# Community Land Model Urban (CLMU)

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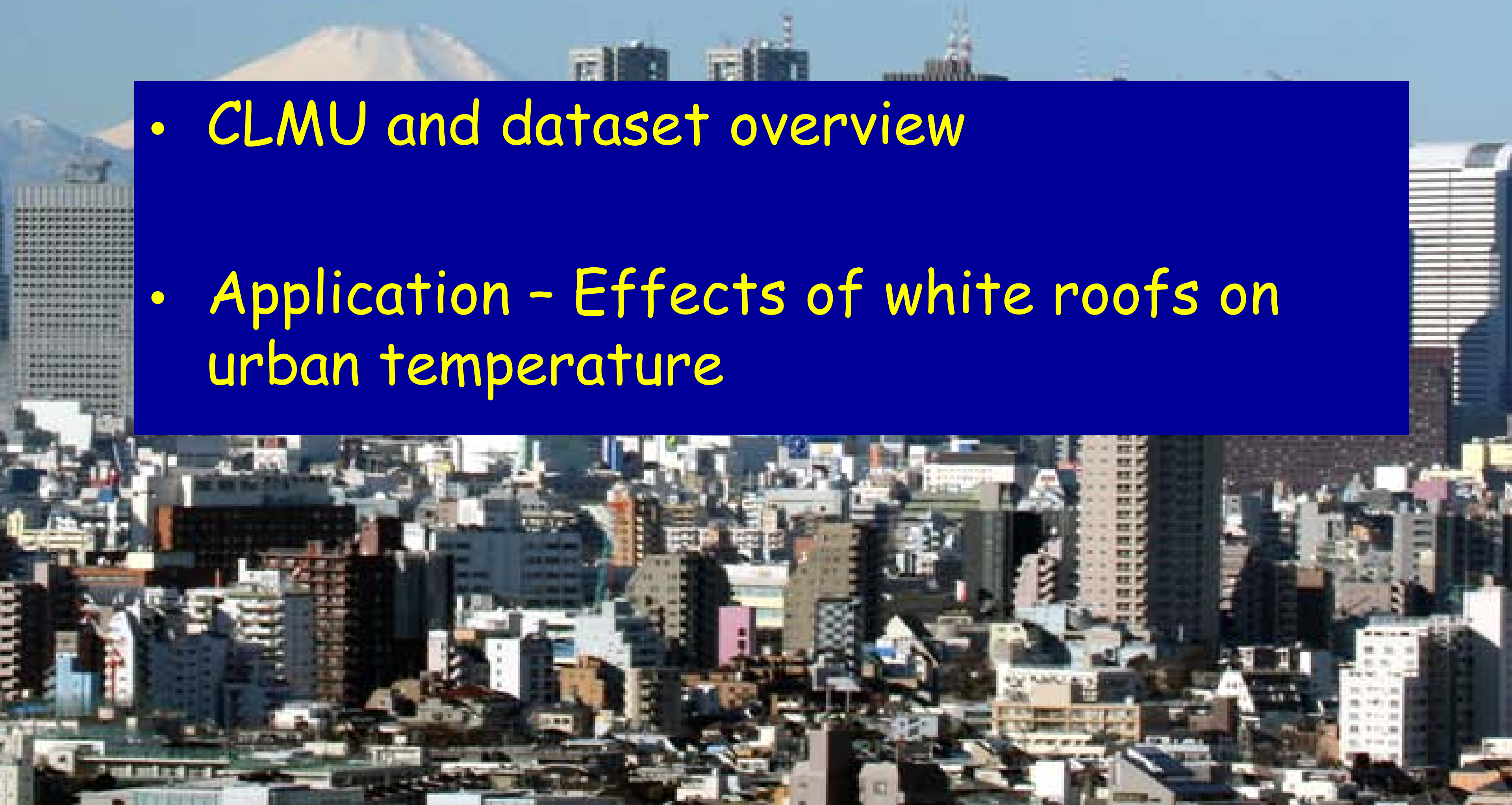
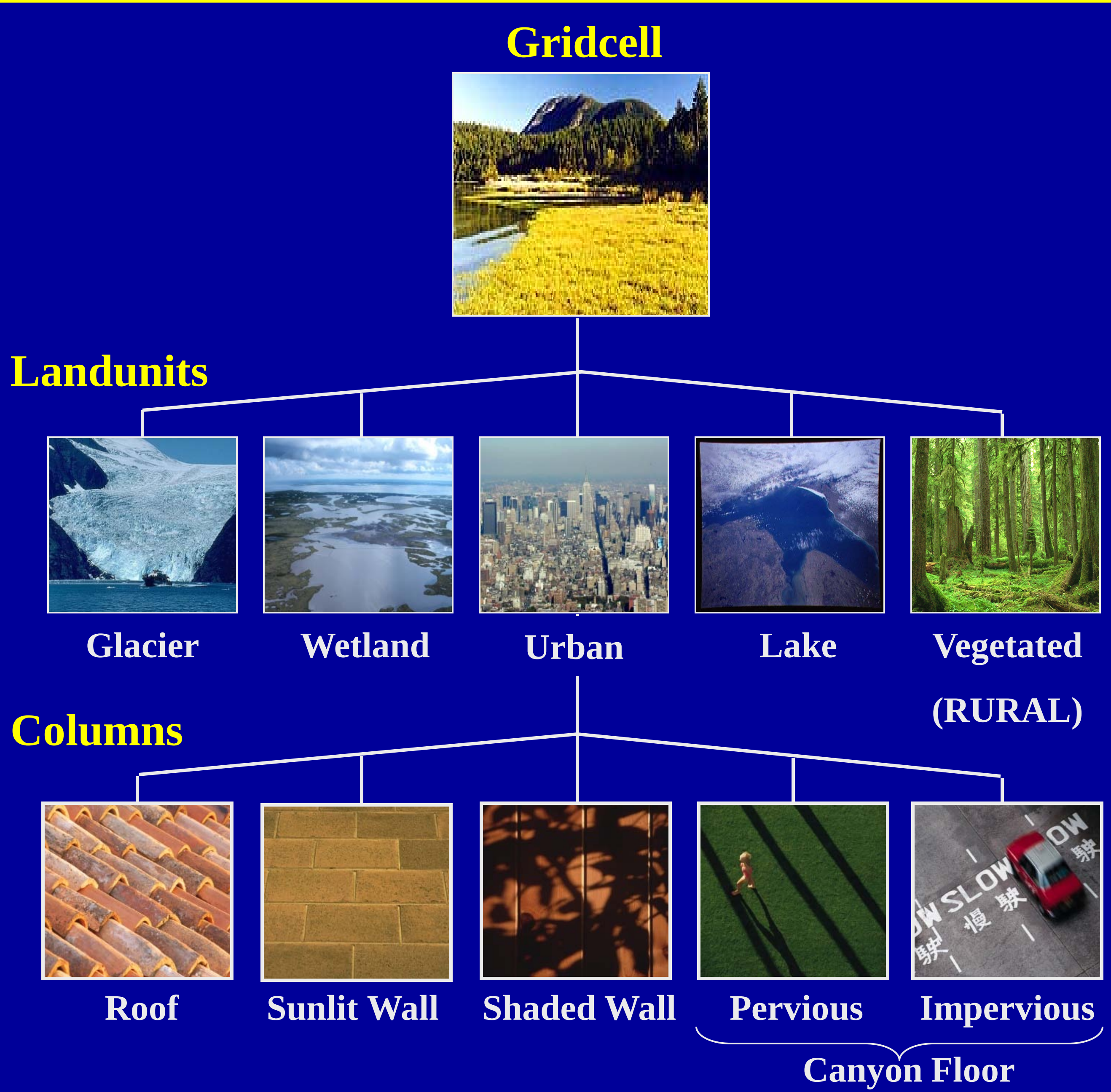
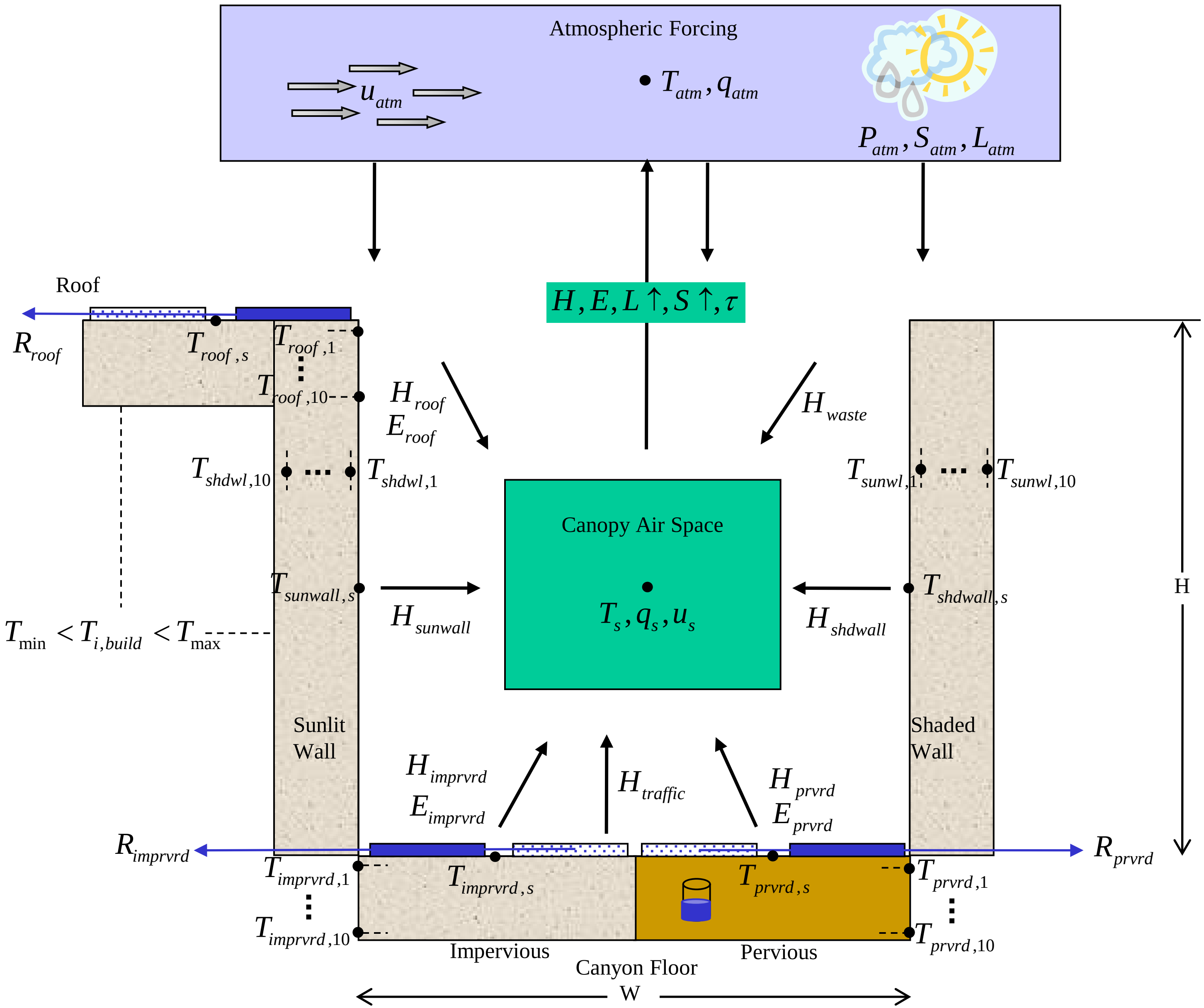
- CLMU and dataset overview
- Application – Effects of white roofs on urban temperature



