

IOWA STATE UNIVERSITY

Dept. of Geological & Atmospheric Sciences

Improved Understanding of Urbanization for IA Building Energy Use Modeling

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Ohio State University

NOAA National Geophysical Data Center

Outline

❖ **Building energy use modeling**

- Global building energy use
- US 50-state building energy use
- China building energy use

❖ **Global urbanization modeling**

- Urban area mapping
- Urbanization dynamics
- Future urbanization

❖ **Challenges**

BUILDING ENERGY USE MODELING

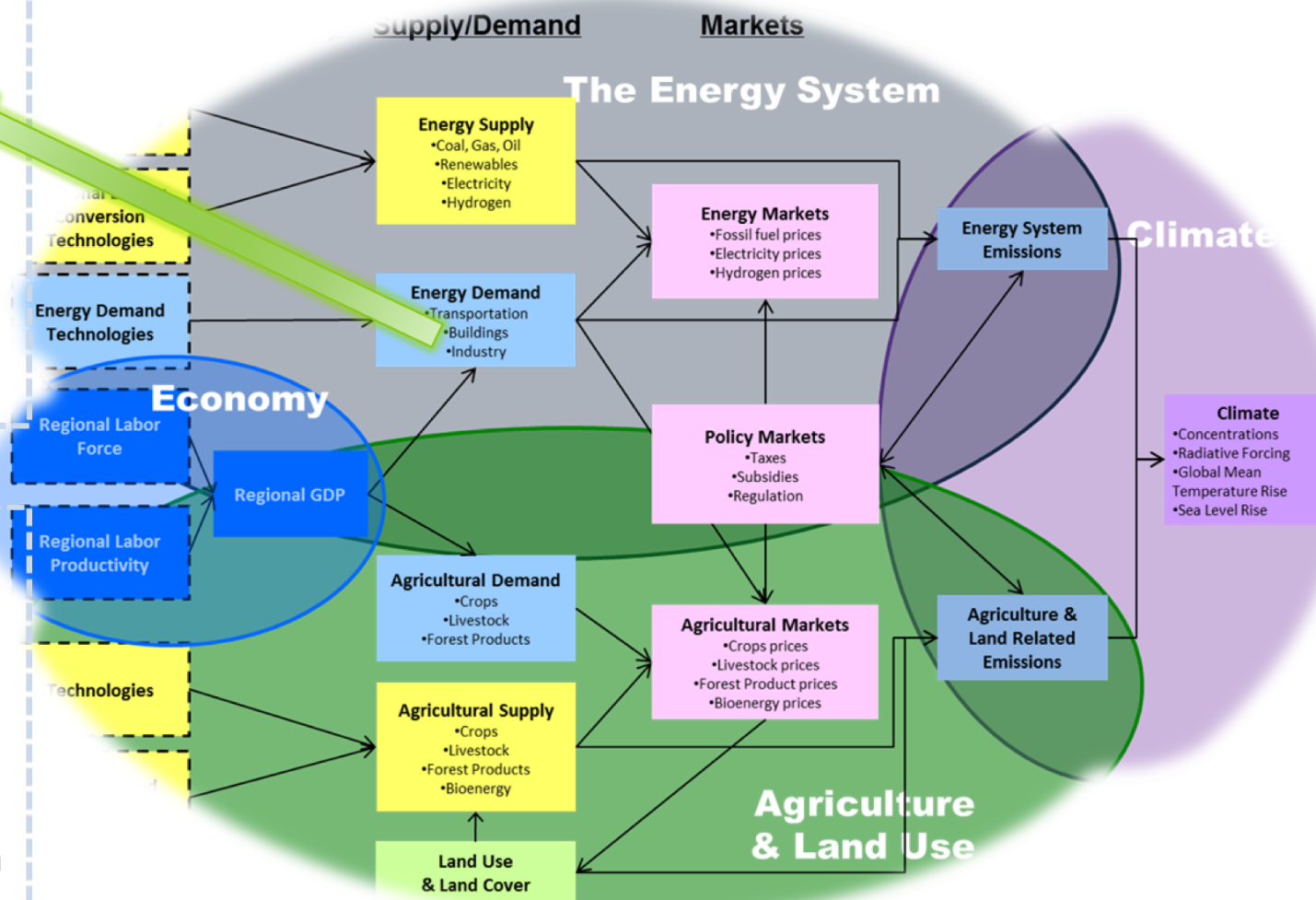
GCAM Human and Earth Systems

Buildings

- ❖ 2005 to 2100 in 5 year time-steps
- ❖ 14 global regions
- ❖ 151 agricultural and ecological zones

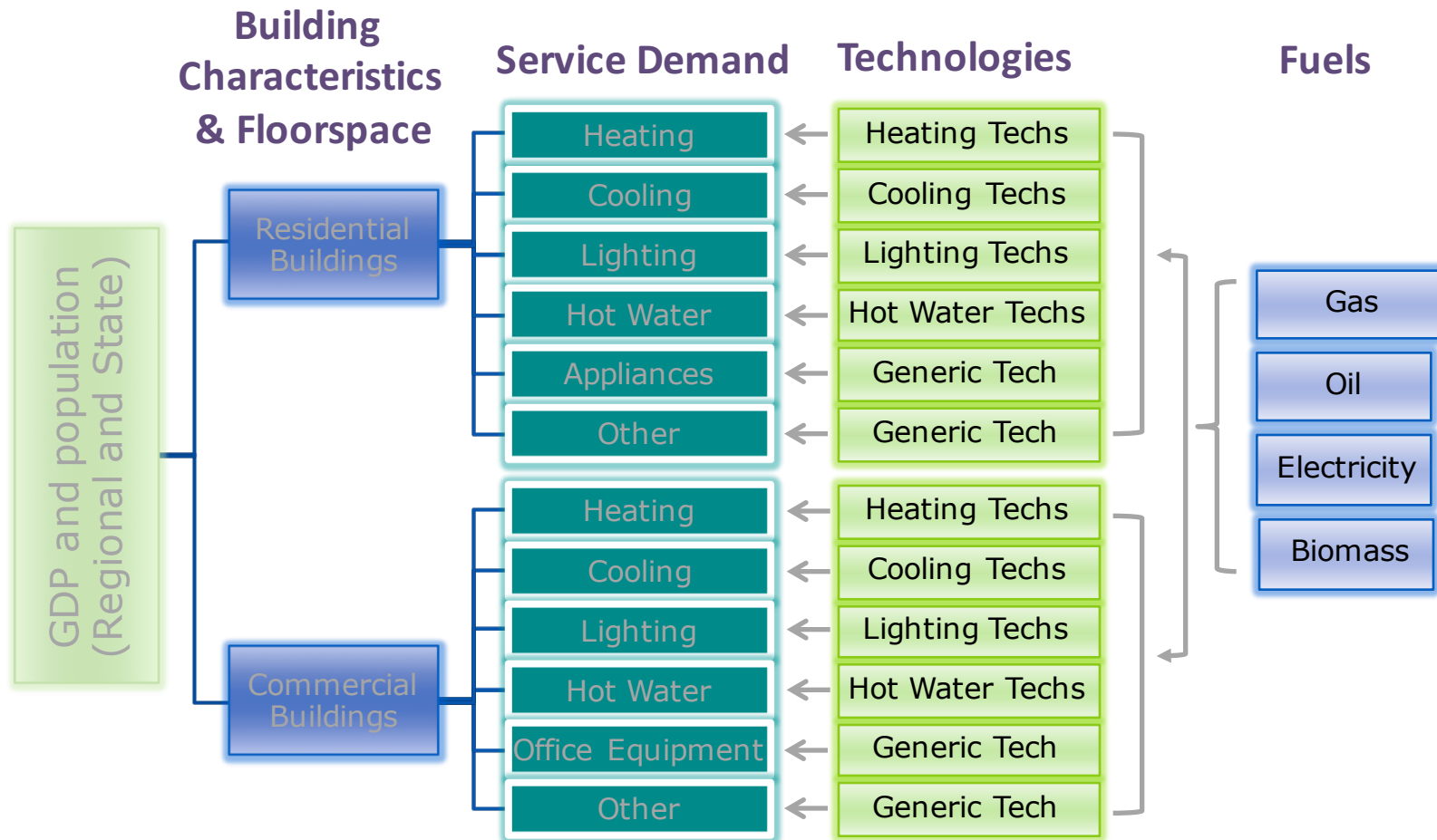
Applications:

- ❖ IPCC assessment reports (RCP 4.5)
- ❖ U.S. Climate Change Science Program
- ❖ U.S. Climate Change Technology Program
- ❖



Building Energy Use Model

Nested, service-based building energy models in the long-term global integrated assessment framework, GCAM



Service Demands Modeling

Demand for Space Heating Service [GJ-output/m²] :

$$Q_{H,t} = k_H \cdot (HDD_t \cdot ShellEff_t \cdot SurfaceRatio_t - \lambda_H InternalGain_t) \cdot \left[1 - \exp\left(-\frac{\ln 2}{\alpha_H} \cdot \left(\frac{Y_t}{P_{H,t}}\right)\right) \right]$$

Space Heating Requirement (satiated demand)

Economic Behavior

Climate Change
Effect

Demand for Space Cooling Service [GJ-output/m²]

$$Q_{C,t} = k_C \cdot (CDD_t \cdot ShellEff_t \cdot SurfaceRatio_t + \lambda_C InternalGain_t) \cdot \left[1 - \exp\left(-\frac{\ln 2}{\alpha_C} \cdot \left(\frac{Y_t}{P_{C,t}}\right)\right) \right]$$

Space Cooling Requirement (satiated demand)

Economic Behavior

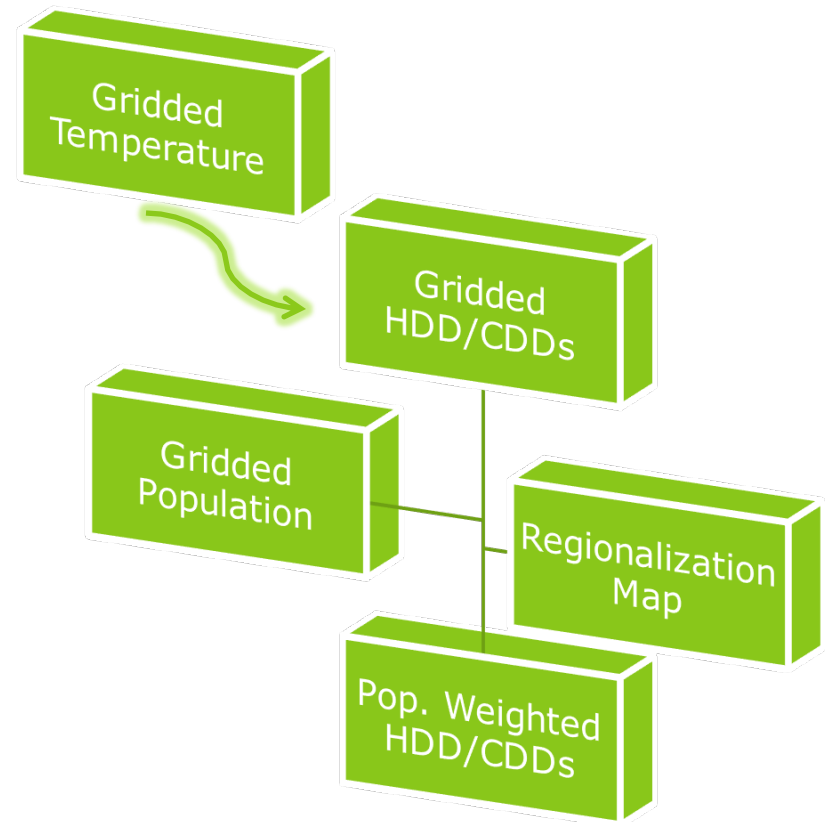
Demand for Other Services (water heating & cooking, lighting, other appliances):

$$Q_t = k_i \cdot q_i \left[1 - \exp\left(-\frac{\ln 2}{\alpha_i} \cdot \left(\frac{Y_t}{P_t}\right)\right) \right]$$

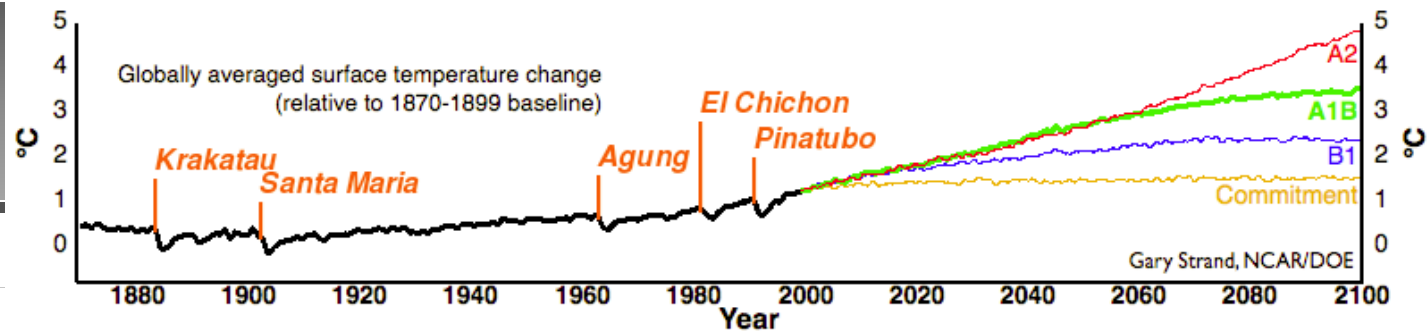
Climate Change Impact in Buildings

-Population Weighted HDD/CDDs

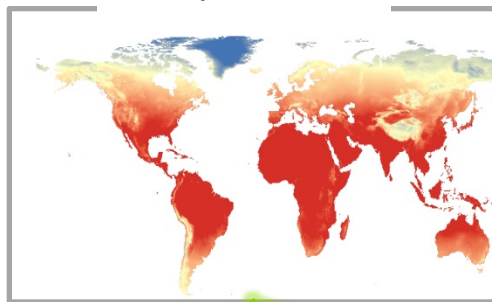
- ❖ Degree-days are essentially the summation of temperature differences from a human comfort level over time.
- ❖ Heating degree day (HDD) and cooling degree day (CDD) are measured in “degree-days” below (HDD) or above (CDD) the set point (typically 18°C).
- ❖ HDD and CDD need to be “population-weighted” (or otherwise-weighted) to reflect regional aggregated heating and cooling requirement with a changing population distribution.



