High-resolution simulations of the Urban Heat Island

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Zooming in: From regional to local

(Oleson et al., 2013)
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
  - Performed 1-km simulations; half-hourly output; 8 experiments; 10 years each
- Validation versus MODIS imagery and weather stations

NUDAPT building fraction →

(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

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

Nighttime

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

(Courtesy J. Boehnert, NCAR)
## HRLDAS Experiments

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Description</th>
<th># Urban categories</th>
<th>NUDAPT?</th>
<th>Irrigated?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Vegetation only</td>
<td>0</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>B1</td>
<td>1-category urban</td>
<td>1</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>C1</td>
<td>3-category urban</td>
<td>3</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>D1</td>
<td>3-category urban with NUDAPT</td>
<td>3</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

*(Monaghan et al., in preparation)*
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 $T_{\text{rad}}$

MODIS:

(Monaghan et al., in preparation)
Correlation of MODIS LST and HRLDAS $T_{rad}$ by Experiment

Veg = Vegetated areas
CU: Commercial urban
HU: Heavy urban
LU: Light urban

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

(Monaghan et al., in preparation)
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

(Monaghan et al., in preparation)
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

- Daily mortality counts 1999-2006
- Race and ethnicity
- Temperature, 1999-2006
- Median house value
- Mean construction date
- Central Air Conditioning
Local Scale: HRLDAS vs. Wx Obs
Day-minus-Night LST: 2006 July/Aug
48-day composite

HRLDAS

MODIS
Can we reduce uncertainty by adding complexity to our simulations?
Breakdown of HRLDAS Trad components
Correlation of MODIS LST and HRLDAS $T_{\text{rad}}$ by Experiment

Veg = Vegetated areas
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C2: C1 + irrigation
D2: D1 + irrigation

Blue: Low correlation
Red: High correlation

(Monaghan et al., in preparation)