodology



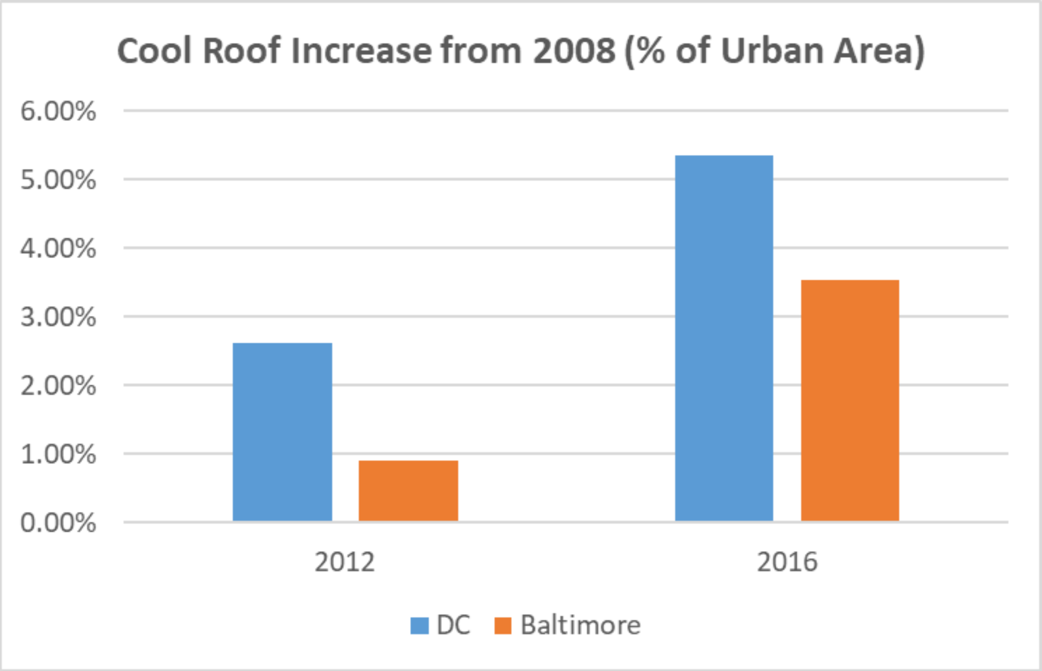
Washington, DC - (2008 - 2016)				
Before	After	Percent of Whole	Percent of Urban	Area (m2)
Light Urban	Water	0.01%	N/A	22,500
Light Urban	Vegetation	0.23%	0.35%	404,100
Light Urban	Dark Urban	1.32%	2.02%	2,338,200
Dark Urban	Water	0.07%	0.11%	123,300
Dark Urban	Vegetation	11.56%	17.69%	20,525,400
Vegetation	Water	0.06%	N/A	108,900
Water	Water	9.49%	N/A	16,846,200
Vegetation	Vegetation	24.43%	N/A	43,356,600
Water	Vegetation	0.66%	N/A	1,164,600
Dark Urban	Dark Urban	43.97%	67.28%	78,047,100
Vegetation	Dark Urban	1.61%	2.46%	2,851,200
Water	Dark Urban	0.36%	0.56%	645,300
Light Urban	Light Urban	2.39%	3.65%	4,239,000
Dark Urban	**Light Urban**	**3.49%**	**5.34%**	**6,200,100**
Vegetation	Light Urban	0.31%	0.47%	544,500
Water	Light Urban	0.04%	0.06%	70,200