# CLM Subgrid Structure



# CLMU (Oleson et al. 2008a, b, JAMC; Oleson et al. 2010, NCAR Tech Note)



# Creating a Global Urban Dataset

1. Spatial extent of urban areas derived from a population density dataset (LandScan) and calibrated within 33 regions of similar urban character
2. For each region, four classes of urban density are identified based on population density and evaluated with satellite imagery
3. Urbanization classes linked to set of typical building morphology, thermal and radiative characteristics

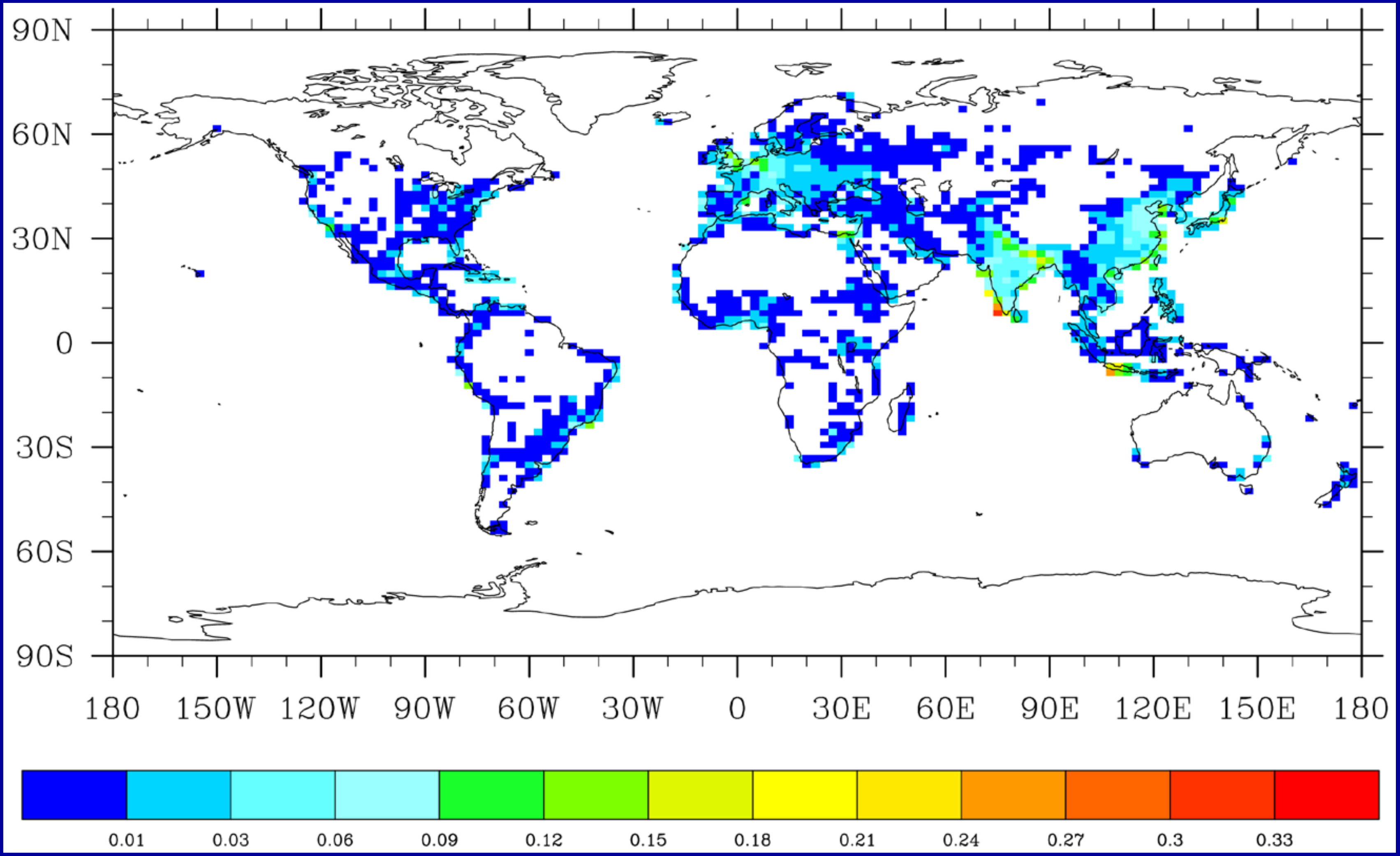
Jackson, T., J. Feddema, K. Oleson, G. Bonan, and J. Bauer, 2010: Parameterization of urban characteristics for global climate modeling, *A. Assoc. Am. Geog.*, accepted.

# Urban Density Classes

| Urban Class | H/W | Building Heights (m) | Pervious Fraction (%) | Population Density (km2) | Typical Building Types |
|---|---|---|---|---|---|
| Tall Building District (TBD) | 4.6 | 40-200+ | 5-15 | 14,000 – 134,000+ | Skyscrapers |
| High Density (HD) Residential/ Commerical/ Industrial | 1.6 | 17-45 | 15-30 | 5,000 – 80,000+ | Tall apartments, office bldgs, industry |
| Medium Density (MD) Residential | 0.7 | 8-17 | 20-60 | 1,000 – 7,000 | 1-3 story apartment bldgs, row houses |

Urban extent is sum of TBD, HD, and MD.

