Applying DRCOG high-resolution land-cover data to urban ecosystem service modeling

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Urban Heat: A Cause for Concern

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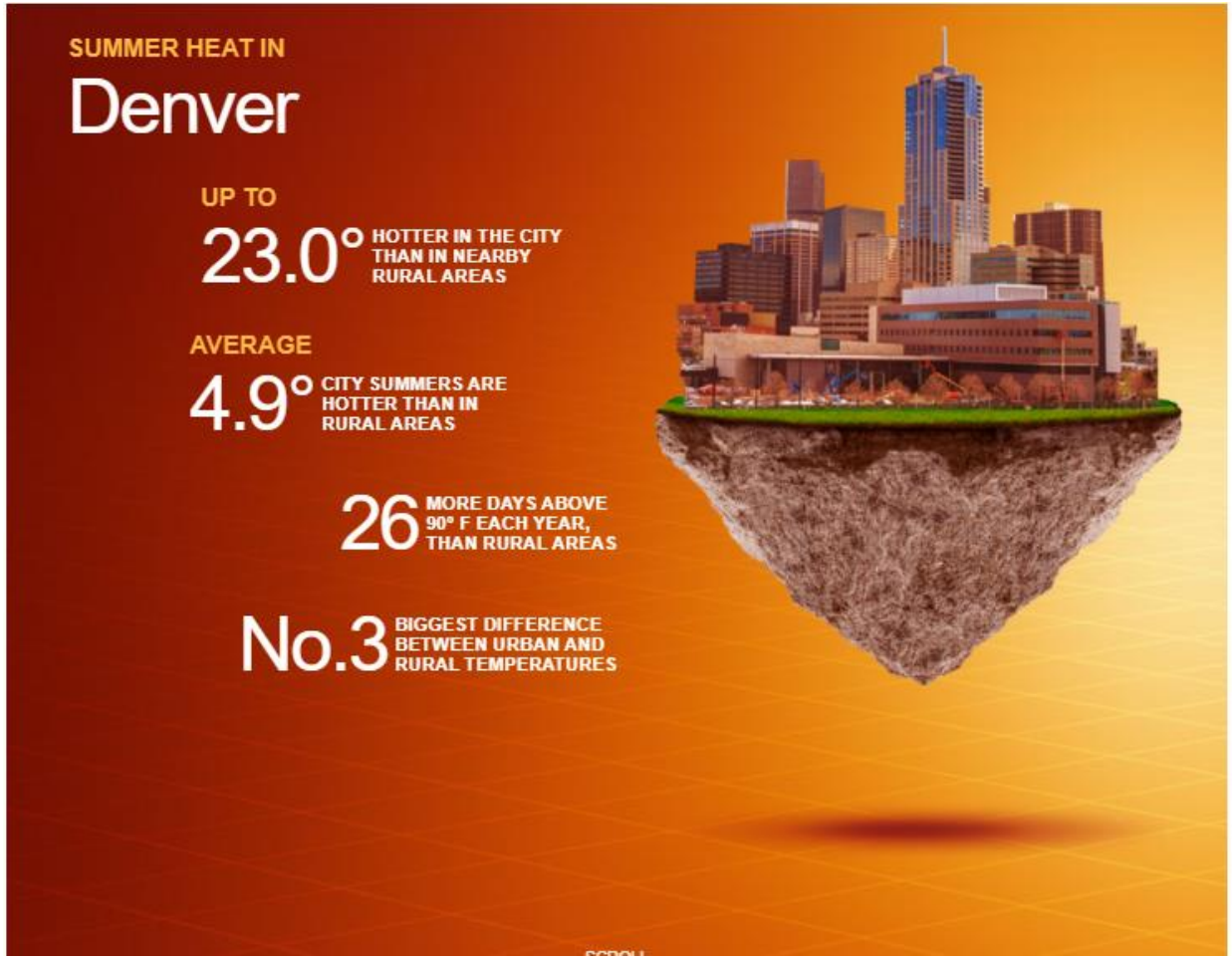
Denver weather: Heat wave continues as triple-digit temperatures break records

Denver has topped 100 degrees for the third day in a row



https://www.climatecentral.org/news/urban-heat-islands-threaten-us-health-17919

Urban Heat: A Cause for Concern

- What is the Urban Heat Island?
- What drives within city urban heat variation
- How hi-resolution land-cover data can answer pressing issues of urban heat
- What are the next steps in urban ecosystem modeling

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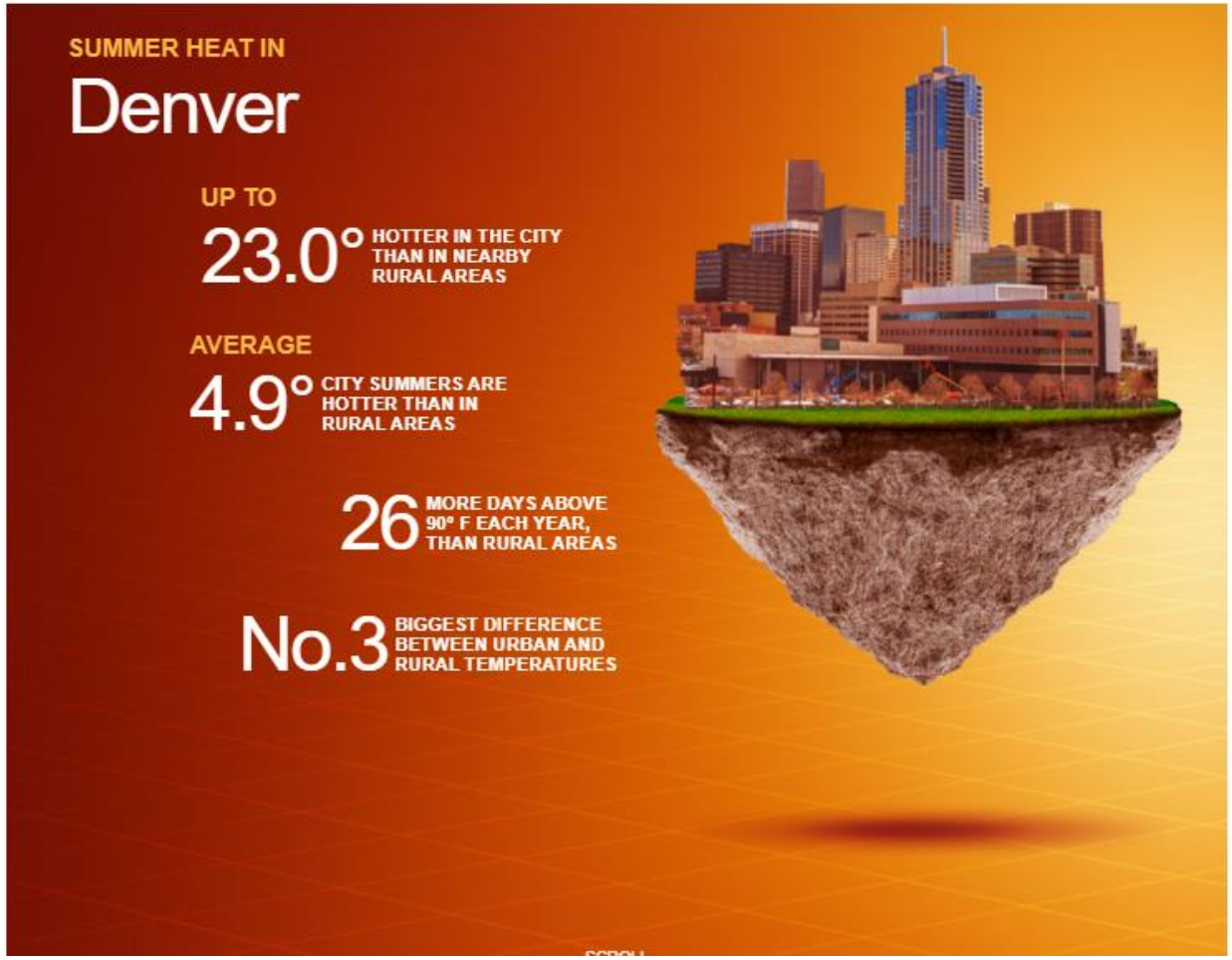

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Urban Heat: The Urban Heat Island

- The central urban core is significantly warmer than the outer rural areas.
- Daytime urban surface temperatures are higher rural areas
- Nighttime urban surface and air temperatures are higher than rural areas

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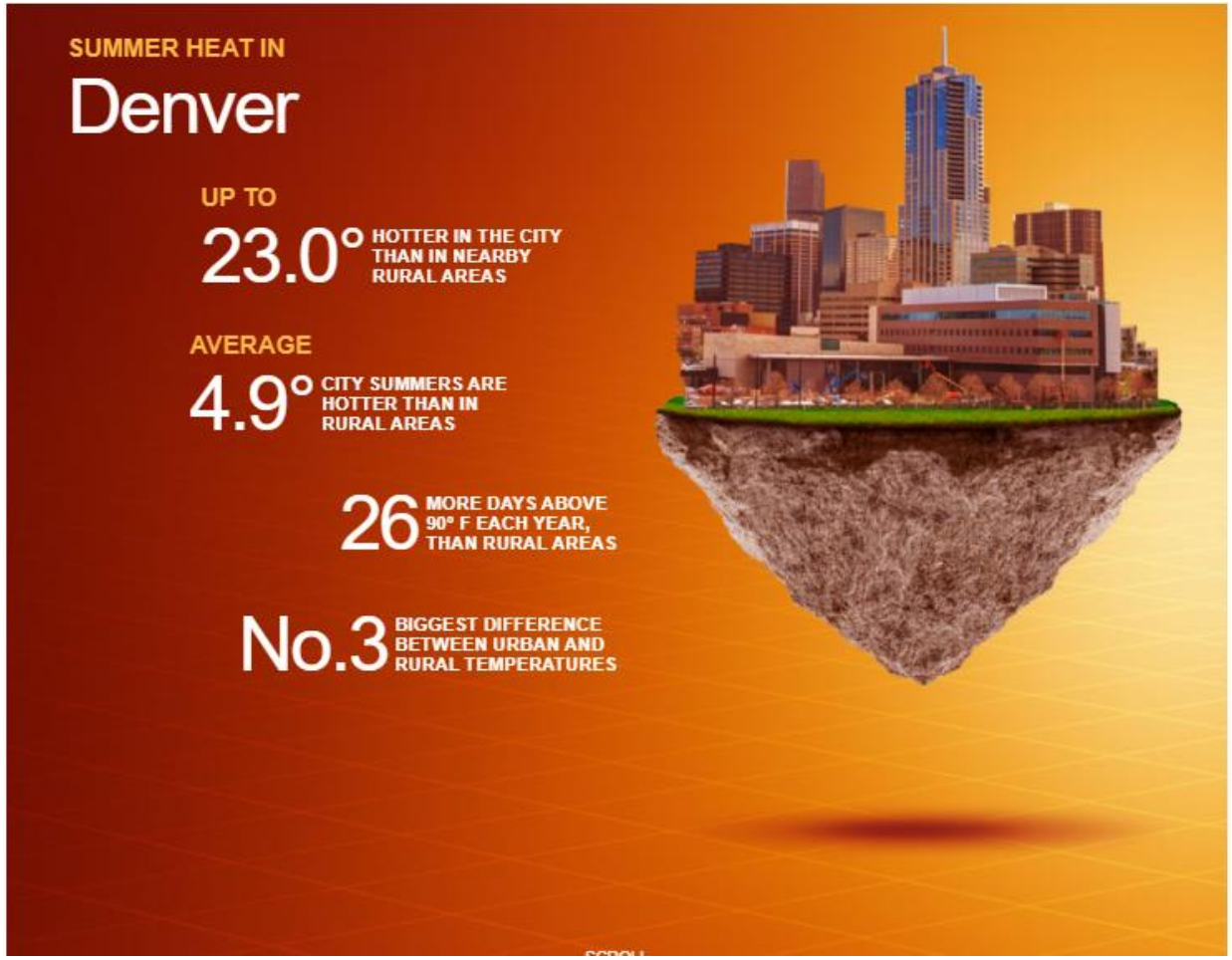

