Demonstrating the Added Value of WUDAPT for Urban Modelling

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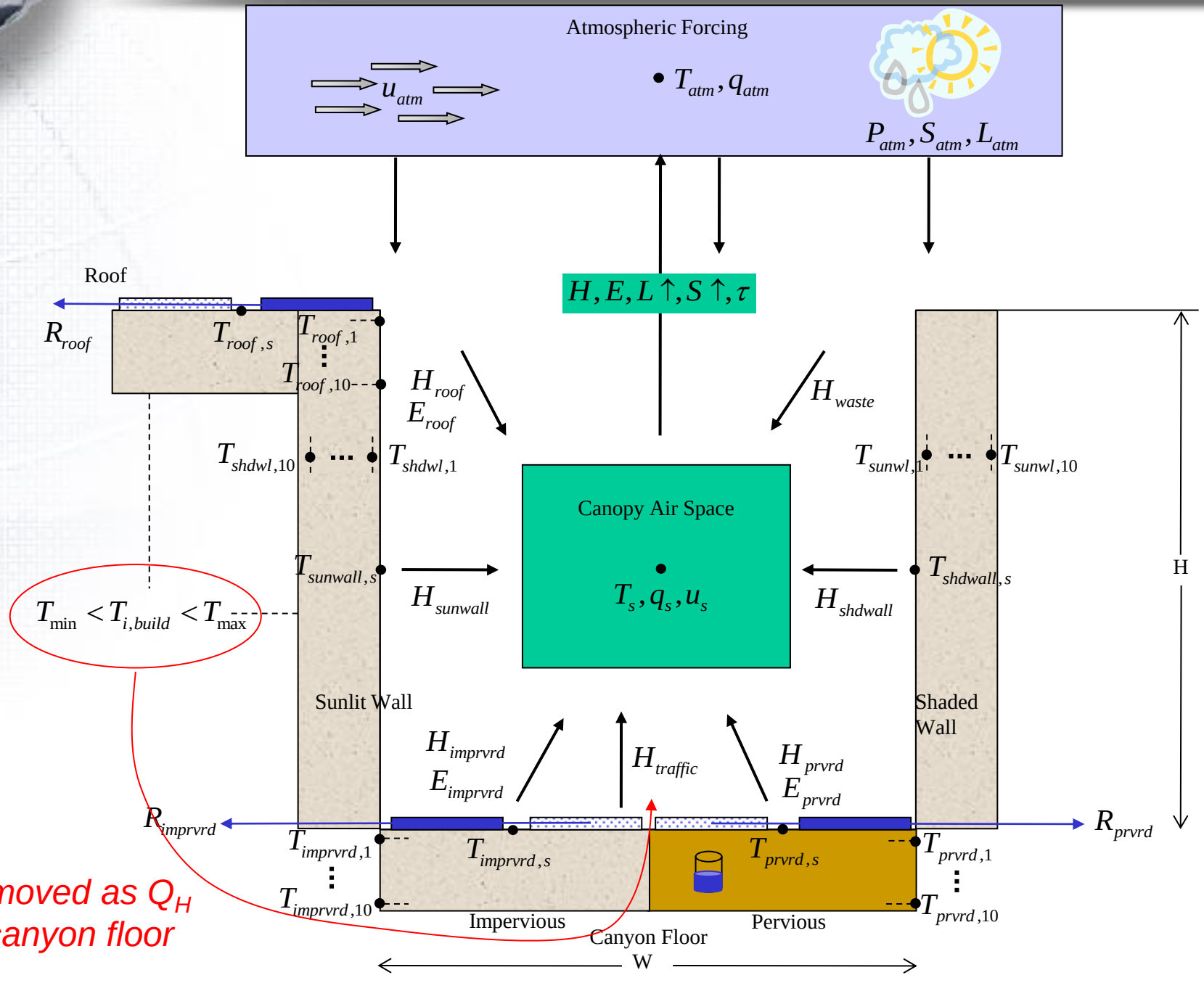
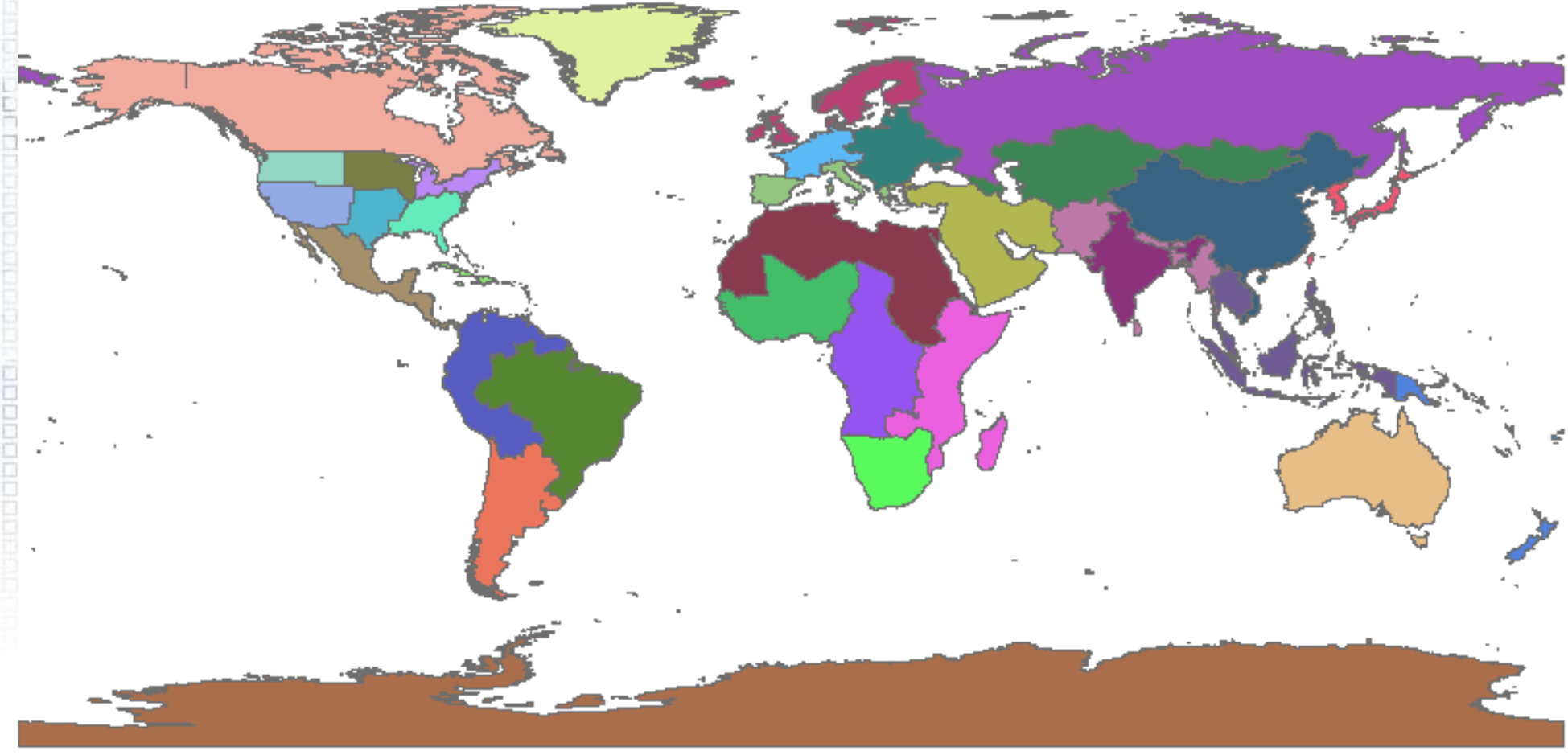
Representing urban areas in ESMs: e.g. CLMU



