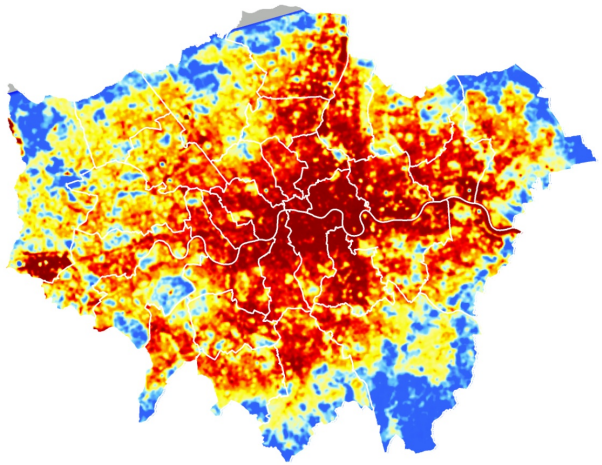
LUCID

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



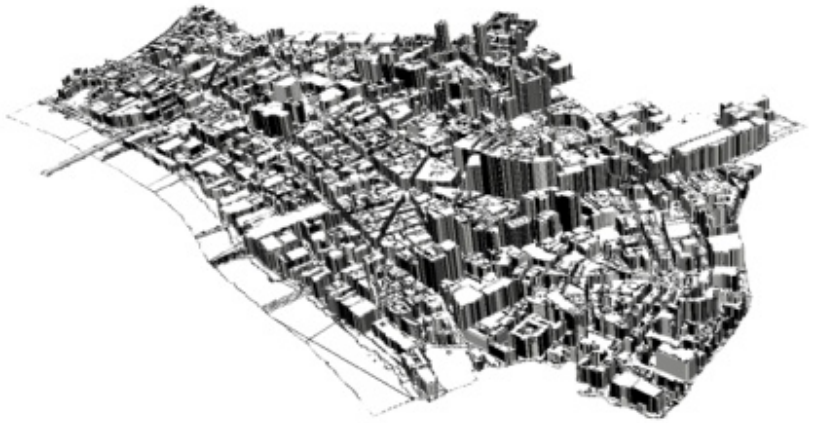
The urban climate

- 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).

Urban features	Impact
Canyon geometry - increased surface area and multiple reflection	Increased absorption of short -wave radiation
Canyon geometry - reduced sky view factor	Decreased long-wave radiation loss
Buildings & traffic - direct addition of heat	Anthropogenic heat source
Construction materials	Increased sensible heat storage
Green space	Decreased evapotranspiration
Canyon geometry - wind speed	Decreased total turbulent heat transport

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

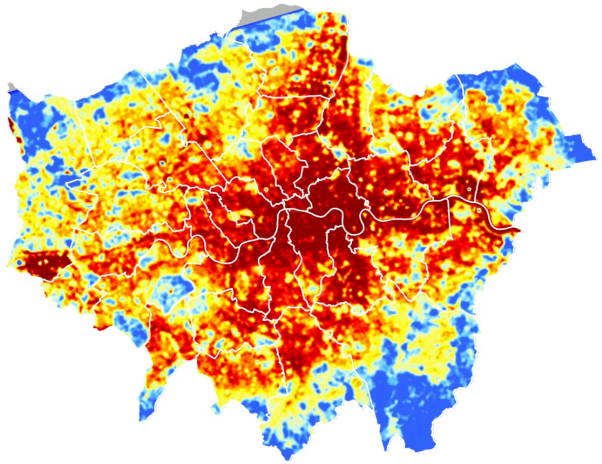
Focus
- London

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:

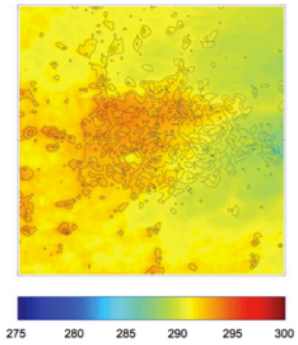
- Site specific hourly air temperature

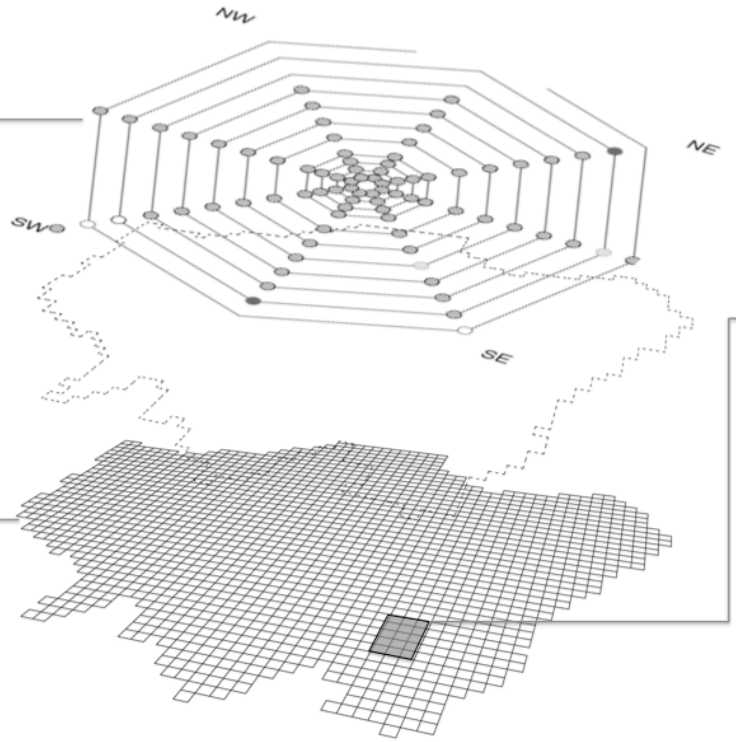
LondUM

Atmospheric model at 1km grid.

Features:

- 1.5m height surface temperatures



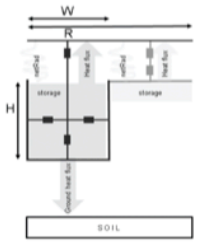


Arup Outdoor Room

Urban canyon radiative exchange model. Linked to LondUM

Features:

- Air & surface temperature

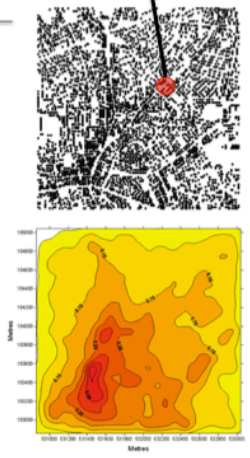


ADMS

Atmospheric dispersion model. Linked to LondUM

Features:

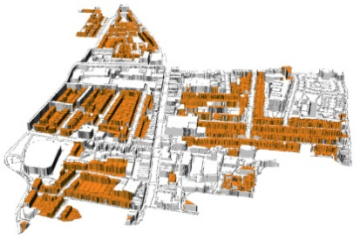
- Perturbations on temperature & humidity