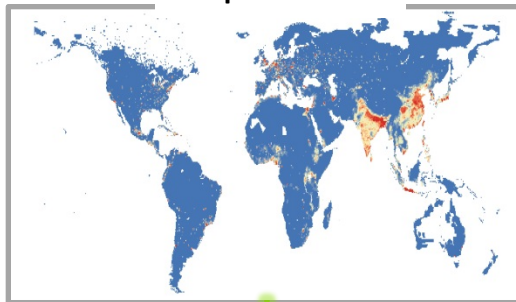
HDD/CDDs (CCSM A2)



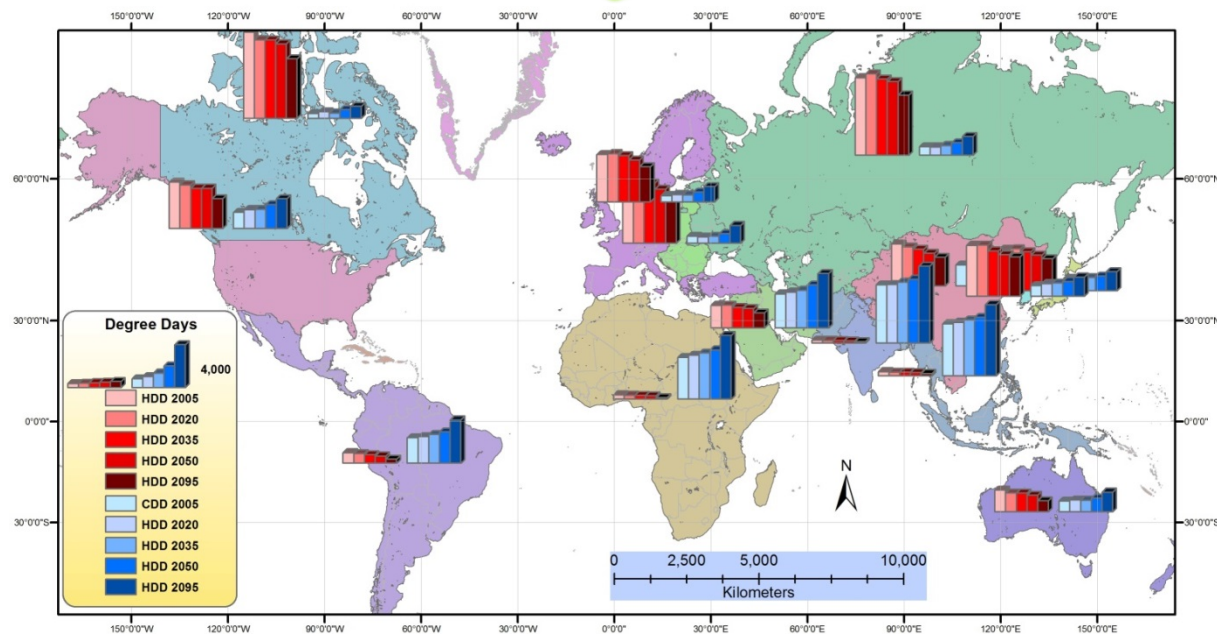
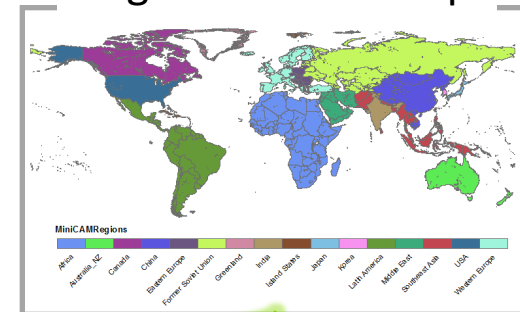
Temperature



Population

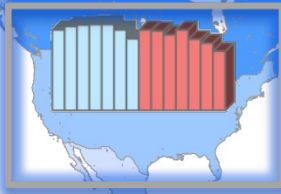
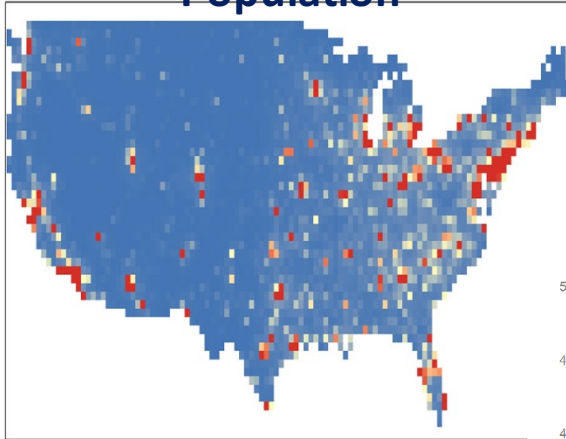


Regionalization Map

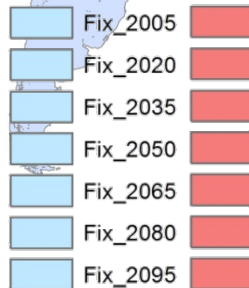
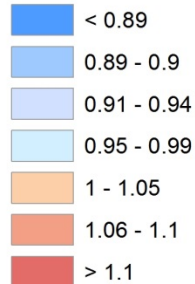


Building Energy Use Under Climate Change

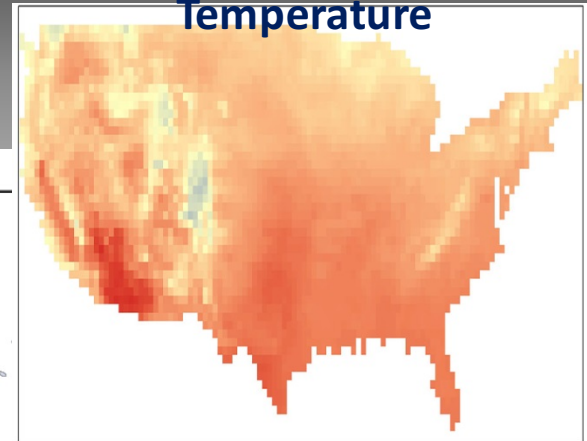
Population



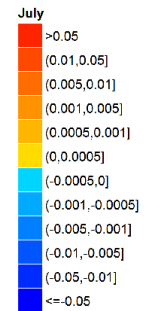
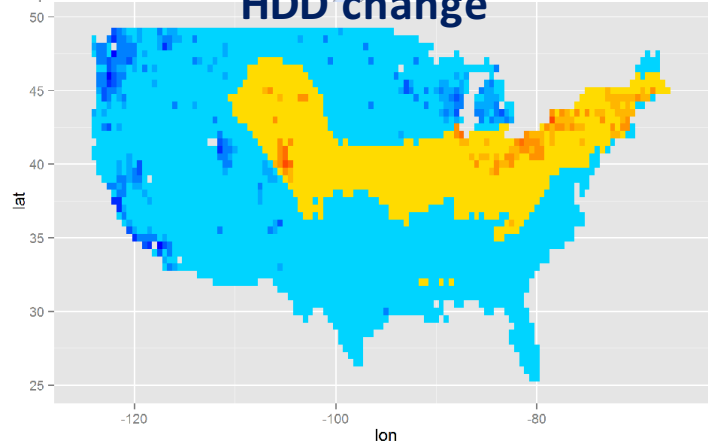
Ratio (Climate / no Climate)



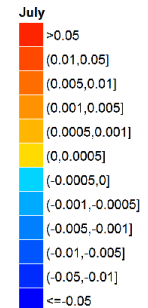
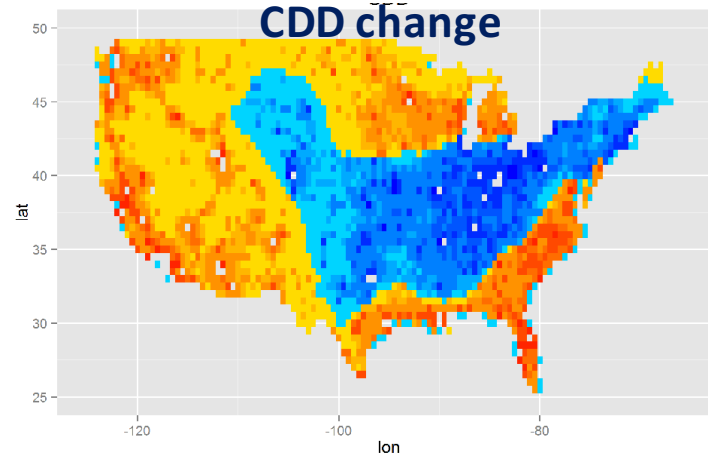
Temperature



