Recent Enhancements to the Integrated WRF-Urban Modeling System

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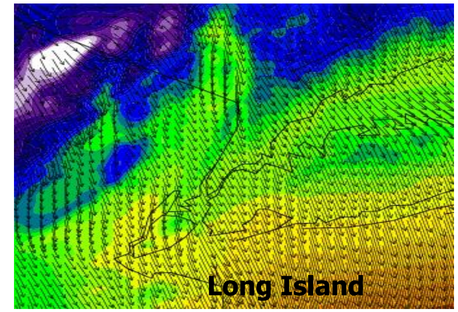
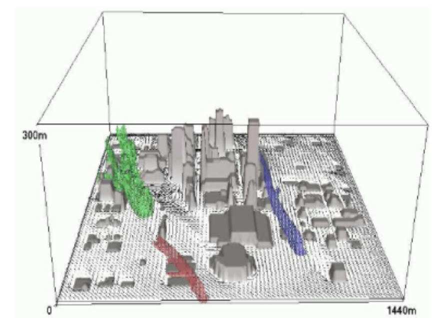
Integrated Urban Modeling for the Weather Research and Forecast (WRF) Model

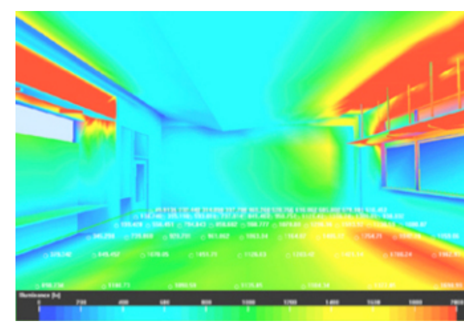
- Increasing urban environmental risks
  - Climate change and sea-level rise
  - Indoor and outdoor air quality
  - Human thermal stress and health
  - Water resources and management
  - Extreme weather events, flood
- Need to develop high-res urban prediction and assessment tool
  - We can represent multiple scale interactions from mesoscale (~ 10 km) and building scale (~ 10 m).



Mesoscale models



Urban Scale models (CFD, LES)



Building scale models

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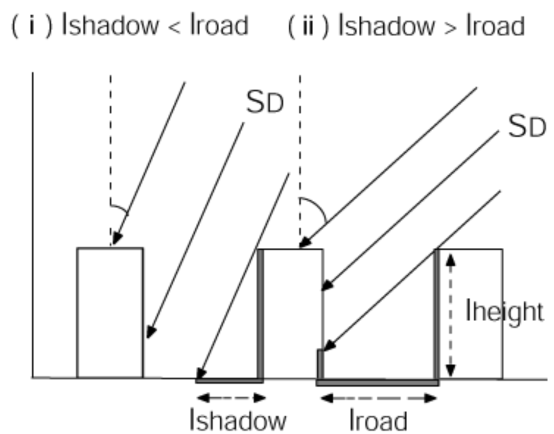
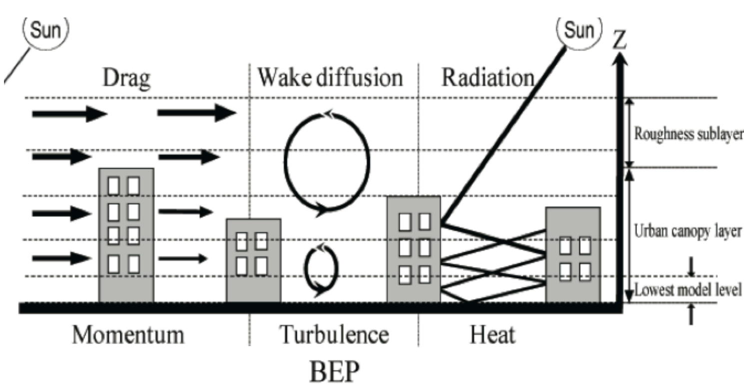
Three urban parameterization schemes coupled to the Noah LSM in WRF-Urban

1. **Bulk parameterization**: no urban canopy, modify surface characteristics. Available since WRF V2.0 (Liu et al., 2006, *JAMC*).

2. **Single-layer Urban Canopy Model (SLUCM):** 2-D urban geometry, street canyons, shadowing from buildings, multi-layer roof, wall and road models. Available in WRF V2.2 (Kusaka et al., 2001, *BLM*).

