LUCID

Mike Davies
Today

• Very brief overview and flavour of the ‘LUCID’ project

• The ‘Urban Heat Island’ (UHI)

• Some key messages
  – The urban climate
  – Impact on energy, comfort and health
The urban climate

- One of the best-known effects of urbanisation on the local climate is urban warming.
- This phenomenon is commonly referred to as the ‘Urban Heat Island’ (UHI).

<table>
<thead>
<tr>
<th>Urban features</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canyon geometry - increased surface area and multiple reflection</td>
<td>Increased absorption of short-wave radiation</td>
</tr>
<tr>
<td>Canyon geometry - reduced sky view factor</td>
<td>Decreased long-wave radiation loss</td>
</tr>
<tr>
<td>Buildings &amp; traffic - direct addition of heat</td>
<td>Anthropogenic heat source</td>
</tr>
<tr>
<td>Construction materials</td>
<td>Increased sensible heat storage</td>
</tr>
<tr>
<td>Green space</td>
<td>Decreased evapotranspiration</td>
</tr>
<tr>
<td>Canyon geometry - wind speed</td>
<td>Decreased total turbulent heat transport</td>
</tr>
</tbody>
</table>
Why should we care about the UHI?

• In London during the 2003 heat wave, the maximum temperature difference between urban and adjacent rural locations reached 9°C on occasions.

• Impact on energy, comfort and health

• Summer disbenefits vs. winter benefits
Future?

Cities may warm due to:

- **Climate Change**

- The intensification of the *Urban Heat Island (UHI)* effect from:
  - climate change (longer periods of weather conducive to formation of UHI)
  - growth
  - human response to higher temperatures (e.g. air conditioning)
LUCID

(‘The development of a Local Urban Climate model and its application to the Intelligent Development of cities’)

**Timescale**
- 2007 – 2010

**Focus**
- London

**Scales**
- City, neighbourhood, street and building

**Team**
- UCL
- University of Reading and Met Office
- Brunel University
- LSHTM
- CERC
- EMC
- Arup
- GLA
Main work undertaken

- Suite of ‘Urban Climate’ models developed
- Suite of ‘Impact’ models developed
- Collection of field data
- Application of models and interpretation of field data to address key question – what is the UHI increment on energy, comfort and health?
LUCID urban climate models covering three scales: city, neighborhood, street

**LSSAT**
ANN model for 77 fixed temperature stations.
Features:
- Site specific hourly air temperature

**LondUM**
Atmospheric model at 1km grid.
Features:
- 1.5m height surface temperatures

**Arup Outdoor Room**
Urban canyon radiative exchange model. Linked to LondUM.
Features:
- Air & surface temperature

**ADMS**
Atmospheric dispersion model. Linked to LondUM.
Features:
- Perturbations on temperature & humidity
LUCID ‘impact’ models

Energy:
- Dwellings
- Non-domestic

Comfort:
- Dwellings
- Non-domestic

Health:
- External
- Dwellings
LUCID urban climate models

1. Outputs from the city-scale urban climate model

LondUM model: example outputs
Outputs from the city-scale urban climate model

LondUM Average Daily Minimum Screen Temperature in degrees Celsius for the period 26th May - 19th July 2006

Equal ranges mapping method

- > 15.0
- 14.7 - 14.9
- 14.4 - 14.6
- 14.1 - 14.3
- 13.9 - 14.0
- 13.6 - 13.8
- 13.3 - 13.5
- 13.0 - 13.2
- 12.7 - 12.9
- 12.5 - 12.6
- 12.2 - 12.4
- 11.9 - 12.1
- 11.6 - 11.8
- 11.4 - 11.5
- 11.1 - 11.3
Outputs from the city-scale urban climate model

LondUM Urban Heat Island Intensity in degrees Celcius on 7th May 2008 at 9 pm

Equal ranges mapping method

- 5.2+
2. ADMS model
Case study: Olympic Parkland site development
Temperature perturbations to the upwind boundary layer profile at 2m due to land use variations (19:00 on 10/06/2006)
Case study: Olympic Parkland site development

