NCAR | NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Advancing urban-resolving CESM via a new global high resolution urban dataset

2024 CESM Workshop

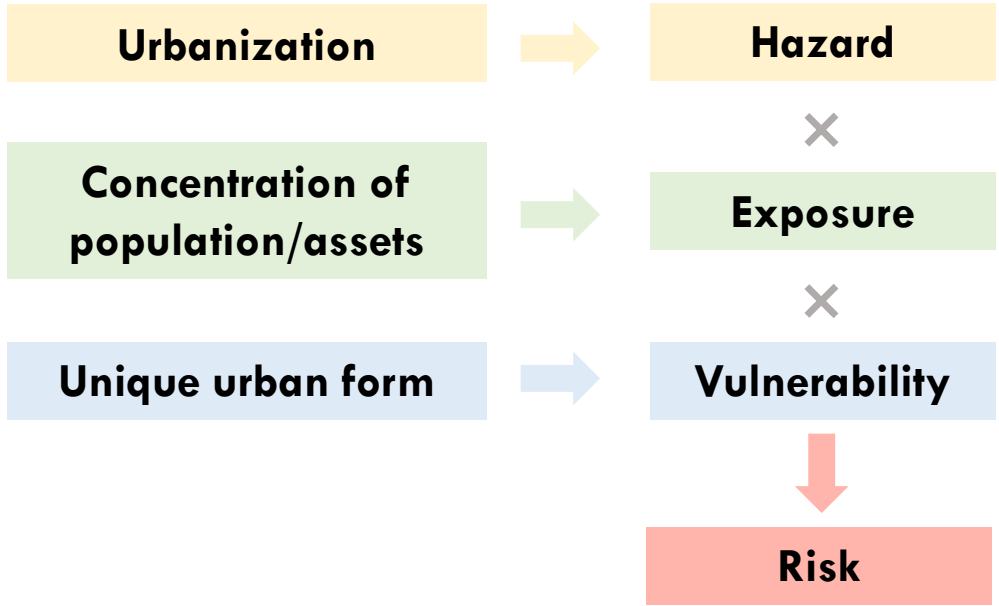
Land Model Working Group

06/10/24

Yifan Cheng*

Collaborators: TC Chakraborty, Keith W. Oleson, Yangzi Che, Weilin Liao, Xinchang Li, Matthias Demuzere, Lei Zhao

The initiative of explicitly representing urban in CESM is too coarse-grained to resolve spatial heterogeneity and provide accurate urban climate projections.



The initiative of explicitly representing urban in CESM is still too coarse-grained to resolve spatial heterogeneity and provide accurate urban climate projections.

Urbanization → **Hazard**

×

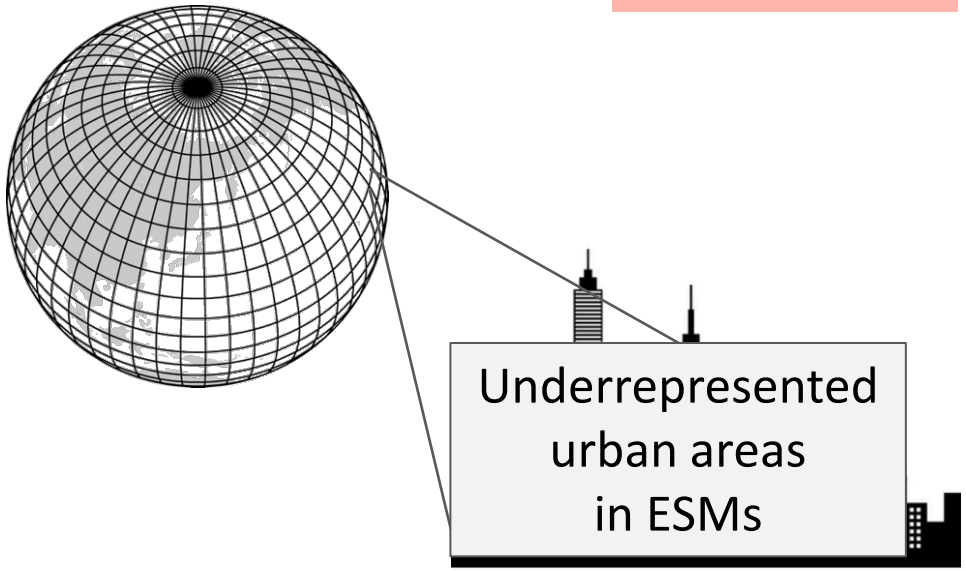
Concentration of population/assets → **Exposure**

×

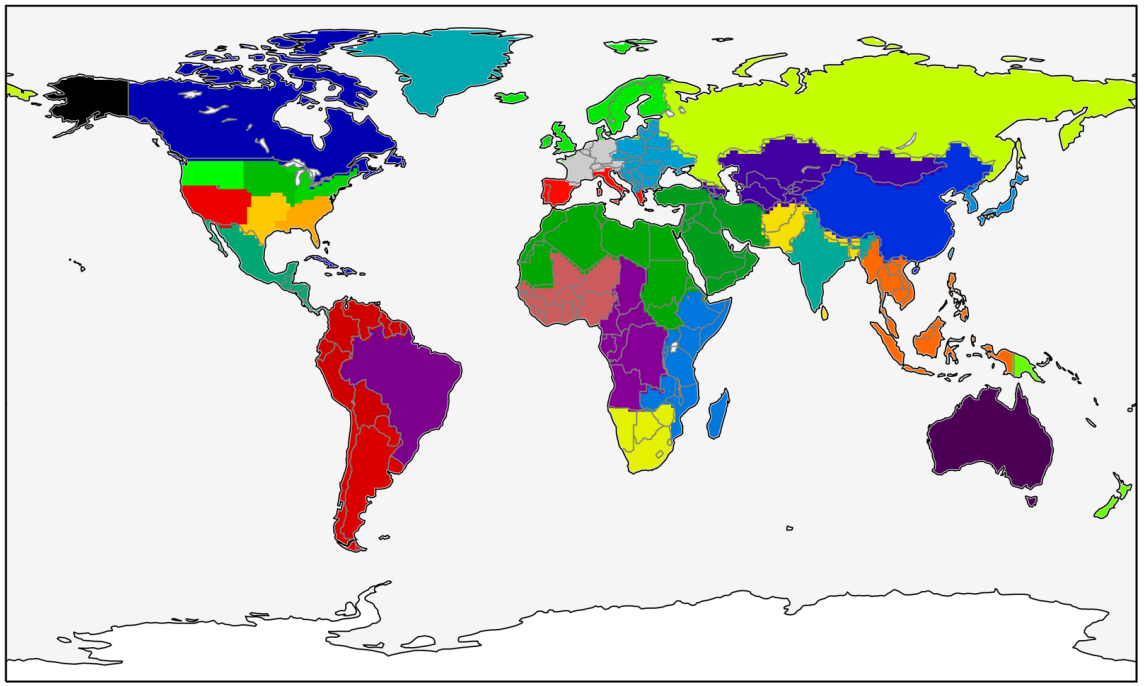
Unique urban form → **Vulnerability**

↓

Risk



33 regions

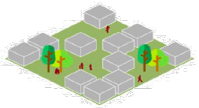


Data source: *Jackson et al. (2010)*

3 density classes

Tall Building District (TBD)

skyscrapers



High Density (HD)

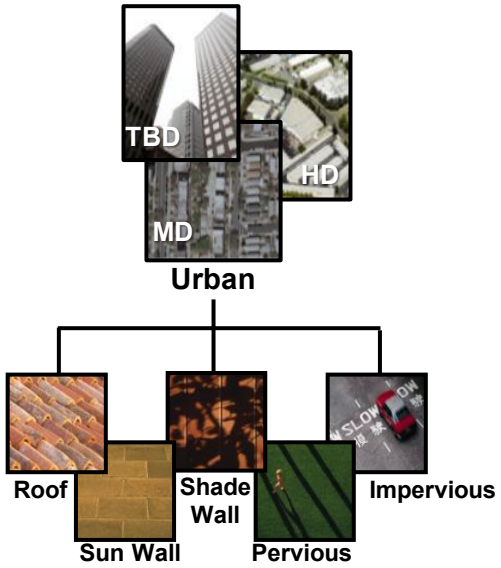
tall apartments, office buildings, industry