HDD change

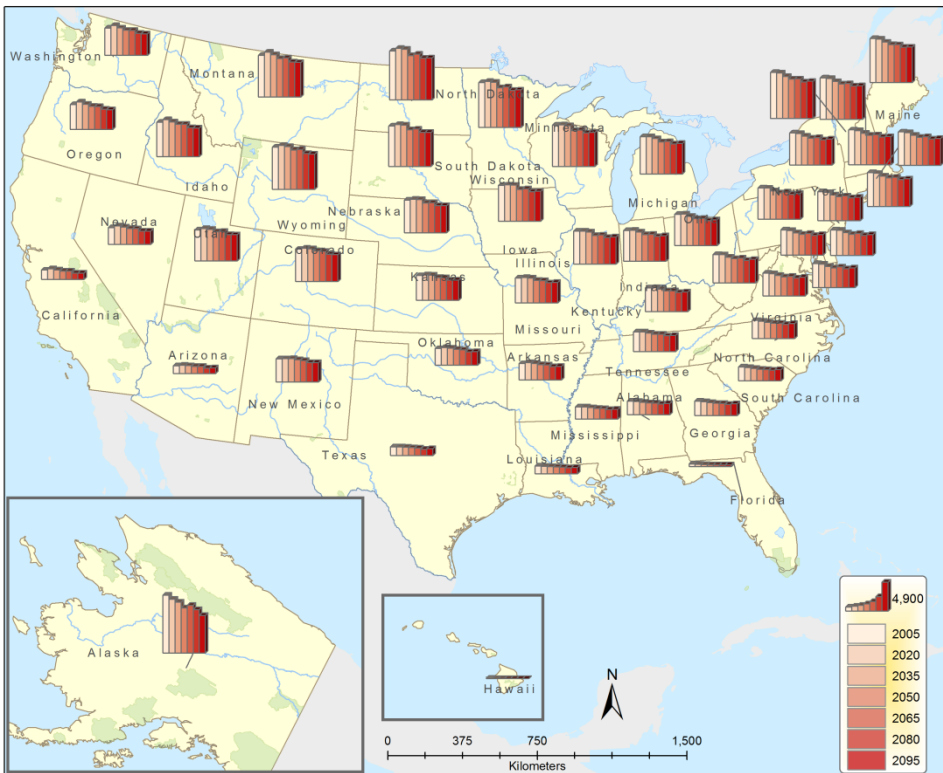


CDD change

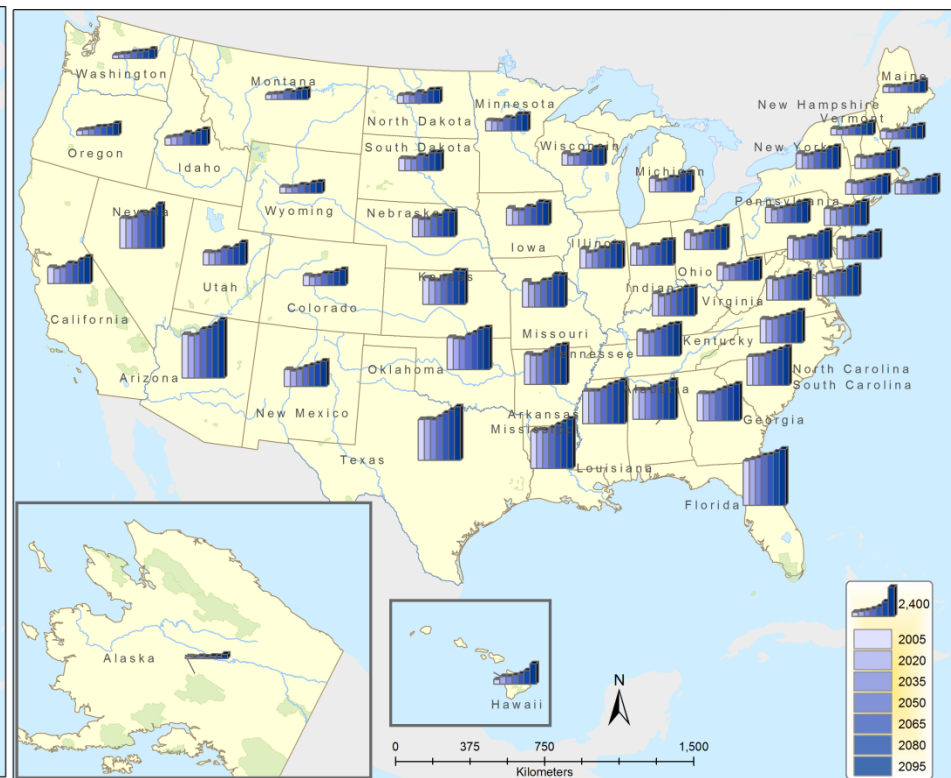


State Level HDD/CDDs

Heating Degree Days



Cooling Degree Days

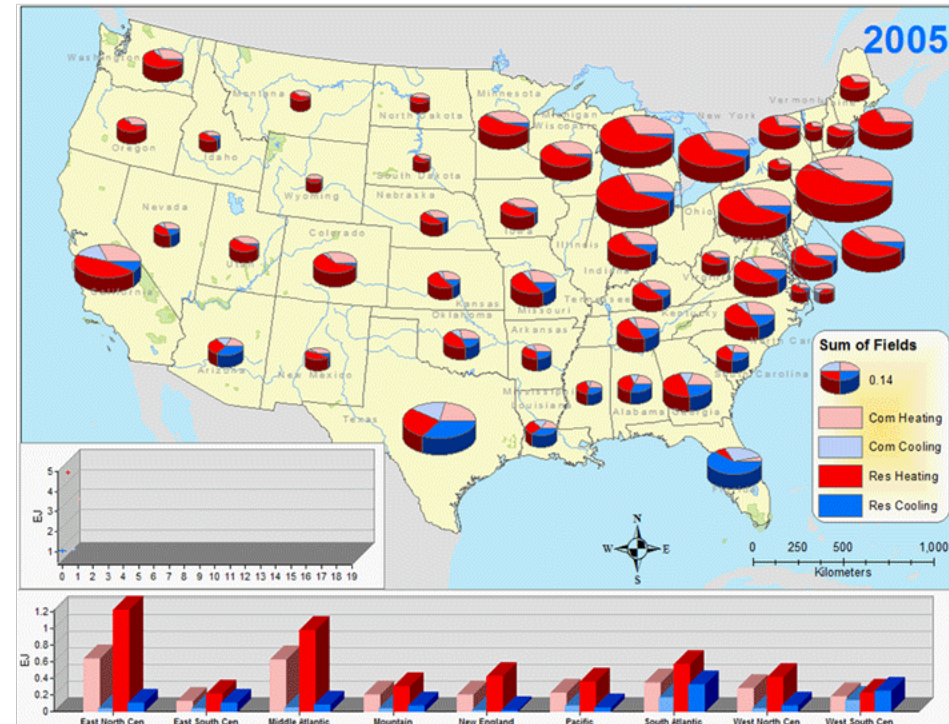
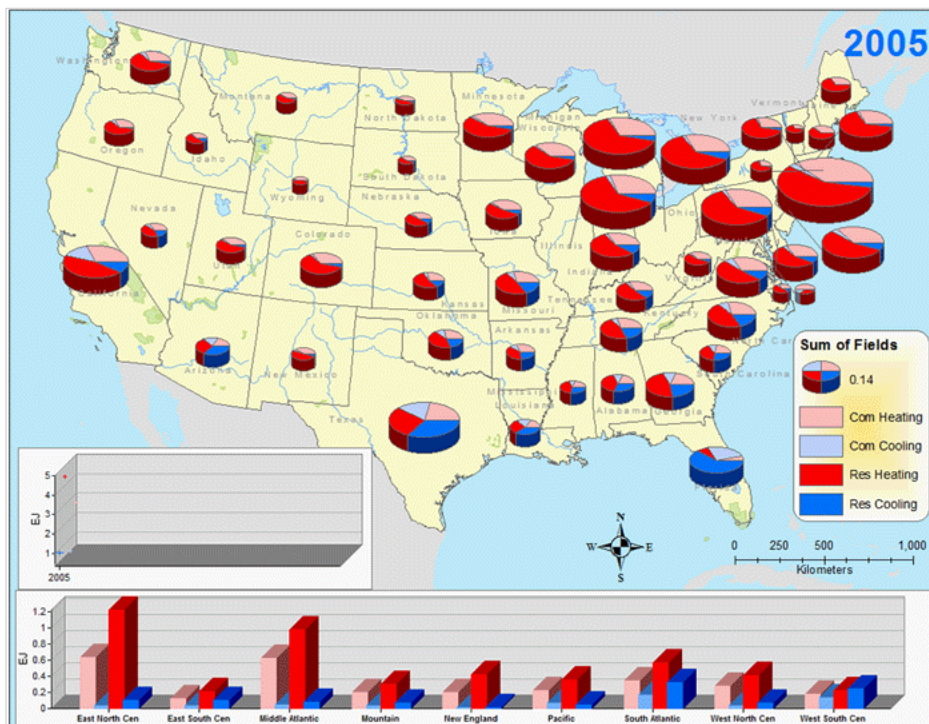


Climate Change (HDD/CDDs) Impacts

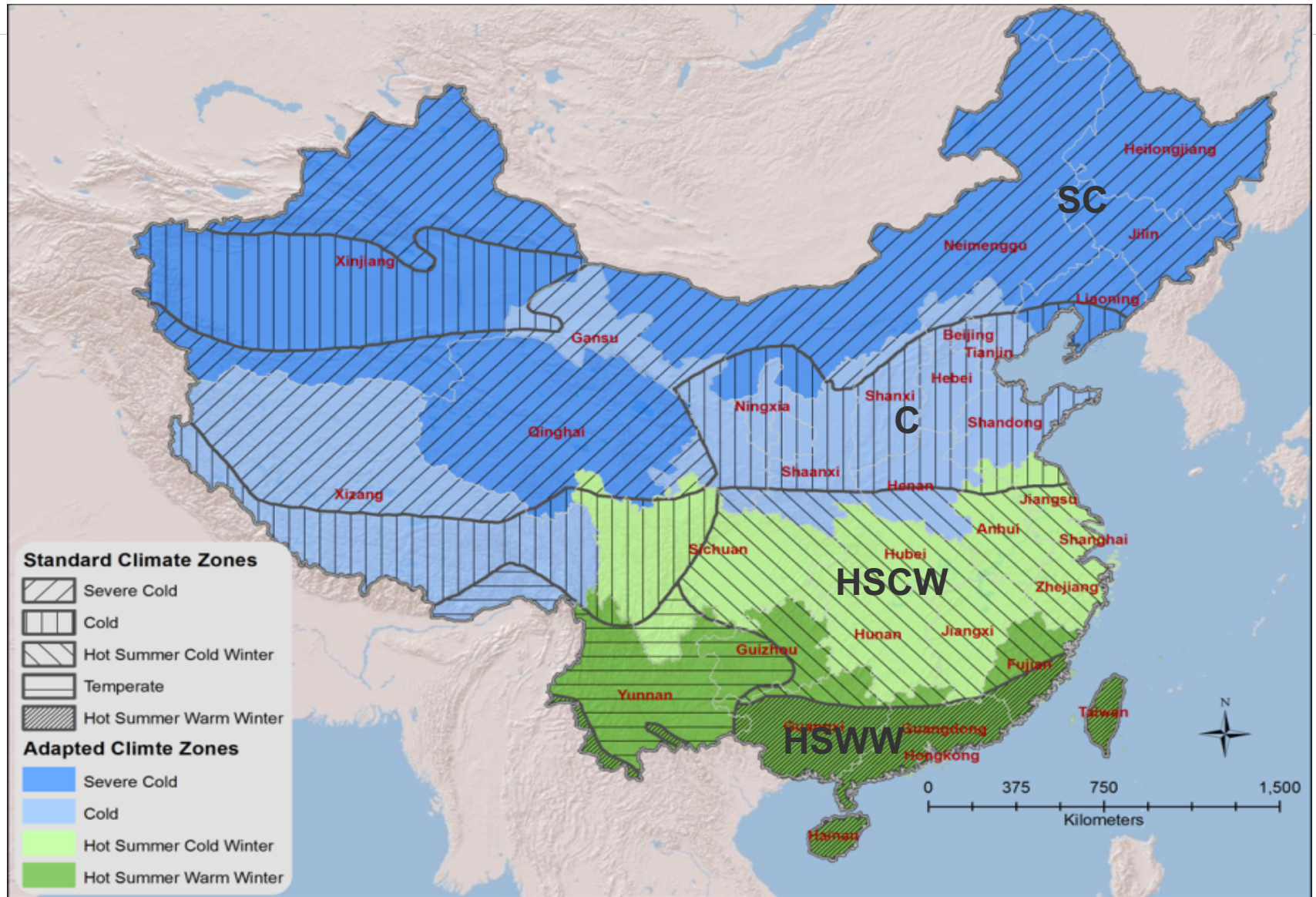
- Total energy use
- Energy use in sectors
- Spatial difference