# Urban Fraction of Land at 1.9°X2.5°

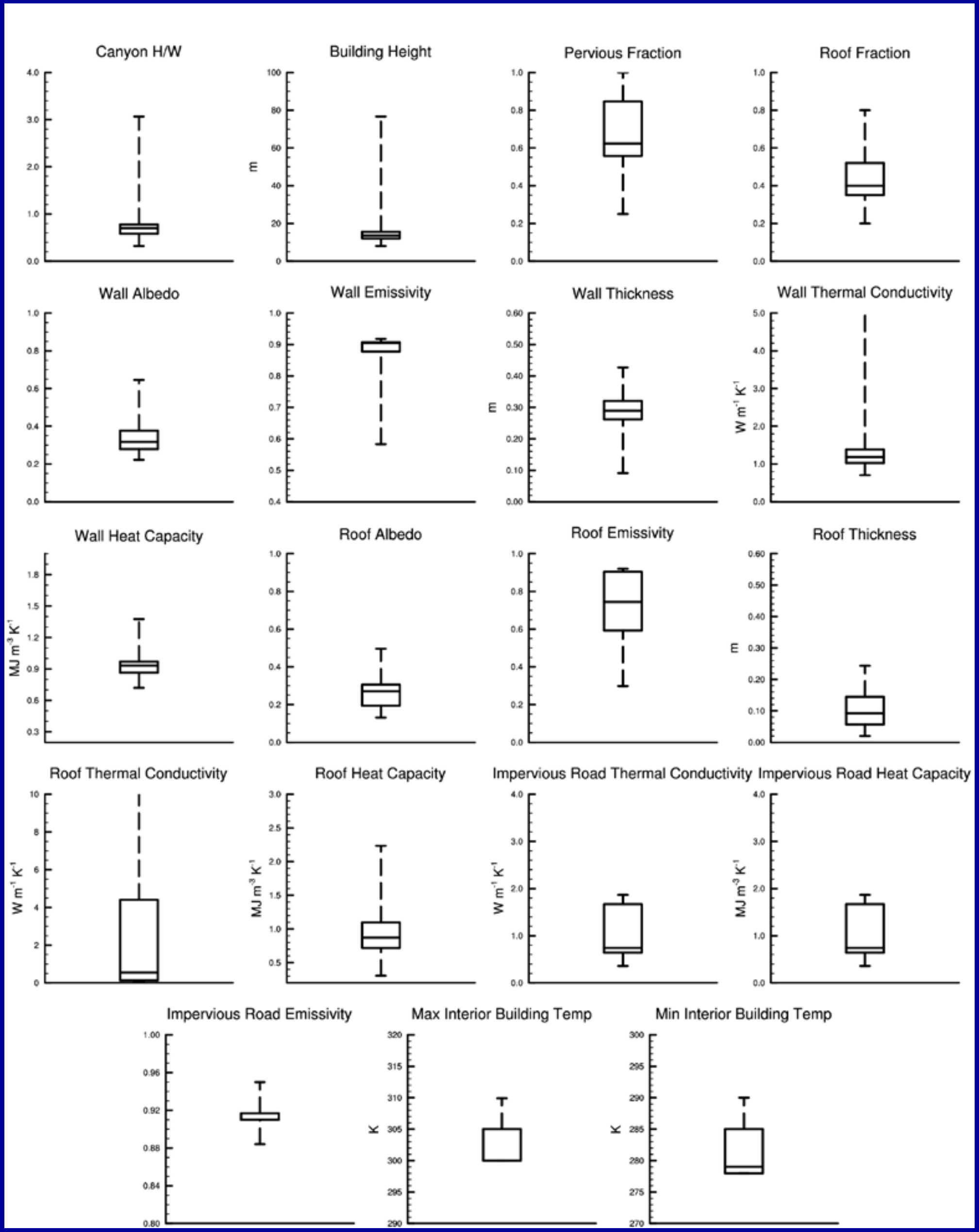


# Building properties

For the global model, we choose dominant density type by area to define building properties – primarily Medium Density

- Morphological
  - Building height
  - Building height to street width ratio
  - Pervious fraction
  - Roof fraction
- Roofs, walls, pervious/impervious canyon floor
- Radiative
  - Albedo
  - Emissivity
- Thermal
  - Heat capacity
  - Thermal conductivity
- Building interior mimimum and maximum temperatures

# Building properties at 1.9°X2.5°




Properties reflect the medium density urban class:

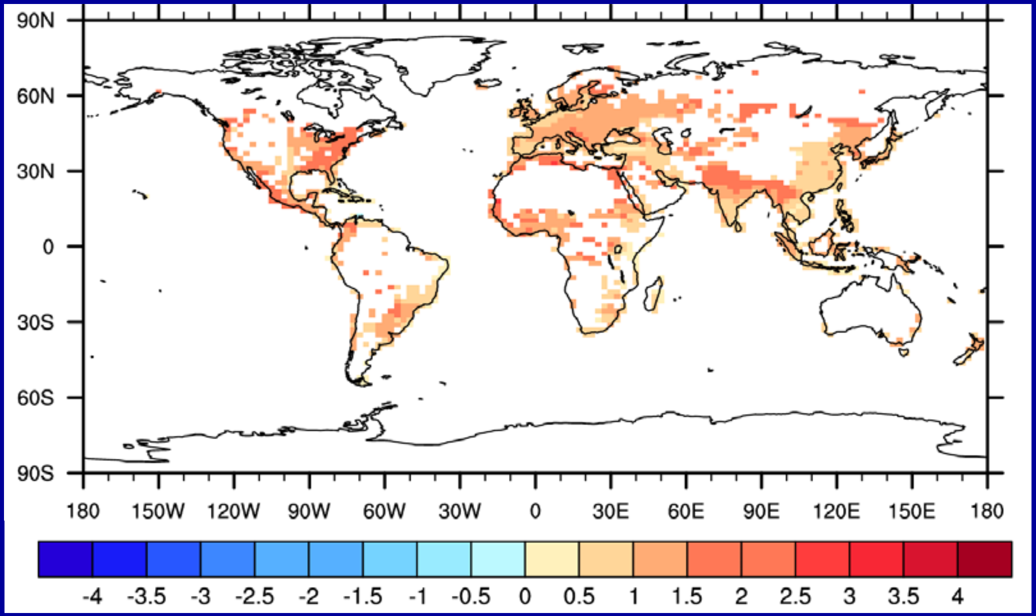
- Small H/W
- Low Building height
- Large pervious fraction
- Medium roof fraction