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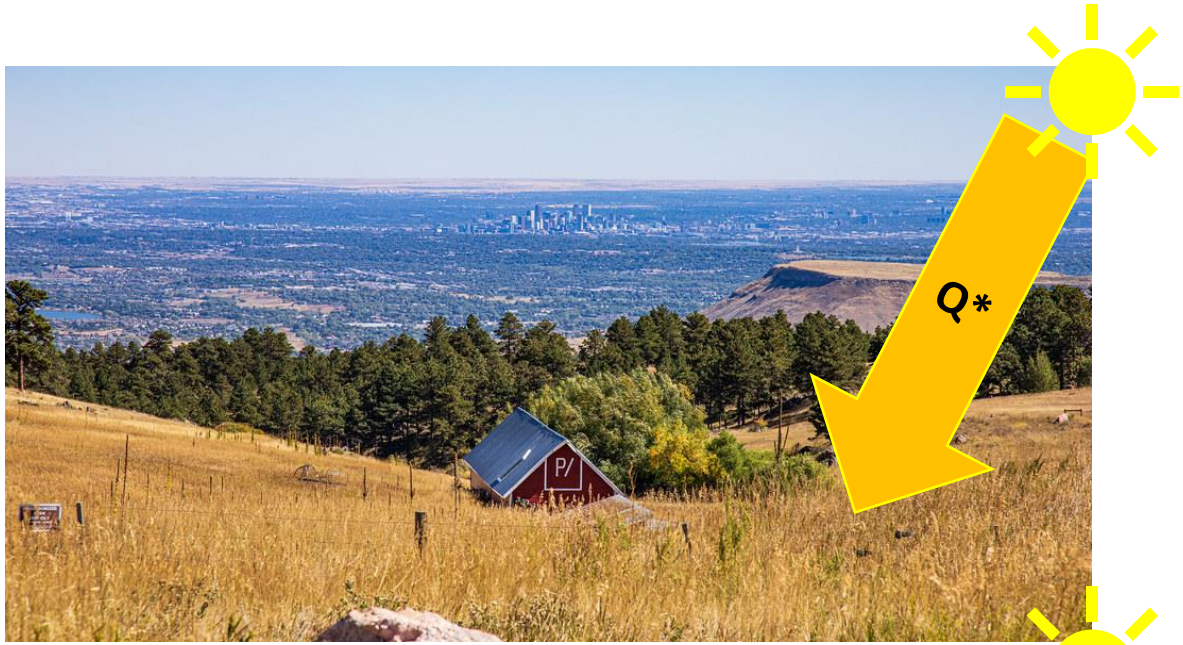
Urban Heat: The Urban Heat Island Explained!

- Q* is the net radiation
  - Little difference between urban and rural areas



Urban Heat: The Urban Heat Island Explained!

- Rural and Urban differ in the storage and release of heat energy
- Q_E= “Latent Heat Flux”
  - Evaporative cooling
  - More vegetation = more cooling
- Q_S = “Storage Heat-Flux”
  - More impervious surfaces = greater stored heat
- Q_H = “Sensible Heat-Flux”
  - Heat radiating from surfaces
  - More impervious surfaces = greater sensible heat

Urban Heat: The Urban Heat Island Explained!

- Rural and Urban differ in the storage and release of heat energy

- $Q^* = Q_E + Q_S + Q_H$
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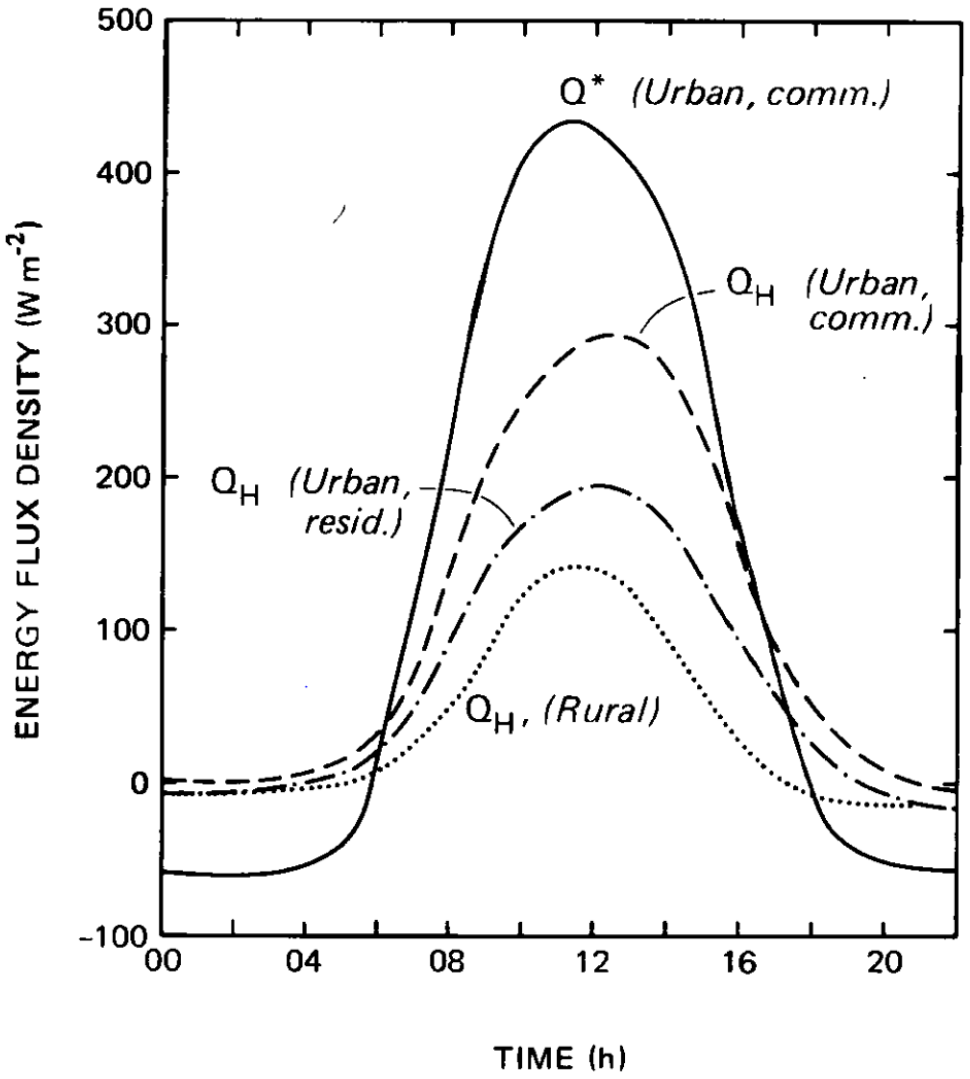


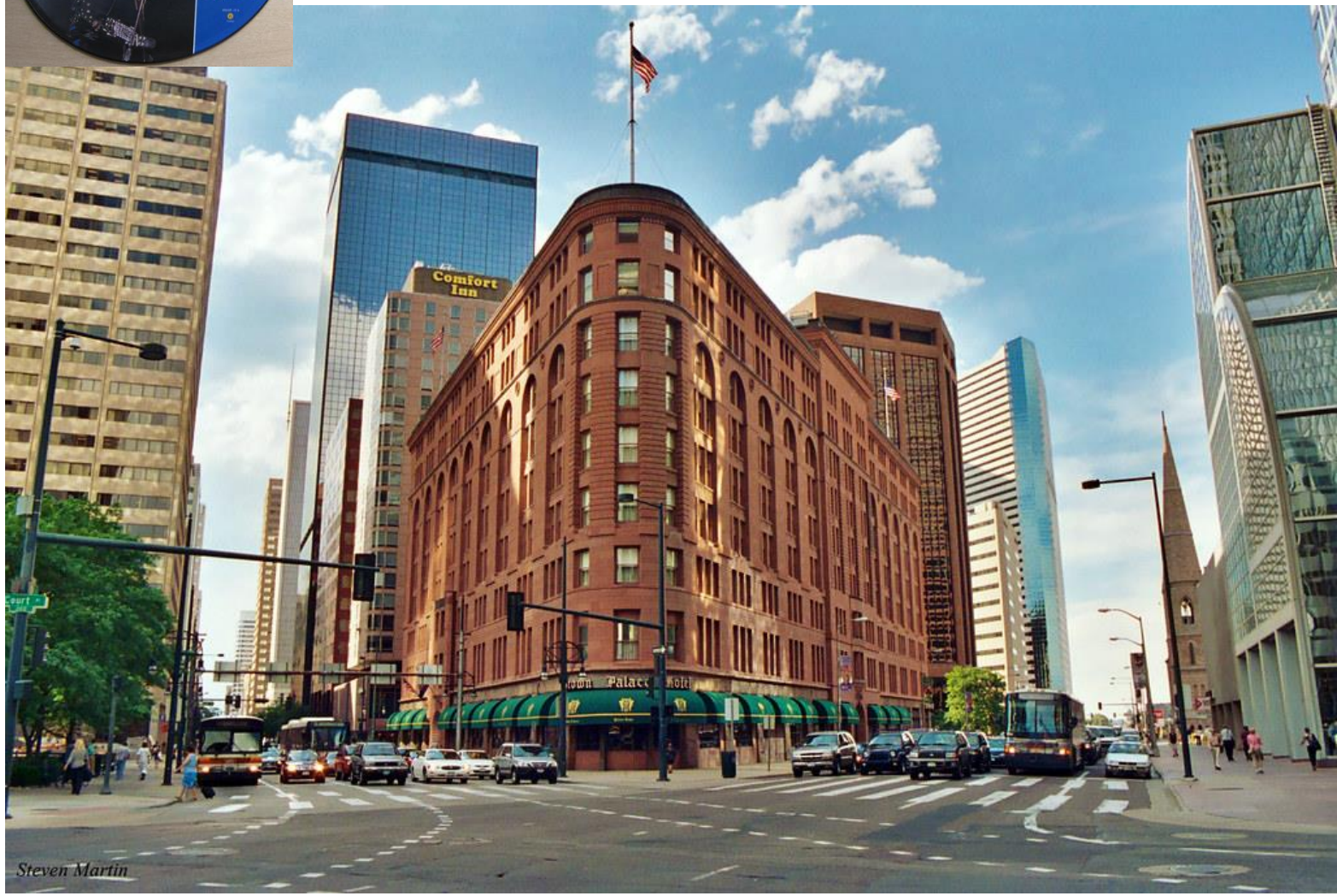
Oke, T. R. (1988)

