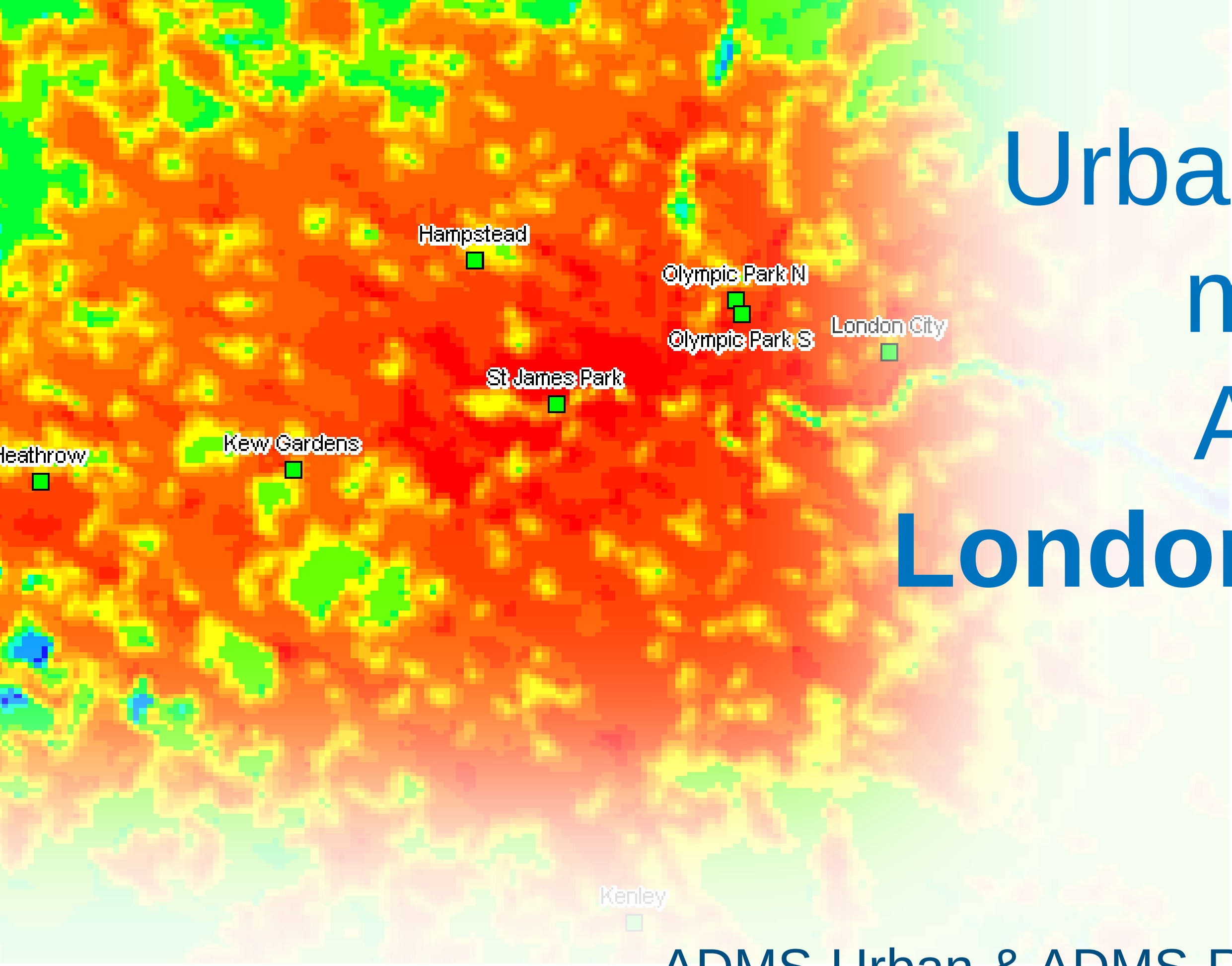

Urban Heat Island modelling with ADMS-Urban: **London case study**

Stephen Smith

ADMS-Urban & ADMS-Roads User Group Meeting

10th November 2016

London

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    - Source data (land use & anthropogenic data)
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    - Temperature perturbations
    - Heat maps
- Summary