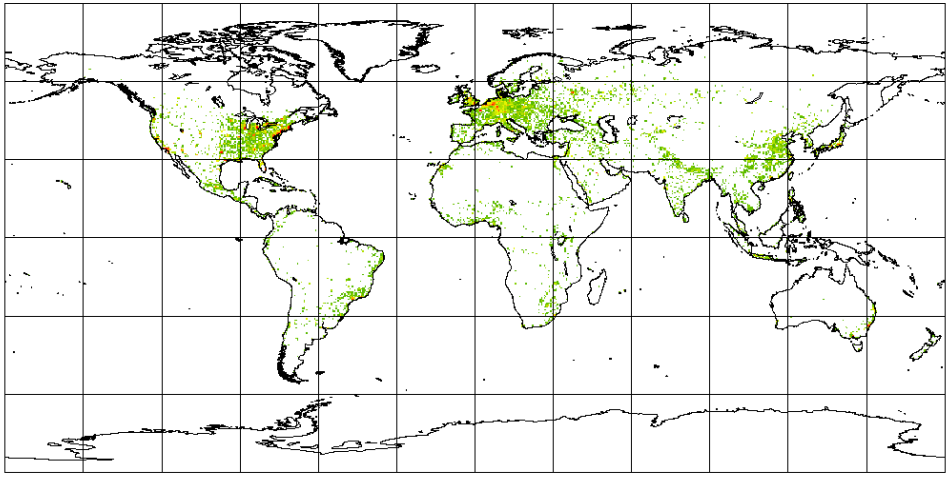
Q_F removed as Q_H from canyon floor

33 Regions With Similar Urban Character



Urban land cover

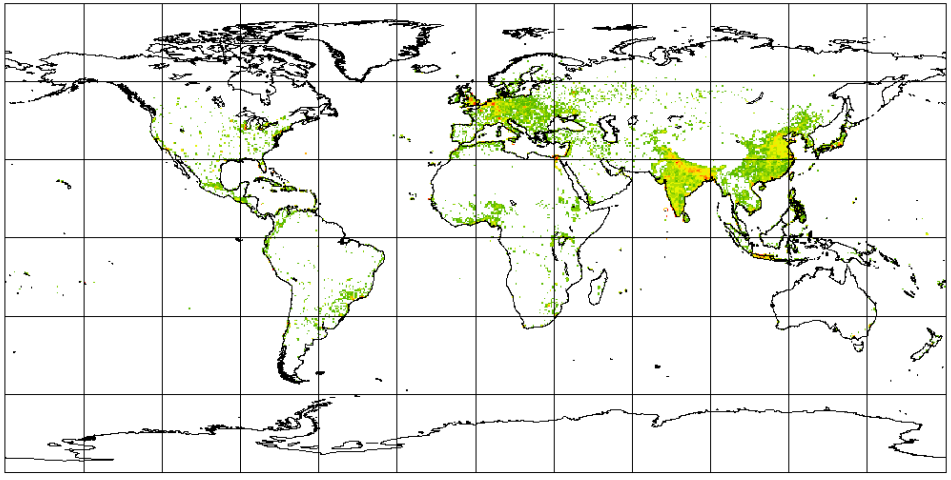
HYDE 3.0



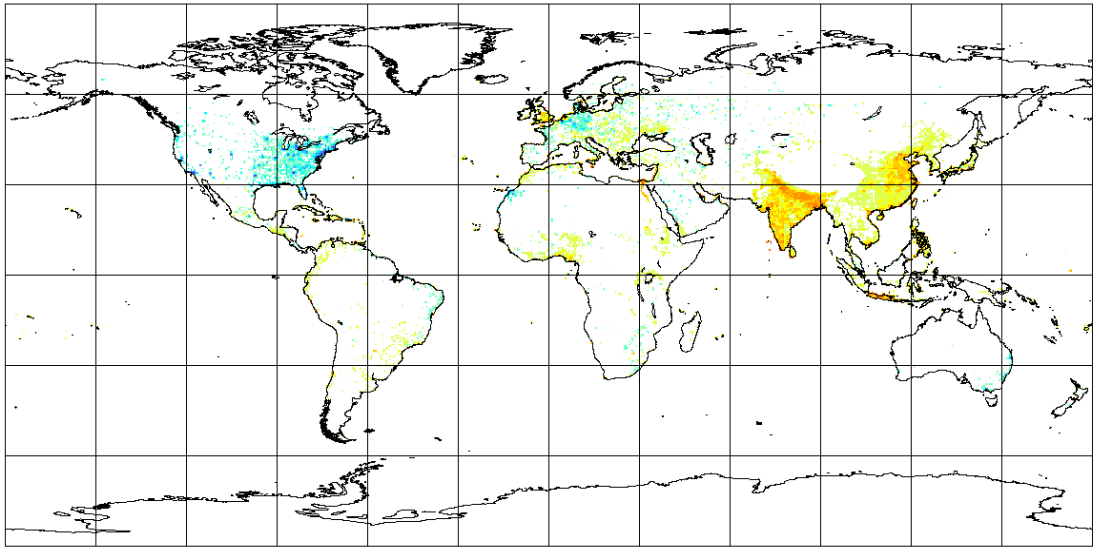
% Grid Cell

- 0
- 0 - 1
- 1 - 2.5
- 2.5 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 30
- 30 - 50
- 50 - 100

Jackson and Feddema 2004



Difference



% Difference

- -100 - -50
- -50 - -25
- -25 - -10
- -10 - -5
- -5 - -2.5
- -2.5 - -0.5
- -0.5 - 0.5
- 0.5 - 2.5
- 2.5 - 5
- 5 - 10
- 10 - 25
- 25 - 50
- 50 - 100

Defining Urban Classes (US)

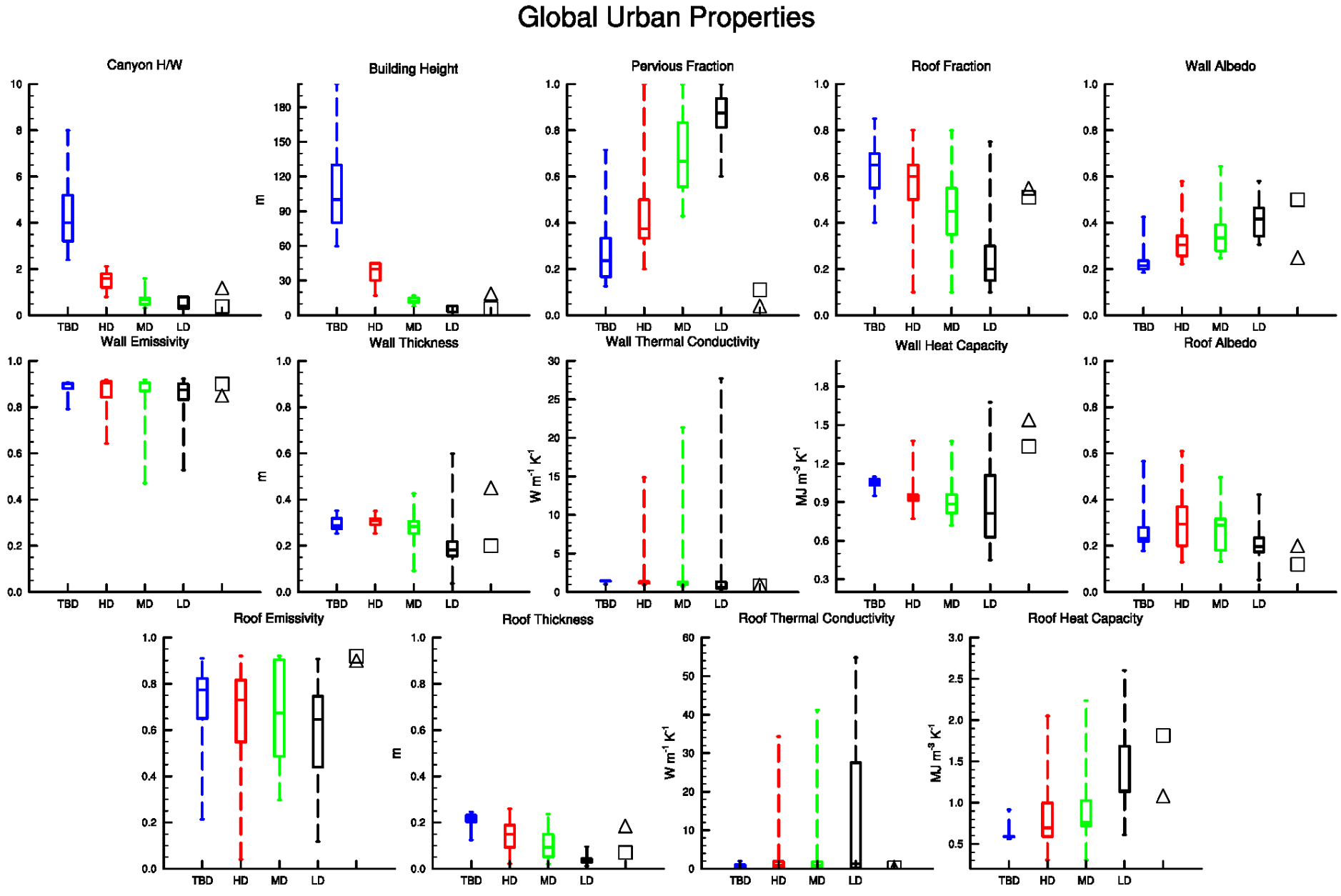
Low Density

Medium Density

High Density

CBD

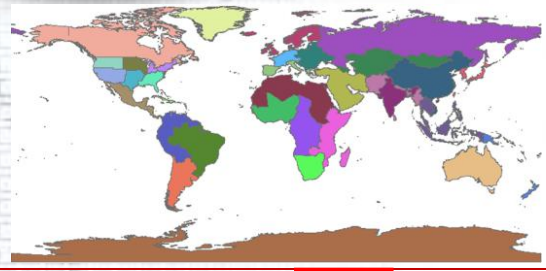
Variables required by the model



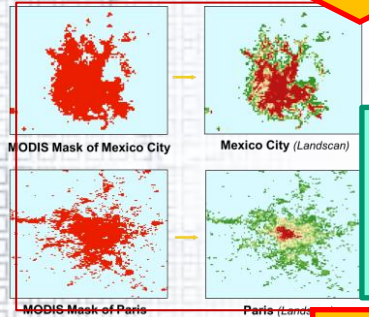
Creating the CLMU input dataset (Version 2)