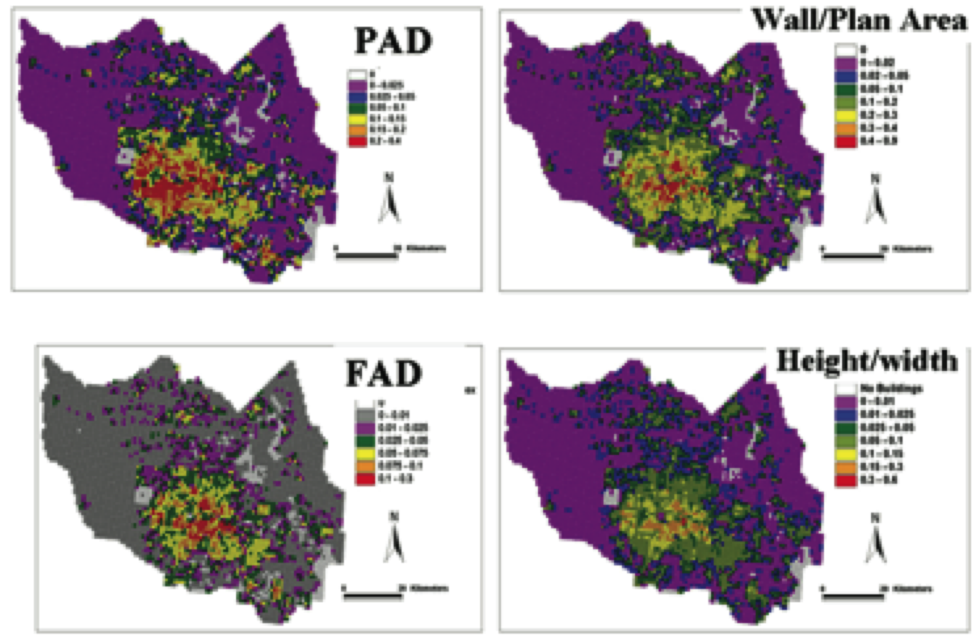
3. **Multi-layer Urban Canopy Model (BEP):** Directly interact with PBL scheme, multiple vertical layers, effects of buildings on momentum and heat fluxes. Available in WRF3. 1 (Martilli et al., 2002, *BLM*).





Detailed maps of urban canopy parameter in WRF-Urban

National Urban Database and Access Portal Tool (NUDAPT), led by Jason Ching (UNC). Released in WRF v3.5, April 2013.



Example of NUDAPT gridded urban canon parameters for Houston, Texas. Plan area density (PAD), frontal area density of the buildings (FAD).

How to use the data?

http://www.ral.ucar.edu/research/land/technology/urban.php

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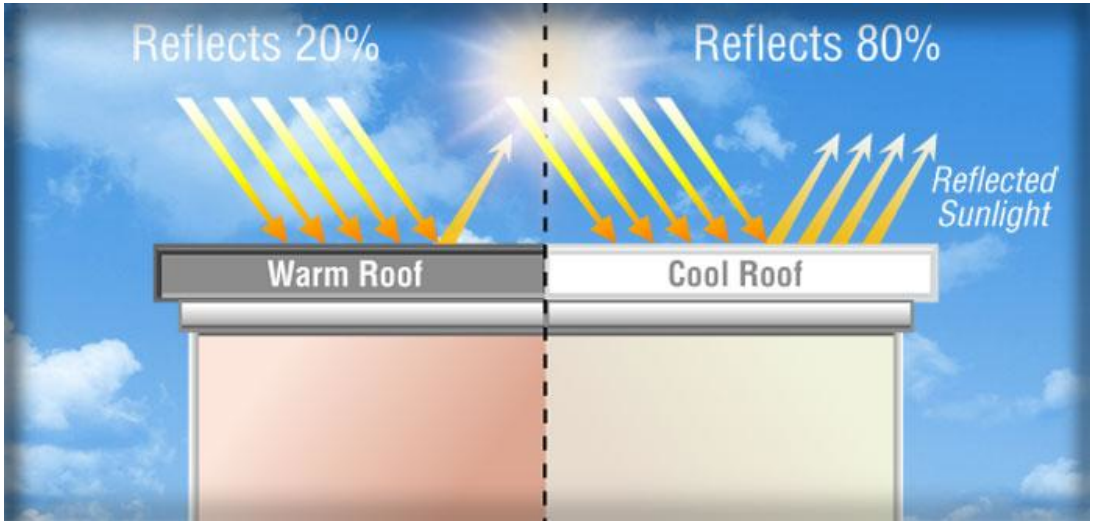
Ching et al., 2009, *Bull. American Meteorol. Soc.*