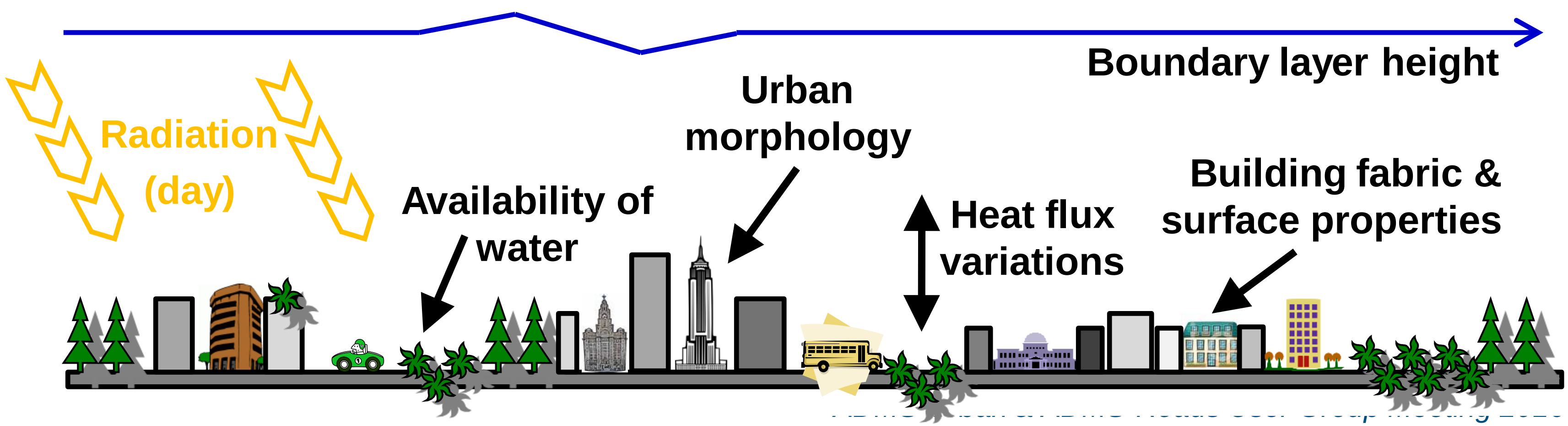
Motivation

- Local governments are increasingly interested in **green infrastructure**, knowing it can lead to:
  - elevated community health and well-being
  - improvements in air quality
  - reductions in the impact on the local climate
- Urban areas can have a large effect on the local climate, increasing the temperature; known as the Urban Heat Island (UHI)
- **New developments** can be designed, constructed and operated with minimal impact on the local climate
- Increasingly, the impact of new developments on **local climate** are considered alongside the impacts on **air quality**
- ADMS-Urban has been developed to model changes in the local climate due to land use and anthropogenic heat emissions allowing a joined up approach to planning assessments