Urban Heat: Hot IN the City

- UHI is a well-studied phenomenon comparing urban and rural areas
- The same energy equation applies within urban areas
  - Cities are a heterogenous mixture of green, blue, and grey infrastructure
- Urban heat can be mitigated through modifying urban land covers

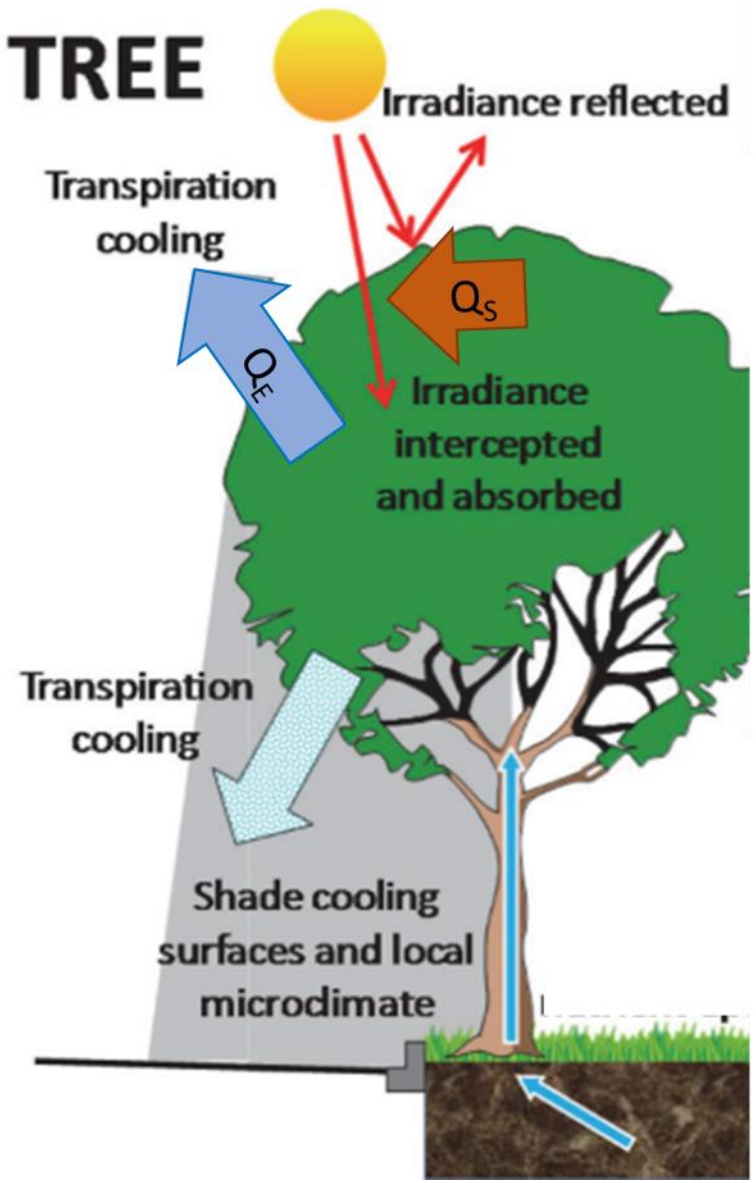
Urban Heat: Hot IN the City

- Urban streets and buildings offer little to no latent heat flux
- Asphalt and concrete can store large loads of heat energy
- Stored heat energy is then released after sundown, making night air temperatures warmer



Urban Vegetation: Cool in the City

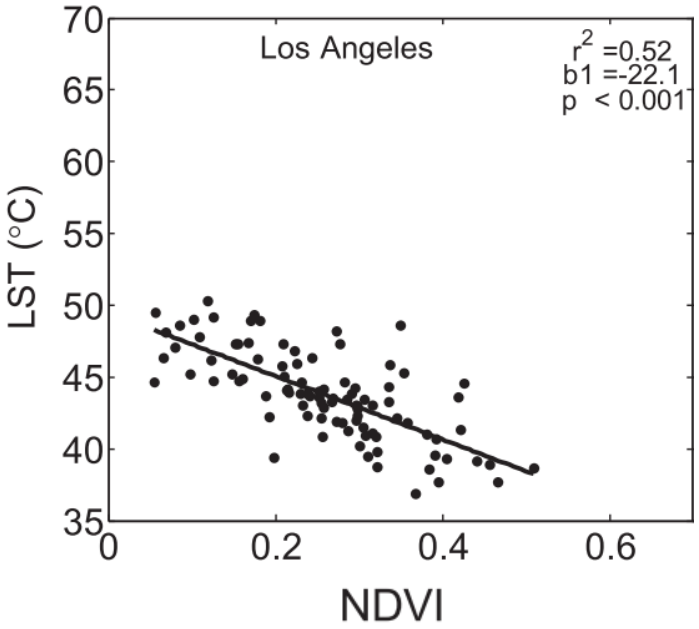
- Urban vegetation:
  - Increase latent heat flux (Q_E) through transpiration
  - Reduce heat storage (Q_S) through biological properties
  - Reduce sensible heat flux (Q_H) through shading of surfaces, and replacement of impermeable surfaces



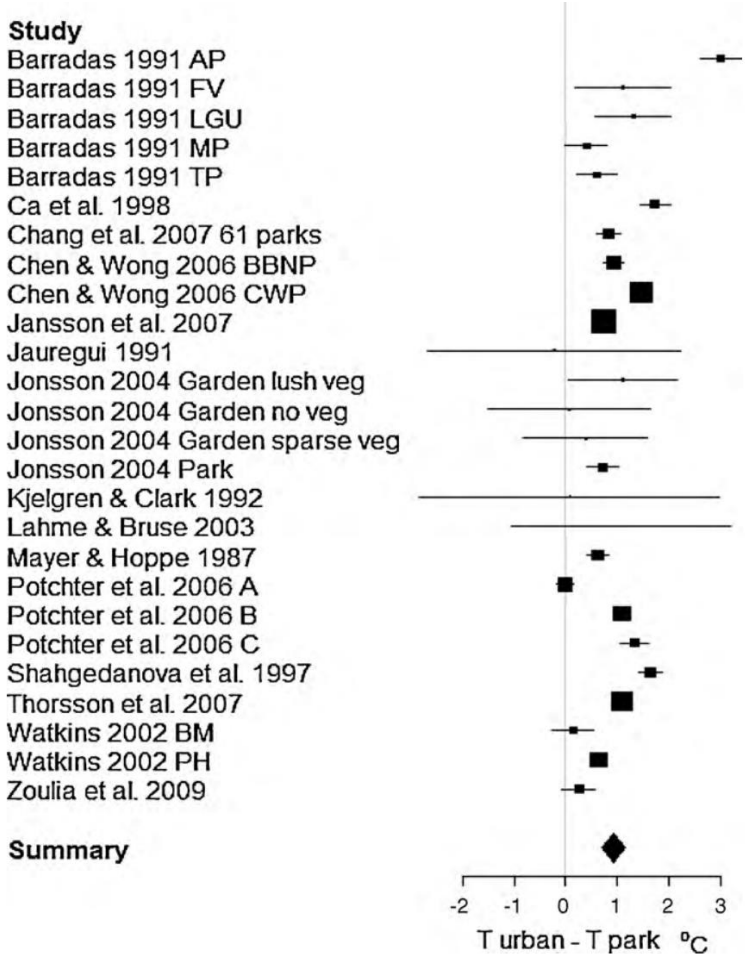
Livesley, S.J., et al (2016).
Journal of Environmental Quality

Urban Heat Research: What's Been Done

- Urban vegetation reduces within city land surface temperature
- Greener urban landcovers can lower within city air temperature



SA Shiflett *et al* (2017).



D Bowler *et al* (2010).

Urban Heat Research: The Future

- What is lacking?
  - Comparison across cities of varying regional climates
  - Connecting high resolution land cover to changes in air temperature
  - Determine the effect sizes of different urban land covers on air temperature

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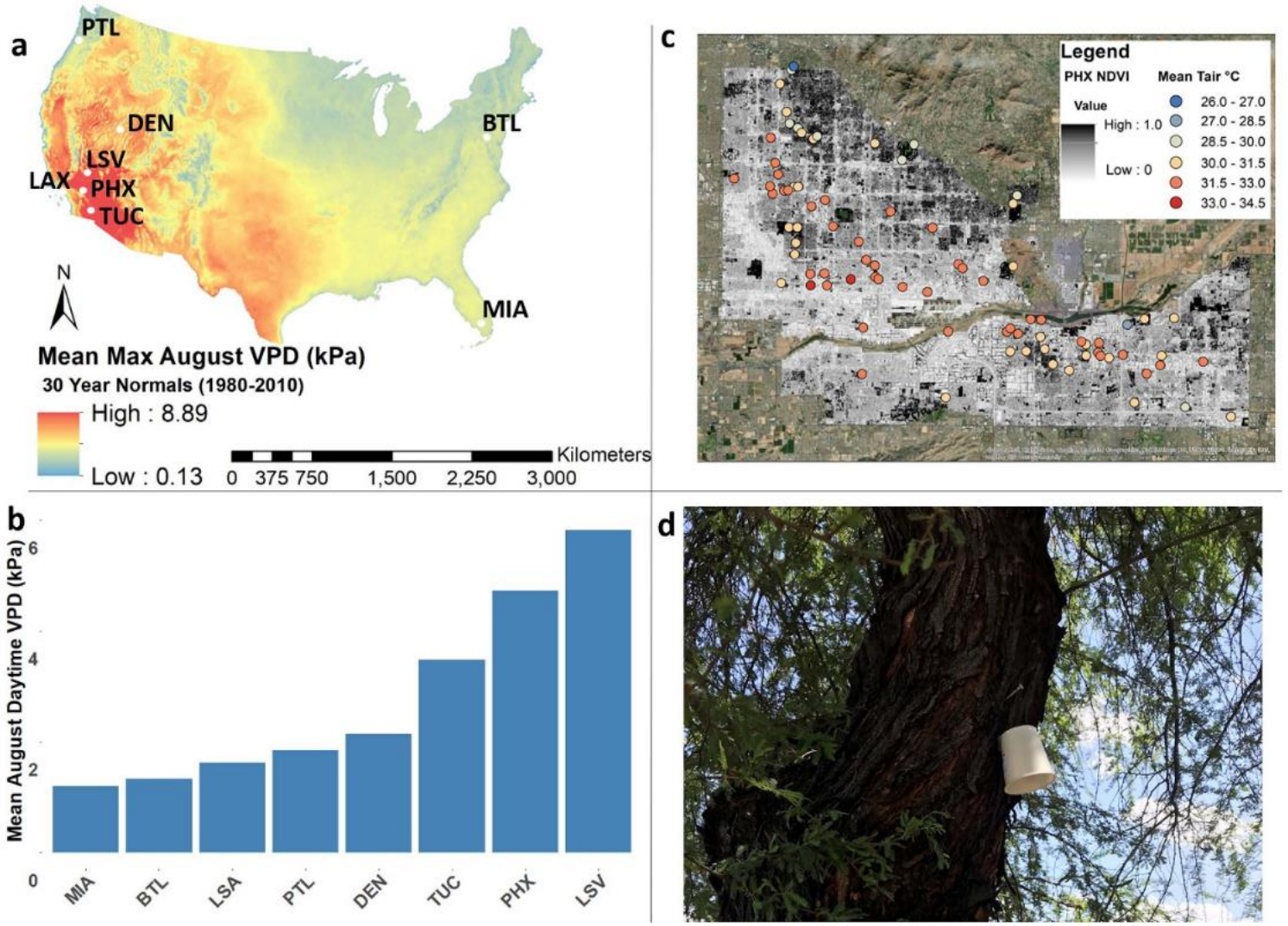