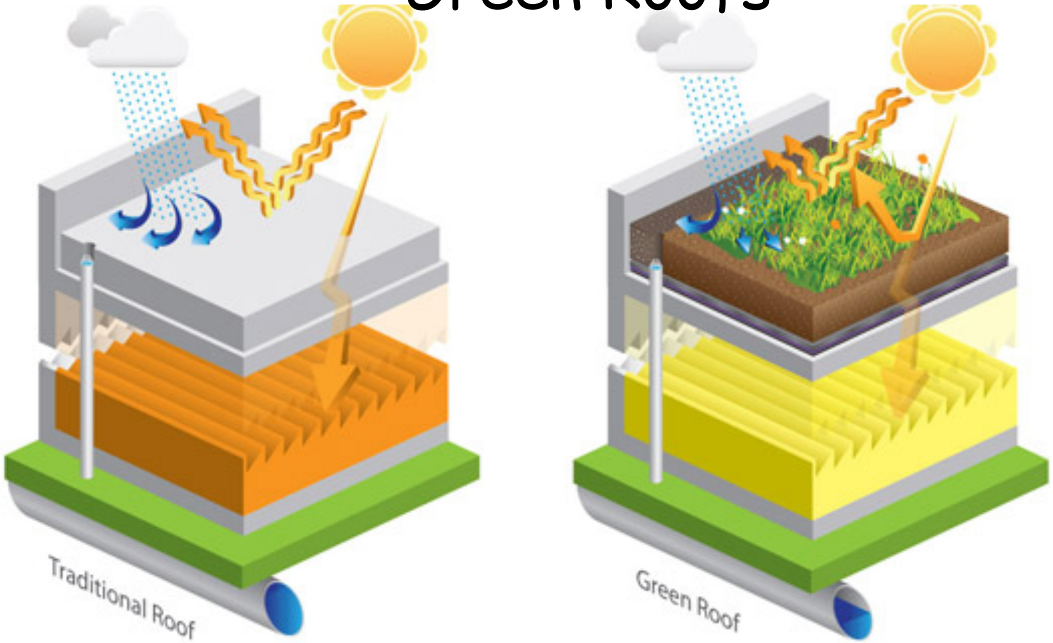
WUDAPT: Facilitating advanced urban canopy modeling for weather, climate, air quality and environmental analyses

Led by Jason Ching

Cool Roofs



Green Roofs



Assess mitigation and adaptation strategies in urbanized areas.

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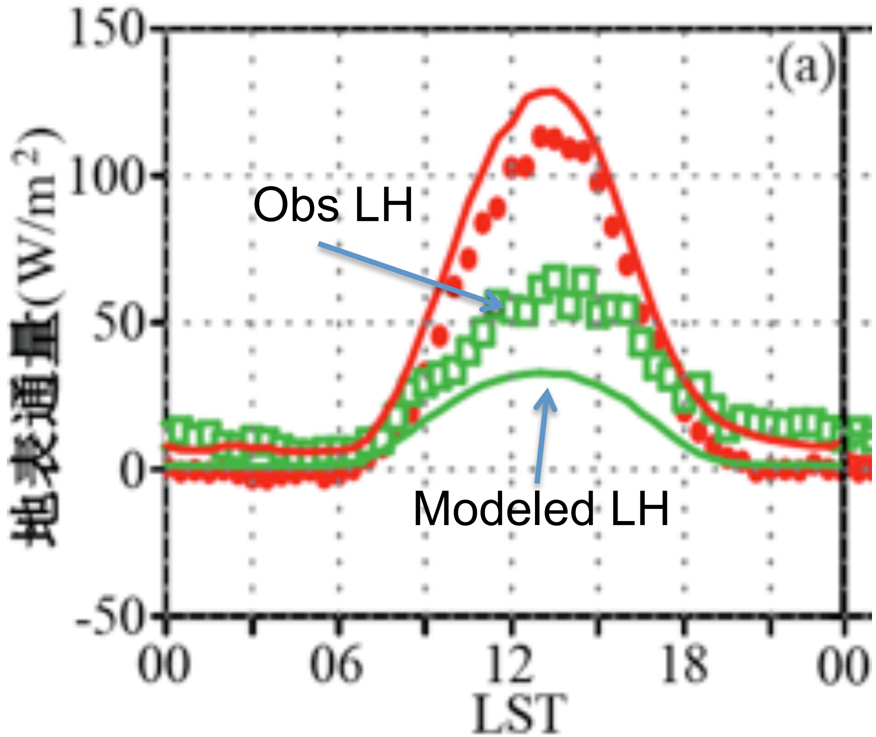
Urban Hydrologic Modeling



Annual average of heat fluxes for July 2009-2010:

Dashed: observations from Beijing 320-m tower (from 140-m height),

Solid: SLUCM simulated

Red: sensible heat flux
Green: latent heat flux

SLUCM significantly underestimate city latent heat fluxes

Urban Hydrologic Modeling

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The International Urban Energy Balance Models Comparison Project: First Results from Phase 1

Underestimating city latent heat fluxes is a common problem in urban parameterization schemes (Grimmond et al., 2010)

Deficiencies in WRF-Urban hydrologic cycle:

1) Lawn irrigation (urban oasis effects)
2) Influences of city micro-climate on potential evaporation
3) Pavements and roof runoff and evaporation
4) Anthropogenic moisture sources

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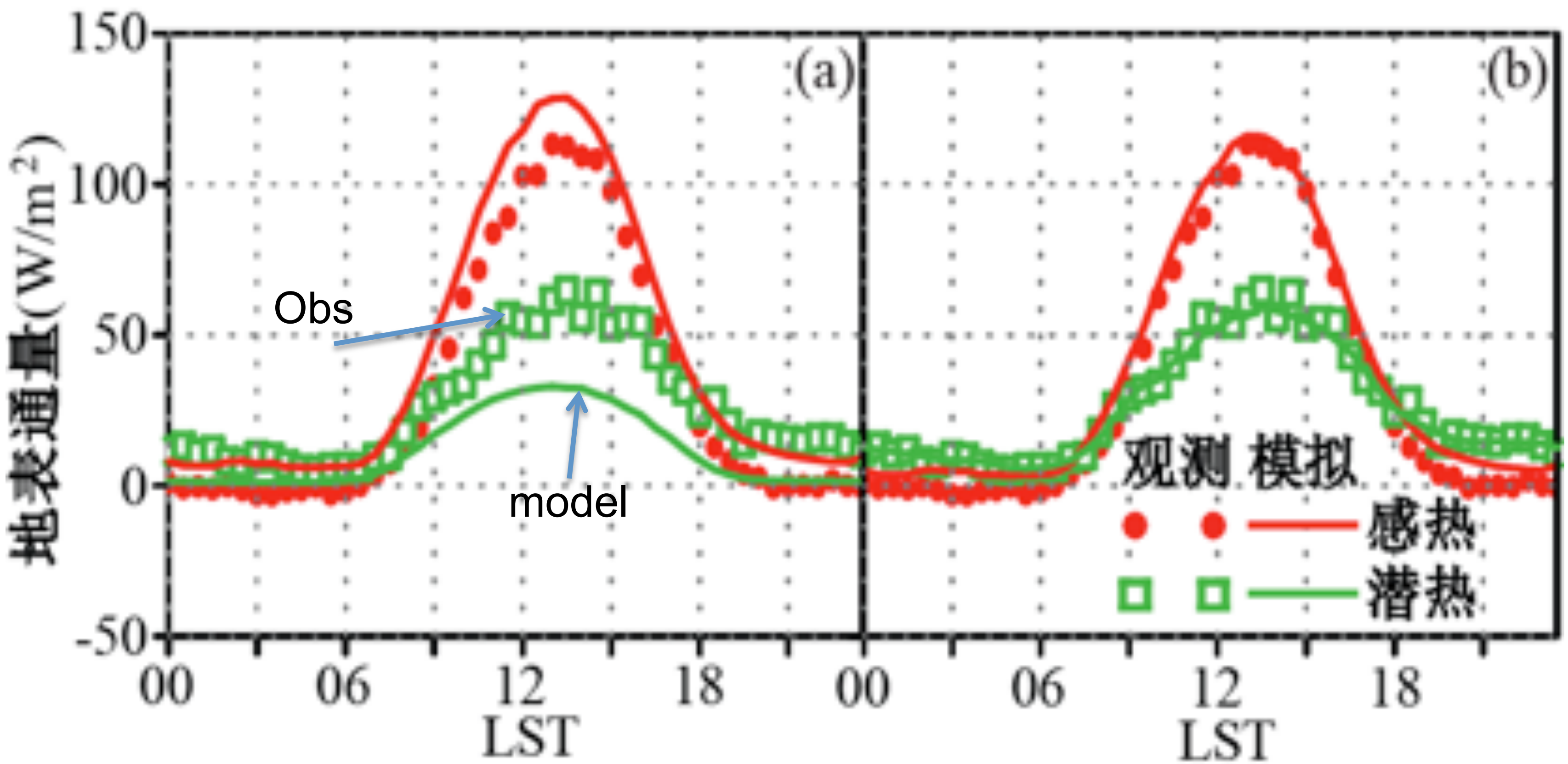
Improve Urban Hydrologic Modeling

