Incorporating Urban Systems in Global Climate Models: The Role of GIScience

Johannes Feddema
Trisha Jackson
Pei-Ling Lin
John Bauer
University of Kansas

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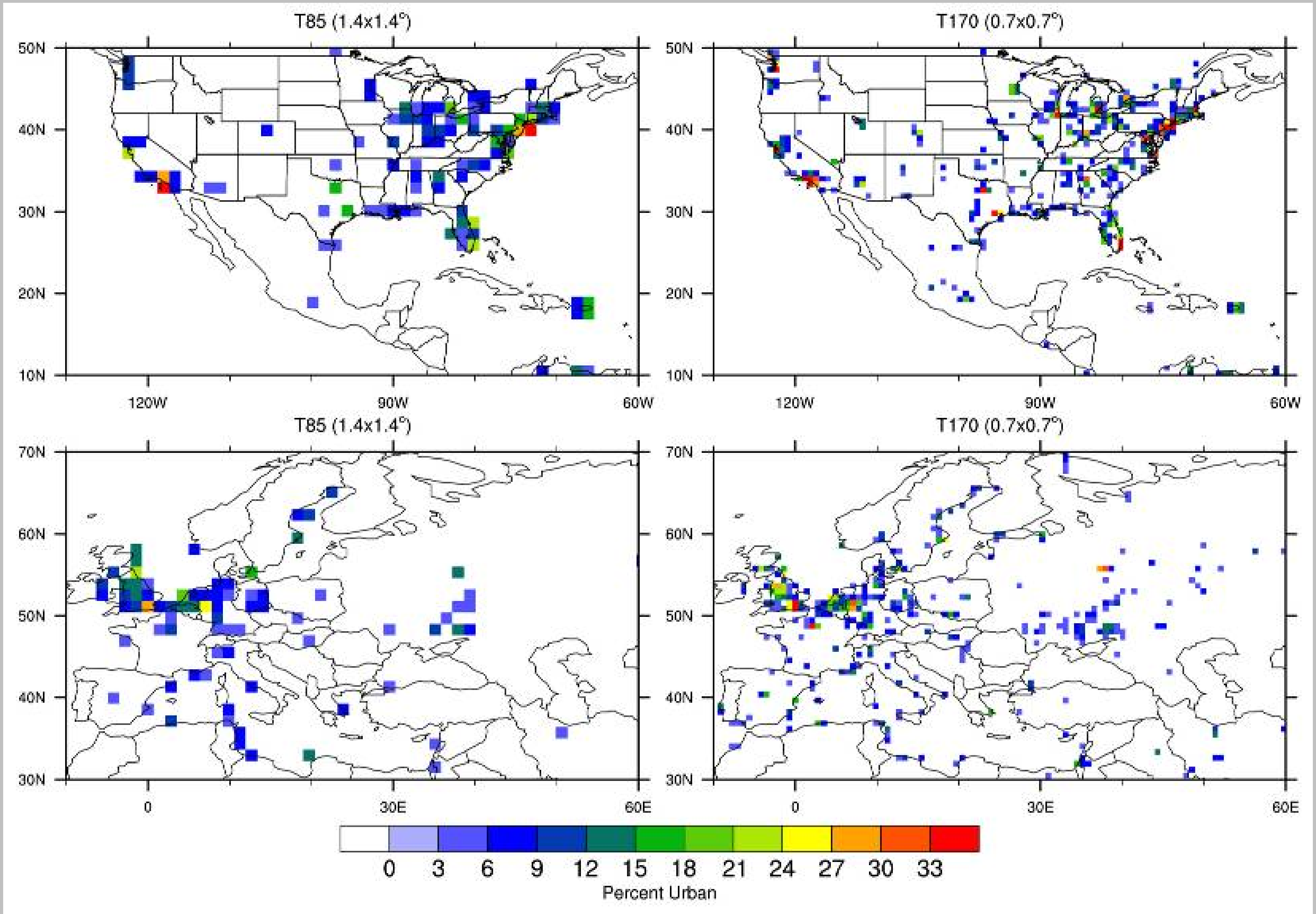
Motivation:

- **Urbanization is a significant component of anthropogenic land cover change**
- **Urban areas affect local climate; does this scale to a global impact?**
- **The majority of people live in urban areas and experience urban climates**
- **Urban areas are detectable at the GCM grid scale**
- **Urban areas are expected to expand significantly in the near future**
- **Urban areas are the main source of anthropogenic emissions**

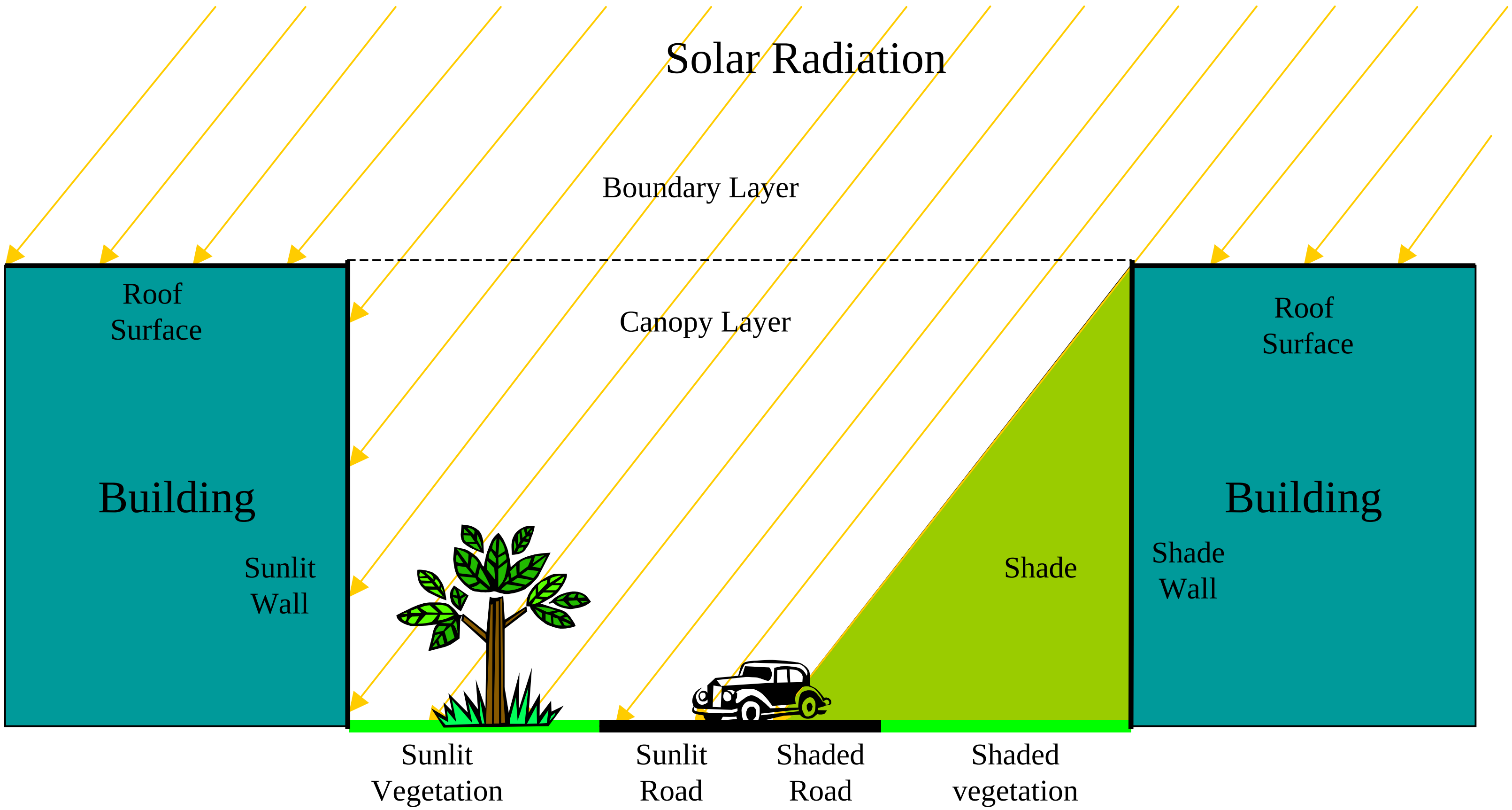
Percent Urban at Climate Model Resolutions

IPCC AR4 | The Future?



Preliminary Data

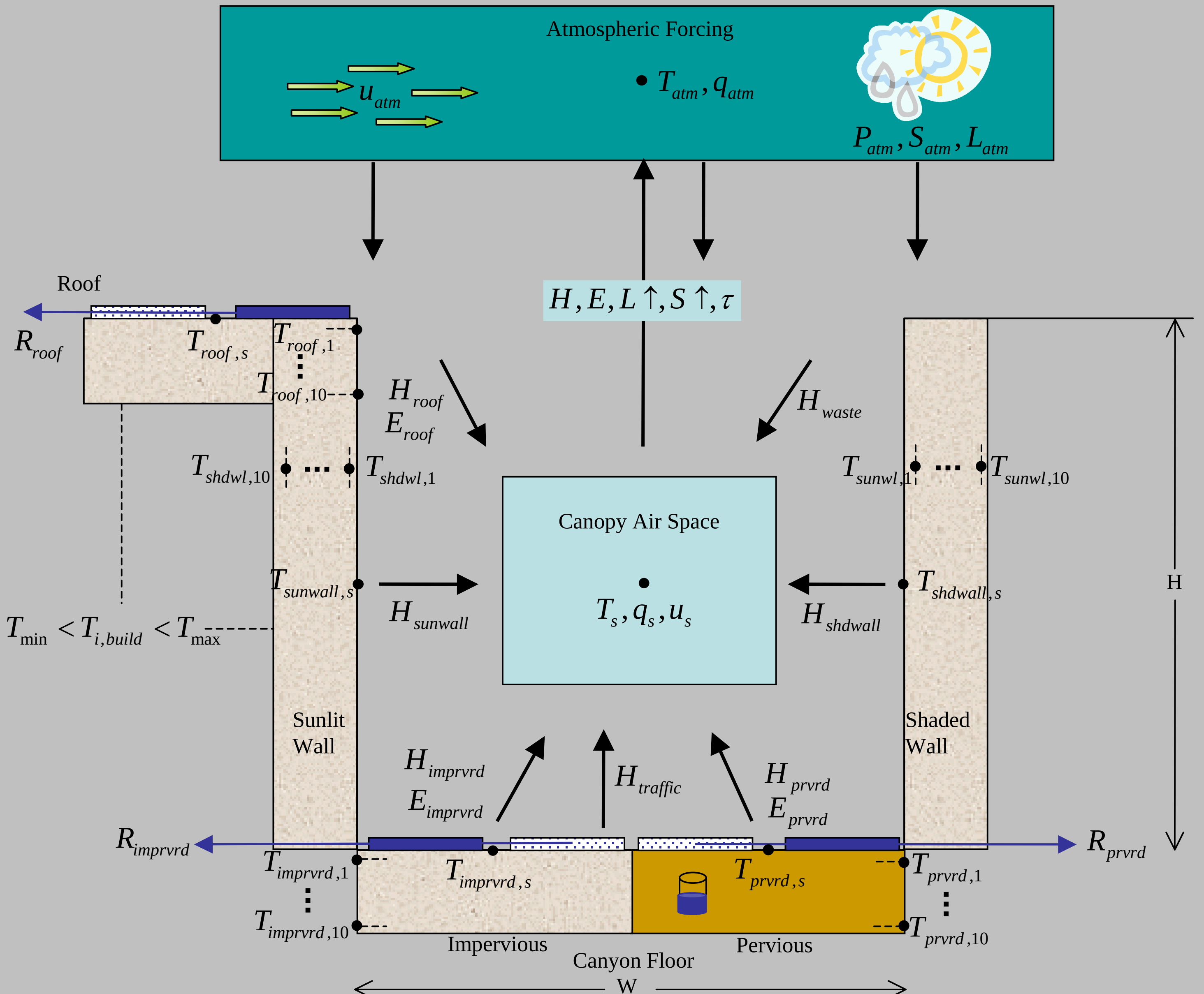
CLM Urban Canyon Model



Model Parameter/data needs

- **Global delineation of urban areas**
- **Geometric and radiative properties of the canyon**
- **Surface and conductive properties of walls, roofs (road properties assumed constant)**
- **Information on human activity and energy consumption levels**