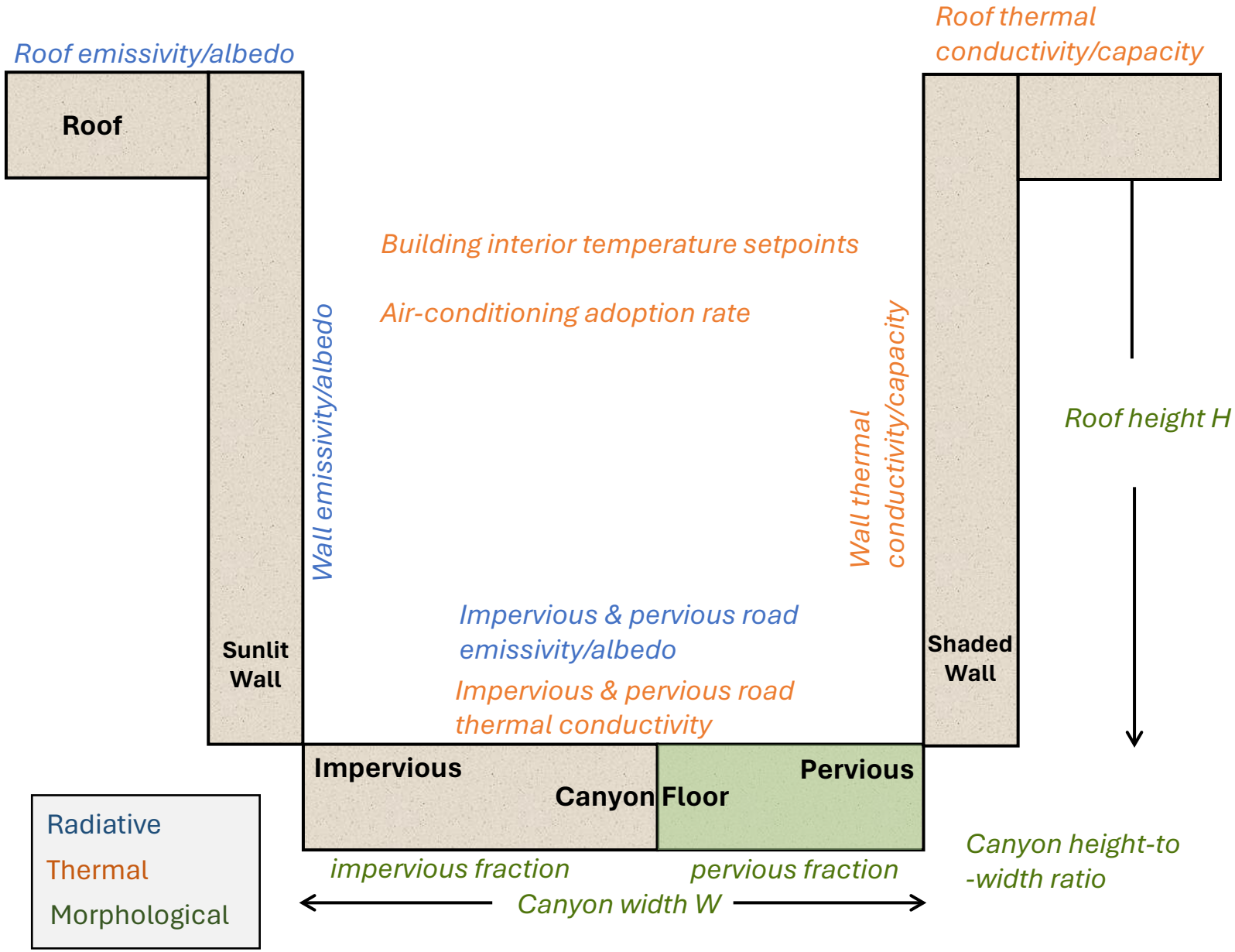
Medium Density (MD)

1-3 story apartments, row houses

Icon source: *Chen et al. (2019)*

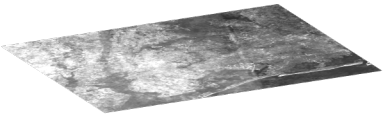
We built a global 1km continuous urban surface property dataset based on the urban parameterization scheme embedded in CLMU.



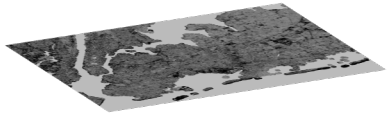


We leveraged the remote sensing imageries with multi-source derivation to generate the 1km dataset.

Sentinel-2



ASTER

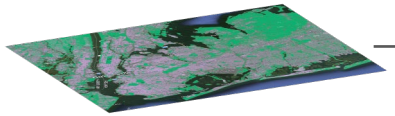


Microsoft Global Building Footprints

East Asia Building Footprints

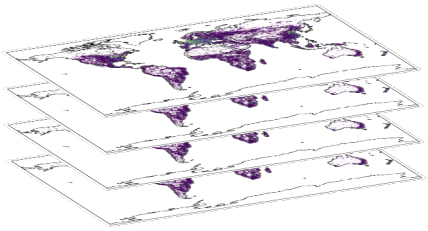
ESA WorldCover

Segmented Urban Facets Imagery



Global land cover datasets

(e.g., *Gao & O'Neil (2020), Li et al. (2021),* etc.)



Support user-defined urban extent

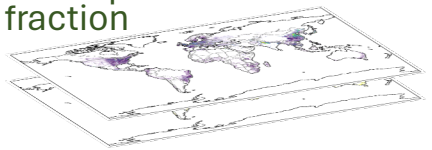
Facet-level radiative properties

Emissivity
roof | impervious road | pervious road | wall

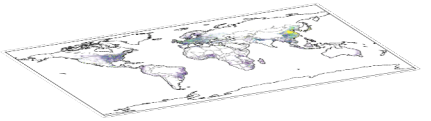
Albedo
roof | impervious road | pervious road | wall

Morphological properties

Roof / pervious road fraction

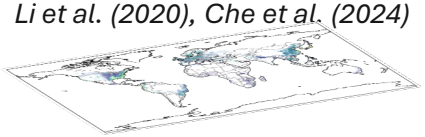


Urban fraction

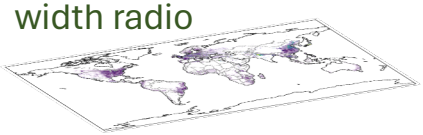


Roof height

Li et al. (2020), Che et al. (2024)



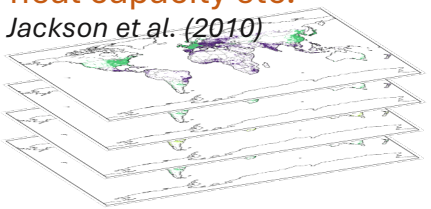
Canyon height to width radio



Thermal properties

Roof / wall conductivity/ heat capacity etc.

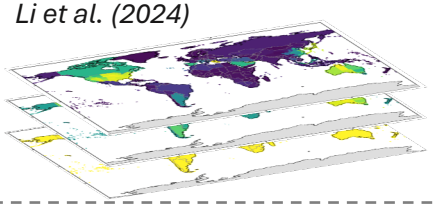
Jackson et al. (2010)



+

Air conditioning adoption rate

Li et al. (2024)

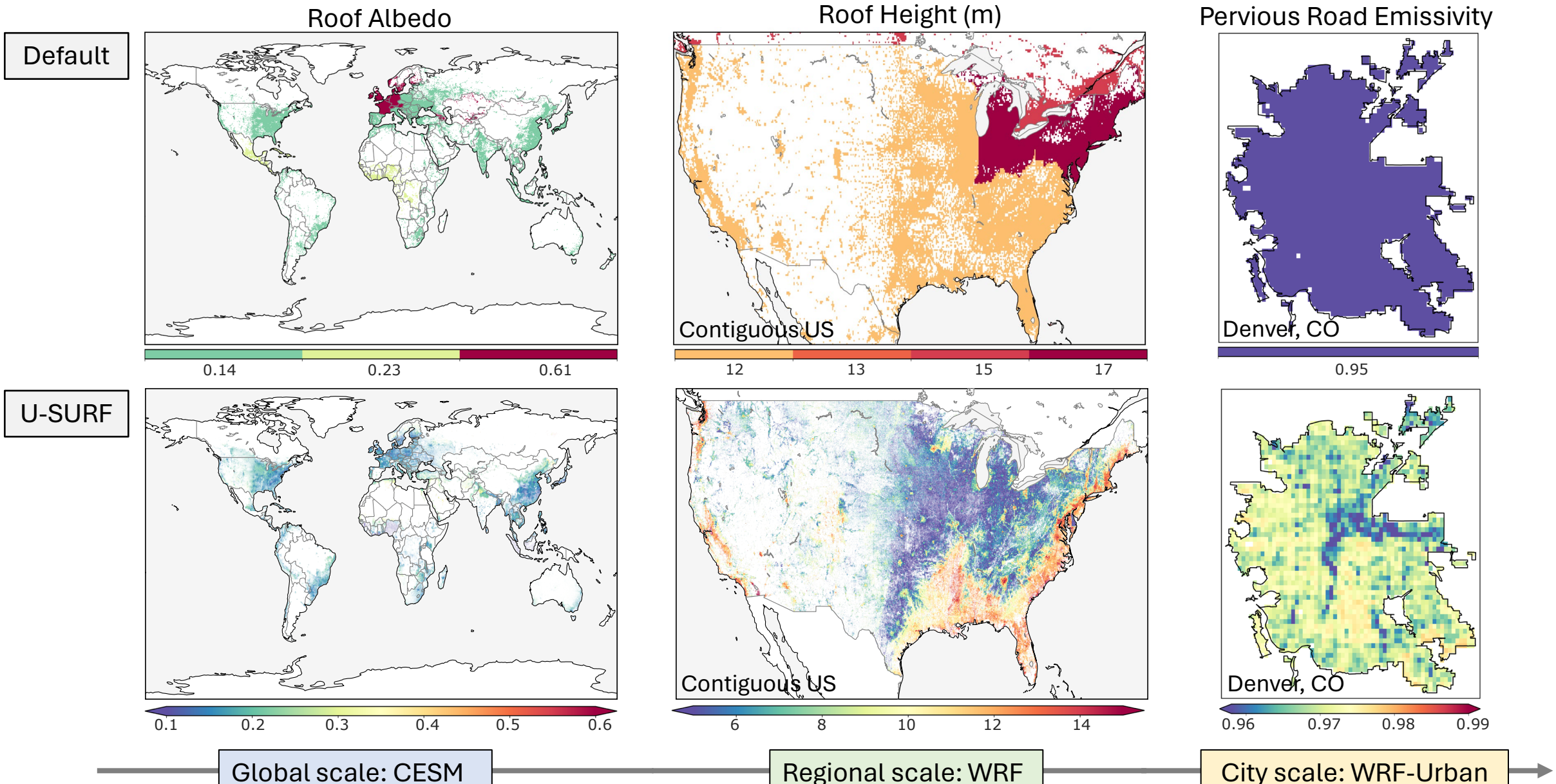


U-SURF

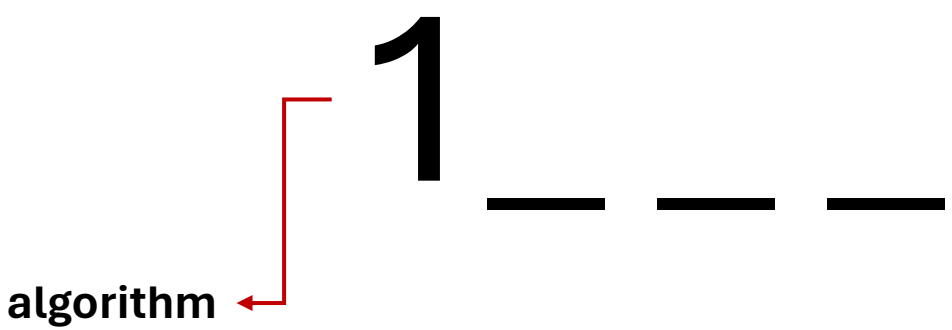
Global continuous 1km urban surface property dataset

Radiative | Morphological | Thermal

The dataset has shown better spatial heterogeneity, accuracy and can support urban climate modeling across scales.

