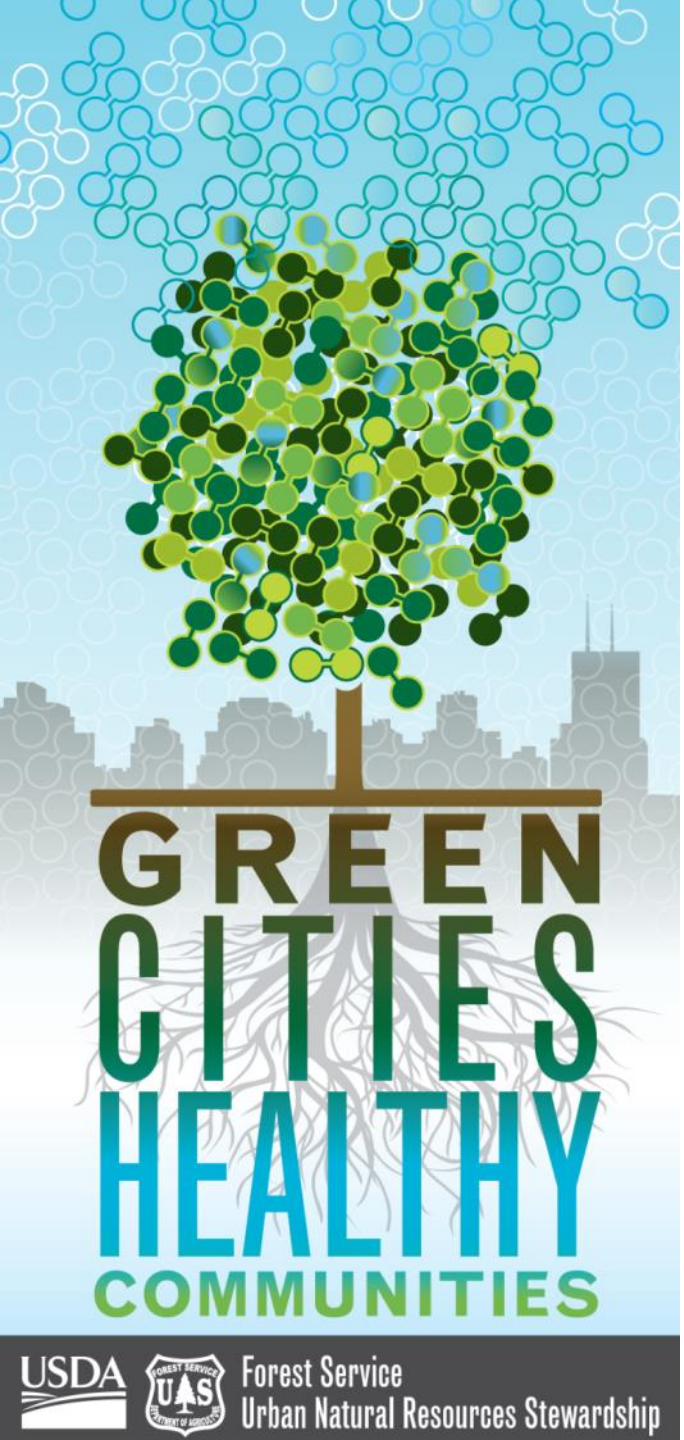

USDA Forest Service

URBAN FOREST CONNECTIONS

webinar series

Second Wednesdays | 1:00 – 2:15 pm ET

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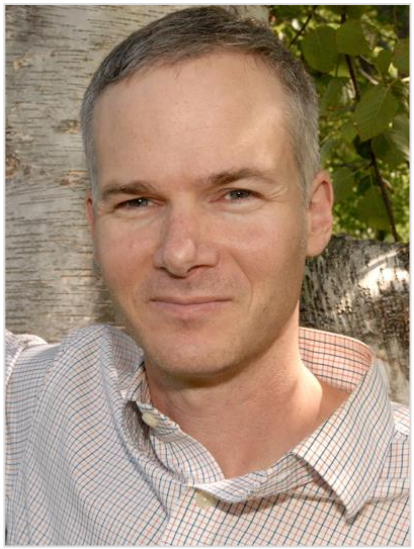
The Effect of Urban Tree Canopy on Microclimate and Heat Islands



Austin Troy

Professor and Chair, Department of Planning and Design

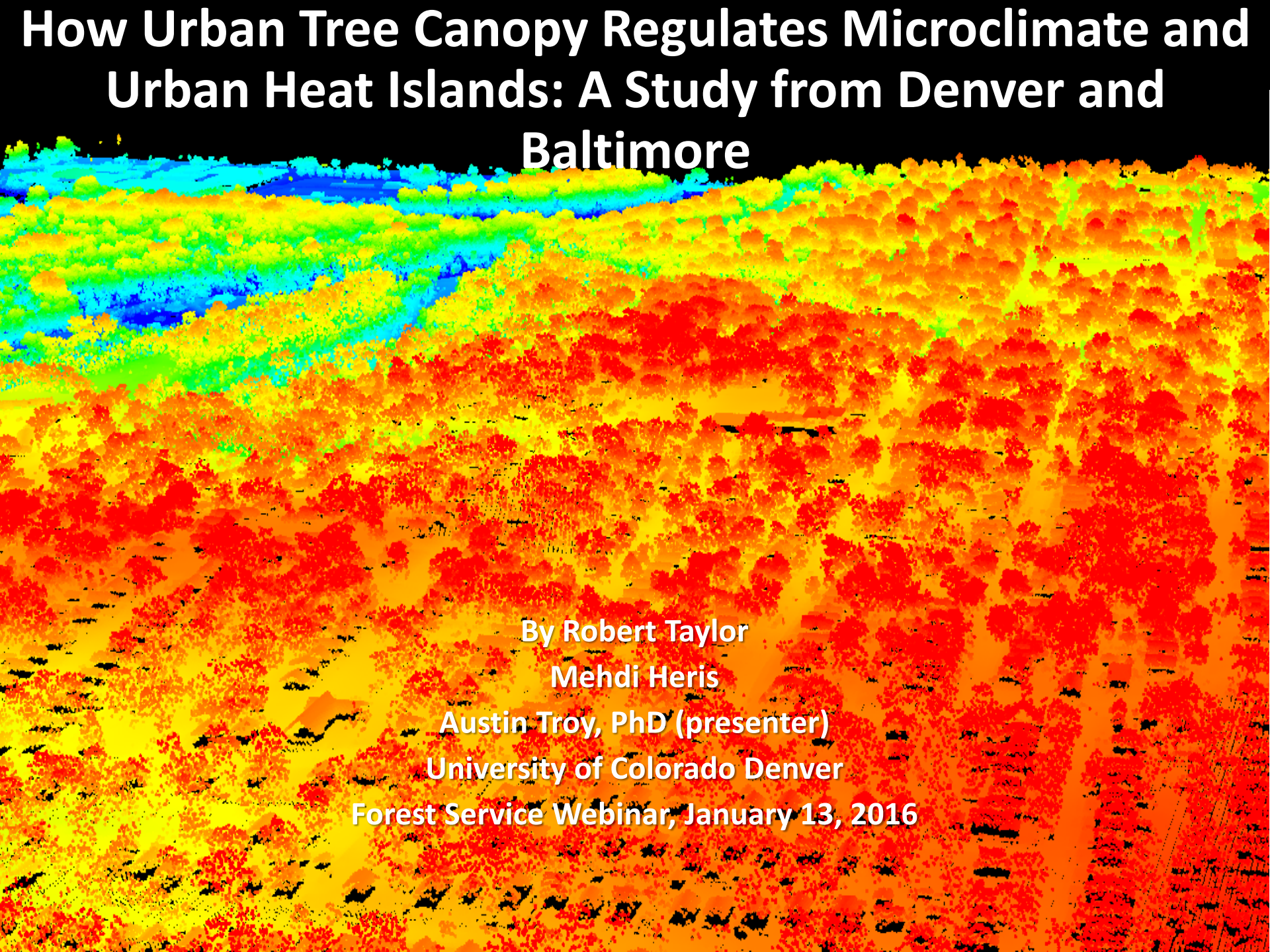
University of Colorado Denver

Sara Davis

Urban Forestry Program Manager

City and County of Denver

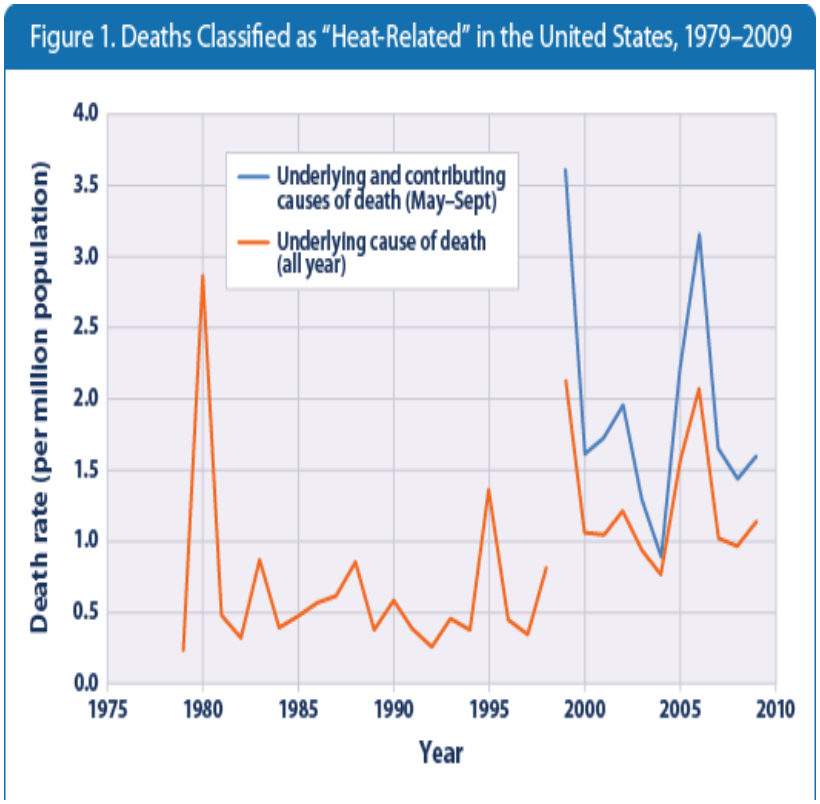
How Urban Tree Canopy Regulates Microclimate and Urban Heat Islands: A Study from Denver and Baltimore

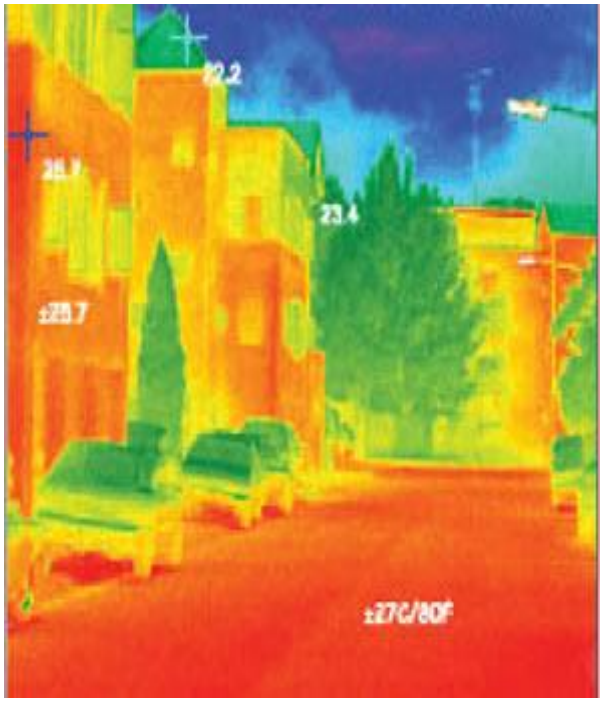


By Robert Taylor
Mehdi Heris
Austin Troy, PhD (presenter)
University of Colorado Denver

Forest Service Webinar, January 13, 2016

Why do we care about urban heat?





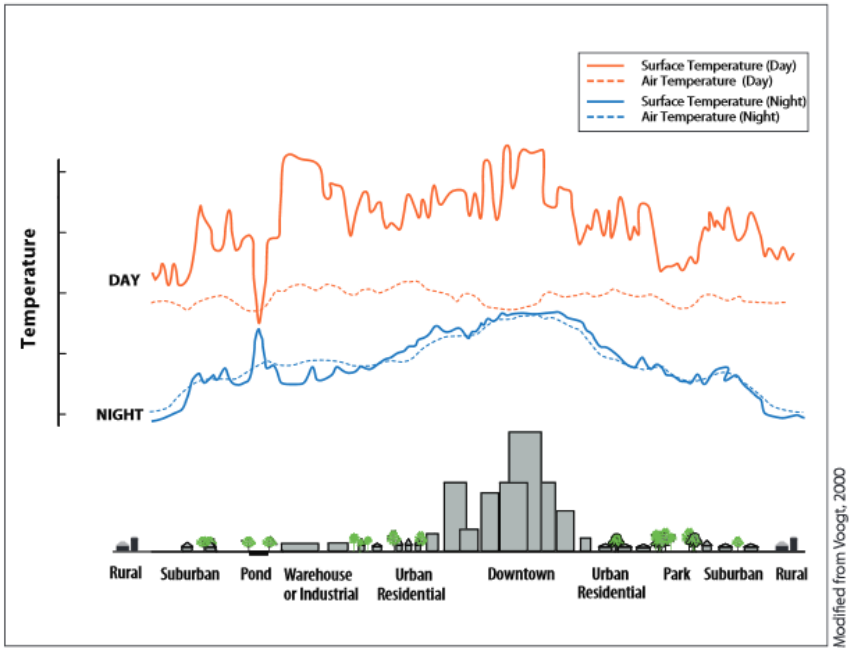
EPA

http://www.urban-climate-energy.com/urbanHeatIsland.htm

How do trees work with urban heat?