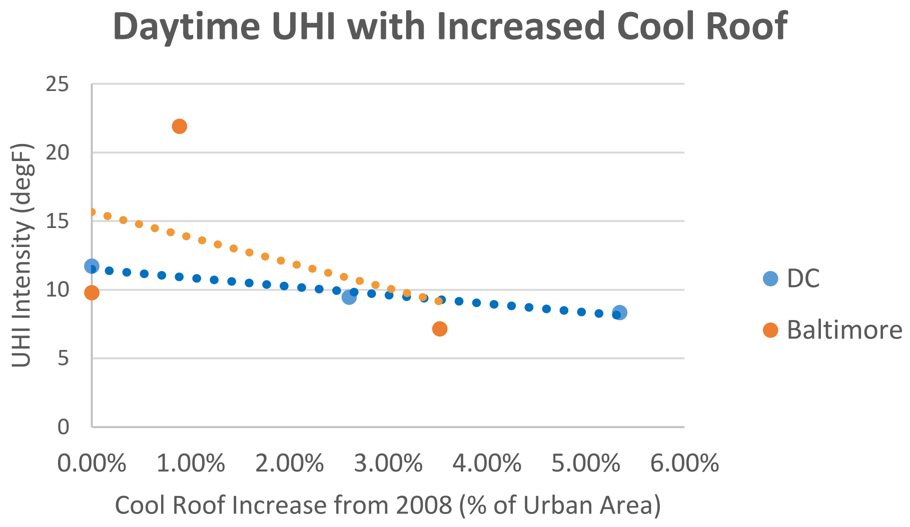
GIS Change Detection - Methodology

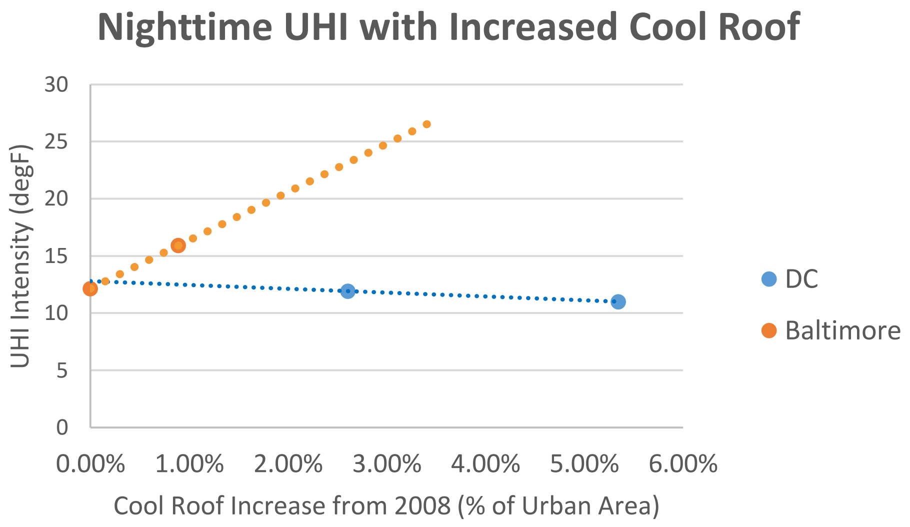


Relative Role of Cool Roofs – Washington, DC vs Baltimore

- Observations
  - DC has slight negative trend in UHI vs % Cool Roof
  - Baltimore has either unclear or positive trend

