The Canadian external urban and land surface modeling system (GEM-SURF): 
Summertime evaluation over the Montreal metropolitan area

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ASI – The Atmospheric System and its Interactions, Urban Climate

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CONTEXT

- Modelisation of urban processes requires very high resolution not achieved in typical NWP (resol. 15 / 2.5 km)
- Importance of micro-scale urban climate evaluation
  - Public alerts (heat waves…)
  - A tool for urban planning

THIS STUDY

- EPiCC (Environmental Prediction in Canadian Cities), summer 2008
- Development of an **external modeling system** at the Meteorological Service of Canada (near future: operational system)
Method for GEM-SURF
The External Urban and land surface Modeling System

GEM-Surface: Low cost, high resolution

Operationnal NWP Regional model

First Atmospheric level

Meteorological Inputs interpolated on the refined grid

Surface atmospheric level (canopy top)

15 km

Outputs:
- Downscaling of wind, temperature, humidity, precipitation, solar and IR radiations

Surface schemes:
- TEB & ISBA

Forcings

Turbulent fluxes, Ts for different facets T, q, wind
Vegetation classes come from a mix of:

- **EOSD** (resolution 25 m): Earth Observation for Sustainable development of forests (Natural Resources Canada), derived from satellite database
- **CCRS** (resolution 250 m): Canada Centre for Remote Sensing MODIS (2005) (program Understanding Canada from space)
Urban classes come from a semi-automatic 60-m classification (Lemonsu et al. 2006):

Decision tree applied to produce urban classes with:

- Satellite database (Landsat, or ASTER), 15 m
- Total Elevation – bald Earth’s topography (DEM and CDED1), 15 m
• Radiative Surface Temperature (°C)
  **July 6th 2008 (11:00 LST)**
  Warm and Sunny

**Urban GEM-Surface**
Resolution: 120 m

**Simulation Period:**
May – September 2008
Run Timestep: **30 min**
Forcing Timestep: **1 h**
Comparison with MODIS satellite data (1 km)

MOD11A1 product, Resolution: 1km
- Atmospheric effects corrected
- Satellite View Angle: 15°

- Radiative Surface Temperature (°C)
  July 6th 2008 (10:54 LST)

Urban GEM-Surface
Resolution: 938 m → upscaling

No assimilation of soil water content

\[ \Delta T = \text{LST}_{\text{off-line}} - \text{LST}_{\text{MODIS}} \]
Clear-sky days
## Comparison with MODIS satellite data (1 km)

### Scores on clear-sky days

<table>
<thead>
<tr>
<th>Days</th>
<th>6 May</th>
<th>13 May</th>
<th>25 May</th>
<th>28 May</th>
<th>2 July</th>
<th>6 July</th>
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<tbody>
<tr>
<td>Range of SVA (°)</td>
<td>30-35</td>
<td>28-42</td>
<td>3-8</td>
<td>22-27</td>
<td>22-27</td>
<td>12-18</td>
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<td>Time (LT)</td>
<td>1124</td>
<td>1130</td>
<td>1100</td>
<td>1048</td>
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<td>Land covers</td>
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<td>Bias (K)</td>
<td>-1.9</td>
<td>-0.9</td>
<td>-0.8</td>
<td>-2.4</td>
<td>1.4</td>
<td>1.3</td>
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<tr>
<td>STDE (K)</td>
<td>2.4</td>
<td>2.8</td>
<td>2.7</td>
<td>3.2</td>
<td>2.2</td>
<td>2.2</td>
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<tr>
<td>Urban</td>
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<tr>
<td>Bias (K)</td>
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<td>-2.1</td>
<td>1.0</td>
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<td>1.9</td>
<td>3.2</td>
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<td>1.8</td>
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<td>Natural</td>
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<td>Bias (K)</td>
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<td>-0.2</td>
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<td>2.1</td>
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</table>
The EPiCC field experiment in Montreal
(Environmental Prediction in Canadian Cities)

• Long term measurements (two years)
• Focus on the Surface Energy Budget, air temperature

• Field data from O. Bergeron, I. Strachan (McGill University)
• Aerial photographs from J. Voogt (UWO)
Evaluation of the Surface Energy Budget

5 months scores (bias and STDE)
Evaluation with measurements
Comparison with the operational model

Towards 0 is better!

Land use land cover:

**URB**
- 37 % impervious surface
- 27 % building
- 22 % short grass and forbs
- 14 % mixed wood forests

**SUB**
- 16 % impervious surface
- 10 % building
- 38 % short grass and forbs
- 36 % mixed wood forests

**RUR**
- 100 % crops
Evaluation of the Surface Energy Budget

- Observations

△ GEM-Surface (120 m)

■ Operational Model (15 km)

Mean diurnal cycle for 9 clear-sky days
Urban site
Near-surface temperature and humidity

Intra-urban near-surface UHI

$T^\circ \ (C)$  
$z=25m$

$T^\circ \ (C)$  
$z=5m$

$q \ (g/kg)$  
$Z=25 \ m$

$RH \ (%)$  
$Z=5m$
Montreal Canopy Urban Heat Island

Nocturnal 2m Air Temperature (simulation, 120m)

6 July, 01:00 LST

UHI : 5-6 °C
Conclusions

URBAN GEM-SURF SYSTEM

- Refinement of the surface and near-surface meteorological variables at low cost
- The system has shown its ability to represent physical processes in a mixed environment (urban and natural surfaces)
- **Added value compared to current operational systems**, but closely dependent on their performance
- Plans to link it with **surface assimilation system** (CALDAS, soil moisture...)

Canada
Further achievement: Country-size 200-m forecasts with the external modeling system GEM-SURF

- Development of an experimental prototype
- Operational implementation in 2012
Surface urban characteristics for all of Canada

**Method**
From 5 m classifications derived from different databases (CanVec, 3D buildings, circa2000, census data) to urban parameters for simulation grid

**Parameters**
fractions of building, vegetation, impervious, building height, street aspect ratio...
Acknowledgments to Maria Abrahamowicz, Nathalie Gauthier, Alexandre Leroux and Vanh Souvanlasy
Thank for your attention!

P.S. : you are welcome to EMS2011-642 (Thursday, 11:00) EPiCC / Vancouver