

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

This research is supported by the Office of Science (BER), U.S. Department of Energy, Cooperative Agreement No. DE-FC02-97ER62402, by the National Science Foundation grant numbers ATM-0107404, and ATM-0413540, the NCAR Weather and Climate Impact Assessment Science Initiative, and the University of Kansas, Center for Research.

Johannes Feddema
Trisha Jackson
Pei-Ling Lin
John Bauer

University of Kansas
Google

Image © 2005 Sanborn
© 2005 Sanborn
Image © 2005 DigitalGlobe

© 2005
Google

Motivation:

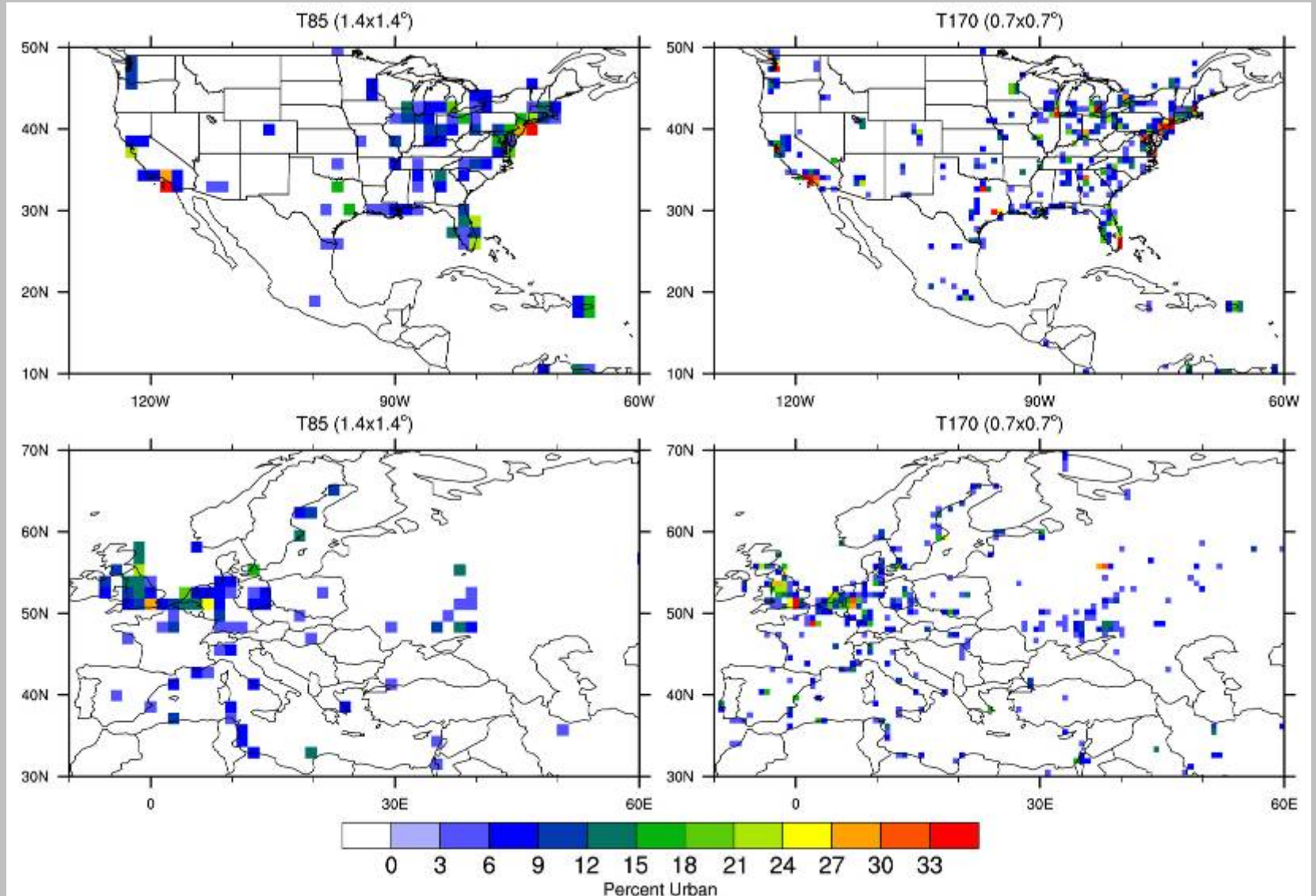


- **Urbanization is a significant component of anthropogenic land cover change**
- **Urban areas affect local climate; does this scale to a global impact?**
- **The majority of people live in urban areas and experience urban climates**
- **Urban areas are detectable at the GCM grid scale**
- **Urban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

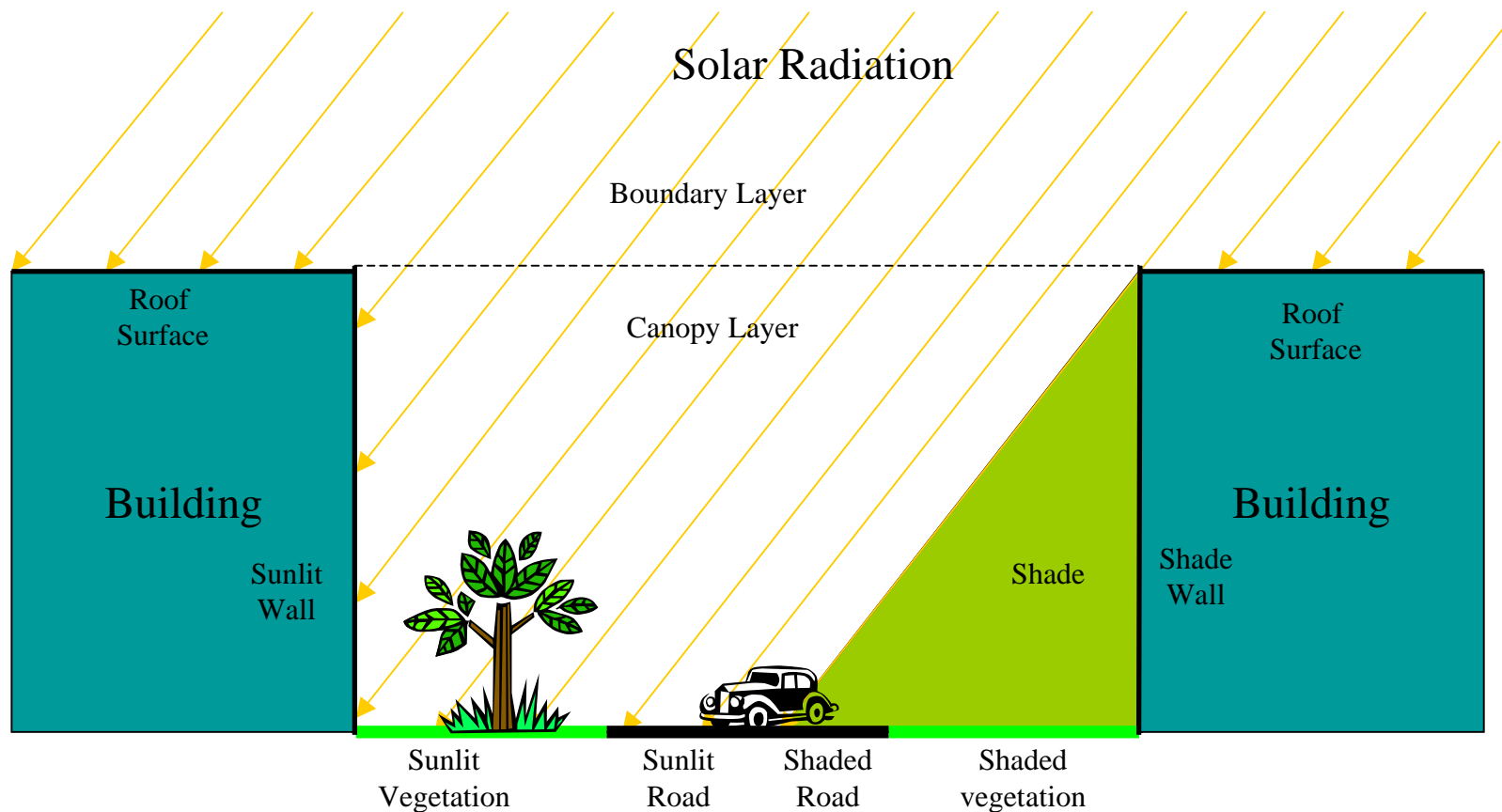
IPCC AR4

The Future?