An Urban Sub-model in the CLM



Offline Validation :

- **Following methods and data used by Masson et al. 2002 for TEB model**
- **Observations from two urban sites (courtesy of S. Grimmond):**

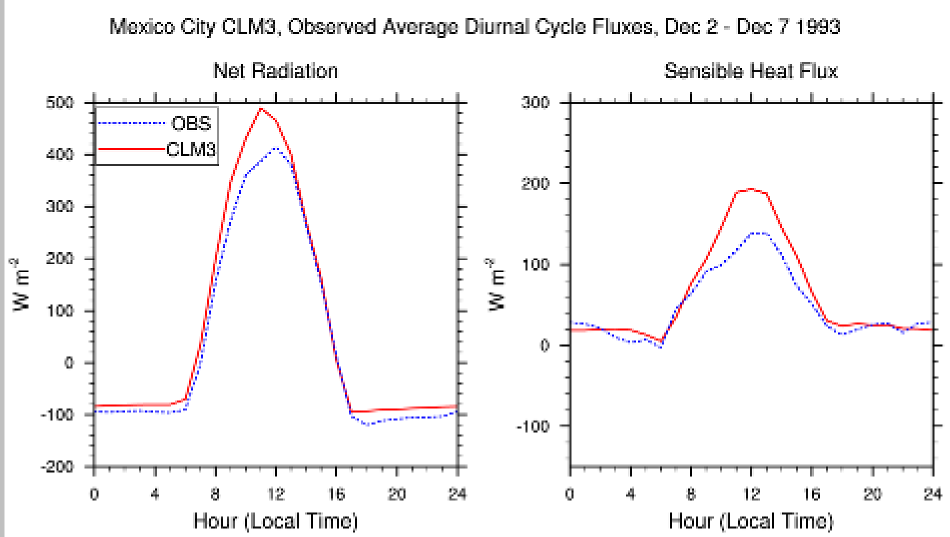
  - Mexico City

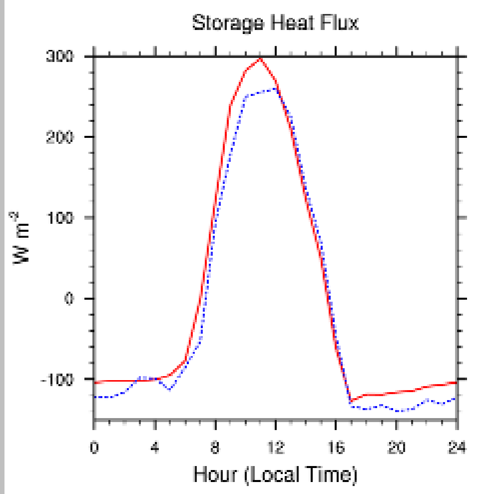
  - Vancouver

Offline Validation – Mexico City

Oke et al. (1999); Dec 1-7, 1993

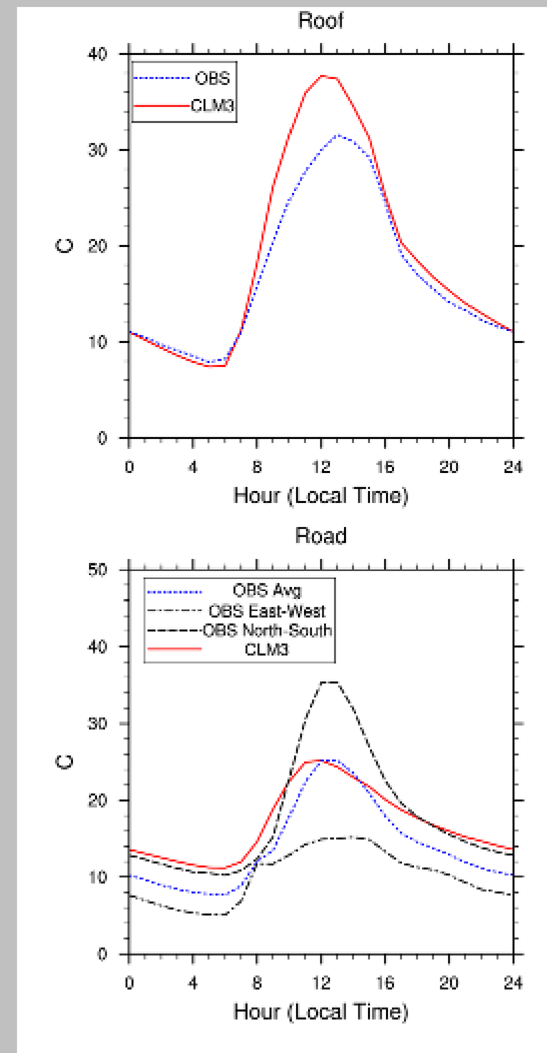
Historic city core (H/W=1.2, H=18m)





Q_S / Q^*

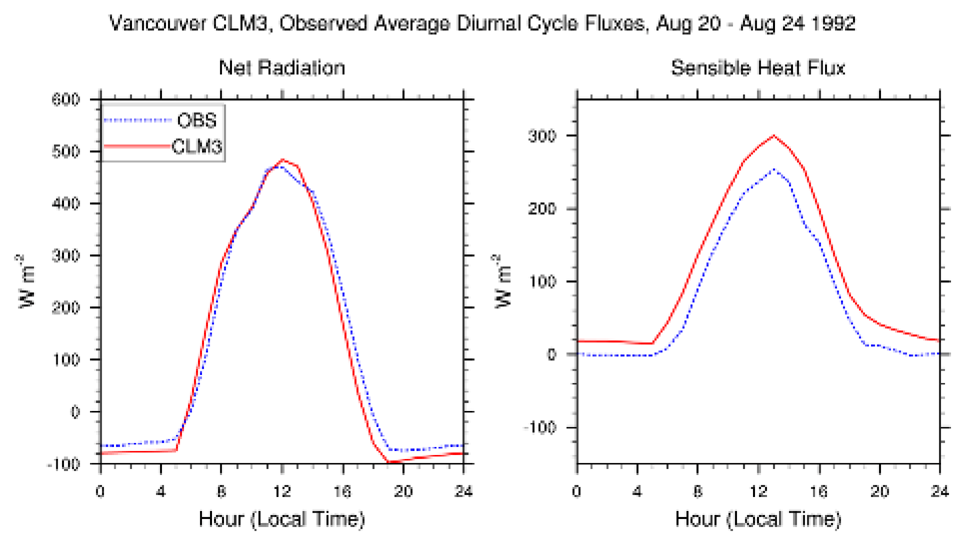
	OBS	Model
Day	0.58	0.55
Night	1.22	1.25

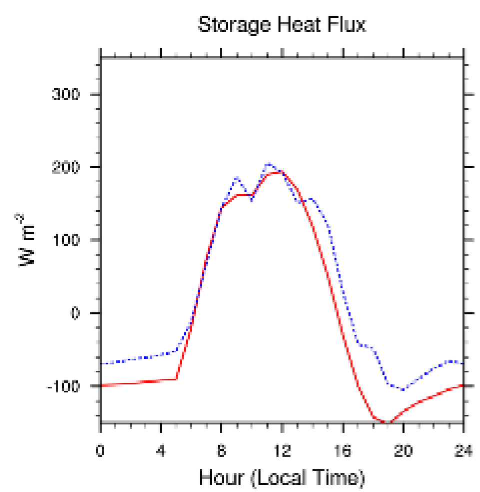


Offline Validation – Vancouver

Voogt and Grimmond (1999); Aug 11-25, 1992

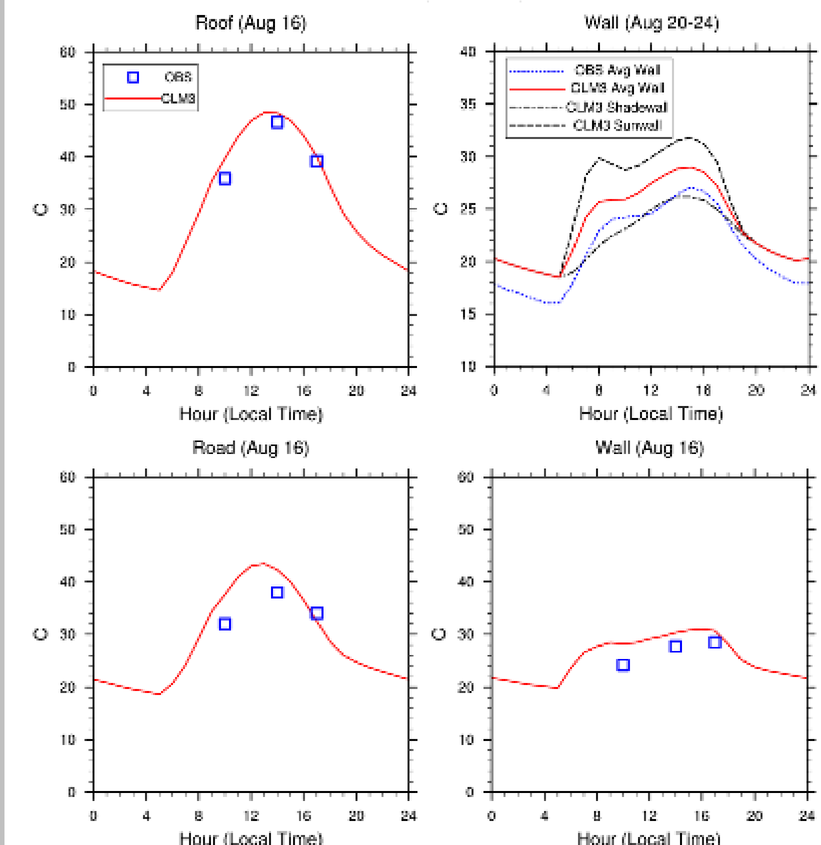
Light Industrial (H/W=0.4, H=6m)