Urban Heat Research: The Future

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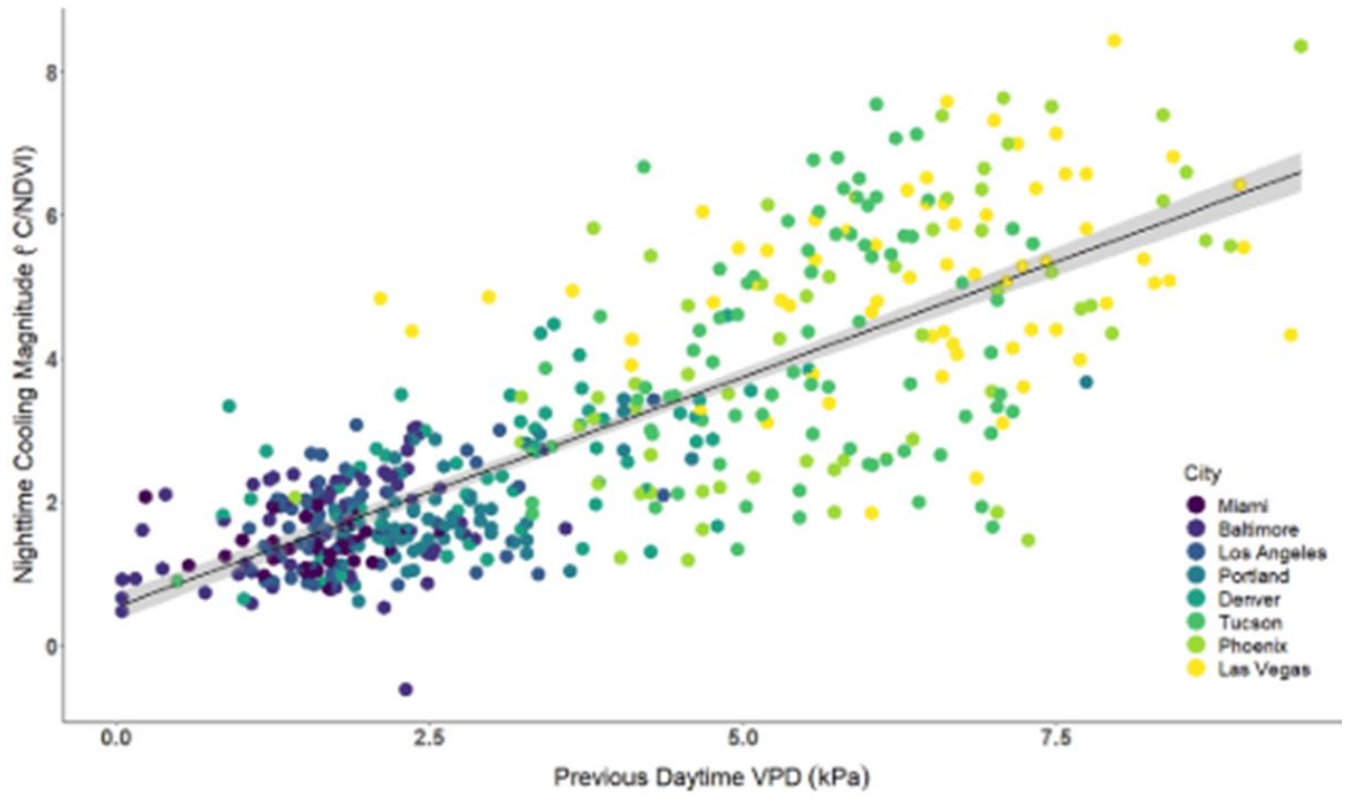

Urban Heat Research: The Future – Enter DRCOG

- What is lacking?
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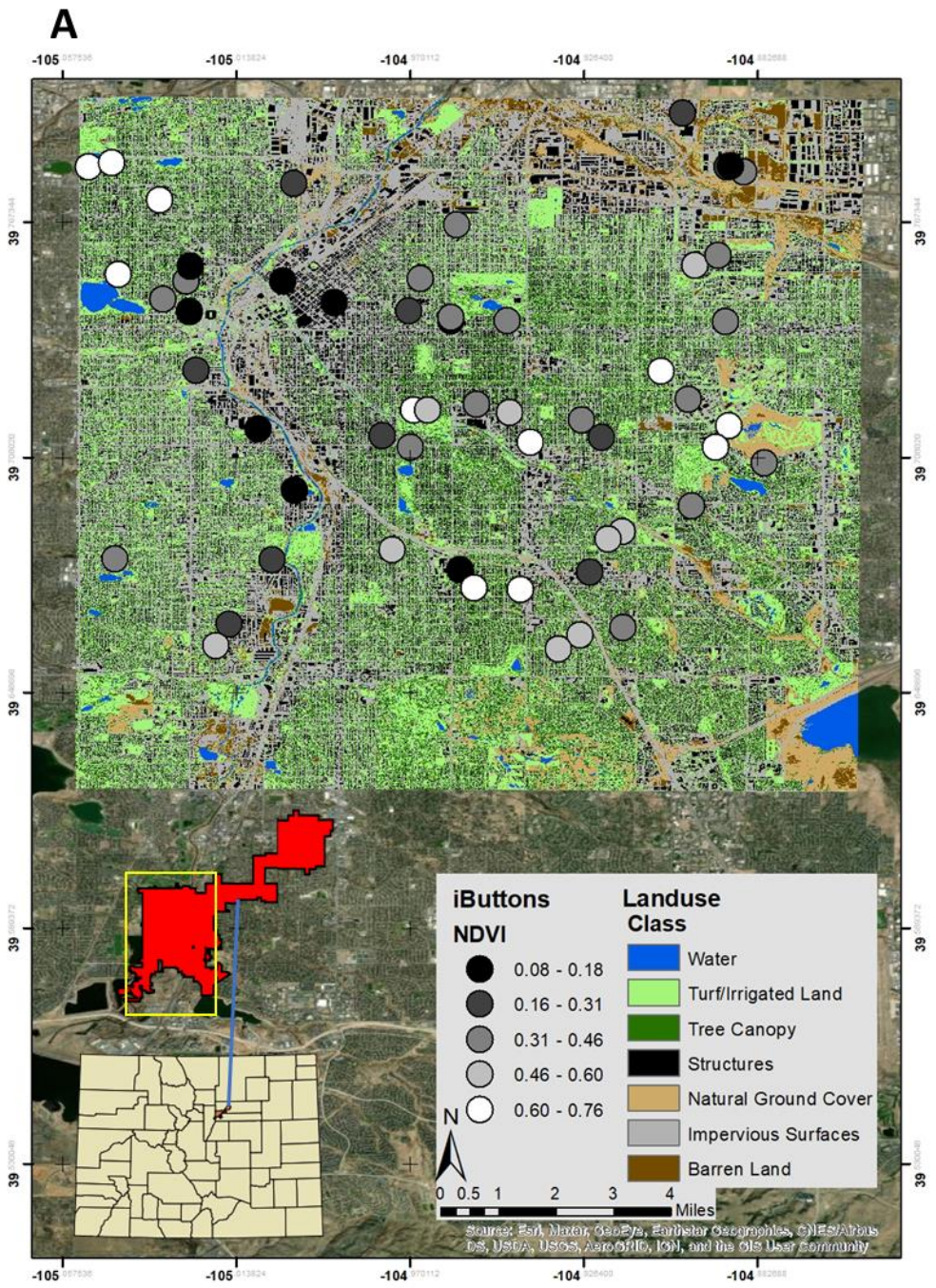
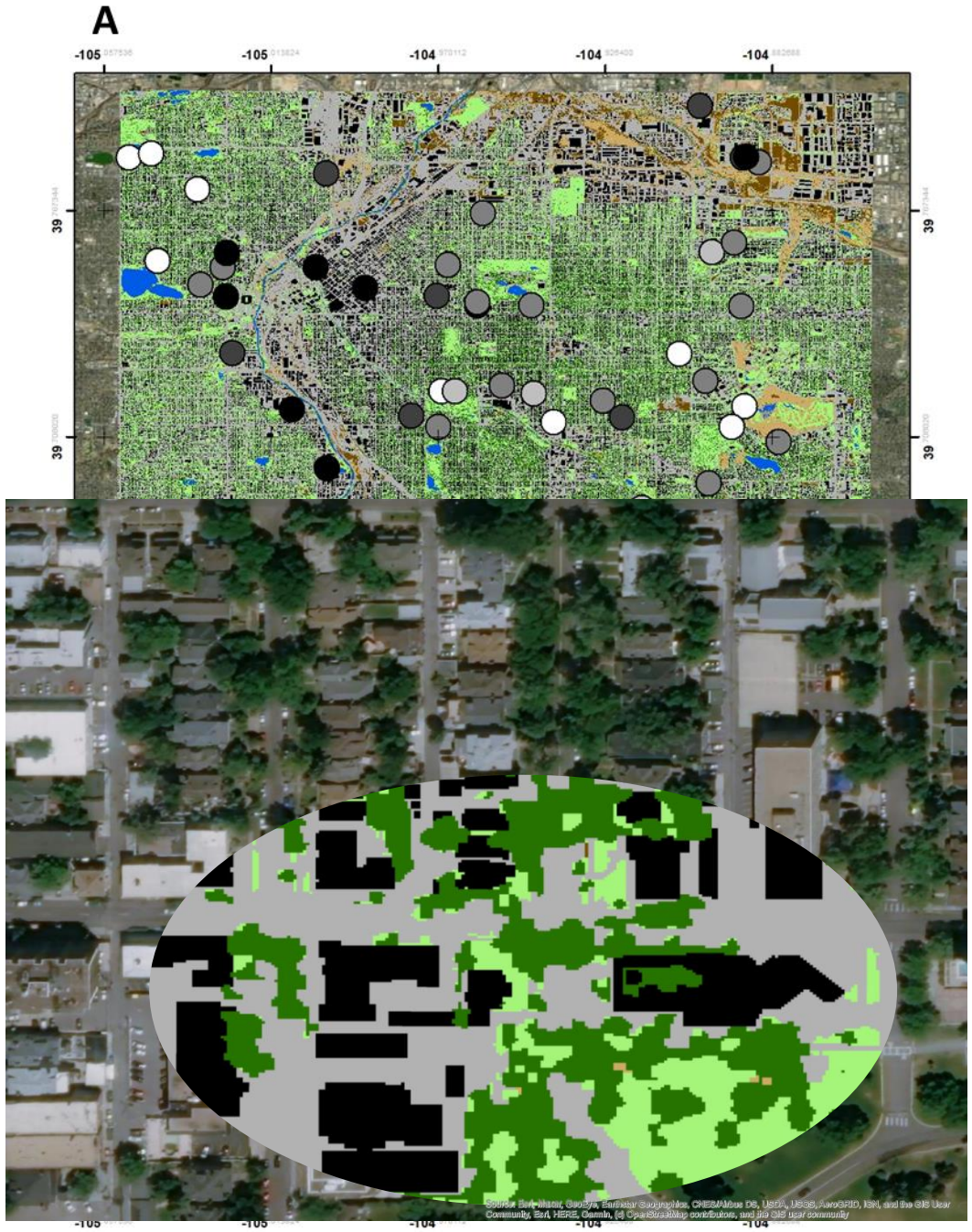