Preliminary Data

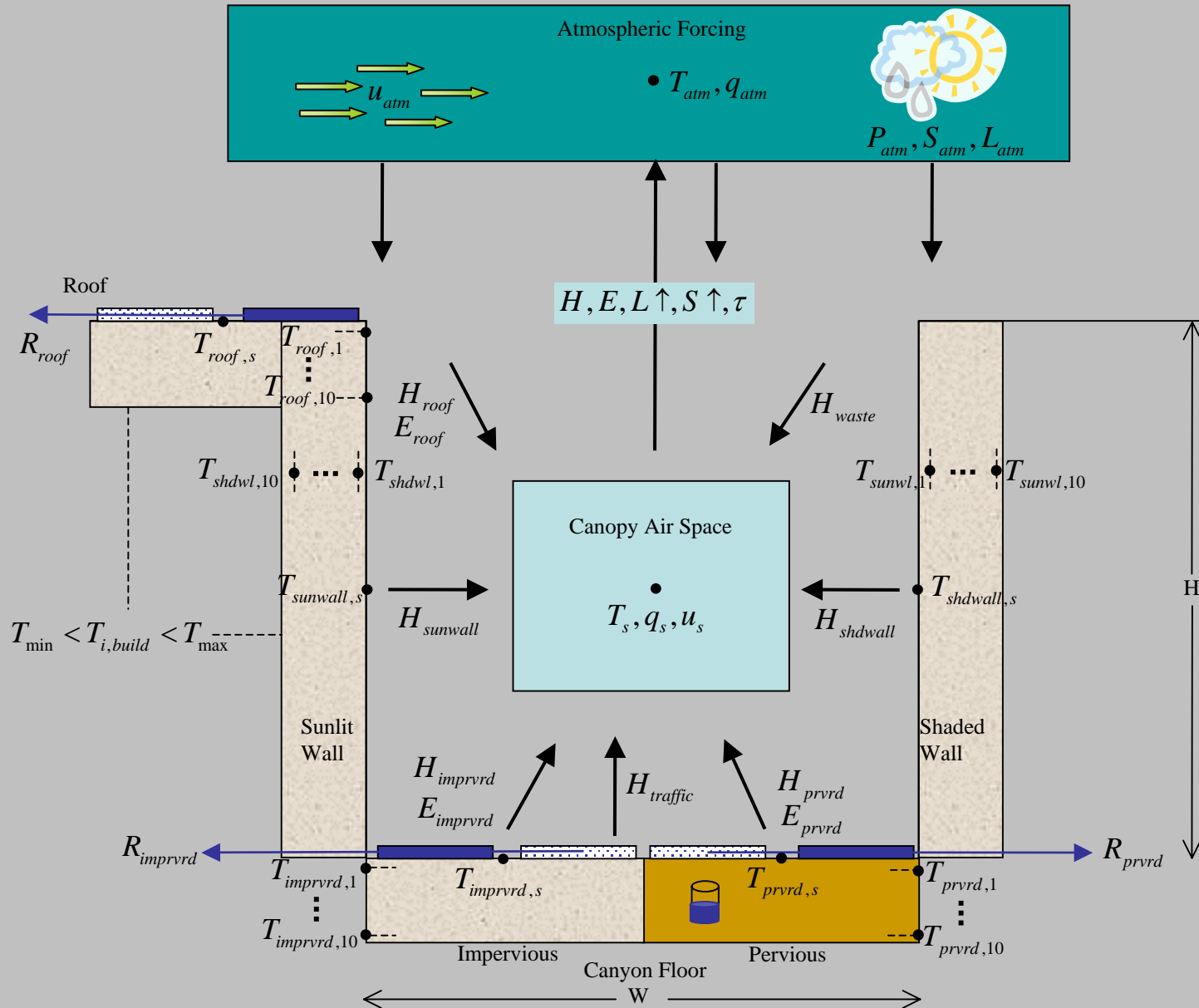
CLM Urban Canyon Model



Model Parameter/data needs

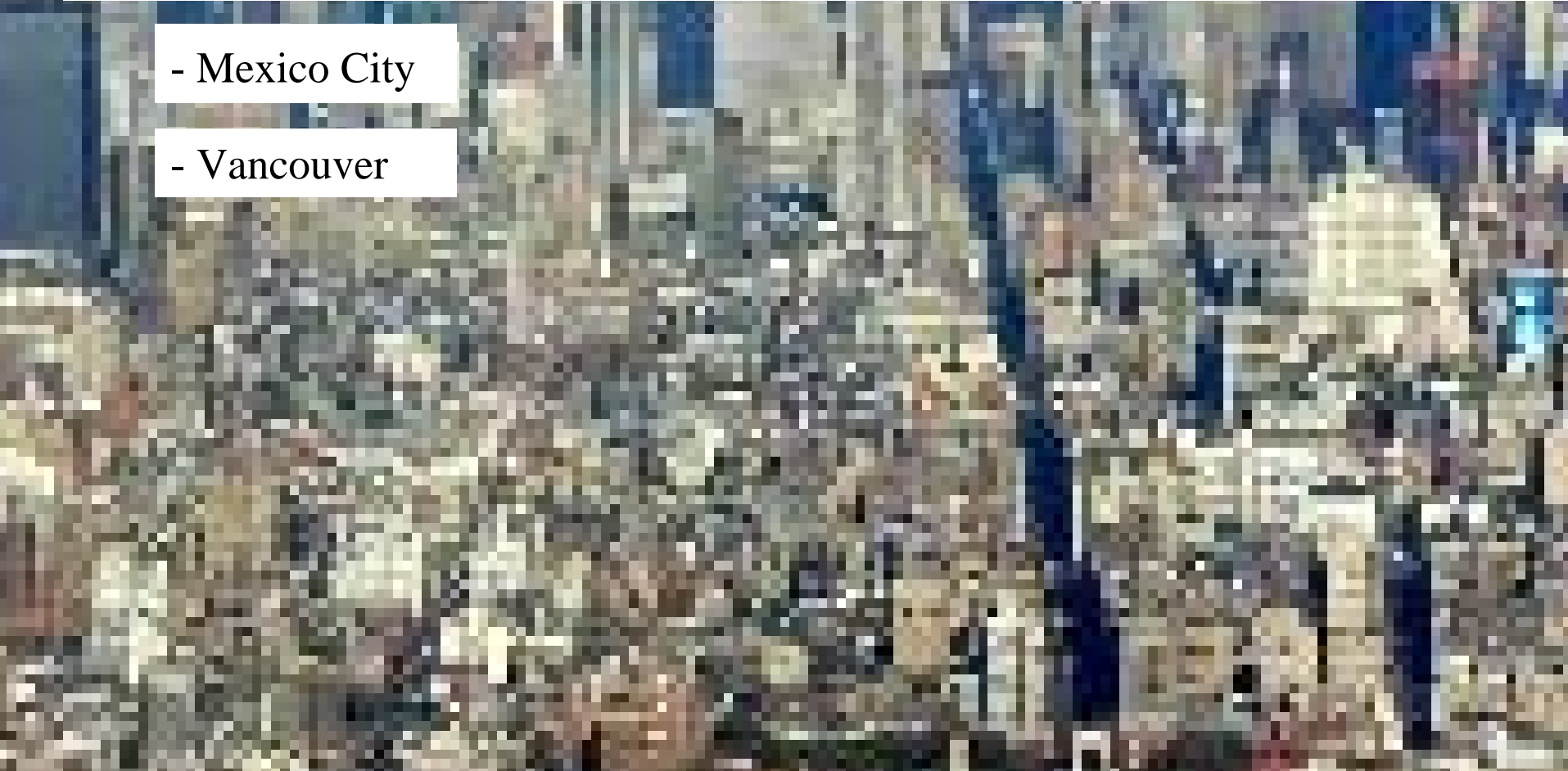
- Global delineation of urban areas
- Geometric and radiative properties of the canyon
- Surface and conductive properties of walls, roofs (road properties assumed constant)
- Information on human activity and energy consumption levels

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

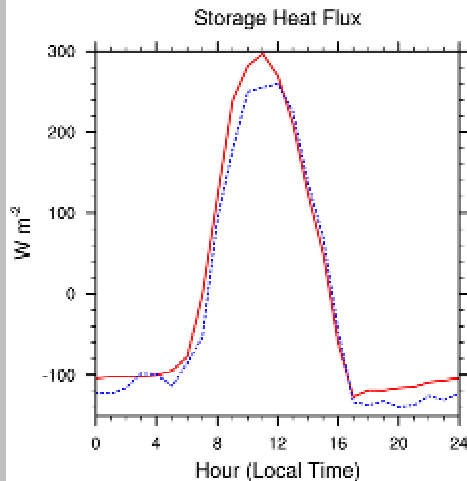
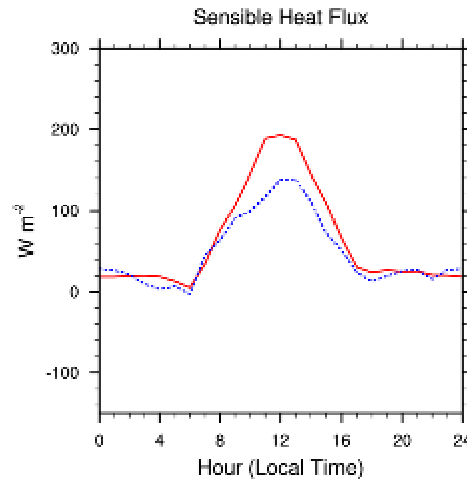
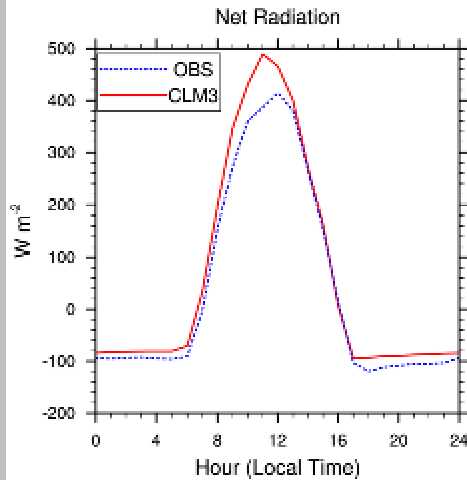


Offline Validation – Mexico City

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

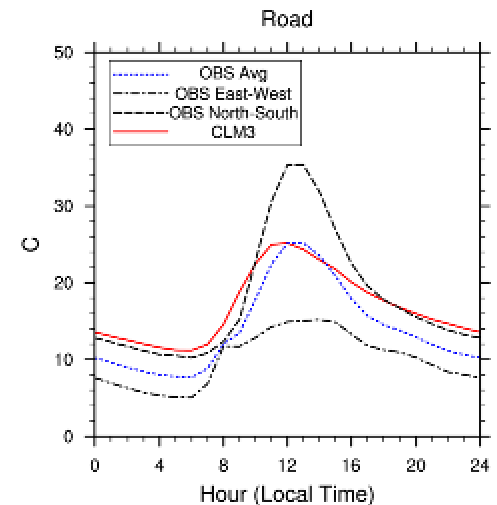
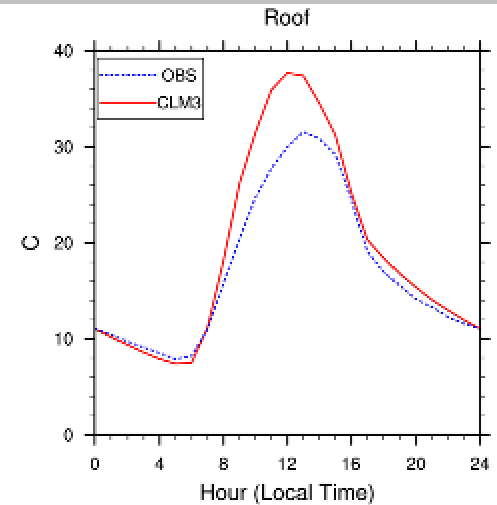
Historic city core (H/W=1.2, H=18m)

Mexico City CLM3, Observed Average Diurnal Cycle Fluxes, Dec 2 - Dec 7 1993



$$Q_s / Q^*$$

	OBS	Model
Day	0.58	0.55
Night	1.22	1.25

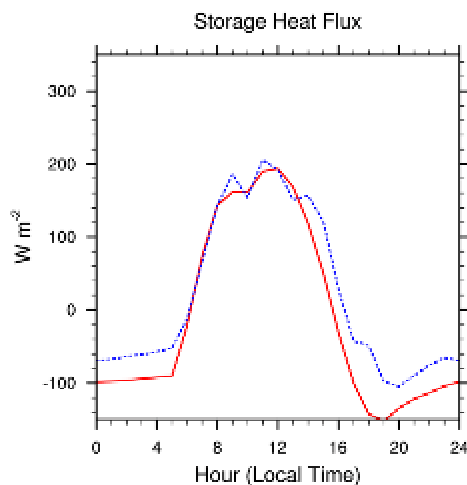
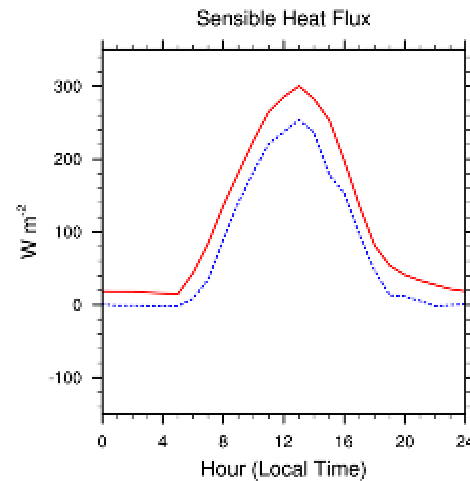
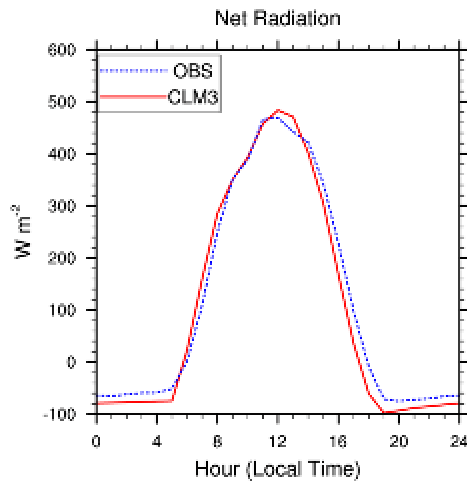