SLUCM improve city evaporation simulation (right panel) by considering: 1) lawn irrigation, 2) urban oasis effect, 3) evaporation from impervious surfaces, and 4) anthropogenic moisture



Miao and Chen, 2013

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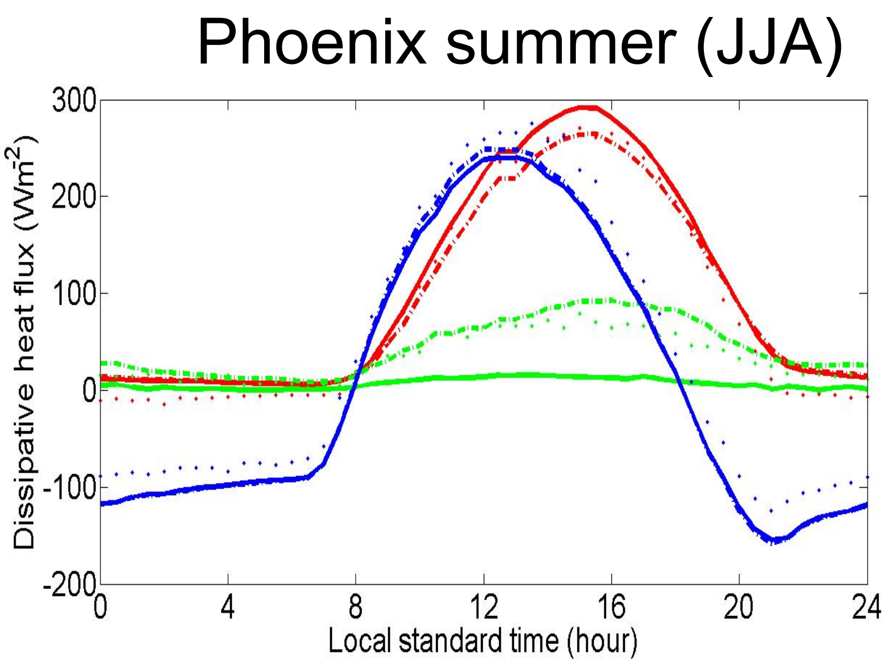
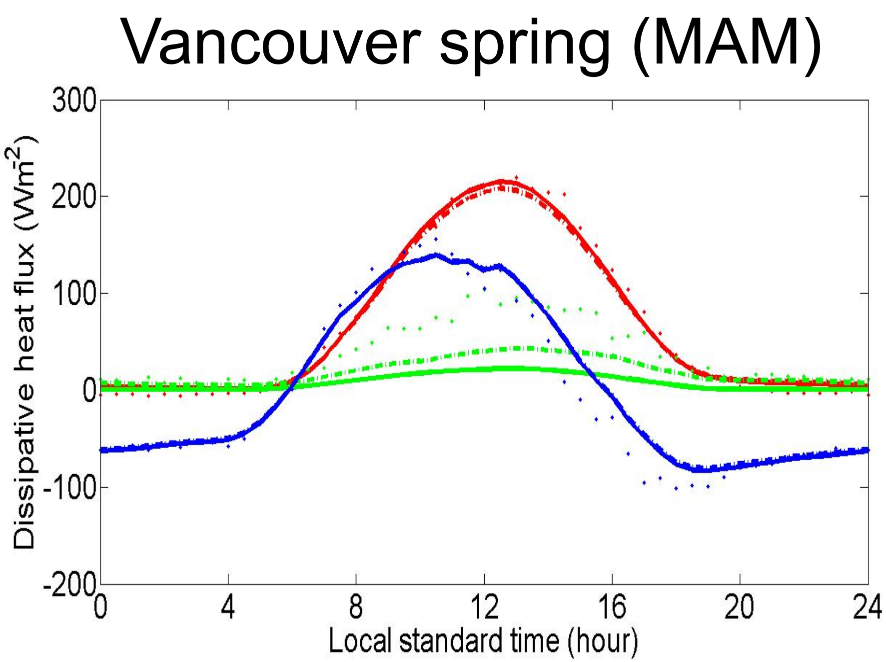
Improve Urban Hydrologic Modeling





