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High-resolution simulations of the Urban Heat Island

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Zooming in: From regional to local



Land surface model simulations of Houston's urban heat island.

- Employ the offline version of the Noah LSM, called "HRLDAS"; 1-layer UCM
- Driven by the ~14-km NLDAS-II forcing fields
- Use of 30-m Nat. Land Cover Database to specify 3 urban types
- Treatment of urban land use fraction explicitly with NUDAPT (Ching et al. 2009)
 - This 2D treatment provides more realistic spatial depiction of heat island over the default 3-category urban "look up table" treatment
 - Performed1-km simulations; half-hourly output; 8 experiments; 10 years each
- Validation versus MODIS imagery and weather stations



NUDAPT building fraction \rightarrow

(Burian et al. 2003)

1-layer Urban Canopy Model





Kusaka et al. (2001)

Simulations of the Houston Heat Island August 2010 Average 2-m Temperature

Daytime

Nighttime

August 2010 Average Daily Cycle of Air Temperature over Houston, TX



August 2010 Average Daily Cycle of Air Temperature over Houston, TX



(Courtesy J. Boehnert, NCAR)

HRLDAS Experiments

| Experiment | Description | # Urban categories | NUDAPT? | Irrigated? |
|------------|------------------------------|-----------------------|---------|------------|
| A1 | Vegetation only | 0 | No | No |
| B1 | 1-category urban | 1 | No | No |
| C1 | 3-category urban | 3 | No | No |
| D1 | 3-category urban with NUDAPT | 3 | Yes | No |

Validation of HRLDAS Simulations

Validation Methodology

1. Employ remotely-sensed land surface temperature (LST) from NASA MODIS

- Used MODIS instruments onboard satellites "Terra" and "Aqua"
- 10 years of 4x daily data: 2003-2012
- Advantages: Spatially comprehensive, lots of data points
- Disadvantages: Cloud impacts, view angle biases, radiative temperature

2. Employ 17 weather stations from short-term EPA field program.

- Installed throughout city
- Hourly data, 2005-2006
- Advantages: Air temperature, better temporal resolution, no cloud problem
- Disadvantages: Short record, cannot cover entire city





Using MODIS for validation: Caution!



(Hu et al., submitted)

MODIS Terra LST Versus HRLDAS T_{rad}



Correlation of MODIS LST and HRLDAS T_{rad} by Experiment

Veg = Vegetated areas CU: Commercial urban HU: Heavy urban LU: Light urban Terra Night LST vs HRLDAS Trad



Blue:Low correlationYellow:Medium correlationRed:High correlation

A1: Vegetation Only
B1: 1-urban category
C1: 3-urban categories
D1: 3-urban categories, 2-d urban fraction
A2: A1 + irrigation
B2: B1 + irrigation
C2: C1 + irrigation
D2: D1 + irrigation

Correlation Statistics for Experiments versus 17 urban weather stations August 2006





- A1: Vegetation Only
- B1: 1-urban category
- C1: 3-urban categories
- D1: 3-urban categories, 2-d urban fraction
- D2: D1 + irrigation

Next Steps: Toronto

Toronto SIMMER simulations

Working with Claus Rinner and Heather Hart, Ryerson U. to integrate high quality Toronto land use data



1-m Quickbird-based map (toronto.ca/open; courtesy C. Rinner)

What have we learned?

 Offline urban heat island simulations can provide long-term records of urban extreme heat exposure with good accuracy but without the huge expense of running simulations coupled to an atmospheric model.

• Satellite data, when used with care, can be used to validate such simulations.

Urban morphology matters.

• Green matters (a lot!).

Extra Slides

Example datasets used in SIMMER



Local Scale: HRLDAS vs. Wx Obs



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Day-minus-Night LST: 2006 July/Aug 48-day composite

HRLDAS







30N

Can we reduce uncertainty by adding complexity to our simulations?



Breakdown of HRLDAS Trad components



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