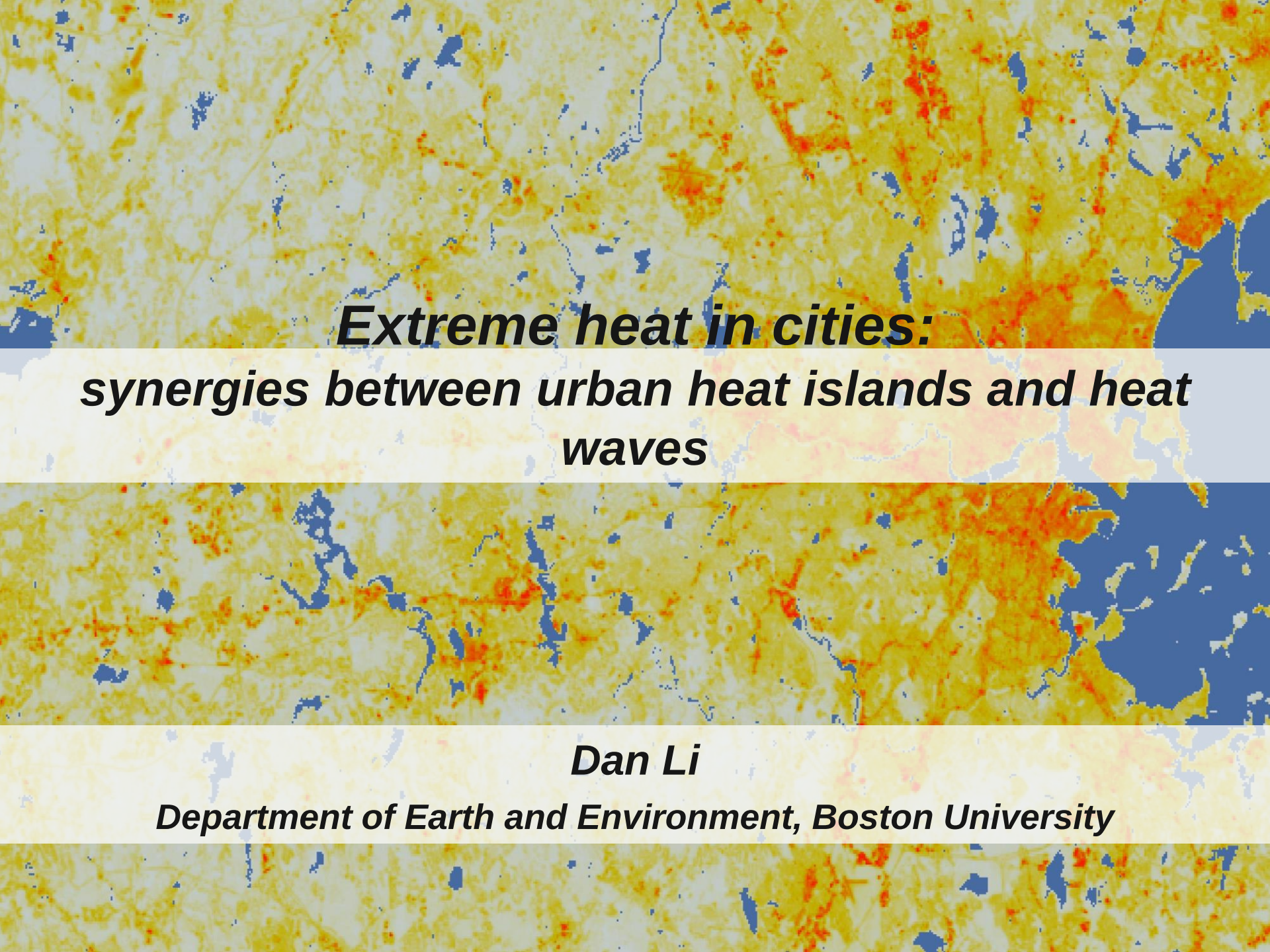

Extreme heat in cities: synergies between urban heat islands and heat waves

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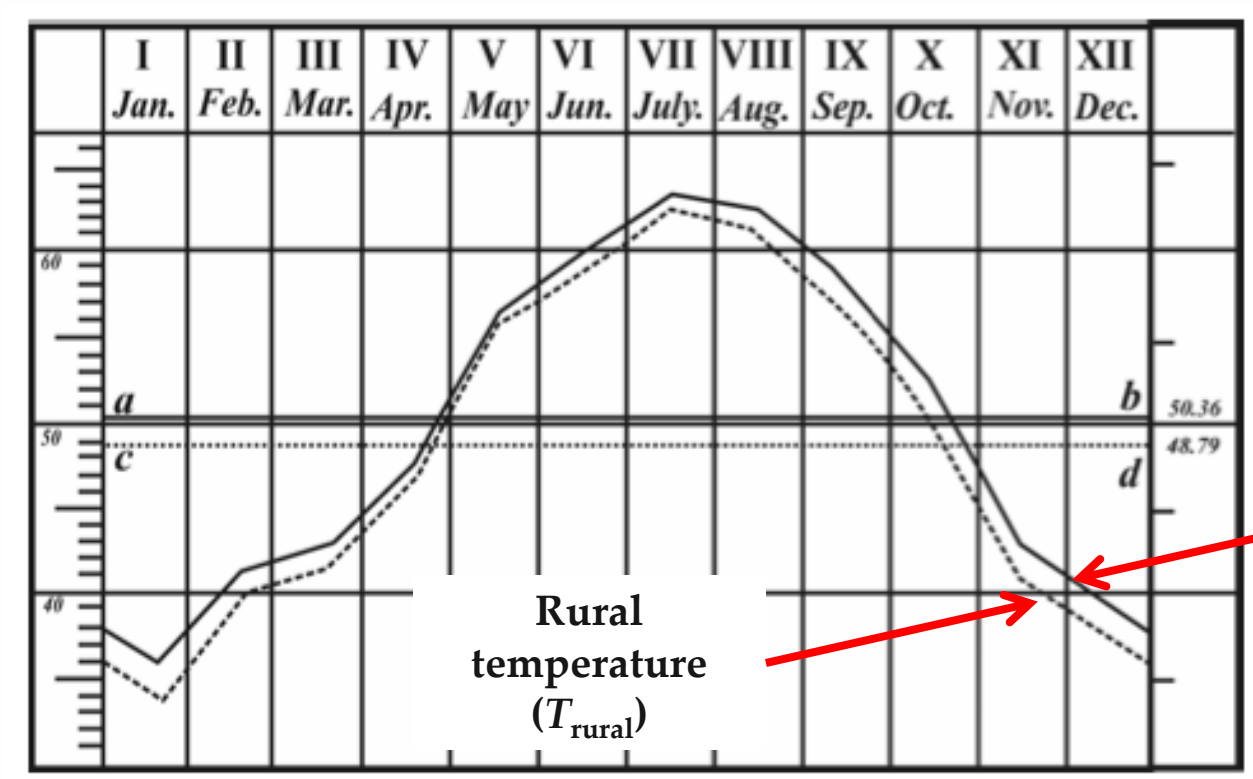
Outline

- Urban Heat Islands (UHIs) and Synergies with Heat Waves (HWs)
- Urban Climate Modeling within the Earth System Modeling (ESM) Framework
- From Simulations to Understanding

Urban Heat Island (UHI)