Spatial data

33 Regions

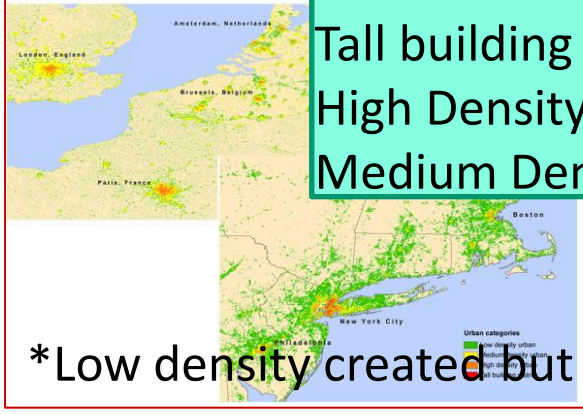


Class delineation



LandScan population data to discriminate urban class

Final Product*



Tall building district
High Density
Medium Density

*Low density created but not used

Urban property data

Urban morphology

> 10 cities used to define urban properties by region

Building types

3 most common wall and 3 most common roof types

Building use properties

AC/heating usage
Interior temperature ranges

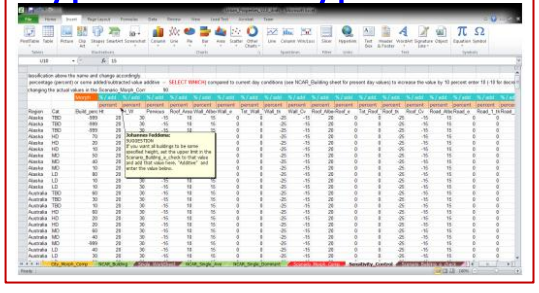
Building material properties

Virtual wall reconstructions including window types
Materials look-up table

Scenario generator

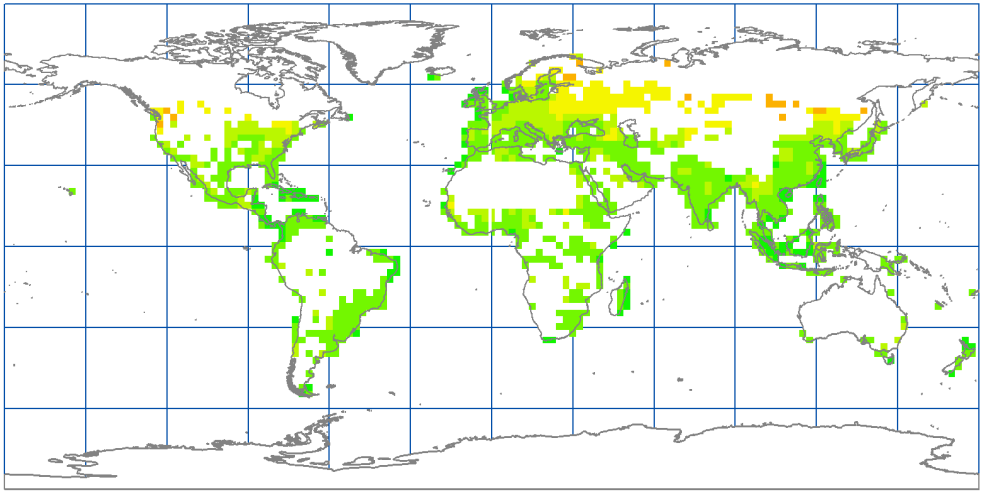
Change wall types, urban morphology and building material properties (IPCC scenarios etc.)

GCM data by Region with 4 Urban types, 3 Building types and typical road type

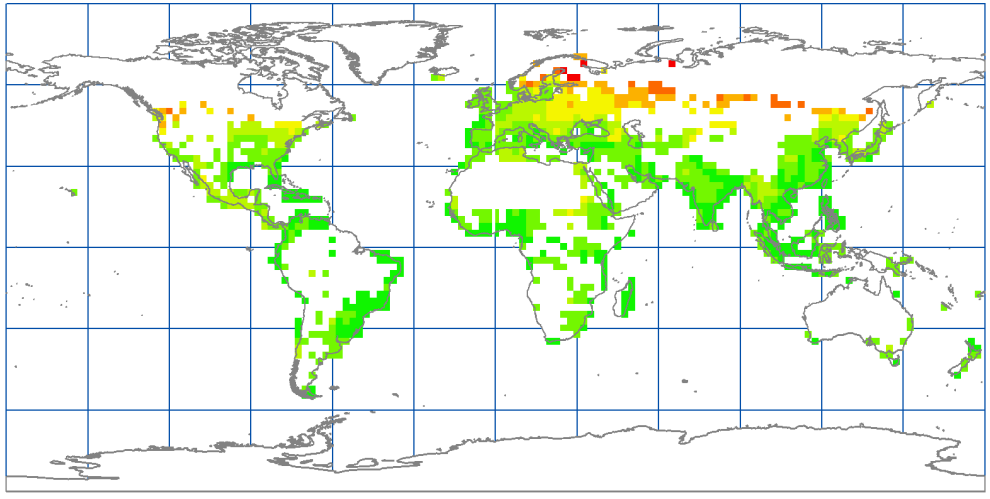


Urban Heat Island Comparison: Parameterization Sensitivity

Vancouver Parameters Applied Globally



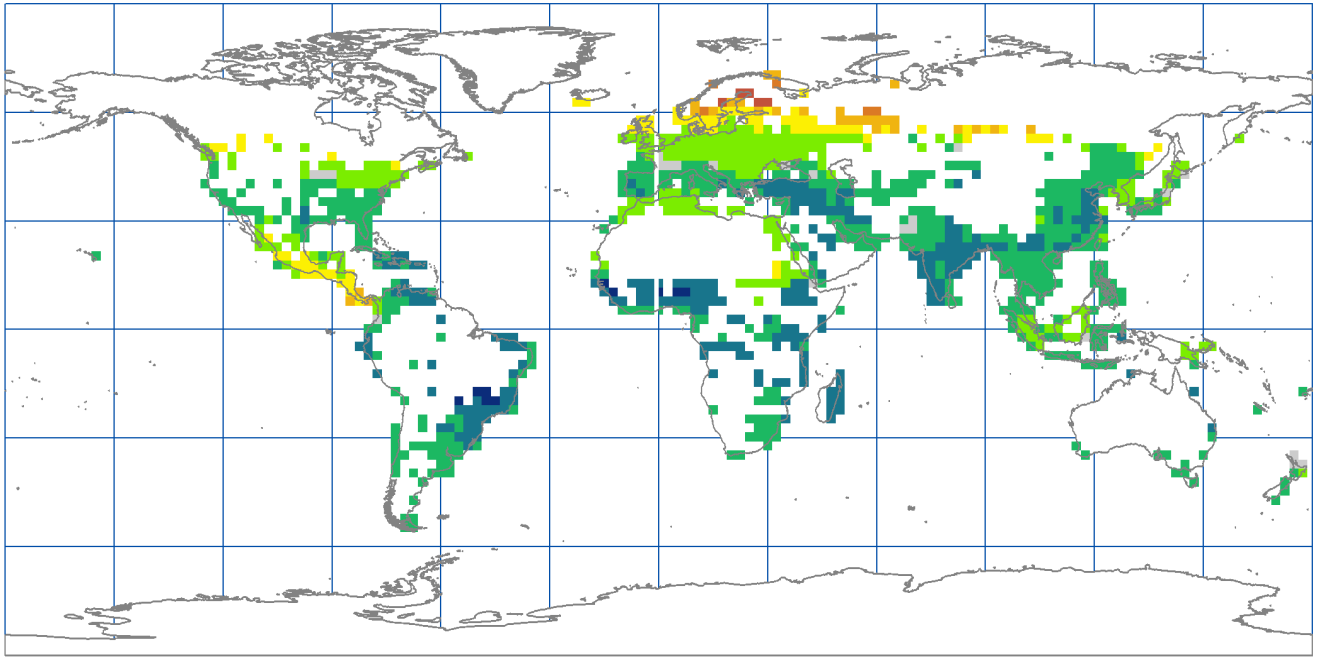
Global Parameter Set



Urban - Rural Temperature Difference (K)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5

Difference: Global - Vancouver



Global - Vancouver UHI Temperature Difference (K)

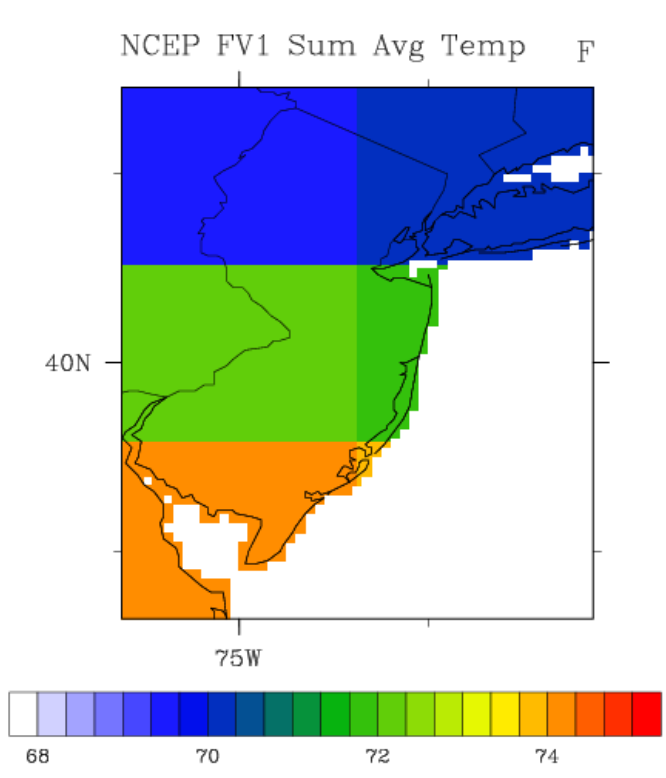
- -0.75 - -0.50
- -0.50 - -0.25
- -0.25 - -0.01
- -0.01 - 0.01
- 0.01 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25