Theory & model overview

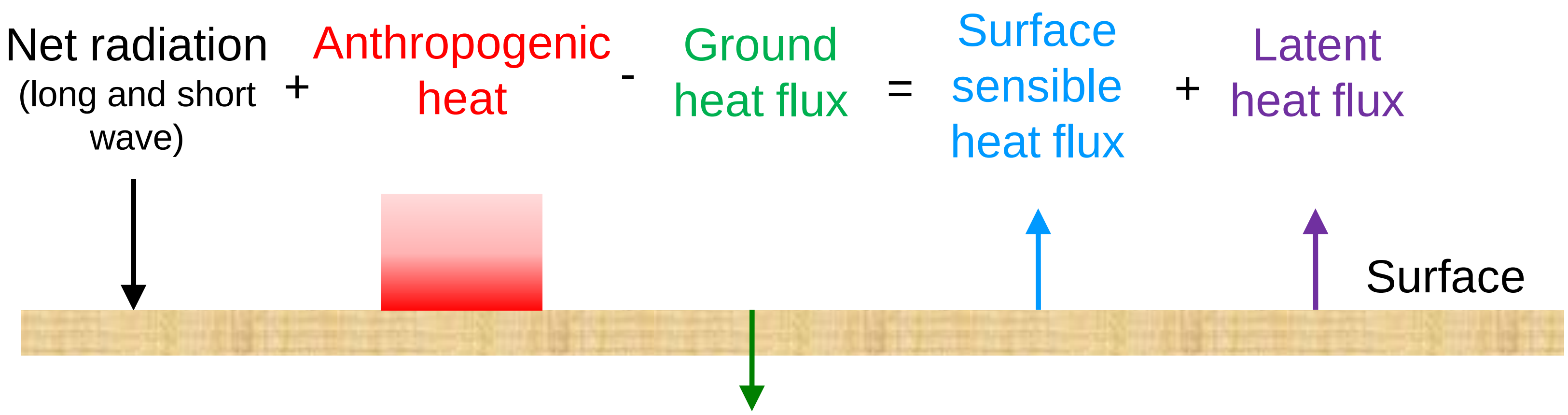
- Urban fabric and morphology influences climate
- Climate variations: local & city scale
- Meteorological conditions change:
  - Wind speeds reduce
  - Turbulent mixing increases

  due to high building densities
  - Boundary layer height increases due to the increase in turbulent mixing
  - Urban fabric retains more heat & has less moisture than rural areas – alters heat flux balance
- Pollutant dispersion is influenced by meteorological variations. Also:
  - Chemical reaction rates are temperature dependent (e.g. ozone production)
  - UHI temperature increases alter relative plume buoyancy