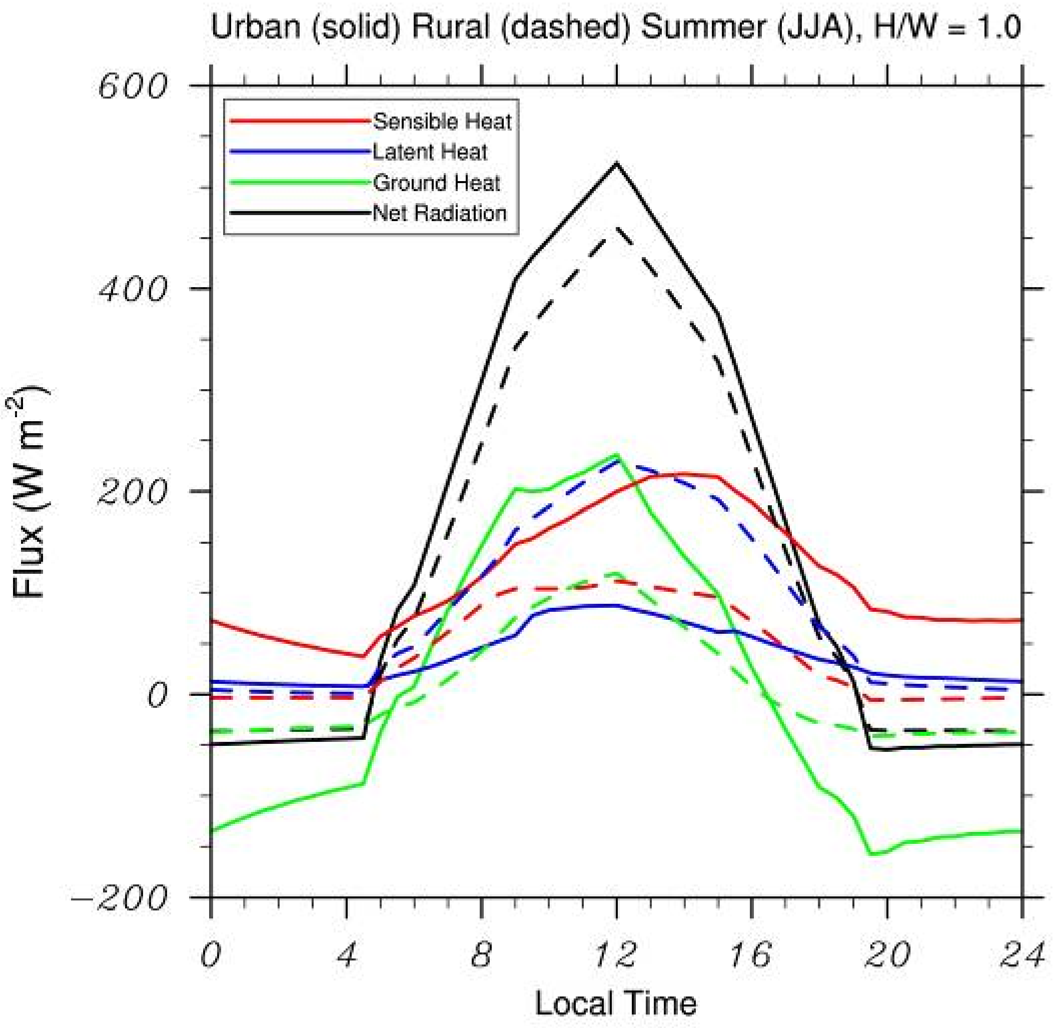
Q_S / Q^*

	OBS	Model
Day	0.38	0.32
Night	1.17	1.39



Simulated Urban Energy Balance Characteristics

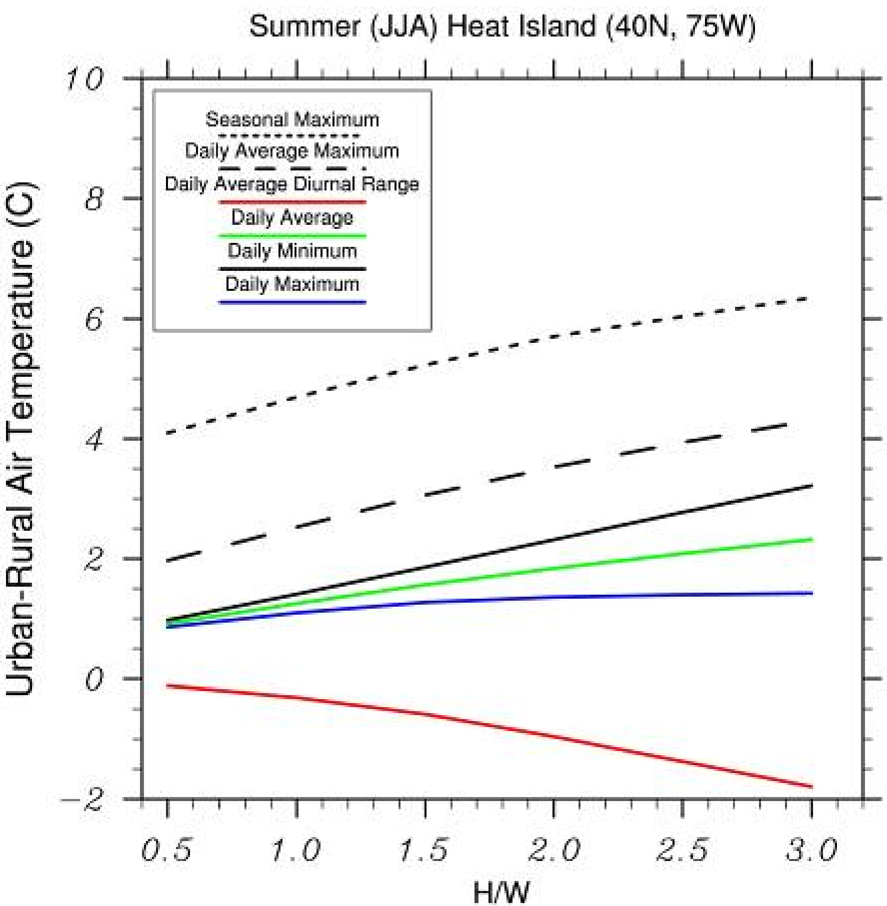
- NCEP atmospheric forcing
- Rural grassland
- Default city with H/W=0.5,…,3.0



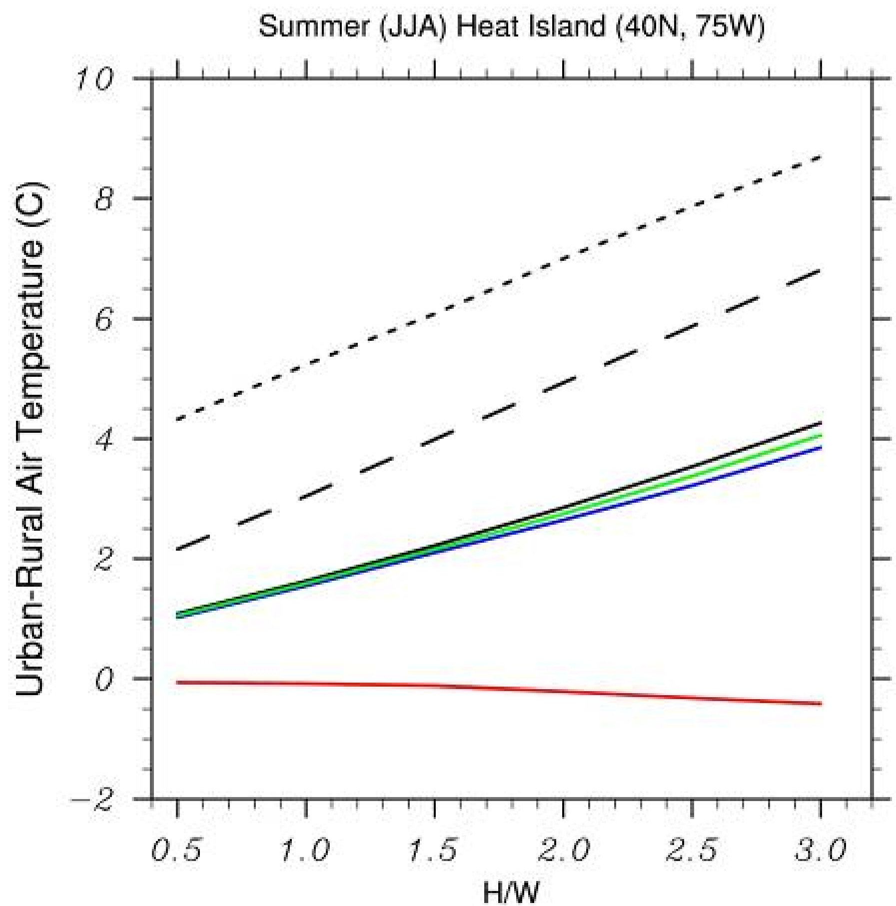
Simulated Urban Heat Island

- NCEP atmospheric forcing
- Rural grassland
- Default city with H/W=0.5,…,3.0

Without Q_f

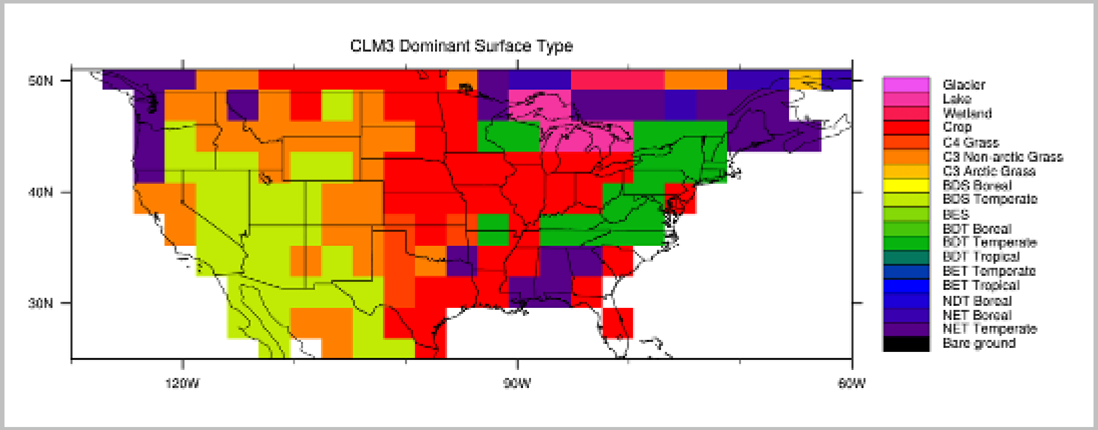


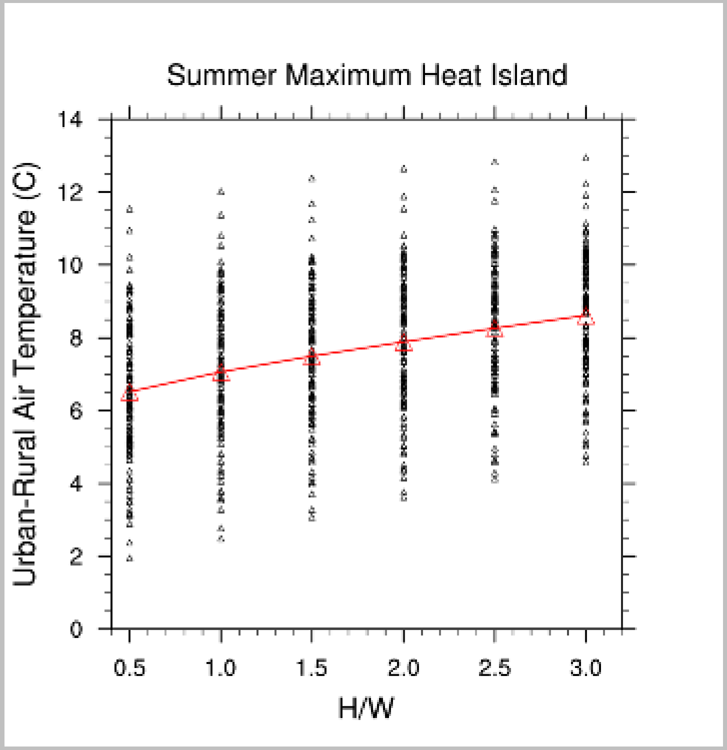
With Q_f

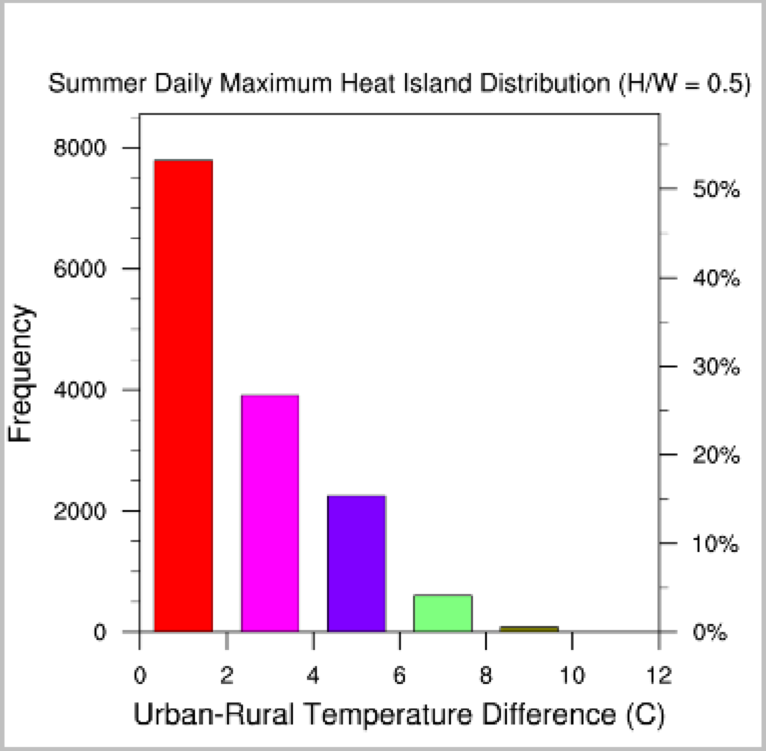


Variability in Simulated Heat Island caused by Climate and Rural Environment

- Atmospheric forcing from CAM (offline model)
- Default city with H/W=0.5,…,3.0
- Rural environment from CLM Surface Data