Fixed Climate

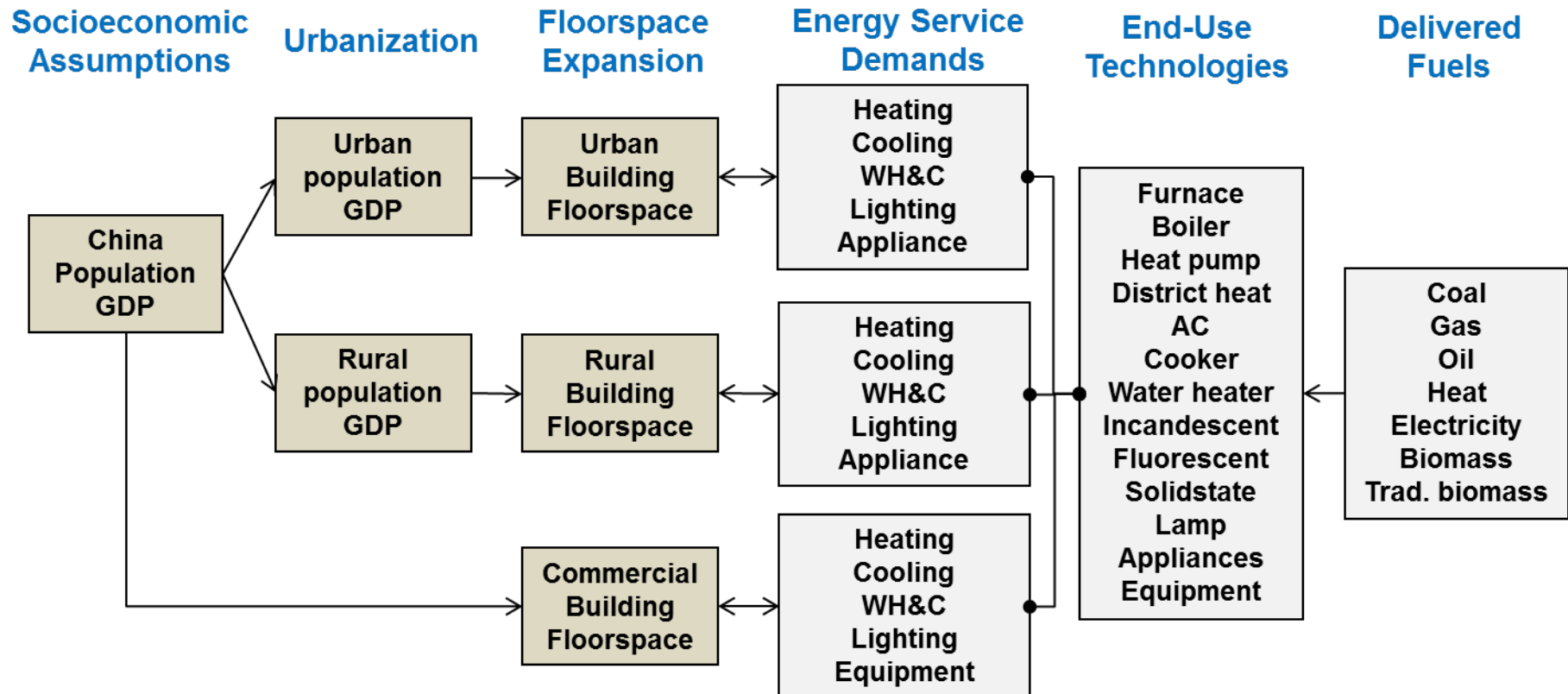
A2 Climate



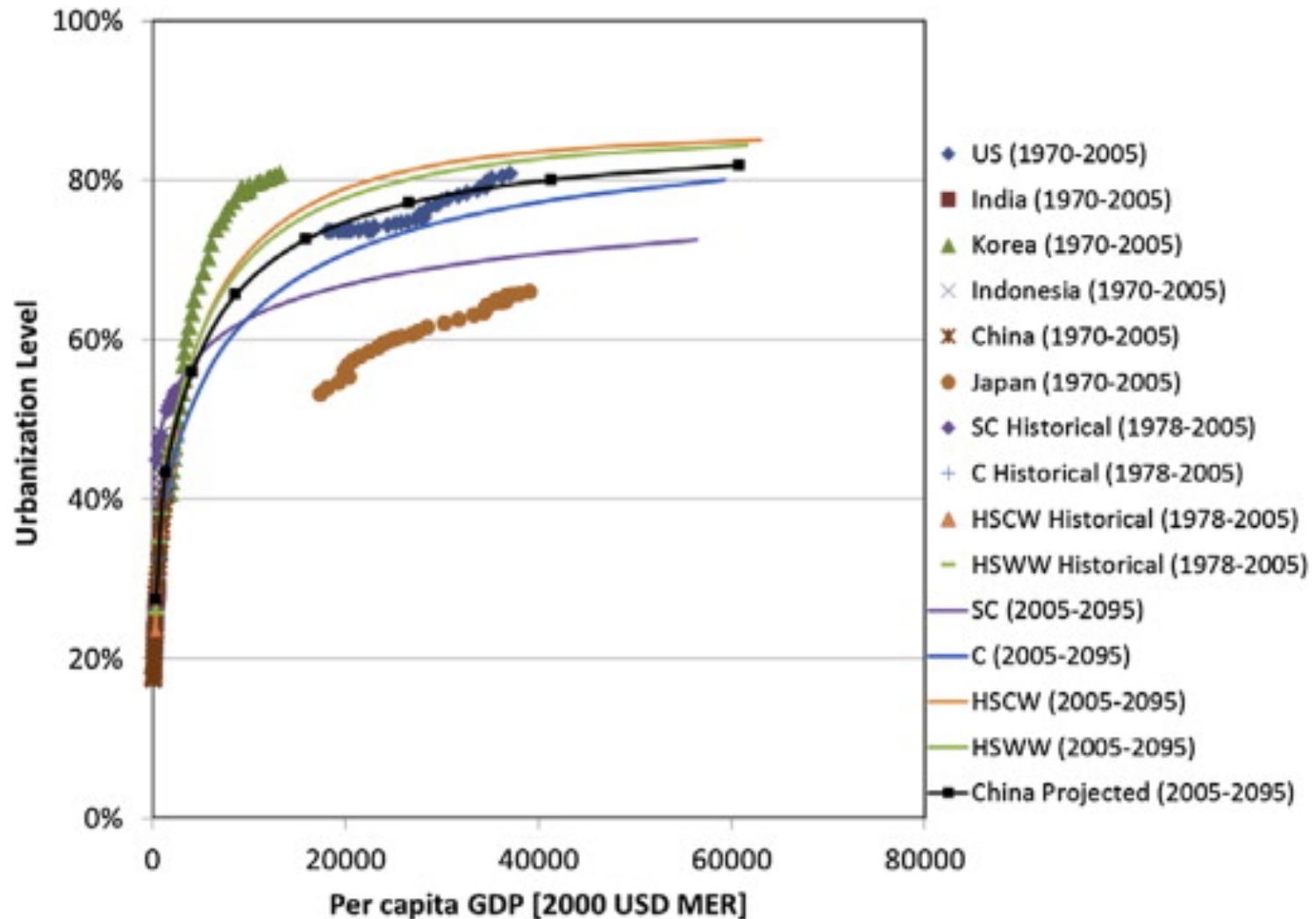
Building Energy Modeling at Climate Zone Level in China



Modeling Structure

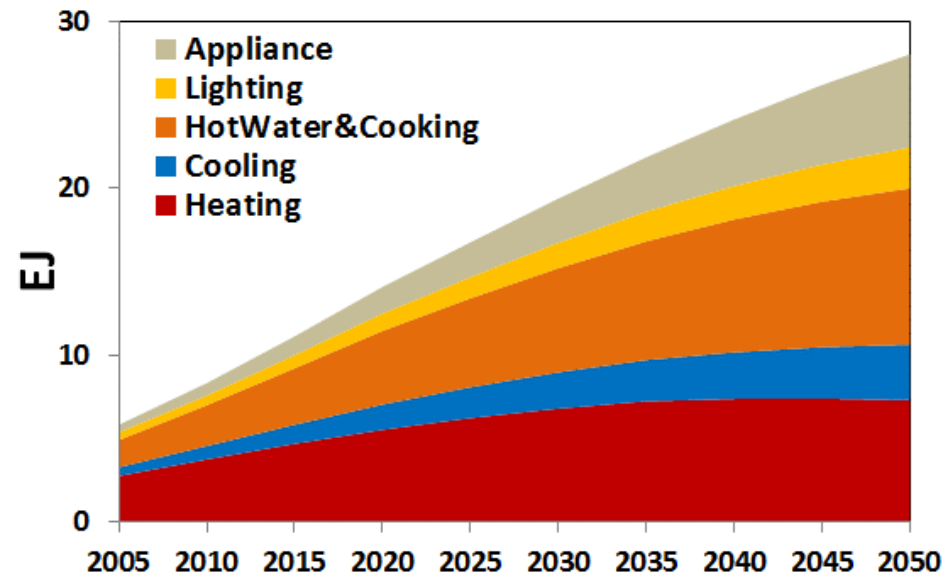


Urbanization Projection in China

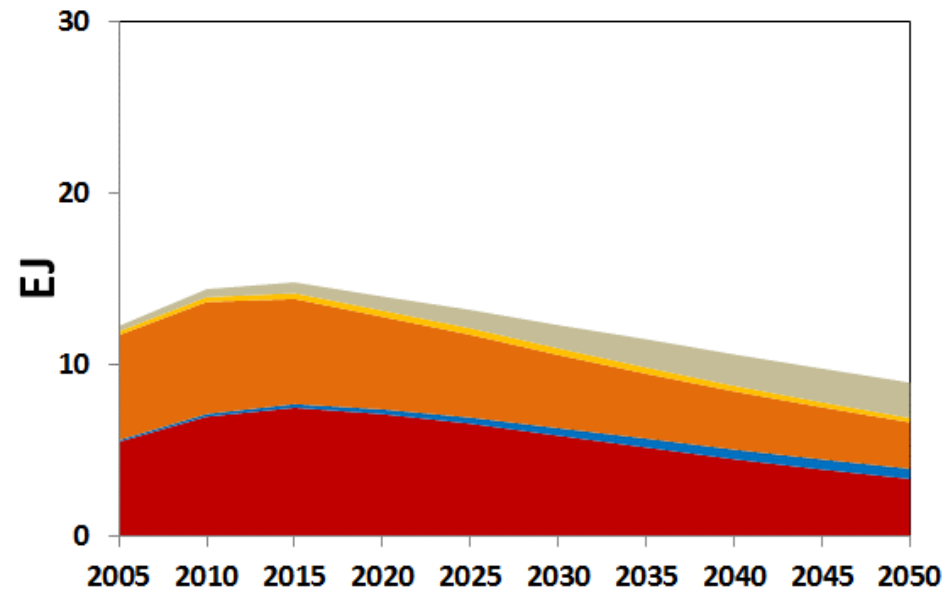


Building Energy Use in China

Urban



Rural



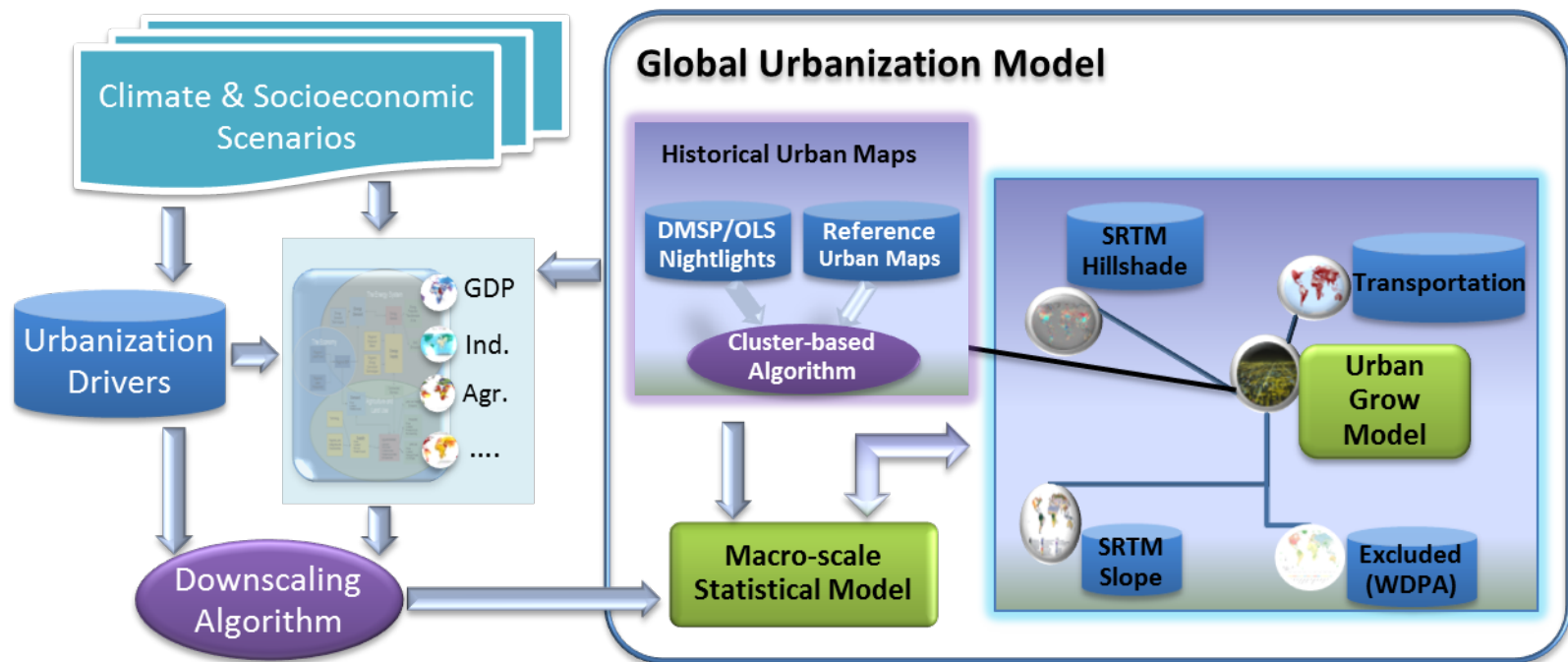
Motivations

- ❖ **Urban population is projected from 50% in 2010 to 70% in 2050**
- ❖ **~80% GDP, ~70% energy consumption and emissions**
- ❖ **Urbanization shows important impacts on environment**
 - Regional Building energy use under climate change
 -
- ❖ **A consistent global urban map series is lacking**



Objectives

- I. A consistent global urban map series
- II. An integrated modeling framework to project global urban sprawl
- III. A series of global urban extent maps in 21st century under scenarios