Offline Validation – Vancouver

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

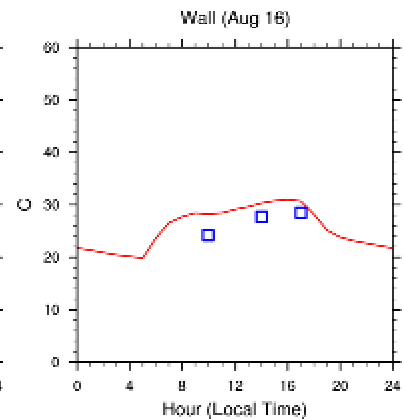
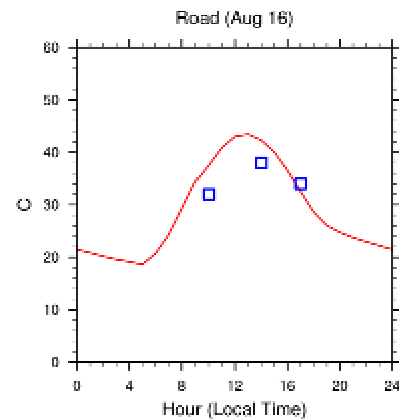
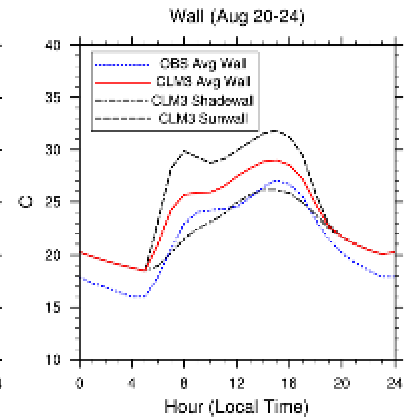
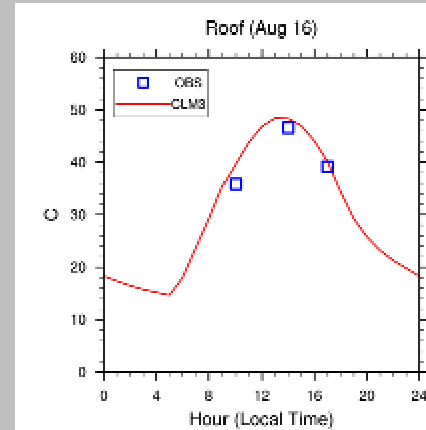
Light Industrial (H/W=0.4, H=6m)

Vancouver CLM3, Observed Average Diurnal Cycle Fluxes, Aug 20 - Aug 24 1992



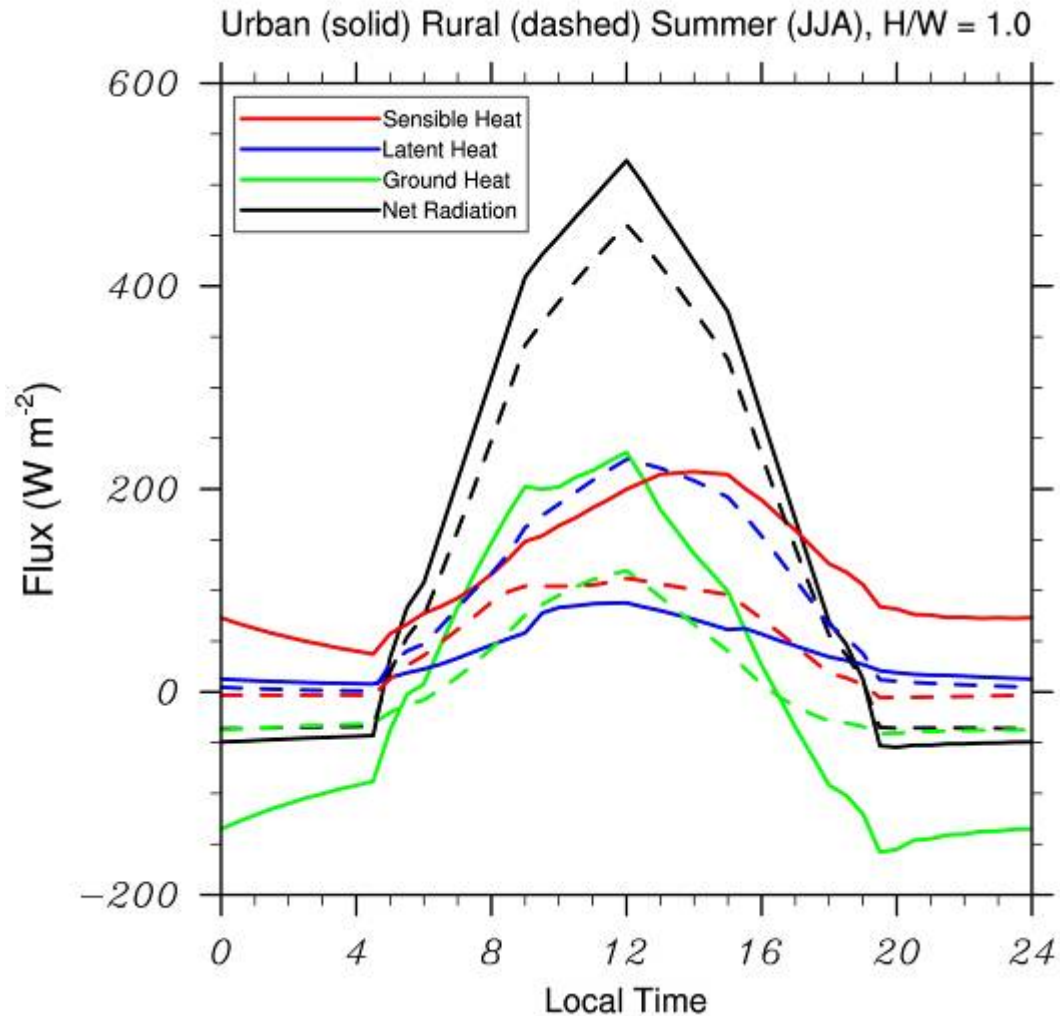
$$q_s/q^*$$

	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 $H/W=0.5, \dots, 3.0$

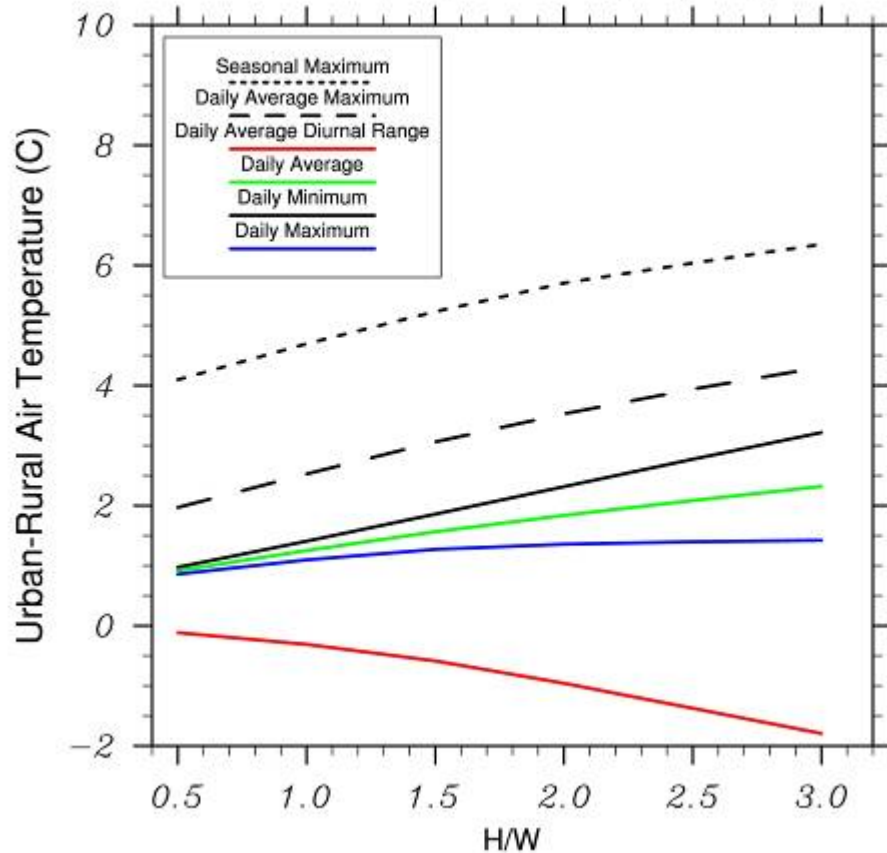


Simulated Urban Heat Island

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

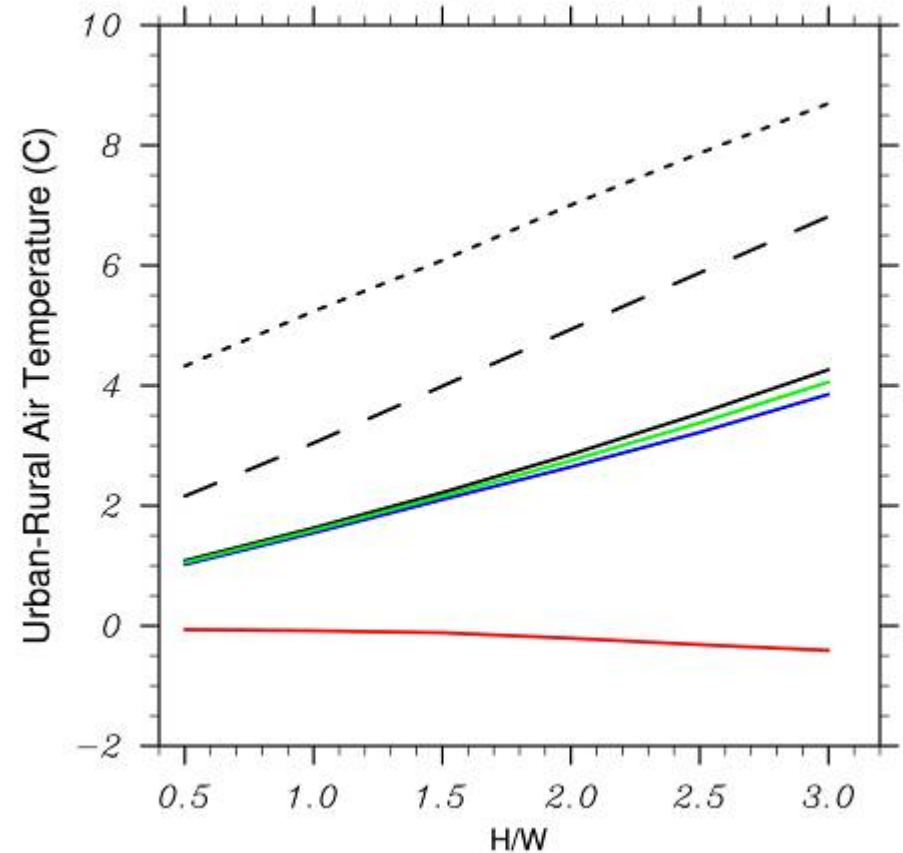
Without Q_f

Summer (JJA) Heat Island (40N, 75W)



