Benefits of explicit urban parameterization in regional climate modeling to study climate and city interactions

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Modeling of urban climate
Different approaches

For most of meteo/climate models:

- Cities do not exist and urban processes are not modeled (= vegetation)
- Cities are described as rock covers with high roughness and treated by SVAT models
  - Imperviousness
  - Surface heating capacities at daytime
  - Roughness effect on airflow
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  ▶ Imperviousness
  ▶ Surface heating capacities at daytime
  ▶ Roughness effect on airflow

But not account for radiative effects related to 3D urban geometry

▶ 2000s: new generation of urban canopy models
Modeling of urban climate
Town Energy Balance (TEB) model (Masson 2000)

- Concept of mean urban canyon (Oke 1982)
  - Urban elements: roof, road, walls
  - Mean morphological characteristics
  - Mean radiative and thermal properties

- Physical processes including:
  - Radiative and energetic exchanges
  - Water and snow
  - T, H, U inside canyon

Source: Toulouse centre-ville, Google Earth
ALADIN-Climate regional climate simulations over France for past period
- Version: limited-area model ALADIN-Climate V6
- Spatial domain: Metropolitan France
- Horizontal resolution of 12 km
- Vertical grid: 92 levels
- Simulation period: 1980-2009
- Lateral boundary conditions: ERAinterim reanalyses (80 km resol)
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SURFEX land surface modeling system
- ISBA for natural soils and vegetation
- TEB for urban areas
- Land surface covers and properties defined with ECOCLIMAP v2 database
  - 3% of France is « urban »
Sensitivity experiments

Sensitivity analysis on representation of urban areas and urban processes

- Exp **CITY**  Urban areas explicitly modeled by activating TEB in SURFEX
- Exp **ROCK**  Urban areas modeled as rock covers with high roughness
- Exp **VEG**  Urban areas replaced by local vegetation and modeled with ISBA

1) Evaluation of default configuration (**ROCK**)

by comparison with SAFRAN analyses (8-km resolution over France)

<table>
<thead>
<tr>
<th>Seasonal biases (mod - obs)</th>
<th>DJF</th>
<th>MAM</th>
<th>JJA</th>
<th>SON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily precip rate (mm day⁻¹)</td>
<td>+0.23</td>
<td>+0.40</td>
<td>-0.41</td>
<td>-0.07</td>
</tr>
<tr>
<td>Incoming solar rad (W m⁻²)</td>
<td>+12.7</td>
<td>+34.0</td>
<td>+40.7</td>
<td>+23.1</td>
</tr>
<tr>
<td>Tmin (°C)</td>
<td>-1.12</td>
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<td>+0.09</td>
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</tr>
<tr>
<td>Tmax (°C)</td>
<td>+0.64</td>
<td>+0.42</td>
<td>+2.79</td>
<td>+1.31</td>
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Sensitivity analysis on representation of urban areas and urban processes

- **Exp CITY** Urban areas explicitly modeled by activating TEB in SURFEX
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- **Exp VEG** Urban areas replaced by local vegetation and modeled with ISBA

1) **Evaluation of default configuration (ROCK)**
   by comparison with SAFRAN analyses (8-km resolution over France)

2) **Comparison of sensitivity experiments**
   for daily precipitation and near-surface temperatures
   - **ROCK vs VEG**  >>  What urban effects with simple approach ?
   - **CITY vs VEG**  >>  What benefit of sophisticated parameterization ?
Sensitivity experiment results

Daily precipitation rates

- No significant impact on precipitation rates

\( \Delta RR \text{ (mm day}^{-1} \text{)} \)

grey = non-significant difference
Sensitivity experiment results
Near-surface temperatures

- No significant impact on precipitation rates

- Significant impact on Tmin and Tmax for all seasons
  - Maximum warming effect over urban areas
  - Regional impact of cities on temperature
  - Impact more pronounced for CITY than ROCK

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<td><strong>JJA</strong></td>
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Urban heat island modeling
Evaluation for Paris area

Evaluation of urban heat island modeling by comparison with long-term observation time series in Paris region

\[ ICU = \text{Turb} - \text{Trur}_{\text{avg}} \]

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Distribution of UCI (Tmin) intensity (1980-2009)

Source: https://www.geoportail.gouv.fr/carte
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Distribution of UCI (Tmax) intensity (1980-2009)

Distribution of UCI (Tmin) intensity (1980-2009)
Conclusions

- Regional impact of cities on near-surface temperatures (even at 12-km spatial resol) with a maximum warming effect localized over cities

- Using the TEB model instead the simple slab approach:
  - More pronounced urban effects (intensity and spatial extension)
  - Better simulation of nocturnal urban heat island with TEB
    >> important for sanitary impacts on urban population

- Relevant to activate urban canopy model for RCM simulation
  - No additional computational cost
  - Impact studies
Thank you for your attention

Contact: aude.lemonsu@meteo.fr

M. Daniel, A. Lemonsu, M. Déqué, S. Somot, A. Alias, V. Masson, 2018: Benefits of explicit urban parameterization in regional climate modeling to study climate and city interactions, *Climate Dynamics, in review*