Temperature perturbation (degrees C)

-2.5 to -2
-2.0 to -1.5
-1.5 to -1
-1.0 to -0.5
-0.5 to -0.1
-0.1 to 0.1
0.1 to 0.5
0.5 to 1
1.0 to 1.5
1.5 to 2
2.0 to 2.5

Differences in predicted temperatures (2m) due to land use variations (19:00 on 10/06/2006)
Messages from the city-scale

- Urban land-use distribution is key to urban temperatures
- London’s current scattered greening cools London
- Advection is important
- To affect city-scale UHI the greening needs to be large
- Building form has a moderate impact
- Anthropogenic heating likely to be important
- Albedo: Increasing albedo → daytime cooling
LUCID ‘impact’ models

1. Energy - heating and cooling degree days

![CDH VS distance-2008 (Base 12)](chart1)

![HDD VS distance-2008(Base 15.5)](chart2)
2. Energy: detailed models
Methodology – data extraction (same principles for energy, comfort models)

- Additional geometric features calculated as a f(Age, Type) according to Chapman
  - Roof Covering
  - Roof Structure
  - Wall Structure
  - Wall Finish
  - Window Type
  - Double Glazing Extent
  - Wall Insulation
  - Wall Cavity
  - Heating System
  - Heating System Age
  - Main Fuel Type
  - Main Heating Fuel
  - Loft Insulation
3. Comfort: dwellings

(a) Modelling

• UHI vs. thermal quality of dwellings
(b) Monitoring

- Modelling of indoor environmental conditions for the 110 real London dwellings.
- Test model and extend to study health impacts across London.
Average bedroom air temperature during a five-day hot spell (28th June to 2nd July 2009) plotted against the distance of the dwelling from the British Museum.
4. Comfort: non-domestic

- 20 location dependent hourly weather files
- Model - typical (Econ 19) naturally ventilated office building
- Some relationship between ‘comfort’ and distance from centre
- Significant impact of very local microclimatic effects
- How many ‘local’ weather files do we need?
5. Health

Average of daily min of temperature (26 May – 21 Jun 2006)

Use empirical temperature-mortality relationship for London

Tertile: London only

- Light blue: 9.97 – 12.36
- Blue: 12.37 – 13.01
- Dark pink: 13.02 – 13.82

Input data: city-scale LondUM simulations
Calculate mortality burden by UHI zone

Threshold = 24.8 °C
Slope = 3.8% per °C
Messages from the impact models

• Energy
  – UHI currently has a significant net energy benefit for London.
  – This balance will depend critically on future uptake of air conditioning.

• Comfort
  – Thermal quality of dwellings seems more important than location in UHI.
  – Current stock is vulnerable to heat.
  – Significant impact of very local microclimatic effects.
  – How many ‘local’ weather files do we need?

• Health
  – UHI has significant impact on mortality.
  – Indoor vs. outdoor exposure.
Notes

• Adaptation of the *external* environment
  [i.e. modify location on ‘hockey stick’ ]

• The proper adaptation of buildings will provide enhanced protection to heat via direct modification of the *indoor* environment
  [i.e. increase the threshold temperature]

• Thus attempts to offset projected increases in temperature should integrate external and internal strategies

![Diagram showing the relationship between risk and Tmax with a current threshold of ~25 deg.C.](image)
End

Mike Davies
michael.davies@ucl.ac.uk
LUCID publications

Book chapter

Journal


**Conference**


Bohnenstengel S.I., Porson A., Clark P., Belcher S.E., (2009), *Impact of urban parameters on the surface energy balance in urban areas*, 89. AMS annual meeting, Phoenix (USA).

Bohnenstengel S.I., Porson A., Clark P., Davies M. Belcher S.E., (2009), *Simulations of the London urban climate: the LUCID project*, 89. AMS annual meeting, Phoenix (USA).


Other (non refereed)


Submitted (journal)