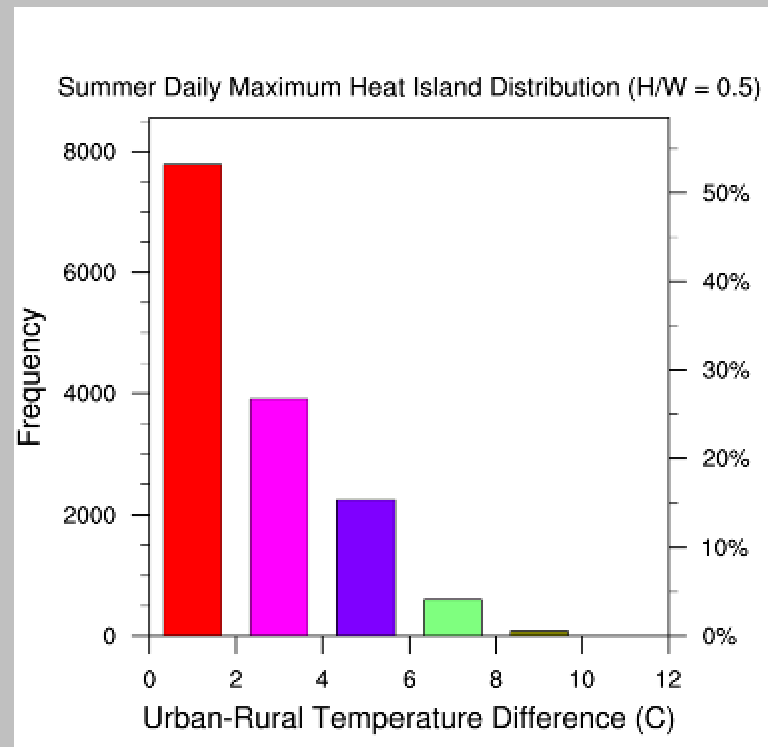
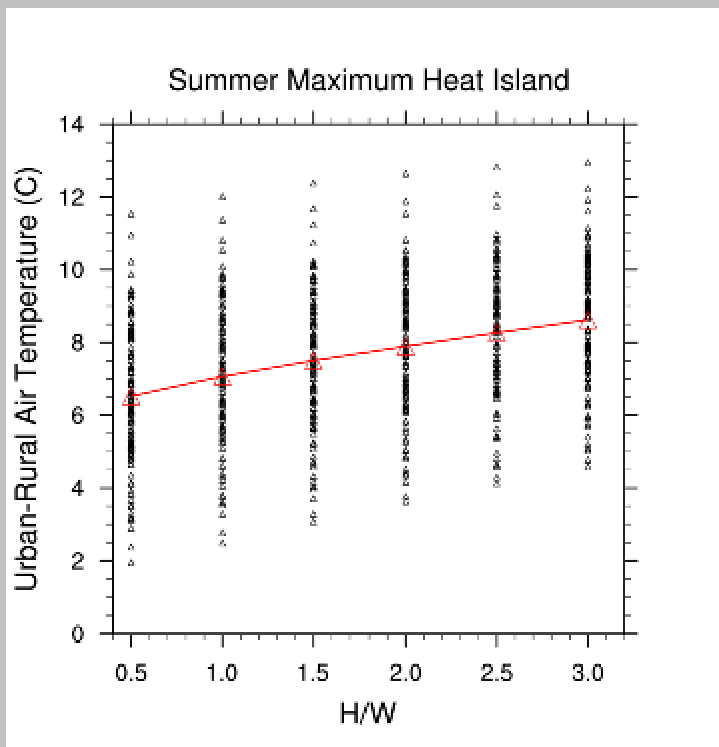
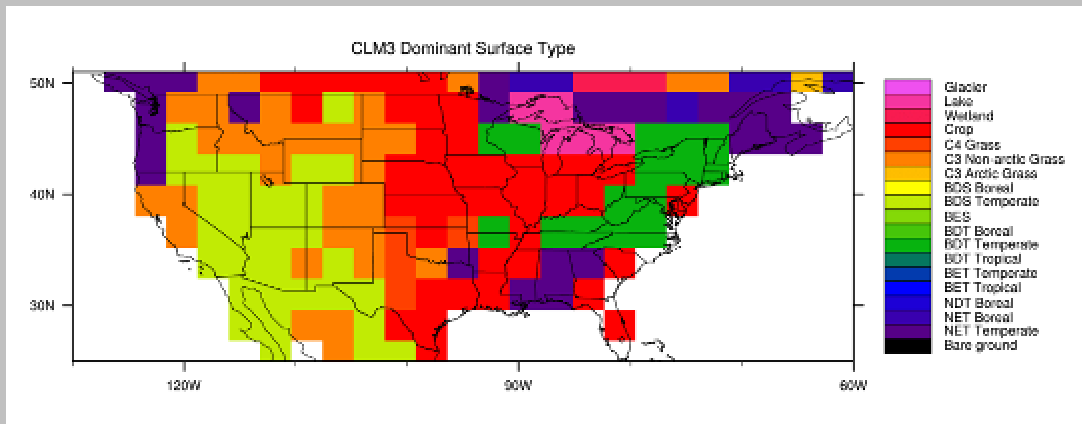
With Q_f

Summer (JJA) Heat Island (40N, 75W)



Variability in Simulated Heat Island caused by Climate and Rural Environment

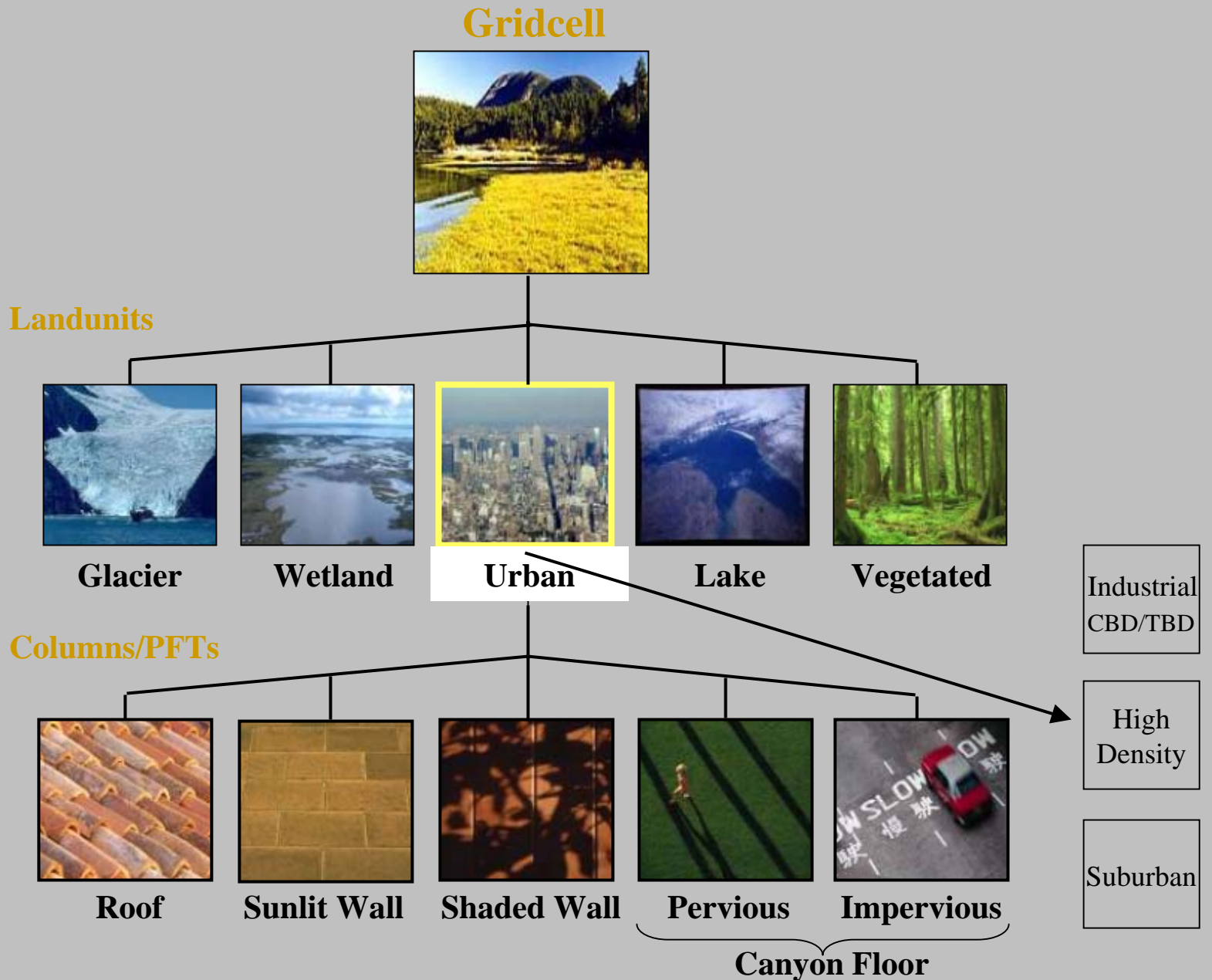
- Atmospheric forcing from CAM (offline model)
- Default city with $H/W=0.5, \dots, 3.0$
- Rural environment from CLM Surface Data