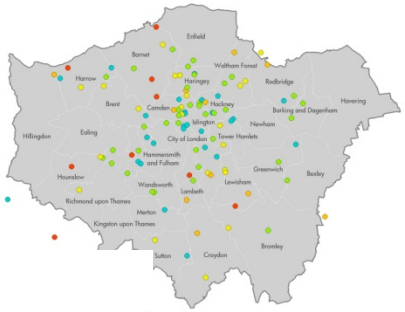


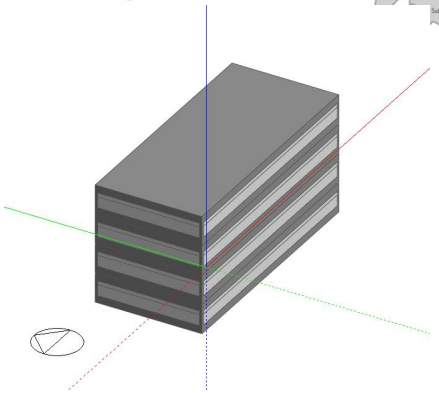
LUCID ‘impact’ models

Energy:

- Dwellings
- Non-domestic







Comfort:

- Dwellings
- Non - domestic

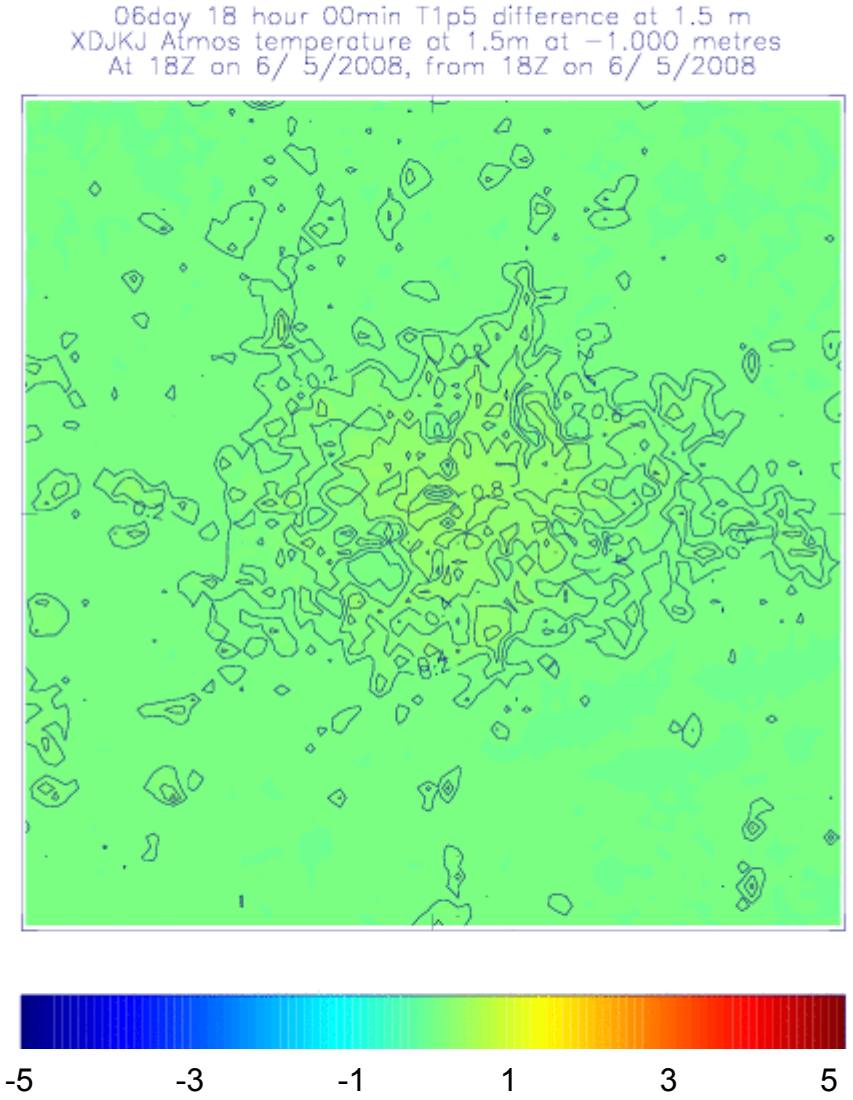
Health:

- External
- Dwellings

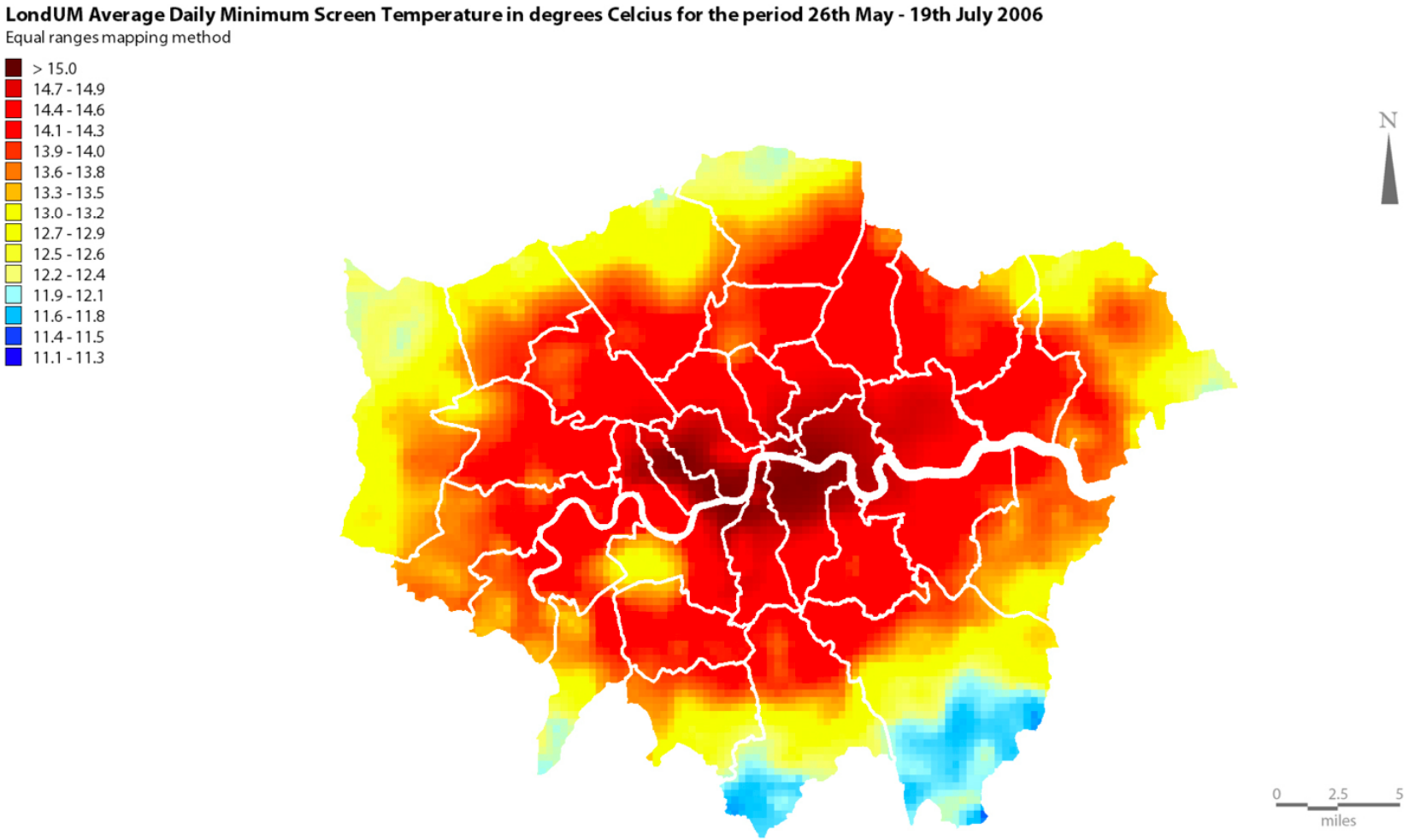
LUCID urban climate models

1. Outputs from the city-scale urban climate model

LondUM model: example outputs



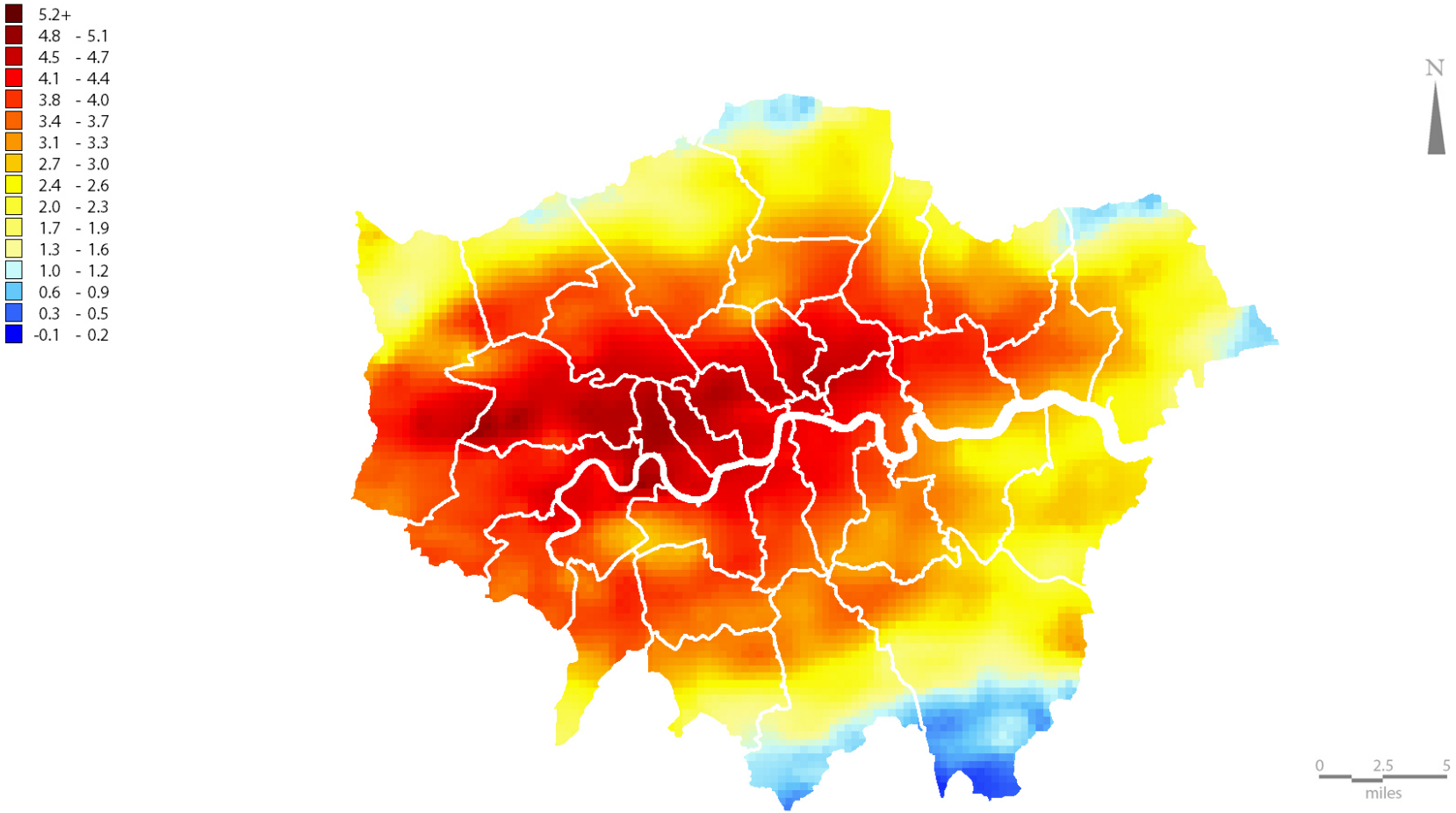
Outputs from the city-scale urban climate model