Urban Mapping from Nightlights

A cluster-based method

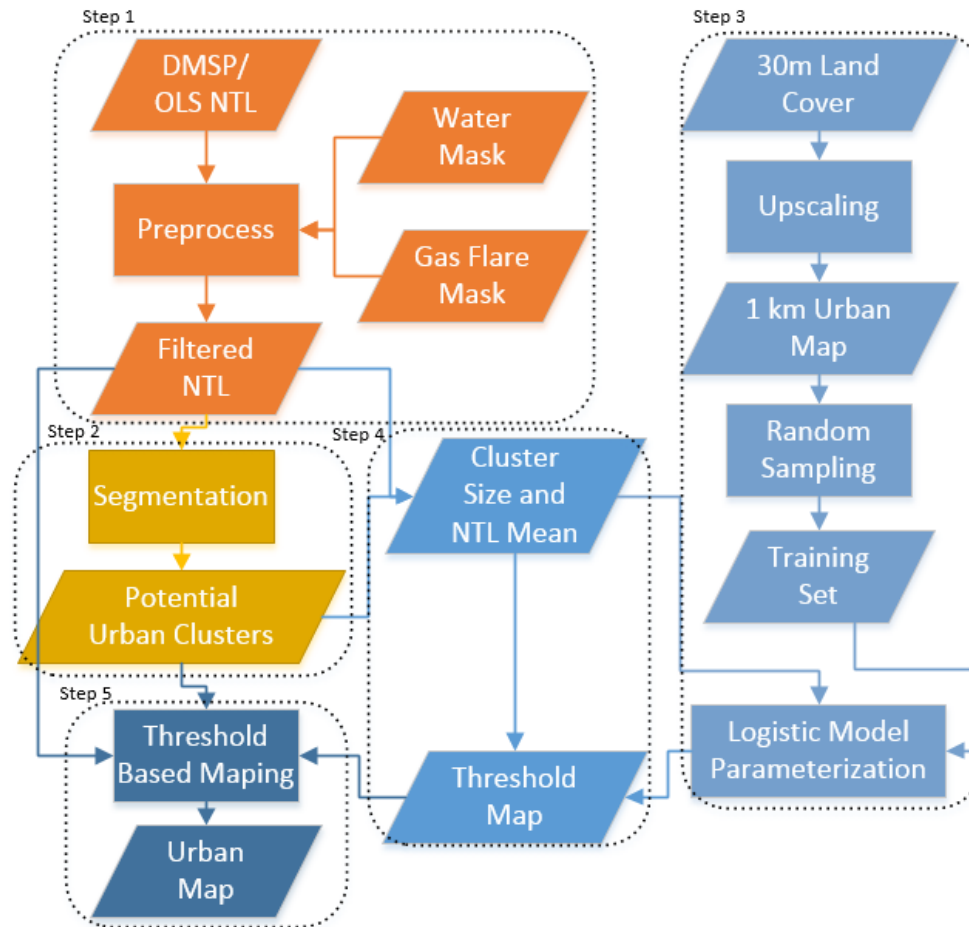
1. Data Preprocess

2. Urban Clusters Segmentation

3. Logistic Model

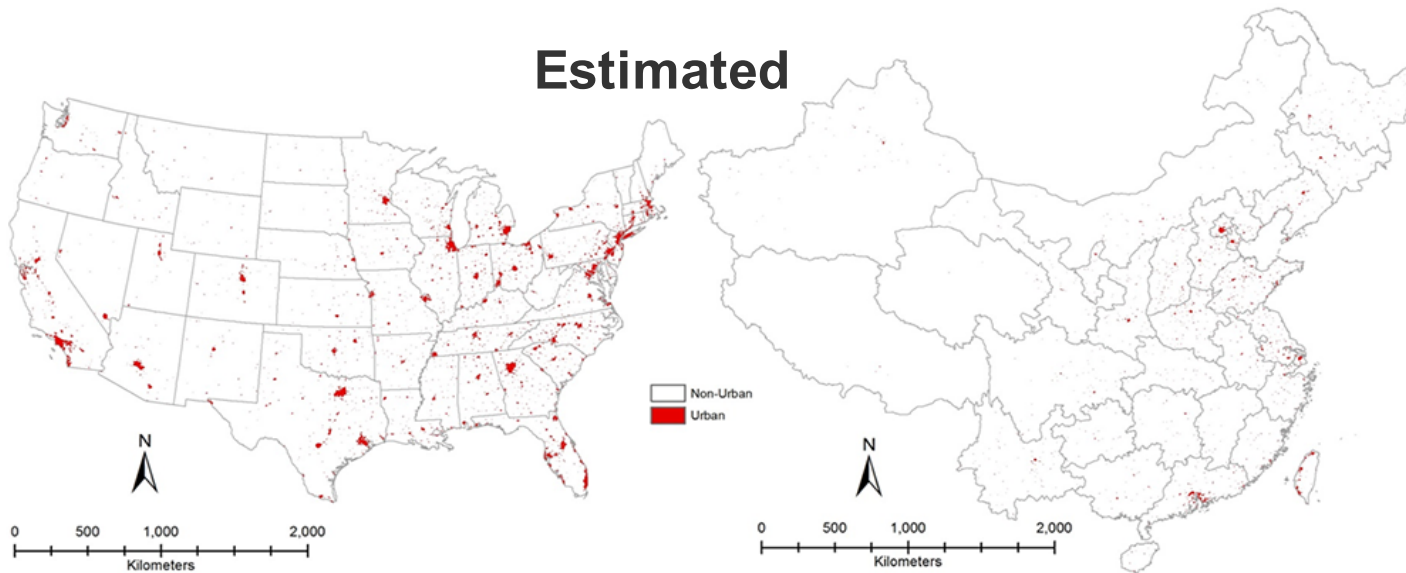
4. Thresholds Estimation

5. Urban Extent Delineation

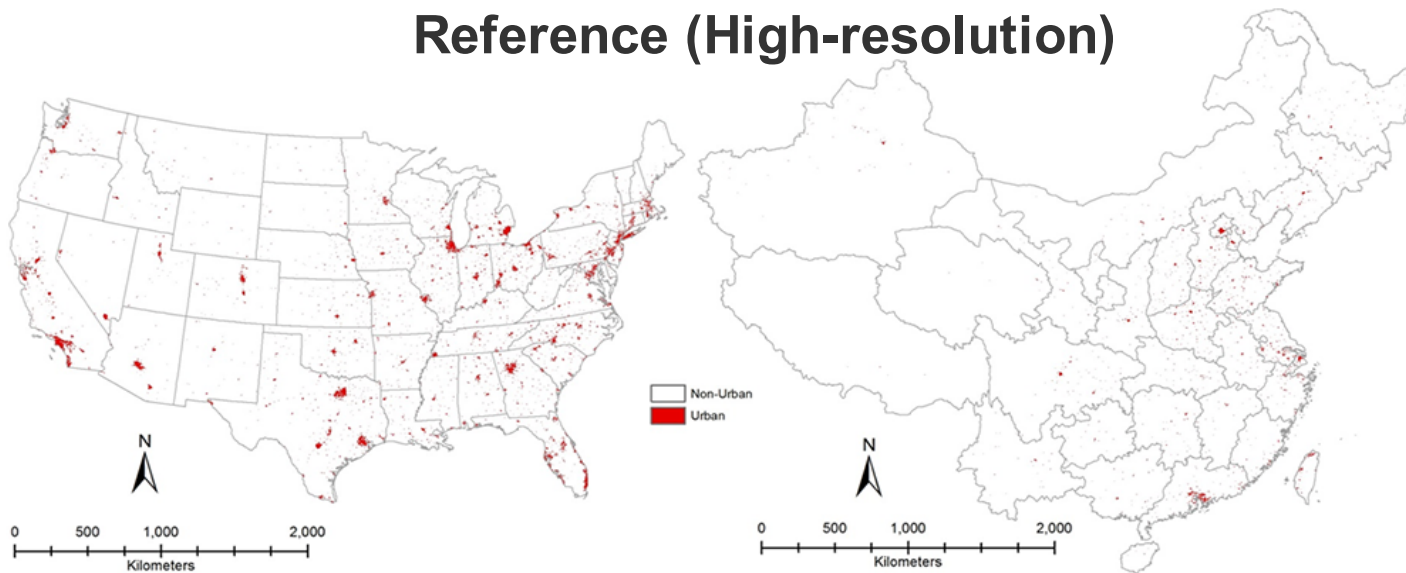


Urban Extent from Nightlights (NTL)

Estimated

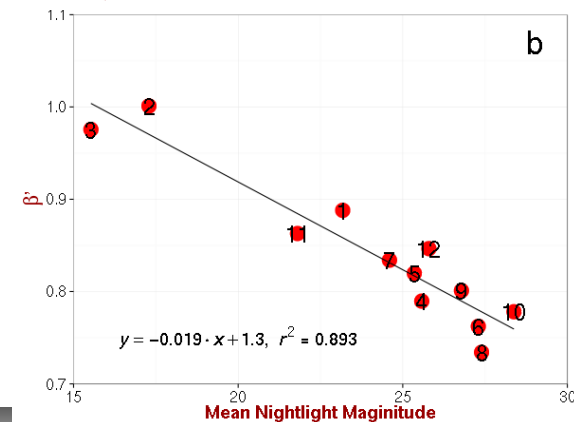
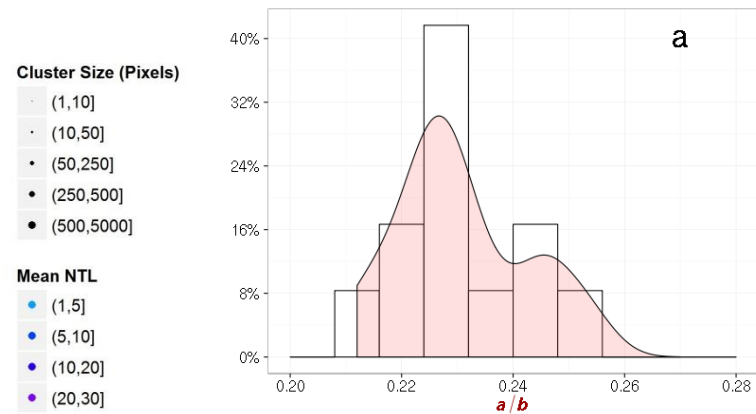
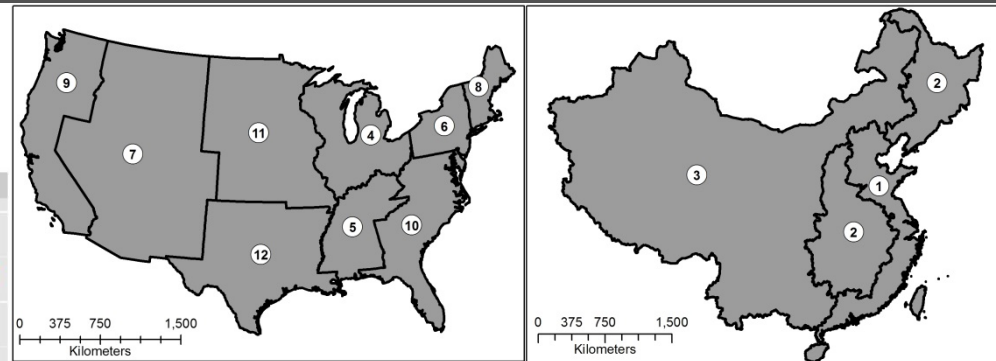
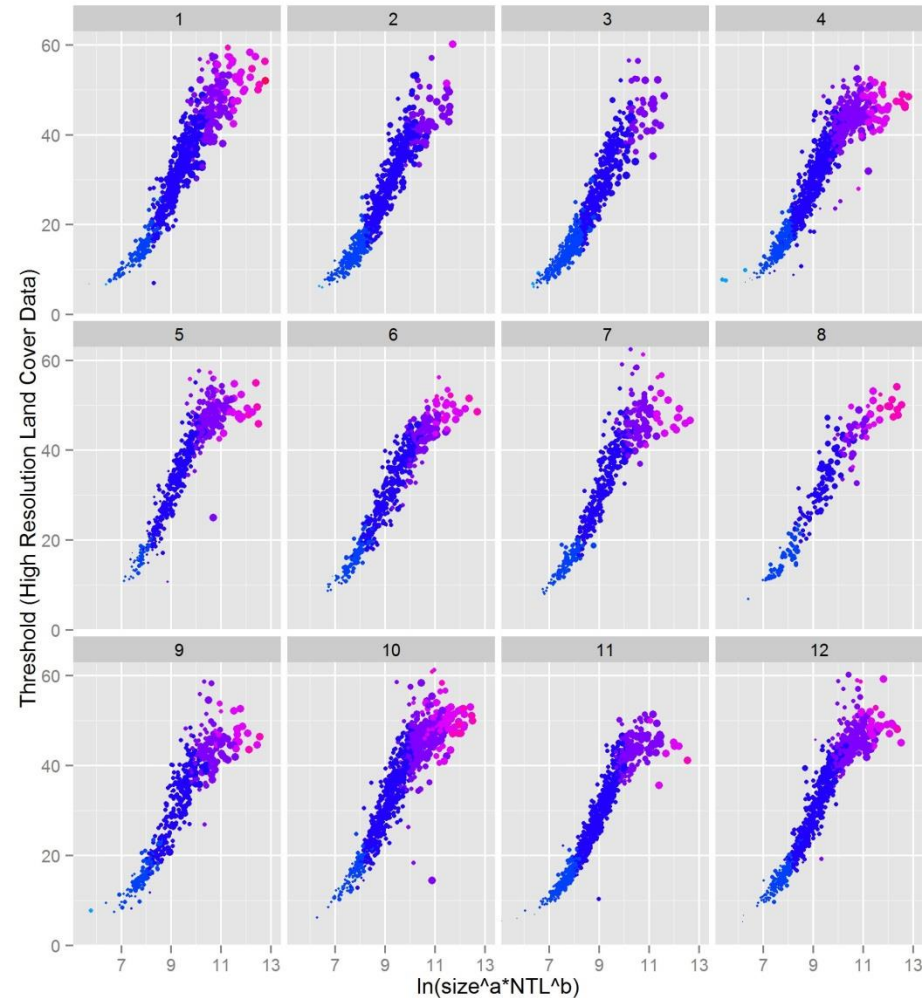