- Evapotranspiration: e.g. 40,000 GPY for large oak. ET cools air by using heat from air to evaporate water and can reduce temp. Effects can be up to 9ºF
- Direct shade (we'll get to this later): in summer only 10-30% of sun's E reaches area below
- Higher emissivity and less stored heat

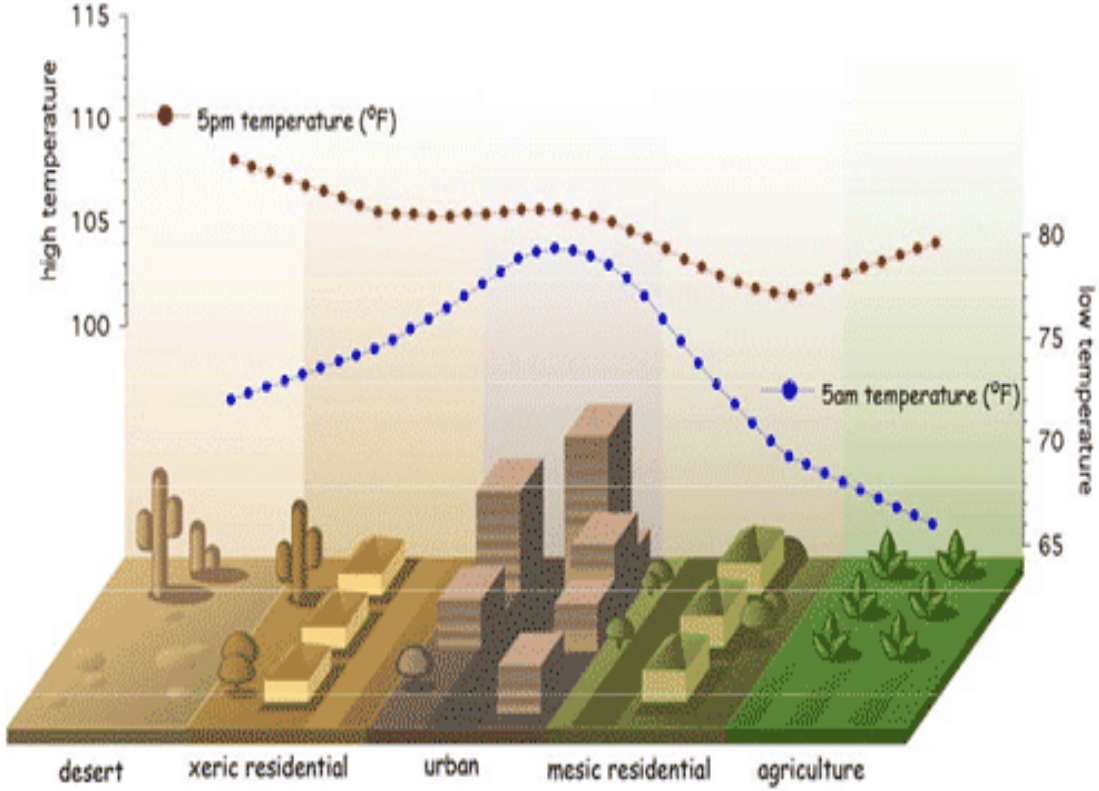
Figure 2: Variations of Surface and Atmospheric Temperatures

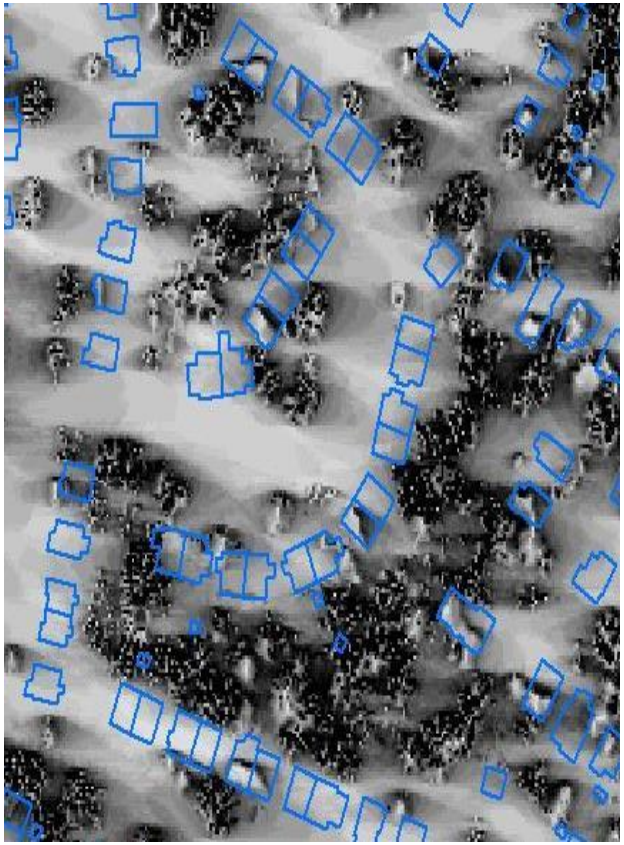


Surface and atmospheric temperatures vary over different land use areas. Surface temperatures vary more than air temperatures during the day, but they both are fairly similar at night. The dip and spike in surface temperatures over the pond show how water maintains a fairly constant temperature day and night, due to its high heat capacity.

* Note: The temperatures displayed above do not represent absolute temperature values or any one particular measured heat island. Temperatures will fluctuate based on factors such as seasons, weather conditions, sun intensity, and ground cover.

Our project: Urban heat at two scales





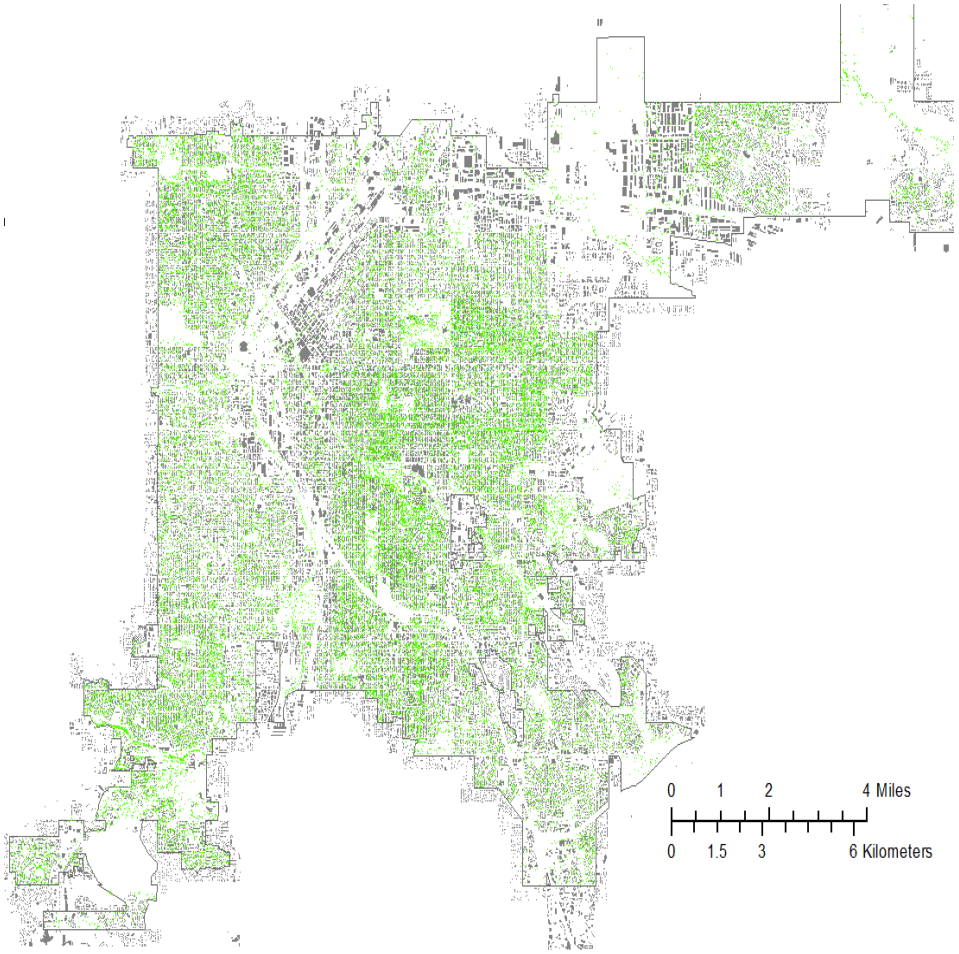
http://thinkgreendegrees.com/wp-content/uploads/2012/08/urban-heat-island-comparison.gif

Research Questions

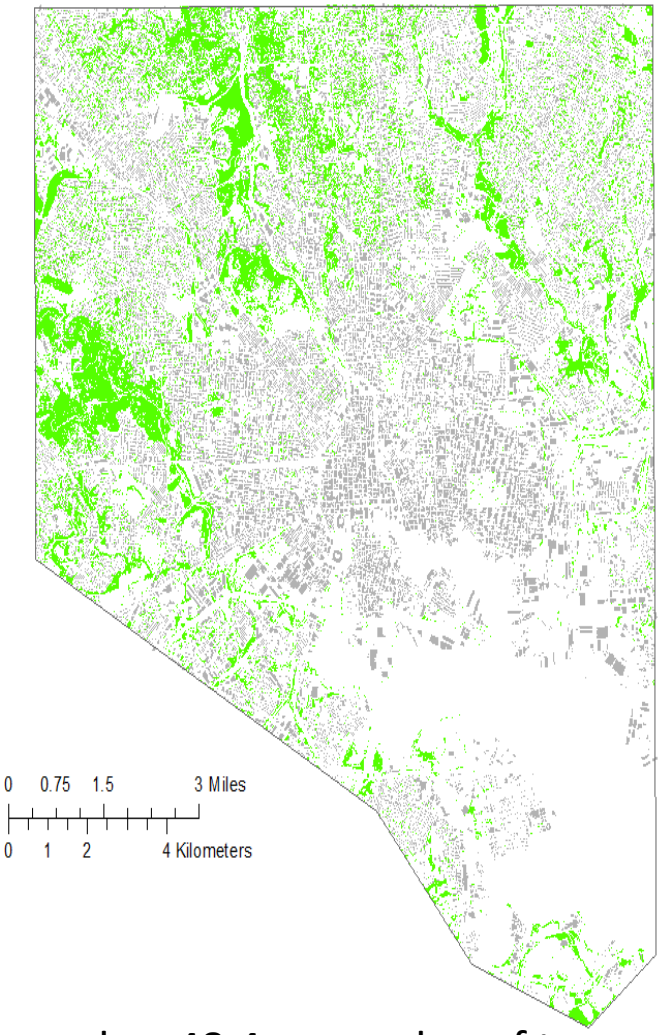
1. How does the urban heat island effect differ in a humid temperate city (Baltimore) versus and semi-arid zone city (Denver)?
2. How does the spatial pattern of tree canopy mediate trees' influence on urban heat? Is there an optimal pattern for planting trees to get the most heat mitigation for the same amount of trees? How does this effect vary between a semi arid (Denver) and humid (Baltimore) environment
3. How can we calculate the amount of tree shade that directly hits buildings and does the quantity of tree shade intersecting with buildings vary between Denver and Baltimore?

