Continental and Regional-Scale Urban Warming Signals are Detectable and Increasing with Urban Evolution: Implications and Uncertainties

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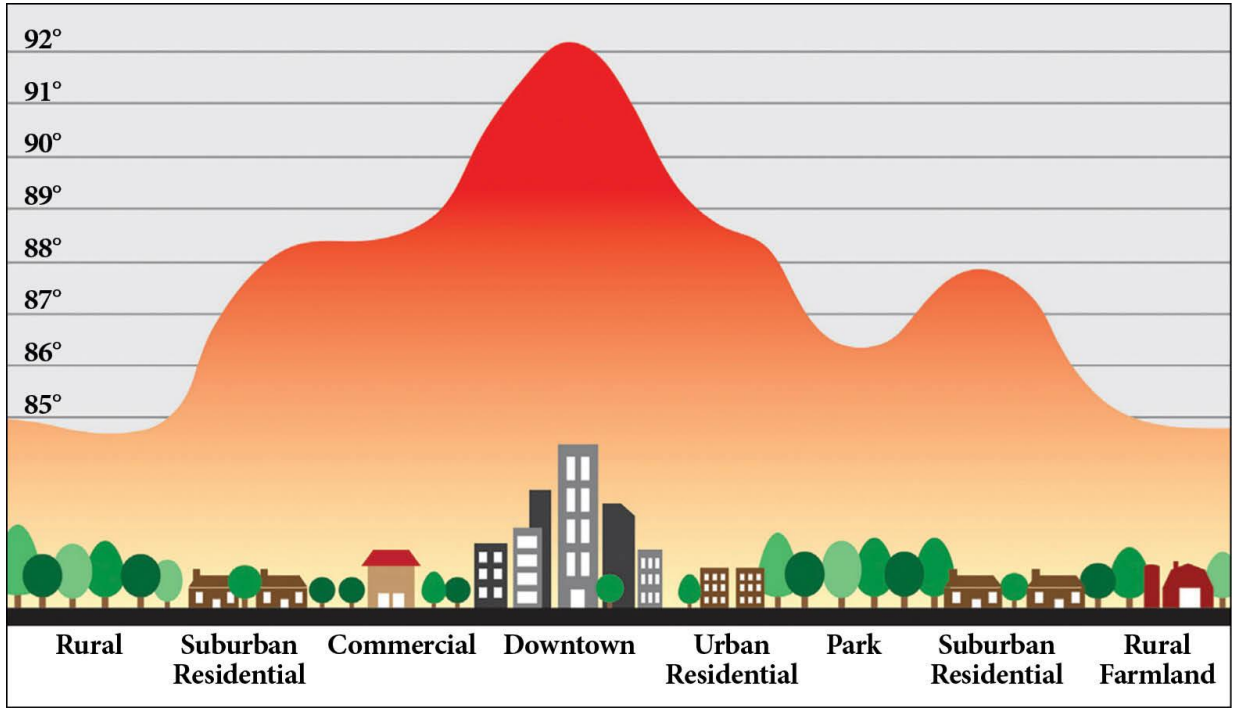
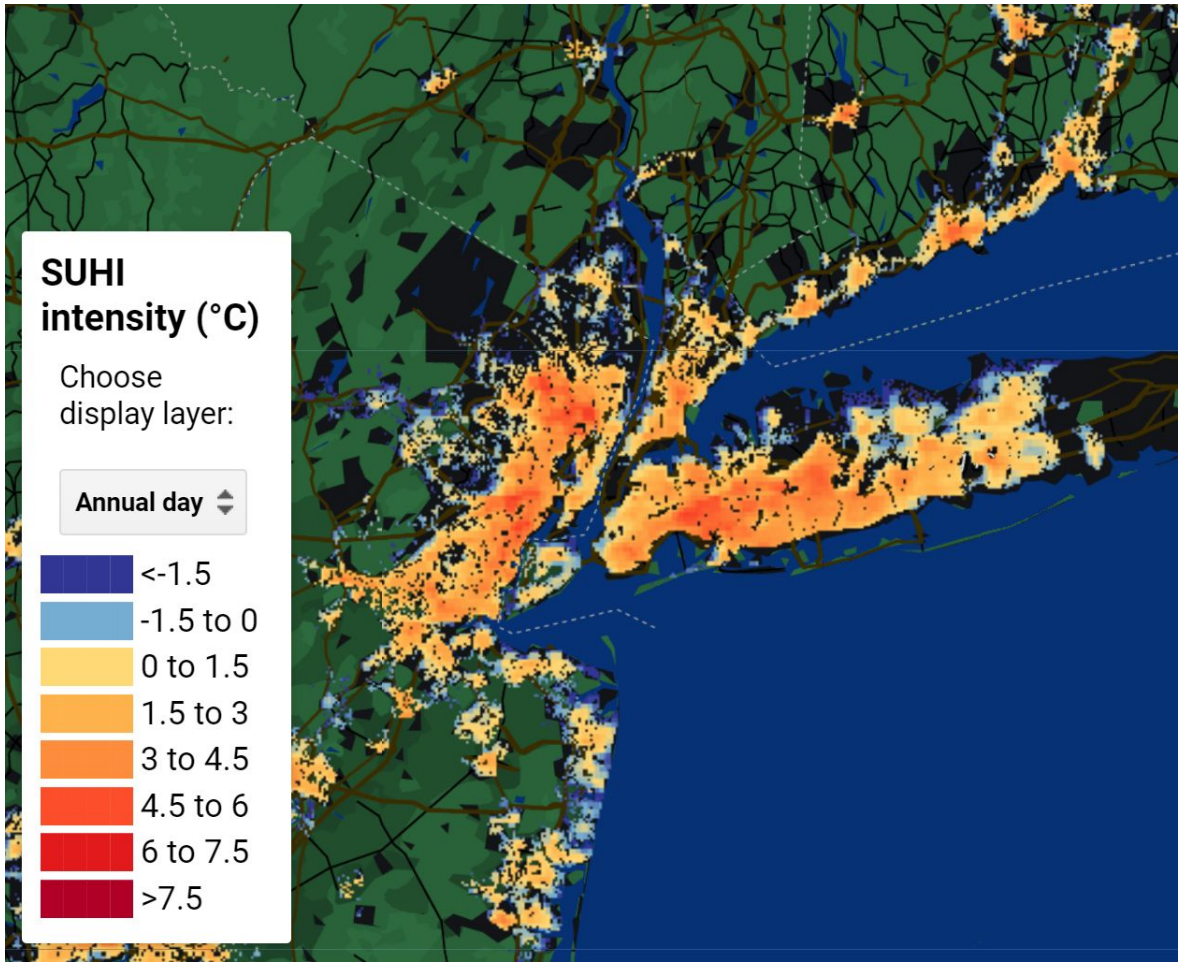
COMPASS
Coastal Observations, Mechanisms, and Predictions Across Systems and Scales