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**

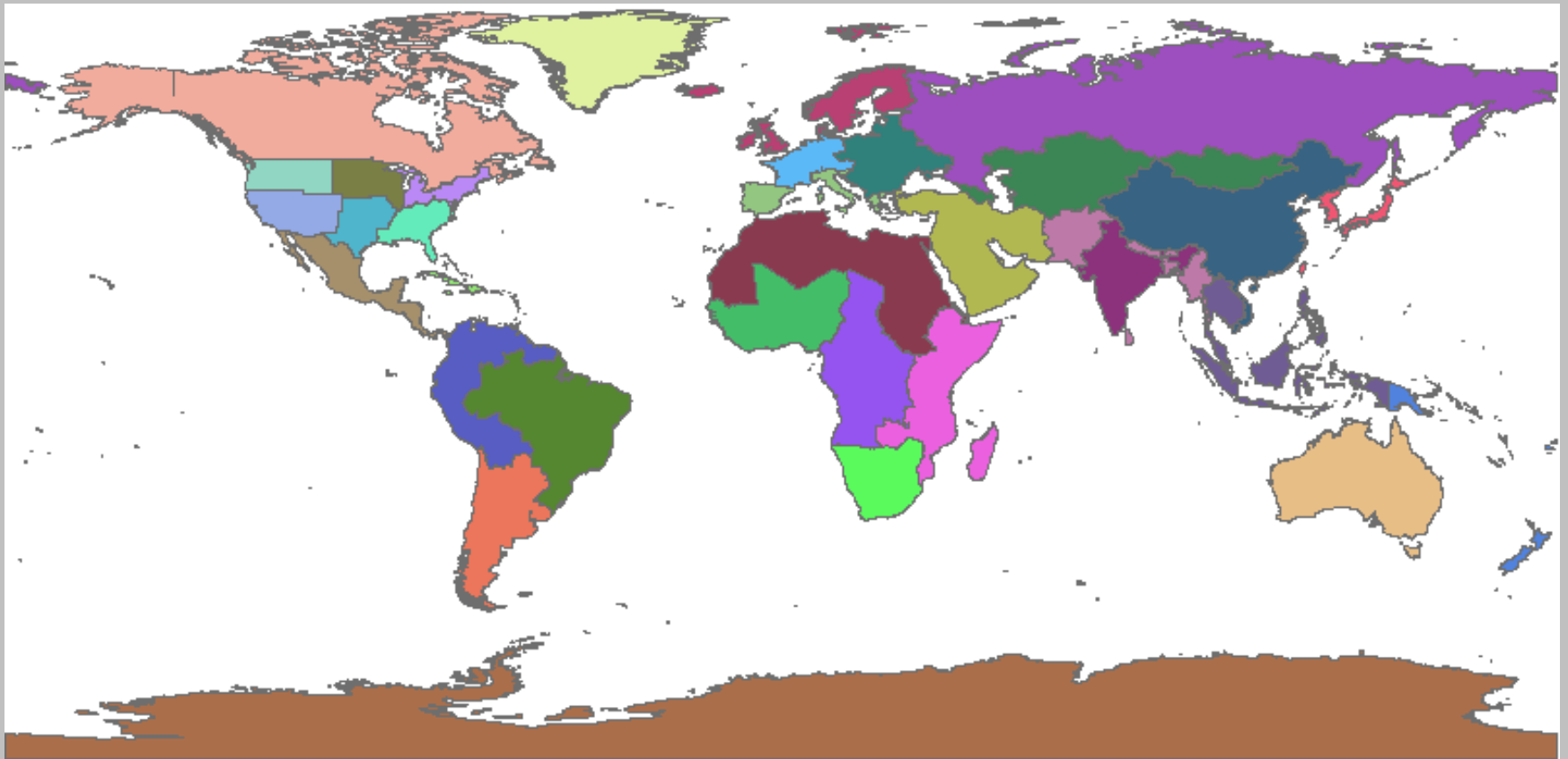
Representing urban areas in CLM/CCSM



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



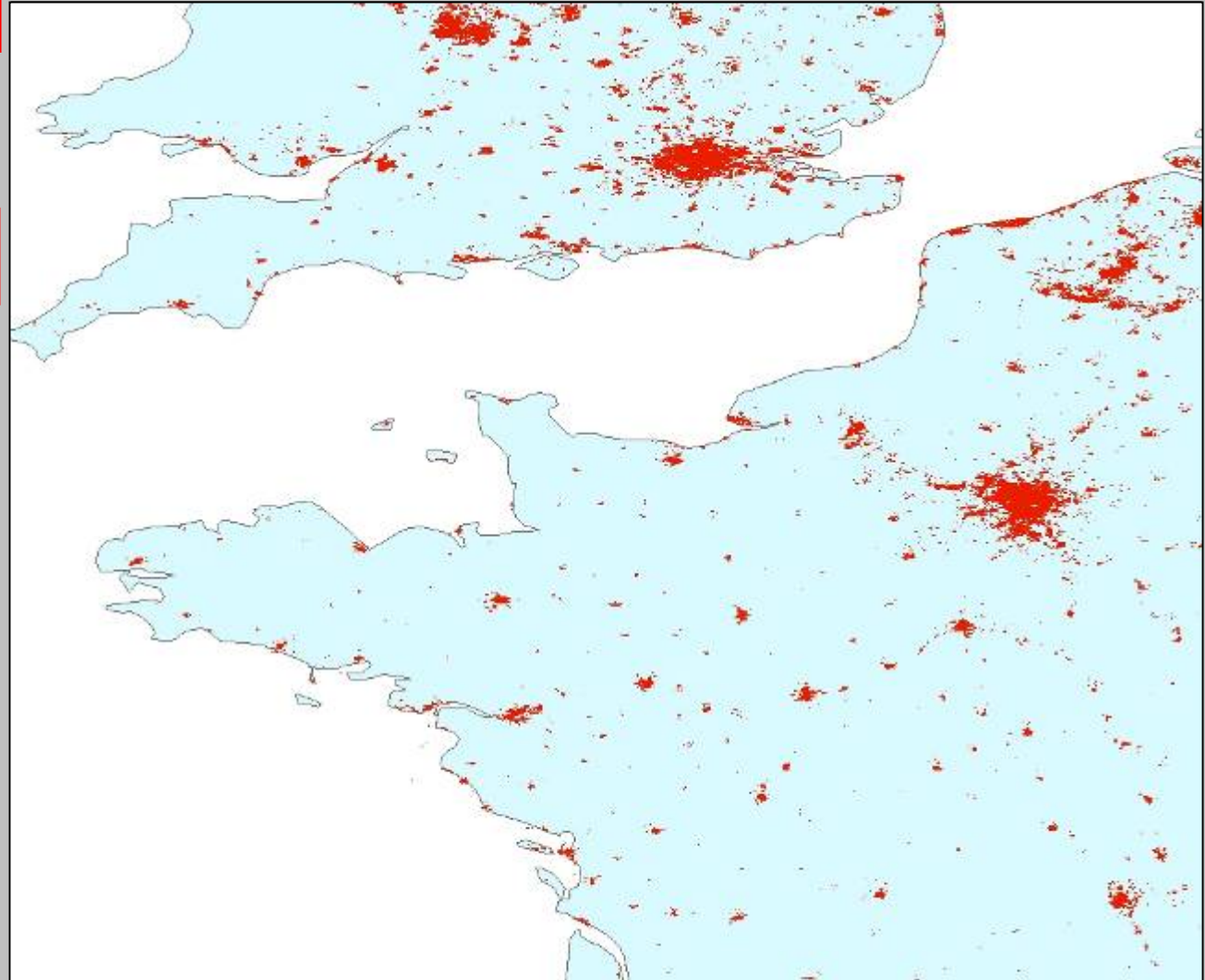
Creating a Global Urban Dataset

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

Compare Global Satellite Products

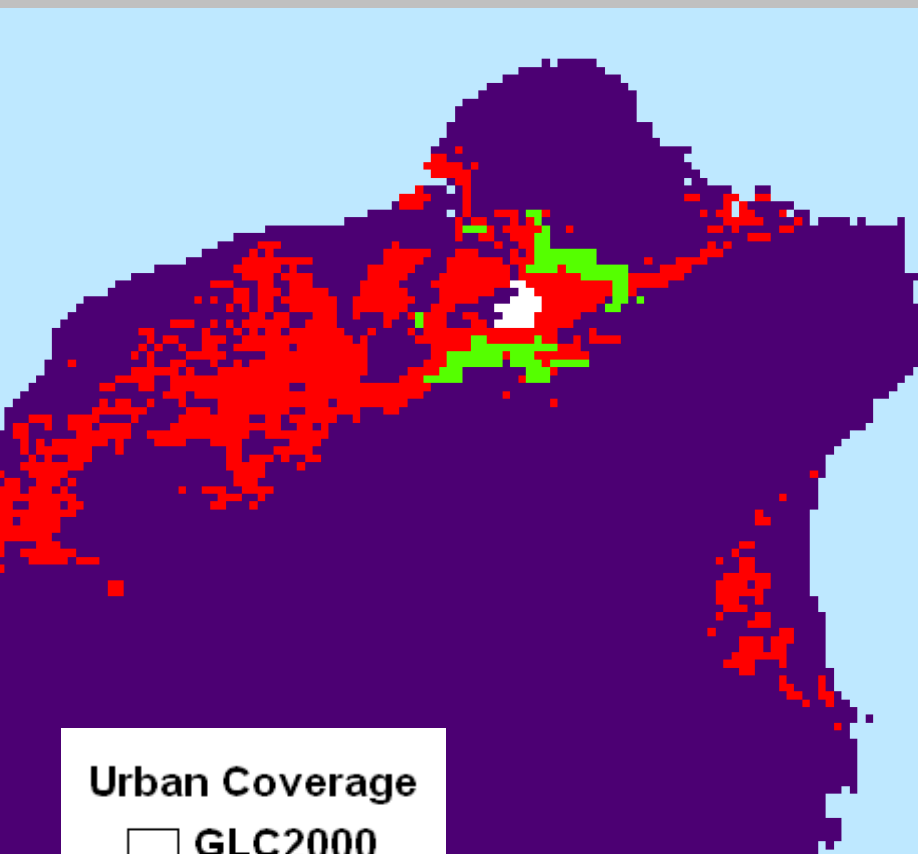
1km resolution

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



Evaluation of Satellite Products

Taipei, Taiwan

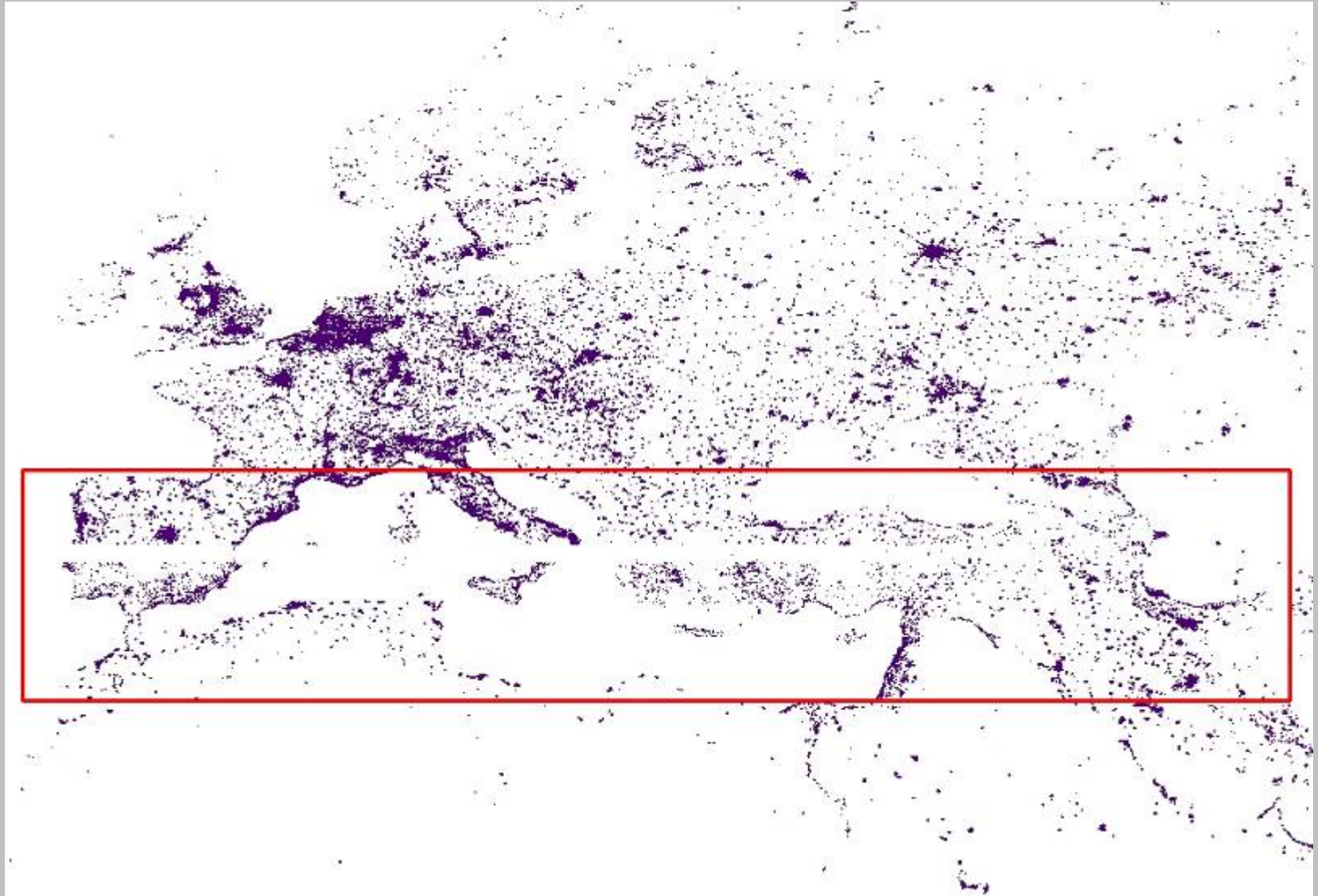


Urban Coverage

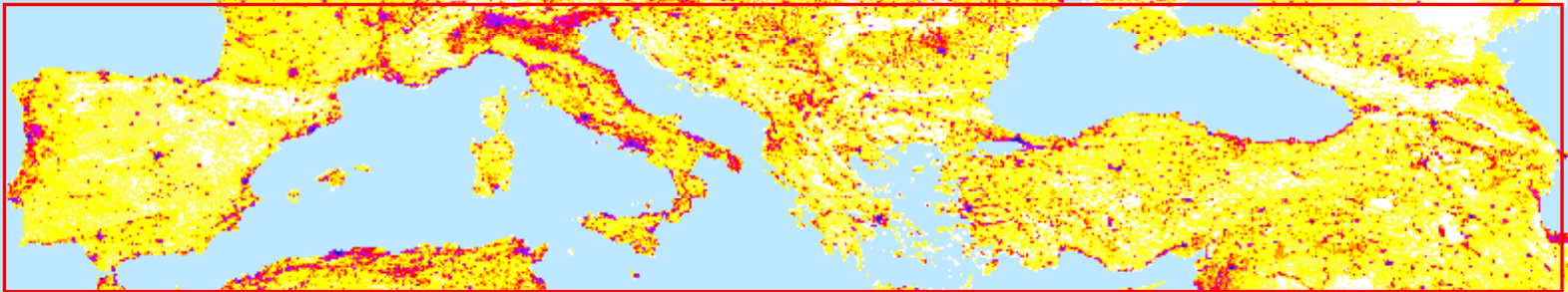
-  GLC2000
-  DISCover
-  MODIS



MODIS issues



LandScan 2004



Limitations of Satellite Products

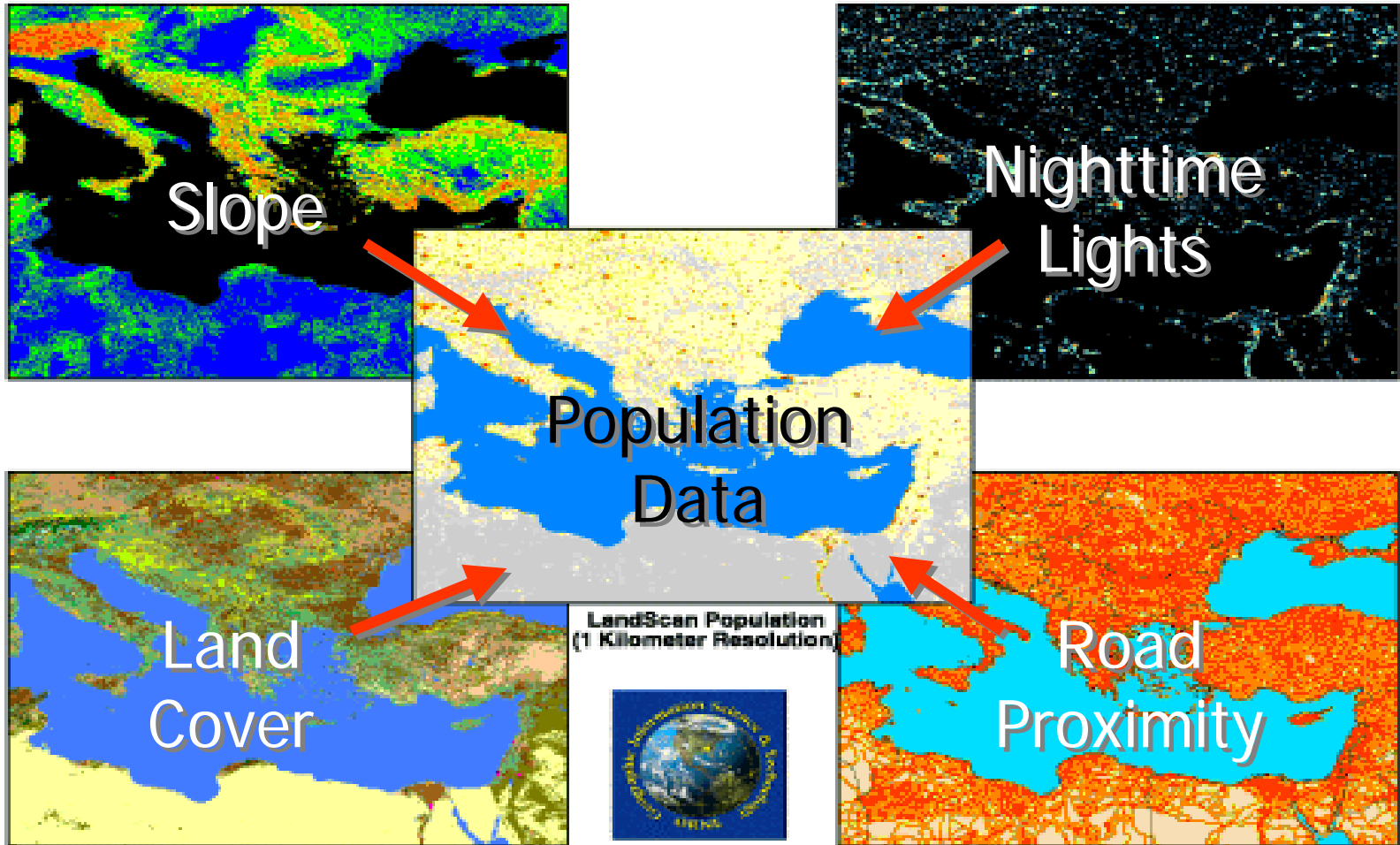
- Disagree on what constitutes urban areas