Question 1: Heat island in Denver vs. Baltimore

Tree Canopy Comparison



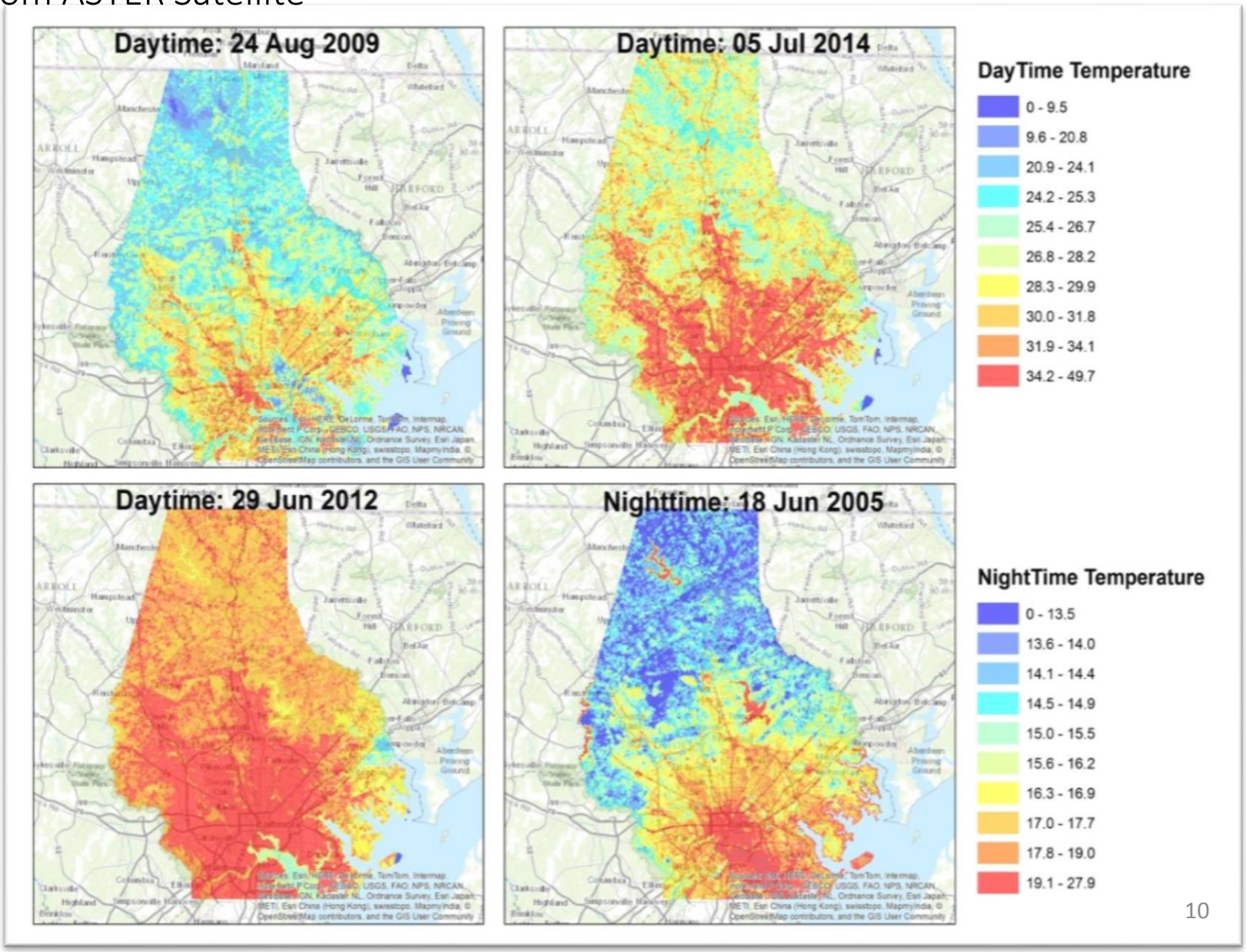
Denver has 31.8 square km of tree canopy coverage