The local urban warming signal

- Urban Heat Islands: Cities are hotter than surroundings
- Leads to heat stress, higher energy use, secondary air pollution, etc.
- Most studied topic on urban impacts on climate



Rauf *et al.*, 2020

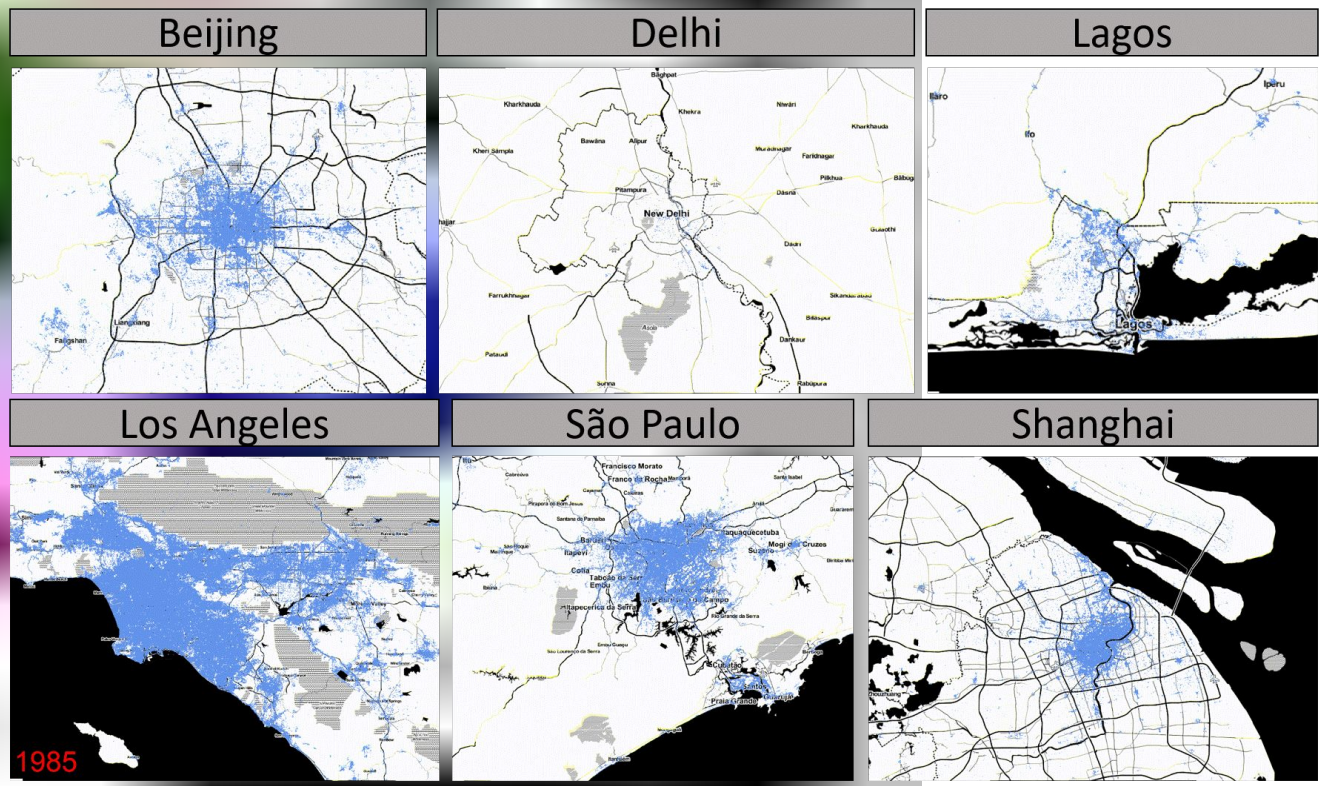


Spatial variability of surface urban heat island intensity

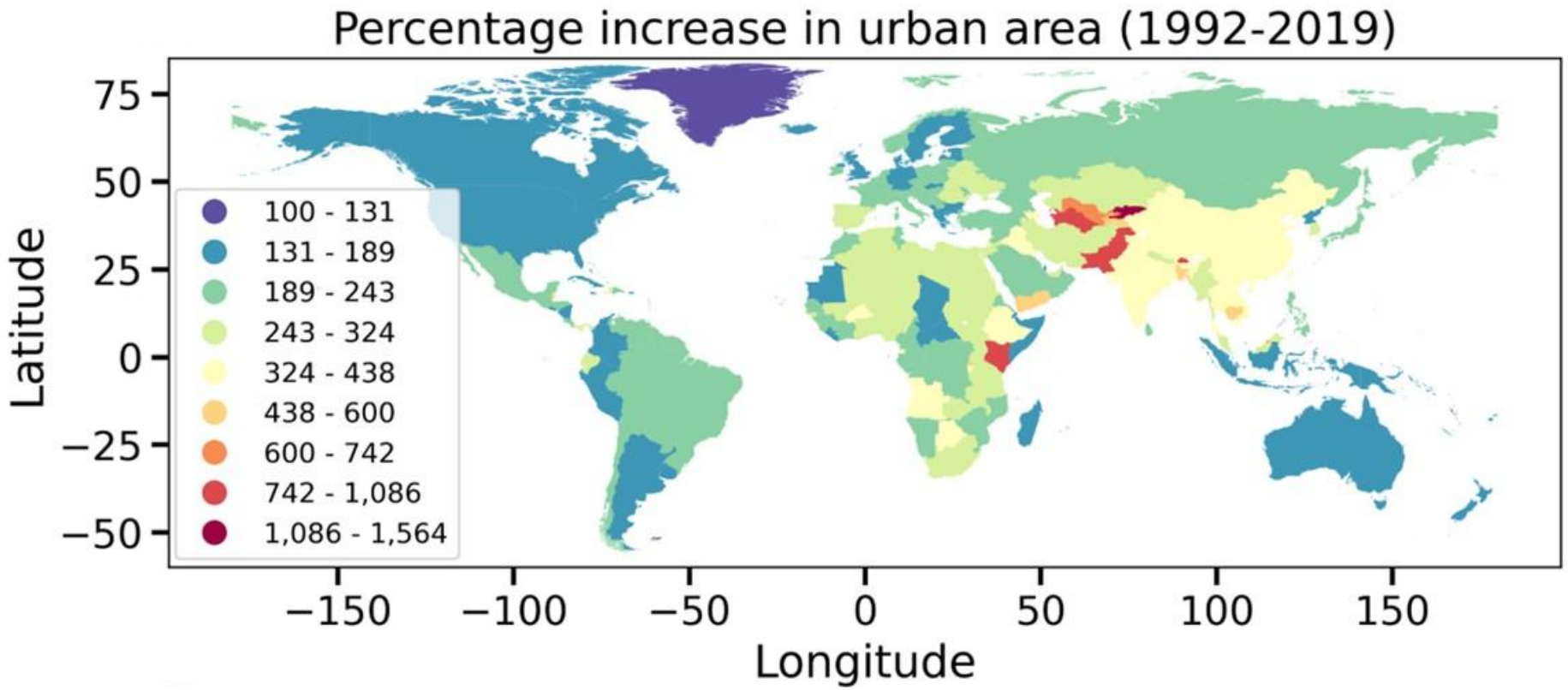
Chakraborty and Lee, 2019

Rapid urban expansion over time

Urban areas have grown tremendously in the last few decades



Inability to resolve urban impacts across scales

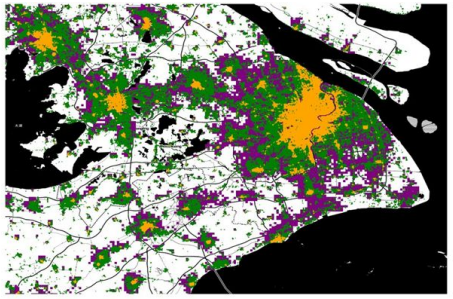


Urban Evolution = Change in urban properties + extent over time

- Observations systematically disregard urban influence on climate
- Climate models rarely consider urban areas or their evolution

Chakraborty and Qian, 2024

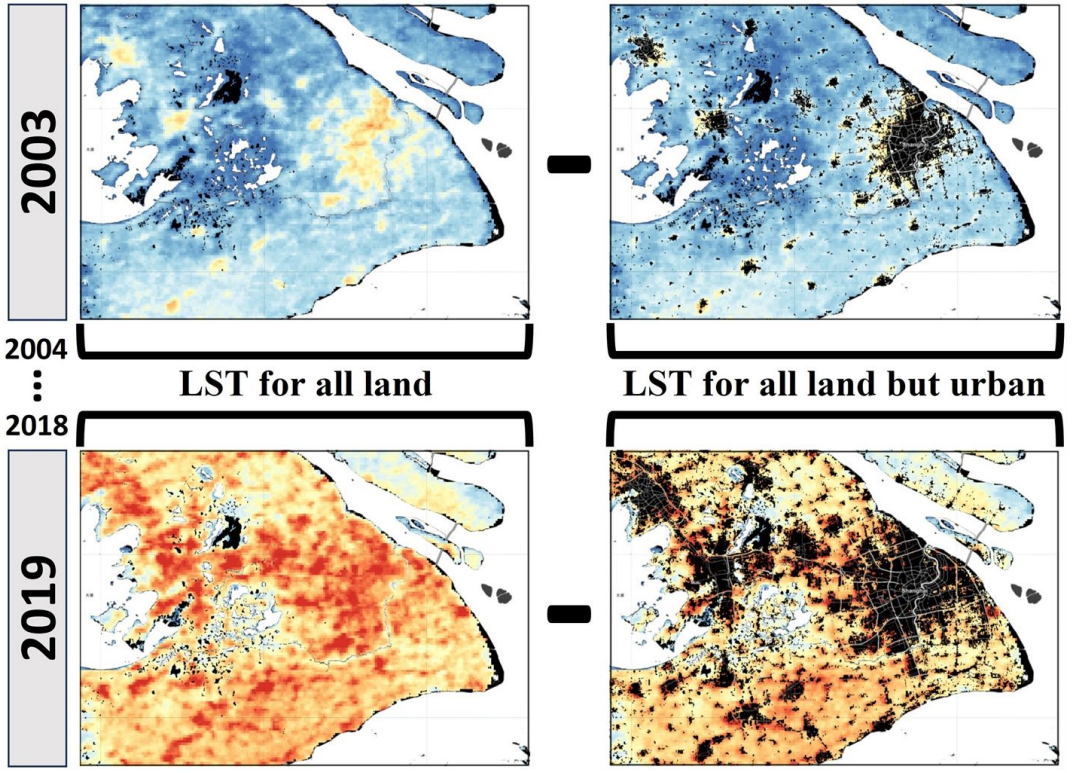
Isolating urban warming signals across scales



Past urban land
Added between past and present
Expected to be added in the future