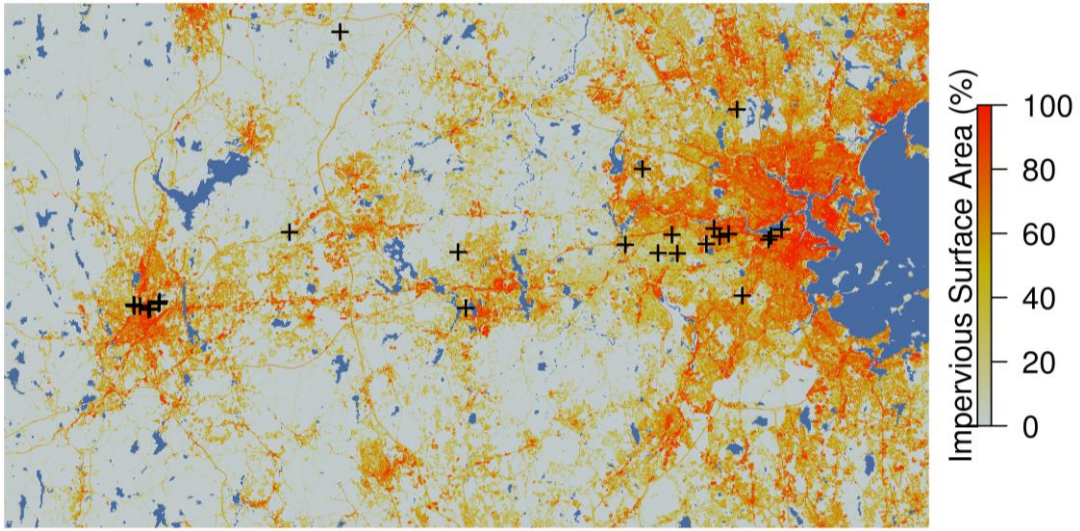
Howard (1833) The climate of London



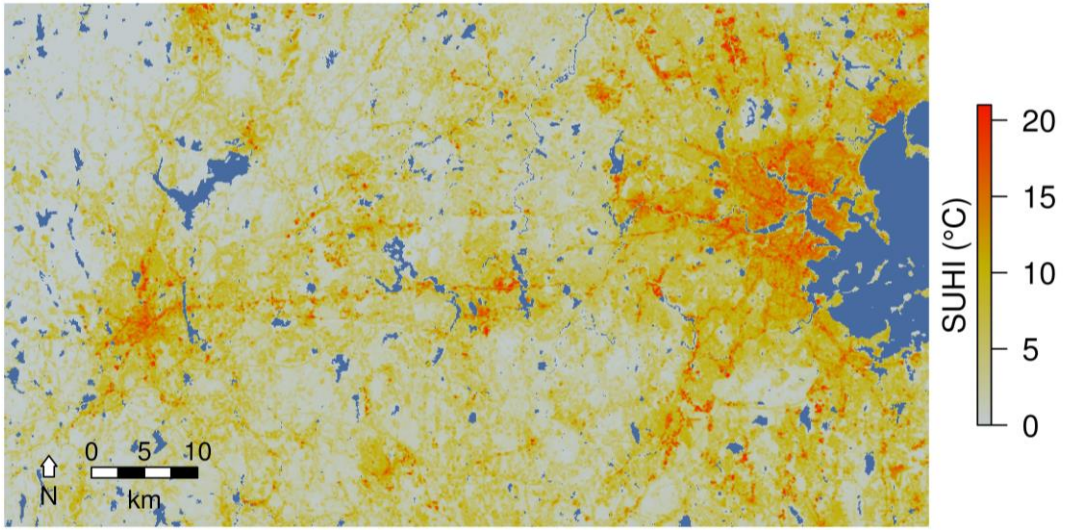
Luke Howard
1772-1864

$$UHI\ intensity = T_{urban} - T_{rural} = \Delta T$$

Surface UHI from Satellites



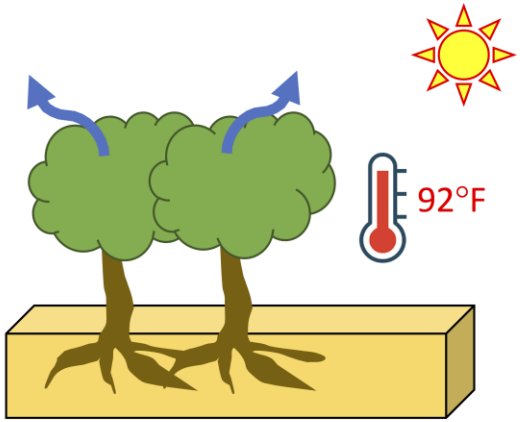
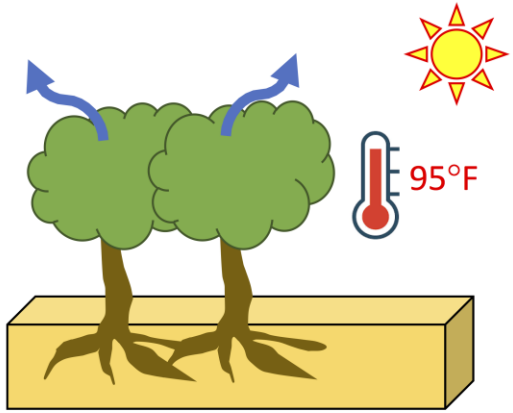
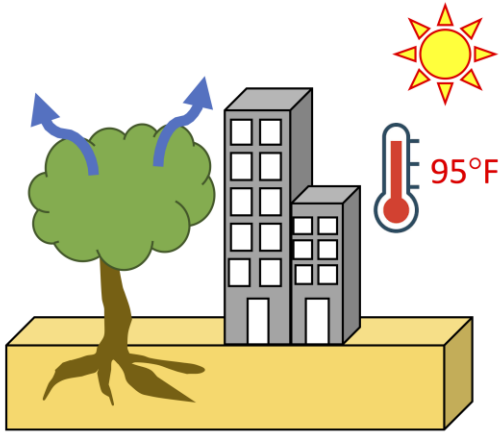
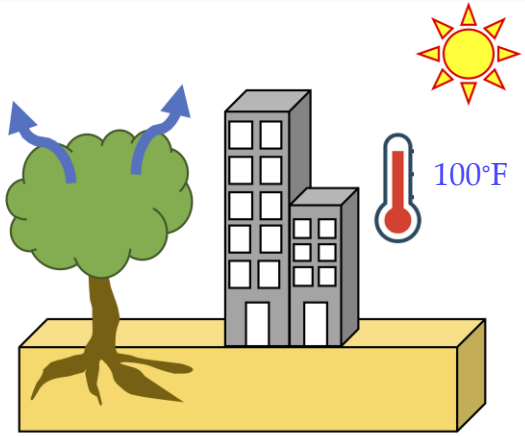
Impervious surface fraction



Summertime surface UHI

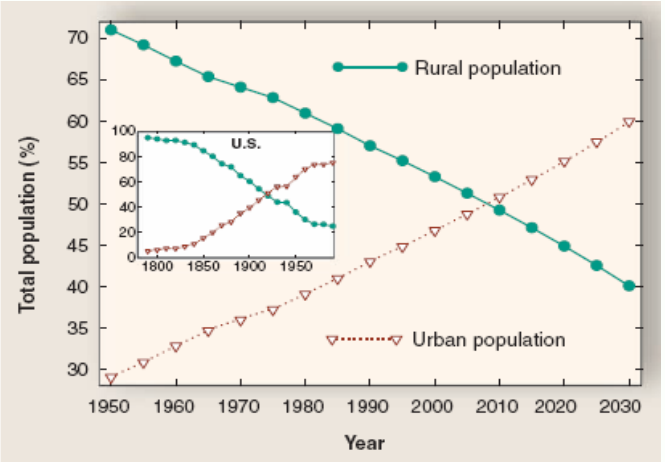
Wang et al. (2017) JAMC

Synergies between UHIs and Heat Waves (HWs)