Baltimore has 48.4 square km of tree canopy coverage

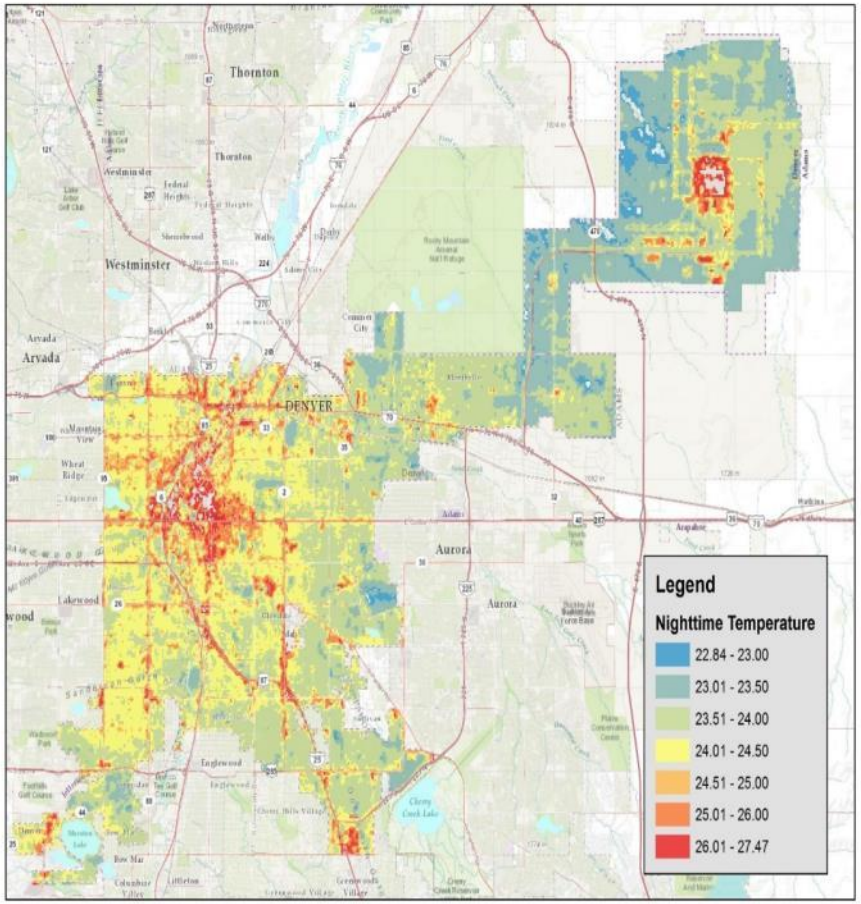
Surface Temperature: Baltimore

From ASTER Satellite

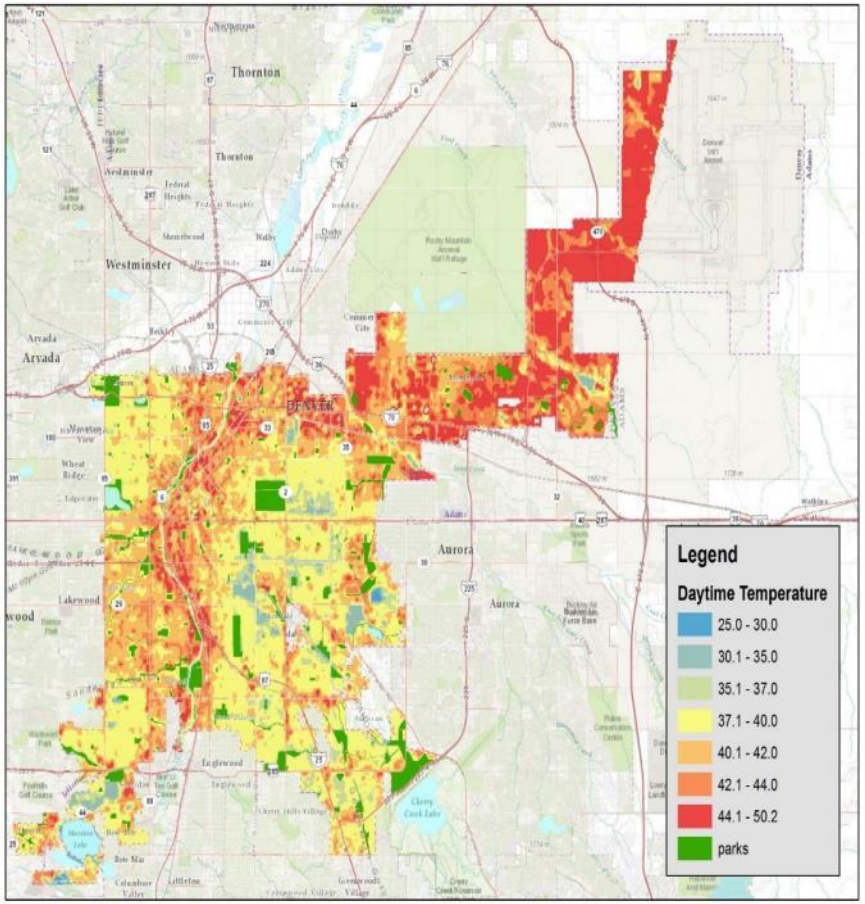


Surface Temperature: Denver

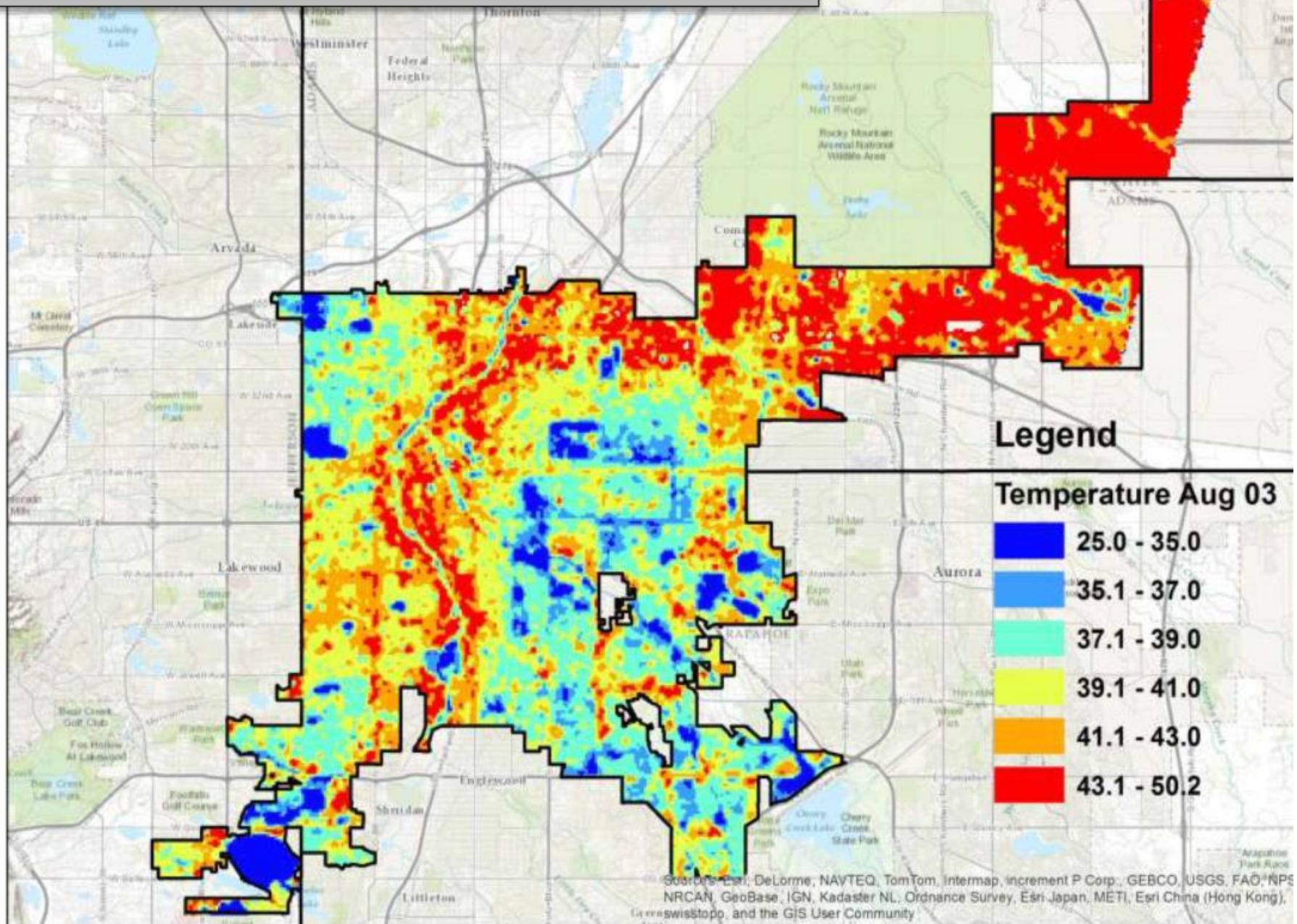
Nighttime August 2003



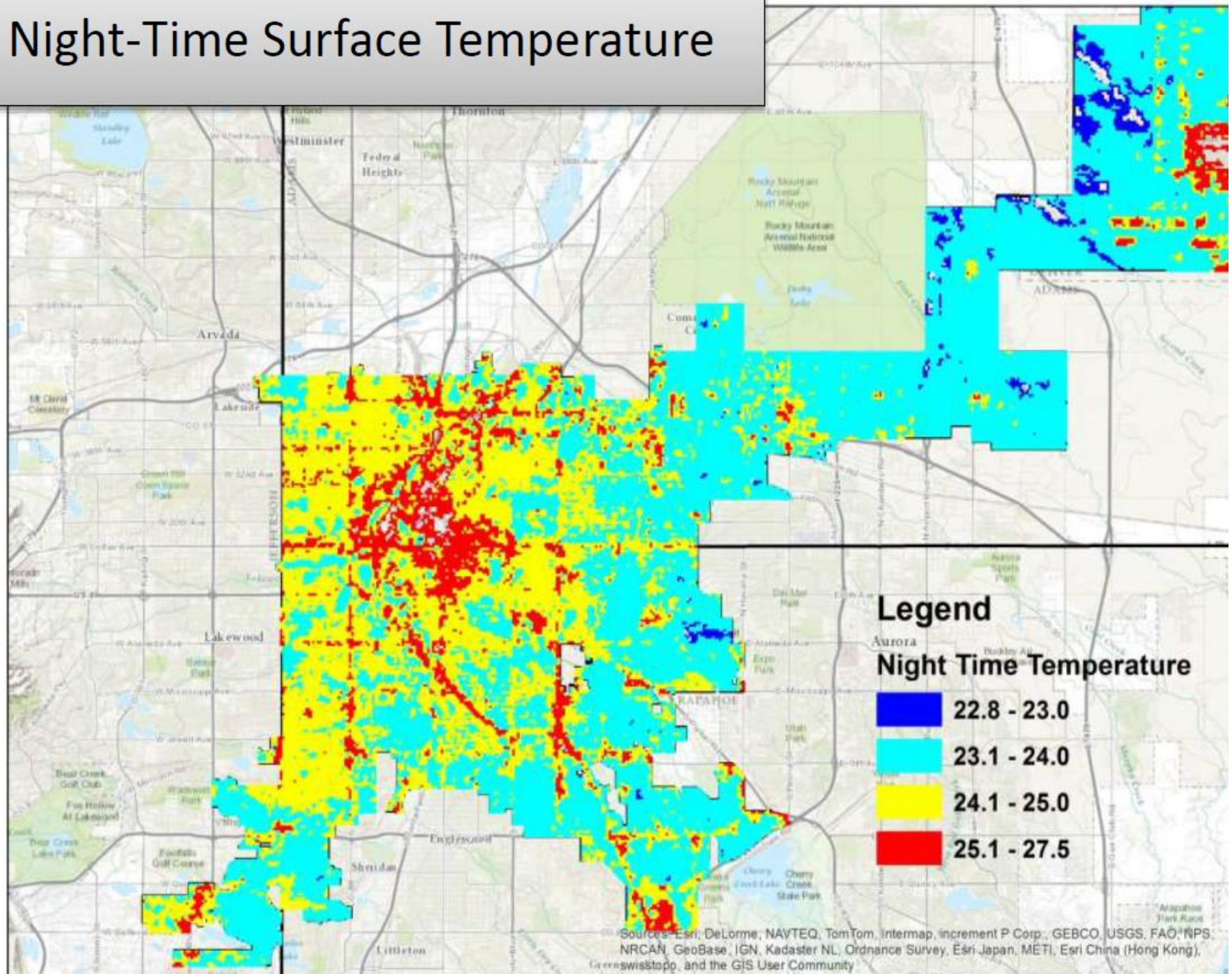
Daytime June 2012

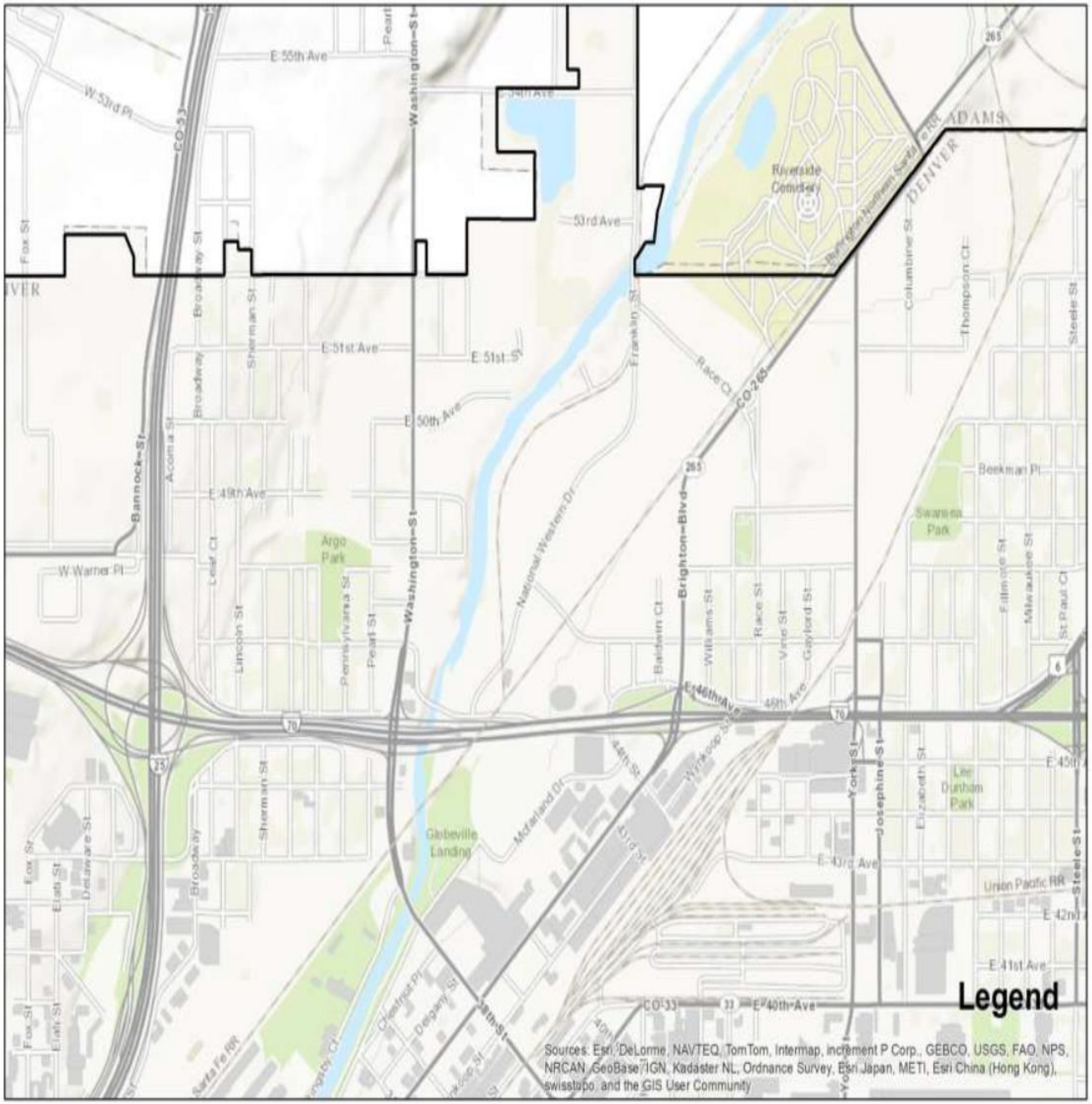


Day-Time Surface Temperature



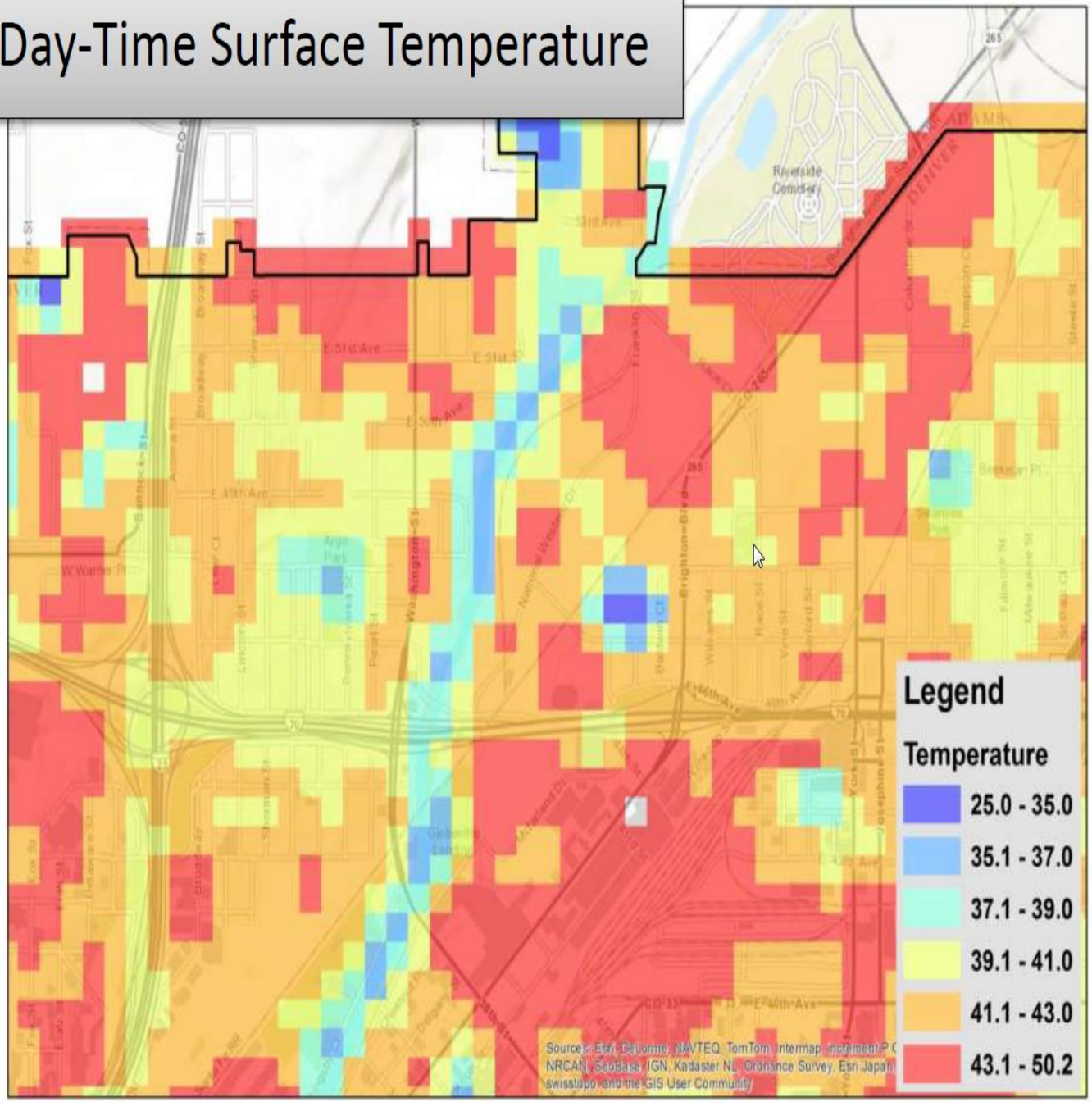
Night-Time Surface Temperature



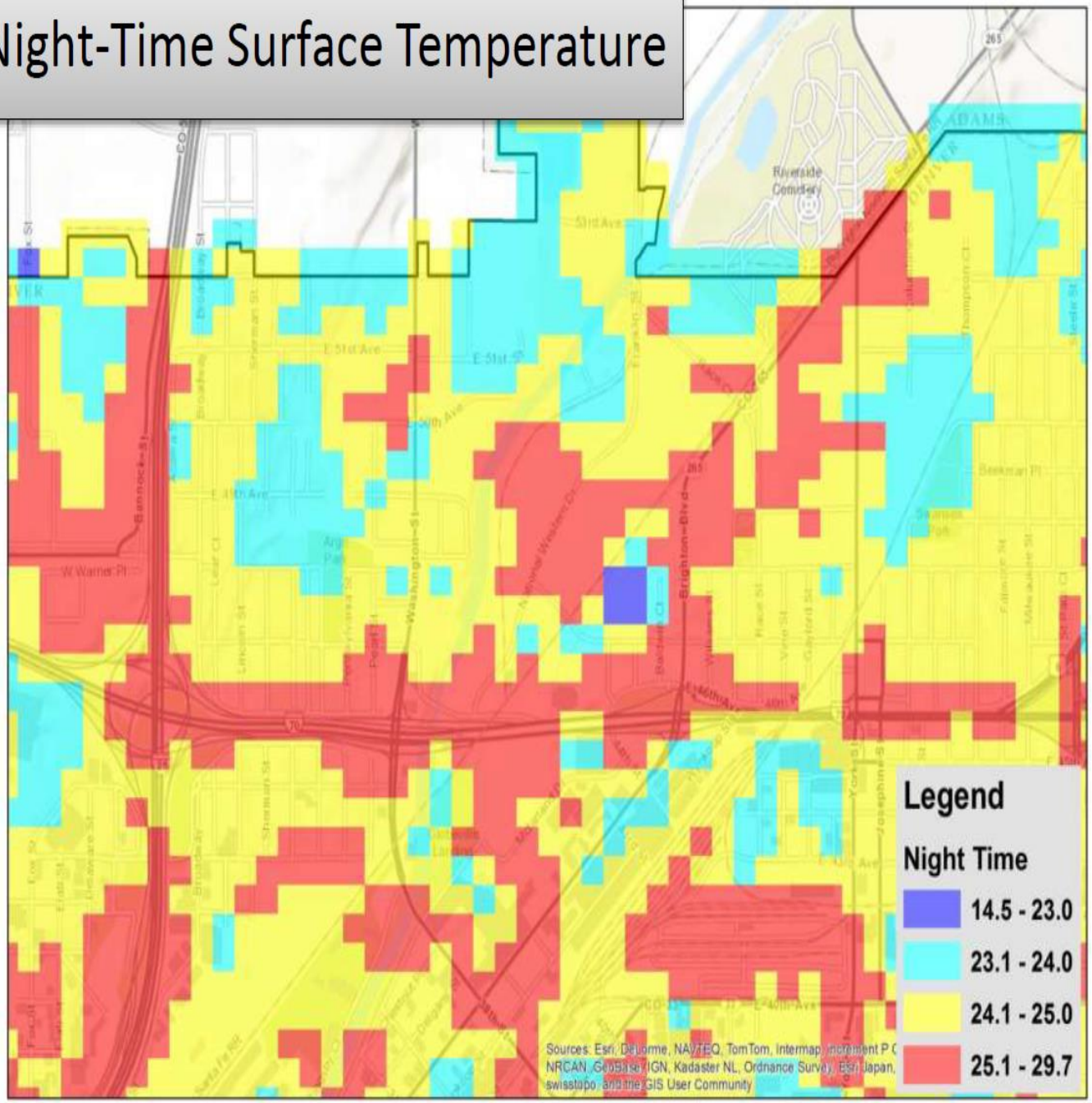


E 55th Ave
W 53rd Pl
CO-53
Washington St
Pearl
53rd Ave
Riverside Cemetery
ADAMS
DENVER
Fox St
Broadway St
Sherman St
E 51st Ave
E 51st St
Franklin St
Race Ct
CO-265
Columbine St
Thompson Ct
Steele St
E 50th Ave
Acoma St
Bannock St
E 49th Ave
Beekman Pl
Swansea Park
Argo Park
W Warner Pl
Leaf Ct
Lincoln St
Pennsylvania St
Pearl St
National Western Dr
Brighton Blvd
Baldwin Ct
Williams St