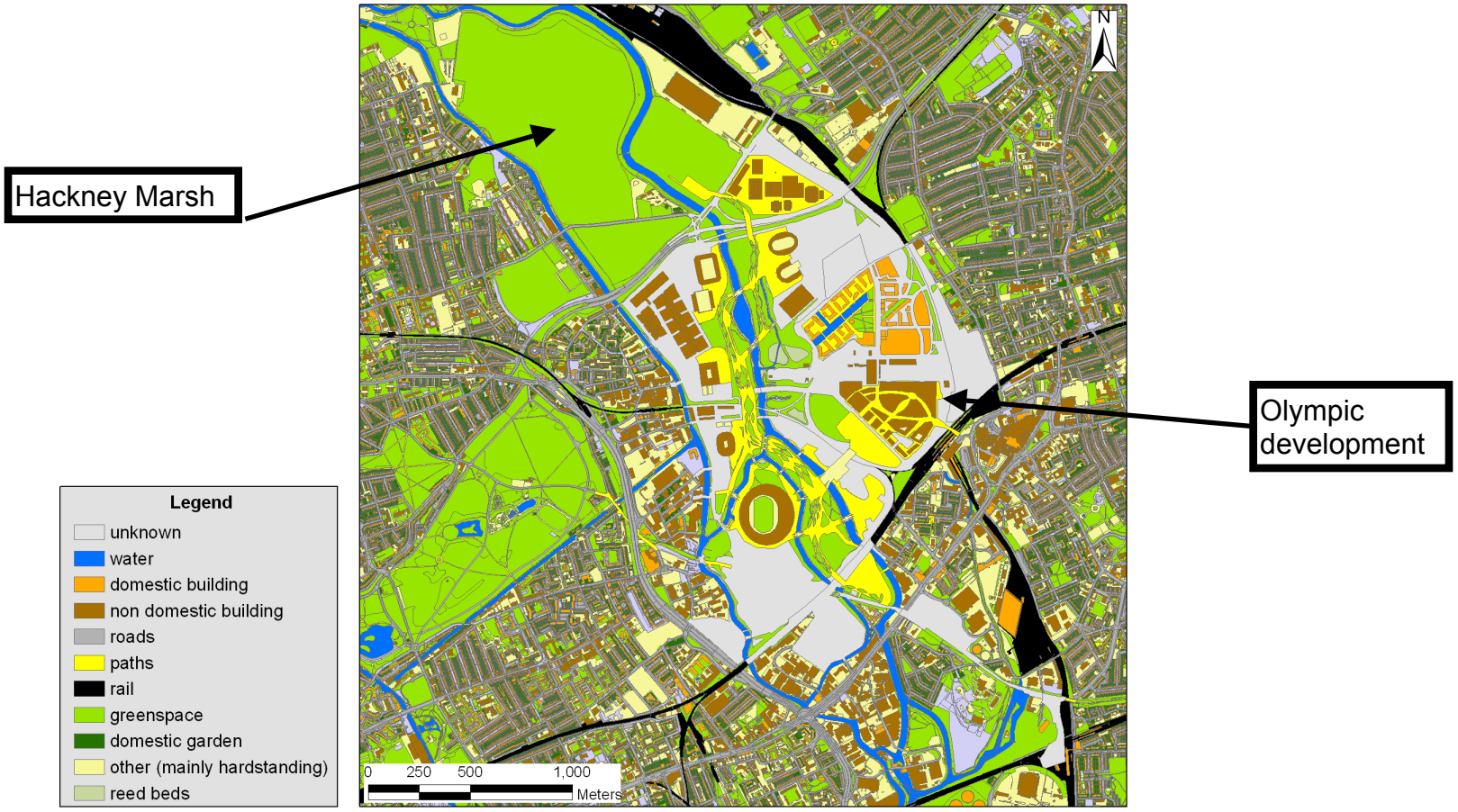
Outputs from the city-scale urban climate model

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

Equal ranges mapping method

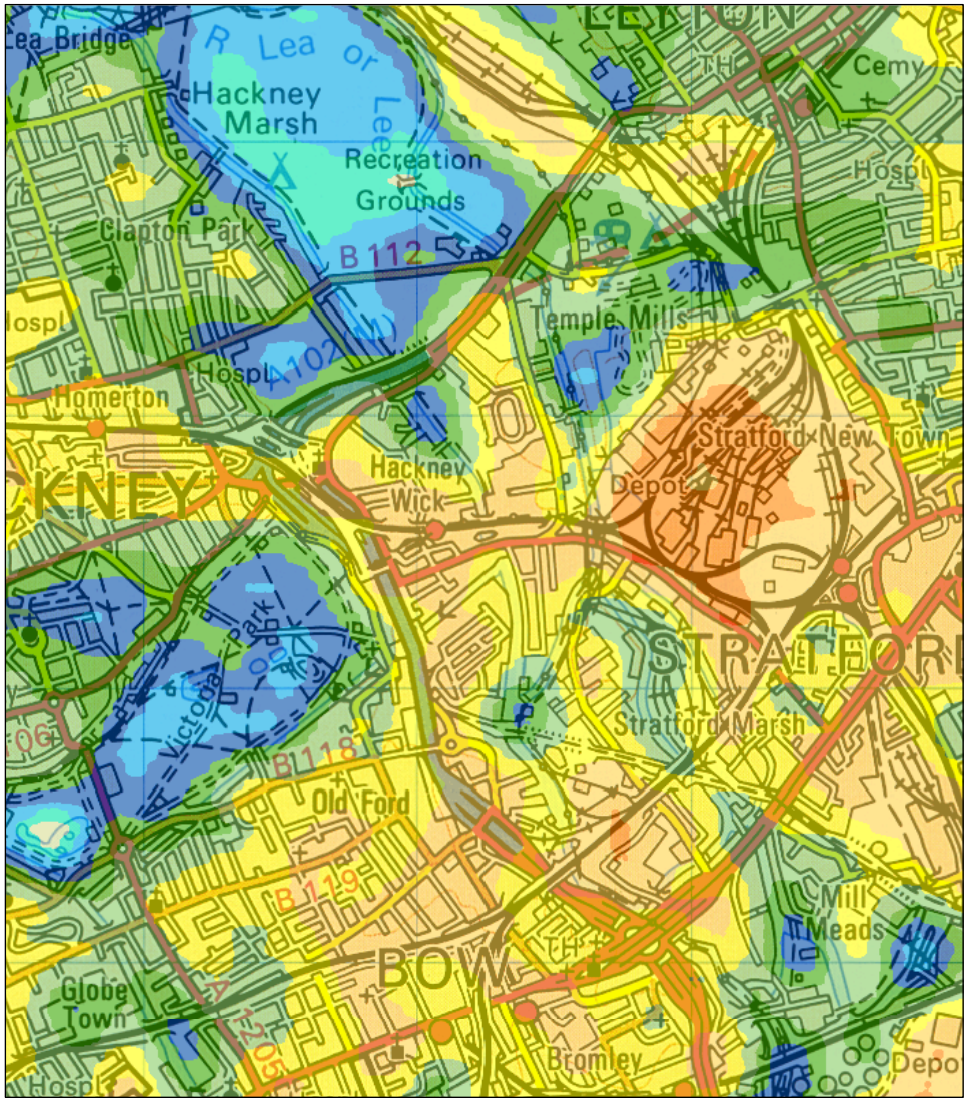


2. ADMS model
Case study: Olympic Parkland site development



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)