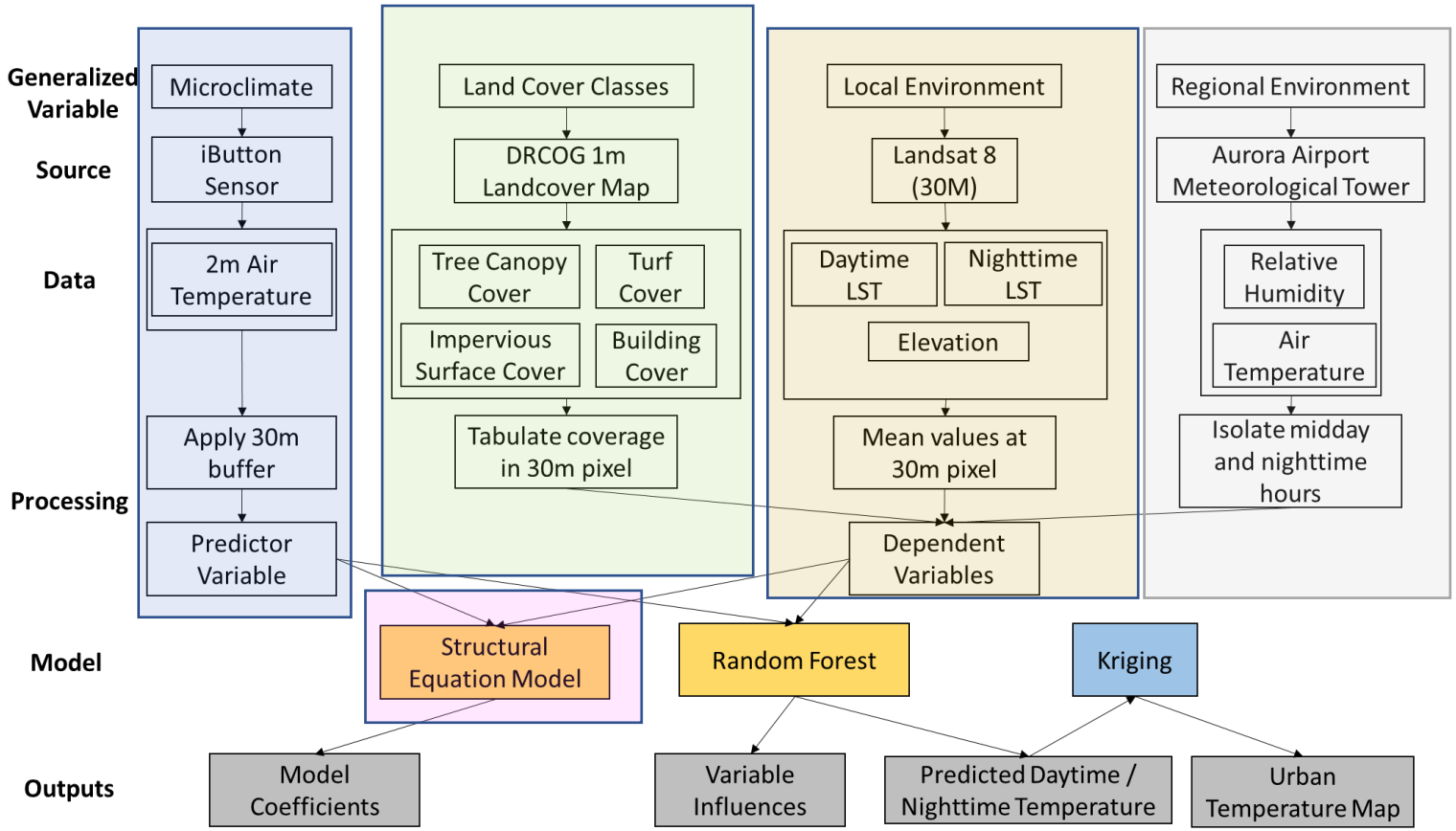
Modelling Urban Land Cover Drivers of Intra-urban Heat With Hi-Res Data

- Hi-resolution land cover combined with microclimate sensors can answer the “**how**”, “**when**”, “**where**”, and “**what**” of extreme urban air temperatures



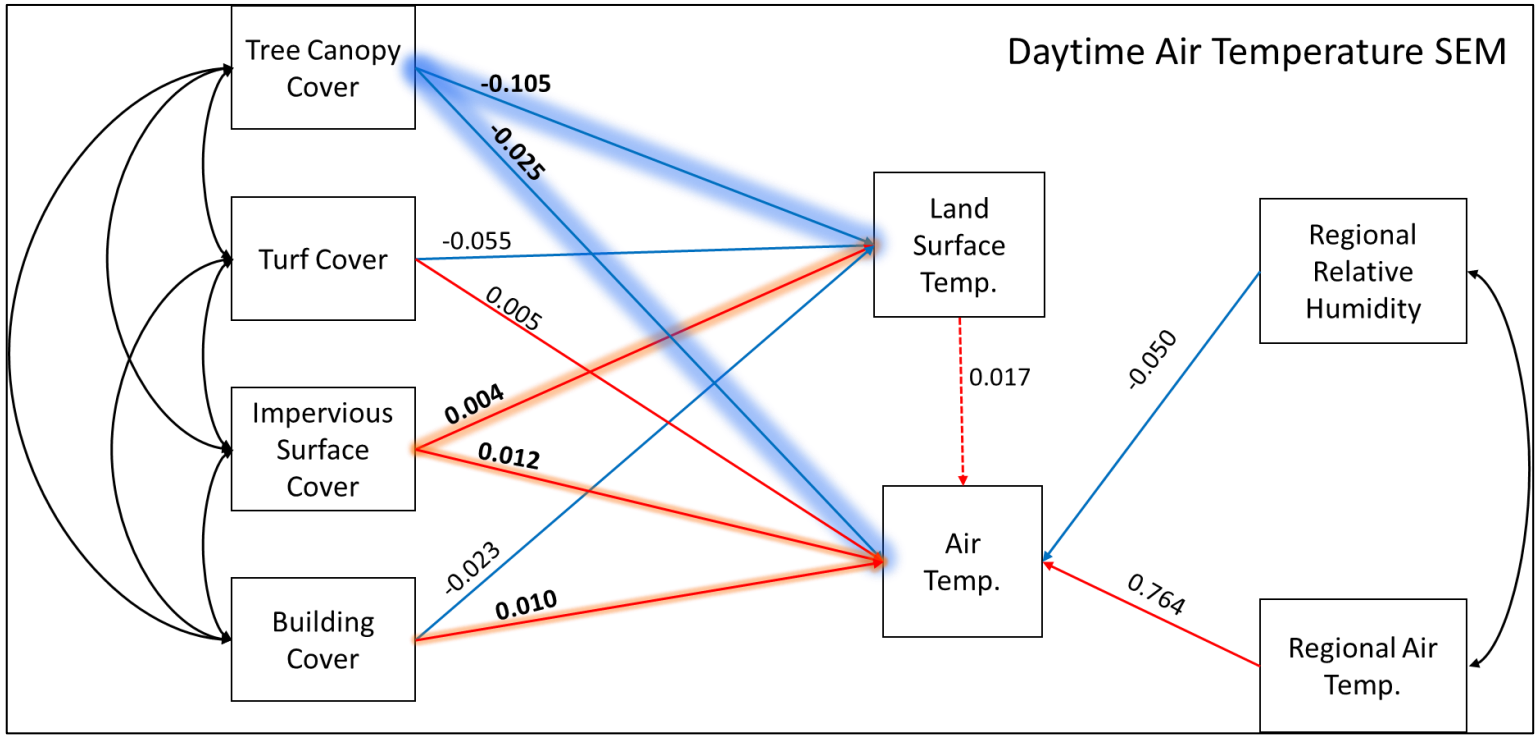
Modelling Urban Land Cover Drivers of Intra-urban Heat With Hi-Res Data

- **How** does urban land cover effect air and surface temp. and **when** are those effects the strongest?
  - Relate air temp. from the Denver sensor deployment, satellite derived land surface temperature, regional day and night climates, with hi-resolution DRCOG landcover data through a model which considers related variables



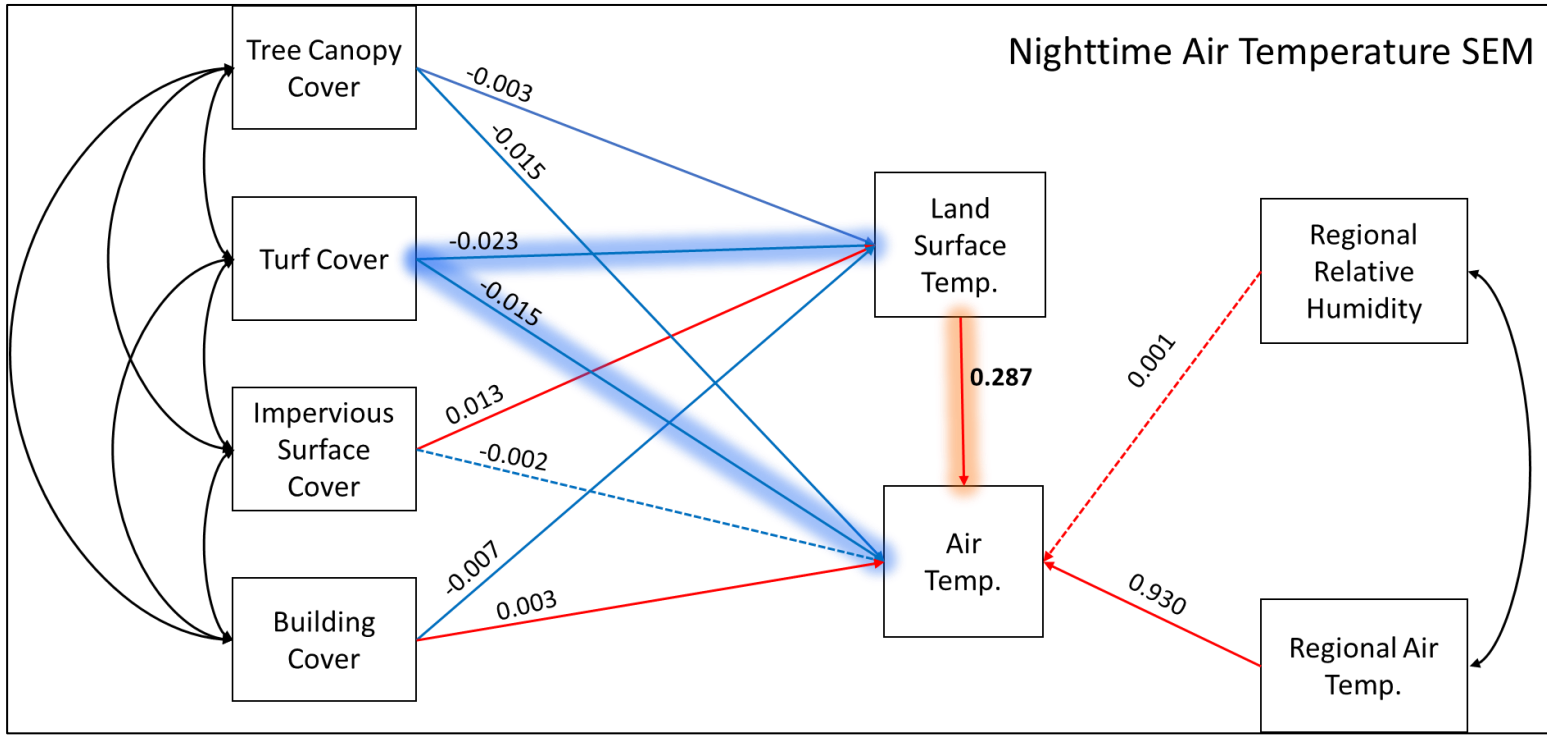
Modelling Urban Land Cover Drivers of Intra-urban Heat With Hi-Res Data