Green: latent heat fluxes
Red: sensible heat
Blue: storage heat

Solid: old model
Dots: observation
Dashed: new model

Yang et al. (2014) paper

To be released in 2015

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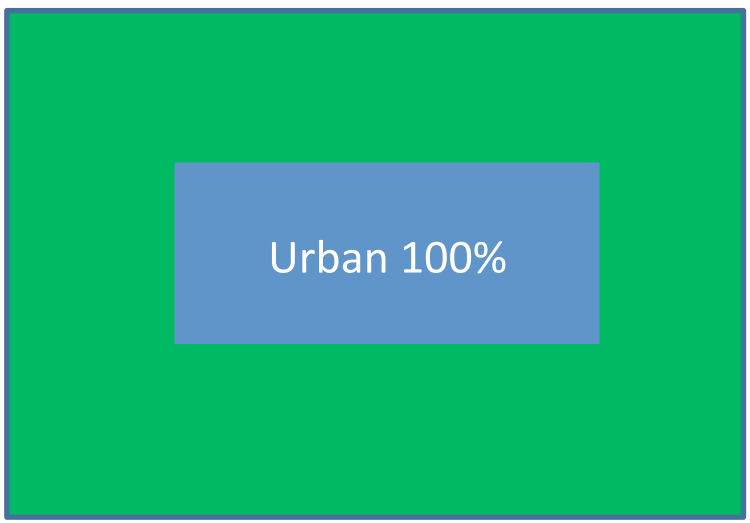
New mosaic/tiling approach in the WRF-Noah released in WRF V3.6 (spring 2014)

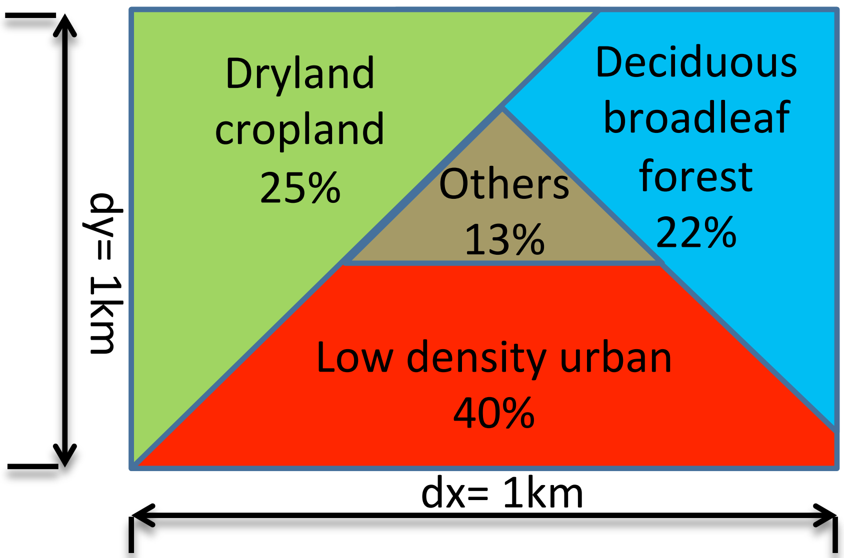
Dan Li

Elie Bou-Zeid, Michael Barlage, Fei Chen, James A. Smith

WRF-Noah



WRF-Noah-mosaic (N=4)