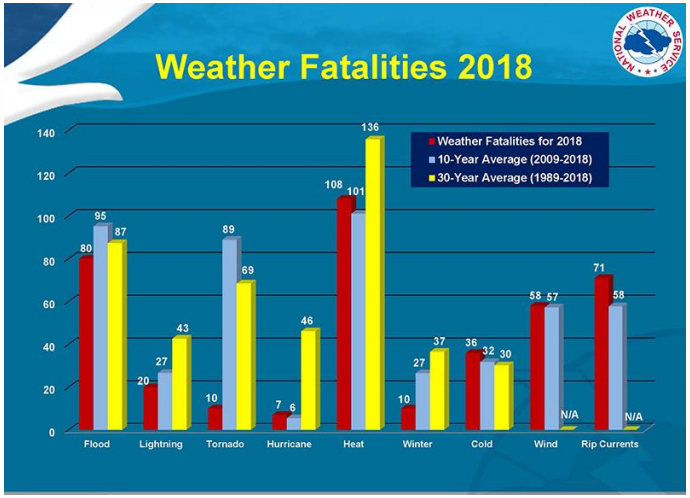
LOCATION	AVERAGE SUMMER CONDITIONS	HEAT WAVE CONDITIONS
RURAL		
URBAN		

Credit: Joy Winbourne, Sarah Garvey, Lucy Hutyra

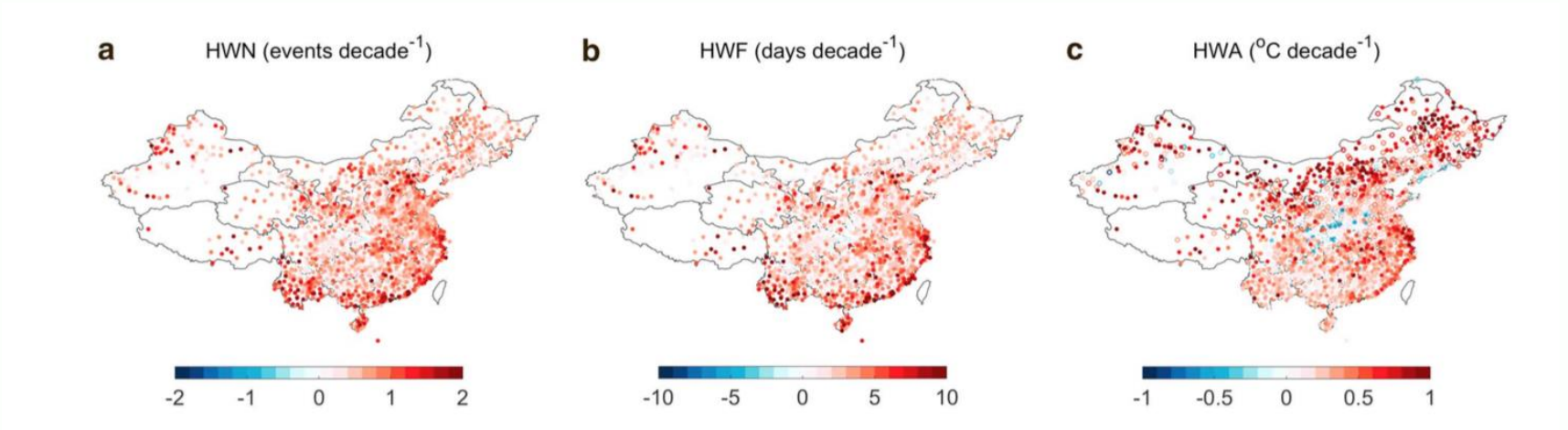
Why is this important?



