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

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Urban Heat: A Cause for Concern
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

Denver weather: Heat wave continues as triple-digit temperatures break records
Denver has topped 100 degrees for the third day in a row

Urban Heat: The Urban Heat Island

- The central urban core is significantly warmer than the outer rural areas.
- Daytime urban surface temperatures are higher than rural areas.
- Nighttime urban surface and air temperatures are higher than rural areas.
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
Rural and Urban differ in the storage and release of heat energy

\[ Q^* = Q_E + Q_S + Q_H \]
\[ Q_H = \text{"Sensible Heat-Flux"} \]
- Heat radiating from surfaces
- More impervious surfaces = greater sensible heat

Urban Heat: The Urban Heat Island Explained!

• 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 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:
  • 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

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


Study
Barradas 1991 AP
Barradas 1991 FV
Barradas 1991 LGU
Barradas 1991 MP
Barradas 1991 TP
Ca et al. 1998
Chang et al. 2007 61 parks
Chen & Wong 2006 BBNP
Chen & Wong 2006 CWP
Jansson et al. 2007
Jauregui 1991
Jonsson 2004 Garden lush veg
Jonsson 2004 Garden no veg
Jonsson 2004 Garden sparse veg
Jonsson 2004 Park
Kjelgren & Clark 1992
Lahme & Bruse 2003
Mayer & Hoppe 1987
Potchter et al. 2006 A
Potchter et al. 2006 B
Potchter et al. 2006 C
Shahgedanova et al. 1997
Thorsson et al. 2007
Watkins 2002 BM
Watkins 2002 PH
Zouila et al. 2009

Summary

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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  • Comparison across cities
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Urban Heat Research: The Future – Enter DRCOG

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

![Nighttime Air Temperature Regional Ref. 23°C Value](image)
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.
• 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”
• 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
• 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
Modelling Urban Land Cover Drivers of Intra-urban Heat With Hi-Res Data

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• 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
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!

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