Model Validation:

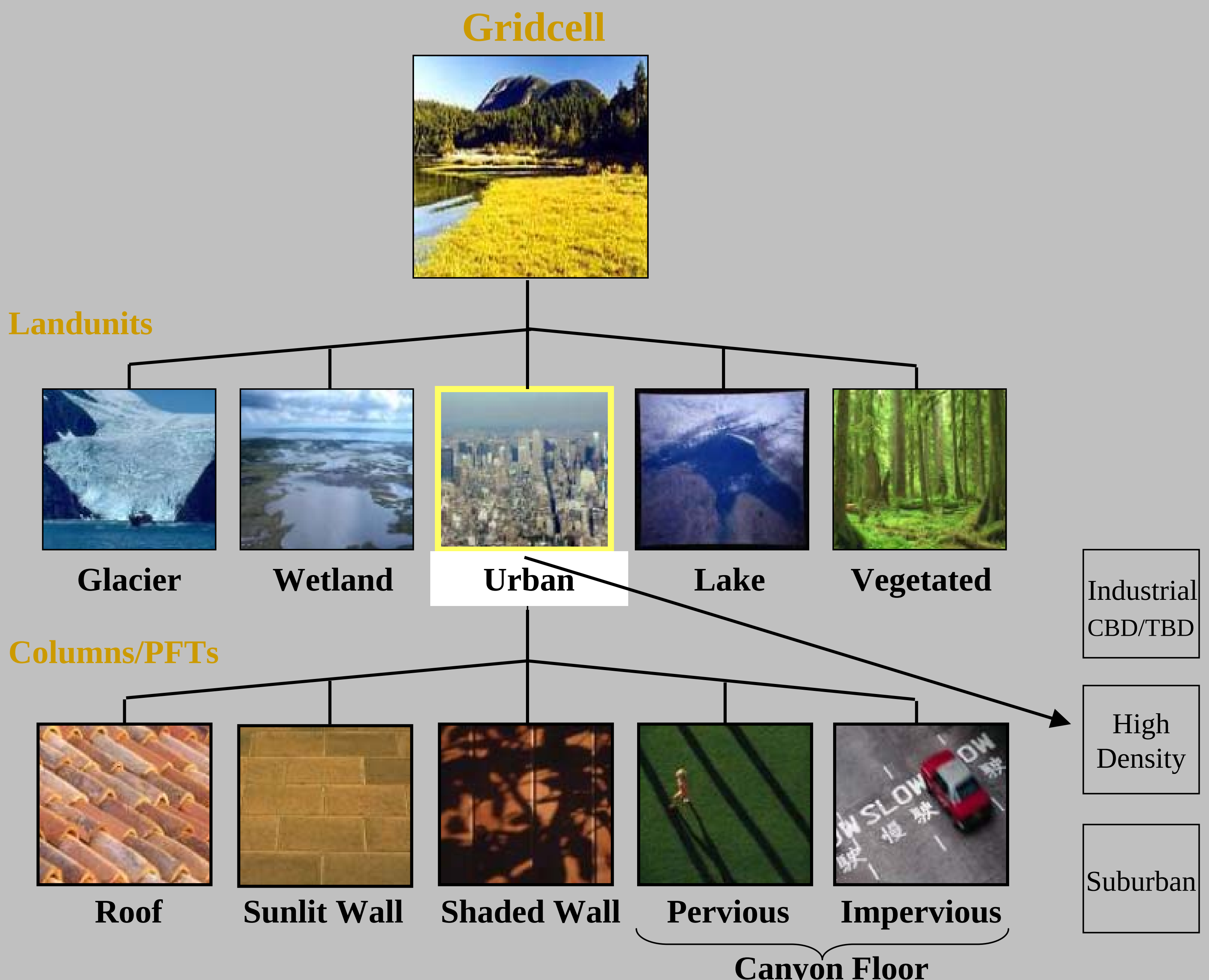
- **Limited validation demonstrates that the urban model shows promise in simulating fluxes and temperatures**

- **Qualitative analysis indicates that the urban model reproduces some general observed characteristics of heat islands:**
  - An urban heat island that increases in intensity with height to width ratio.
  - A decrease in the diurnal temperature range.

- **At a given height to width ratio, a wide range of heat islands is simulated depending on prevailing meteorological conditions and the nature of the rural surface.**

- **A dataset needs to be developed to conduct global simulations**

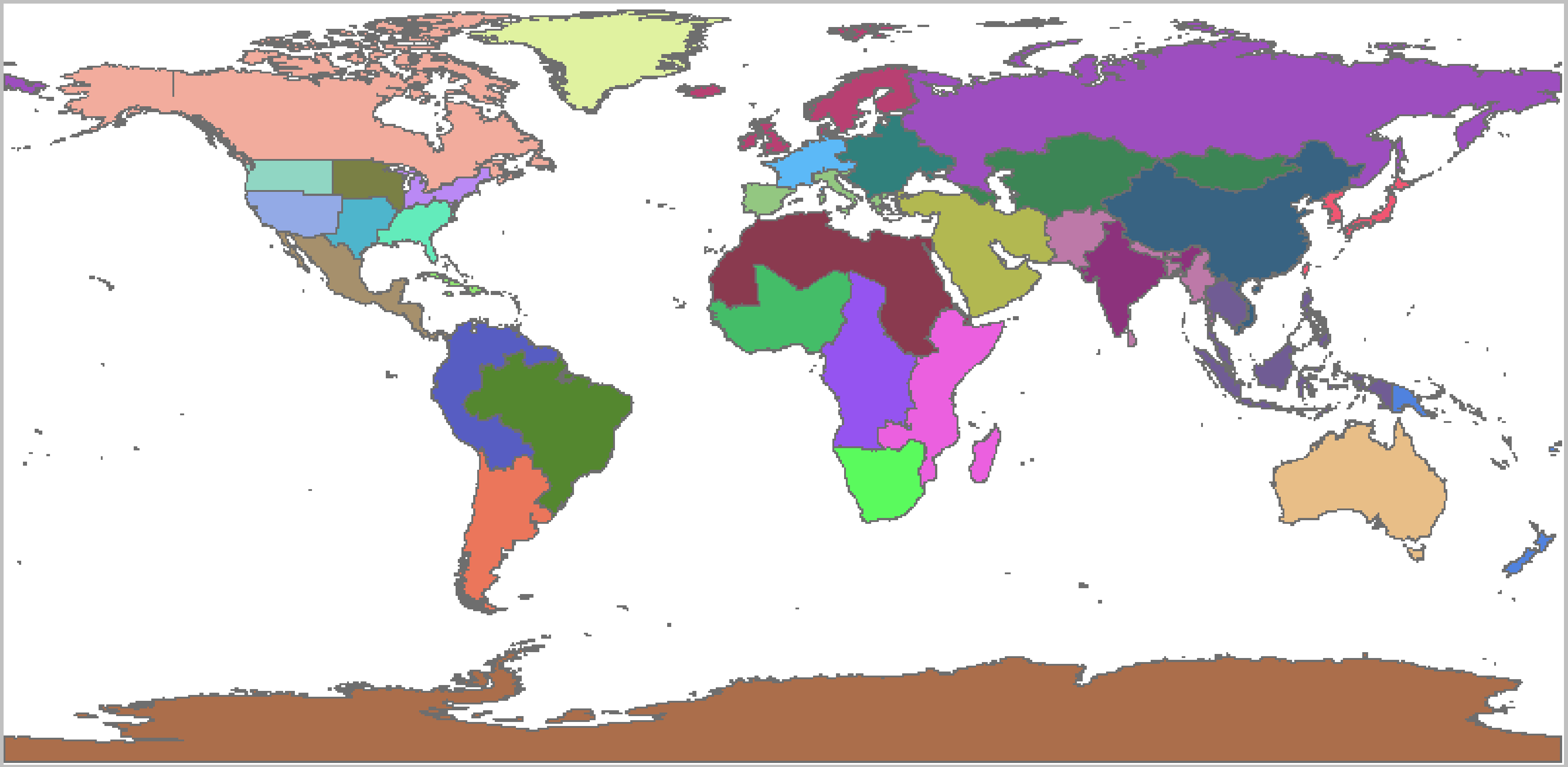
Representing urban areas in CLM/CCSM



Creating a Global Urban Dataset

1. Divide world into manageable portions
2. Define urban extent
3. Delineate three degrees of “urbanness”
4. Compile database of building properties

30 Regions With Similar Urban Character



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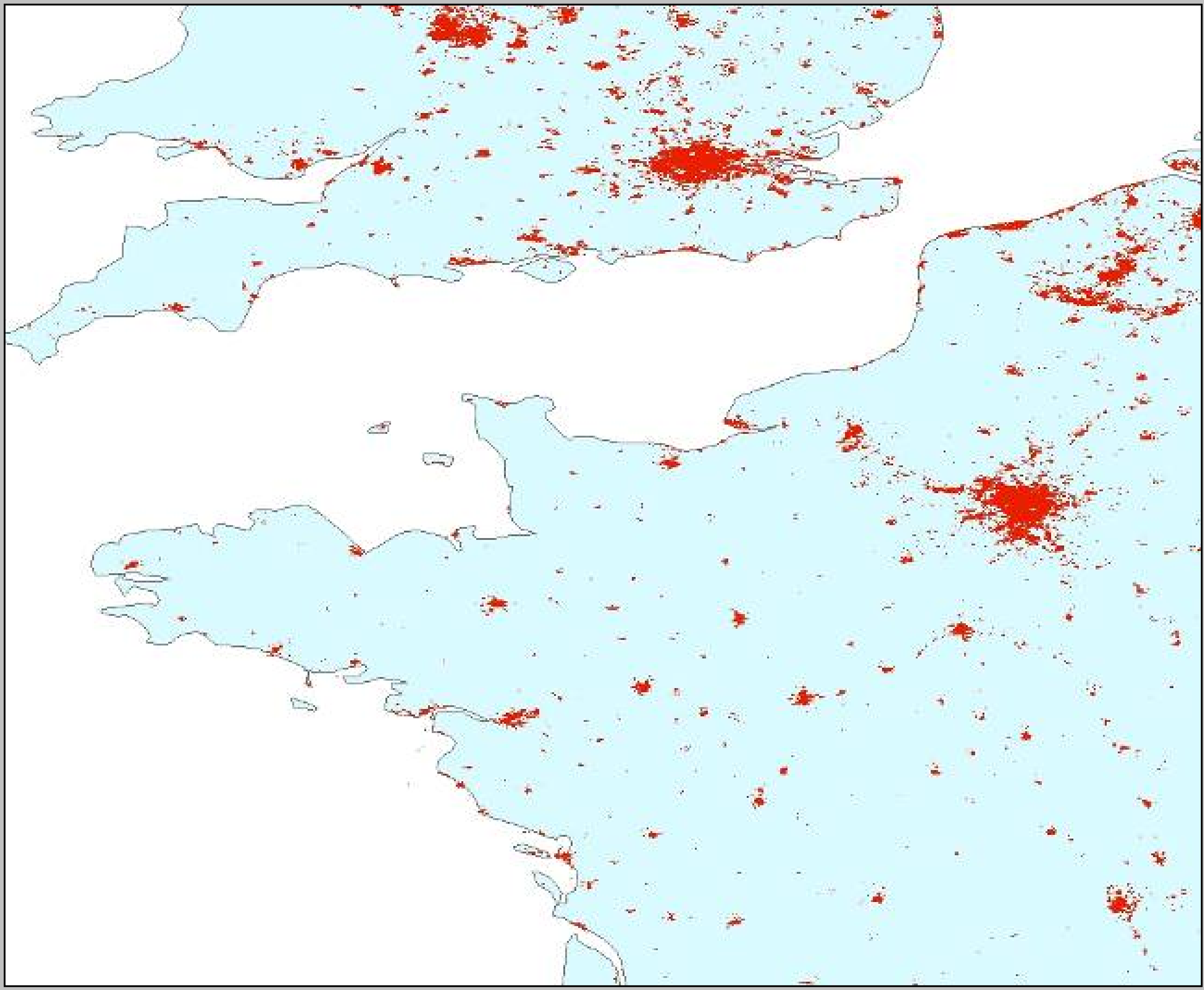
Compare Global Satellite Products