Land surface temperature (LST) in K

293.15 298.15 303.15

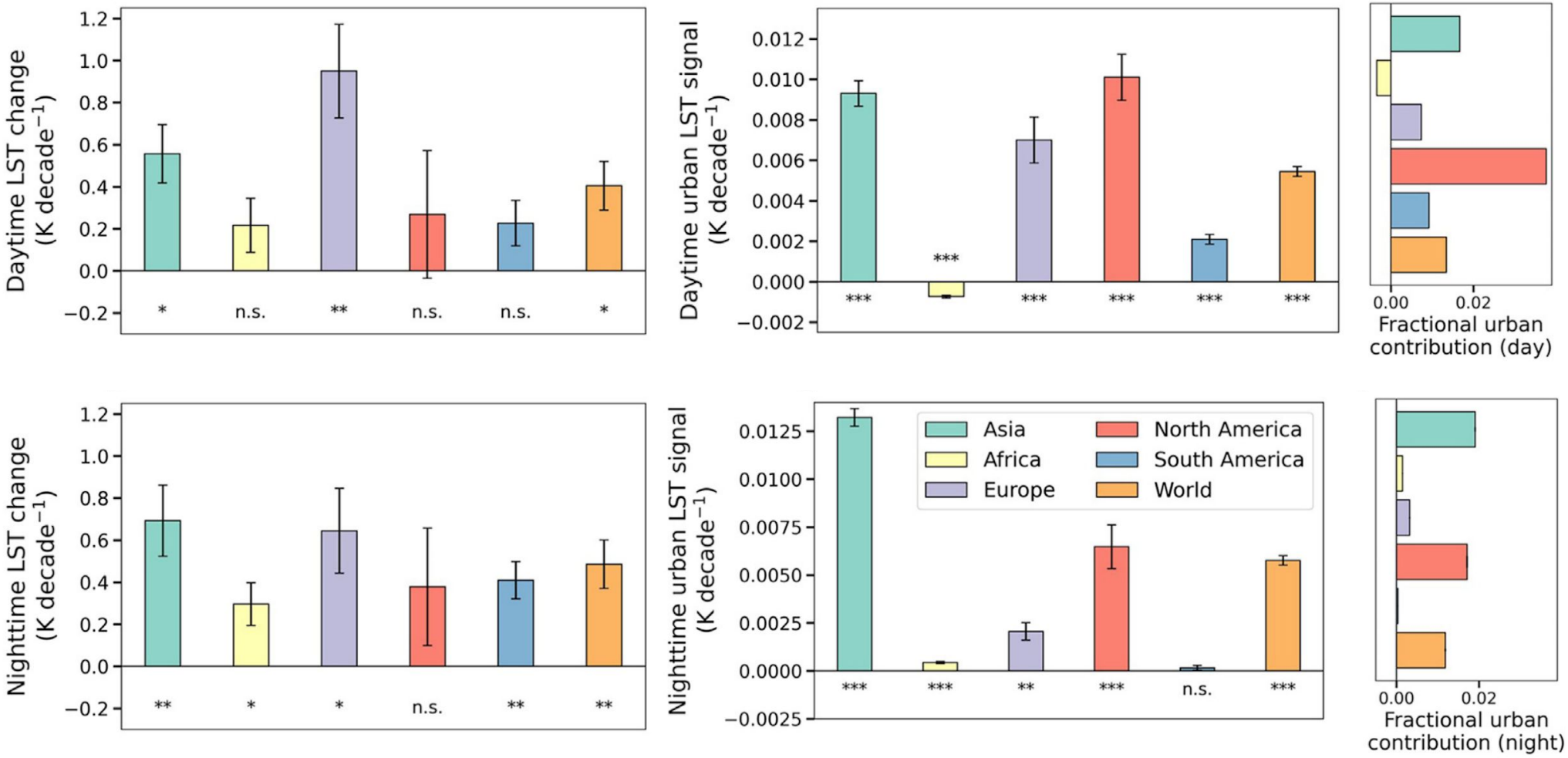


$$\Delta LST_u = LST_{all} - LST_{all-u}$$

LST = Land Surface Temperature

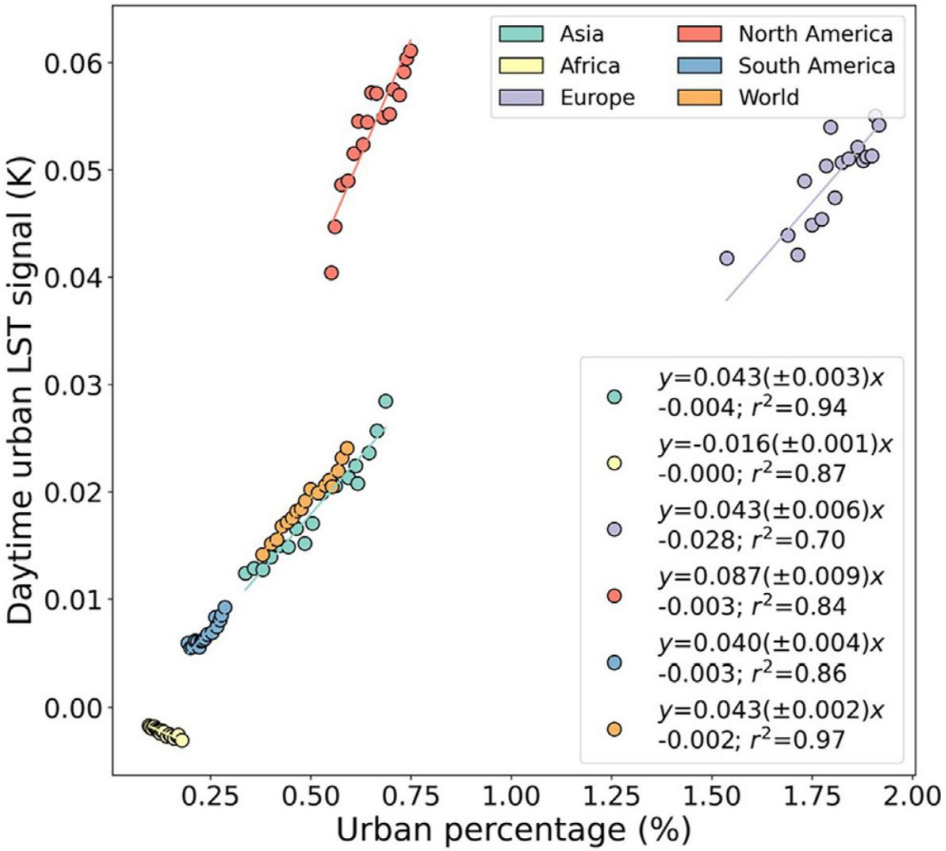
- We isolate urban temperature (LST) signals for the world, all continents, and select rapidly urbanizing regions
- Similar analysis done for other variables that can be impacted by urbanization

Continental-scale urban warming signals



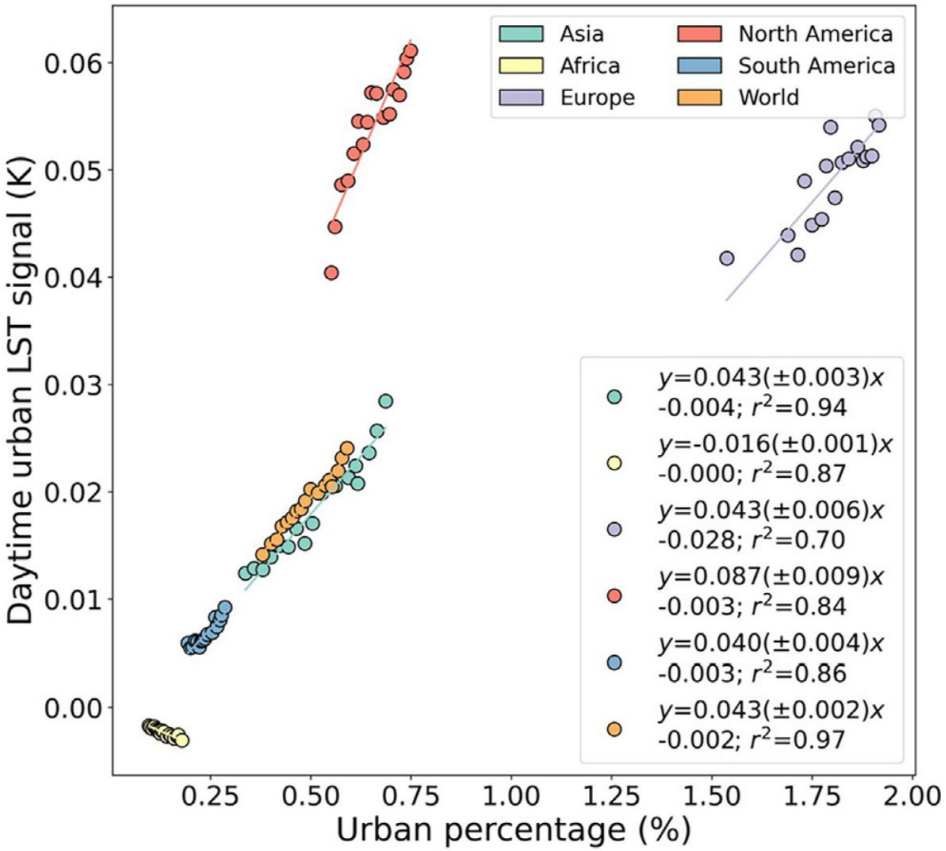
Up to 4% contribution of urban evolution to continental-scale warming during daytime; Urbanization in Africa shows cooling signal