- How does urban land cover effect air and surface temp. and when are those effects the strongest?
  - Tree cover significantly reduces daytime surface and air temp. more than impervious surfaces and buildings increase temp.
  - Land surface temperature has a negligible effect on daytime air temperature



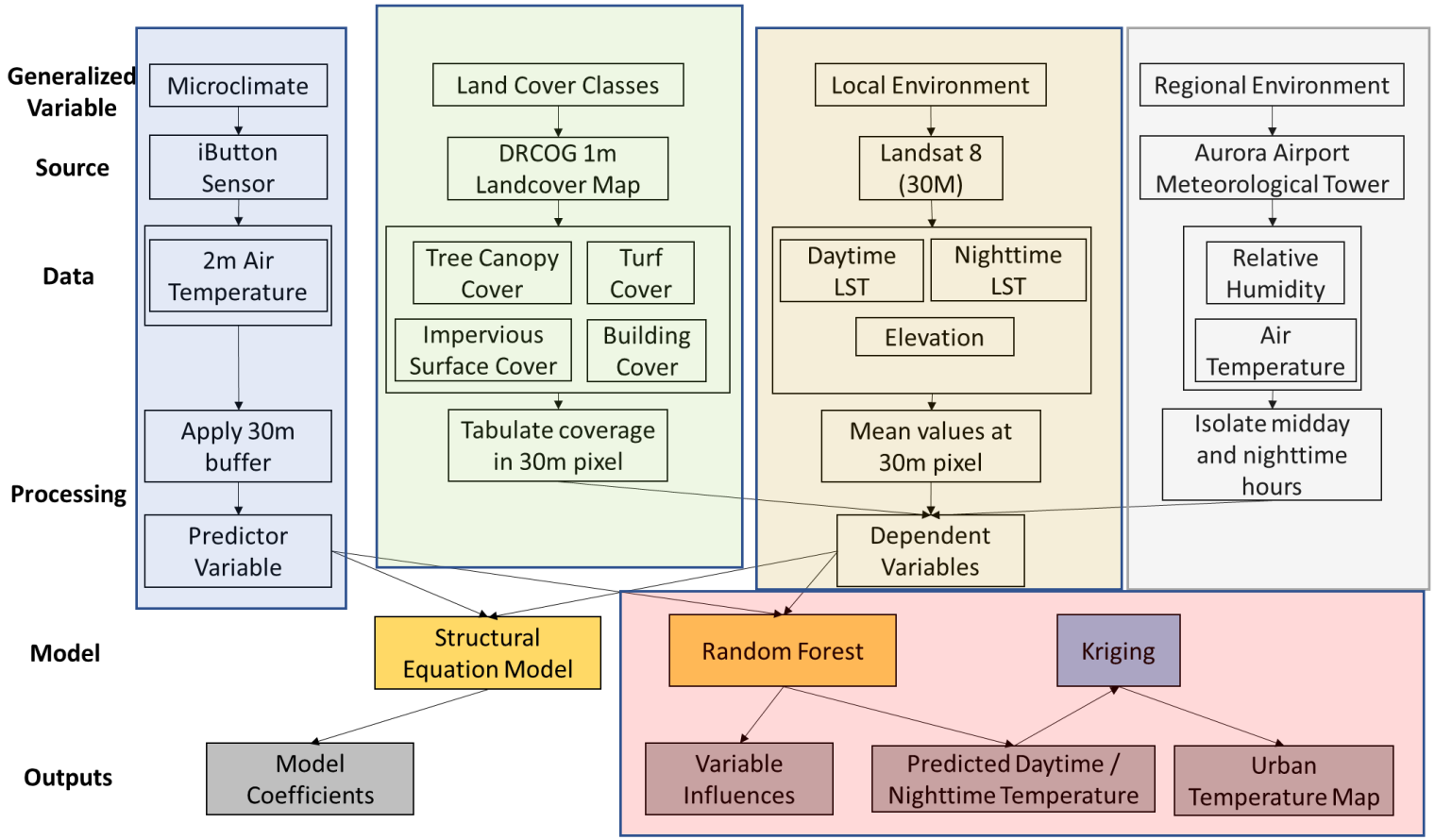
Modelling Urban Land Cover Drivers of Intra-urban Heat With Hi-Res Data

- **How** does urban land cover effect air and surface temp. and **when** are those effects the strongest?
  - Turf reduces nighttime temp. more than tree canopy
  - Land surface temperature is a major driver of nighttime air temperature



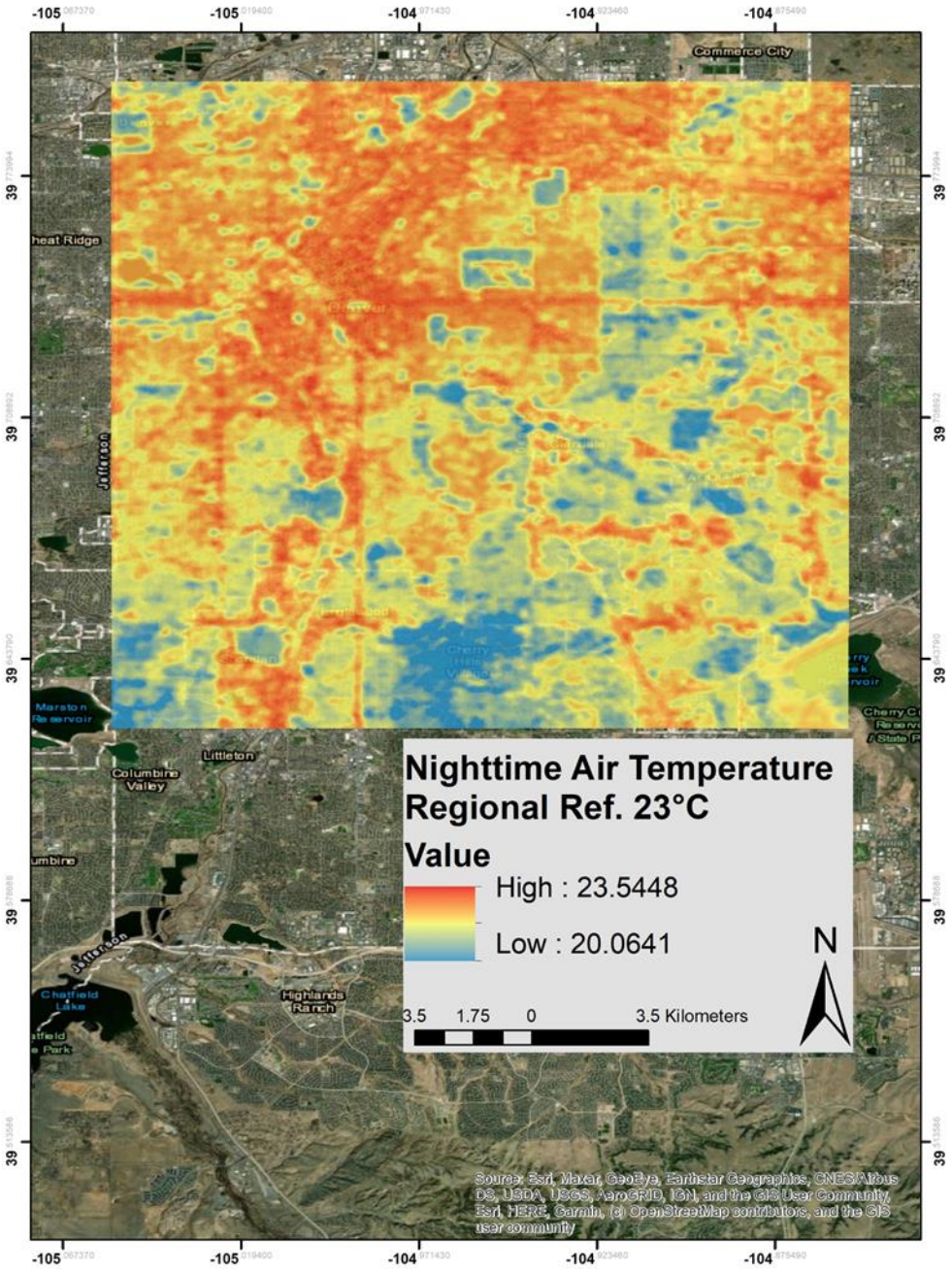
Modelling Urban Land Cover Drivers of Intra-urban Heat With Hi-Res Data

- **Where** are the hottest and coolest areas of an urban area?
  - Use the same parameters as before, now run through a model to calculate relative influences and predict air temp. for the DRCOG mapped area