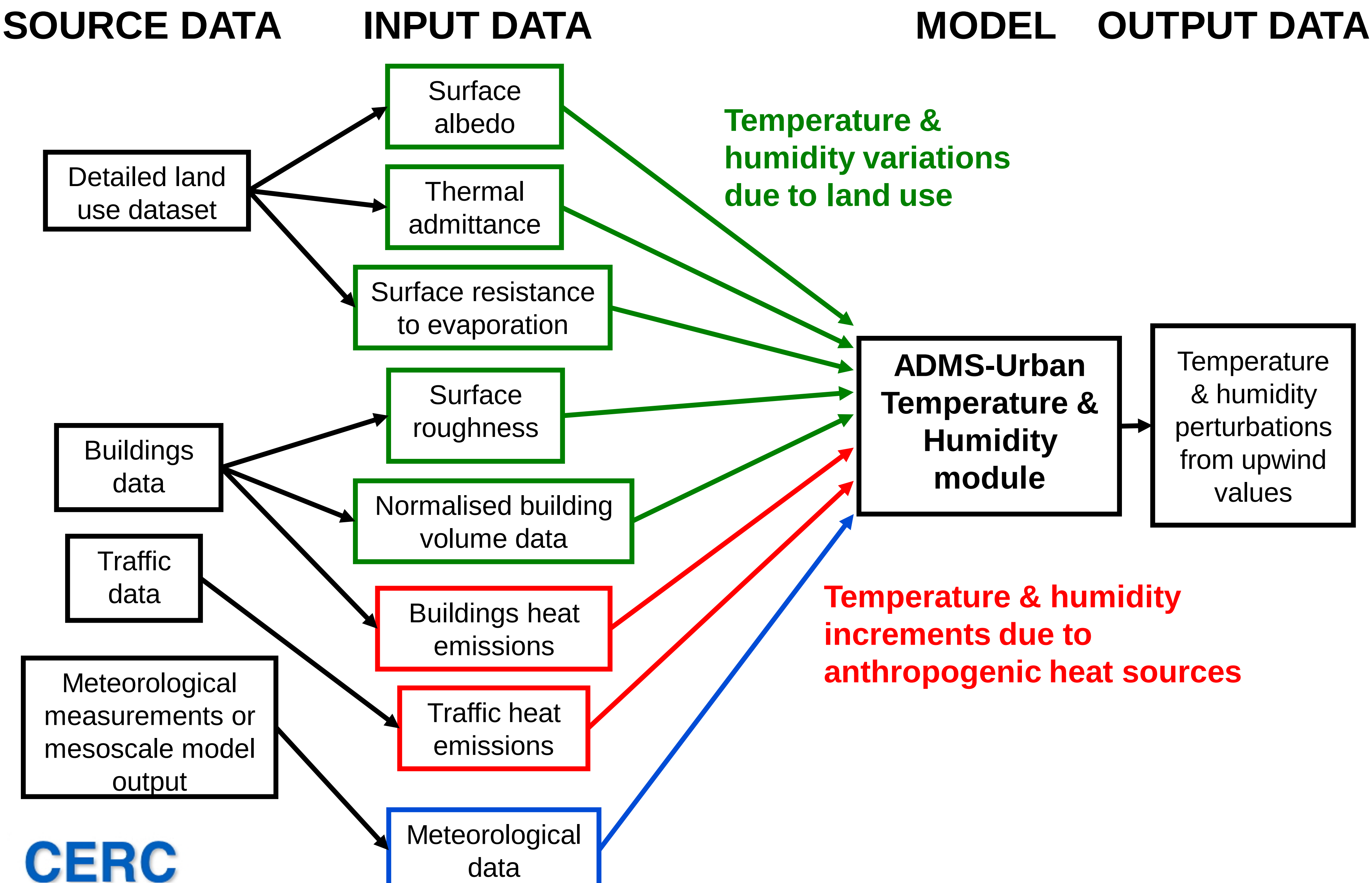
Theory & model overview

- The **surface energy balance** equation defines how much heat is available at the surface to be converted into surface sensible and latent heat:



- Surface sensible heat flux, together with friction velocity and temperature, define the upwind profile

Theory & model overview



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Model applications

- To date, primarily research applications
  - Hamilton I, Stocker J, Evans S, Davies M and Carruthers D, **2014**: *The impact of the London Olympic Parkland on the urban heat island.* Journal of Building Performance Simulation, **7**, issue 2
  - Virk G, Jansz A, Mavrogianni A, Mylona A, Stocker J and Davies M, **2014**: *The effectiveness of retrofitted green and cool roofs at reducing overheating in a naturally ventilated office in London: Direct and indirect effects in current and future climates*. Indoor and Built Environment .
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  - Maggiotto G, Buccolieri R, Santo M A, Leo L S and Di Sabatino S, **2014**: *Validation of temperature-perturbation and CFD-based modelling for the prediction of the thermal urban environment: the Lecce (IT) case study.* Environmental Modelling and Software, **60**, pp. 69-83
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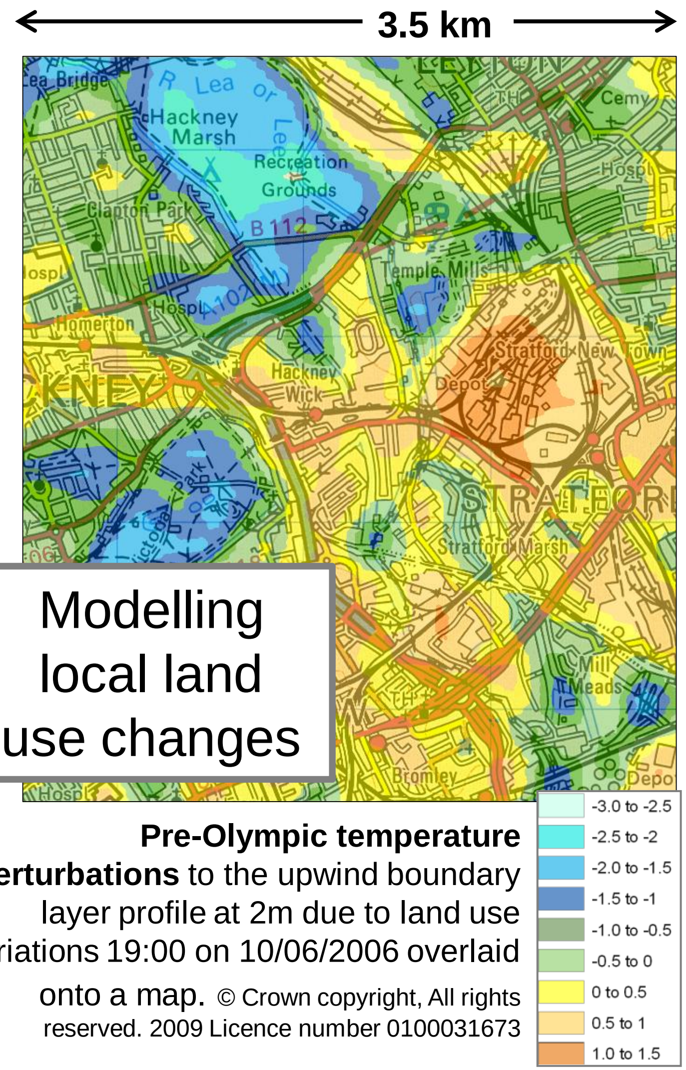