# The Urban Heat Island (UHI)

Processes contributing to the UHI:

- Increased shortwave absorption due to trapping inside urban canyon (lower albedo)
- Decreased surface longwave radiation loss due to reduction of sky view factor
- Reduction of ET due to replacement of vegetation with impervious surfaces
- Increased storage of heat due to larger heat capacity of urban materials
- Reduced turbulent transfer of heat due to reduced wind within canyon
- Anthropogenic sources of heat

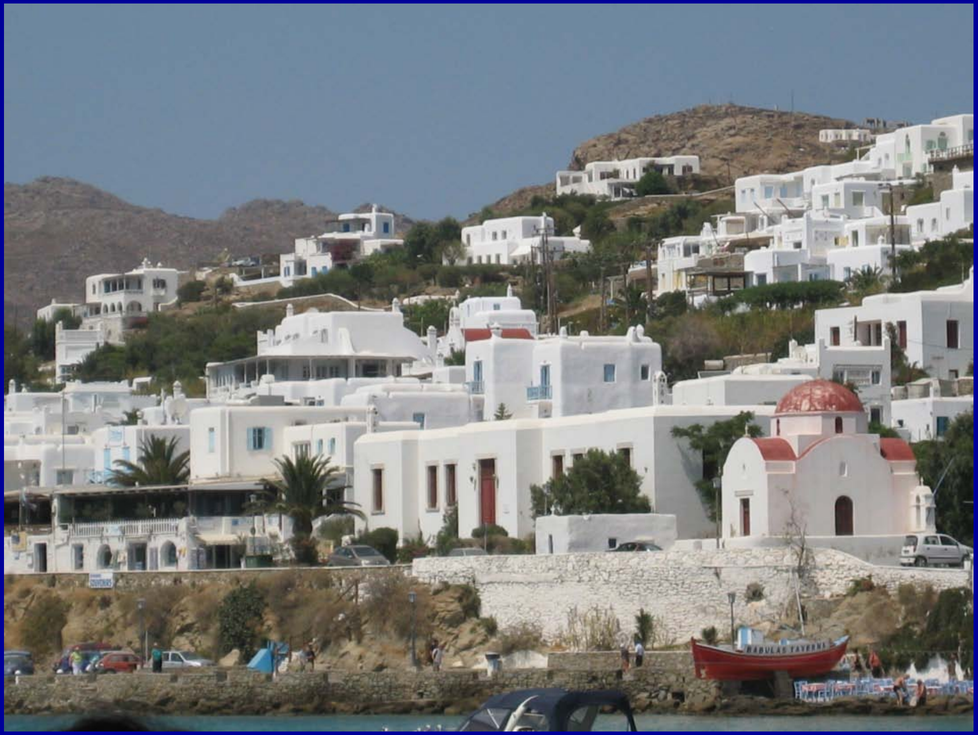
CLMU Annual Urban Heat Island (°C)



# Mitigating the UHI

Increasing the albedo of urban surfaces

Mesoscale modeling studies indicate that city-scale increases in albedo lead to cooler daytime air temperatures (0.5-2°C (Sailor 1995; Taha et al. 1999; Synnefa et al. 2008 [roofs only]).



# CLMU Application - Mitigating the UHI with White Roofs

- Community Atmosphere Model (CAM3.5)
- Community Land Model (CLM3.5)
- 1.9° latitude X 2.5° longitude
- 1941-1999
- Prescribed SST, sea-ice and greenhouse gases
  - 1941-1999: AR4 20$^{th}$ century CCSM ensemble member
- Present day urban description