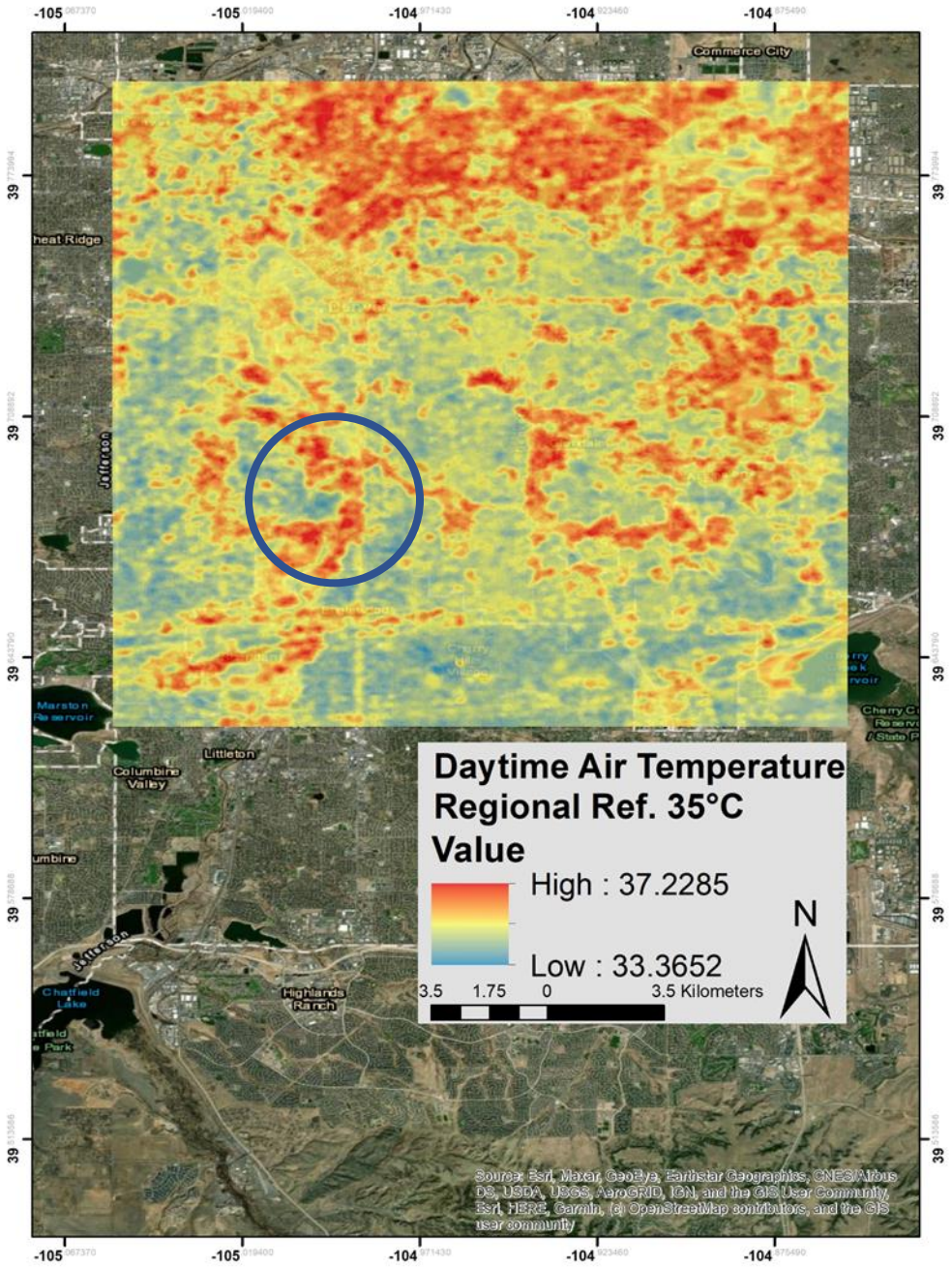
Modelling Urban Land Cover Drivers of Intra-urban Heat With Hi-Res Data

- **Where** are the hottest and coolest areas of an urban area?
  - ~ 3.5 ˚C (6.3 ˚ F) difference across the urban core
  - Air temperature reduction is greatest in areas of high turf concentration



Modelling Urban Land Cover Drivers of Intra-urban Heat With Hi-Res Data

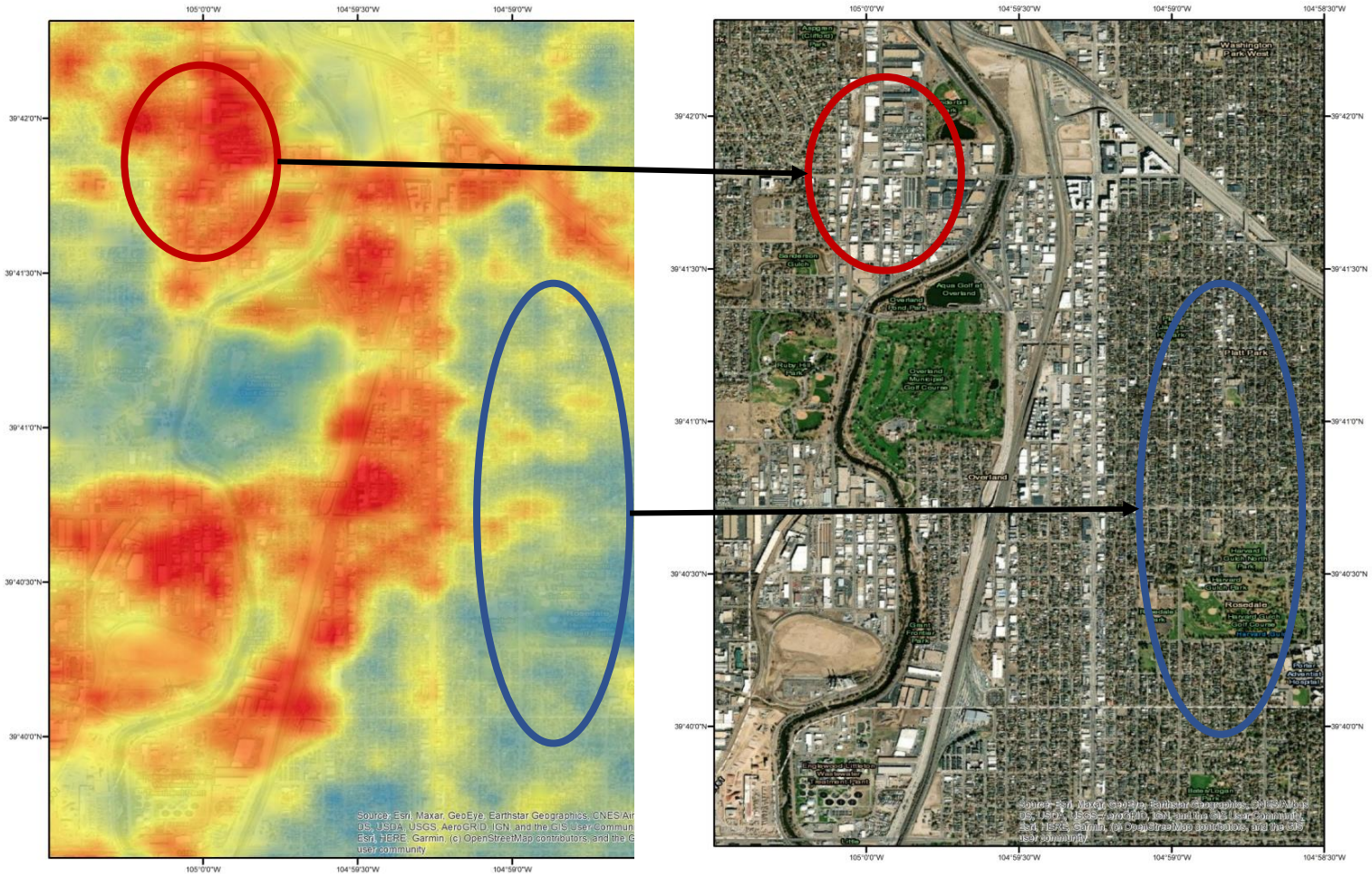
- **Where** are the hottest and coolest areas of an urban area during a heat-wave?
  - ~ 5 ˚C (9 ˚ F) difference across the urban core
  - Areas of extreme heat during daytime heatwaves are primarily industrial
  - Residential areas remain cooler than the reference temp.



Modelling Urban Land Cover Drivers of Intra-urban Heat With Hi-Res Data

- **Where** are the hottest and coolest areas of an urban area?
  - Residential areas and greenspaces stay cooler in the daytime. Commercial and industrial areas become “hot-spots”