Modelling local land use changes

Pre-Olympic temperature perturbations to the upwind boundary layer profile at 2m due to land use variations 19:00 on 10/06/2006 overlaid onto a map.

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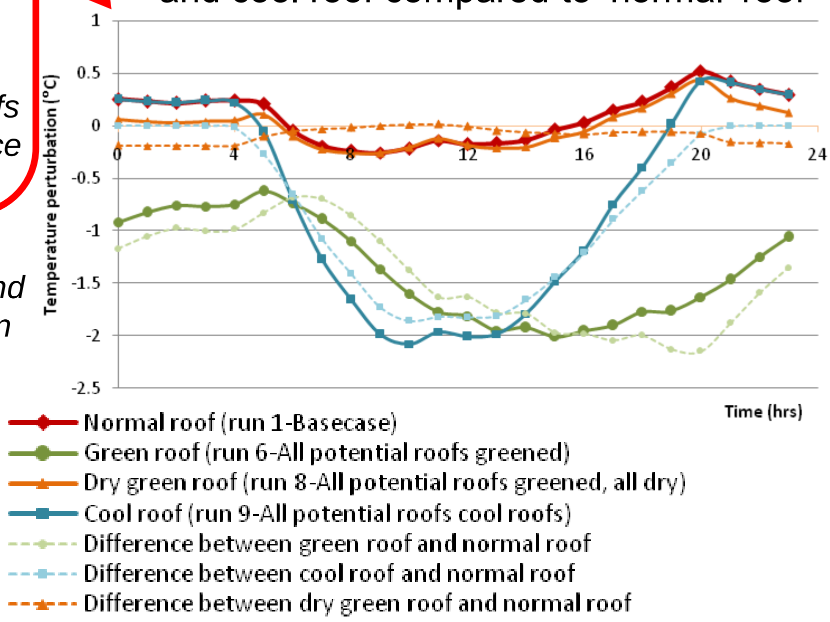
Modelling local climate mitigation scenarios