- Processing flaws and methodological questions
- Do not distinguish between levels of urbanization
- Cannot distinguish differences in urban characteristics based on cultural and regional differences
- Lack of temporal information for historical and future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

Creating a Global Urban Dataset

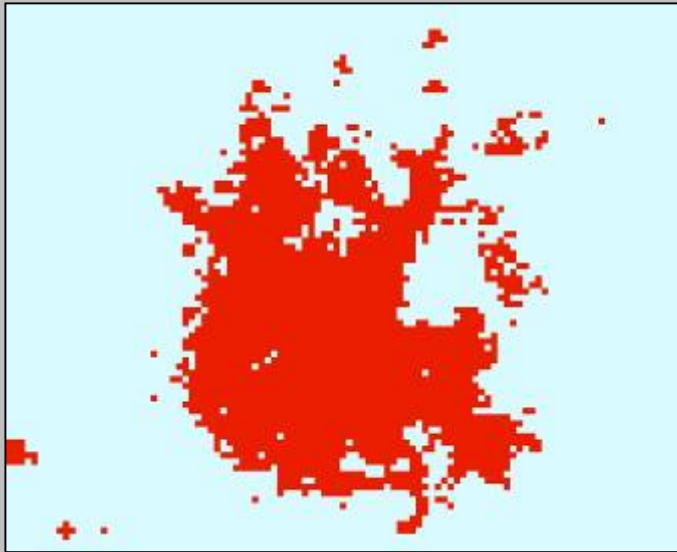
1. Divide world into manageable portions
2. Define urban extent
3. Delineate three degrees of “urbanness”
4. Compile database of building properties

Population Dataset – LandScan

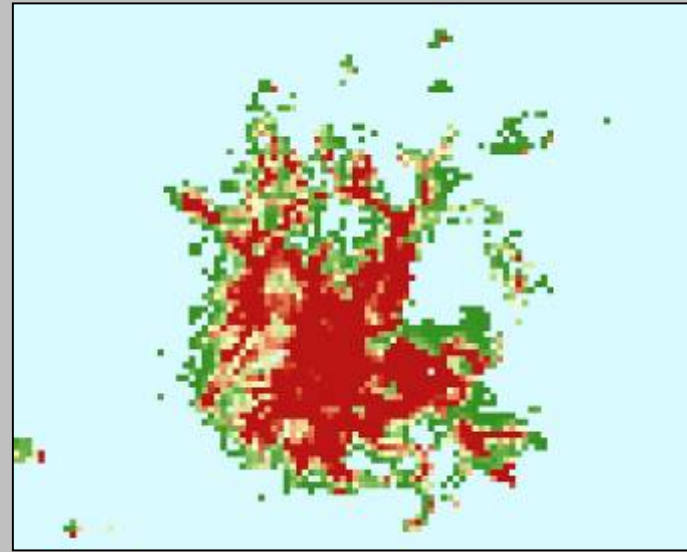
ORNL LandScan Global Population Project
Global Information for Estimating Populations at Risk
Sponsored by U.S. Department of Defense



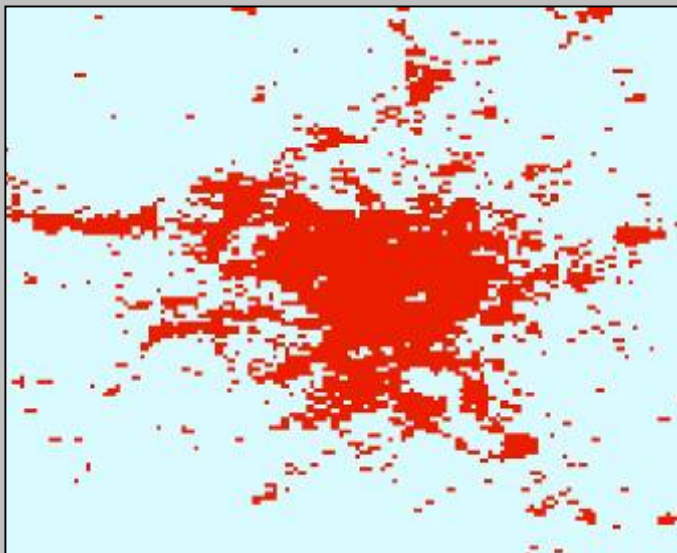
(Dobsen et al, 2000)