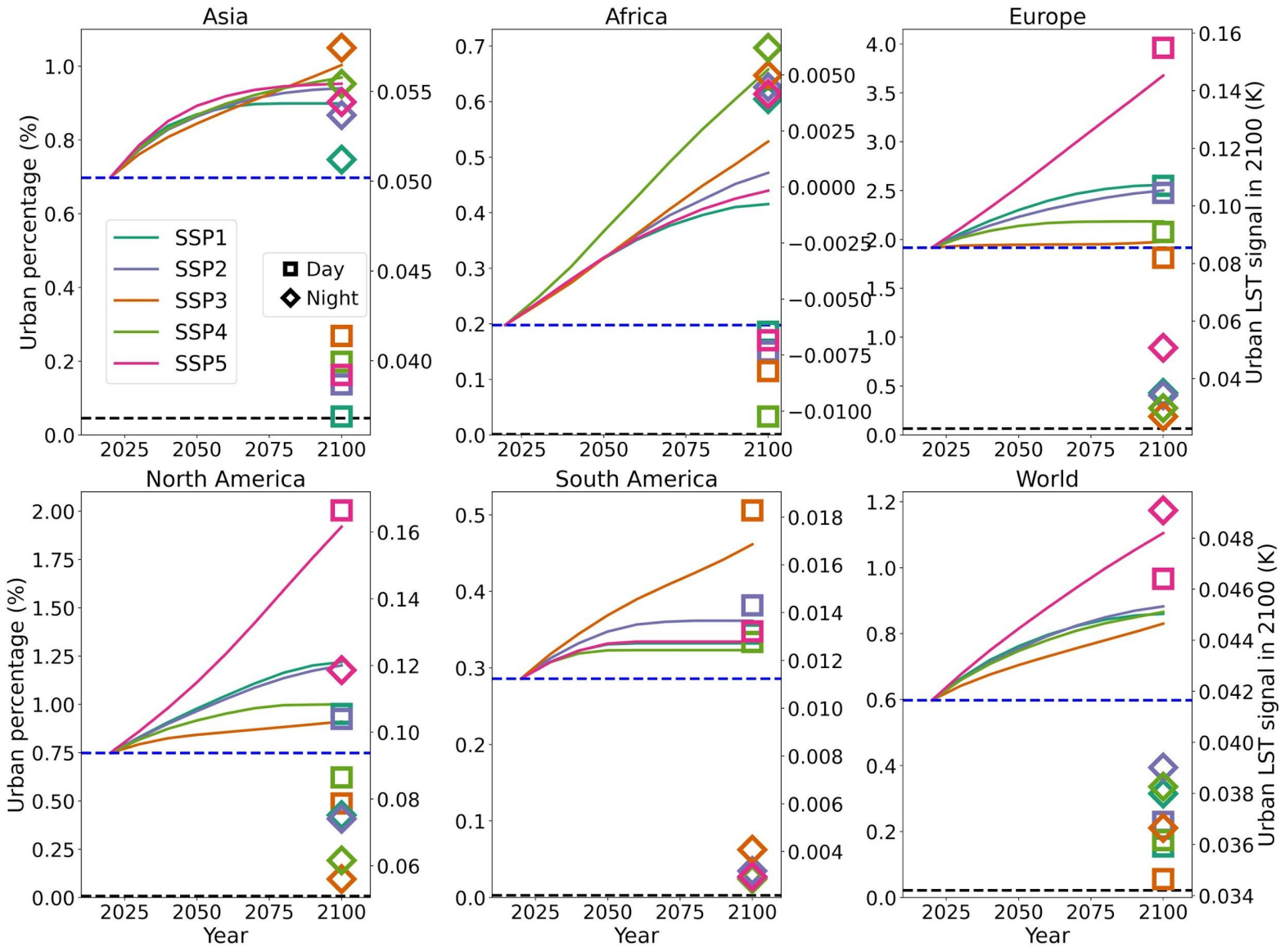
Projecting continental-scale urban warming signals



Projecting impact of future urban evolution on warming through empirical relationships

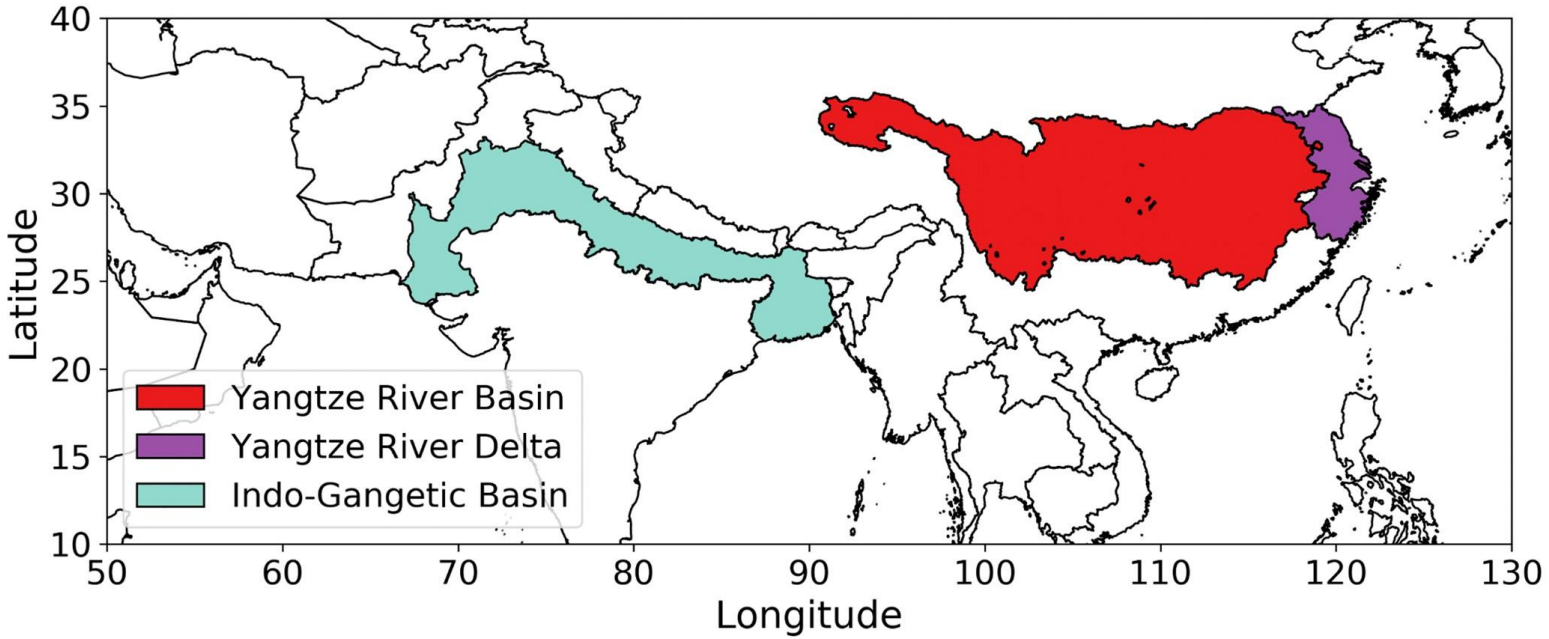
Projecting continental-scale urban warming signals