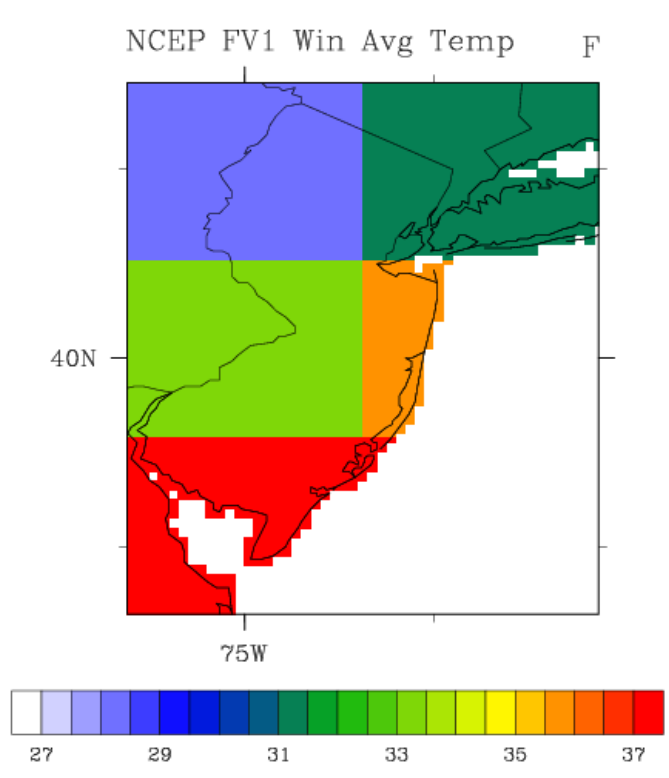
High Resolution Modeling – 1km nested Simulation of North East US

Source:

Peter Lawrence

NCAR





Using CLMU – Example of Climate Mitigation

Assessing how a change in one urban property impacts energy consumption

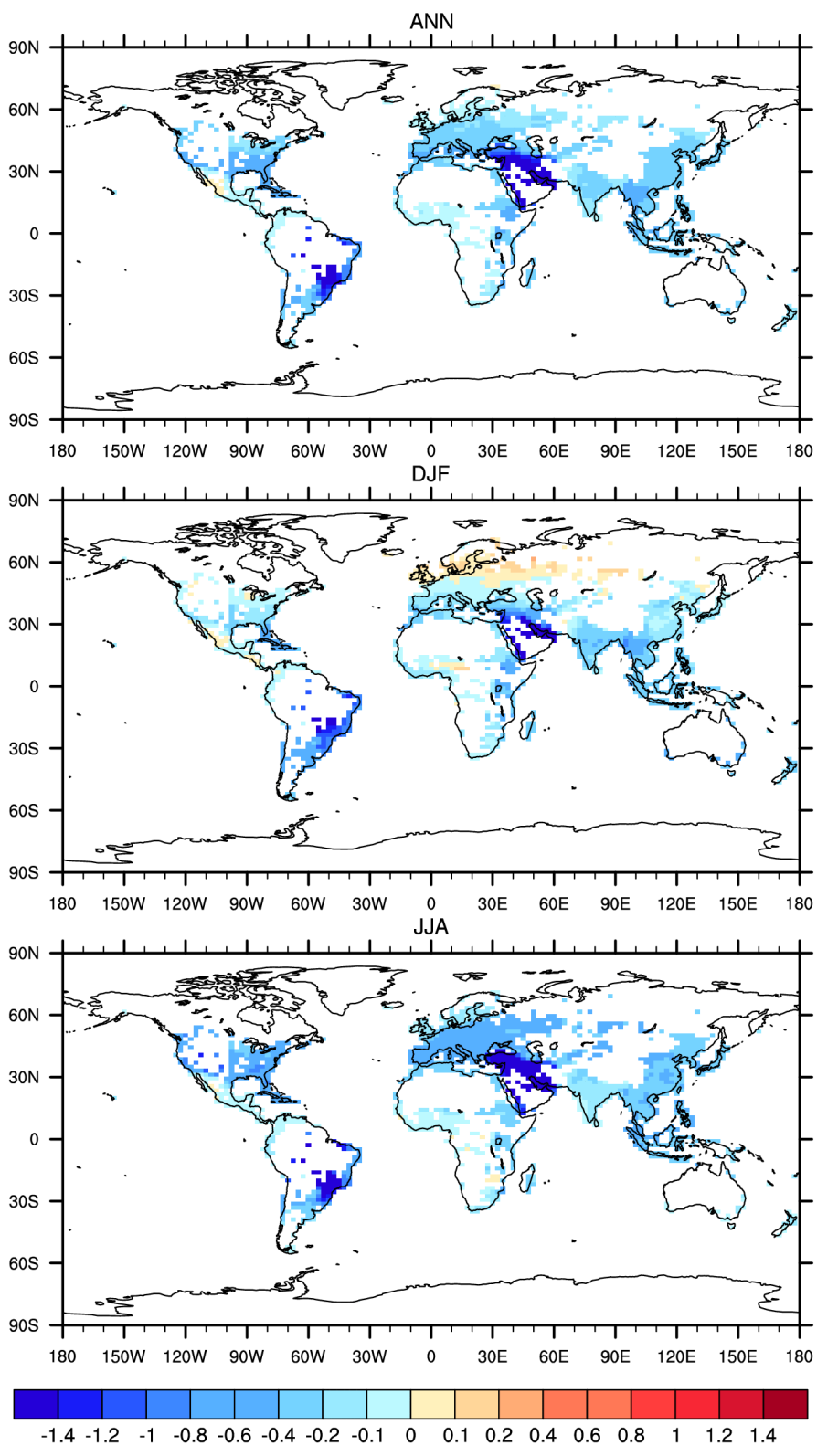
Motivation:

"*If you look at all the buildings and if you make the roofs white and if you make the pavement more of a concrete type of colour rather than a black type of colour and if you do that uniformally, that would be the equivalent of... reducing the carbon emissions due to all the cars in the world by 11 years – just taking them off the road for 11 years*,"

U.S. energy secretary, Professor Steven Chu, highlighting research by Akbari et al. [2009] who calculated that increasing the albedo of urban roofs and pavements globally could produce a negative radiative forcing equivalent to a 44 Gt CO2 emission offset [TimesOnline, 2009].

White Roof Experiment

White roof - Control simulations of the urban heat island (urban minus rural air temperature) for 1980-1999 annual (ANN), DJF, and JJA climatology (°C). Land areas displayed in white are grid cells that have zero urban fraction in the model.



White Roof Experiment: Change in Global Energy Demand

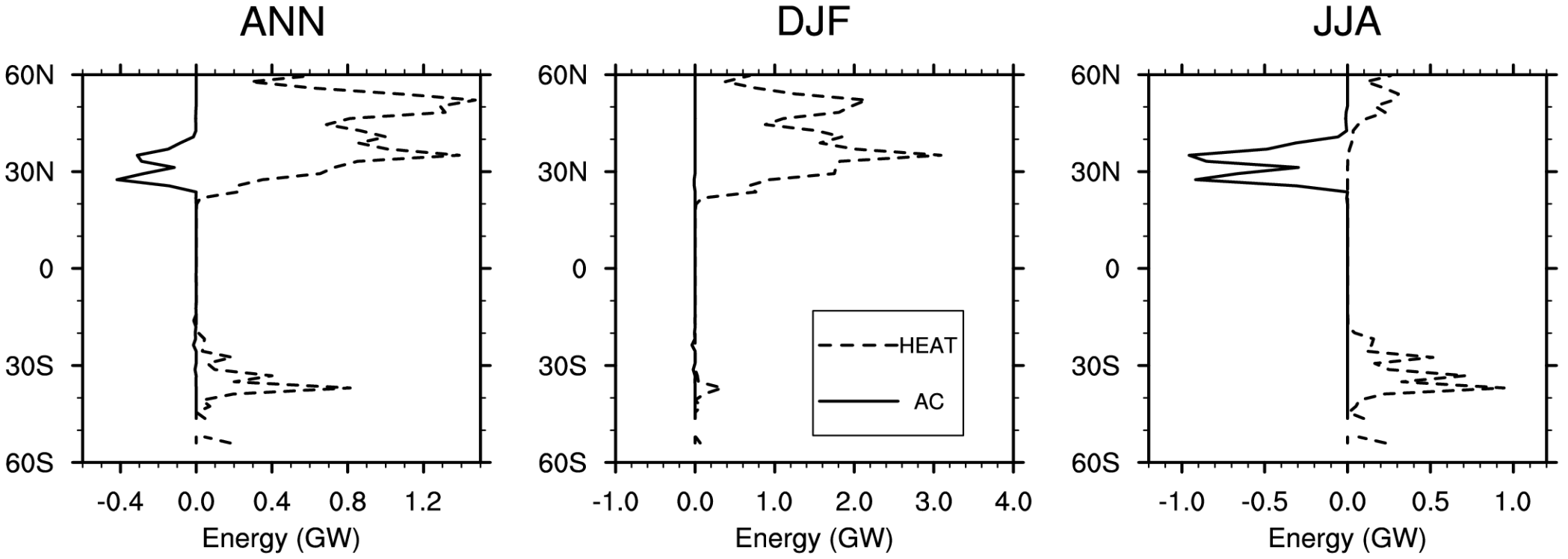


Figure 4. Zonal means of ALB minus CON simulations of urban space heating (HEAT) and air conditioning (AC) energy for 1980-1999 annual, DJF, and JJA climatology (gigawatts).