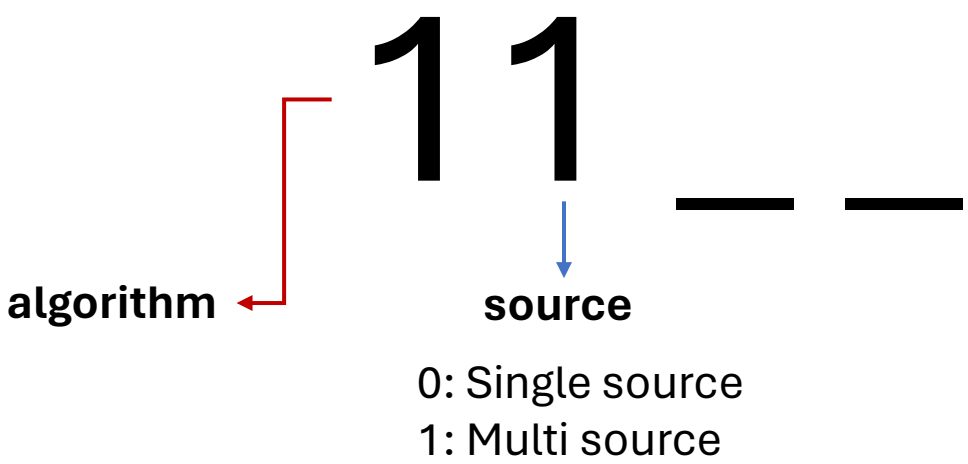


The dataset is available in multiple formats with trackable quality control flags.

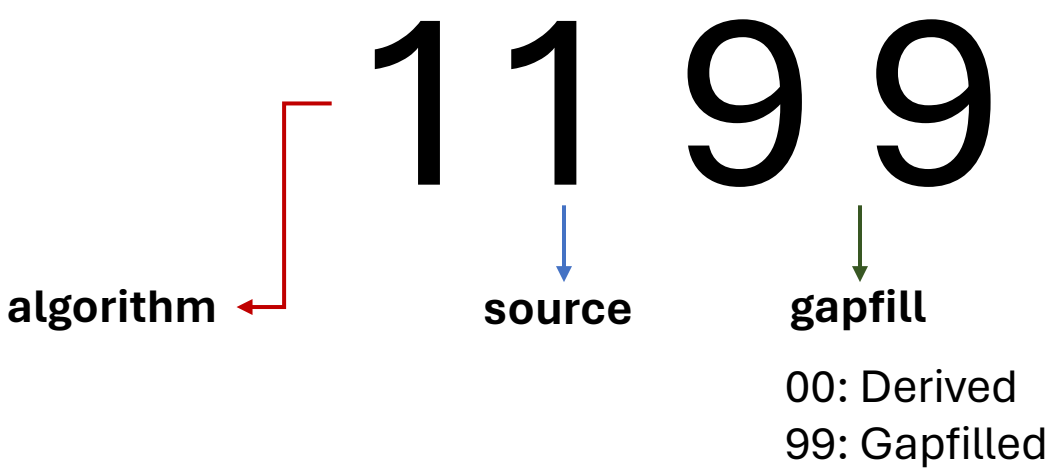


1: Processing based on observation products
2: Processing based on model/assumptions
3: Regridding of existed products w/o further change

The dataset is available in multiple formats with trackable quality control flags.



The dataset is available in multiple formats with trackable quality control flags.

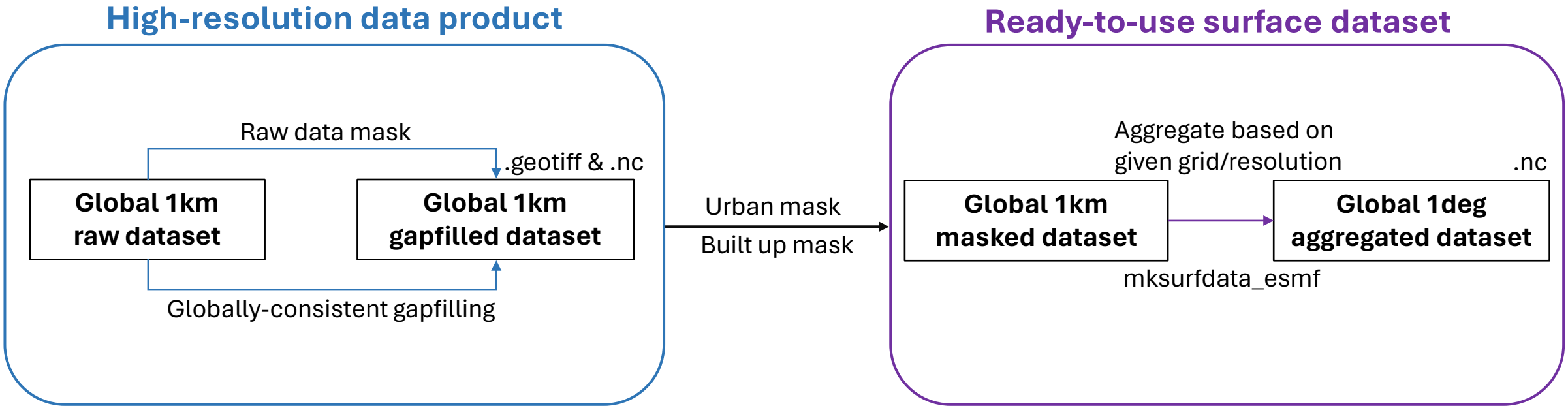


The dataset is available in multiple formats with trackable quality control flags.

1 1 9 9

- 1st 1: **algorithm**
- 2nd 1: **source**
- 9 9: **gapfill**

00: Derived
99: Gapfilled

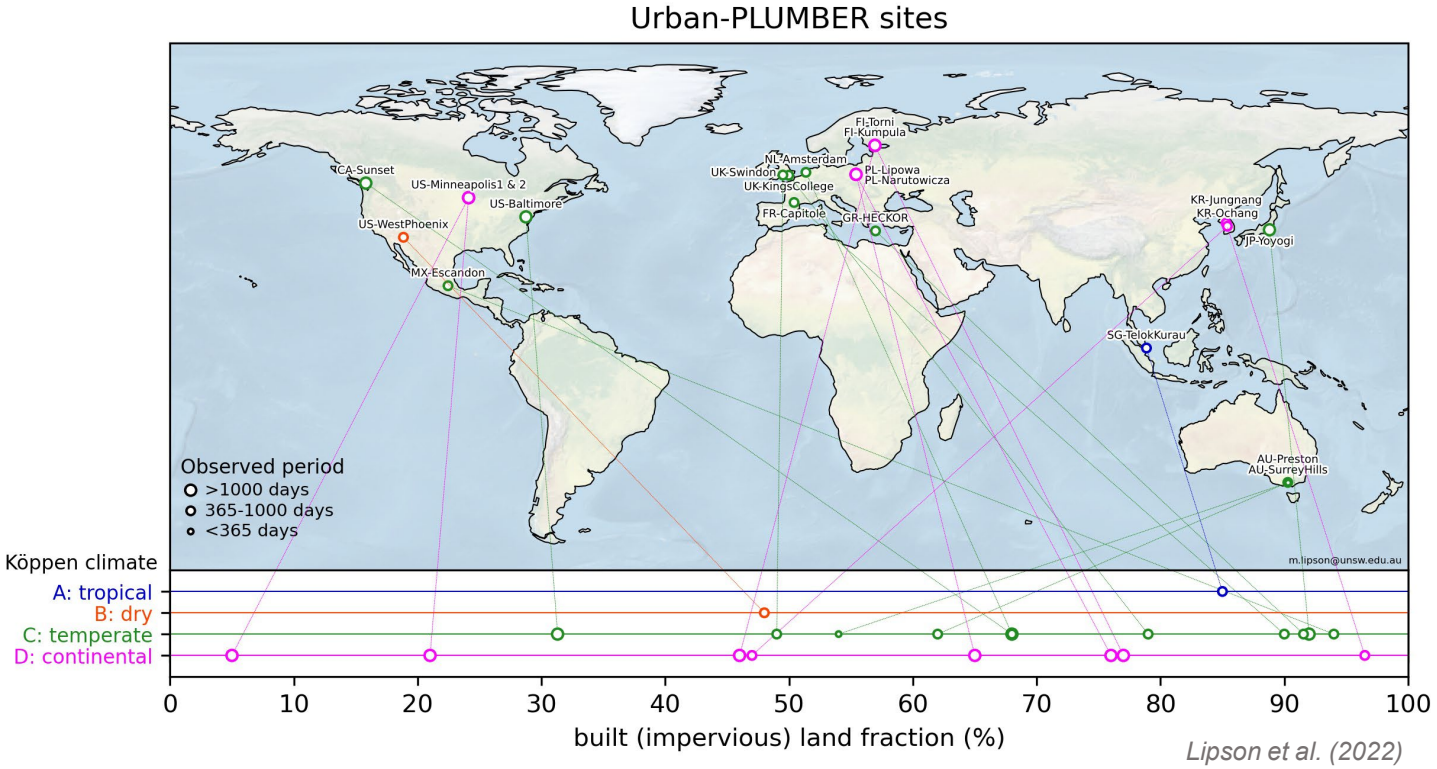


We developed a Google Earth Engine web app for data visualization.