Grimm et al.(2008) Science



https://www.weather.gov/hazstat/

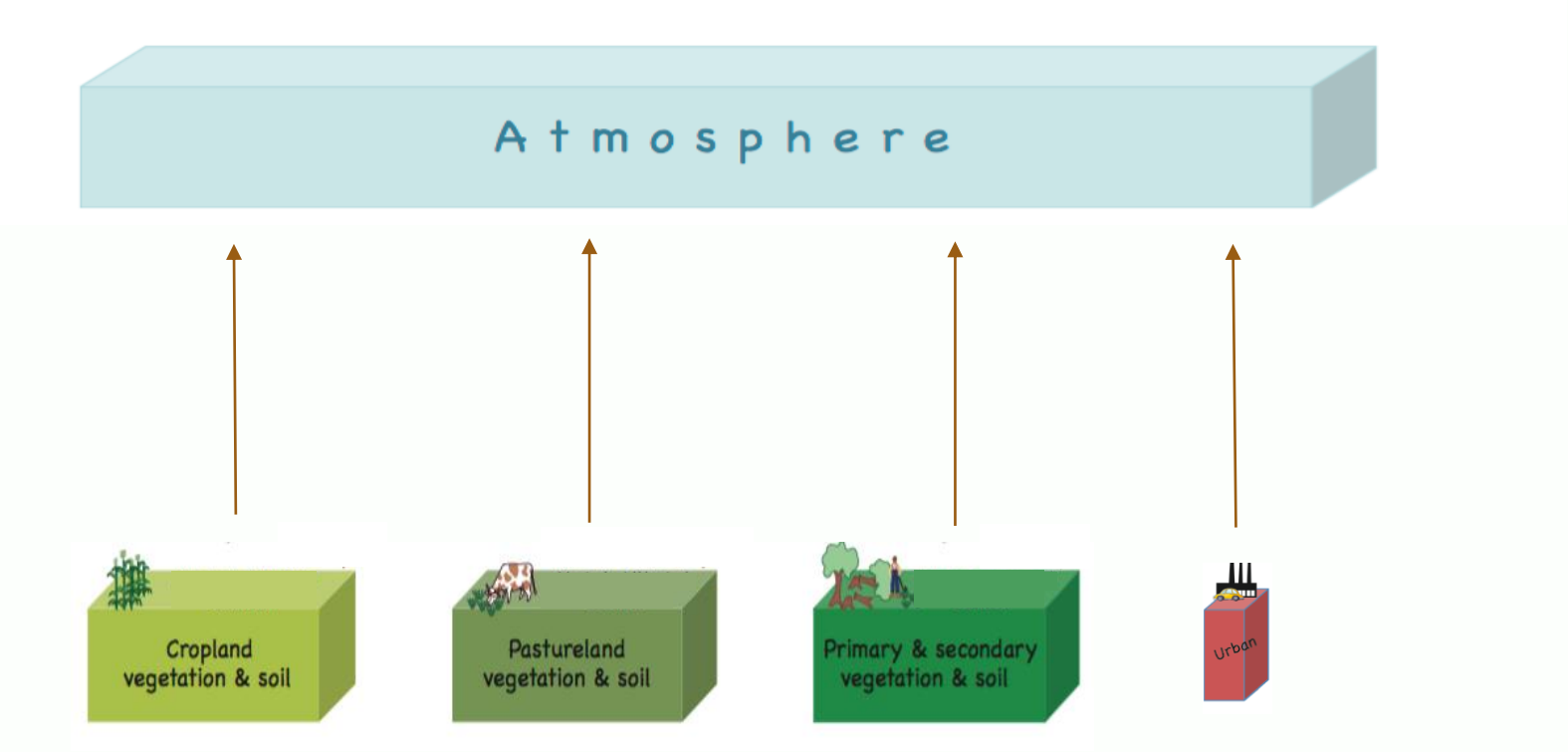


Liao et al.(2018) GRL

Synergies between UHIs and Heat Waves (HWs)

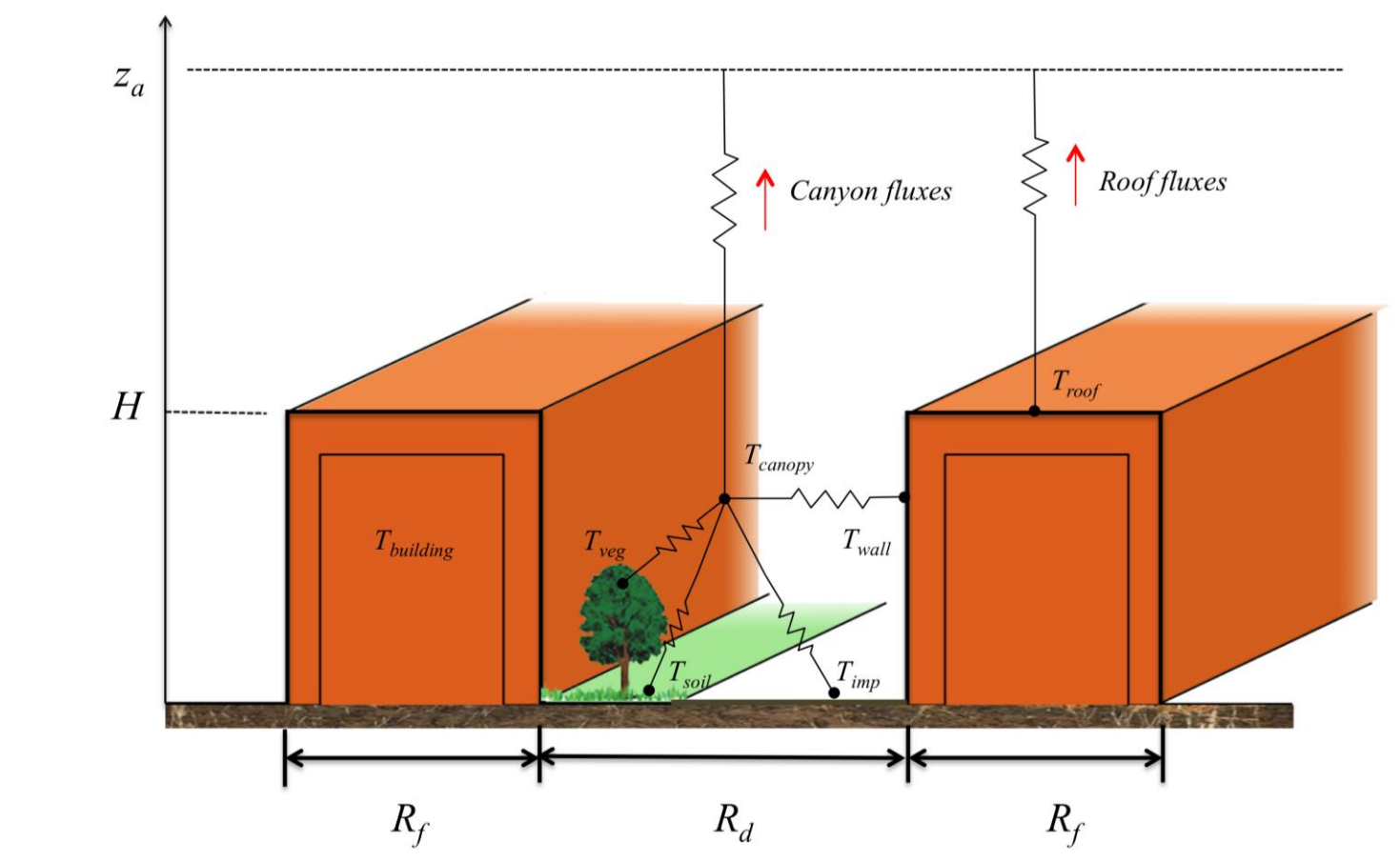
- Anthropogenic heat flux increases under HWs (Ao et al. 2019).
- Urban-rural contrast of evapotranspiration can become stronger under HWs, especially when the rural land is wet (Li and Bou-Zeid, 2013; Li et al. 2015).
- Urban-rural contrast of heat storage can become stronger under HWs (Sun et al. 2017).
- Mean wind speed and pattern change under HWs, which affect turbulent mixing and advection of heat (Li et al. 2016; Ao et al. 2019).

