Modeling the impact of future development pathways in a mid-latitude city on the urban energy balance

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Context

• Incorporating climate knowledge into urban decision-making will be an important component in planning and creating more sustainable cities since urban form once developed becomes fixed.

• Within the urban climate community a move towards greater integration with planning & environmental policy arenas - see for example, Adler & Kern (2008)
  • Establishing science-policy capacity and other policy relevant research to support timely and cost-effective adaptation and mitigation decisions at local scale is essential for regional capacity to assess, design and implement policies.
  
  - Morlot et al., (2009) OECD environmental report

• In this respect, urban climate models (UCMs) are a potentially valuable tool for evaluating some of the impacts of different urban designs, land use, population densities and activities on the surface energy and water balances and the consequent effects on the local atmosphere and hydrology, respectively.

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• However urban climate modeling for this problem are scarce in terms of application
  • Differences in nomenclature, scale, objectives, fiscal and social priorities
  • Dubious as to the value of models ‘knowledge circulation failure’ (Hebbert and MacKillop, 2013)
  • Perceived lack of expertise (Eliasson, 2000 - The use of climate knowledge in urban planning Landscape and Urban Planning 38(1) 31-44)
  • Data starvation
WUDAPT WORKSHOP AT ICUC9

We are holding a WUDAPT workshop at ICUC9 in Toulouse, France on Wed 22 July (16.00 to 18.00). During this workshop you will learn more about how to create a Local Climate Zone (LCZ) classification of your city or any city of interest worldwide. If you are interested in attending, please register at this site.

We intend to have two streams to the workshop:

• a demonstration stream
• a more hands-on stream for those wanting to create an LCZ classification during the two-hour session. This second stream will require some pre-workshop preparation but we will guide you through this process.

We are particularly interested in classifying the C40 cities. Let us know if you want to be involved in this particular initiative.
In this work

• We Propose to use LCZ as a basis to establish a common language / understanding to explore potential climatic consequences of different planning / policy choices
• Study area: Dublin City ~24x44 km grid domain (~1x1 km)
• Meteorological Forcing from a Typical Climatological Year
• Land cover from MOLAND / LCZ

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Methods

• Example of high resolution LCZ map and LCZ classes for Dublin
• Resampled to 1x1 Km (previous slide) based on majority rule
• Correlated with MOLAND LULC
• Fractional coverage + z parameters for each land cover class calculated for SUEWS
  • Alexander & Mills (2015)
• **Technically level 1 data**

<table>
<thead>
<tr>
<th>LCZ</th>
<th>Built</th>
<th>Impervious</th>
<th>Unmanaged</th>
<th>Trees</th>
<th>Grass</th>
<th>Water</th>
<th>(n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Compact Mid</td>
<td>33</td>
<td>55</td>
<td>0</td>
<td>6</td>
<td>6</td>
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<td>61</td>
<td>0</td>
<td>7</td>
<td>10</td>
<td>0</td>
<td>5</td>
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<td>5 Open Mid</td>
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<td>0</td>
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<td>0</td>
<td>5</td>
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<td>52</td>
<td>0</td>
<td>11</td>
<td>23</td>
<td>0</td>
<td>10</td>
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<tr>
<td>8 Large Low</td>
<td>30</td>
<td>61</td>
<td>0</td>
<td>4</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>10 Industrial</td>
<td>16</td>
<td>69</td>
<td>0</td>
<td>8</td>
<td>7</td>
<td>0</td>
<td>5</td>
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<tr>
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<td>2</td>
<td>4</td>
<td>48</td>
<td>45</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>104 Low Plant</td>
<td>3</td>
<td>8</td>
<td>3</td>
<td>18</td>
<td>67</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>105 Bare Rock</td>
<td>9</td>
<td>49</td>
<td>0</td>
<td>14</td>
<td>29</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>106 Bare Sand</td>
<td>6</td>
<td>20</td>
<td>55</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>107 Water</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>—</td>
</tr>
</tbody>
</table>

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Methods

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ICUC9 20- 24 Jul 2015, Toulouse, France