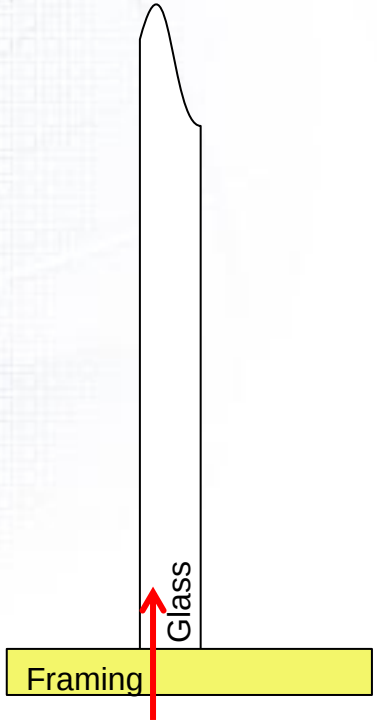
Conclusion:

The globally averaged annual air conditioning demand decreases from 0.09 TW in the CON simulation to 0.02 TW in the ALB simulation, while space heating demand increases from 5.61 TW to 6.30 TW. Thus, the total **global energy demand increases by 0.62 TW** from 5.70 TW to 6.32 TW.

Improved facet representation (e.g. windows)

Policy choices with respect to windows

Single Pane Window



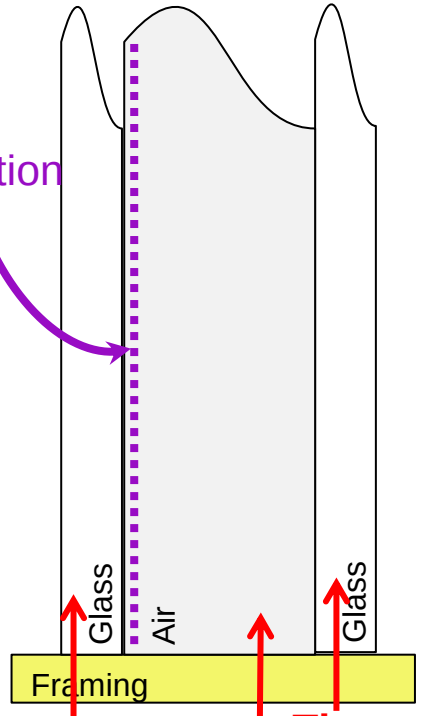
Thermal conductivity 1.29 $Wm^{-1}K^{-1}$

Double Pane Window

Laminar Coating

Affect long- and short-wave radiation independently with respect to:

- Transmissivity
- Absorbtivity
- Reflectivity



Thermal conductivity 1.29 $Wm^{-1}K^{-1}$

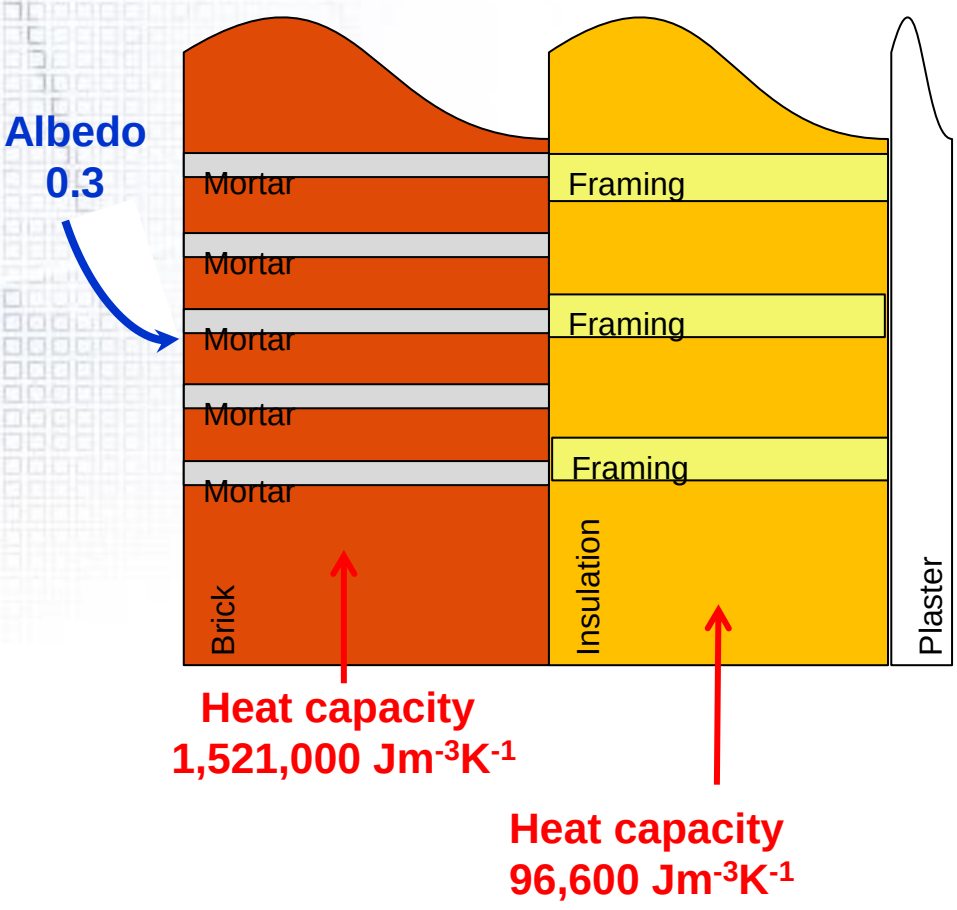
Thermal Conductivity 0.03 $Wm^{-1}K^{-1}$