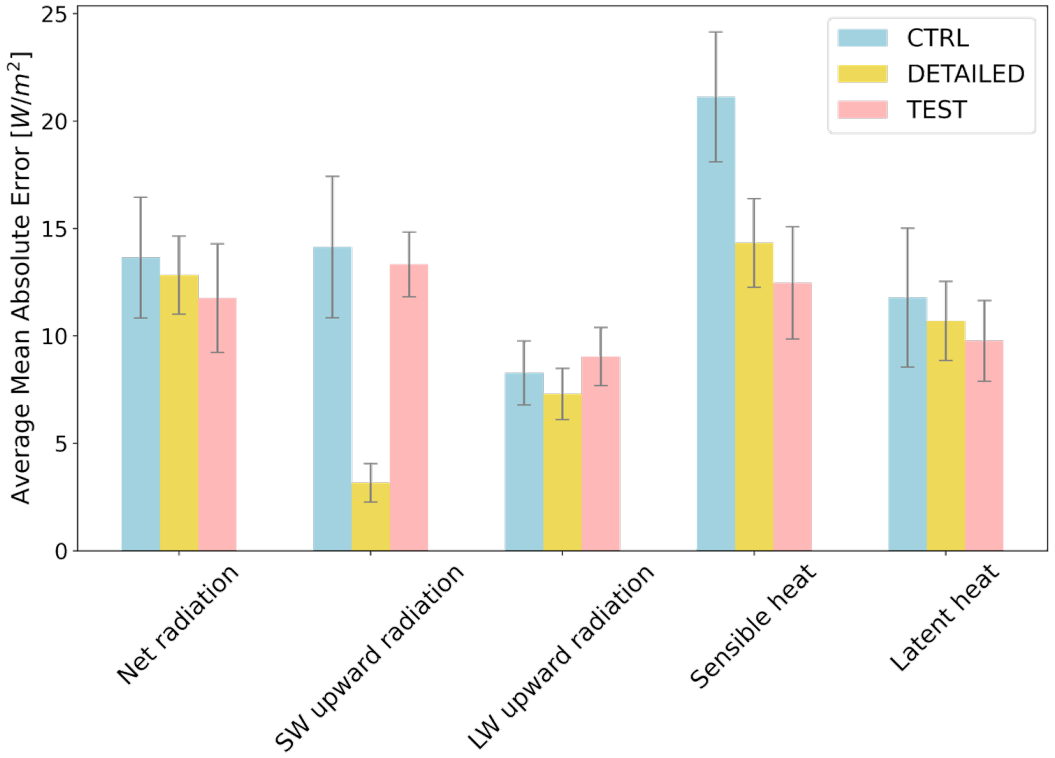
Check out app v1 here:

The new surface dataset showed improvement in modeled fluxes via single-point simulations over 20 Urban-PLUMBER sites.

Case	Radiative	Morphological	Thermal
CTRL	Default CLMU: Oleson & Feddema (2020)		
DETAILED	Default	Urban-PLUMBER	Default
TEST	U-SURF	U-SURF	Default



Lipson et al. (2022)



The spatially-heterogeneous dataset enhanced spatial variability of modeled outputs.

2010-2014 average

Standard Resolution Run
0.9x1.25° globally

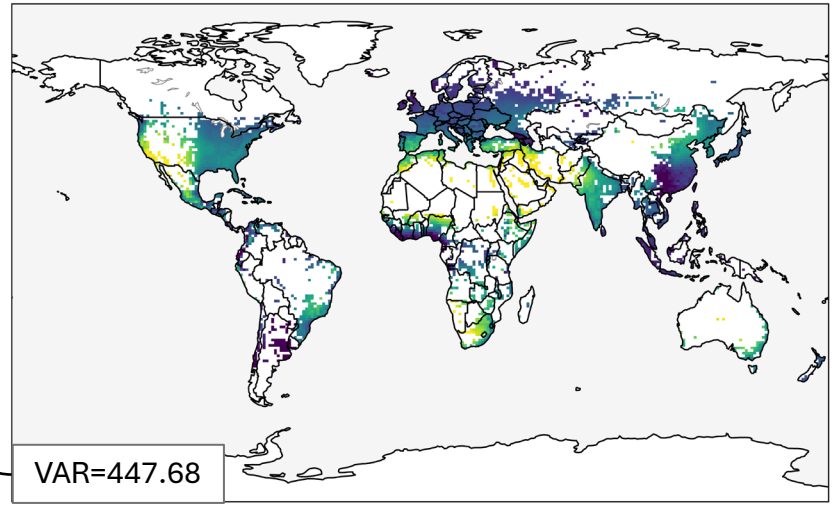
High Resolution Run
0.125x0.125° over CONUS

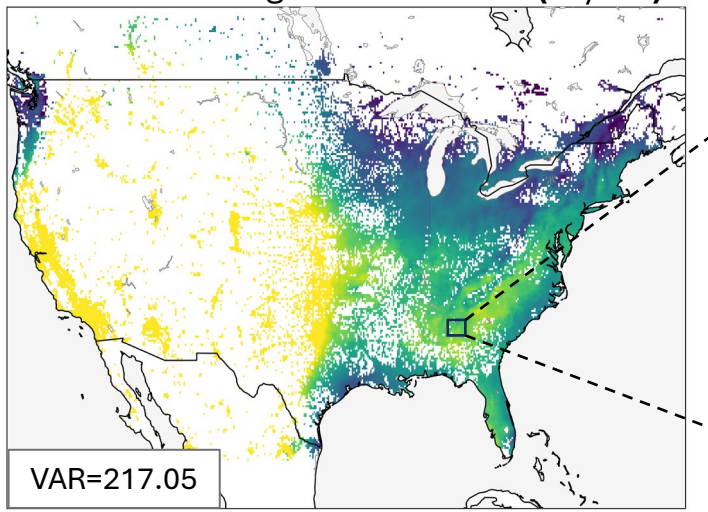
Urban Net Longwave Radiation (W/m^2)

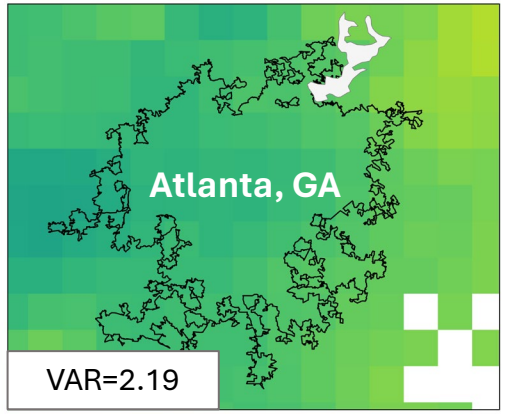
Urban Net Longwave Radiation (W/m^2)