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<table>
<thead>
<tr>
<th>Scenario short name</th>
<th>Alias</th>
<th>Description</th>
<th>Urban Extent</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP-1</td>
<td>Business as usual</td>
<td>As the alias suggests, this scenario explores a continuation of the current, dispersed settlement patterns. Therefore simulates a &quot;business as usual&quot; future, whereby implementation of pre-existing development policies have been weak. Reflecting the current economic climate, several transportation projects are delayed in this scenario until 2020. With the divergence of policy and practice concerning Green Belts in mind, this scenario does not contain a greenbelt layer as outlined in Brennan et al. (2009).</td>
<td>19.8% (+6.1%)</td>
</tr>
<tr>
<td>DP-2</td>
<td>Undirected sprawl</td>
<td>In this scenario development is strongly directed toward an expanded metropolitan footprint (MF), which is extended along key transport corridors. Strictly enforced Strategic Green Belts are used to discourage excessive development in rural areas and link protected areas together. Two types of Green Belts were created; large Outer Green Belts designed to designate areas where development should be kept to a minimum; and smaller Connector Green Belts, designed to preserve links between urban green space and rural areas.</td>
<td>25.8% (+12.1%)</td>
</tr>
<tr>
<td>DP-3</td>
<td>Directed Sprawl</td>
<td>This scenario explores a strong consolidation policy, whereby growth was focused within the existing envelope of the MF and towards a limited number of key towns in the Hinterland. Increased densities were delivered by infilling areas within the MF and in the main towns of the Hinterland. Green Belts were more extensive and strategically placed than DP-2.</td>
<td>25.4% (+11.7%)</td>
</tr>
<tr>
<td>DP-4</td>
<td>Densification</td>
<td>In this scenario, consolidation is promoted, development is focused within the existing MF and development centres. Growth in the Mid-East at public transport nodes within the MF and in designated towns on high quality public transport routes. Although densification within the existing MF was a focus of this scenario, there was a drive to keep towns distinct from one another.</td>
<td>23.2% (+9.5%)</td>
</tr>
</tbody>
</table>
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Results

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### Results

**ICUC9**

#### Context

**Modeling** the impact of future development pathways in a mid-latitude city on the urban energy balance.

#### Methods

- **Urban Feature**
  - **Energy Balance Term** (Relative to non-urban areas)
  - **Urban Effect**
    - **Canyon Geometry**
      - Increased \( K^* \)
      - Increased surface area and trapping of radiation
    - **Air Pollution**
      - Increased \( L_{\downarrow} \)
      - Greater absorption and re-emission
    - **Buildings and Traffic**
      - Addition of \( Q_F \)
      - Direct addition of heat
    - **Construction Materials**
      - Increased \( \Delta Q_s \)
      - Increased thermal admittance at night
    - **Absence of water bodies / vegetation**
      - Increased \( Q_H \)
      - Increased surface / air heating
    - **Canyon Geometry**
      - Decreased \( L^* \)
      - Reduced sky view factor (less nocturnal loss to atmosphere)
    - **Construction Materials**
      - Decreased \( Q_E \)
      - Increased water-proofing / increase runoff
    - **Canyon Geometry**
      - Decreased \( Q_A \)
      - Reduces wind speed

#### Results

- **DP-1**
  - Increased \( 95\% \)
  - Increased \( 32\% \)
  - Increased \( -13\% \)
  - Increased \( 18\% \)
  - Increased \( 54\% \)
  - Increased \( -3\% \)
  - Increased \( 23\% \)
  - Increased \( -3% \)

#### Conclusions

- **Construction Materials**
  - Increased \( \Delta Q_s \)
  - Increased thermal admittance at night
- **Absence of water bodies / vegetation**
  - Increased \( Q_H \)
  - Increased surface / air heating
- **Construction Materials**
  - Decreased \( Q_E \)
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Results

Design 1 reduces the impact of urban development on summertime evapotranspiration by 34.0%

Design 2 reduces the impact on summertime evapotranspiration by 47.7%

Design 3 reduced the impact by 52.2%

The impact of urban development on the annual magnitude of surface / air heating (sensible heat) was reduced by 30.1%, 37.5% and 38.6% in design 1, 2 and 3 respectively.

The impact on heat storage was reduced by 7.9%, 15.8% and 21.7%, meaning the green roof design reduced the impact of urban development the most.


Smart Growth + Smart Design = Optimal Path
Conclusions

• Urban Climate Community
  • UCPs can be employed to furnish a complex model with the required parameters quickly and efficiently
  • Reduces the simulation requirements & allows for results to be extended across a wider urban area
  • LCZ map + meteorology = first pass UEB for every city included in WUDAPT
  • Overcomes the problem of data poor settings while taking into account the “urban effect”
  • SUEWS is capable of reproducing well the UEB at multiple sites within the study area with low RMSE and MFB
Conclusions

• Planning Community
  • LCZ represent a common language between communities for describing the UHI (thus the UEB) and the form and function of a city
  • A LCZ map is likely to coincide with other land use land cover maps – here MOLAND / CORINE areas had clear relationship with LCZ
  • Offers an additional evidence base for policy choice / planning decisions
  • Allows neighbourhoods to be tested for effectiveness in terms of modification (cost-benefit analysis?) leading to optimal L.I.D
Thank you for your attention / Merci pour votre attention / Vielen Dank für Ihre Aufmerksamkeit / Grazie per l'attenzione / Σας ευχαριστώ για την προσοχή σας / 感谢您的关注

I wish to Acknowledge the kind support of the post-graduate travel fund Maynooth University for part-funding my participation at ICUC9

• Contact: paul.alexander@nuim.ie
• Dublin LCZ / UHI paper:
• Some other works cited in presentation:

• Any questions / comments would be most welcome