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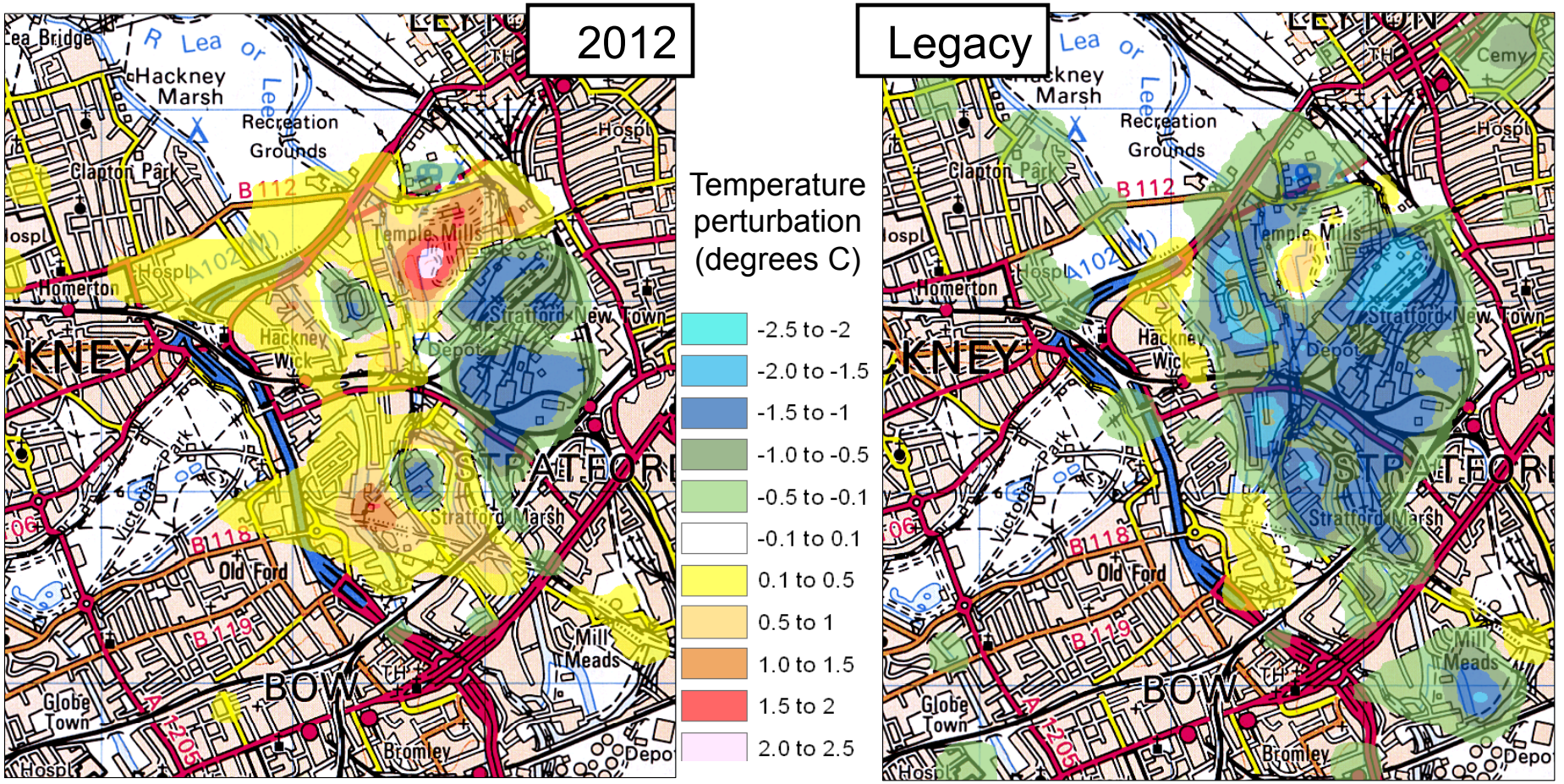


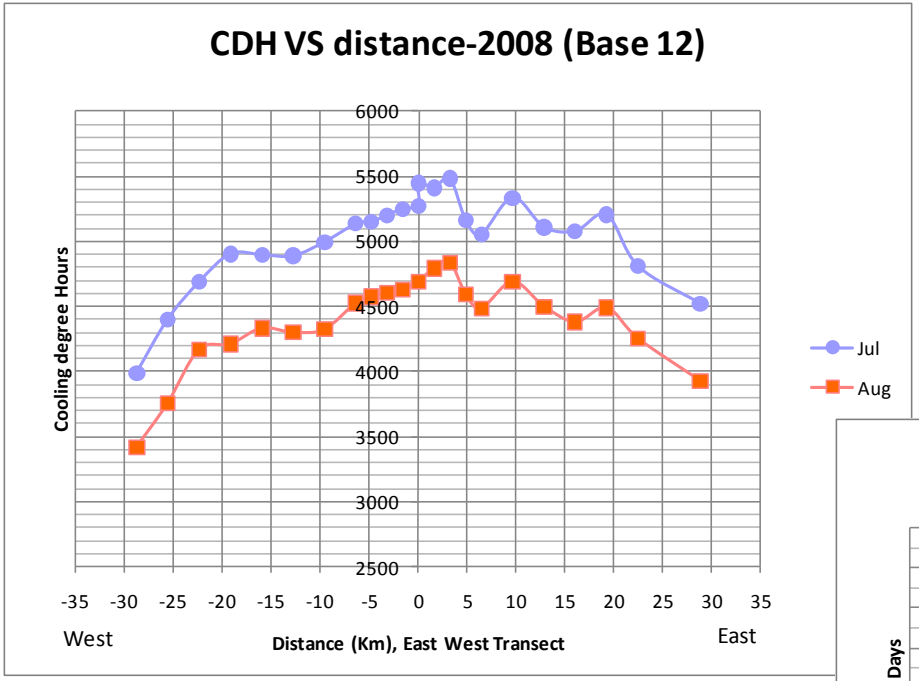
Differences in predicted temperatures (2m) due to land use variations (19:00 on 10/06/2006)

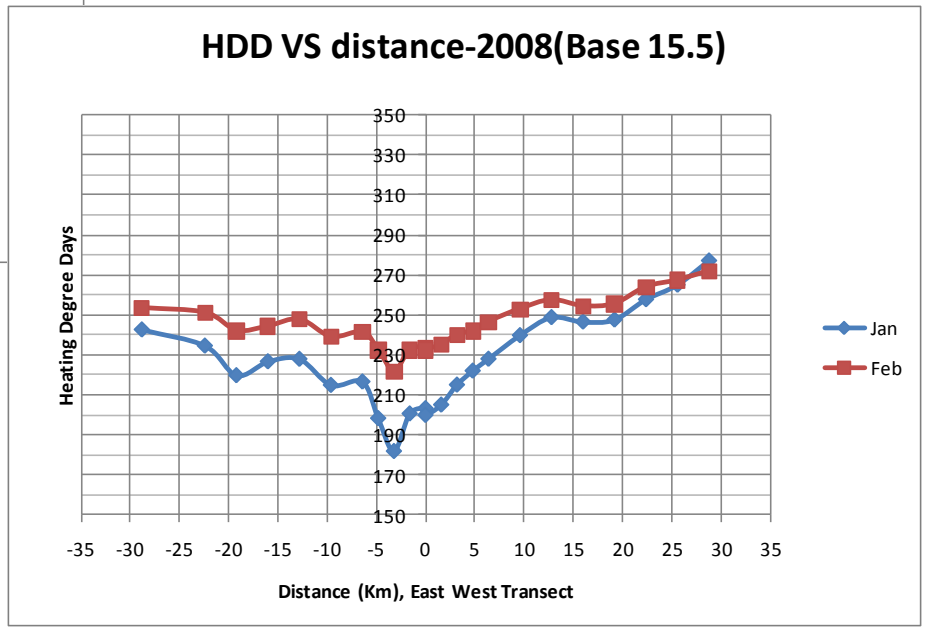
Messages from the city-scale

- 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





2. Energy: detailed models

Methodology – data extraction (same principles for energy, comfort models)