CON – control w/default urban parameter

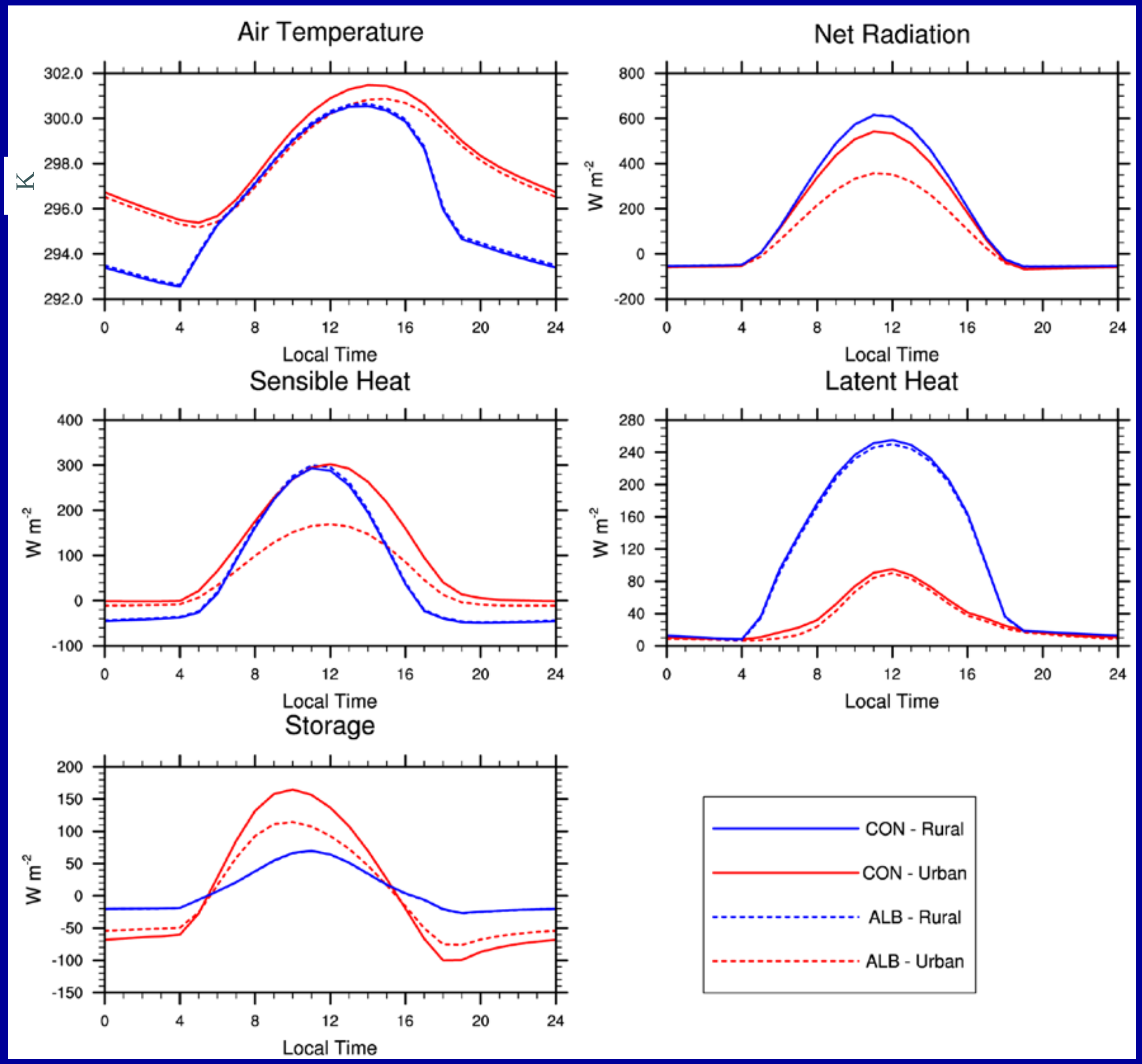
ALB - prescribe global white roof albedo of 0.9.

What is the role of roofs in the urban energy budget and their contribution to the urban heat island?

Oleson, K.W., G.B. Bonan, and J. Feddema, 2010: The effects of white roofs on urban temperature in a global climate model, *Geophys. Res. Lett.*, 37, L03701, doi:10.1029/2009GL042194.

# Mitigating the UHI with White Roofs

JJA average diurnal cycle
40.7N, 287.5E




Urban compared to Rural in the control simulation (CON)

- Available energy partitioned into more storage and less latent heat
- Stored heat released at night
- Warmer urban temperatures, particularly at night