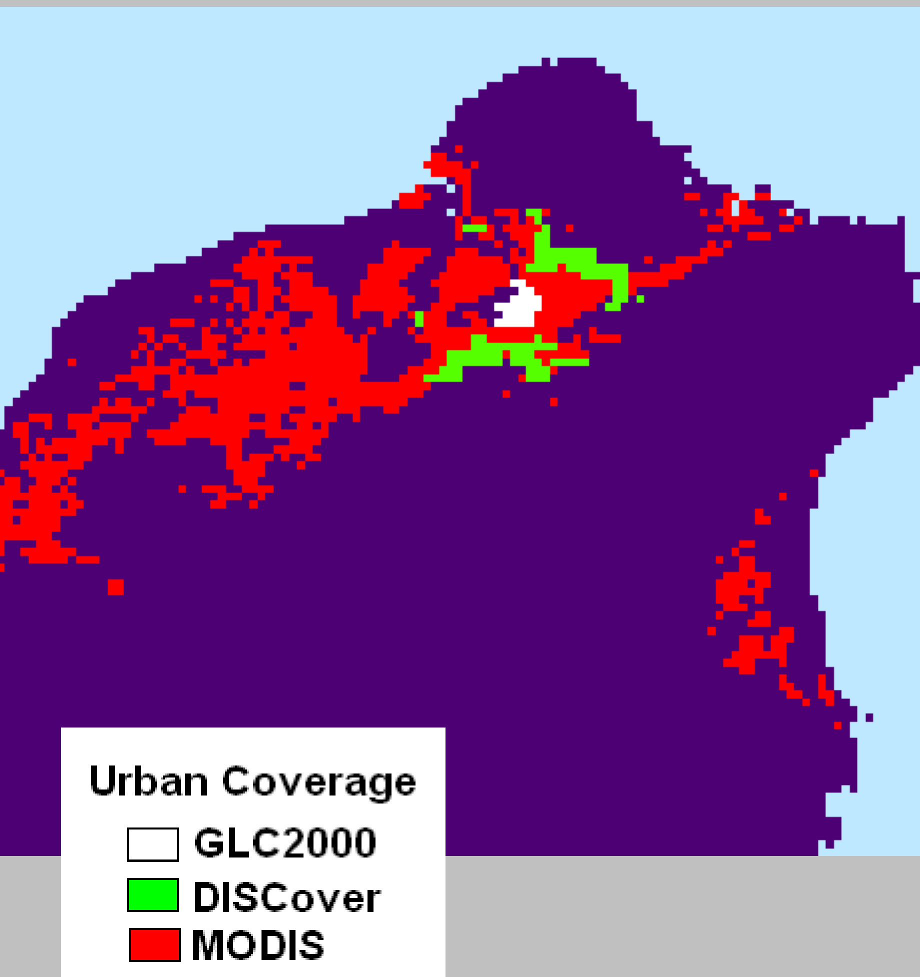
1km resolution

- DISCover
- GLC2000
- MODIS-IGBP
- MODIS-UMD

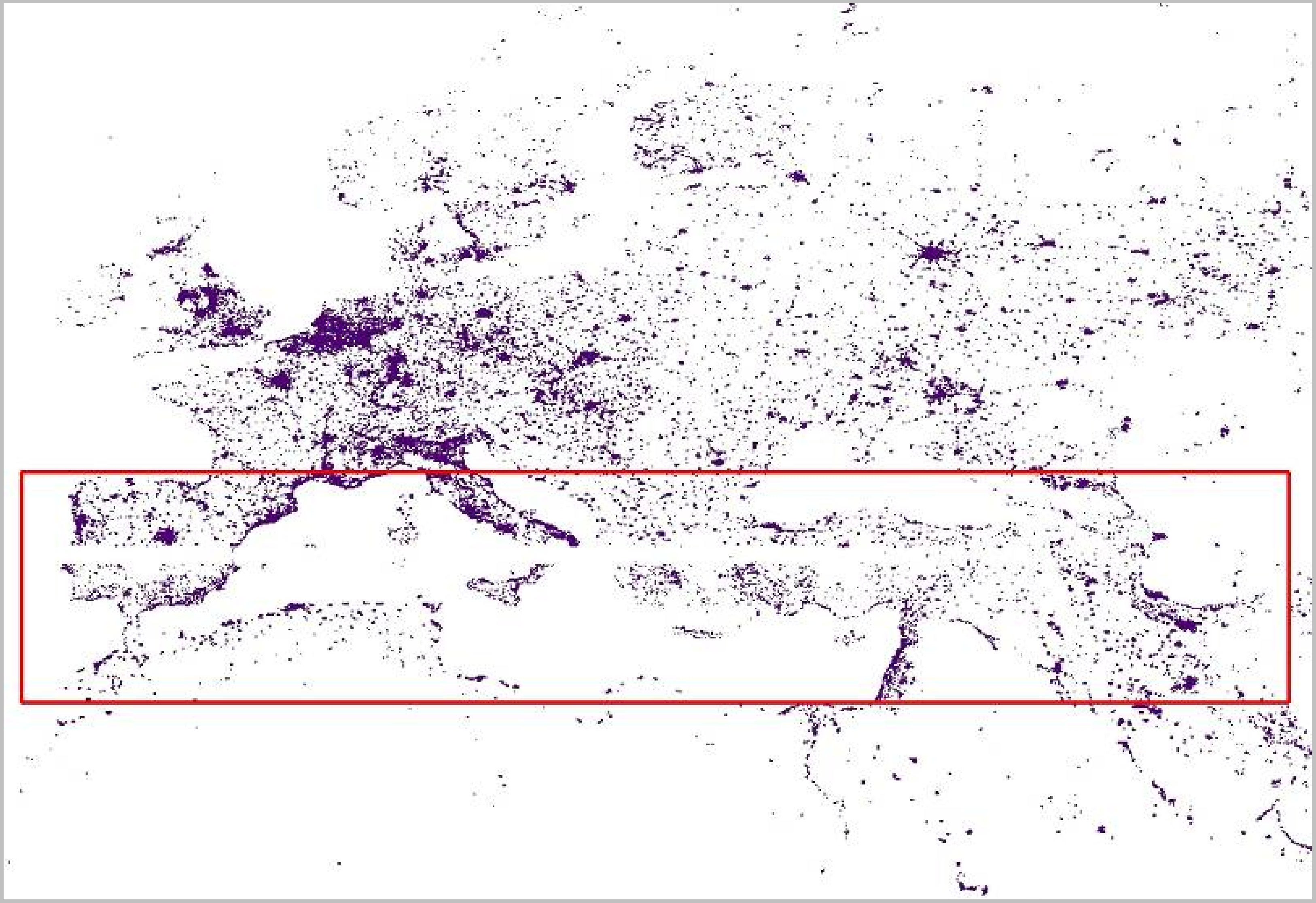


Evaluation of Satellite Products

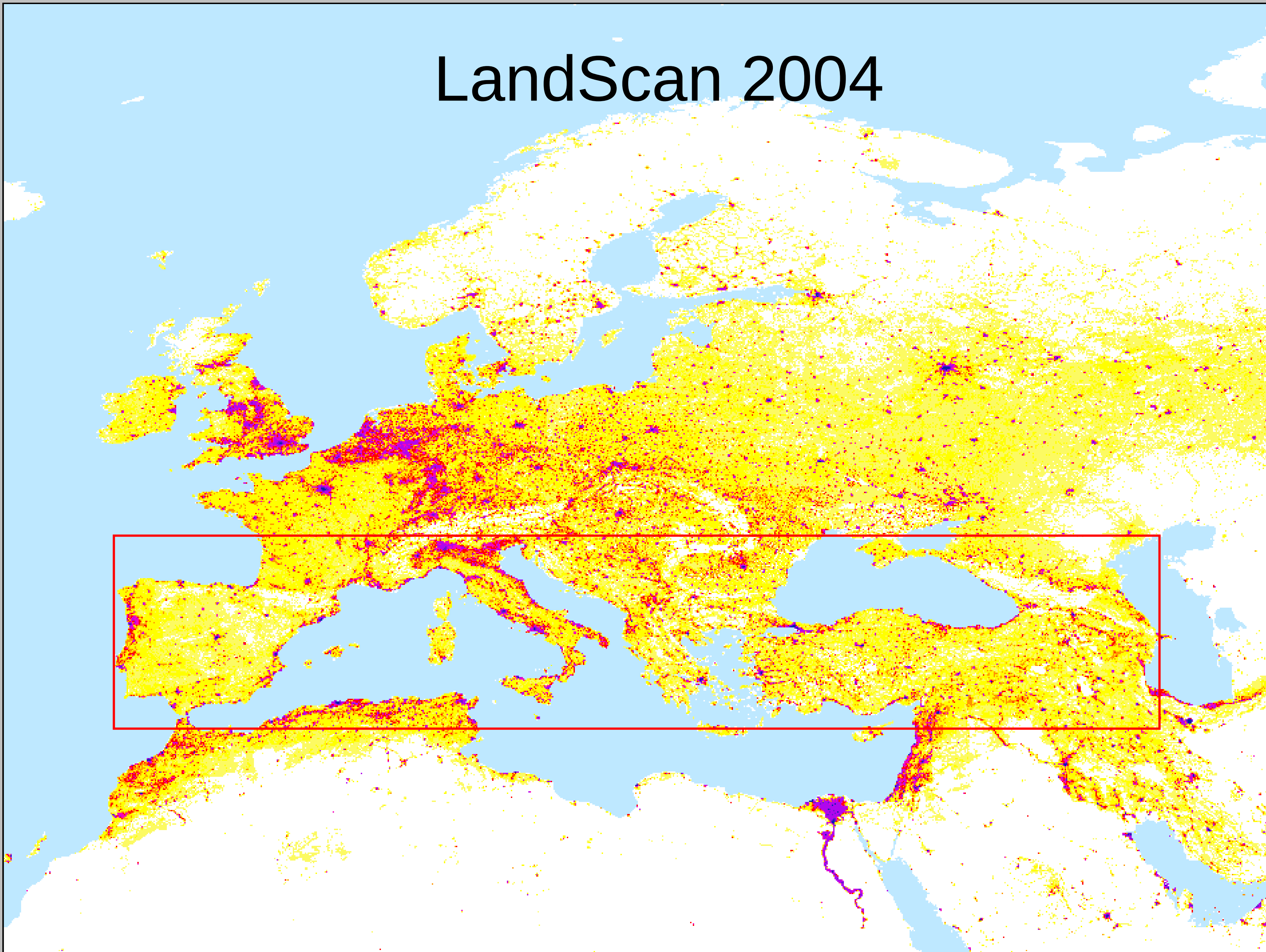
Taipei, Taiwan



MODIS issues



LandScan 2004



Limitations of Satellite Products

- Disagree on what constitutes urban areas
- Processing flaws and methodological questions
- Do not distinguish between levels of urbanization
- Cannot distinguish differences in urban characteristics based on cultural and regional differences
- Lack of temporal information for historical and future projections