type

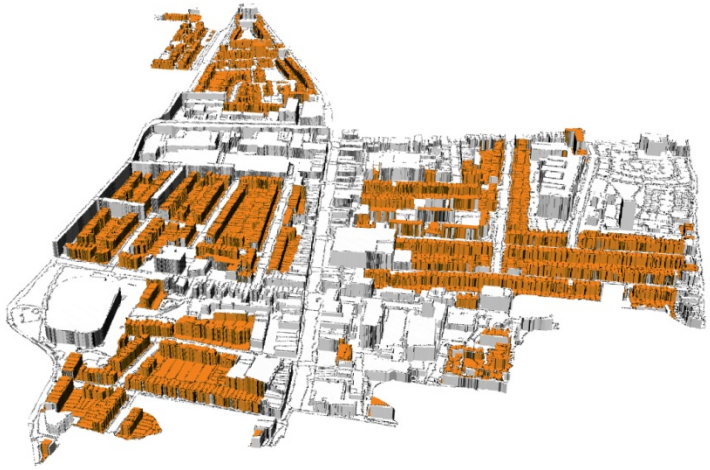
age

- pre 1850
- 1850-99
- 1900-18
- 1919-44
- **1945-64**
- 1965-74
- 1975-80
- 1980-90
- post 1990

Age, type

Additional geometric features calculated as a f(Age, Type) according to Chapman

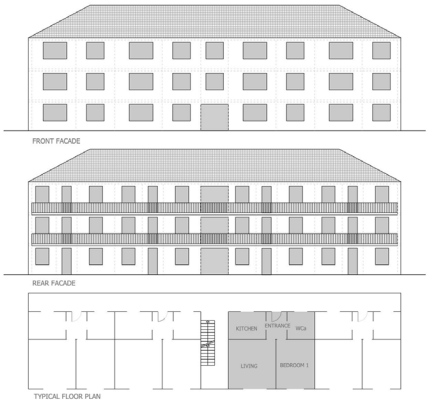
- Roof Covering
- Roof Structure
- Wall Structure
- Wall Finish
- Window Type
- Double Glazing Extent
- Wall Insulation
- Wall Cavity
- Heating System
- Heating System Age
- Main Fuel Type
- Main Heating Fuel
- Loft Insulation