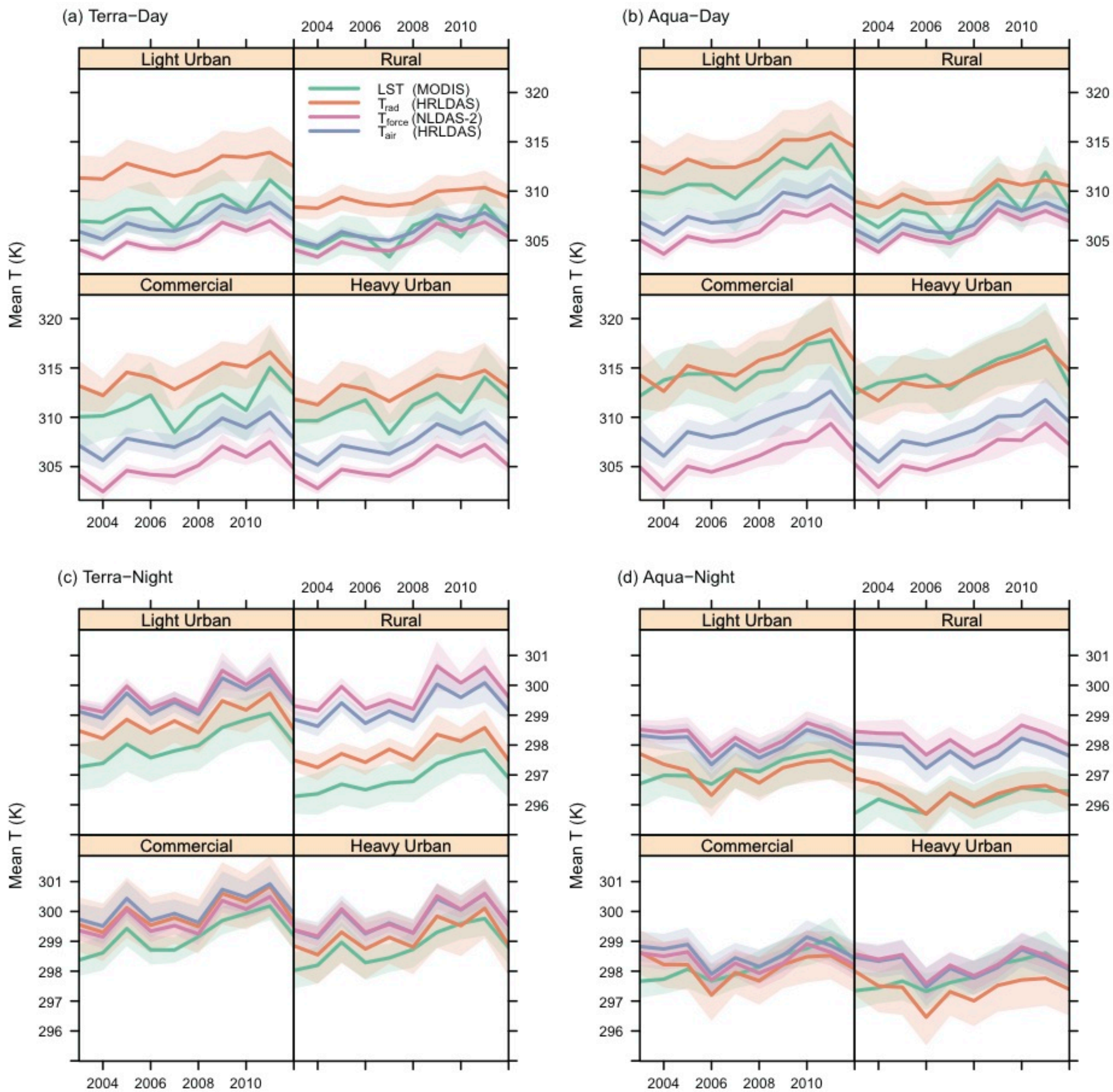


Li et al. 2014: Development and evaluation of a mosaic approach in the WRF-Noah framework, JGR

uHRLDAS (urbanized land data assimilation system) Adding 2m diagnostic

1. When driven by model-level (above 10m) forcing, 2-meter variables (T, q) using MYJ-consistent M-O theory: $T_{2m} = T_{sfc} - SH/(\rho c_p C_{h2m})$

2. Radiative temperature consistent with LW_{up} from the urban area: $T_{rad\text{-}urban} = (Lw_{up\text{-}urb}/\varepsilon_{net})^{1/4}$ where ε_{net} is the sky-view weighted emissivity



uHRLDAS radiative temperature (orange) agrees better with MODIS LST observations (green). Averaged for summer over Houston.

From Monaghan, et al. 2014

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8th WRF Working Group 14 Workshop:

Identifying Land-Surface Model Development Needs For NWP Operational Agencies

Venue: Center Green Facility: Room CG1-3131, 26-27 June, NCAR, Boulder, CO

Agenda

Workshop Goals:

- Identify priorities and gaps in LSM development, land data assimilation, and evaluation and benchmarking for LSM applications to the operational communities;
- Explore the next 5-10 year roadmap towards integrated LSM modeling;
- Re-organize the WRF WG14 to accomplish such roadmap

Thank you!

Session 1: LSM development at operational agencies (Chair: Fei Chen)

09:20 – 09:35	Mike EK (EMC): Future land modeling efforts at NCEP
09:35 – 09:50	Jerry Wegiel (AFWA): AFWA LSM roadmap
10:00 – 12:00	Lunch

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Noah-MP (multiple Parameterization) is unique among LSMs

- **Multiple parameterizations to treat key hydrology-snow-vegetation processes paradigm in a single land modeling framework**
- In a broad sense,
  - Multi-physics ≡ Multi-hypothesis
- **A modular & powerful framework for**
  - Diagnosing differences
  - Identifying structural errors
  - Improving understanding
  - Enhancing data/model fusion and data assimilation
  - Facilitating ensemble forecasts and **uncertainty quantification**