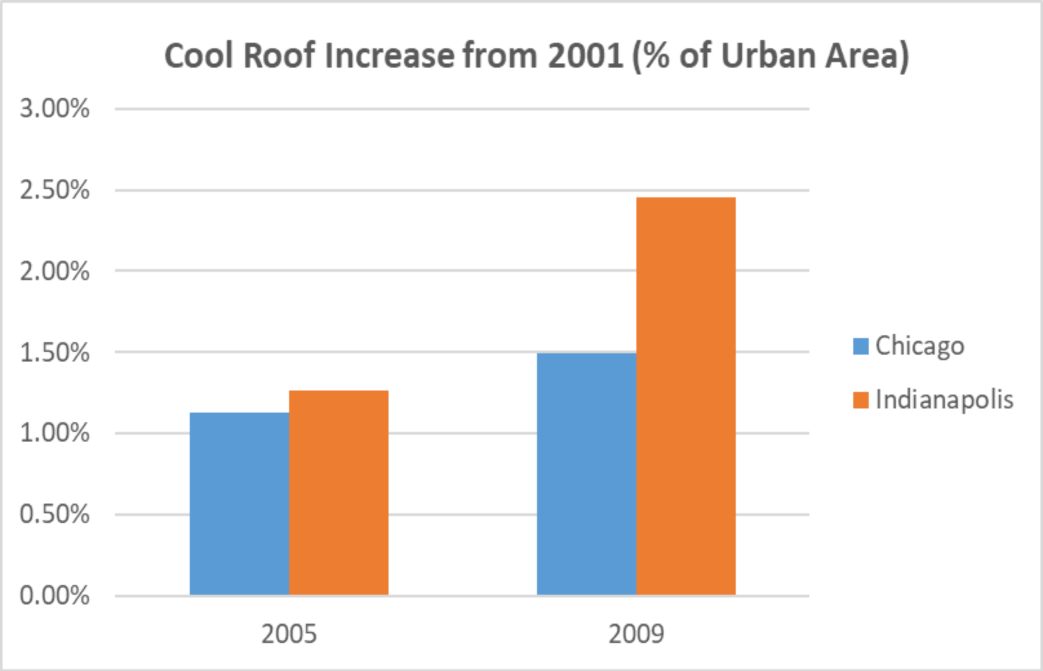


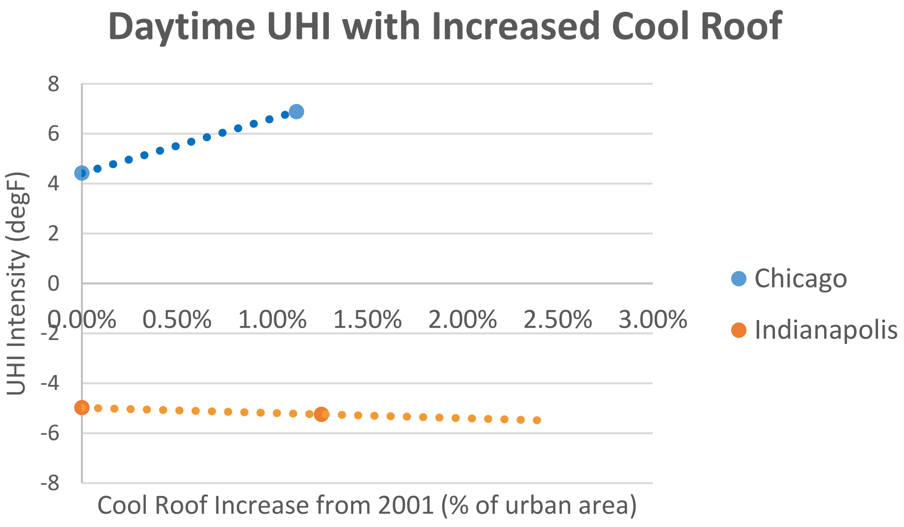




Relative Role of Cool Roofs – Chicago vs Indianapolis

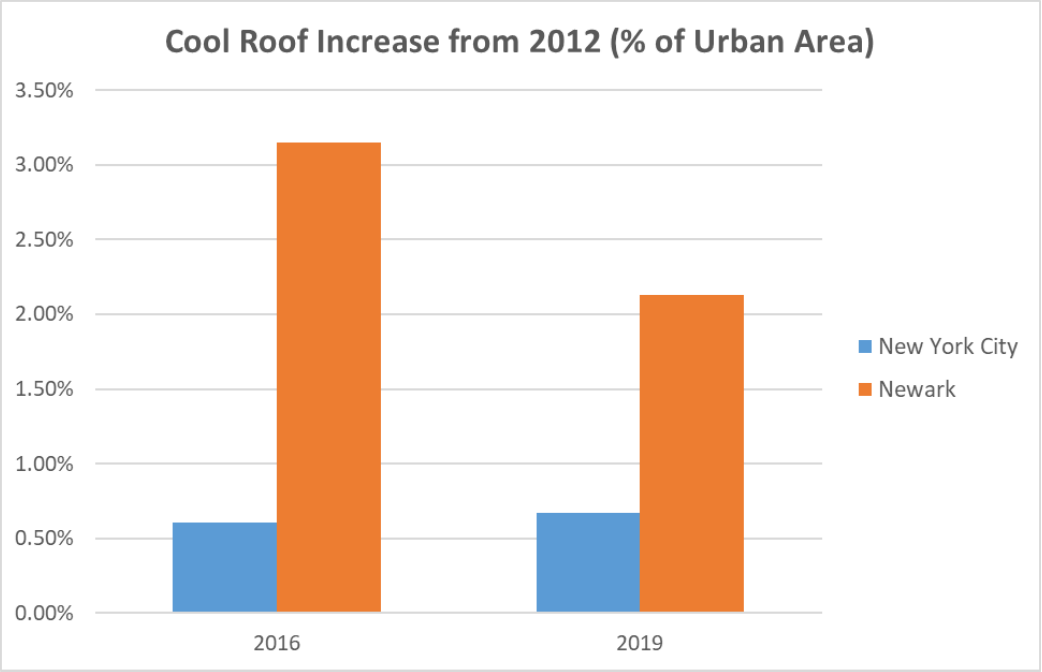
- Observations
  - No Nighttime UHI graph; data was not statistically significant
  - Greater increase from dark to light urban area (cool roof indicator) in control city; reason unclear