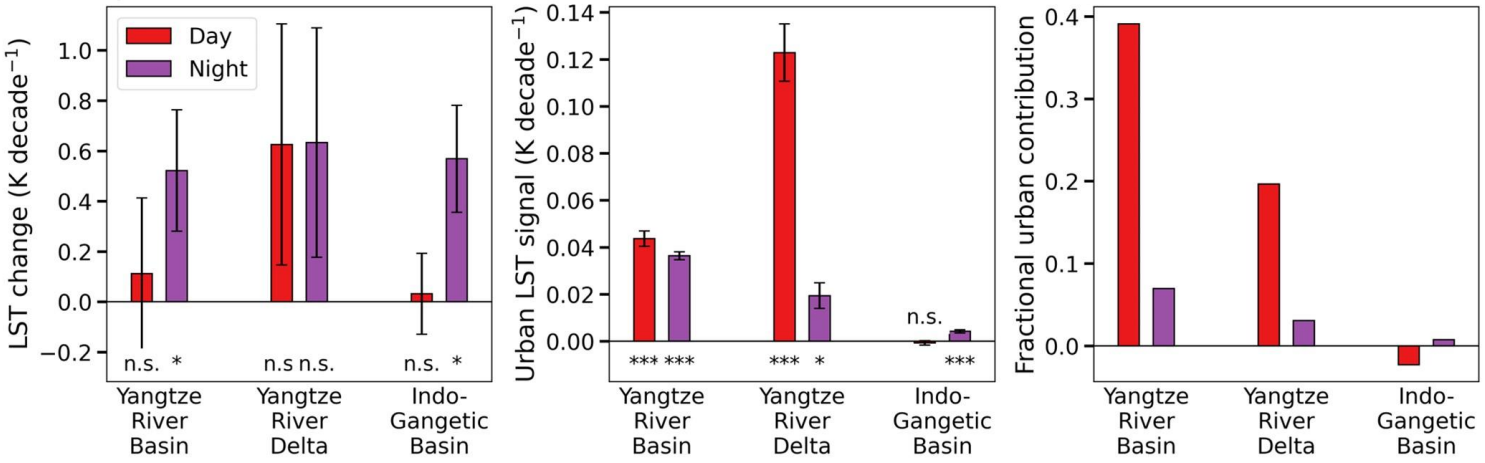




Projecting impact of future urban evolution on warming through empirical relationships