Urban Climate Modeling in ESMs



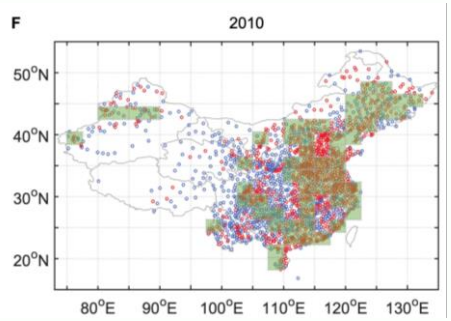
Within each grid cell, there can be multiple land cover types (often called tiles) interacting with the atmosphere, including an urban tile.

Urban Climate Modeling in ESMs

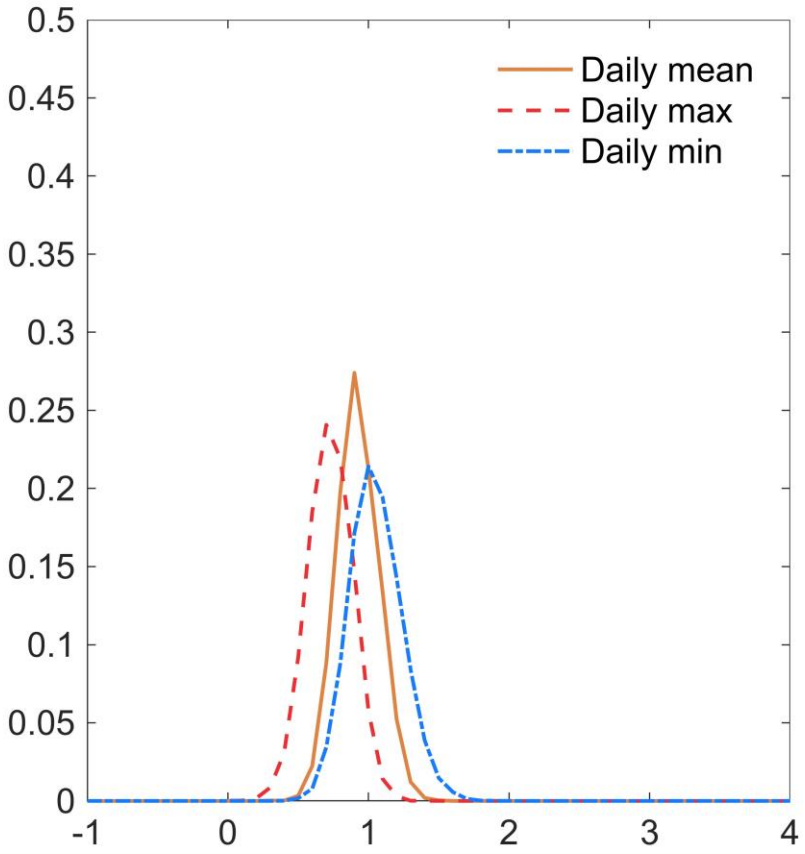


Li et al. (2016 a, b) JAMES

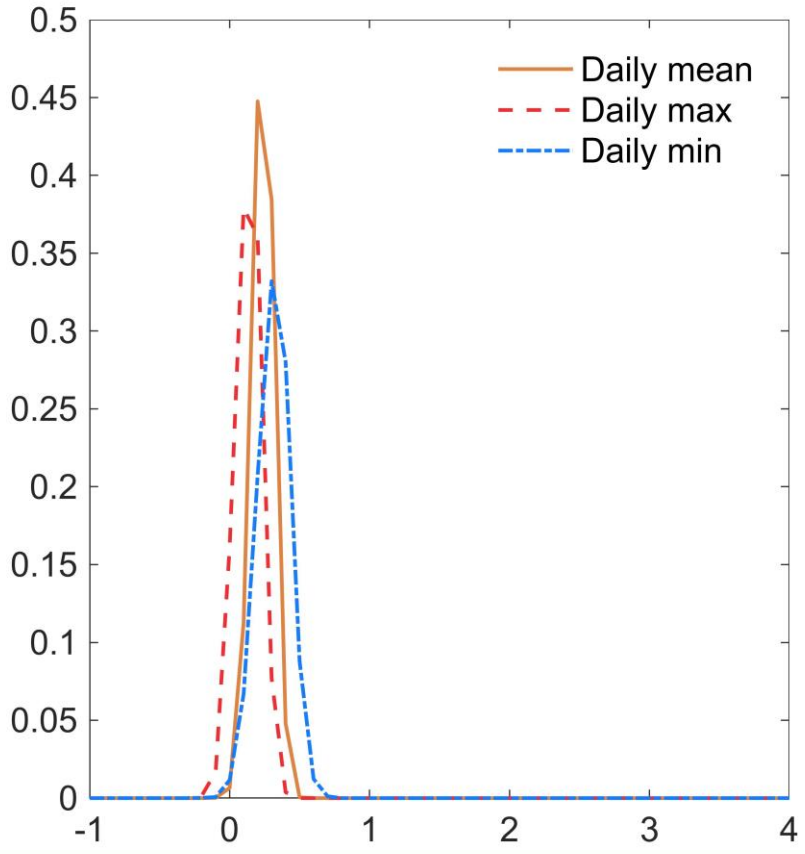
Baseline UHI climatology



Observation



Model

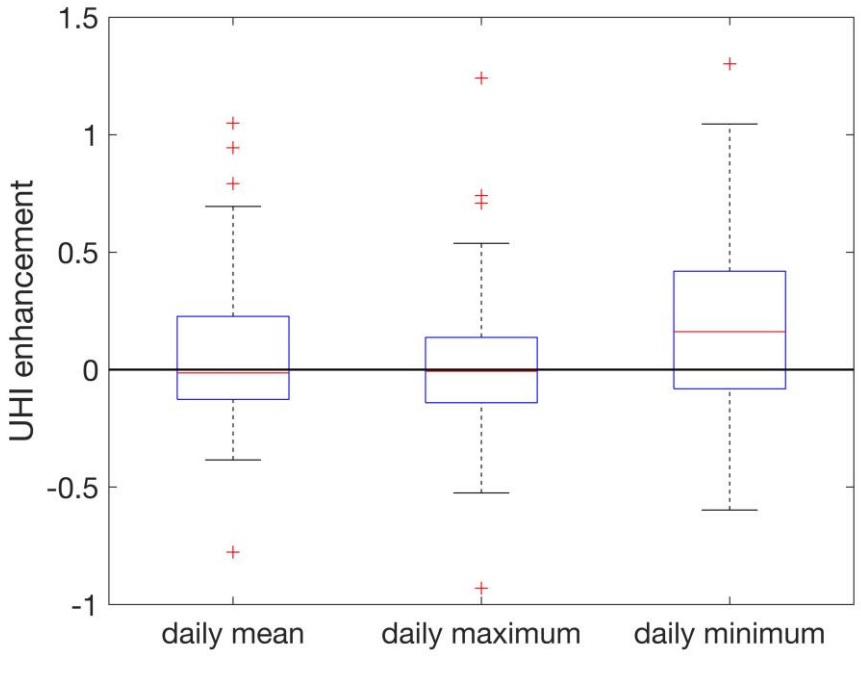


Challenges: baseline UHI climatology

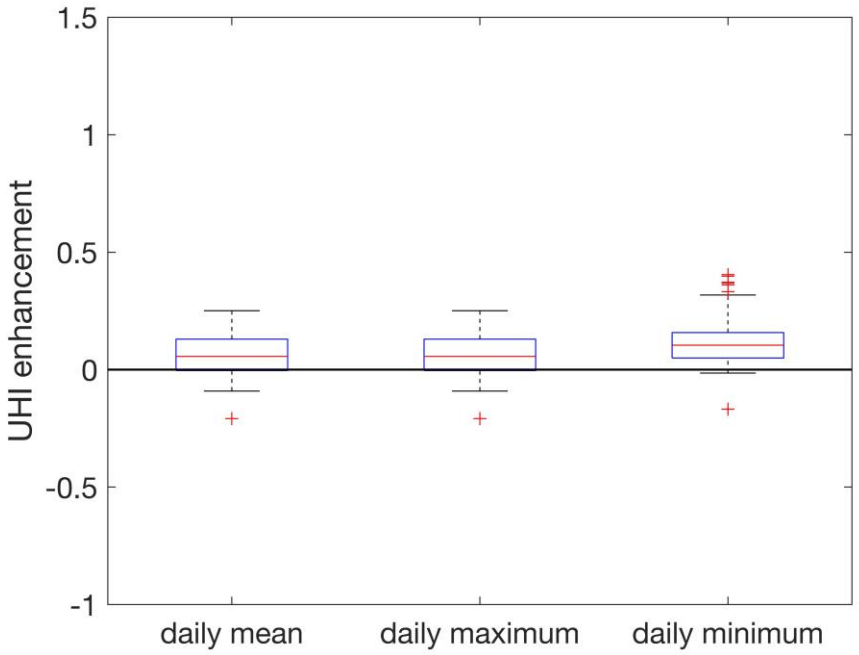