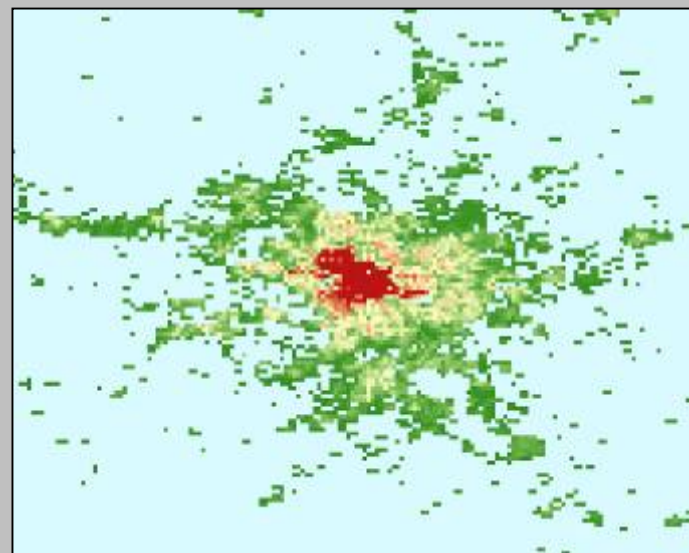
MODIS Mask of Mexico City



Mexico City (*Landsat*)



MODIS Mask of Paris

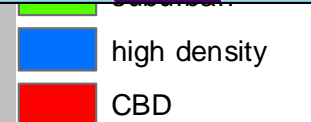
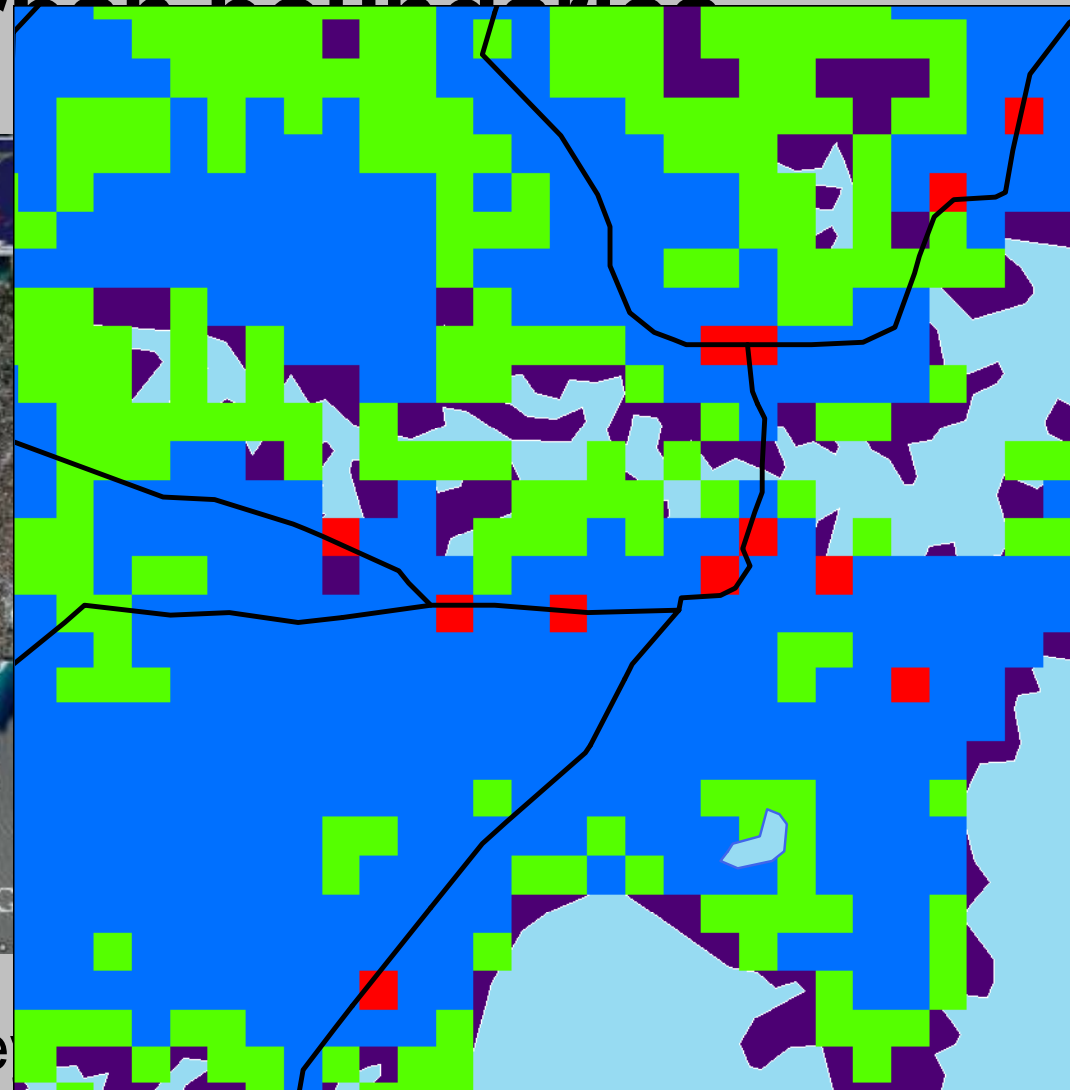


Paris (*Landsat*)