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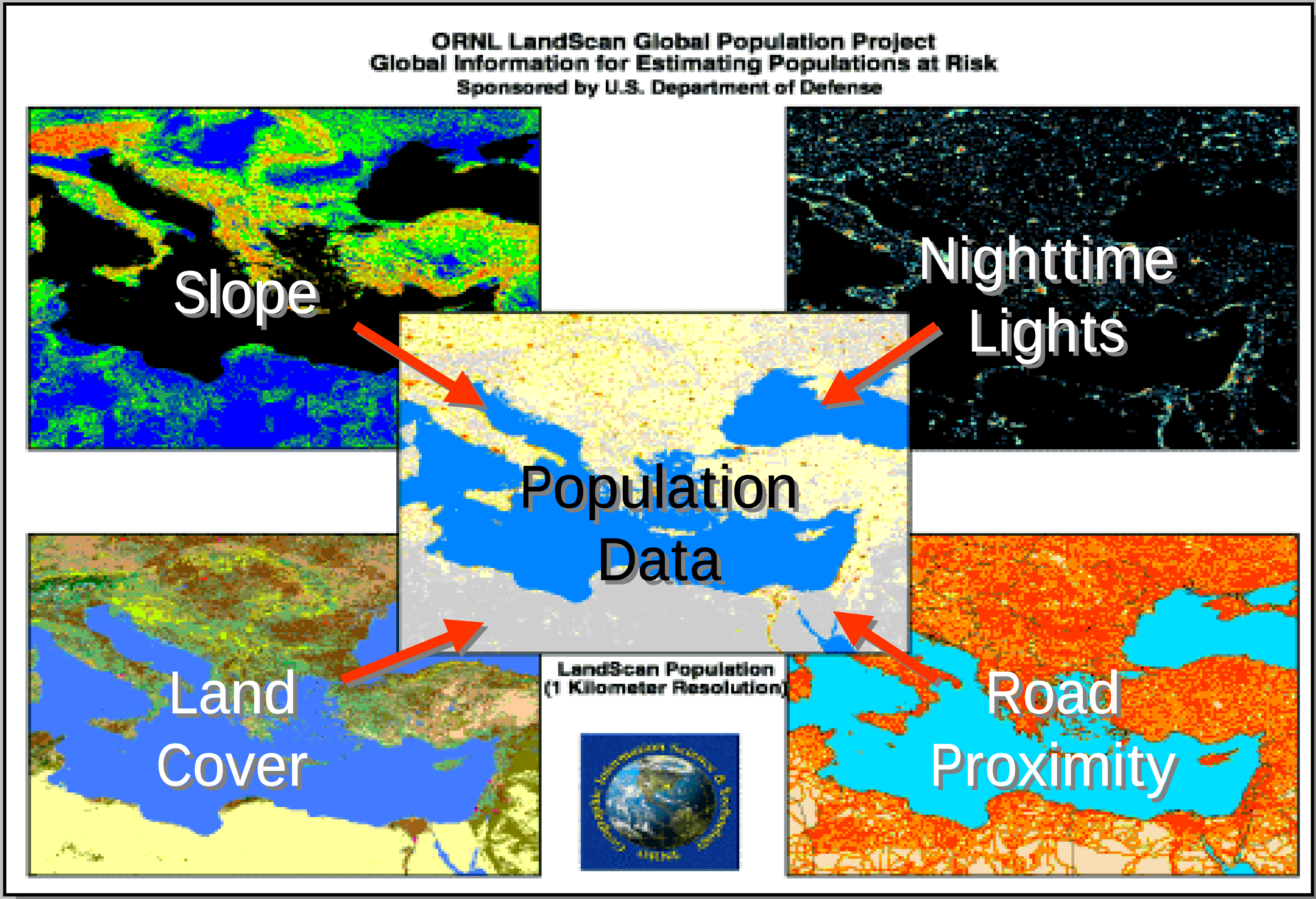
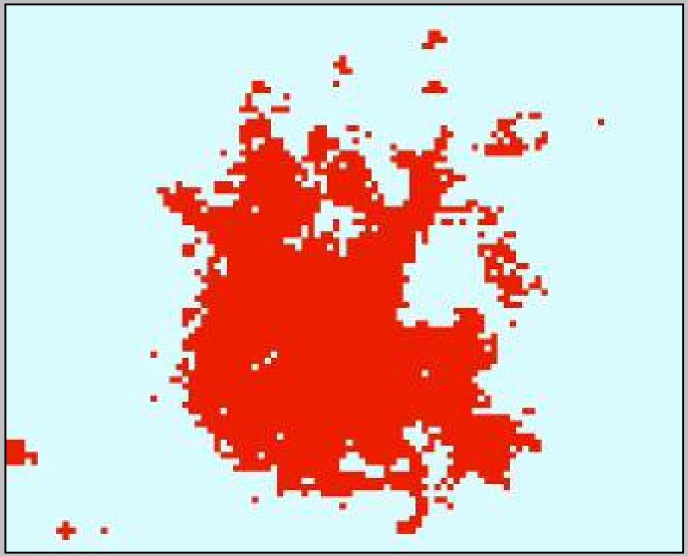
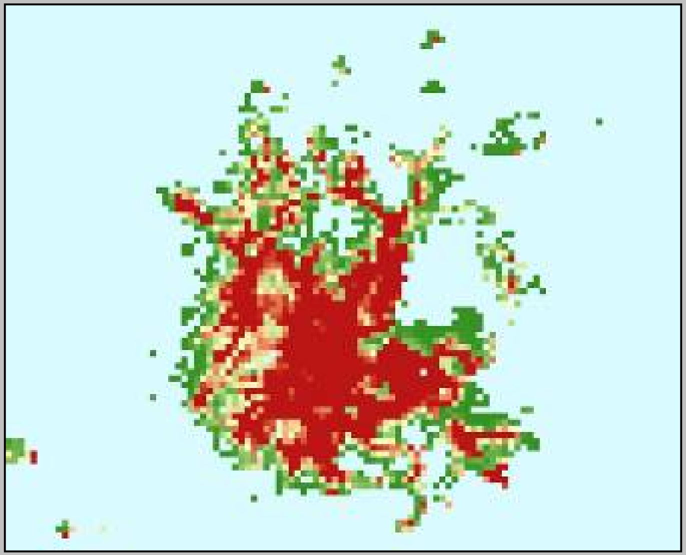
Population Dataset – LandScan



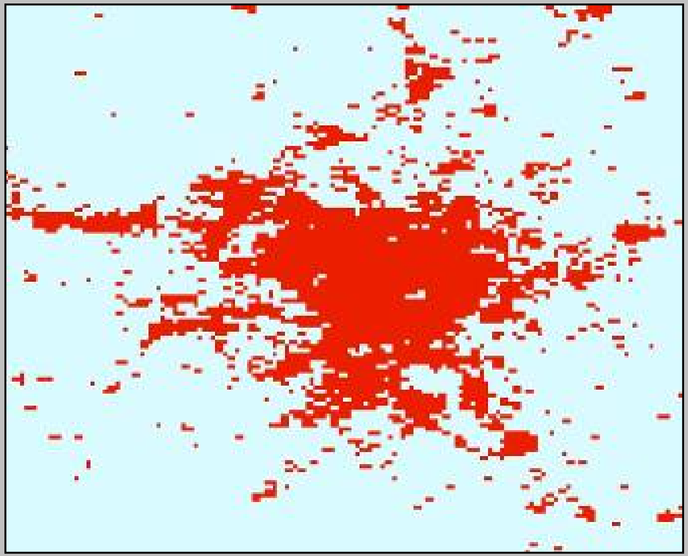
(Dobsen et al, 2000)