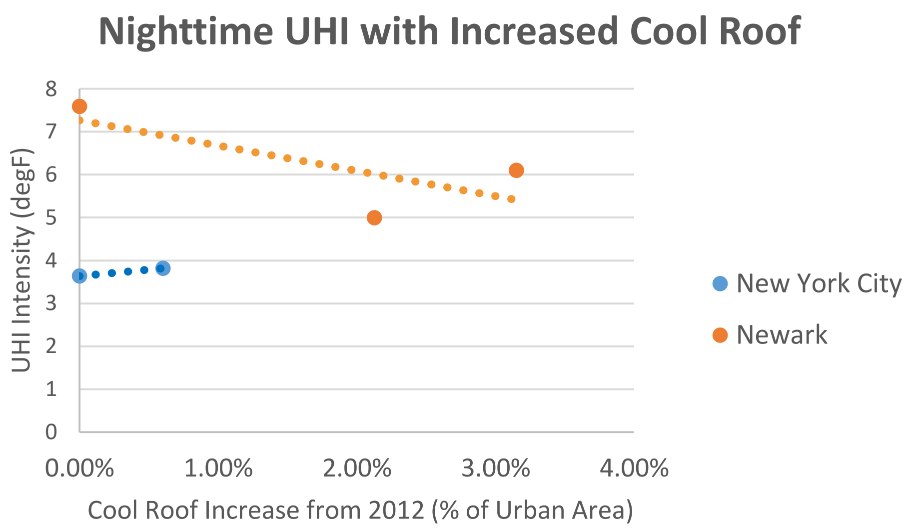




Relative Role of Cool Roofs – New York City vs Newark, NJ

- Observations
  - No Daytime UHI graph; data was not statistically significant
  - Greater increase from dark to light urban area (cool roof indicator) in control city; likely due to city size





Relative Role of Cool Roofs - Conclusions

- Temporal analysis
  - 0 out of 3 city pairs demonstrated relative reduction (RR) in daytime UHI after cool roof mandate
  - 1 out of 3 city pairs demonstrated relative reduction (RR) in nighttime UHI after cool roof mandate

- Percent Cool Roof Analysis: 3 out of 12 cases showed negative trend b/w UHI and % cool roof
- Results indicate uncertain or low impact of cool roof mandates on a city's Urban Heat Island

<table>
<tr><th>Analysis</th><th>Washington, DC vs Baltimore</th><th>Chicago vs Indianapolis</th><th>NYC vs Newark</th></tr>
<tr><td>Daytime UHI (temporal)</td><td>No RR</td><td>No RR</td><td>No RR</td></tr>
<tr><td>Nighttime UHI (temporal)</td><td>No RR</td><td>RR</td><td>No RR</td></tr>
<tr><td rowspan="2">Daytime UHI (% cool roof)</td><td>DC – negative trend</td><td>Chicago – positive trend</td><td rowspan="2">Not statistically significant</td></tr>
<tr><td>Baltimore – unclear</td><td>Indy – unclear</td></tr>
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<tr><td>Baltimore – positive trend</td><td>Newark – negative trend</td></tr>
</table>