Defining urban boundaries

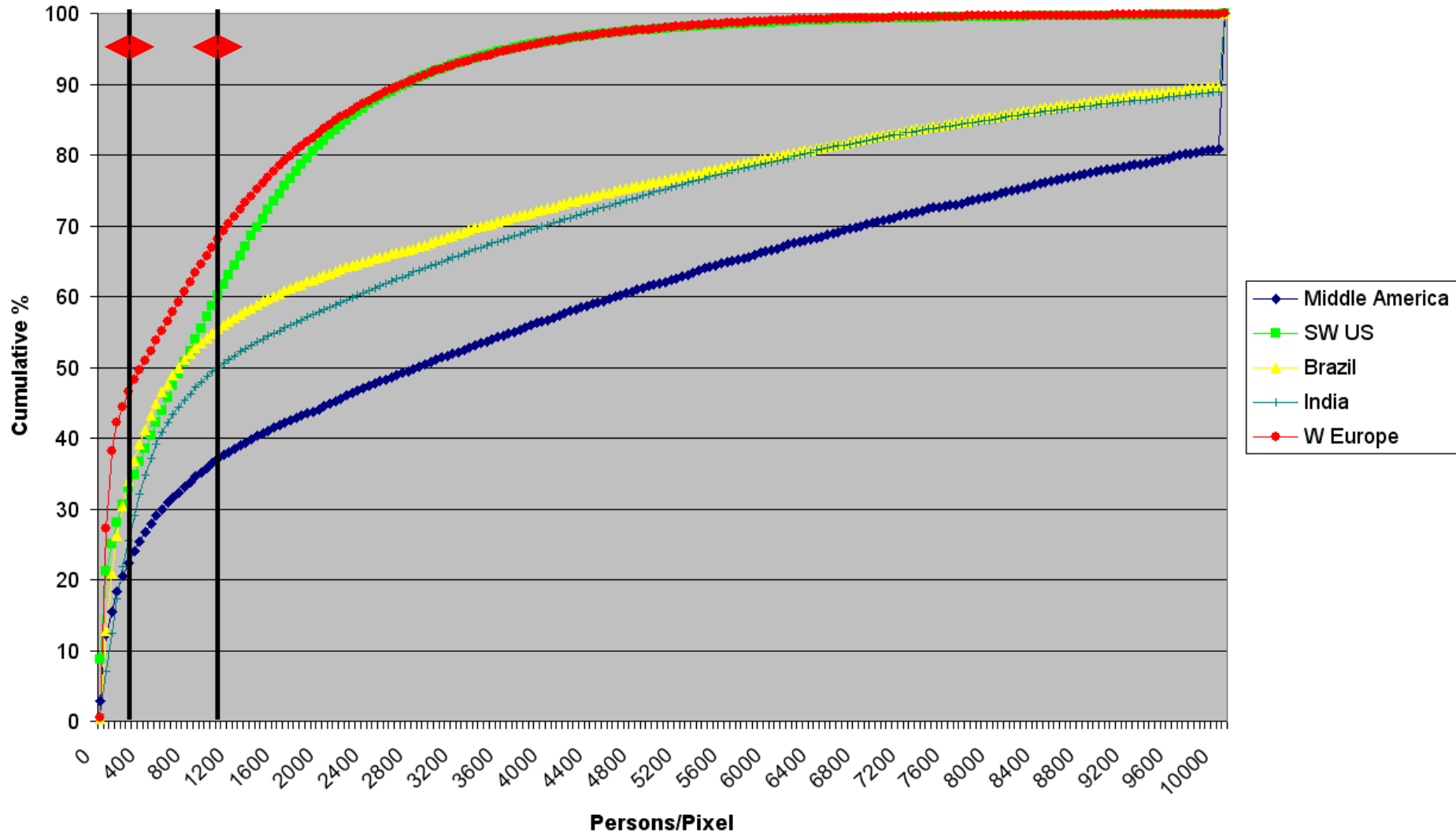


Sydney

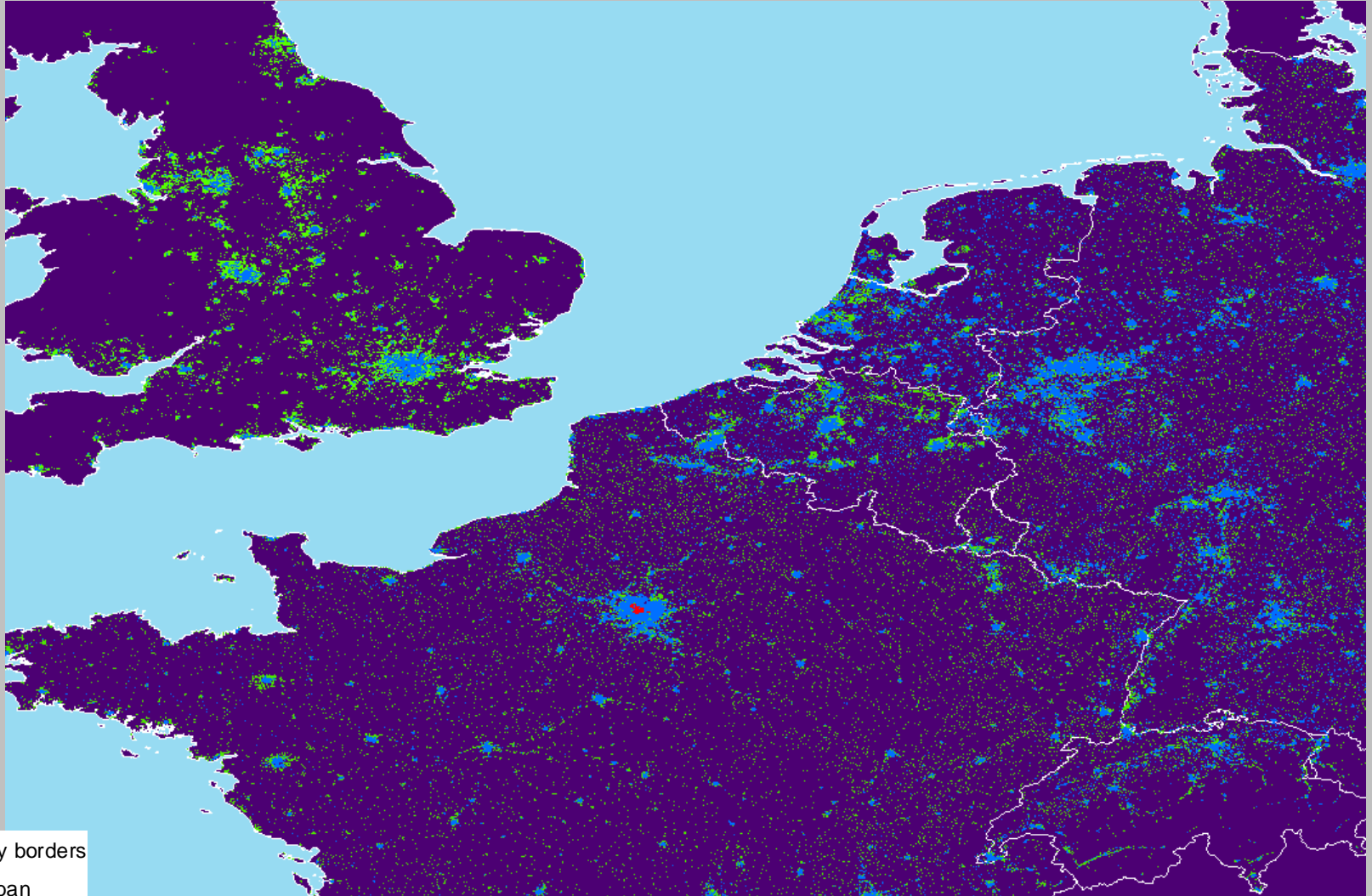


Cumulative Landscan population for MODIS urban grid cells by region

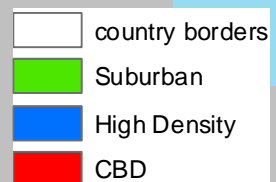
Regional Comparison Urban Population Distribution



Final Product



Value



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**

Building properties

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

World Housing Encyclopedia

EERI / IAEE Encyclopedia



World Housing Enc

- World Map
- About the Project
- Contribution List
- Select Country/Region
- Search the Database
- How to Contribute
- Add/Edit Reports
- Project Archive
- General Resources
- Sponsors
- Web Design Team
- Recent News
- Newsletter

Internet Explorer



Disclaimer:

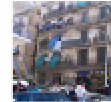
This encyclopedia contains information contributed by earthquake engineering professionals around the world. All opinions, findings, conclusions, and recommendations expressed herein are those of the various participants, and do not necessarily reflect the views of the Earthquake Engineering Research Institute, the International Association for Earthquake Engineering, the Engineering



<http://www.world-housing.net/index.asp>

Algeria

Building Description: Stone masonry apartment building



EERI Reports 75

- 1 General Information
- 2 Architectural Features
- 3 Socio-Economic Issues
- 4 Structural Features
- 5 Evaluation of Seismicity
- 6 Earthquake Damage
- 7 Building Materials and Construction
- 8 Construction Economics
- 9 Insurance
- 10 Seismic Strengthening
- 11 References
- 12 Contributors
- 13 Pictures

Summary

This is a typical residential construction type found in most Algerian urban centers, constituting 40 to 50% of the total urban housing stock. This construction, built mostly before the 1950s by French contractors, is no longer practiced. Buildings of this type are typically 4 to 6 stories high. The slabs are wooden structures or shallow arches supported by steel beams (jack arch system). Stone masonry walls, usually 400 to 600 mm thick, have adequate gravity load-bearing capacity; however, their lateral load resistance is very low. As a result, these buildings are considered to be highly vulnerable to seismic effects.

Created On: Wednesday, June 05, 2002

Last modified On: Tuesday, November 01, 2005

Photo Gallery



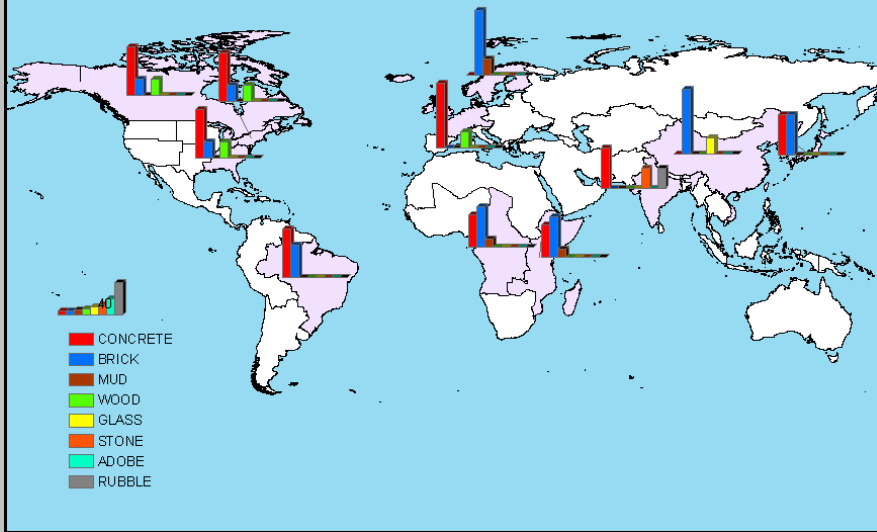
[Browse All](#)

Computing average properties

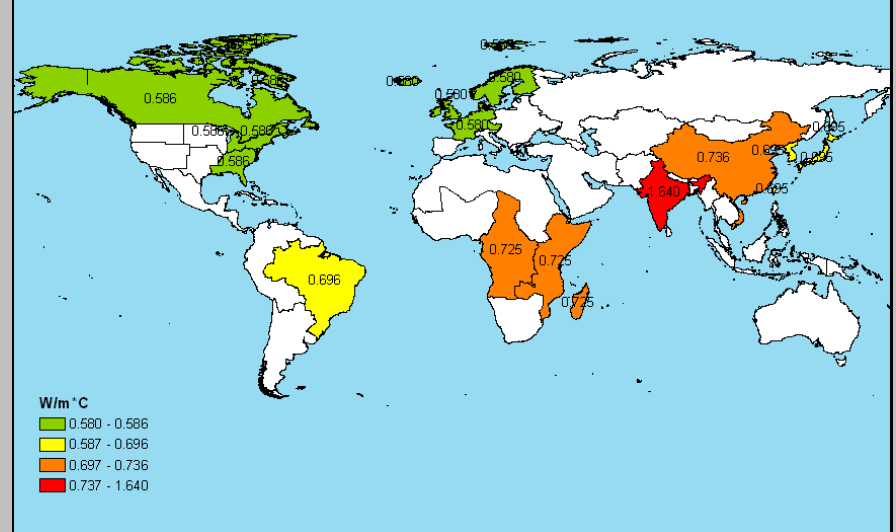
Building Properties							
	Thermal Conductivity (W/mK)	Heat Capacity (MJ/m ³ K)	Albedo	Density (kg/m ³)	Specific Heat (J/kg C)	Emissivity	
concrete	0.7	1075.2	0.225	1280	840	0.92	
brick	0.7	1360.0	0.3	1700	800	0.9	
mud	1.0	1456.0	0.3	1820	800	0.9	
wood	0.1	1127.5	0.5	550	2050	0.87	
glass	0.9	2100.0	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

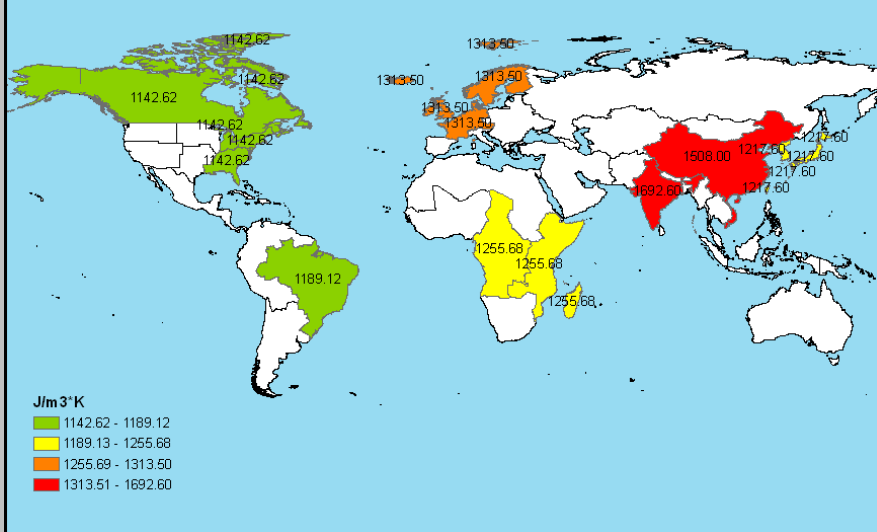
Building Materials of Walls



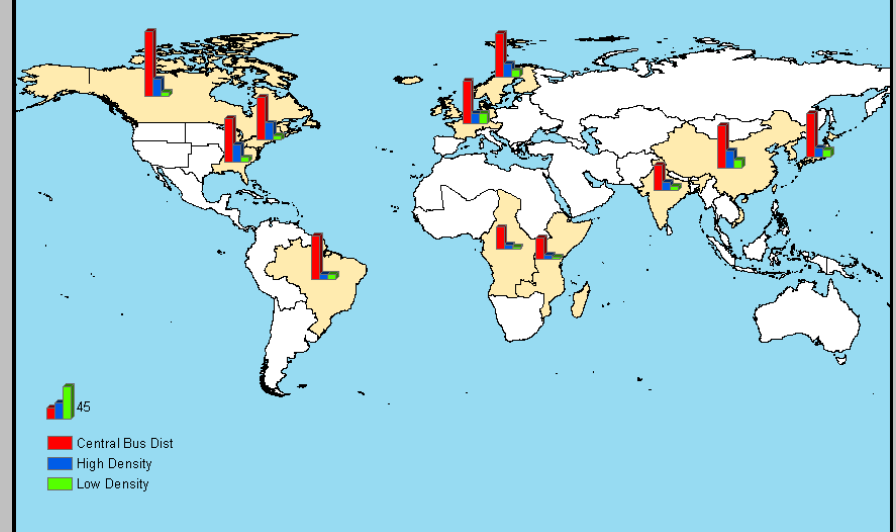
Conductivity of Walls



Heat Capacity of Walls



Estimated Building Heights



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