CTRL

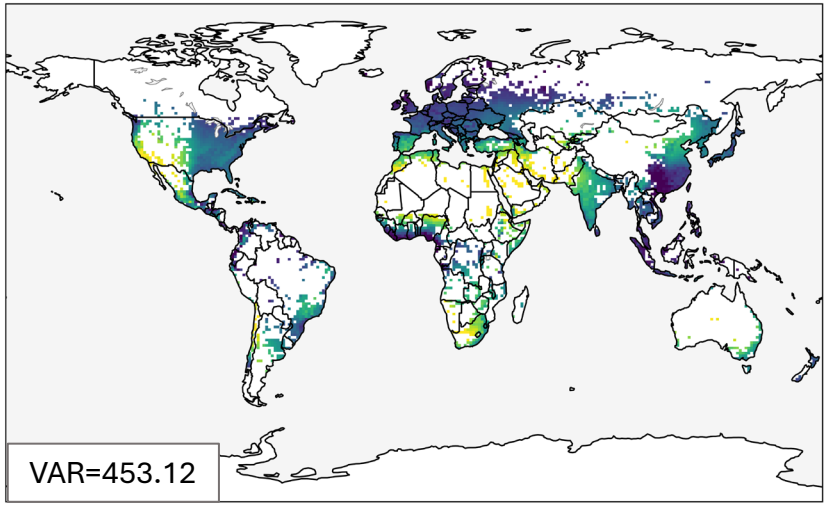
average spatial variance

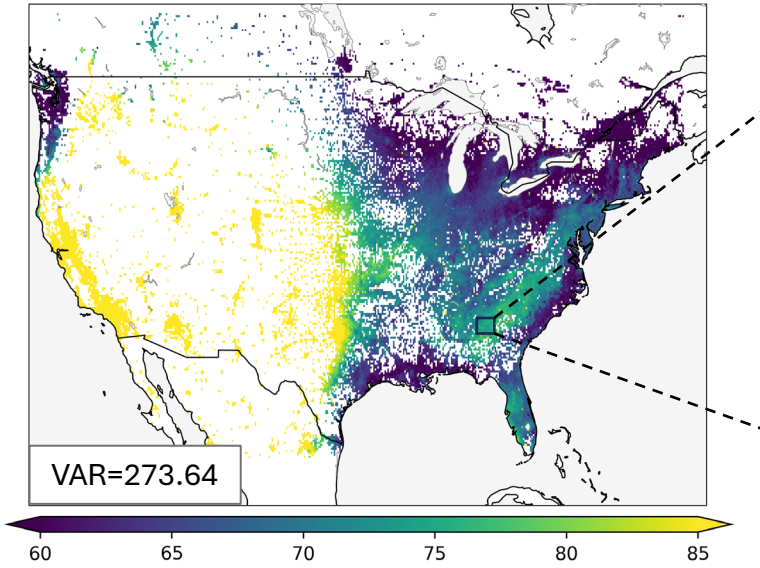


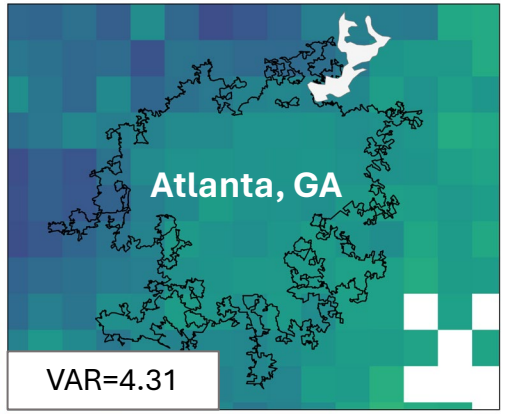




TEST







Simulation

We have observed a nearly universal reduction in urban surface and air temperature by introducing the new dataset.

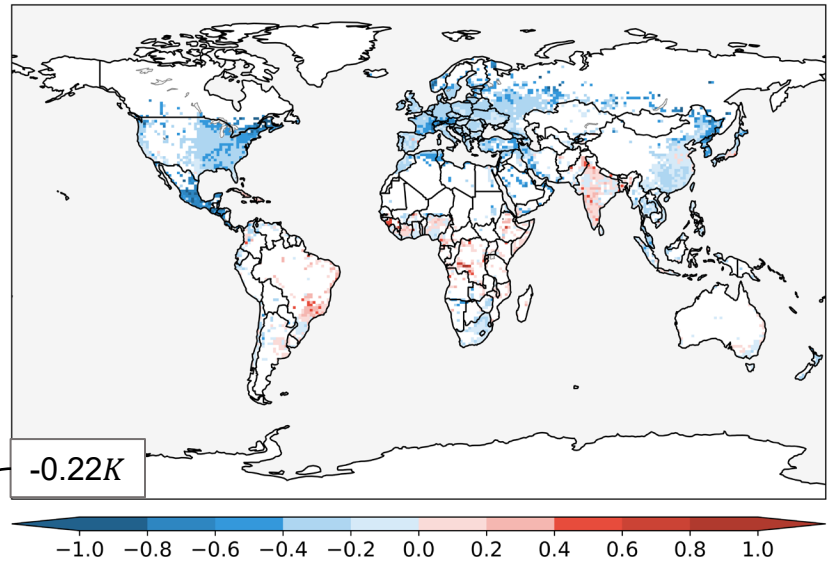
Standard Resolution Run

TEST-CTRL

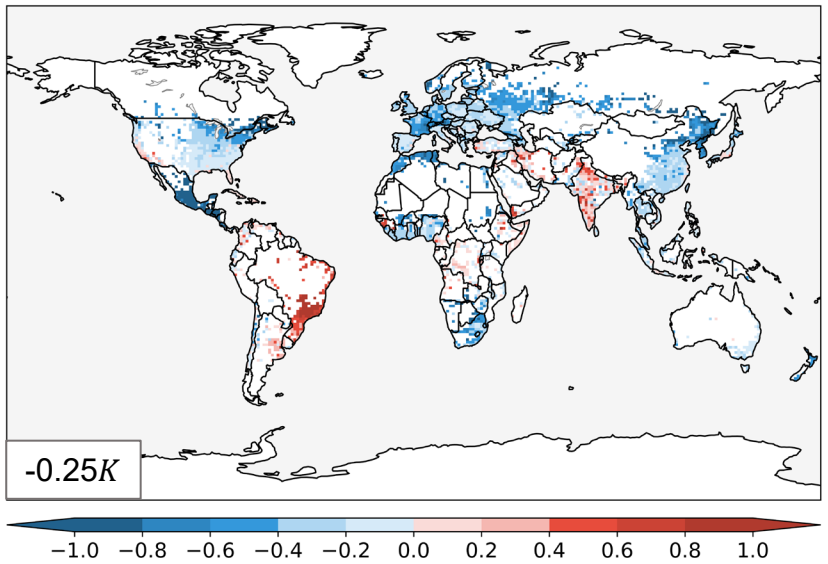
2010-2014 Average

Global average change

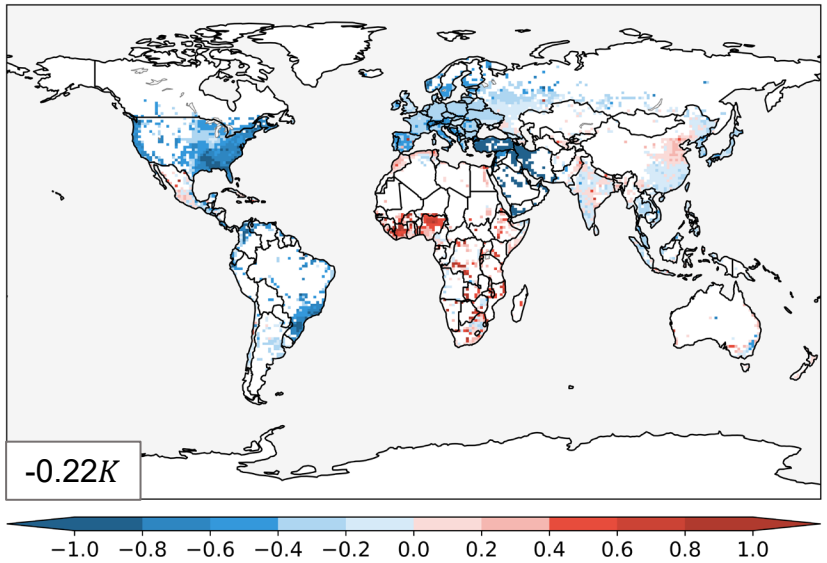
Δ Urban Near-surface Air Temperature (K)



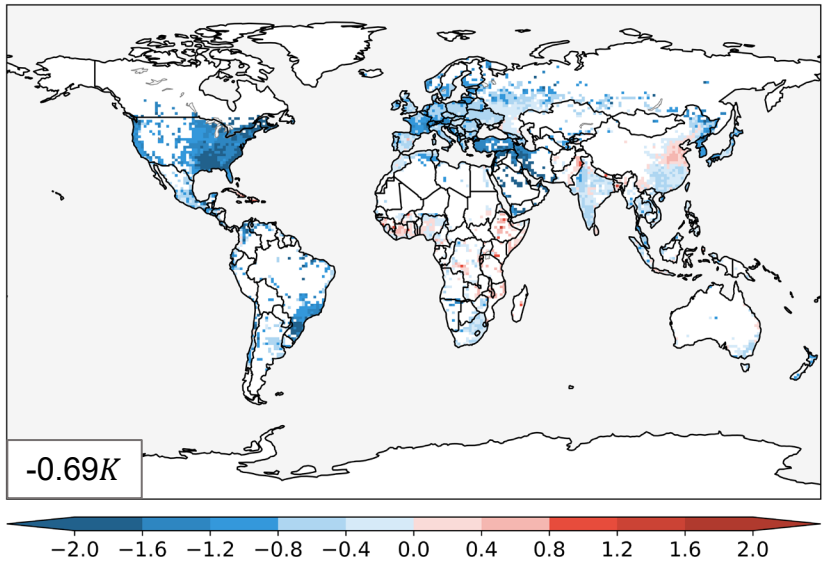
Δ Urban Daily Min Near-surface Air Temperature (K)



Δ Urban Daily Max Near-surface Air Temperature (K)



Δ Urban Skin Temperature (K)

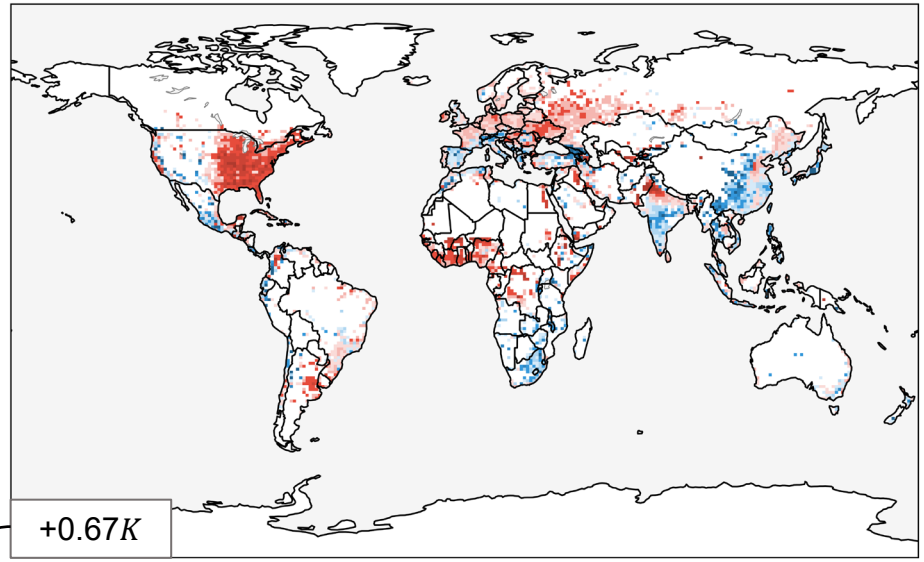


The new dataset can help alleviate the urban warming bias in CESM.