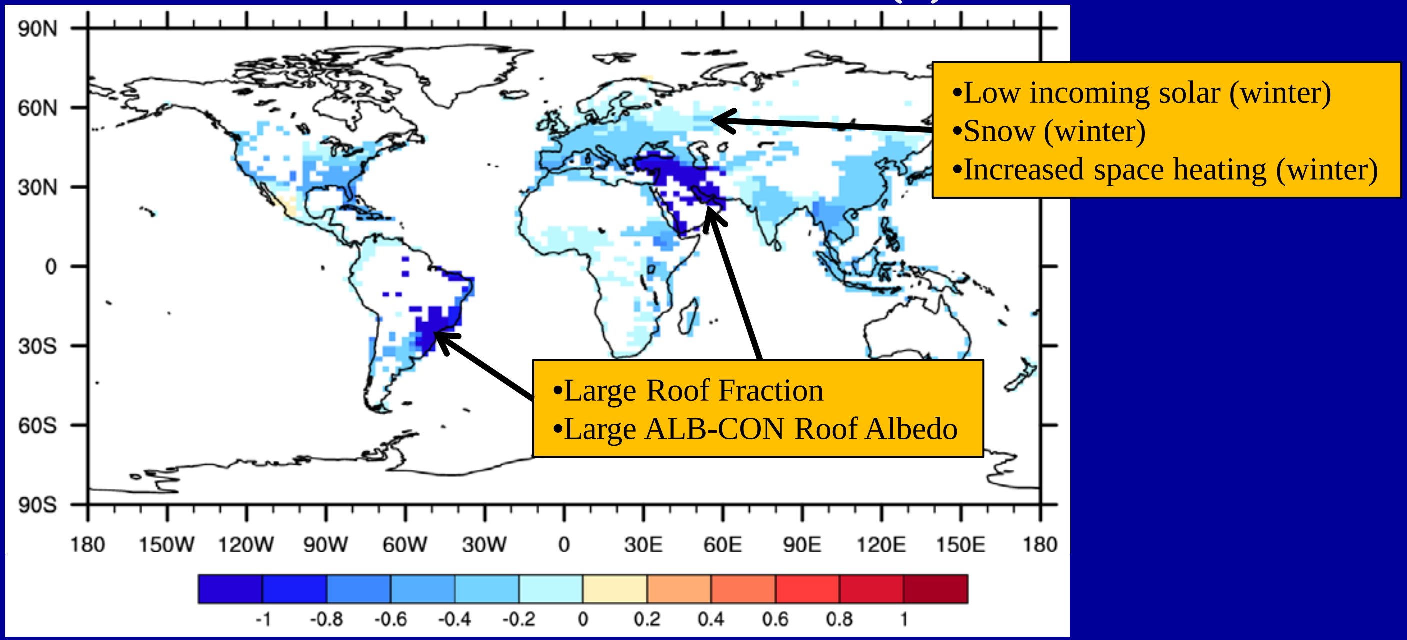
Effects of white roofs (ALB-CON):

- Reduce daytime available energy and sensible heat
- Cools daytime temperatures more than nighttime temperatures
- Cooler daily mean temperature

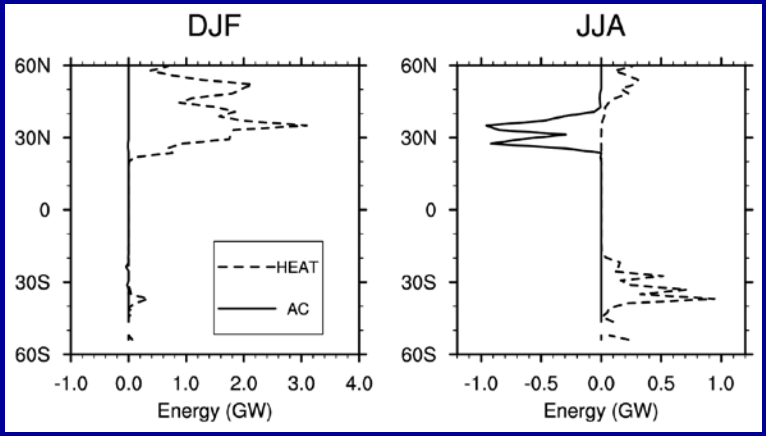
Mean JJA Urban air temperature reduced by 0.5°C

# Mitigating the UHI with White Roofs

ALB — CON Annual Urban Heat Island (C)




ALB — CON Space Heating & Air Conditioning




These are the fluxes required to keep interior building temps within comfort levels (end-use energy). A cost/benefit analysis would need to consider inefficiencies in source to end use energy conversion, costs of various fuel types, etc.

# Mitigating the UHI with White Roofs

## Summary

- Increasing global roof albedo to 0.9 reduces annual UHI by 1/3. Twice as effective in reducing daily maximum temperature as daily minimum temperature.
- Effectiveness of white roofs as a UHI mitigation technique varies according to urban design properties, climate, and interactions with space heating.
- In conclusion, because of the variation in effectiveness and energy considerations, this heat island mitigation method should be evaluated on a case-by-case basis prior to implementation.

# CLMU Community Participation

- Further qualitative and quantitative evaluation of the model and the datasets
- Expand to multiple density classes or develop aggregation methods
- Historical and future urban datasets (static and/or transient)