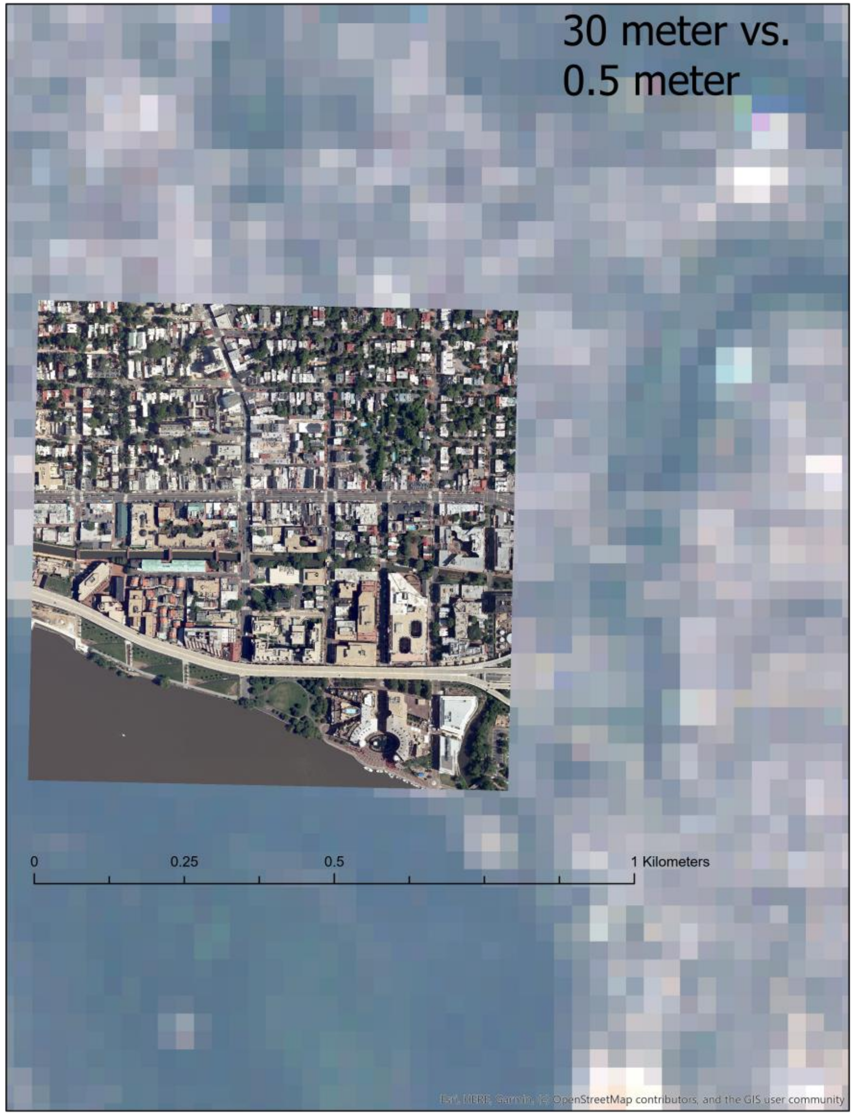
Study Limitations & Areas for Improvement

- Resolution of Imagery
  - Higher resolution orthophoto imagery is relatively available for use in future modeling, but would require significantly larger level of effort from downloading, processing, classifying, and quality controlling (see Level of Effort section below)
- Cloud cover
  - Although satellite imagery was selected that was found to have less than 10% of cloud cover over the entire region (and manual checking was completed), cloud cover would affect the results of this model as it is picked up by the high reflectance categorization
- Areas of interest & Commercial Boundaries
  - Areas of interest were not consistently available for the cities selected. If areas of definite interest (areas that have been commercially designated since the mandate time period), this could limit the variance of results and allow for better classification algorithm results
- Air temperature data
  - Could investigate using NREL data which may provide more granular air temperature data and hence more statistically significant results. Concern with NREL is the use of interpolation rather than solely real-world data
  - Weather Underground includes stations from general public, but higher resolution of real-world data

GIS Change Detection Analysis – Resolution Differences

Much higher resolution would allow for much stronger classification accuracy but would require a significantly larger level of effort.

	Resolution	
	30 meter	0.5 meter
File Size	2GB	100-200GB
Number of Images per Year	1-2	100-200
Total Images per City	3-5	300-600
Approximate Total Project Size	36GB	540GB



Questions and Discussion

Contact Information

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