- Model inputs: urban morphology and materials
- Physical parameterizations: vegetation and hydrological processes, turbulent mixing
- Missing processes: anthropogenic heat flux from traffic, anthropogenic water flux

Synergies between UHIs and HWs

Observation



Model



Challenges: synergies with HWs

- Inadequate representation of building energy consumption and thus anthropogenic heat flux.

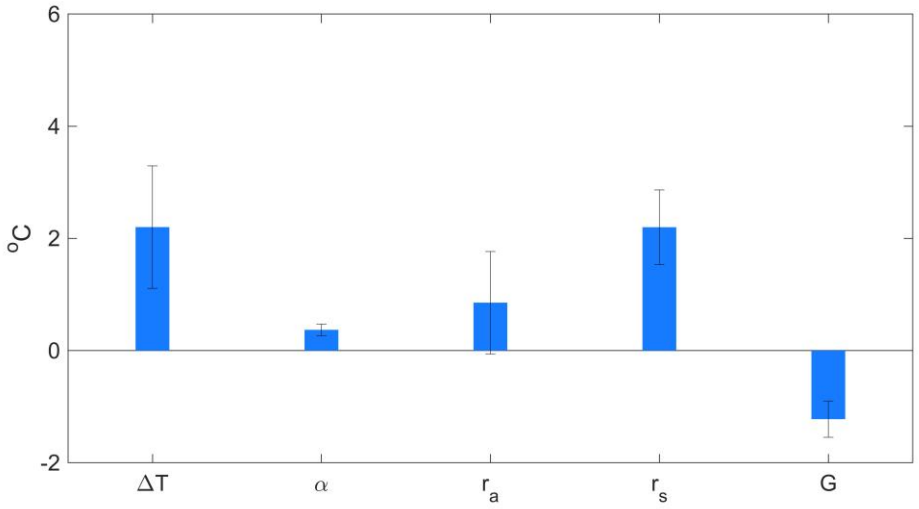
- Vegetation response to environmental changes induced by HWs (e.g., higher evaporative demand) remains debated.