Thermal conductivity 1.29 $Wm^{-1}K^{-1}$

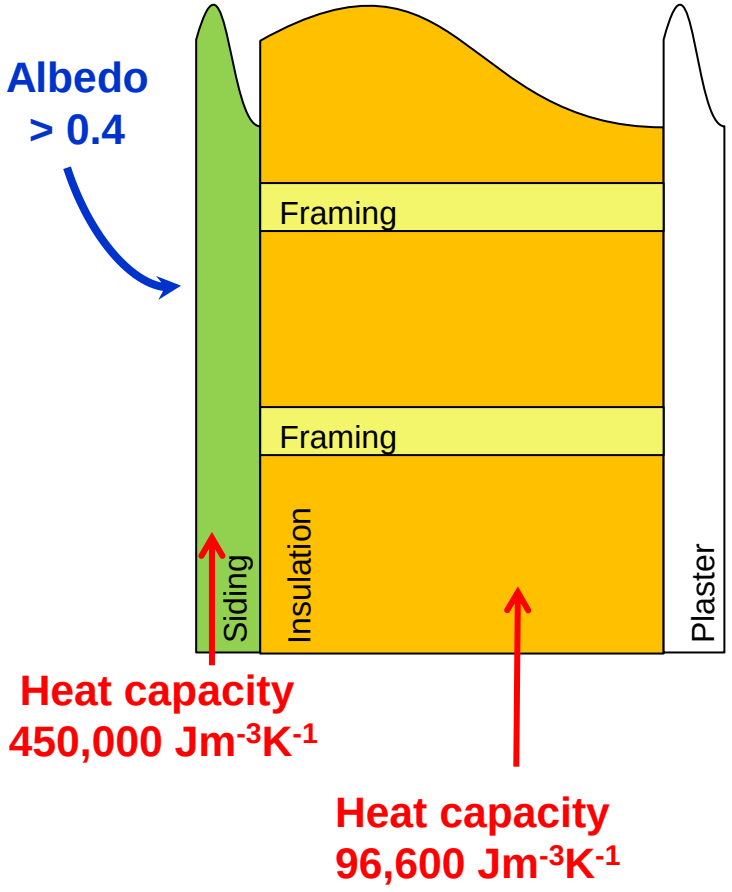
Wall examples

Policy choices with respect to wall types

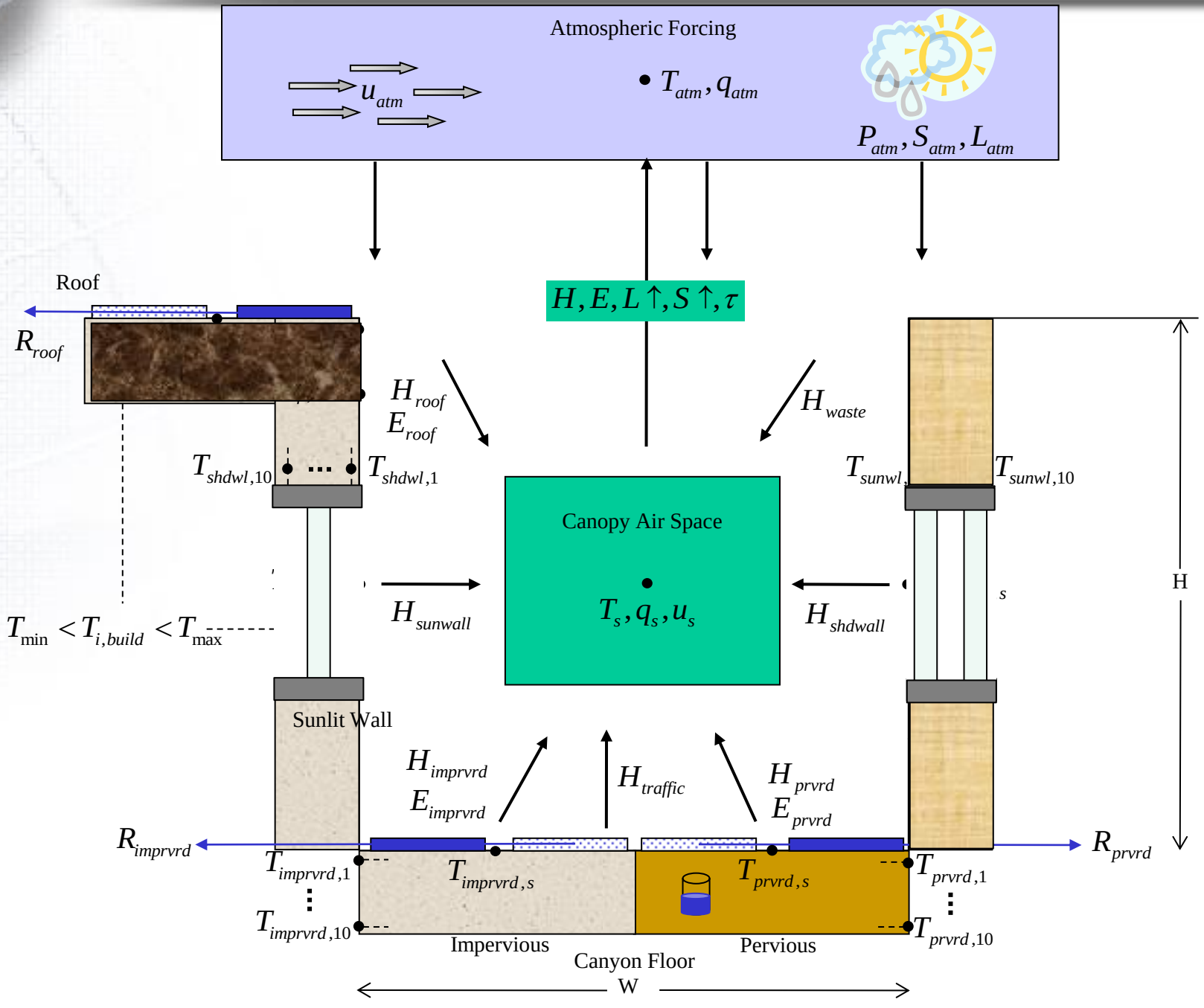
Brick (veneer) wall



Siding wall



CLMU and sensitivity analyses



Some consideration about this approach

- This a top down approach to gather urban properties
  - Very generalized
  - Arbitrary regions
- Need better information on building types and materials
- Need data from under-represented regions
- Need to put more thought into how the models are used and how to improve assessment that incorporates input information

WUDAPT contribution

- Replace the 3 urban classes with LCZ types as appropriate
- Link LCZs to walls by region based on currently identified regional wall types
- Use GeoWiki to get better idea of common wall and window types
- Use GeoWiki to get socio economic and cultural norms (temperature settings; land use layer information – irrigation and other urban features)

Creating the CLMU input dataset (Version 3?)

Spatial data

33 Regions

Redefine regions possibly to city level

Urban property data

Urban morphology

LCZ

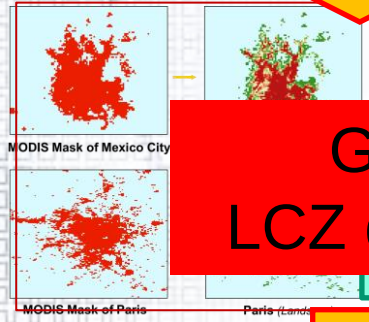
properties by region

Building types

GeoWiki photo/ crowd source App

roof types

Class delineation



GeoWiki LCZ delineation

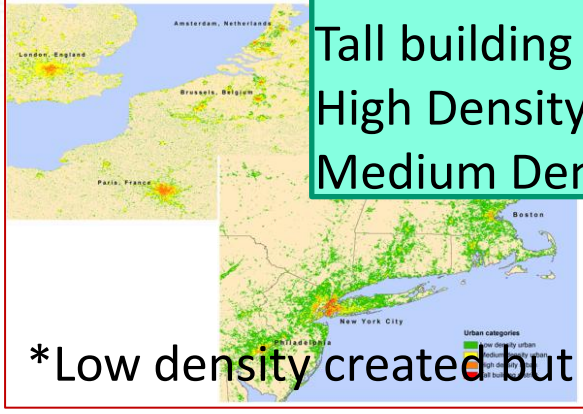
Building use properties

GeoWiki quiz/ Crowd source App

Building material properties

Link wall types and building use to LCZ delineations

Final Product*



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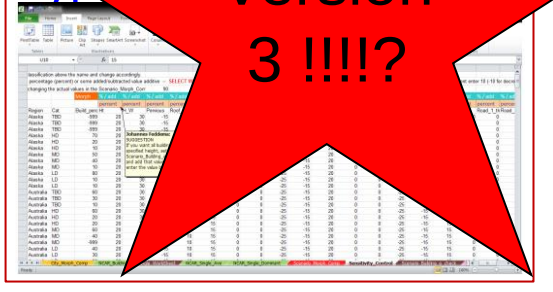
GCM data by region with 4 Urban types, 3 Building types



Version 3 !!!!?

What Information do we need?

Urban Function

Variable	Pt/area	priority	metric	Source	LCZ estimate	Aggregation	Existing Proxy data
Building Use Commercial/Residential/ Industrial/Office/Mixed etc.	Point	High	Drop down choice/other	Subjective	No		
Irrigation	Point	Medium	Yes/no	Subjective	No		satellite
Road type (main artery etc)	Point	Low	Drop down choice/other	Subjective	No		
Temperature setting	Point	High	Tmin/Tmax (°C) or F	Subjective	No		
Occupancy	Point	Low		Subjective	No		
Practices: AC	Point	High	Yes/no	Subjective	No		
Practices: Shutters/shading	Point	Medium	Drop down choice/other	Subjective	No		
Practices: Window opening	Point	Low	Yes/no	Subjective	No		
Building age	Point	Medium	date	Subjective	No		
Building renovation ?Post 1990?	Point	Medium	Yes/no	Subjective	No		

What Information do we need?

Urban Form: Cover

Variable	Pt/area	priority	metric	Source	LCZ estimate	Aggre gation	Existing/ Proxy data
Building fraction	Area	High	No. Floors/Ht. of floor				satellite
Vegetated fraction	Area	High	Fraction/percent				satellite
Road fraction	Area	High	Fraction/percent				
Water fraction	Area	High	Fraction/percent				satellite
Vegetation organization Street trees/ garden/ agriculture etc	Point	Medium	Drop down choice/other (type)	Photo			satellite
Vegetation type	Point	Medium	Drop down choice/other (PFT)	Photo			satellite

What Information do we need?

Urban Form: Geometry (WUDAPT)

Variable	Pt/area	priority	metric	Source	LCZ estimate	Aggregation	Existing/ Proxy data
LCZ	Area	High					
Height	Point	High	No. Floors/Ht. of floor	Photo	No		
Width of Streets	Point	Medium	meters	Photo	Yes		
Contiguous/isolated buildings	Point	Medium	Yes/Now	Photo	Yes/No		
Roof geometry	Point	Low	Drop down choice/other	Photo	No		

What Information do we need?