Race St
Vine St
Gaylord St
Fillmore St
Milwaukee St
St Paul Ct
E 46th Ave
46th Ave
70
25
Sherman St
Broadway
Globeville Landing
McFarland Dr
44th St
43rd St
Winkoop St
York St
Josephine St
Elizabeth St
Lee Dunham Park
E 45th
E 43rd Ave
Union Pacific RR
E 42nd
E 41st Ave
Fox St
Elati St
Delaware St
Chestnut Pl
Delgany St
38th St
CO-33
E 40th Ave
Santa Fe RR
Legend
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

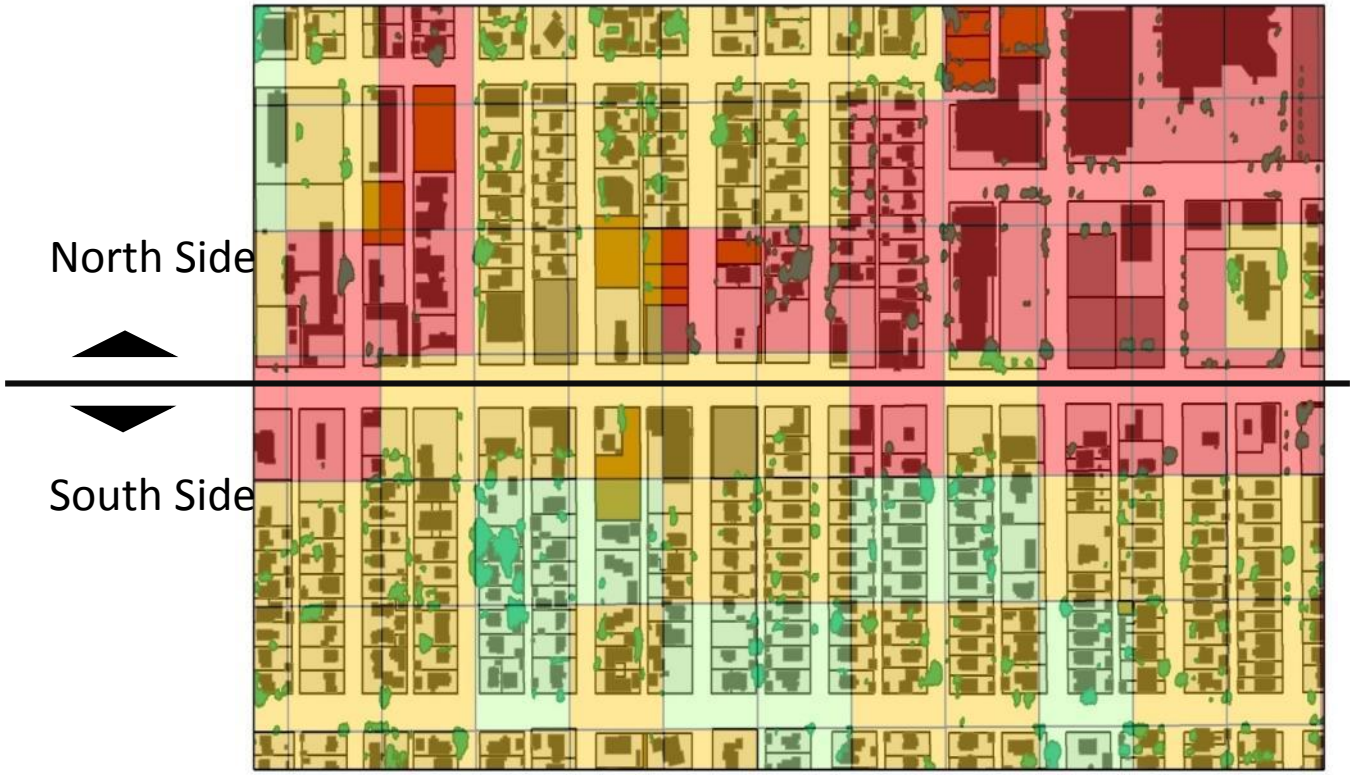
Day-Time Surface Temperature



Night-Time Surface Temperature

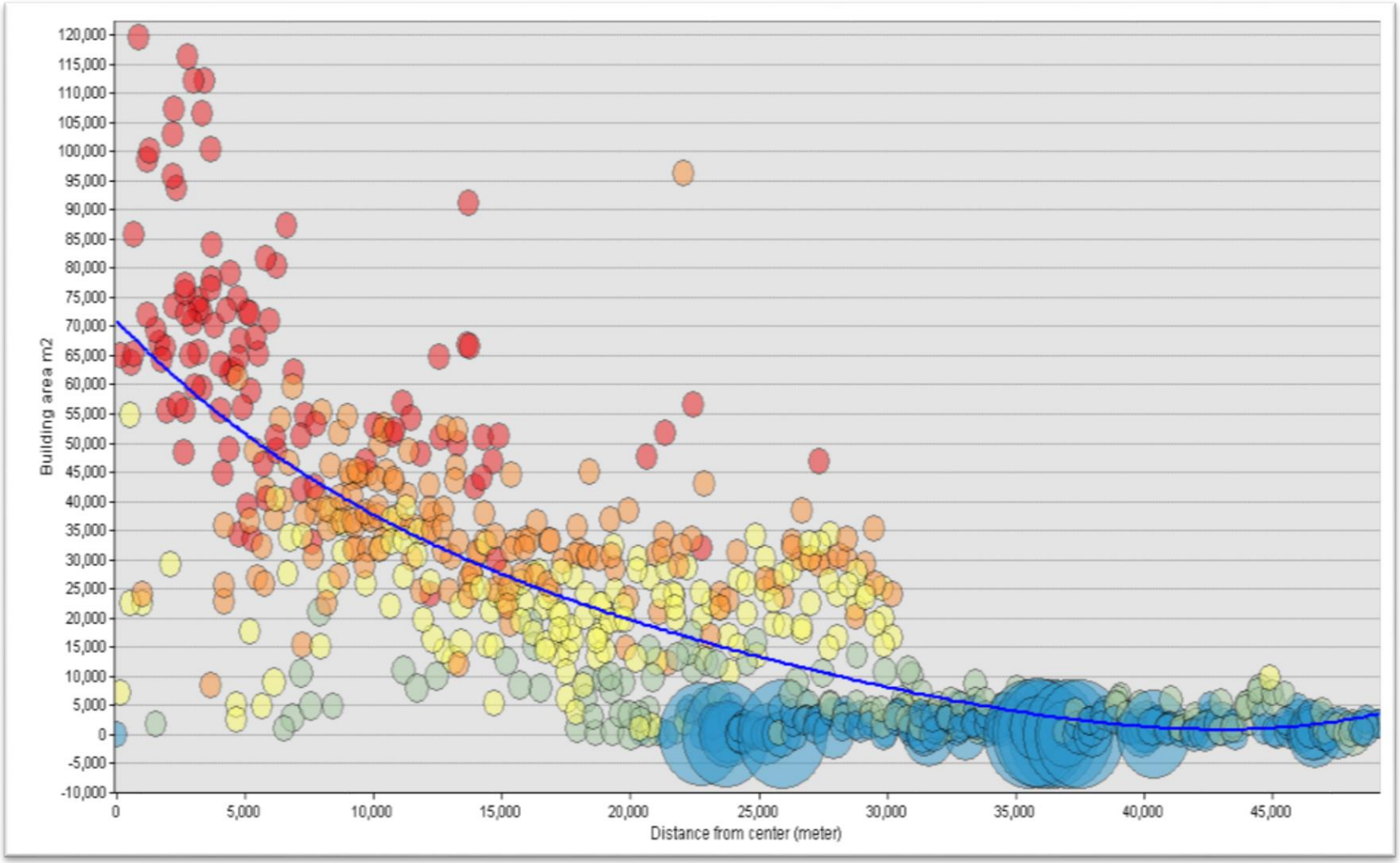


Surface Temperature and Morphology in Denver

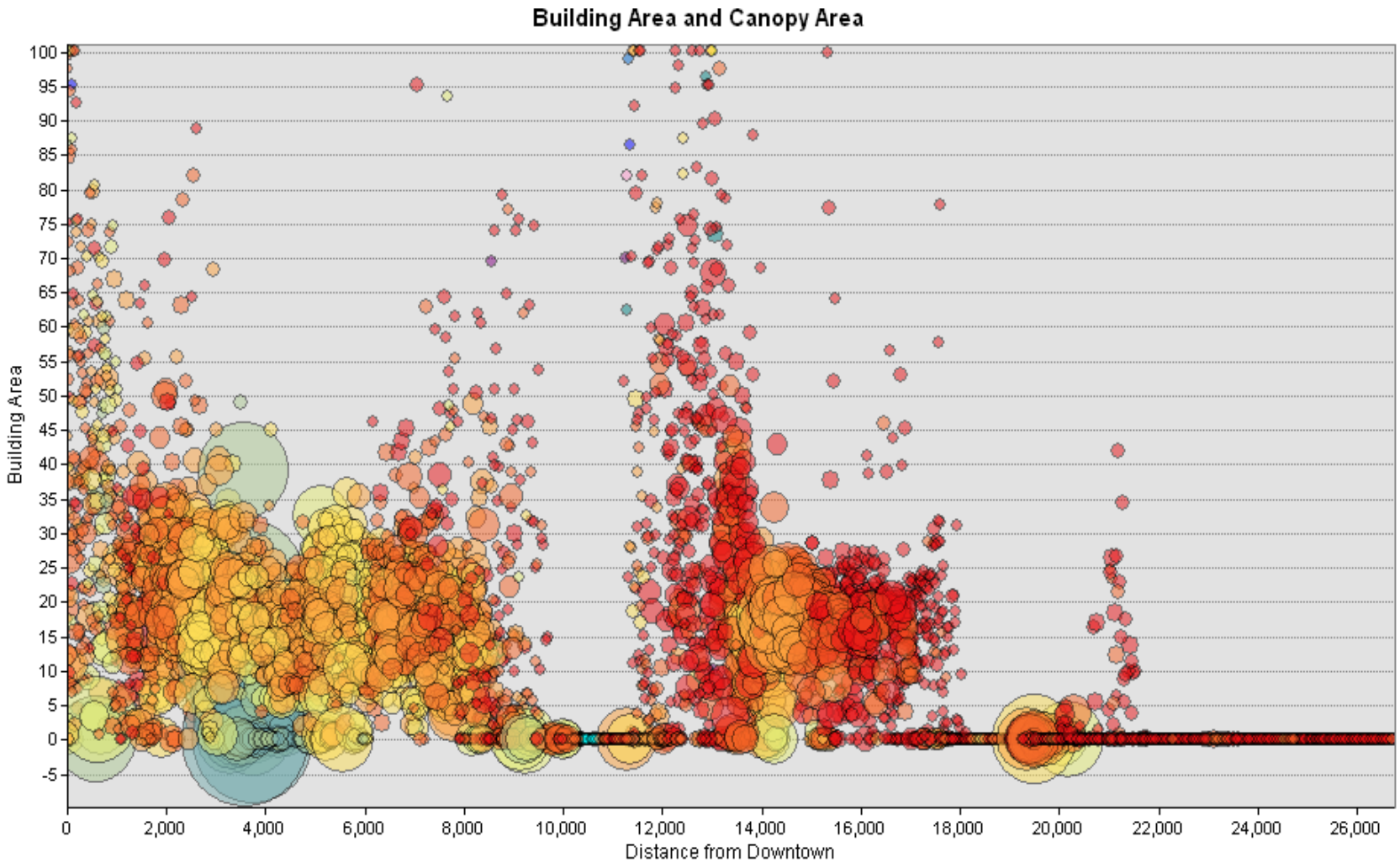


North Side									100
	40.72	102	8%	19%	6.7%	68%	7%	0.76	-0.99
Colfax Corridor	Temperature	roof color	canopy	building area	parking area	impervious surfaces	vacant land	CanImp index	compactness index
South Side	39.46	107.0	12%	20%	0.8%	51%	1%	0.49	-0.90
									90