- No advection between urban and other tiles within the same grid cell.

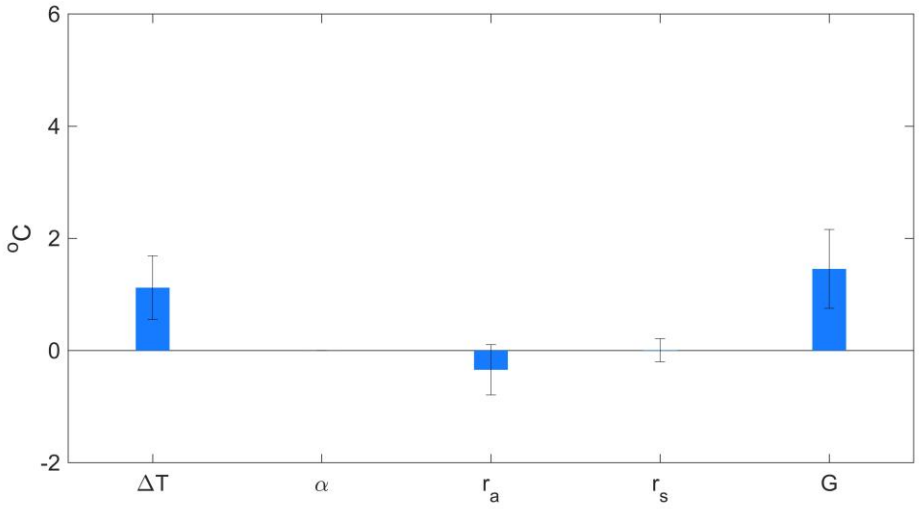
From Simulations to Understanding

- What are the biophysical contributors to the urban heat island effect?

Daytime



Nighttime



Li et al. (2019) Science Advances

How will these contributions change under HW conditions?

Summary

- There is a growing interest in understanding the synergies between urban heat islands and heat waves.

- The modeling of urban heat islands and their synergies with heat waves in global Earth System Models needs to be further improved.

- Developing an attribution method can help diagnose the key factors controlling urban heat islands and how they are altered by heat waves.

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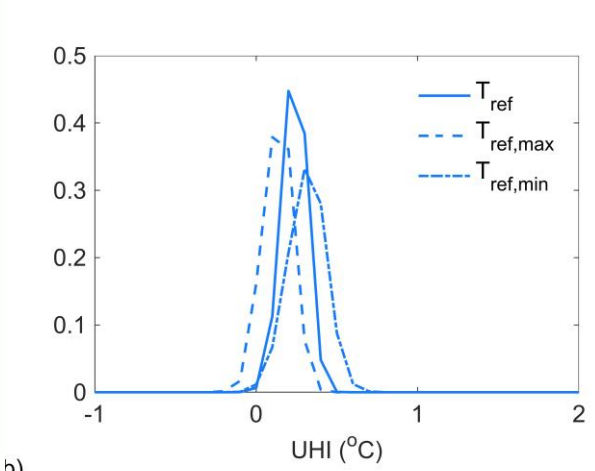
- Collaborators: Sergey Malyshev (GFDL), Elena Shevliakova (GFDL), Mark Friedl (BU), Lucy Hutyra (BU)
- Computational Resources: GFDL, BU, NCAR
- References can be found on http://sites.bu.edu/efm/
- Funding Resources:

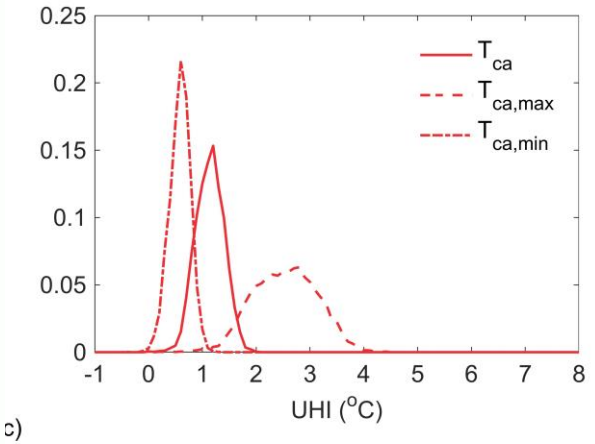
2-m air temperature

Aerodynamic surface temperature

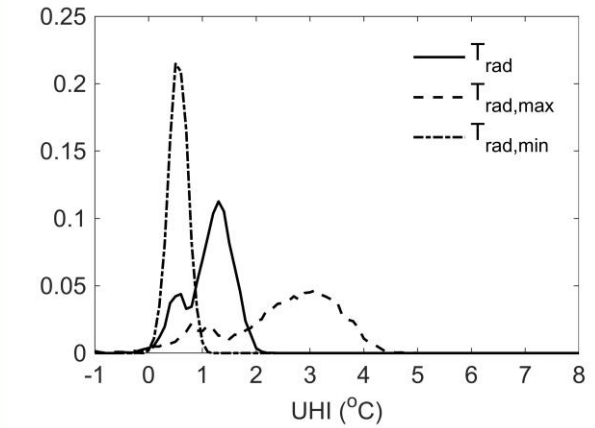
Radiative surface temperature



b)



c)



From Simulations to Understanding

- How do HWs alter the attribution?