Reference (High-resolution)

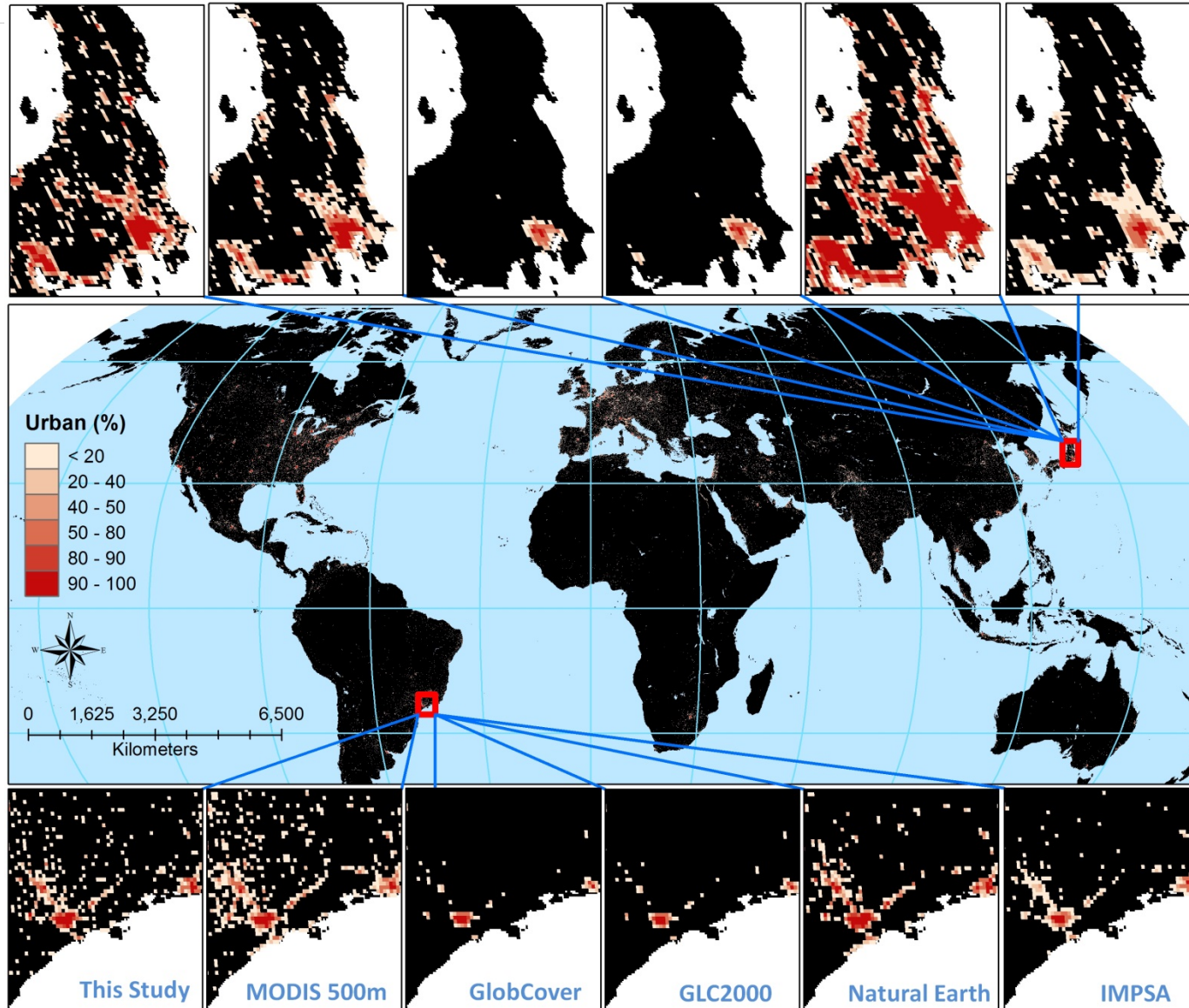


Spatial and Temporal Extension

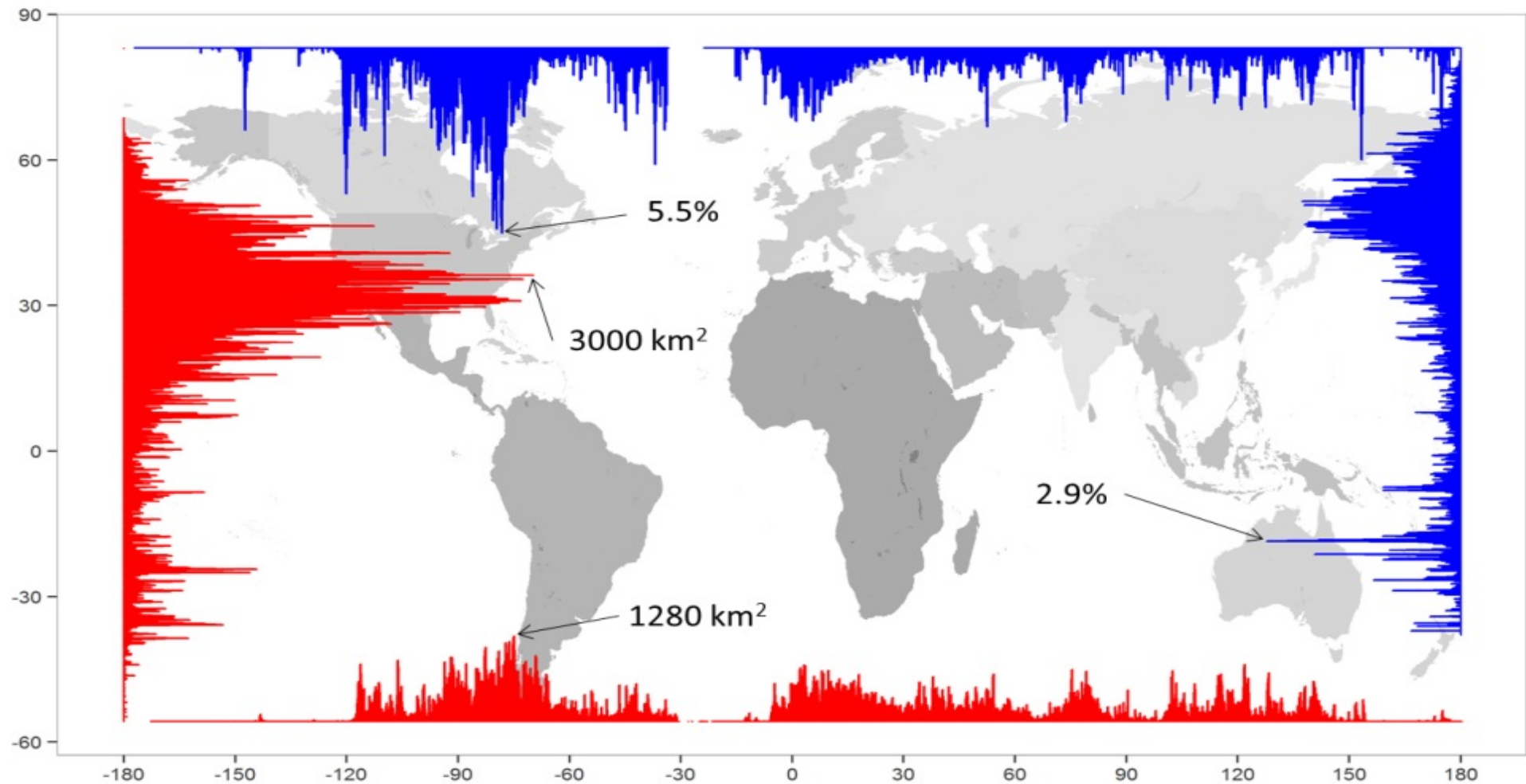
Parameters in the logistic model



Spatial Extension (Global Urban Mapping)



Spatial Pattern of Urban Extent



Temporal Extension (Urbanization in China)

Percentage



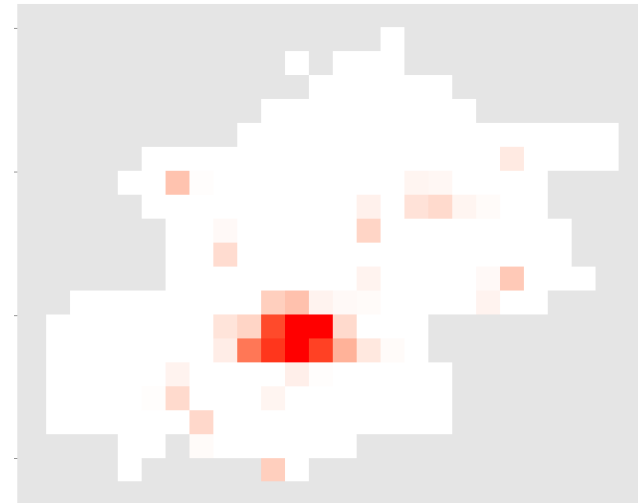
1.00

0.75

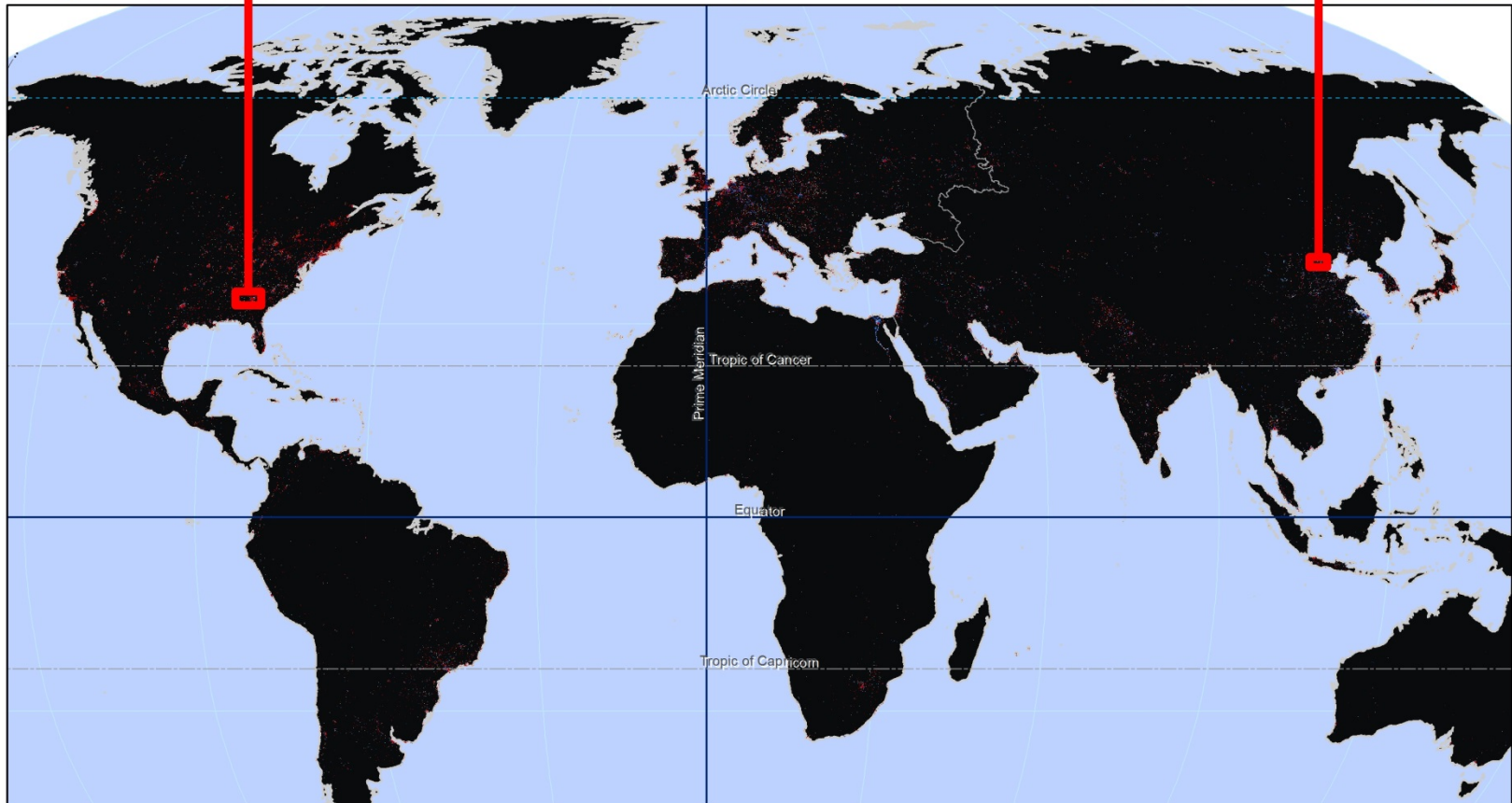
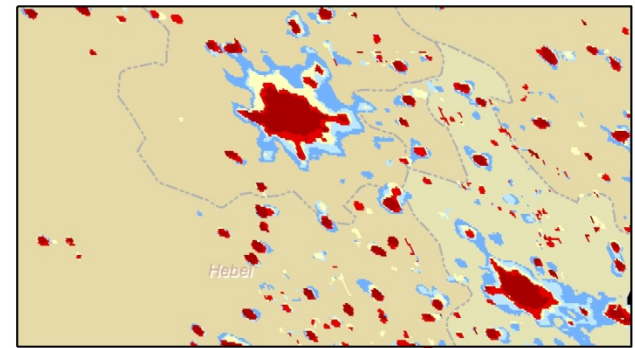
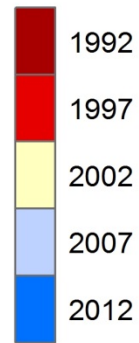
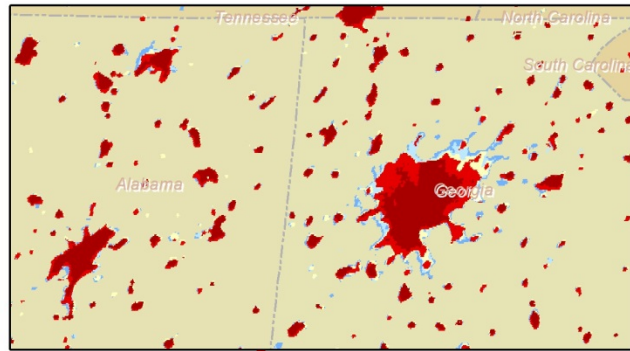
0.50