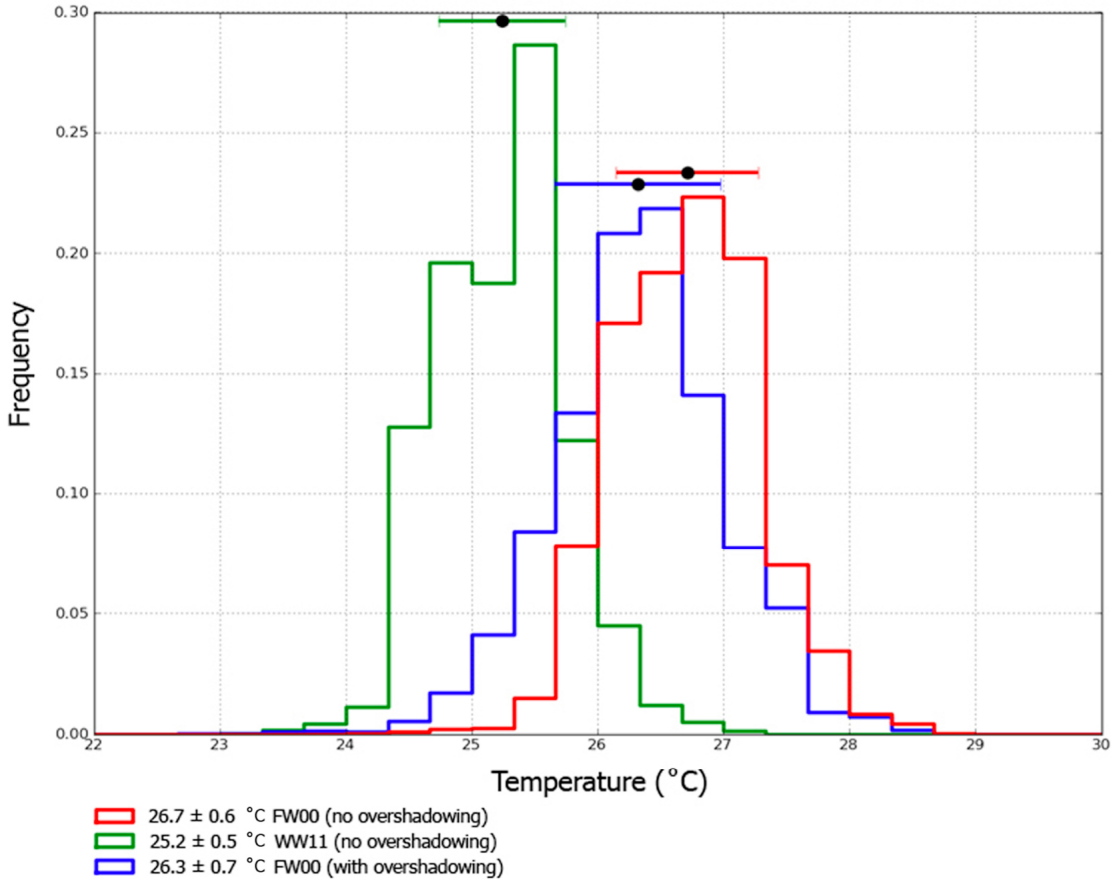


3. Comfort: dwellings

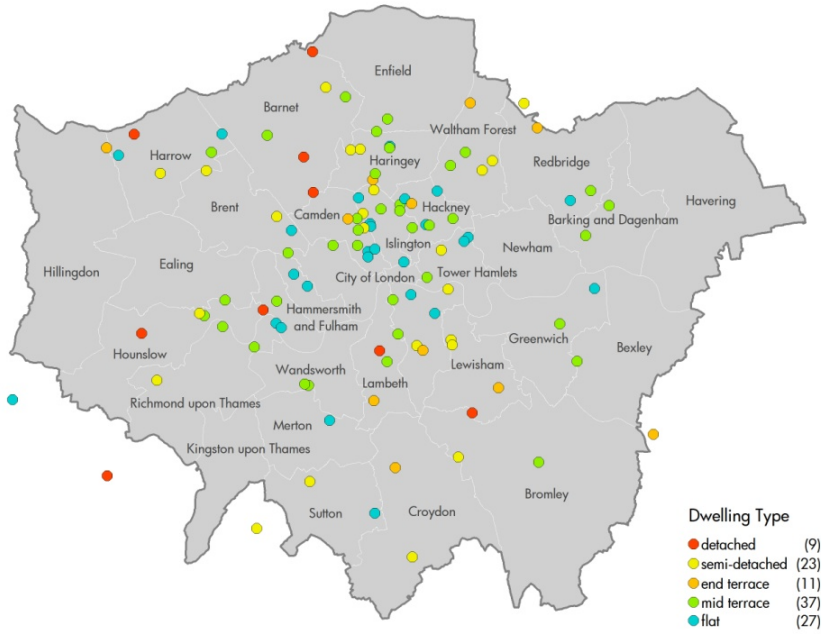
(a) Modelling

- UHI vs. thermal quality of dwellings

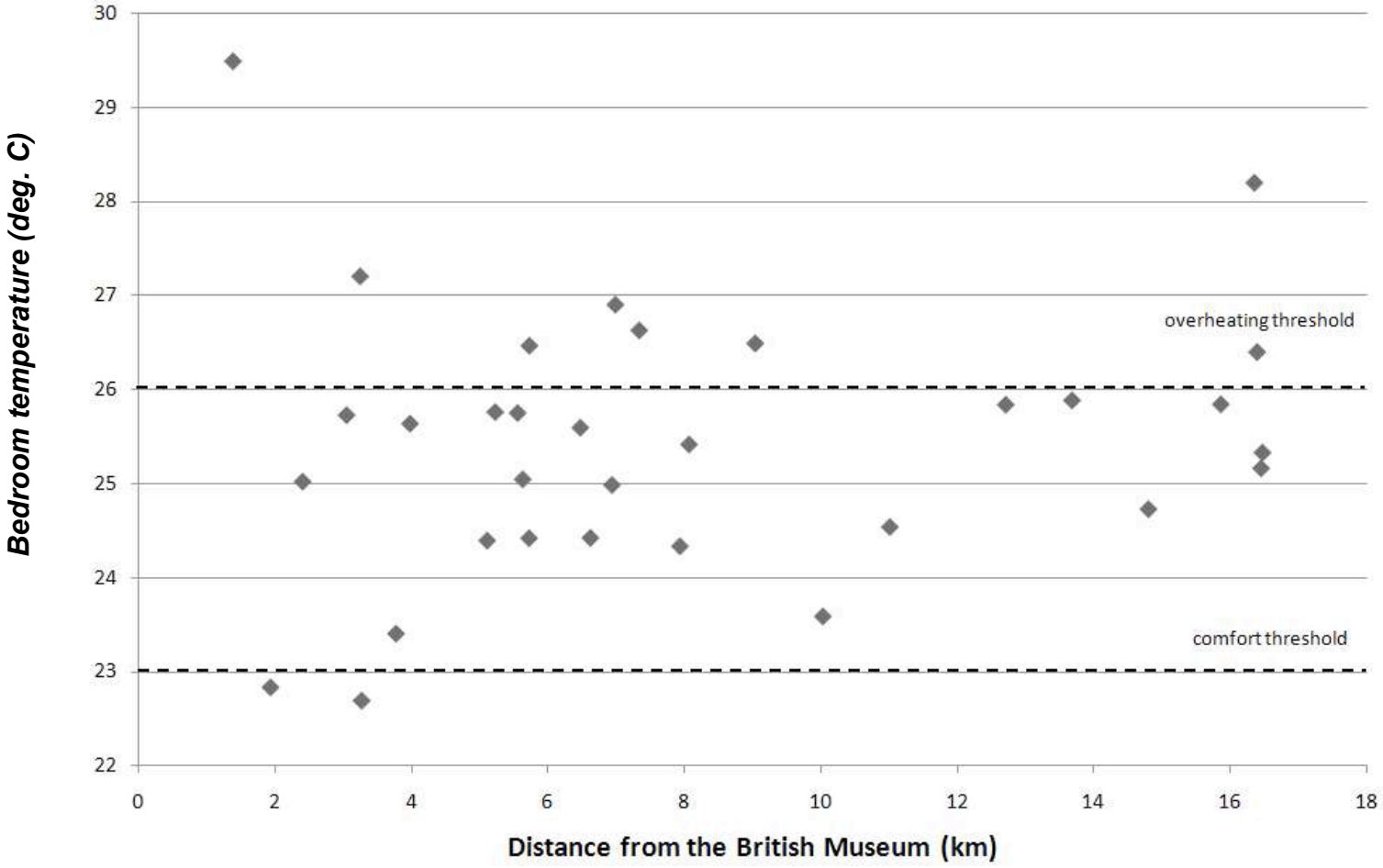




(b) Monitoring



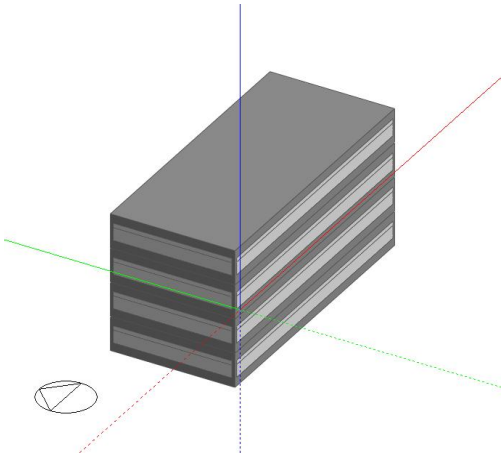
- Monitoring of temperature and humidity in 110 London dwellings during the summers of 2009 and 2010.
- Modelling of indoor environmental conditions for the 110 real London dwellings.
- Test model and extend to study health impacts across London.



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.