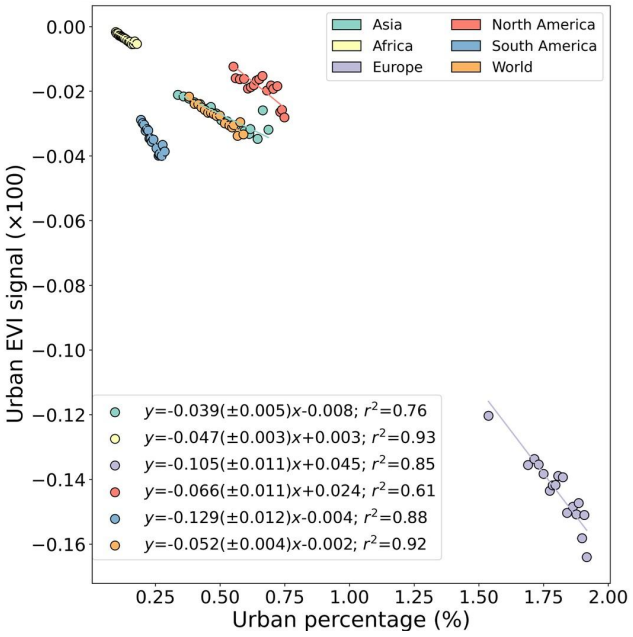
Regional-scale urban warming signals

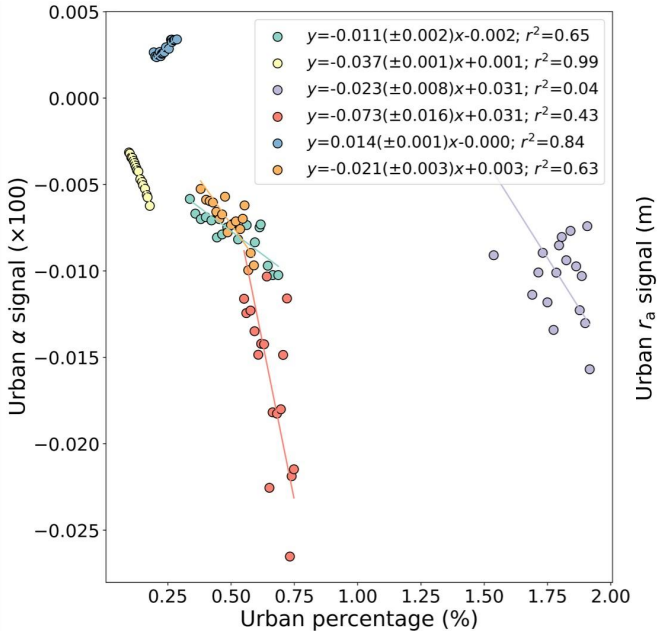


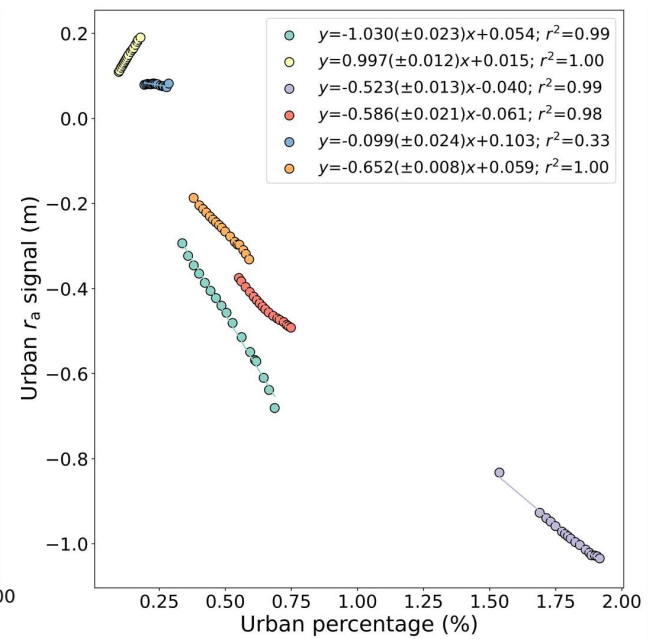


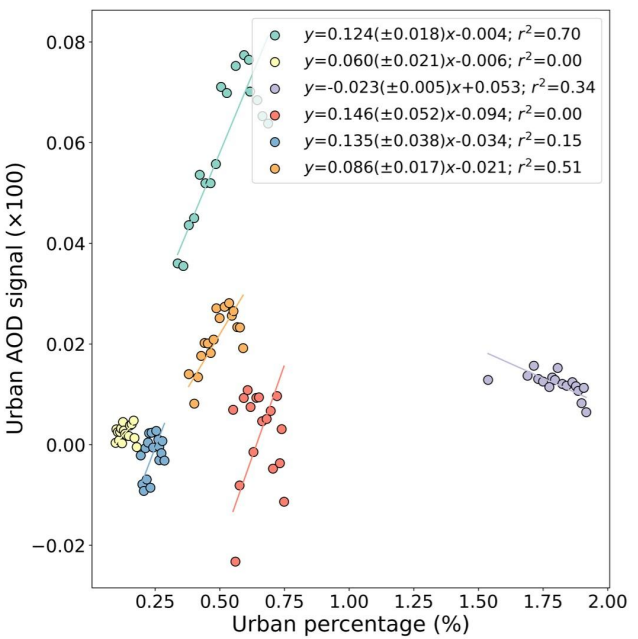
- A similar approach can be used at the regional scale
- Massive contributions (close to 40%) of urban evolution on regional warming for Yangtze River Basin