0.25

Urban Area in Year:1992

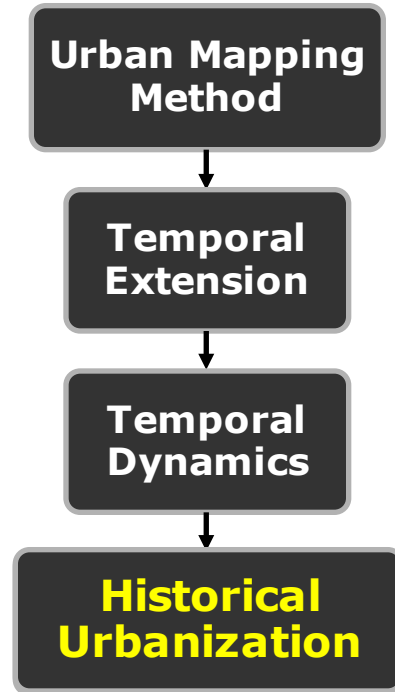


Global Historical Urbanization

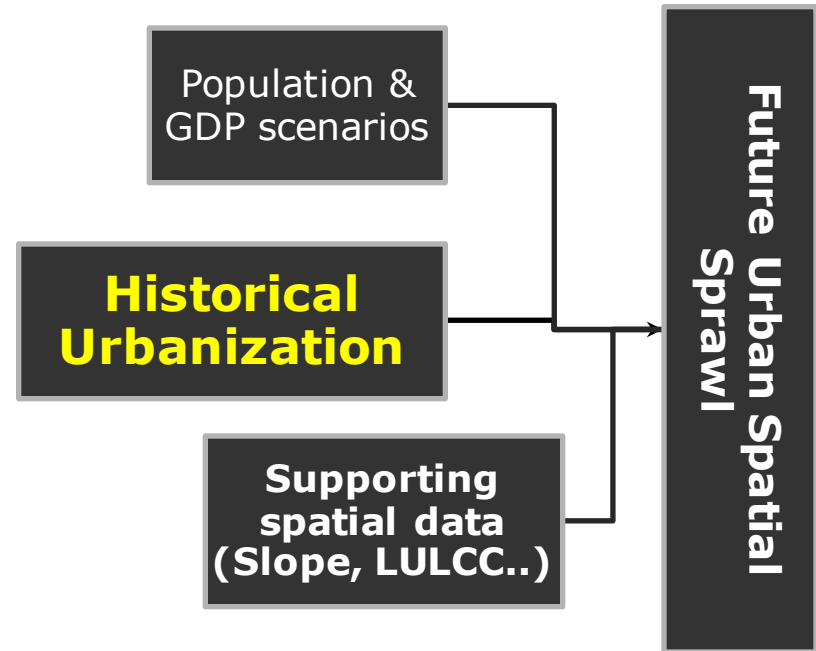


Future Urbanization Modeling

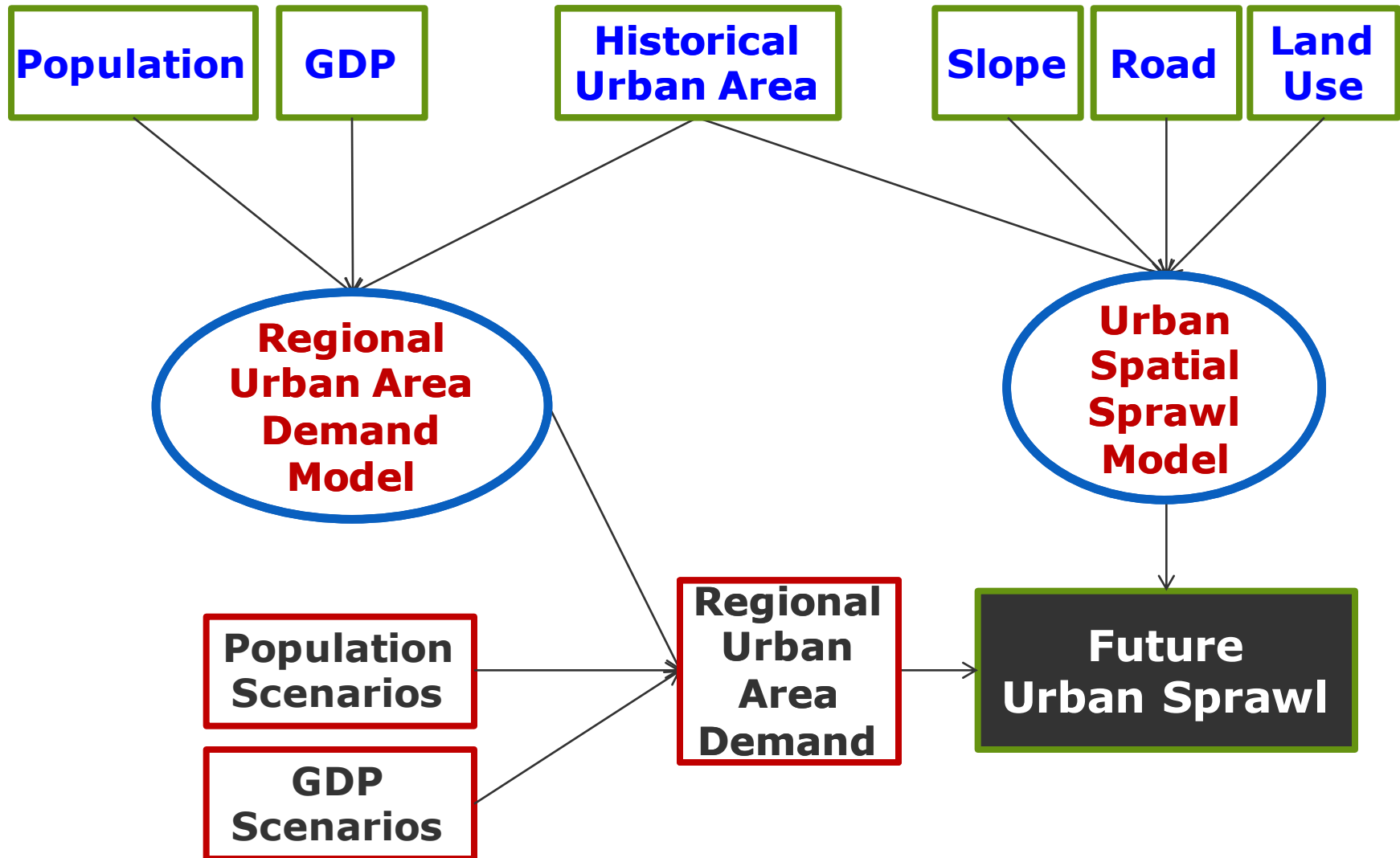
Historical Mapping



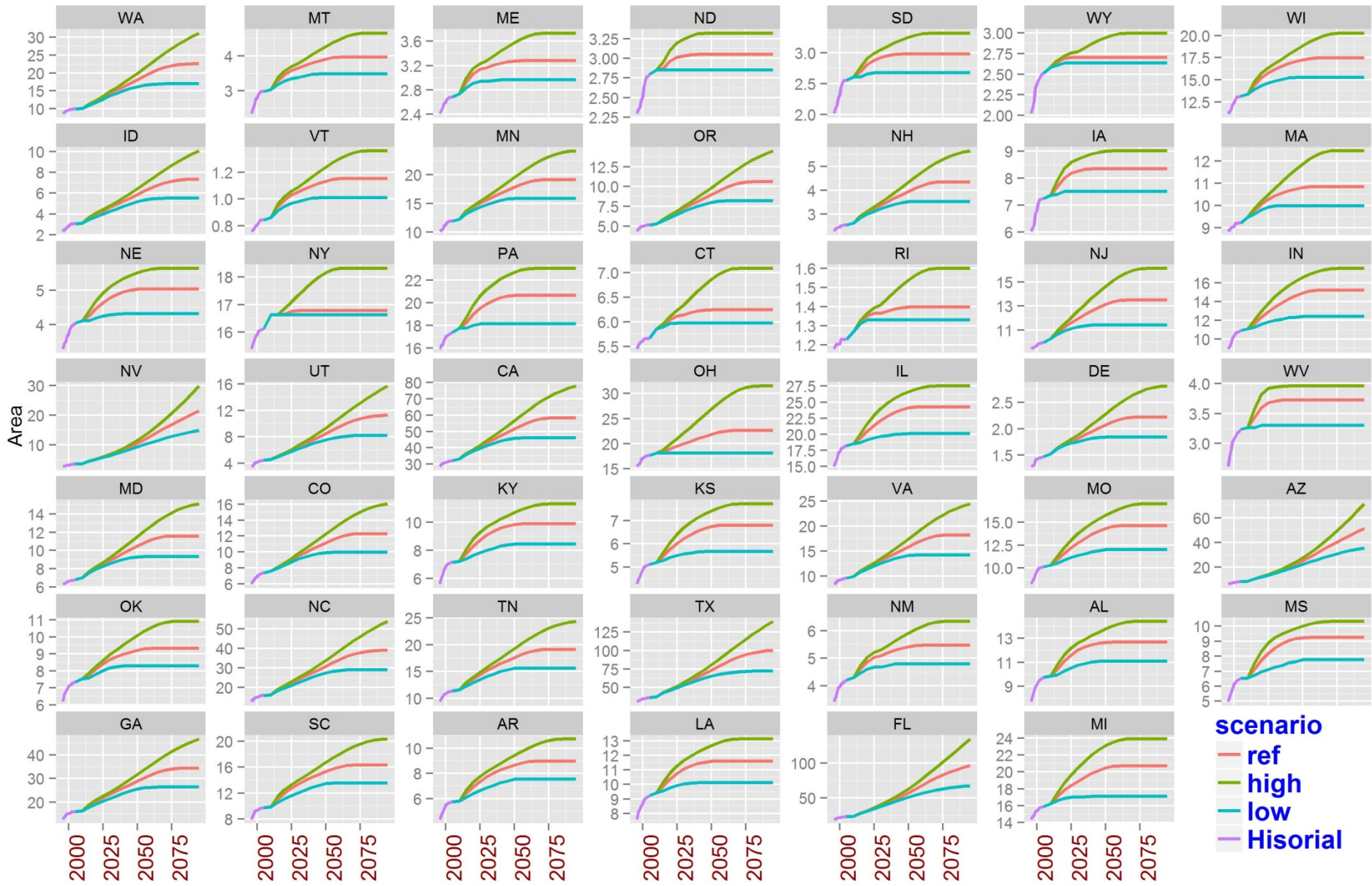
Future Projection



Framework of Urban Sprawl Modeling

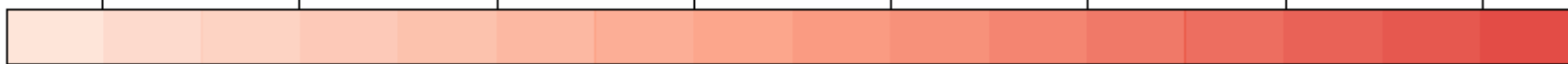


Regional Urbanization under Scenarios



Urbanization in US under Scenarios

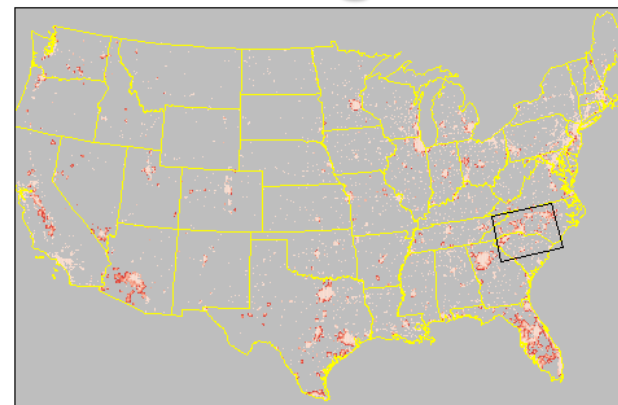
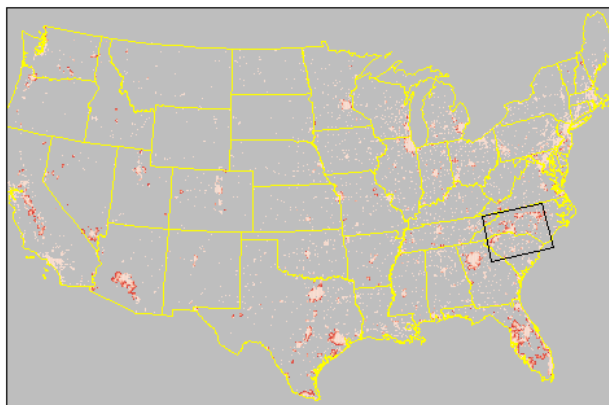
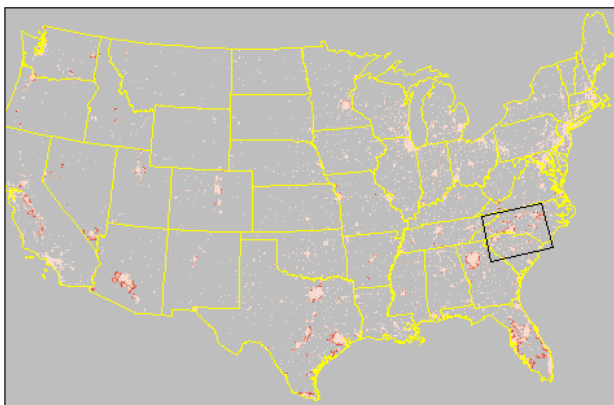
2015 2020 2025 2030 2035 2040 2045 2050



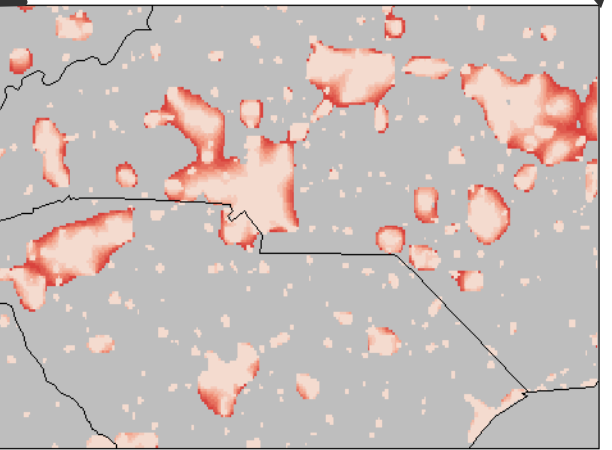
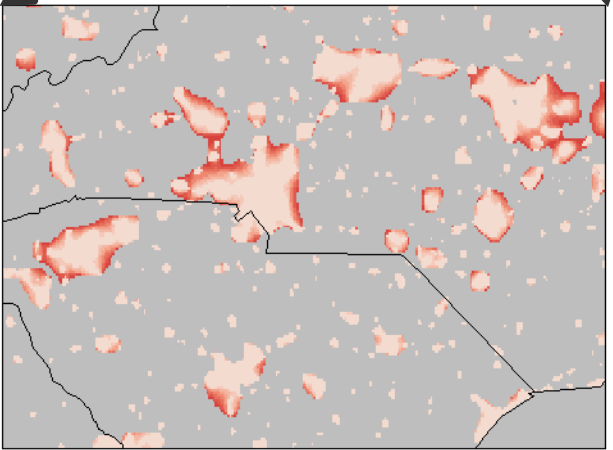