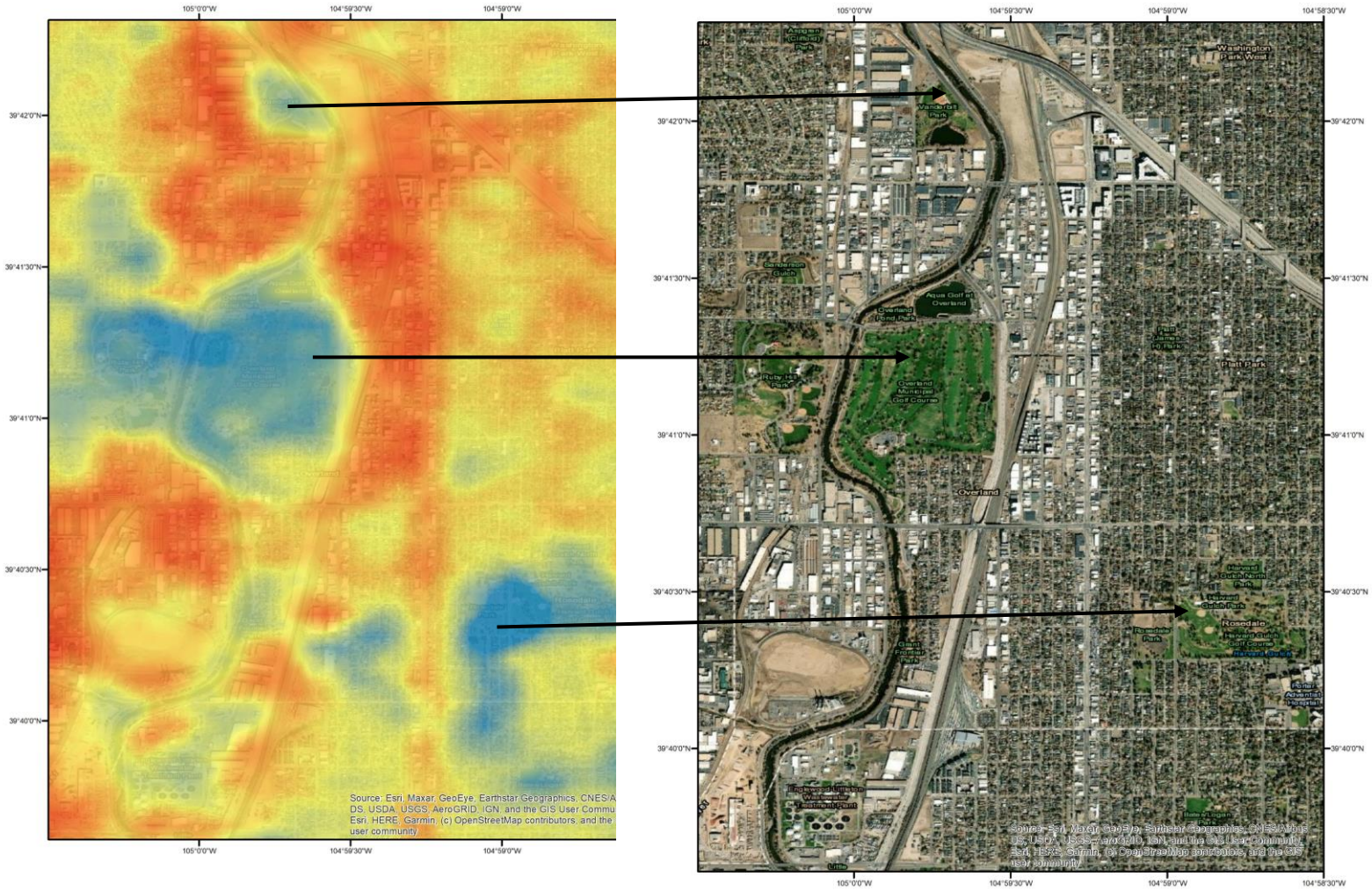
Daytime



Modelling Urban Land Cover Drivers of Intra-urban Heat With Hi-Res Data

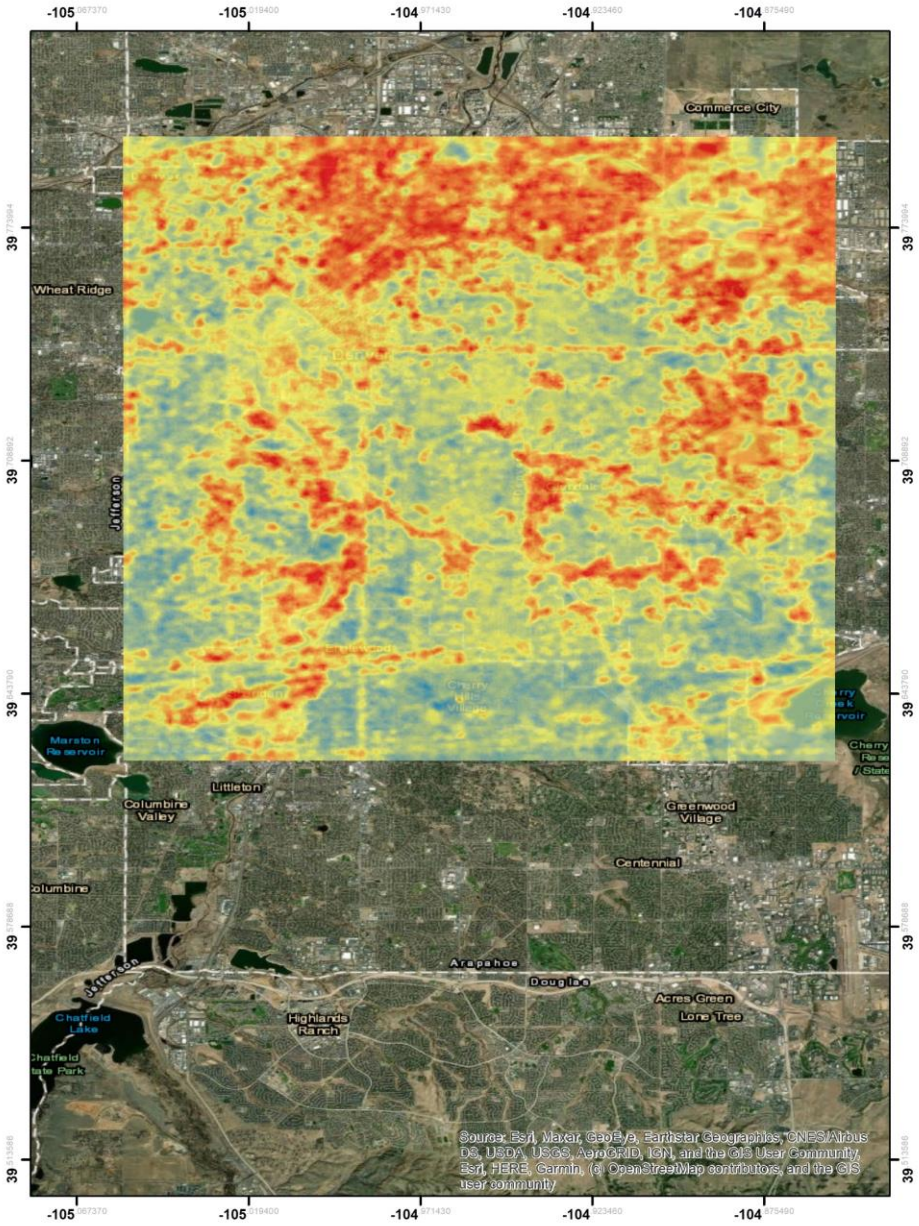
- **Where** are the hottest and coolest areas of an urban area?
  - Residential areas are slightly cooler, but the largest “cool islands” are parks and greenspaces

Nighttime



Modelling Urban Land Cover Drivers of Intra-urban Heat With Hi-Res Data

- **What** more can be done with this data?
  - Analyzing how extreme heat effects different socio-economic groups
  - Make estimates of increases or decreases in urban heat when replacing landcover types
  - Future climate modelling for the Front Range



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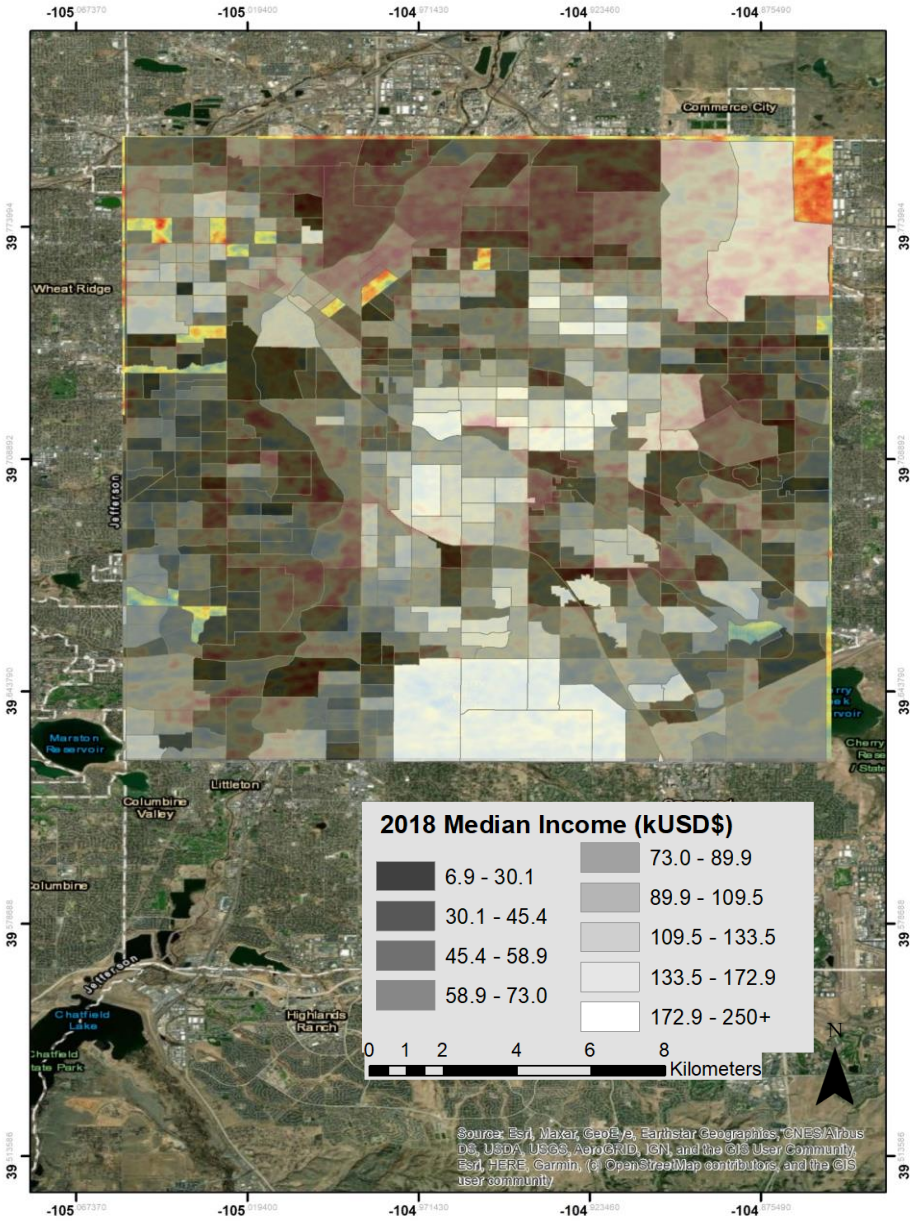

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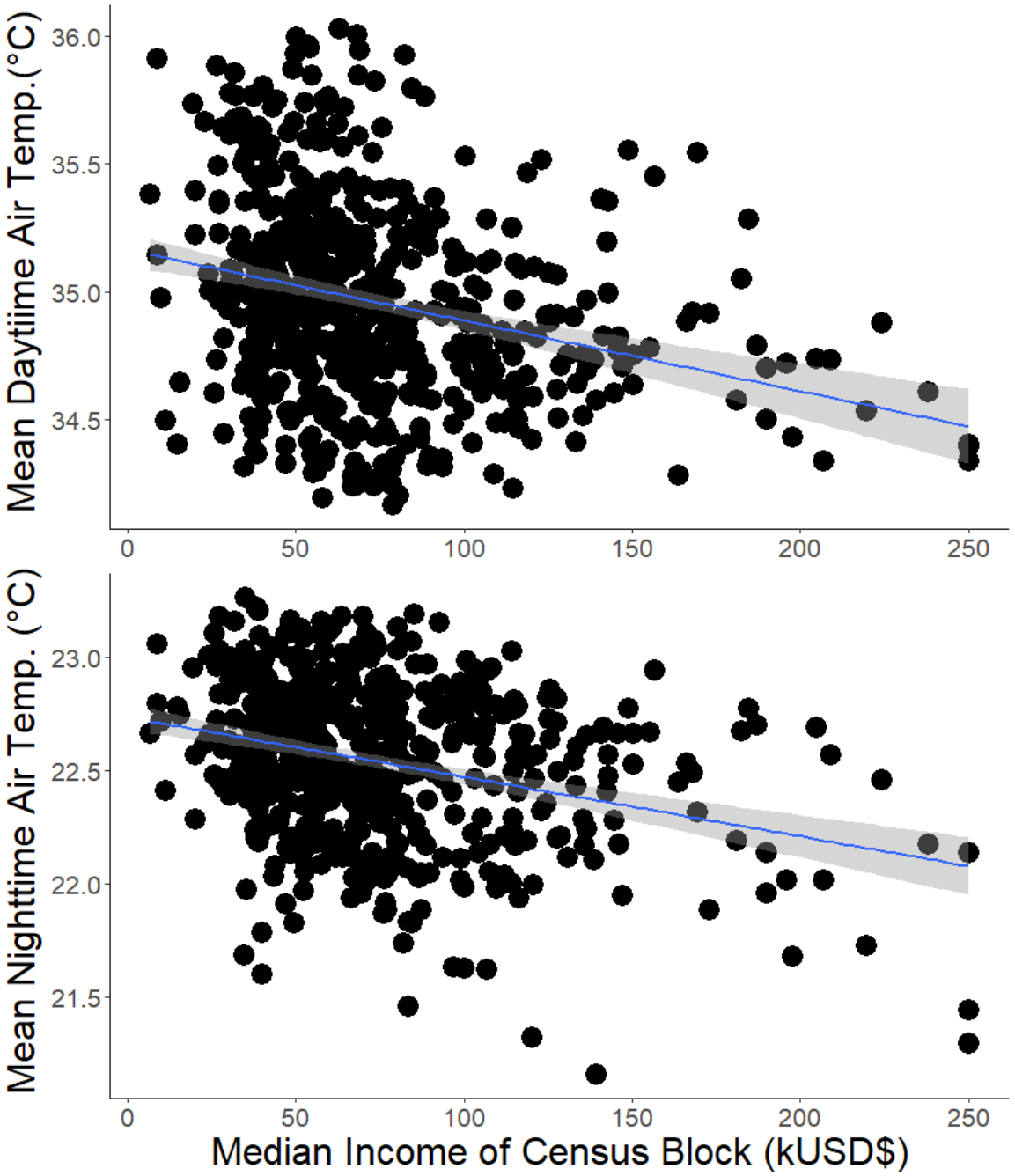

Further Engagements Between Research and Stakeholders

- **How** does DRCOG envision future use of the hi-res data, and the involvement of regional researchers?
  - Models of different services derived from landcover? (rainwater infiltration, air pollution mitigation, access to greenspaces…)
  - New applications for future urban planning?

Thank you!

Contact for Dr. Peter Ibsen

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