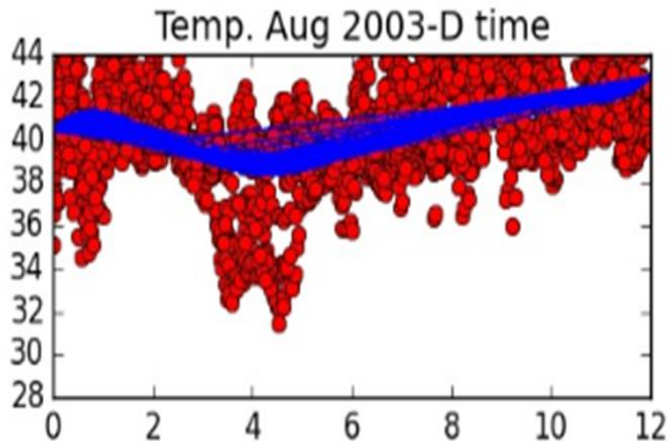
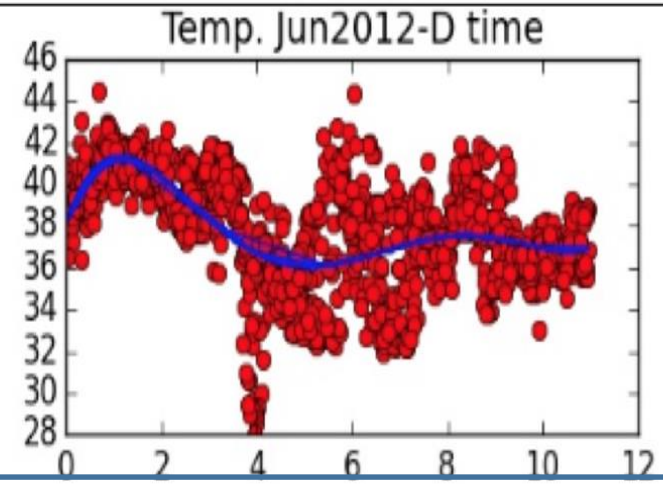
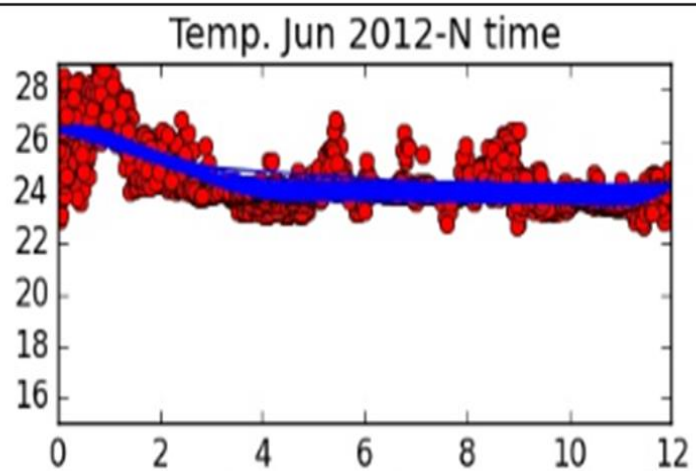
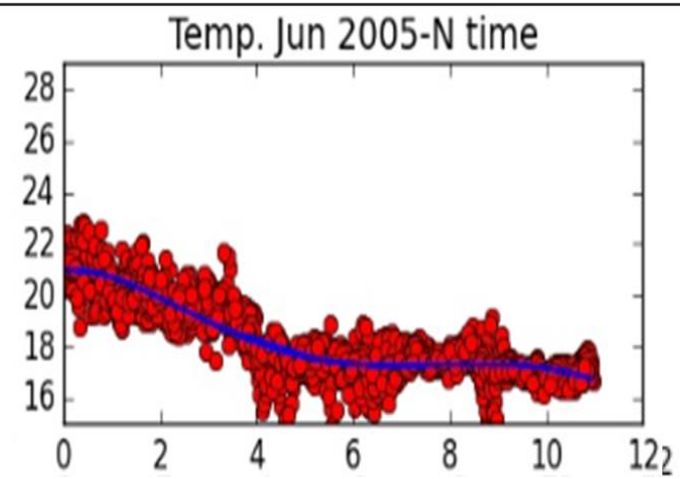
Baltimore: trend of building area (vertical axis), distance from center (horizontal axis), average patch area radius of circles), and temperature (color)



Denver: trend of building area (vertical axis), distance from center (horizontal axis), average patch area radius of circles), and temperature (color)



Transect analysis

Parameter	Denver	Baltimore
Daytime temperature		
Nighttime temperature		

Why?

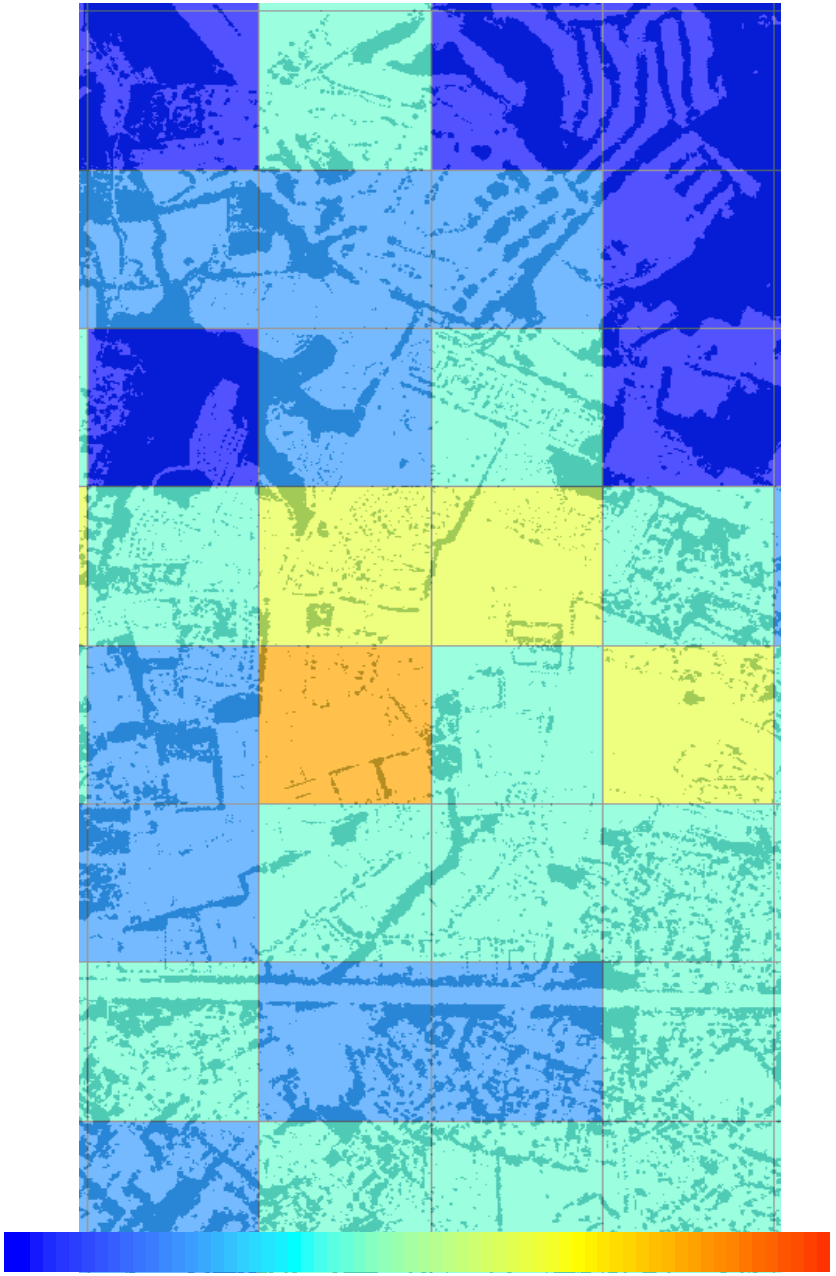
- In eastern city surrounded by natural forest, outskirts cool down much quicker at night due to high emissivity relative to city
- In semi-arid location, trees are not endemic to outskirts, rather urbanization results in MORE trees than would otherwise be there.
- The fact that urbanized areas tend to go along with trees means that heat trapping effect of impervious area is largely offset by increase in tree cover relative to surrounding prairie
- Exceptions: downtown, where tons of building area relative to trees; airport, where lots of impervious area

Question 2: Spatial patterns of trees and urban heat mitigation

Metrics assessed

- Patch edge length
- Patch edge: area ratio
- Patch circularity
- Patch envelope ratio
- Minimum bounding geometry
- Patch density/ number
- Average patch area
- Control variables:
  - Building area
  - Parking area
  - **Total canopy patch area**

All metrics measured at 500 m grid cell



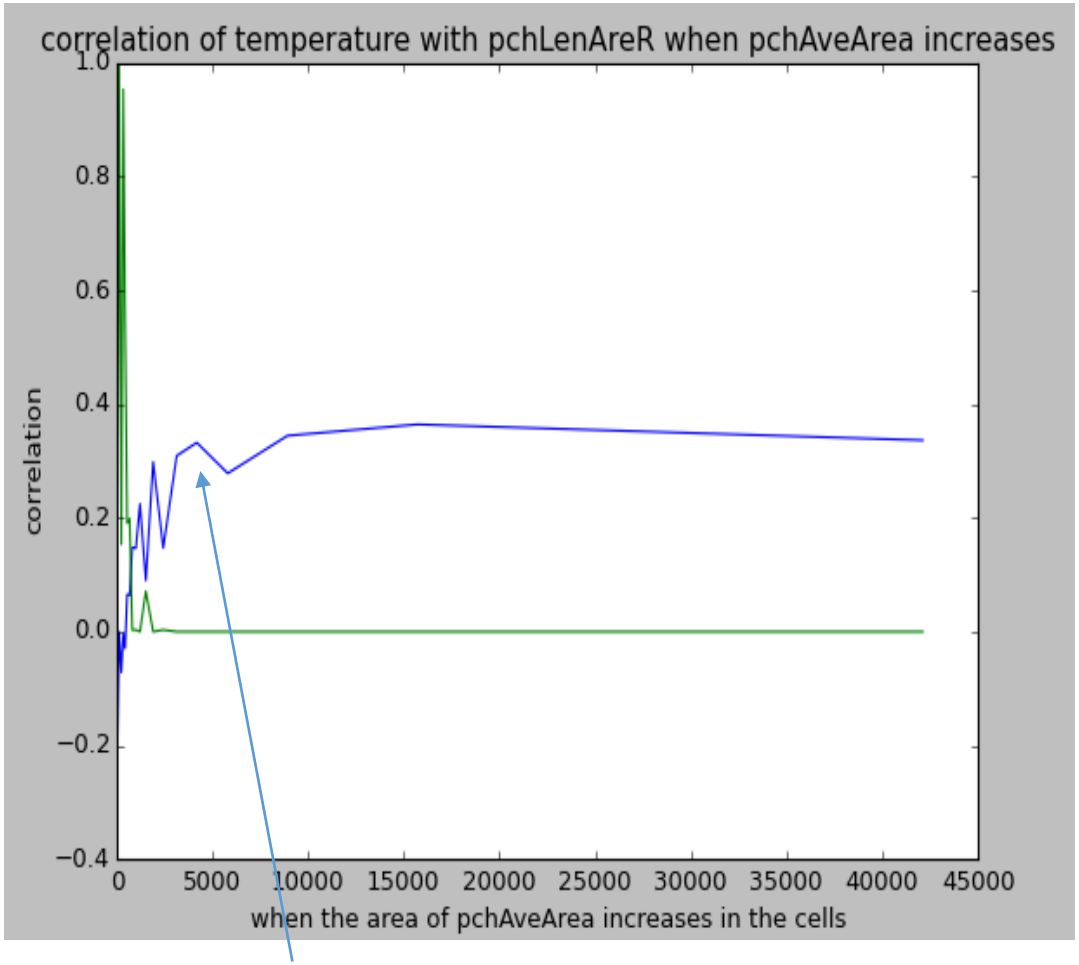
Patch edge area ratio (blue is low, red is high)

Results of multivariate regression

- Models explain about 78% of variance in surface temperature
- Strong positive correlation between temperature and building/ pavement area and negative correlation with tree canopy area.
  - Tree canopy effect: for each additional 10% of the grid cell occupied by trees, see a drop of 0.38° C = fully vegetated grid cell is 3.8 ° cooler than cell without trees
- But does it matter how trees are arranged? When adjusting for total tree and building area the following spatial patch metrics are significant:
  - Average area of patches (lower temperature)
  - Envelope ratio (lower)
  - Number of patches (higher)
  - Edge length of patches (higher)
  - Length to area ratio (higher)

Is there a critical threshold for patch size in terms of trees' impact on heat?

correlation of temperature and patch-length/area-ratio when the patch average area increases



Levelling off point around 5000 sq m.