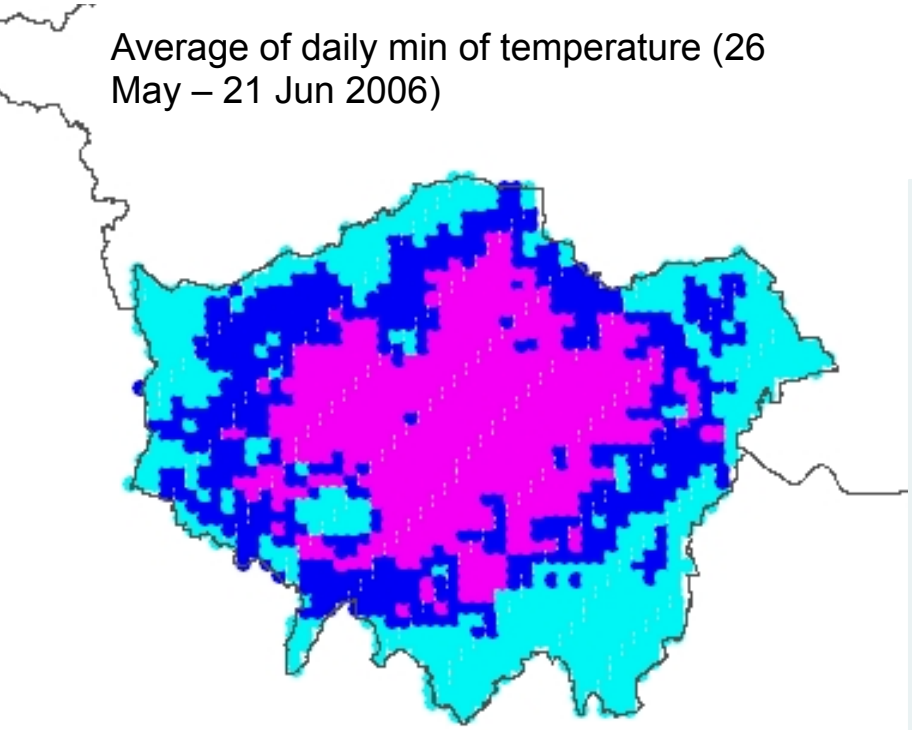
4. Comfort: non-domestic

- 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

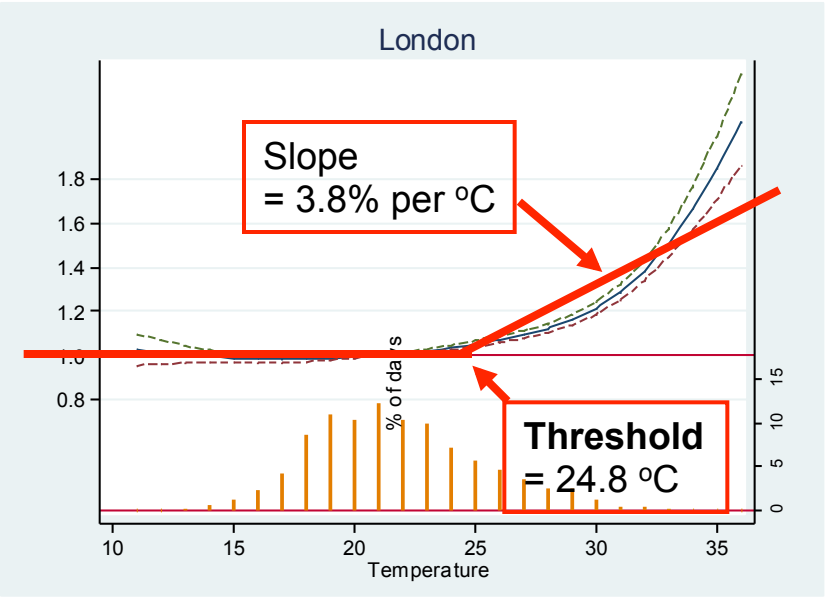
Average of daily min of temperature (26 May – 21 Jun 2006)



Tertile: London only

	9.97 – 12.36
	12.37 – 13.01
	13.02 – 13.82

Use empirical temperature-mortality relationship for London



Input data: city-scale LondUM simulations

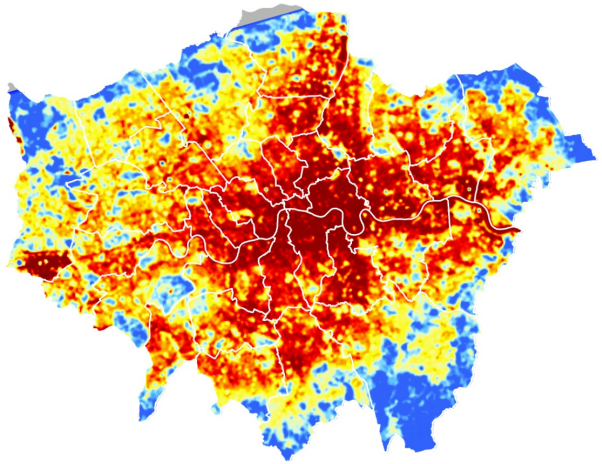
Calculate mortality burden by UHI zone

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

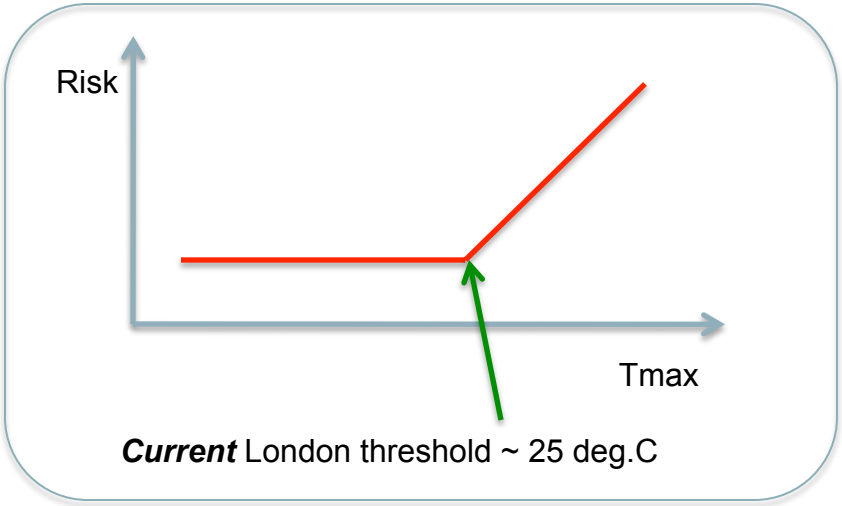


Notes

- 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



End

Mike Davies
michael.davies@ucl.ac.uk

LUCID publications

Book chapter

Davies M., Steadman J.P. and Oreszczyn T., (2009), *Urban Climate and Built Environment*, Chapter in Mumovic D., Santamouris M. (ed.), A Handbook of Sustainable Building Design and Engineering. ISBN: 978-1-84407-596-6.

Journal

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Grimmond C.S.B., Blackett M., Best M.J., Barlow J., Baik J-J., Belcher S.E., Bohnenstengel S.I., Calmet I., Chen F., Dandou A., Fortuniak K., Gouvea M.L., Hamdi R., Hendry M., Kawai T., Kawamoto Y., Kondo H., Krayenhoff E.S., Lee S.-H., Loridan T., Martilli A., Masson V., Miao, K. Oleson, G.Pigeon, A. Porson, Y.-H. Ryu, F. Salamanca, L. Shashua-Bar, G.-J. Steeneveld S., Tombrou M., Voogt J., Young D., Zhang N., (2010): *The international urban energy balance models comparison project: First results from phase 1*. JAMC, 49, 1268-1292.

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Mavrogianni A., Davies M., Chalabi Z., Wilkinson P., Kolokotroni M. and Milner J., (2009), *Modelling domestic stock energy use and heat-related health risk: A GIS based bottom-up modelling approach*. Passive Low Energy Architecture (PLEA) 2009 conference - Architecture, Energy and the Occupant's Perspective, Québec city (Canada).

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Other (non refereed)

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