Continental-scale urban impacts on other variables



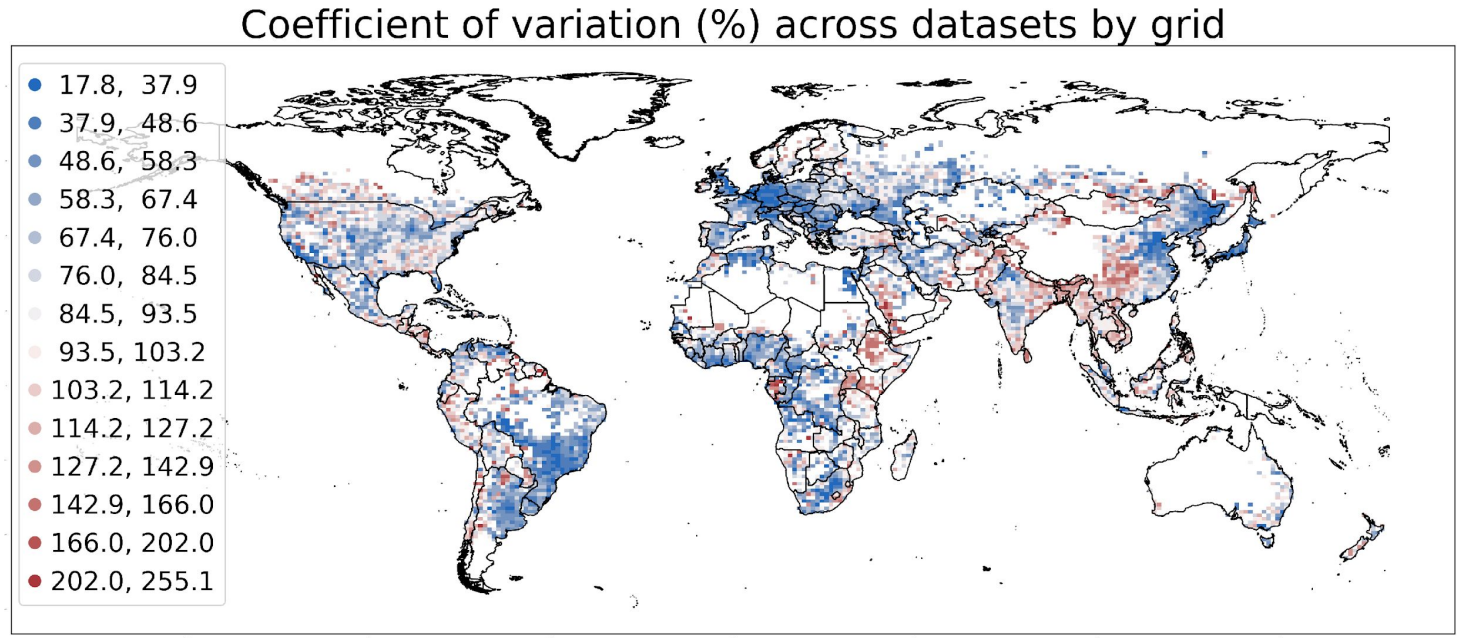




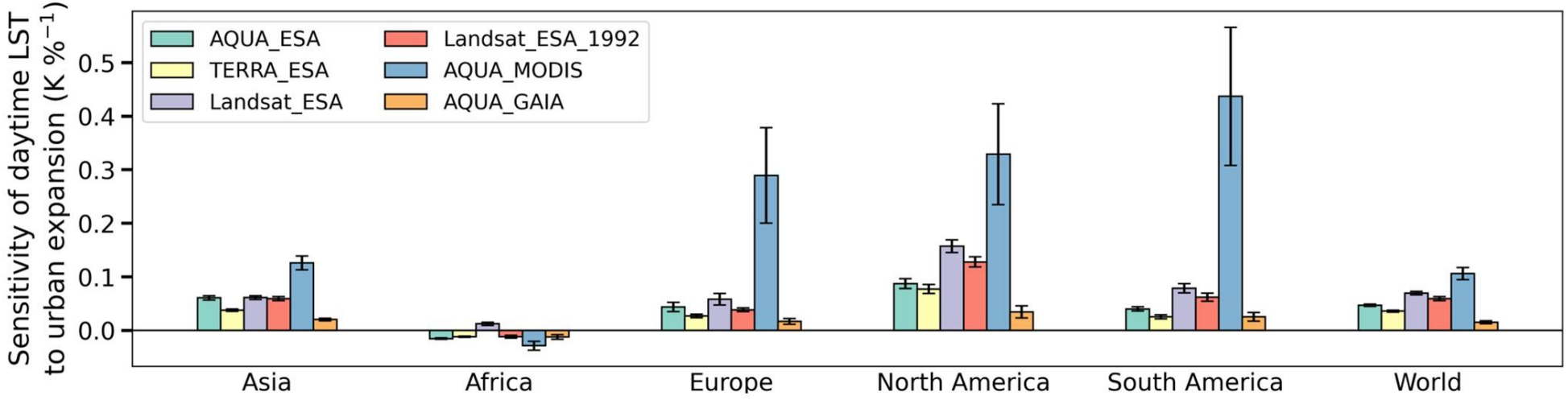


Continental-scale urban signals can be seen for other variables, such as EVI (Enhanced Vegetation Index), α (albedo), r_a (aerodynamic roughness), and AOD (Aerosol Optical Depth)