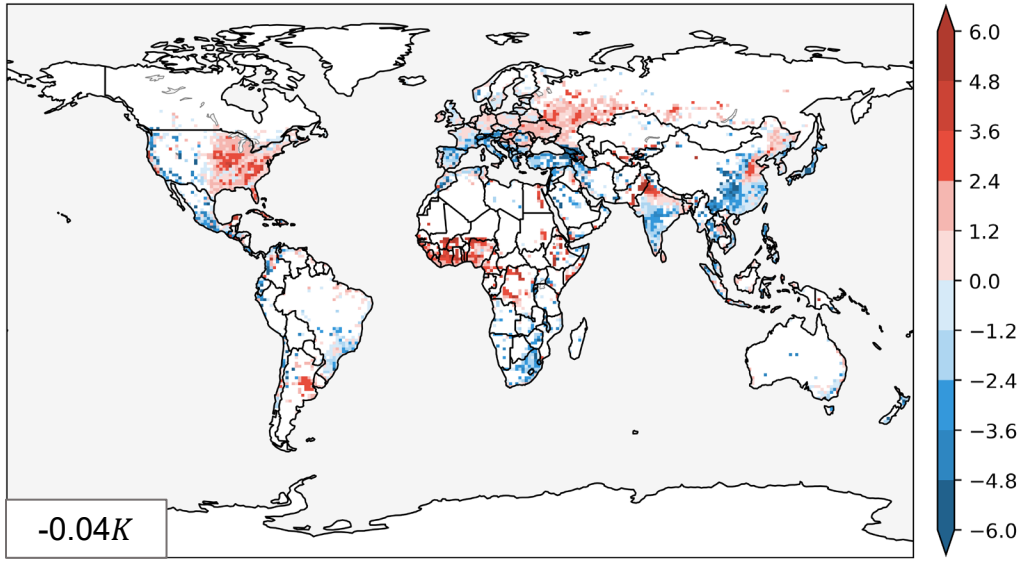
2014 Summer (NH: JJA, SH: DJF)

Urban surface (skin) temperature

CTRL-MODIS

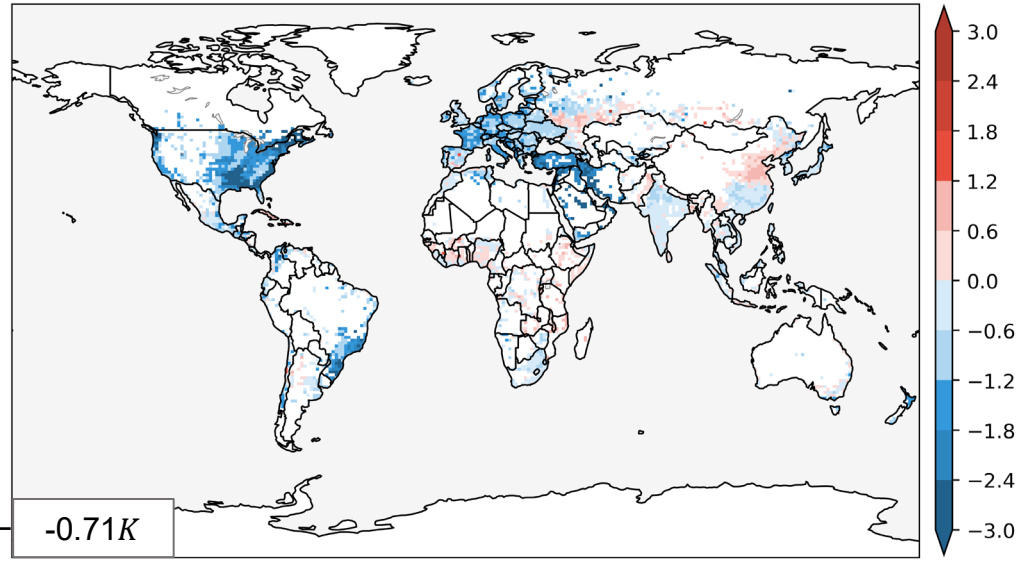


TEST-MODIS



Global average bias

TEST-CTRL

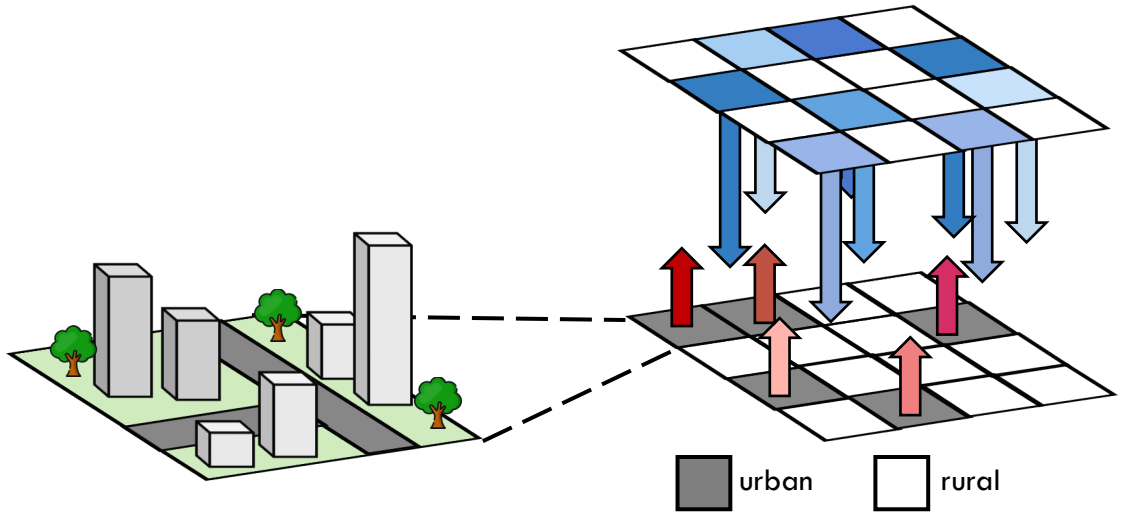


Global average change

Simulation

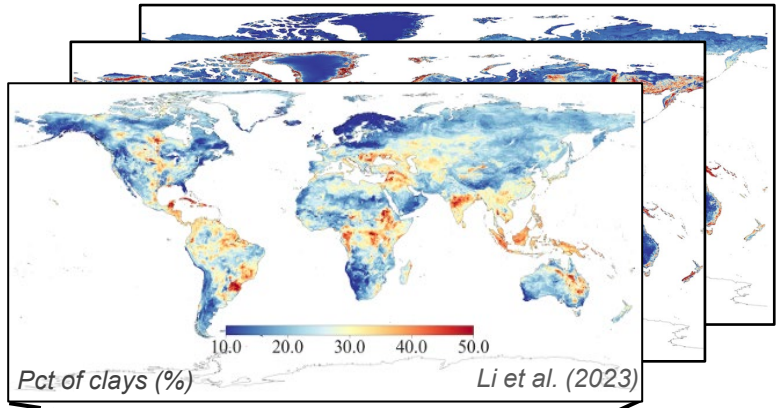
The new dataset has opened up more future opportunities for urban climate and land surface modeling.

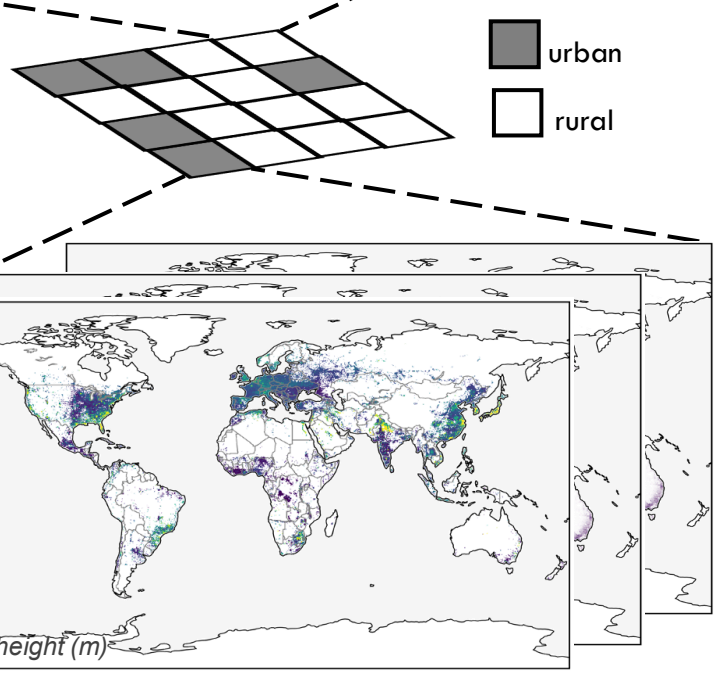
High-res atmospheric forcing



High-res sub-grid structure

Global 1km land surface parameters





Global 1km urban surface parameters: U-SURF

References

1. Gao, J. & O'Neill, B. C. Mapping global urban land for the 21st century with data-driven simulations and Shared Socioeconomic Pathways. *Nat Commun* **11**, 2302 (2020).

2. Jackson, T. L., Feddema, J. J., Oleson, K. W., Bonan, G. B. & Bauer, J. T. Parameterization of Urban Characteristics for Global Climate Modeling. *Annals of the Association of American Geographers* **100**, 848–865 (2010).