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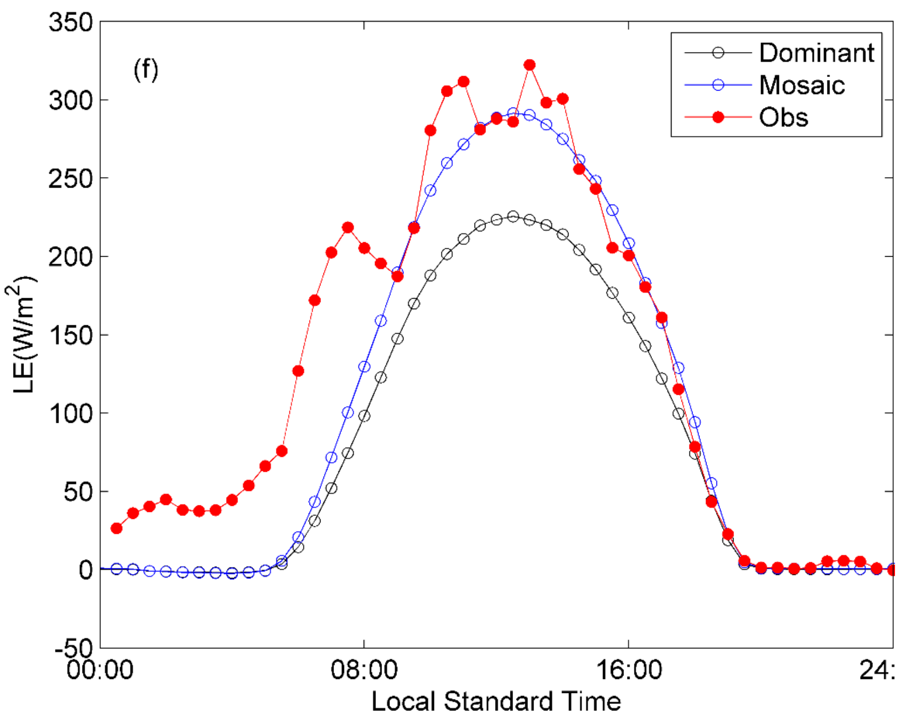
Summary

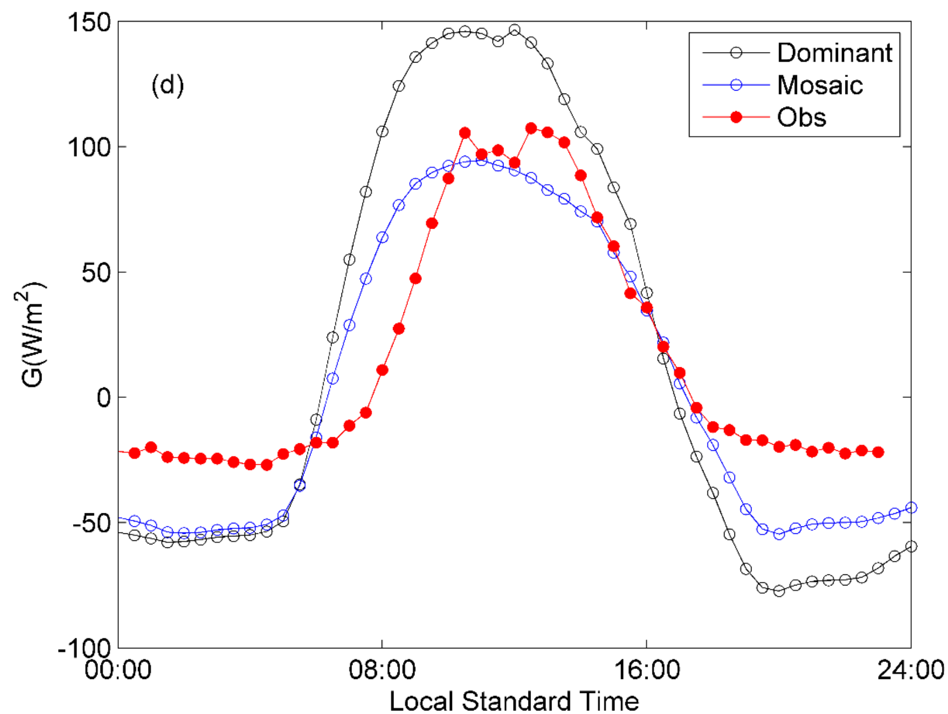
- Numerous hydrologic enhancements are in the final stage of testing; expected to be released in the next version of WRF-Urban.
- The modified uHRLDAS provides new capability of modeling and analyzing city thermal environments.
- The Noah-MP LSM was released in WRF V3.4 in 2012. We will soon start coupling Noah-MP with the single-layer urban model.

A clear-day case: surface fluxes at Cub hill (Towson, MD) simulated by WRF-Urban with Mosaic approach

Latent heat fluxes

Ground heat fluxes





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