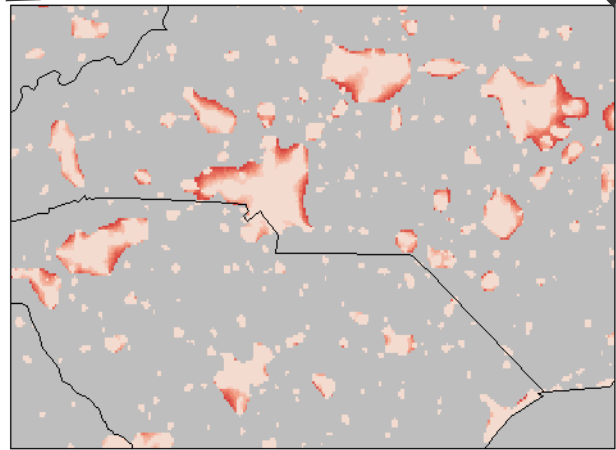
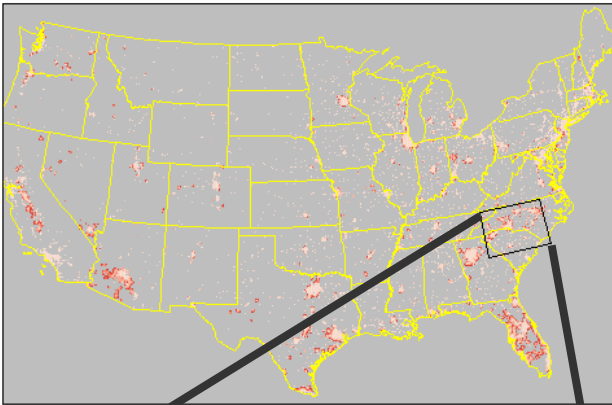
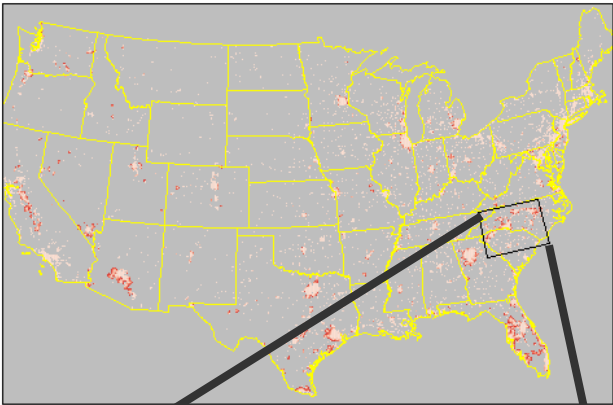
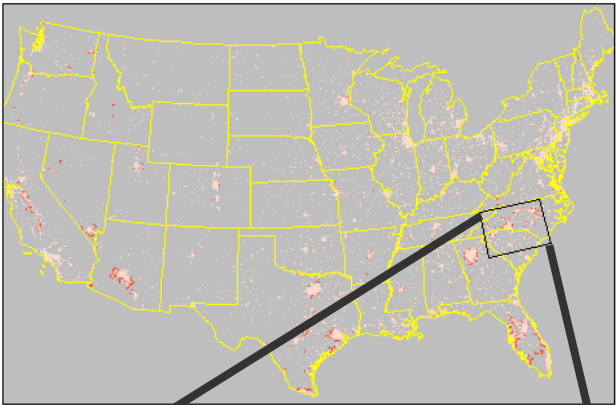
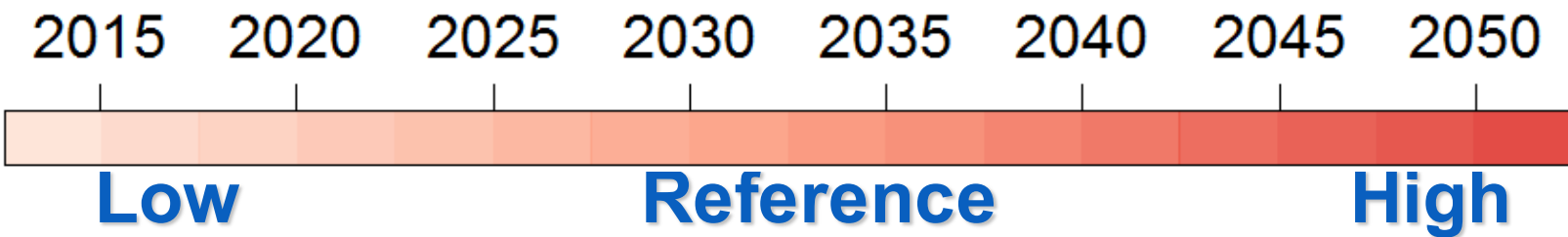
Low

Reference

High



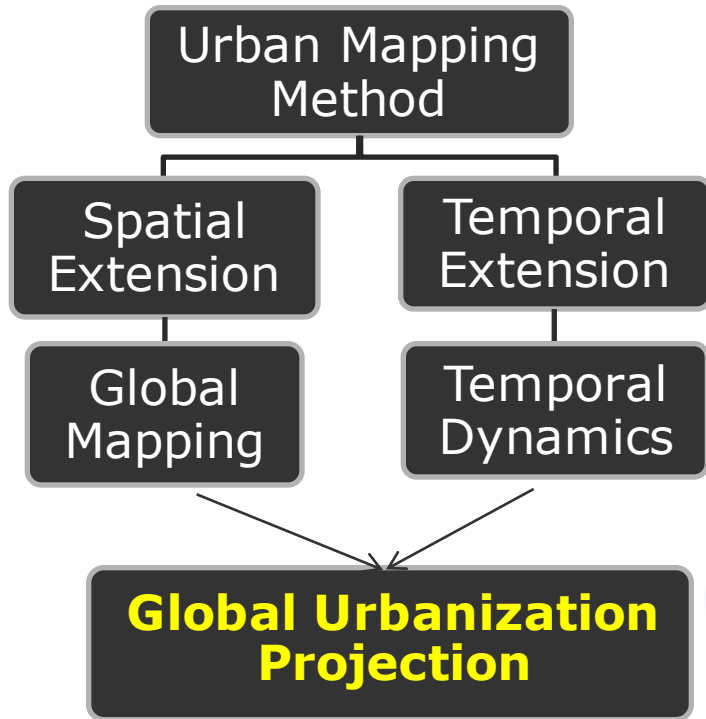
Urbanization in US under Scenarios



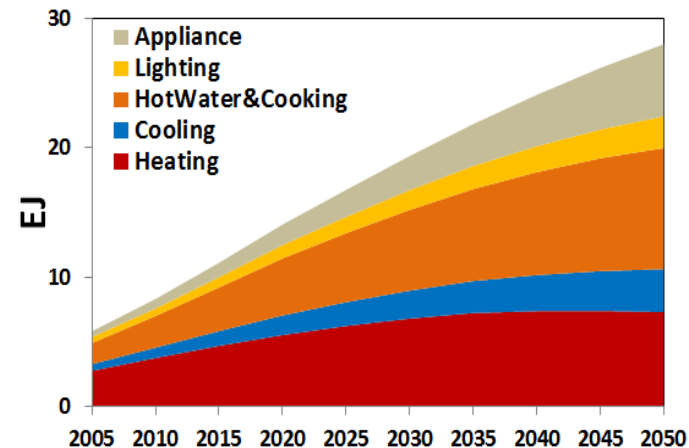
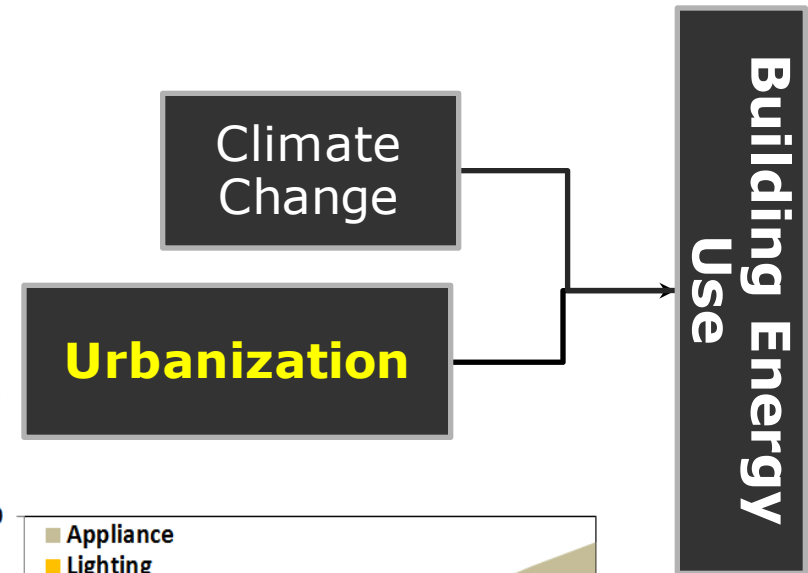
Linking remote sensing data with IA building energy use modeling



Urban Mapping and Projection



Urbanization impacts



Future urban building energy use under urbanization & climate change

Thank You

Acknowledgements



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ENERGY