3. Lawrence, D. M. *et al.* The Community Land Model Version 5: Description of New Features, Benchmarking, and Impact of Forcing Uncertainty. *Journal of Advances in Modeling Earth Systems* **11**, 4245–4287 (2019).

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5. Li, L., Bisht, G., Hao, D. & Leung, L.-Y. Global 1km Land Surface Parameters for Kilometer-Scale Earth System Modeling. Pacific Northwest National Laboratory 2 https://doi.org/10.25584/PNNLDH/1986308 (2023).

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UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Thanks for listening!

Advancing urban-resolving CESM via a new global high resolution urban dataset

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Land Model Working Group

06/10/24

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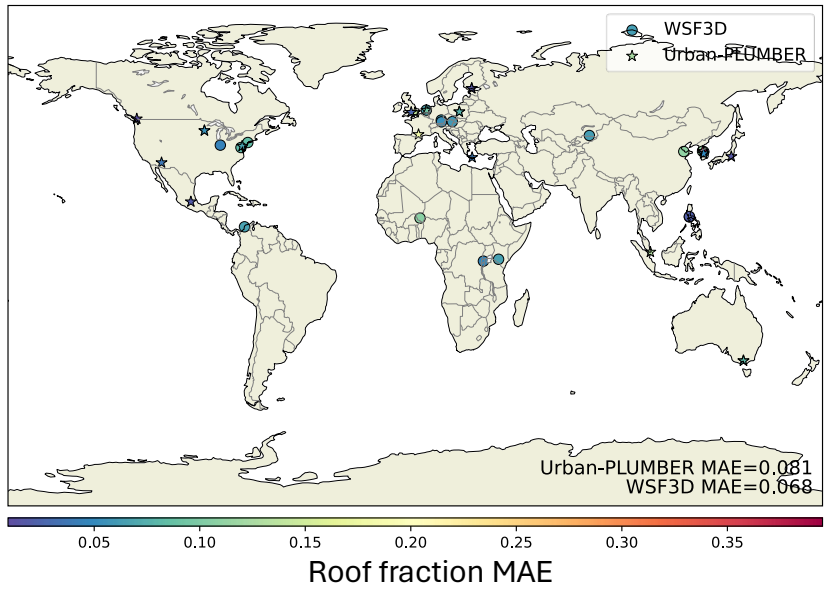
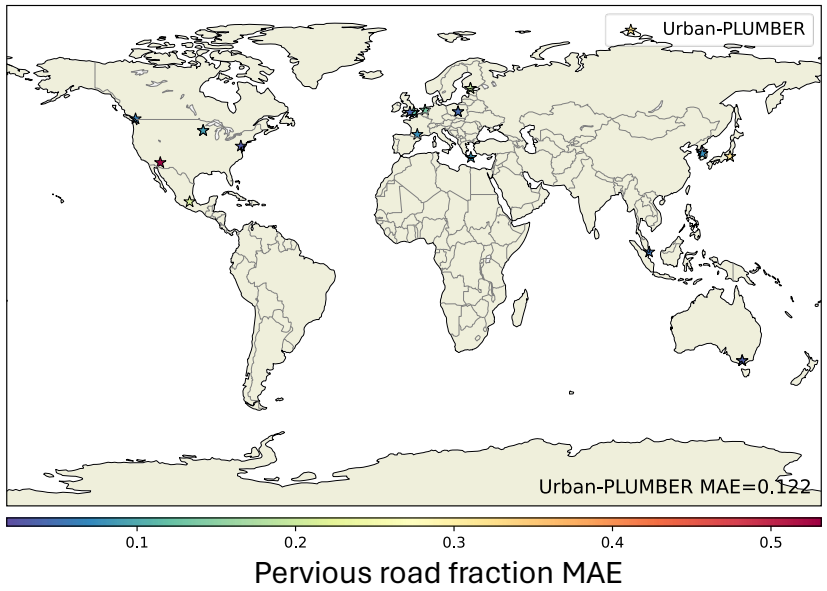
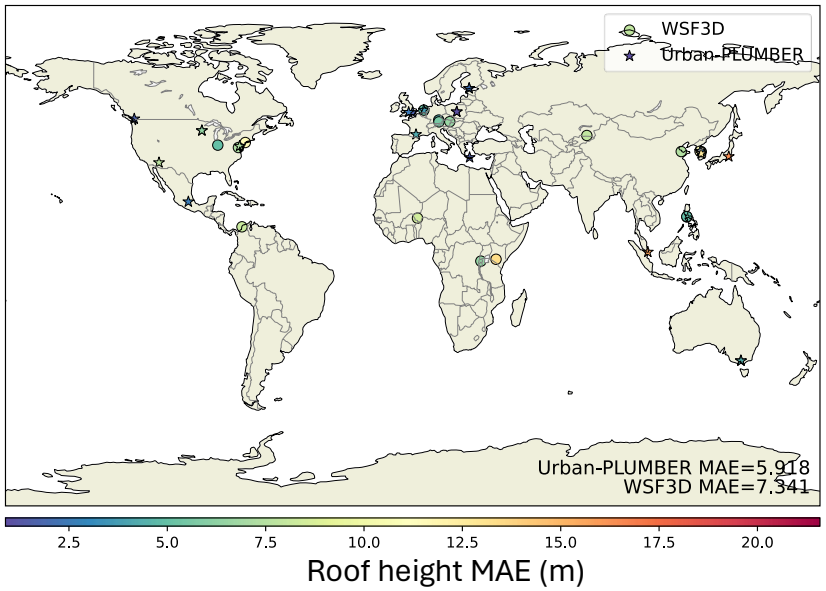
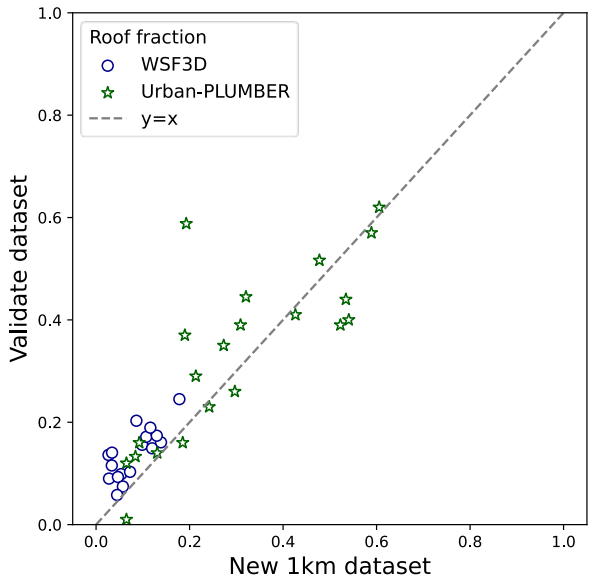
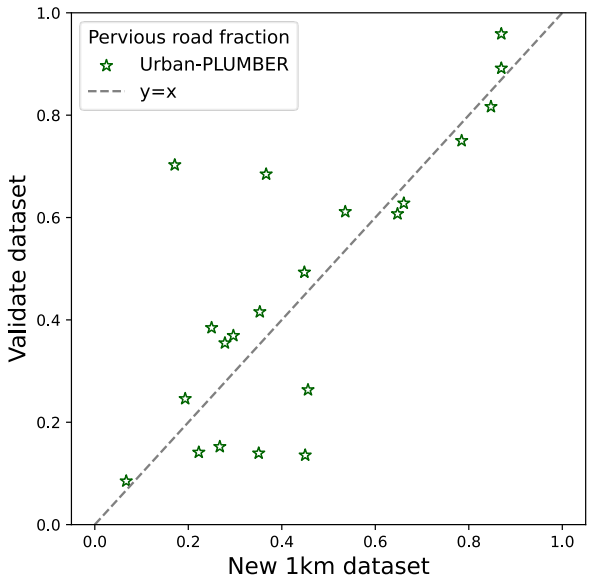
We validated the morphological variables against World Settlement Footprint and Urban-PLUMBER sites.