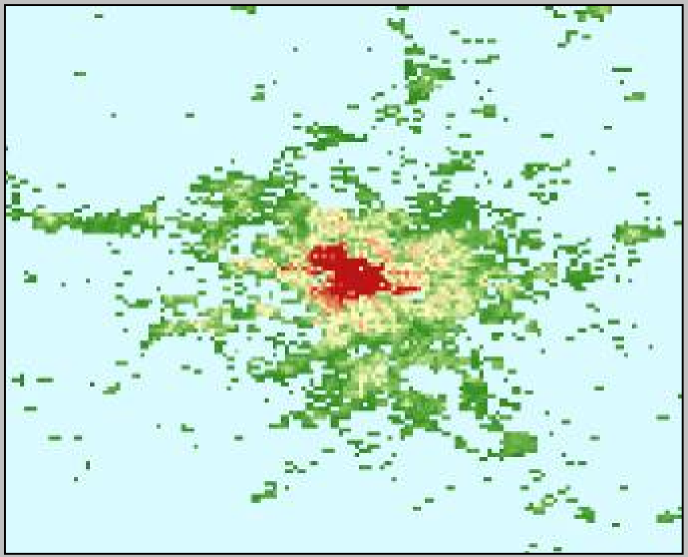
MODIS Mask of Mexico City



Mexico City *(Landscan)*

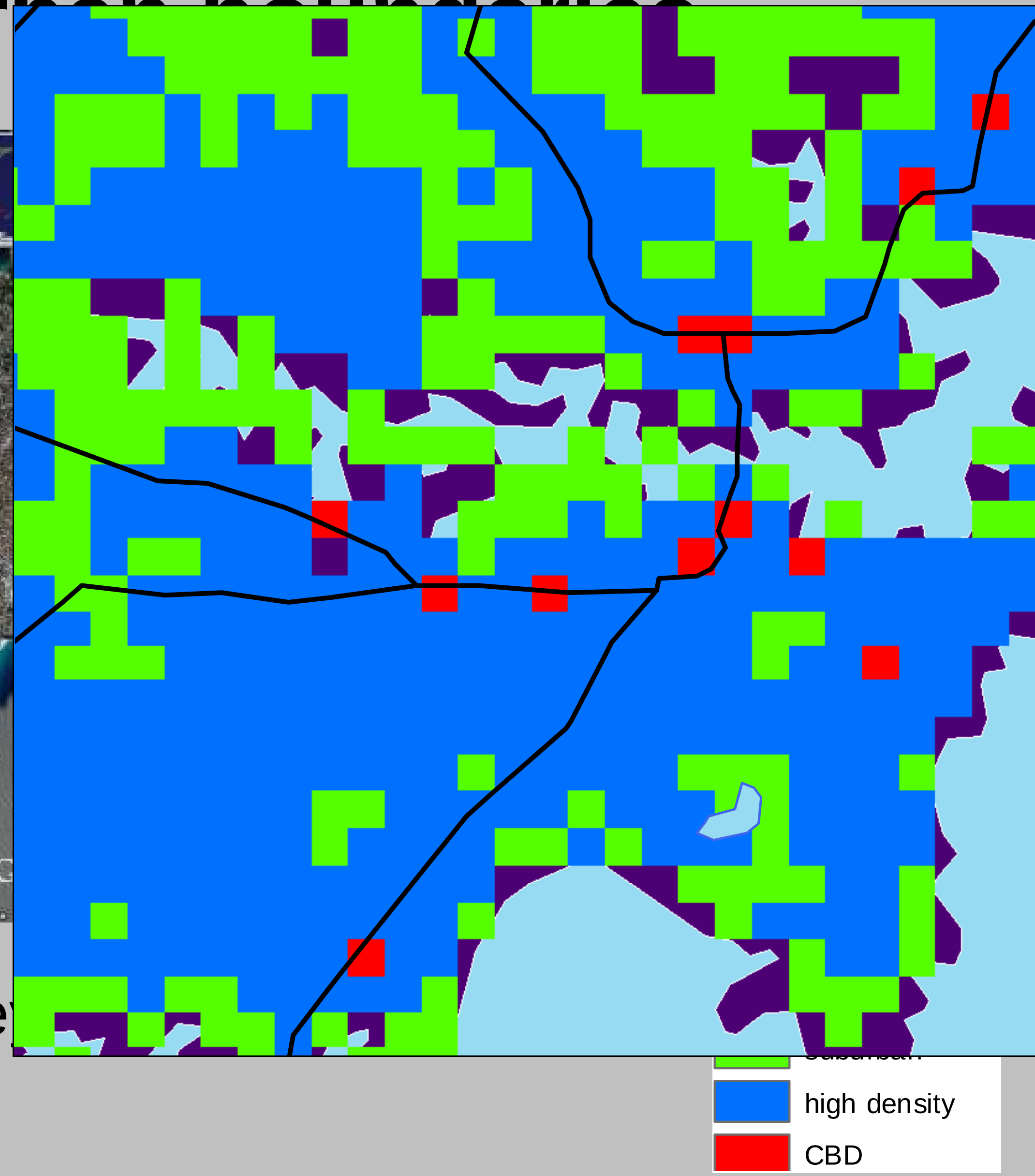


MODIS Mask of Paris



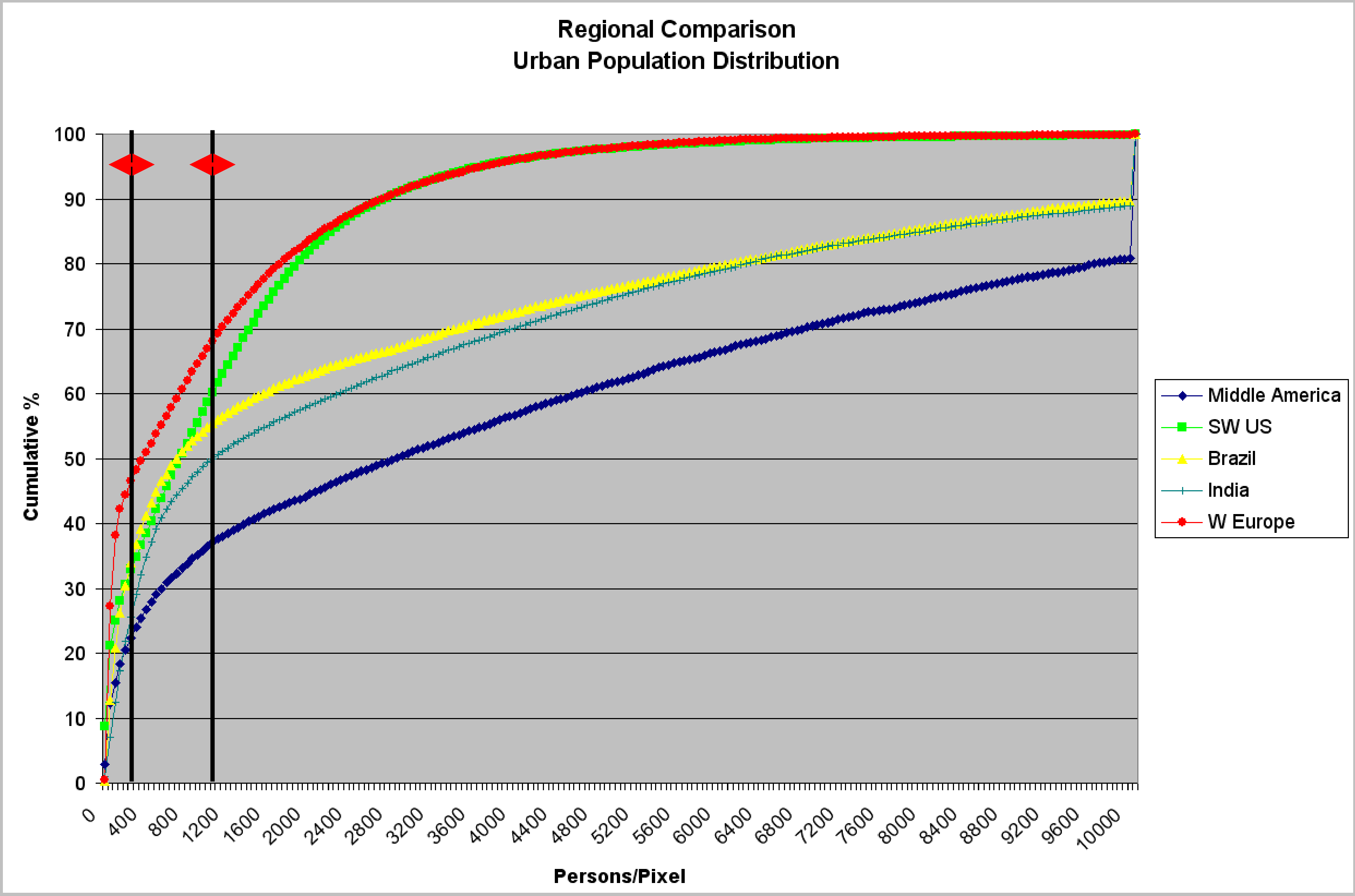
Paris *(Landscan)*

Defining urban boundaries

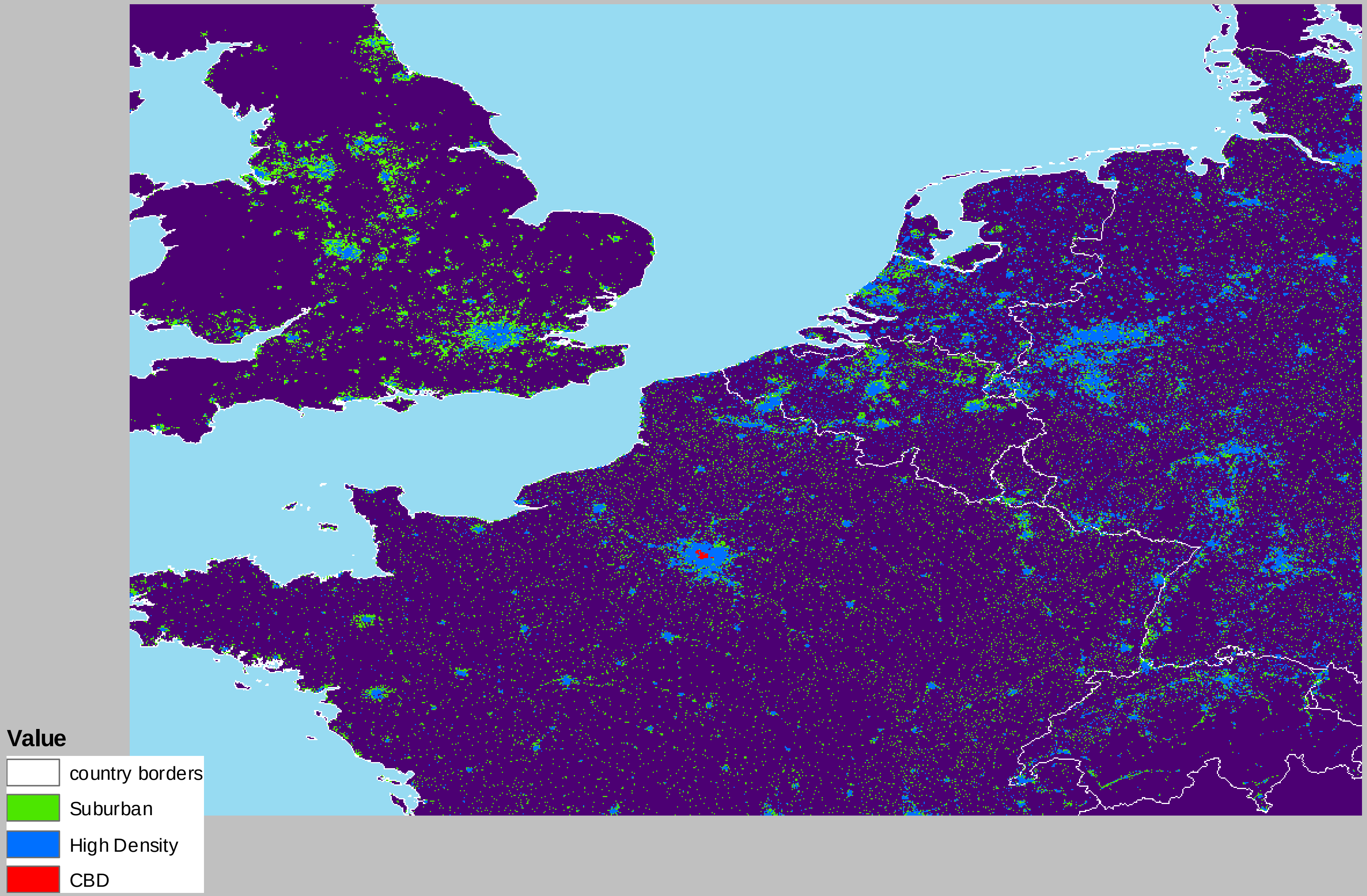


Sydney

Cumulative Landscan population for MODIS urban grid cells by region



Final Product



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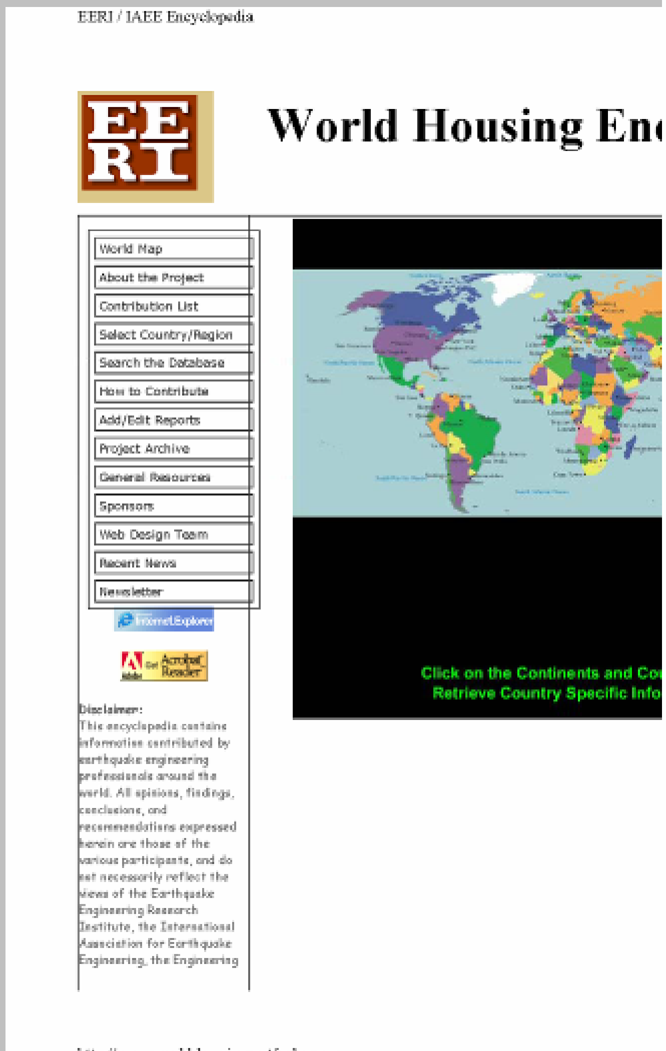
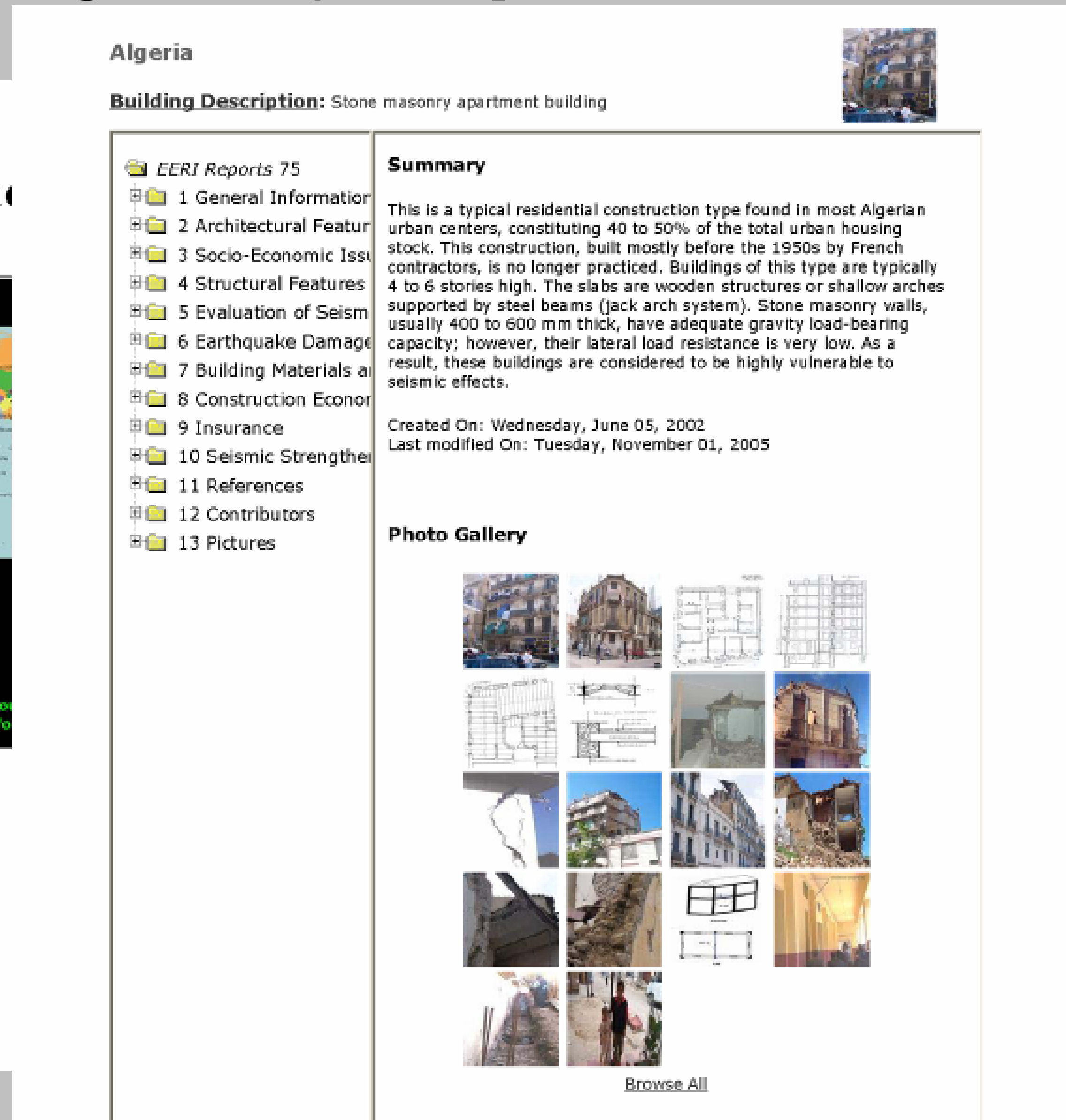
Building properties

- Building height
- Height to width ratio
- Vegetated Fraction
- Properties of building materials
  - Emissivity
  - Albedo
  - Heat capacity
  - Thermal conductivity

World Housing Encyclopedia

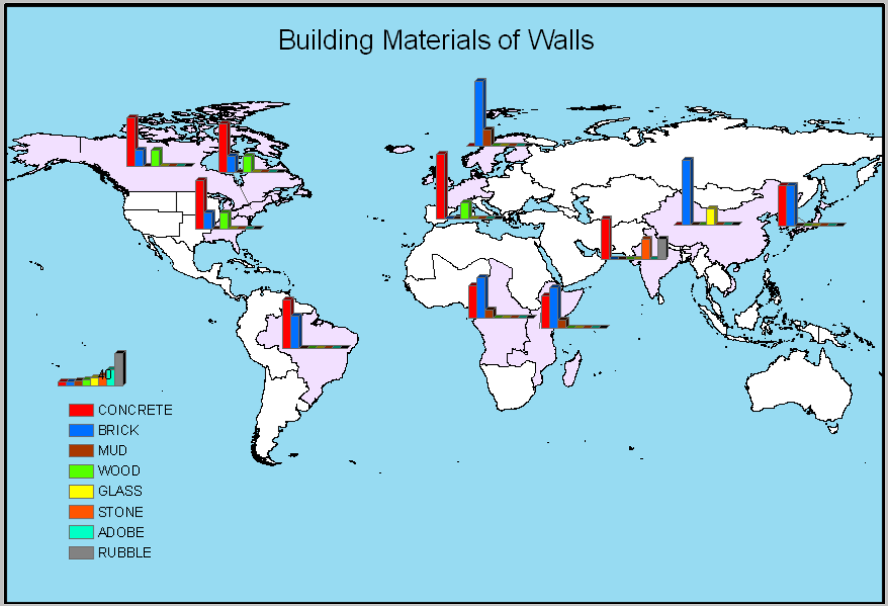


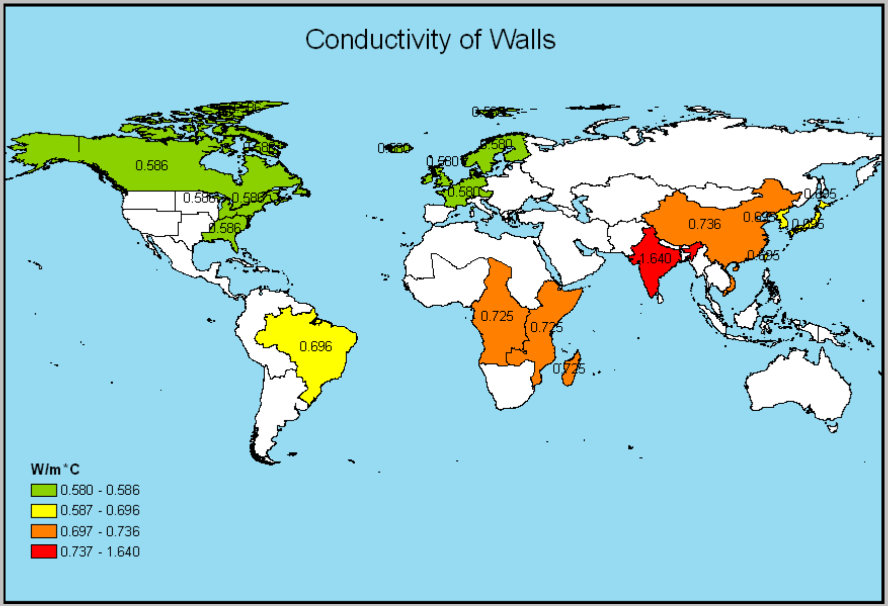


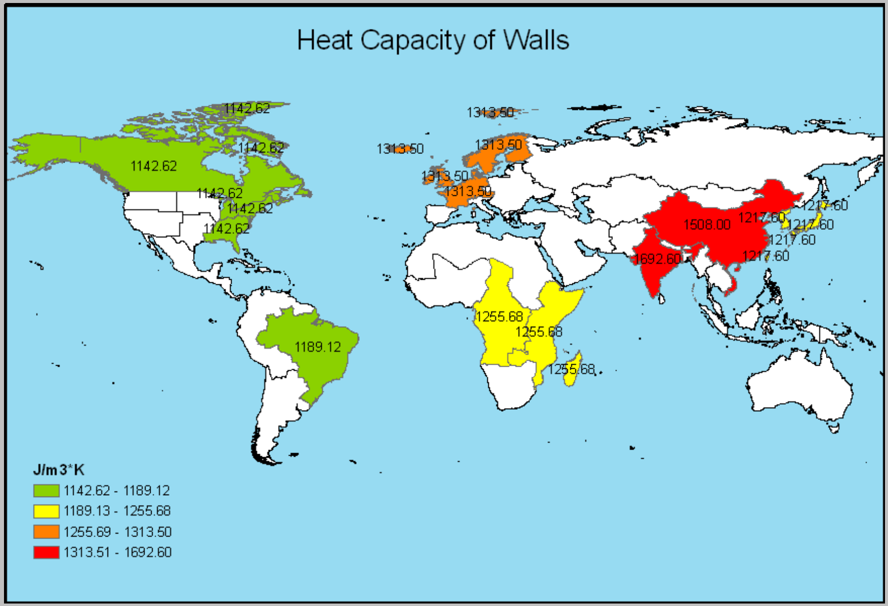