Urban Form: Material

Variable	Pt/area	priority	metric	Source	LCZ estimate	Aggregation	Existing/ Proxy data
Wall type	Point	High	Drop down choice/other	Subjective	No		
Roof type	Point	High	Drop down choice/other	Subjective	No		
Window type	Point	Medium	Drop down choice/other	Subjective			
Road type	Point	Low	Drop down choice/other	Subjective			
Window fraction on wall	Point	Medium	Fraction/percent	Subjective			
Color/Albedo	Point	Medium	Drop down choice/other	photo			

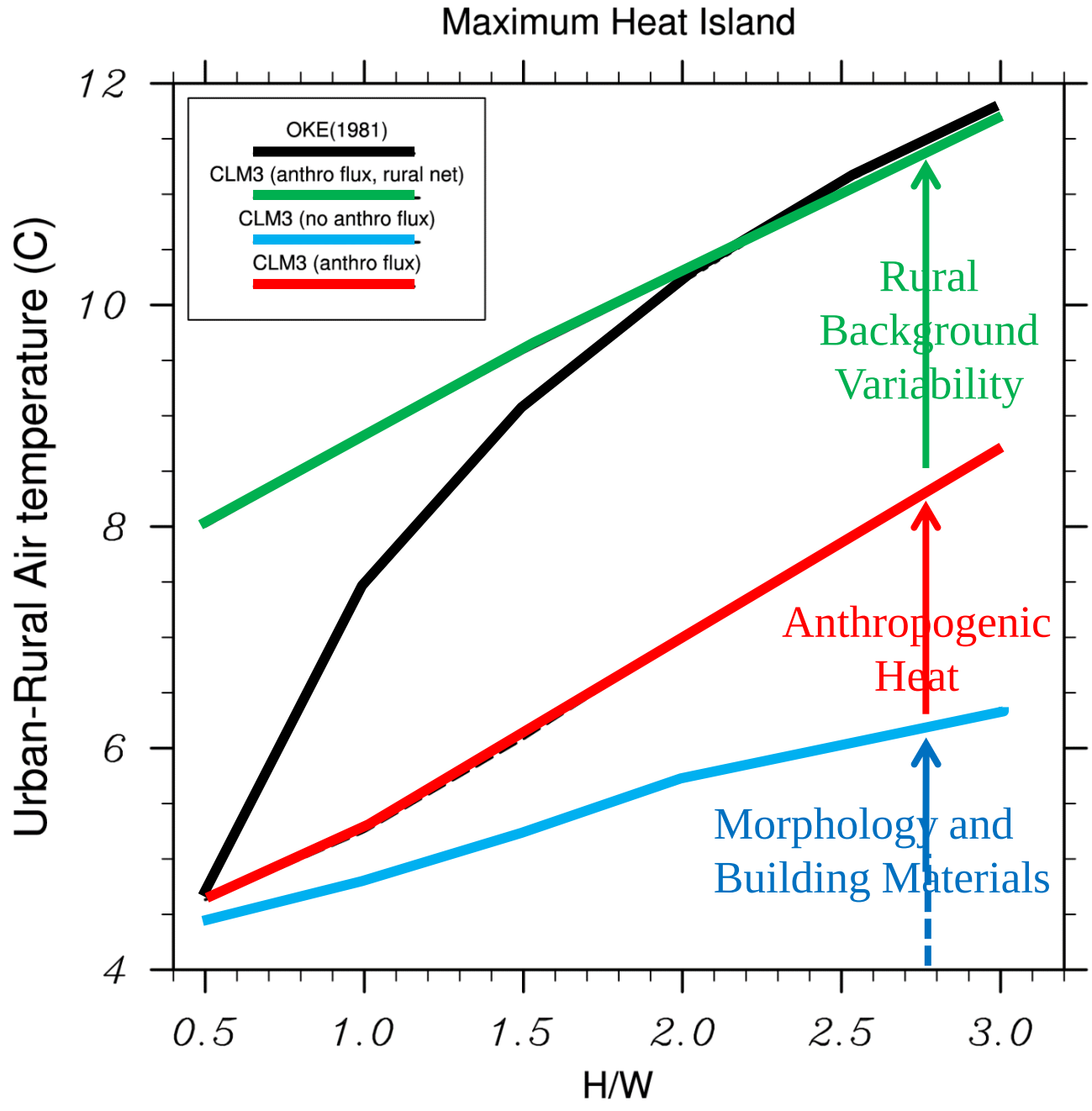
Validation

What are some issues that the modeling community has with respect to validation?

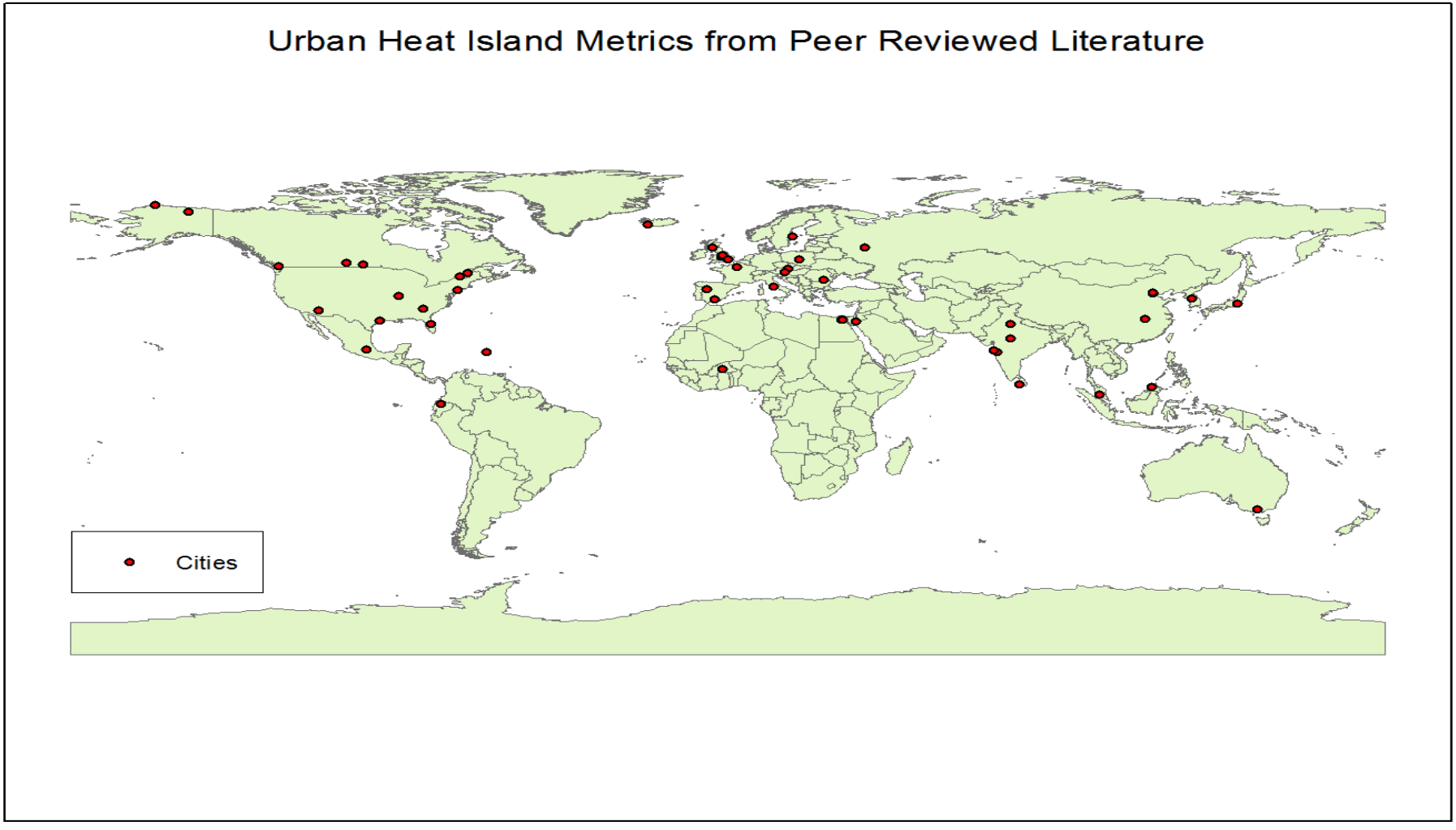
- Representative rural areas?
- UHI climatologies
- Satellite vs other temperature metrics

Influence of anthropogenic heat flux and rural vegetation type on simulations

Maximum annual heat island intensity (urban minus rural air temperature) produced by the urban model for a North American mid-latitude site (40N, 75W) compared to **Oke (1981)** (Equation 1). Model results are shown for no anthropogenic flux (**no anthro flux**), with anthropogenic flux (**anthro flux**), and with anthropogenic flux and rural site modeled as needleleaf evergreen tree (**anthro flux, rural needleleaf evergreen tree**).



Validation – Surface air temperature observations From Stewart and Oke 2012 and other source