Interpretation

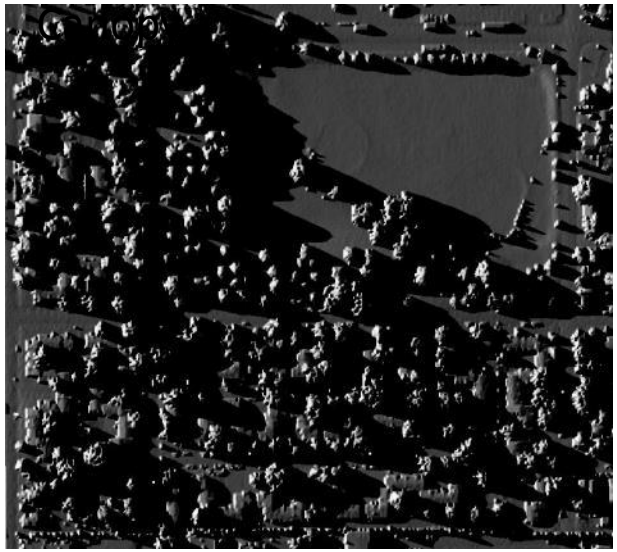
Still a lot to determine, but:

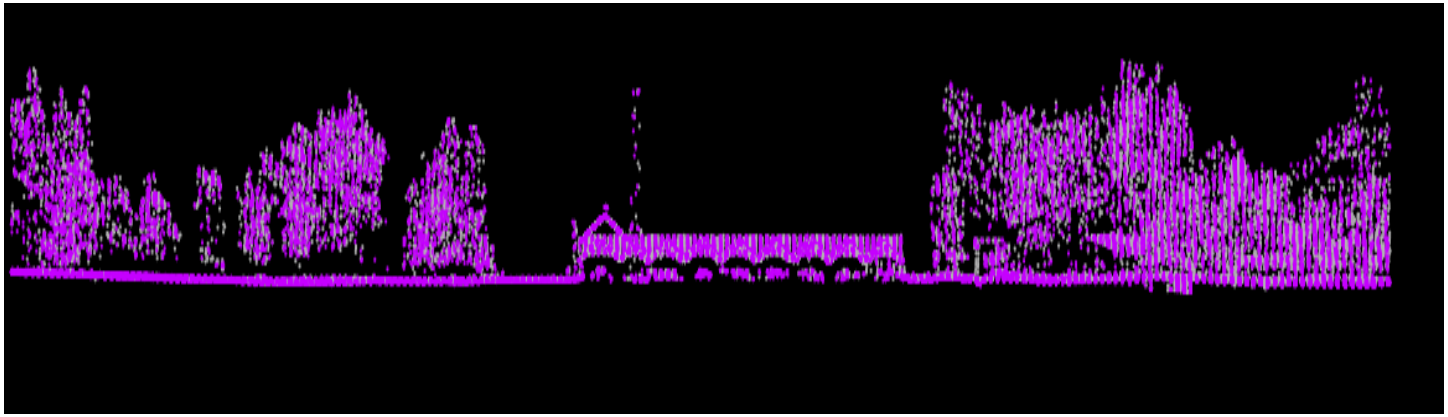
- Trees reduce urban heat significantly
- The way the trees are arranged can boost or detract from that effect somewhat
- After adjusting for the total area of tree canopy, trees have most effect when arranged in areas of large average patch size that are more compact in shape
- Their effect is somewhat reduced by:
  - Lots of edge relative to core
  - Scattering vs. concentrating of trees
  - Small average size of patches
- There appears to be a threshold area around 5000 sq m.

Question 3: Quantifying tree shade hitting buildings: Denver vs. Baltimore

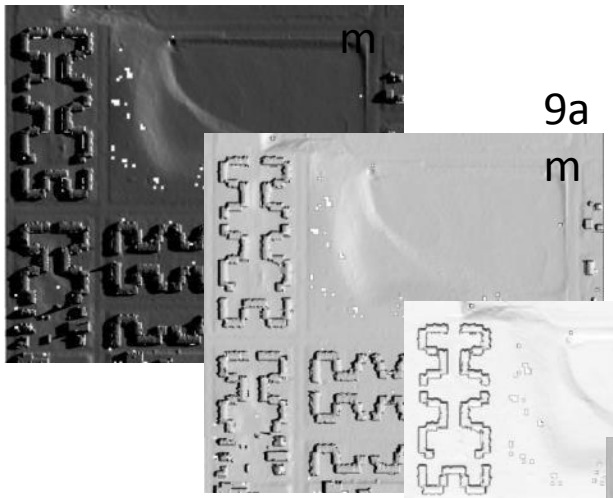
Analysis of shade based on LiDAR

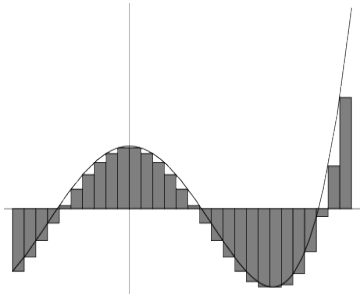
6pm Shadow from Buildings &

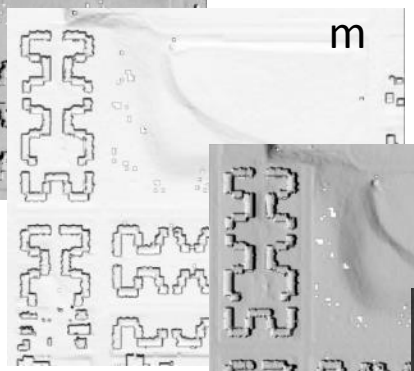


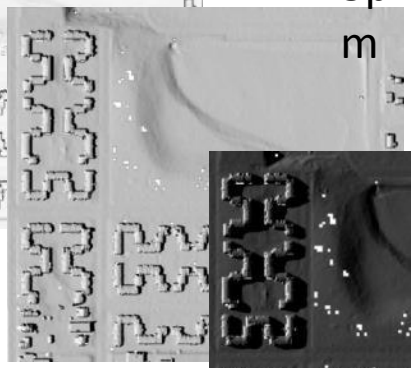


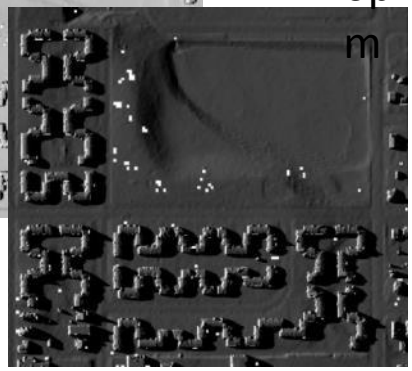
Shade Effects – Integrated over time

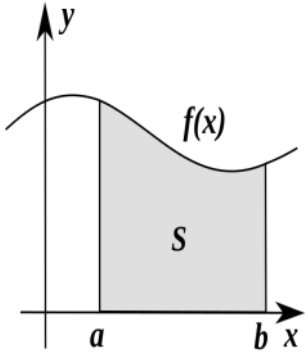












Shade Effects – Isolated & Combined

Tree
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Buildin
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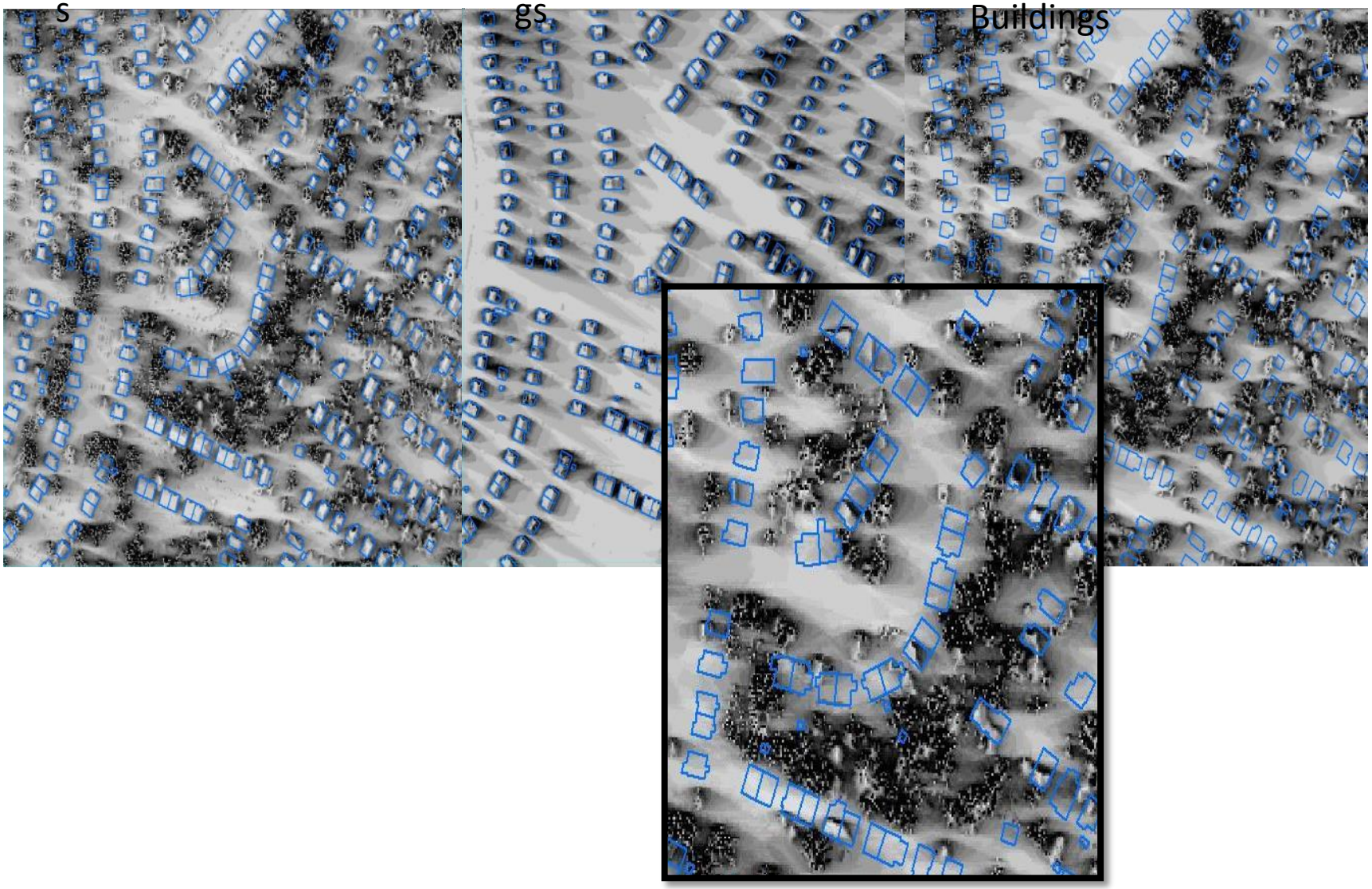
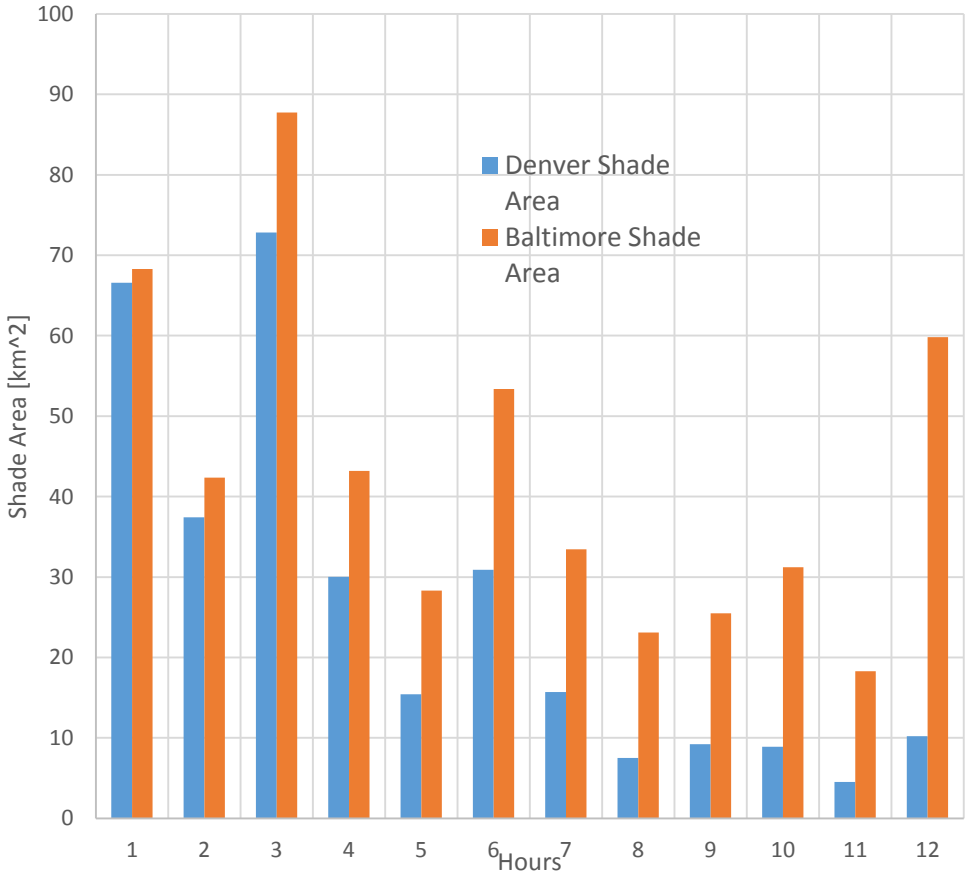
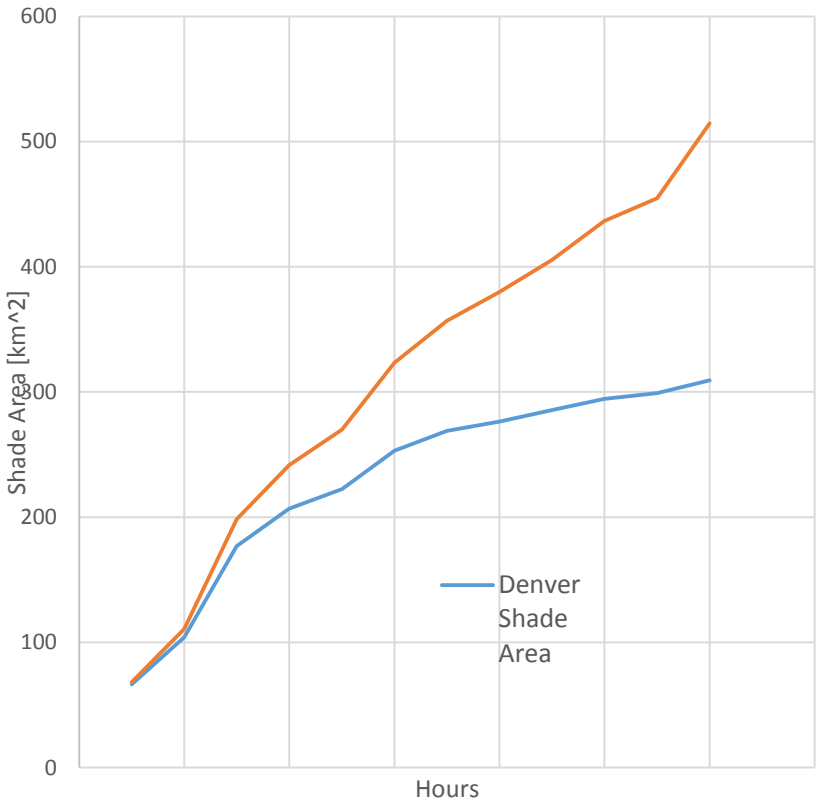
Trees &
Buildings