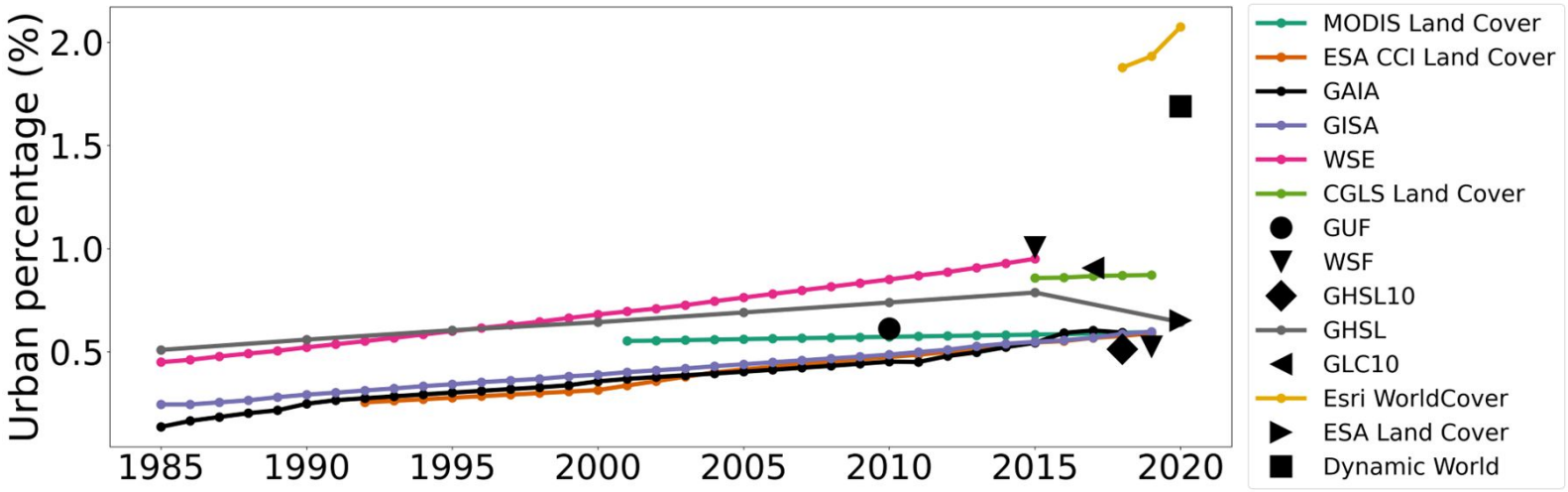
Uncertainties due to dataset choice

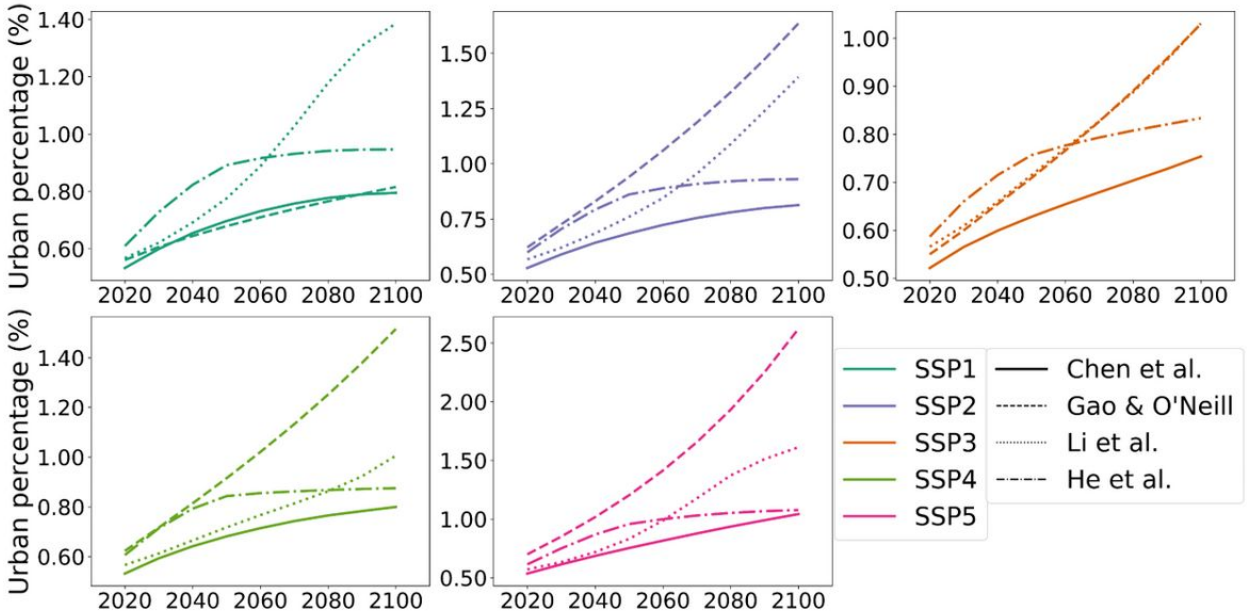


- Global urban land cover datasets disagree on spatial and temporal aspects of urbanization
- Choice of LST products also impacts urban warming signals



Future directions…





Using time series of medium to high resolution satellite data to better constrain spatiotemporal urban extent and properties in process-based models (E3SM)

Co-developing future urban evolution scenarios

IM3

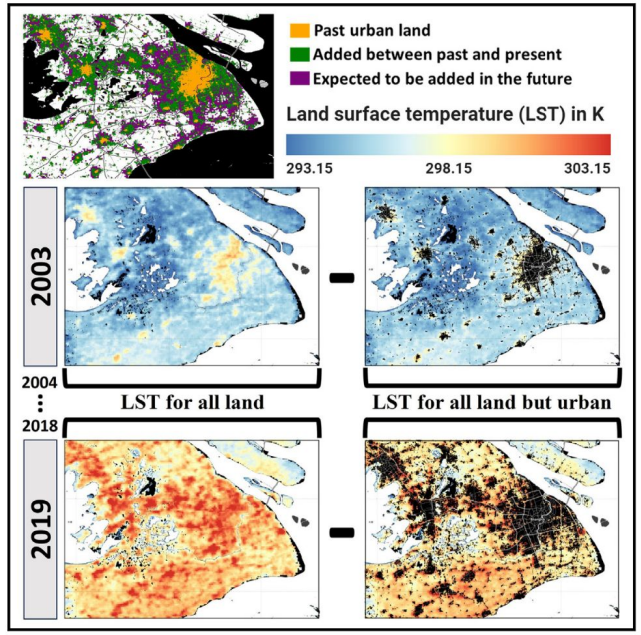
Thank you!

Article

One Earth

Urbanization exacerbates continental- to regional-scale warming

Graphical abstract



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In brief

Urban impacts on climate are generally discussed at the local scale, with urban areas ignored in large-scale climate assessments. We show that urbanization can intensify large-scale warming, especially in rapidly urbanizing regions and countries in Asia. Future urban growth will also influence continental-to regional-scale warming signals. These results fundamentally reframe how both the research community and the public usually think about urbanization, from only a local-scale phenomenon to one with non-negligible regional- and even continental-scale impacts.

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Article

Large disagreements in estimates of urban land across scales and their implications

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Questions?