Computing average properties

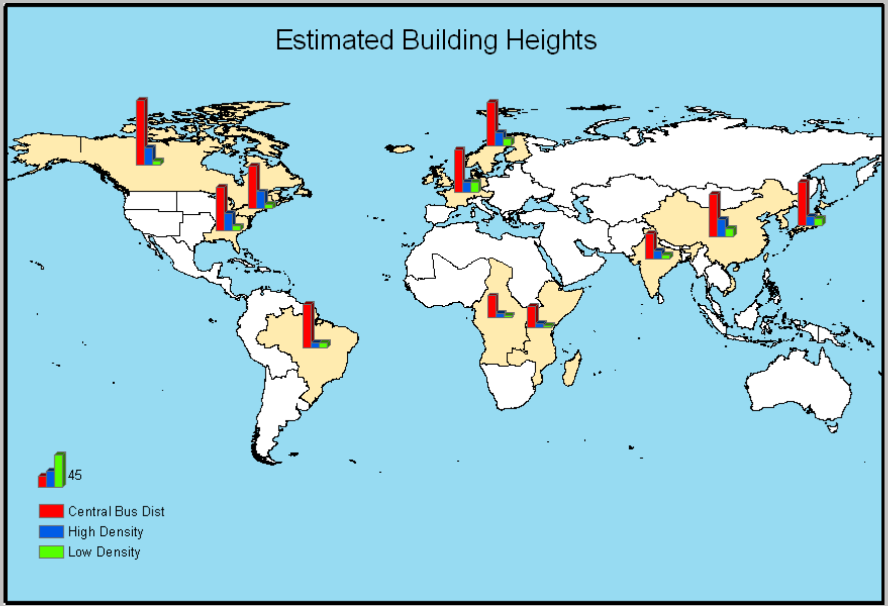
Building Properties						
	Thermal Conductivity (W/mK)	**Heat Capacity** (MJ/m^3 K)	**Albedo**	**Density** (kg/m^3)	**Specific Heat** (J/kg C)	**Emissivity**
concrete	0.7	1075.2	0.225	1280	840	0.92
brick	0.7	1360.0	0.3	1700	800	0.9
mud	1.0	1456.0	0.3	1820	800	0.9
wood	0.1	1127.5	0.5	550	2050	0.87
glass	0.9	2100.0	0.08	2500	840	0.91
stone	2.6	2310.0	0.275	2750	840	0.92
adobe	1.0	1456.0	0.3	1820	800	0.91
rubble	0.8	950	0.275	1900	500	0.92

Sources: T.R. Oke,1987 and J.A.Clarke, 2001









Preliminary data

Further Work

- Compare test run to case study parameters
- Adjust assumptions based on test results
- Initiate development of a transient dataset
- Run a global application to see how different regions respond
- Make urban dataset available
- Proceed to next step in improving land cover datasets