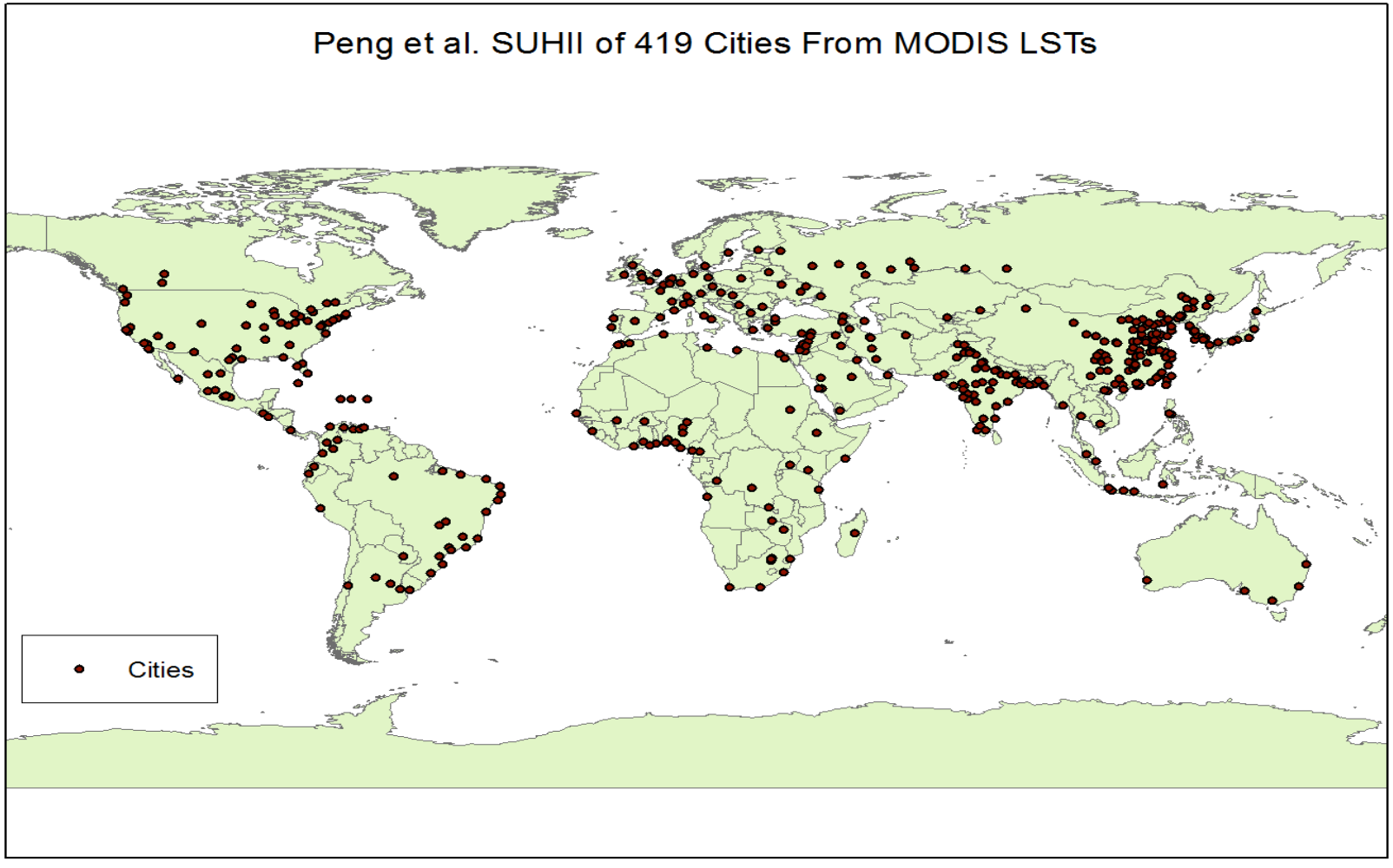


Validation – air temperature observations

Conditions

- Need to be published in peer reviewed articles
- Need to be climatological (at least one month of observations)
- If appropriate monthly observations are aggregated to seasonal and annual if seasonal/annual data are not reported

Validation – Satellite temperature observations 419 cities from Ping et al. 2012

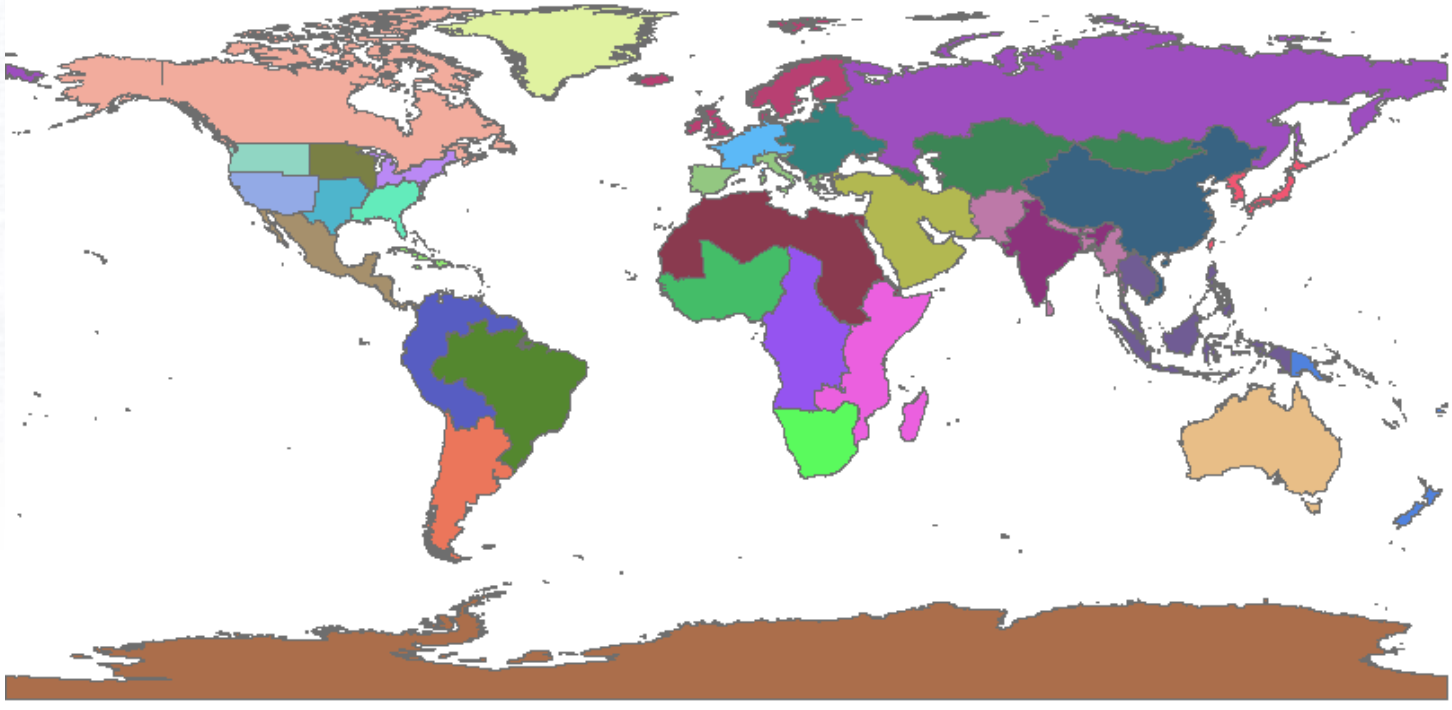


Validation – satellite

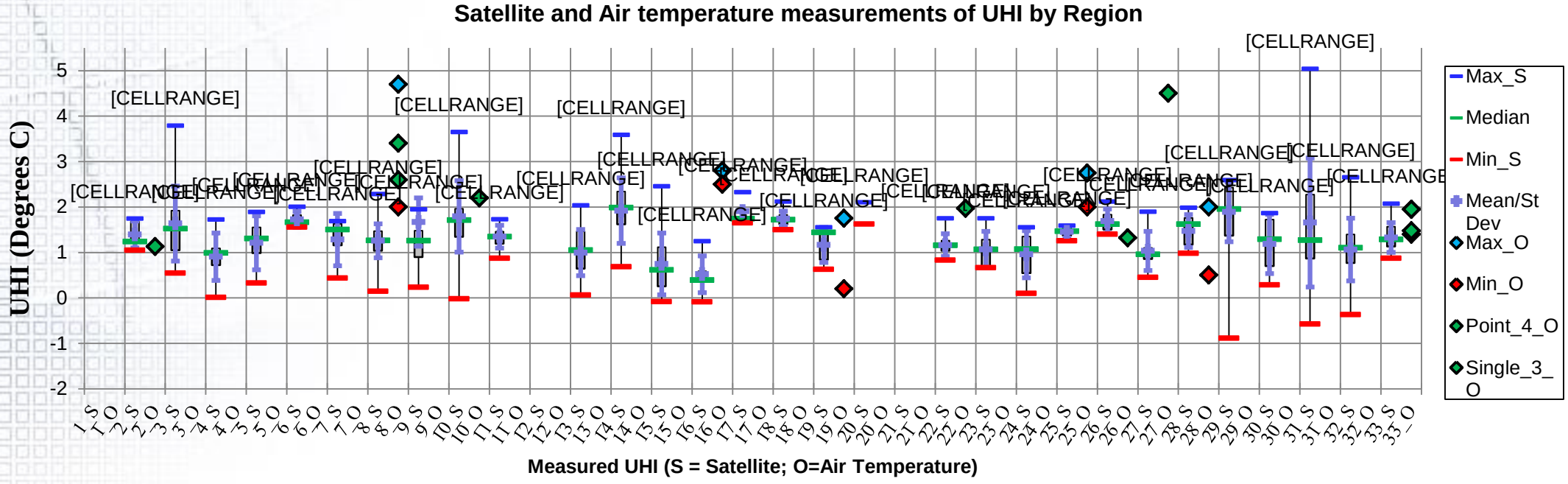
Conditions

- 419 cities from Ping et al. 2012
- Daytime and nighttime observations reported
- For now average daytime and nighttime observations (consider passover times)
- See Hu et al. for potential other issues with these data (time of day and observation angle)

Regions for which data are aggregated



Results


Satellite and Air temperature measurements of UHI by Region
UHI (Degrees C)
5
4
3
2
1
0
-1
-2
[CELLRANGE]
Max_S
Median
Min_S
Mean/St Dev
Max_O
Min_O
Point_4_O
Single_3_O
Measured UHI (S = Satellite; O=Air Temperature)

Questions?