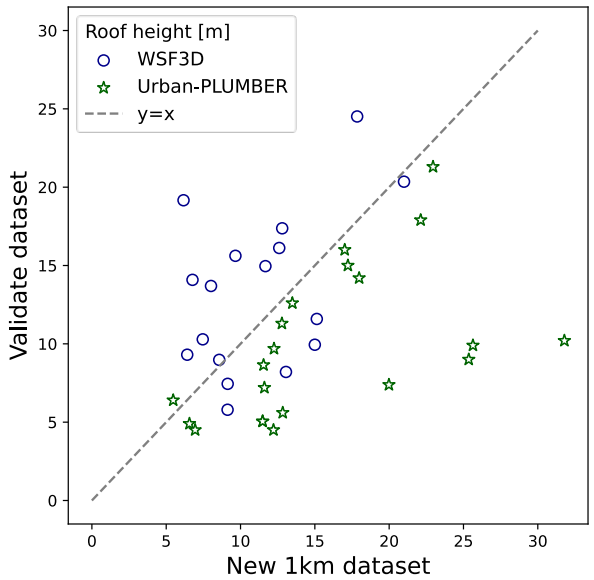




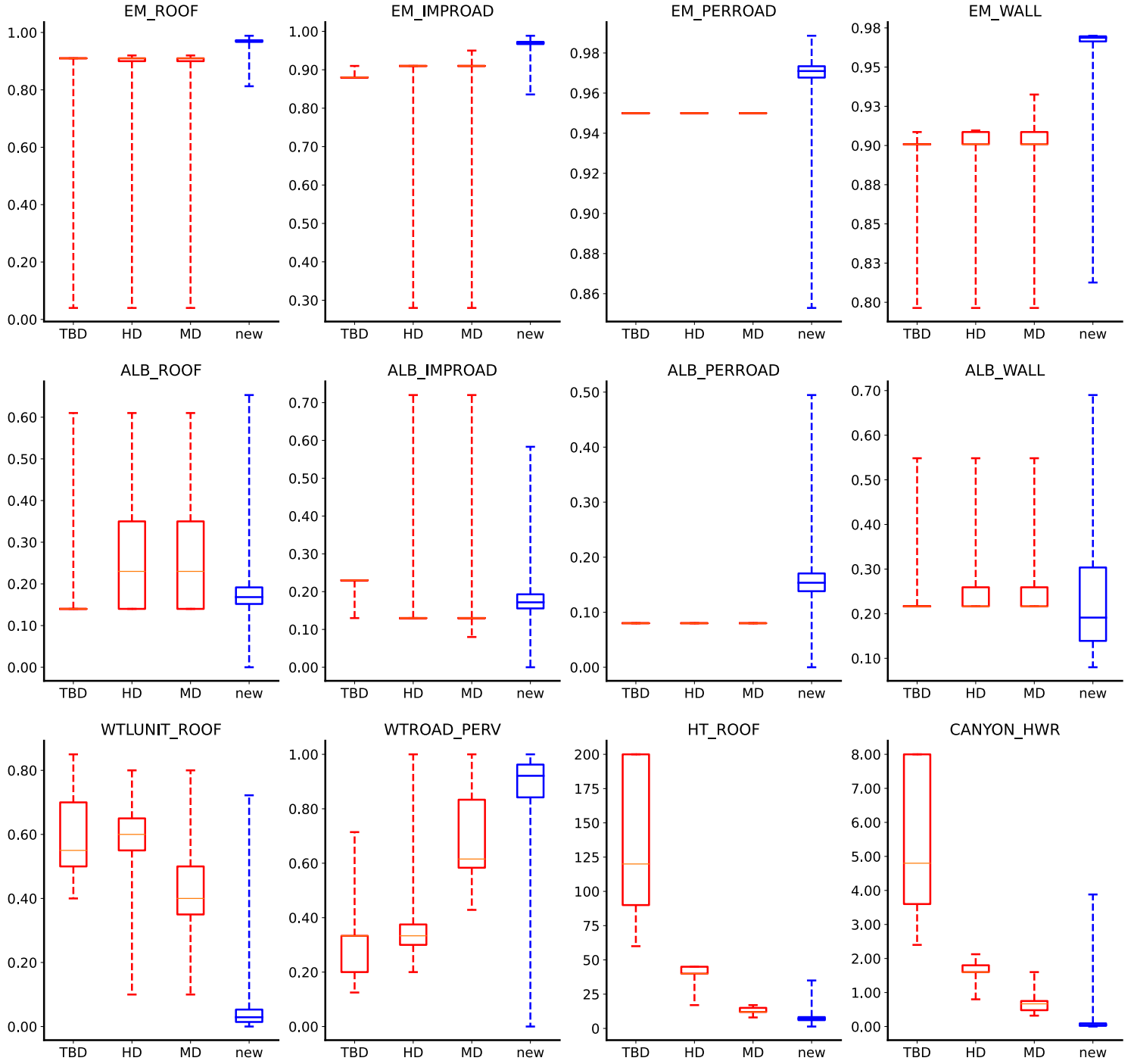








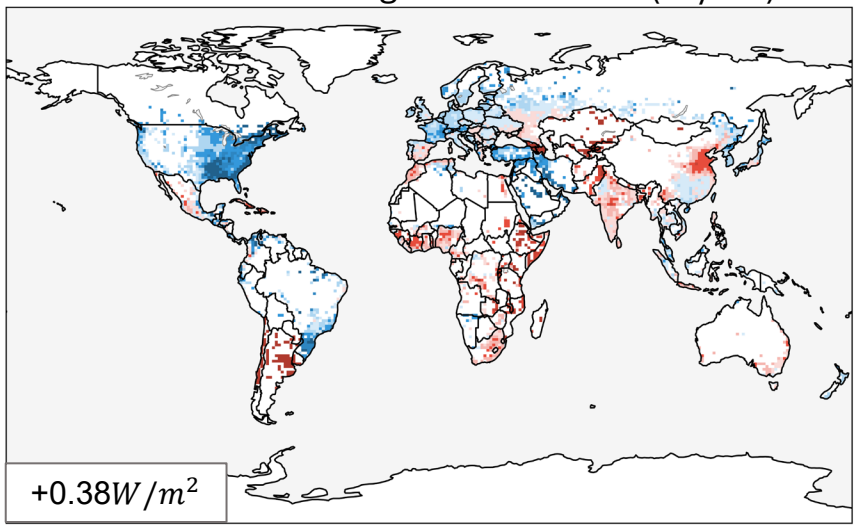
Distribution Boxplots



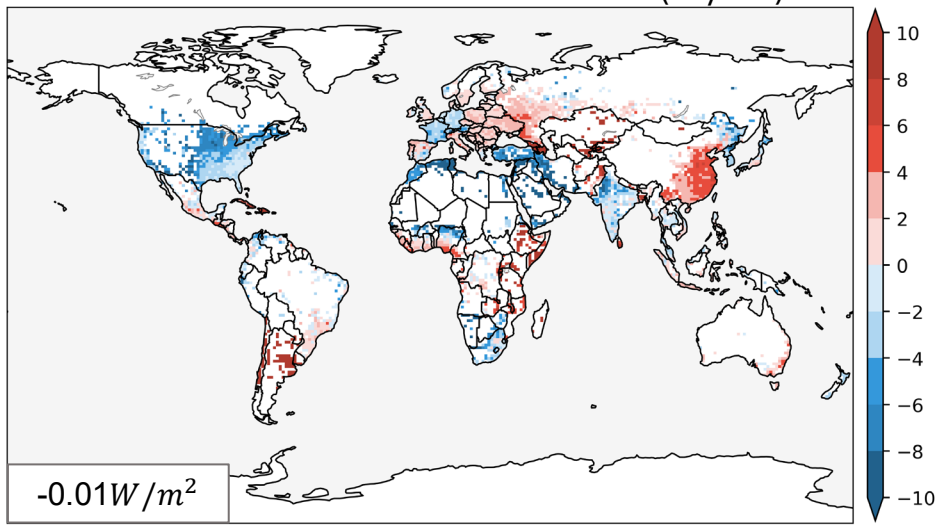
The cooling trend is strongly connected to changes in surface energy fluxes, altered by the new urban surface properties.

TEST-CTRL

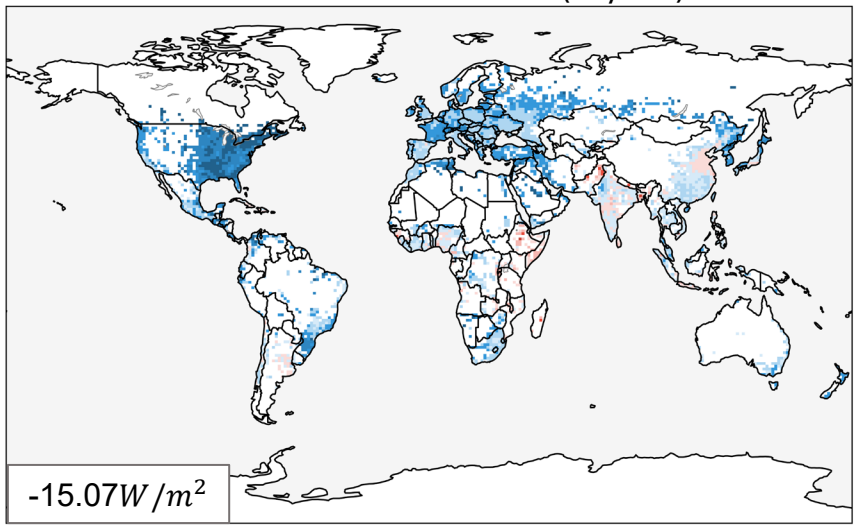
Δ Urban Net Longwave Radiation (W/m^2)



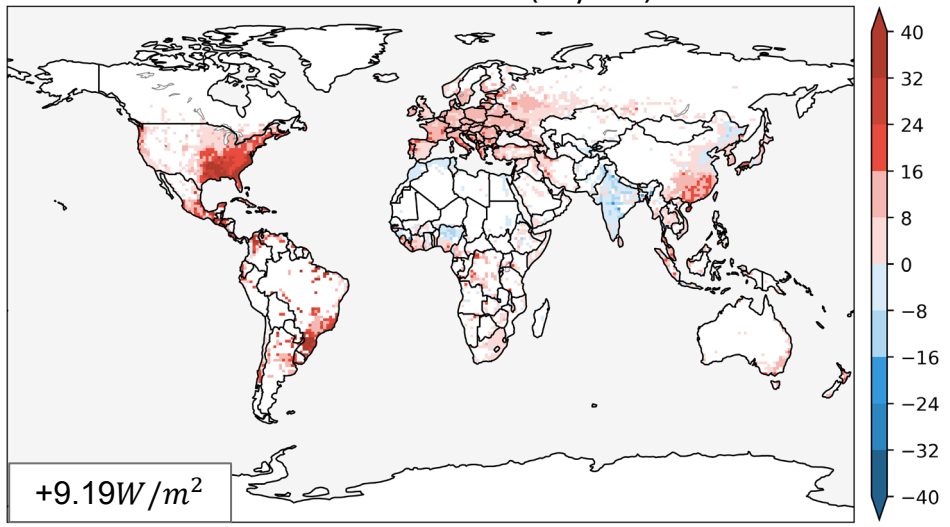
Δ Urban Absorbed Solar Radiation (W/m^2)



Δ Urban Sensible Heat (W/m^2)



Δ Urban Latent Heat (W/m^2)



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