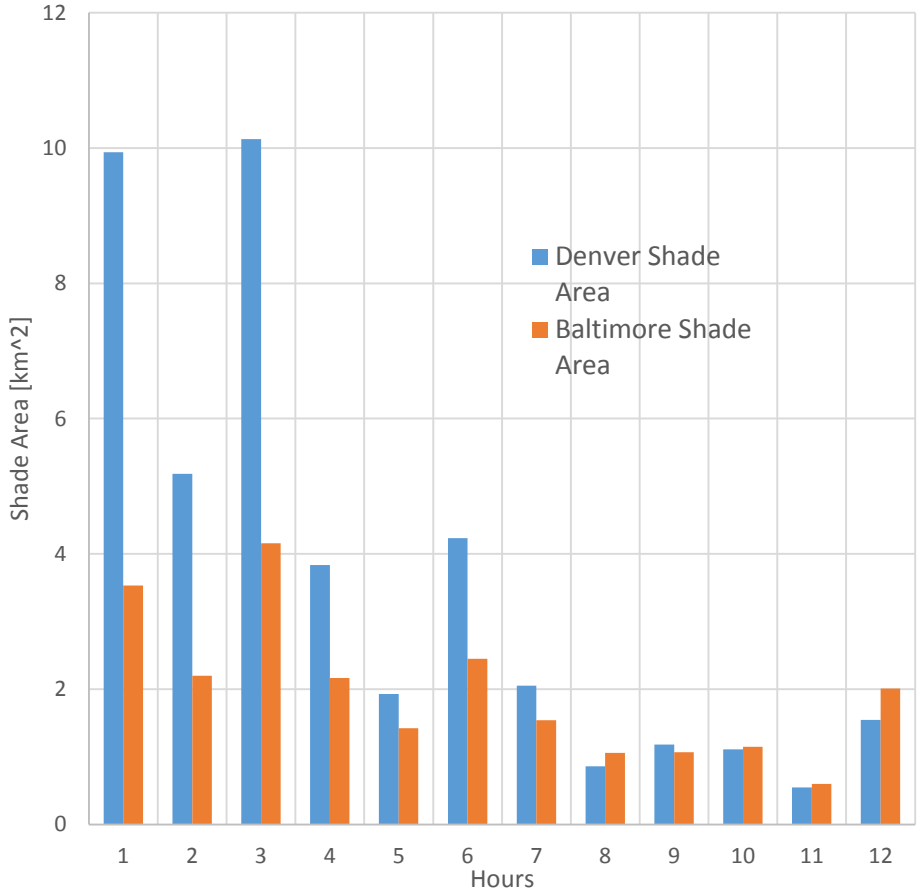
Total Shade Comparison

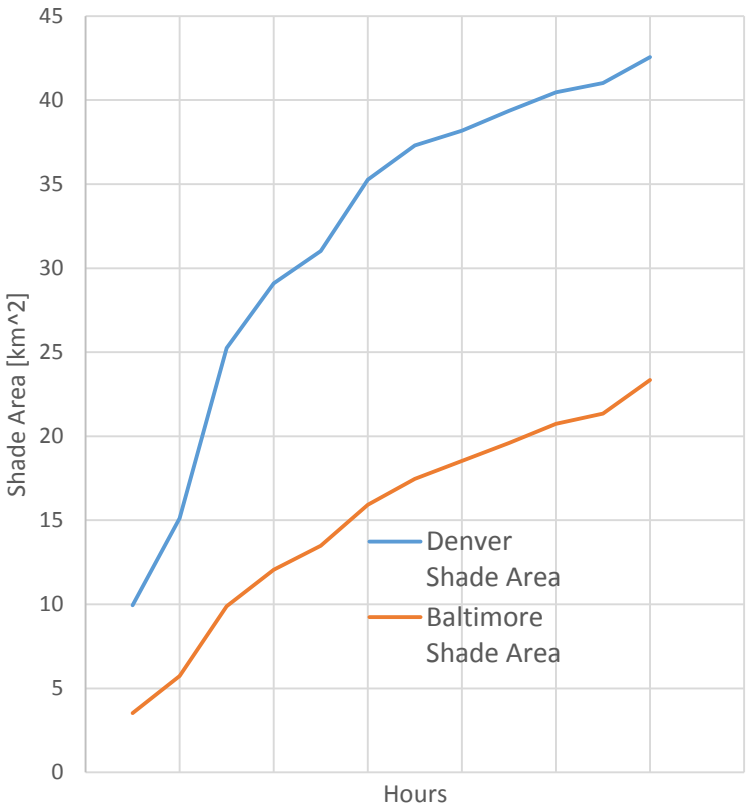




Total Tree Shade : 4 hour interval (summed) * 3 days (June 15, July 15, August 15)

Roof-Tree Intersection Shade Comparison



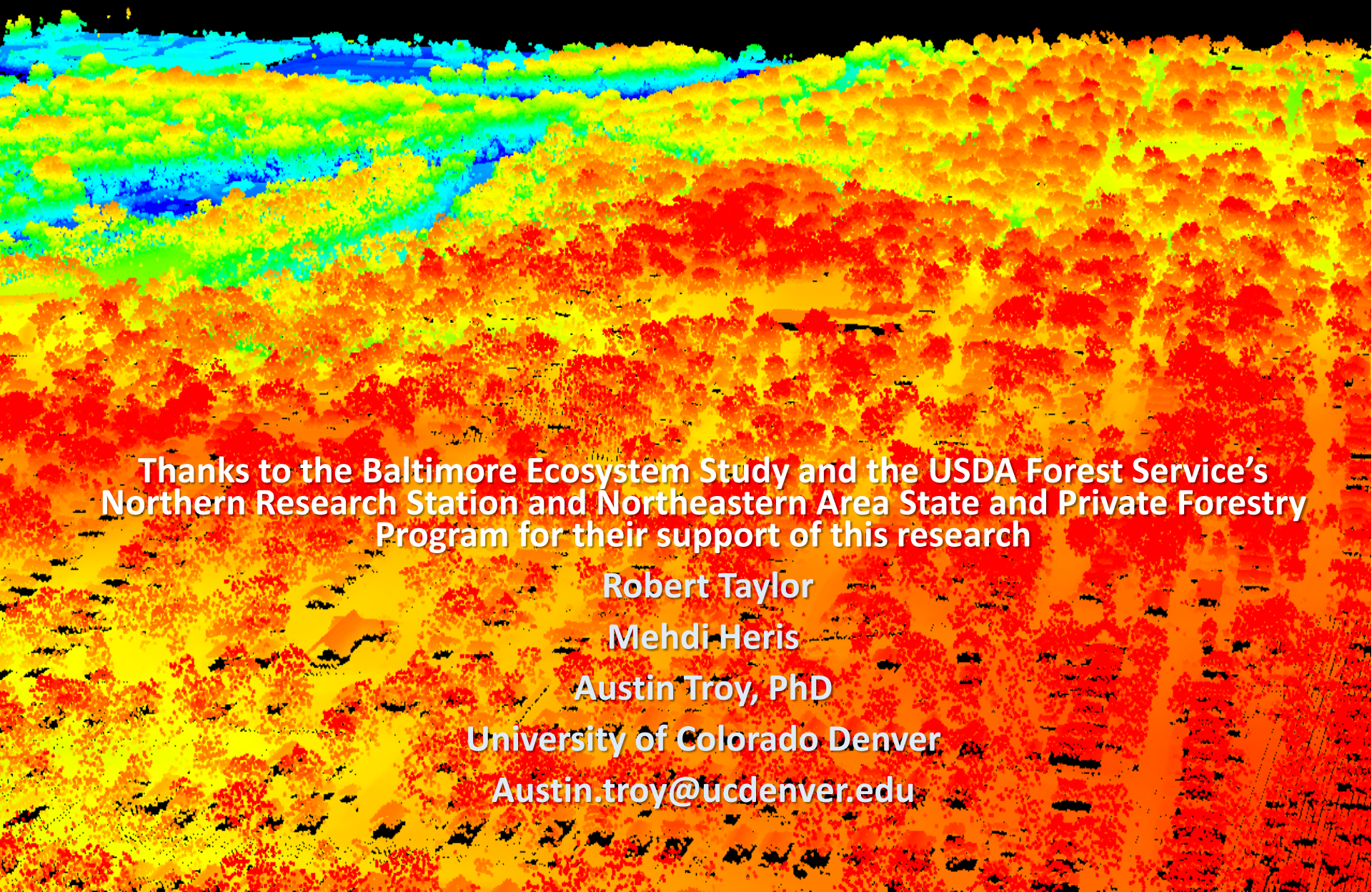


Roof-Tree Intersection Shade : 4 hour interval (summed) * 3 days (June 15, July 15, August 15)

Conclusion and next steps

- Heat island effect is very different in eastern and western US
- Western cities tend to have more trees relative to natural surroundings than do eastern cities
- Spatial pattern of tree canopy has a big impact on heat mitigation. Big patches with more core area better for heat mitigation than scattered, isolated trees (up to certain size). BUT more concentrated forest comes at the cost of less direct shading of buildings, which requires distribution of trees
- Tree shade varies between Denver and Baltimore: more overall tree shade in Baltimore, but more tree shade hitting buildings in Denver by far, probably because more of Baltimore's trees in big patch areas.
- Next step: relate this to energy consumption data

Thanks! Questions?



Thanks to the Baltimore Ecosystem Study and the USDA Forest Service's Northern Research Station and Northeastern Area State and Private Forestry Program for their support of this research

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