Daily temperature variations on green and cool roof compared to 'normal' roof



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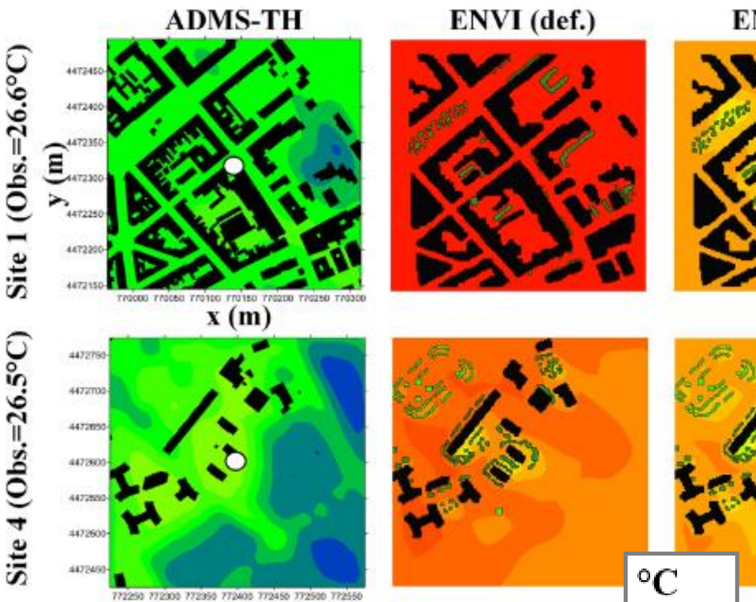
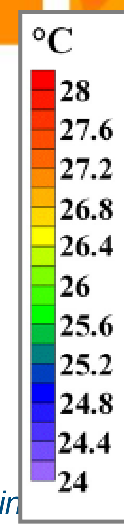
Temperature maps for two sites in Lecce, Italy where ADMS model output is compared to ENVI-met
20:00 on 10/08/2012





City-scale modelling & comparisons to other models

Model applications

- To date, primarily research applications
- The Temperature & Humidity module will be available* as part of ADMS-Urban 4.1 for commercial applications
  - Currently being used by Barcelona Regional to model the Barcelona Urban Heat Island
  - Used for climate modelling in ‘Coupling Regional and Urban processes: Effects on Air Quality’ project (NERC)

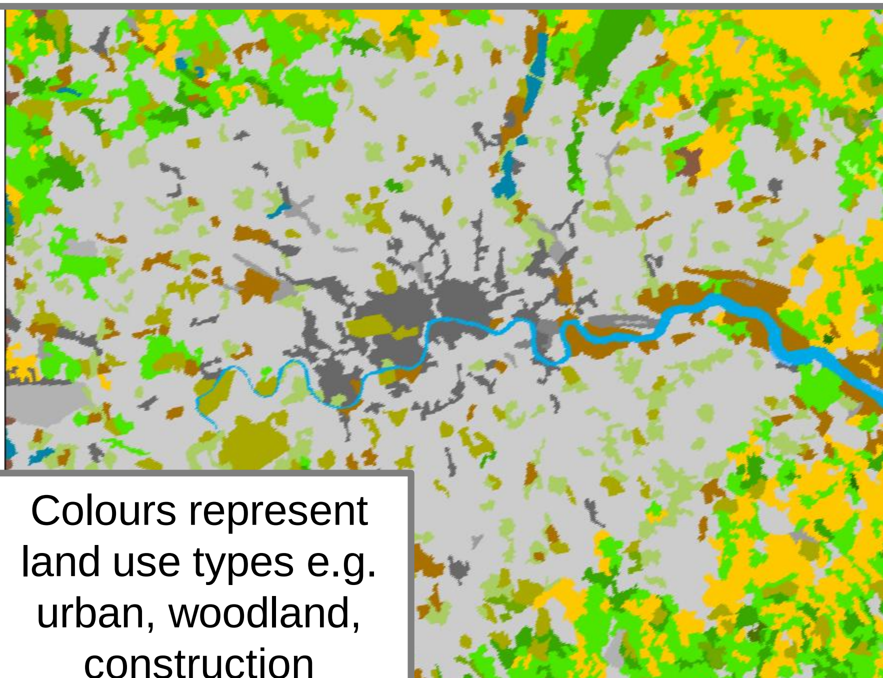
*extended licence required

Case Study: London

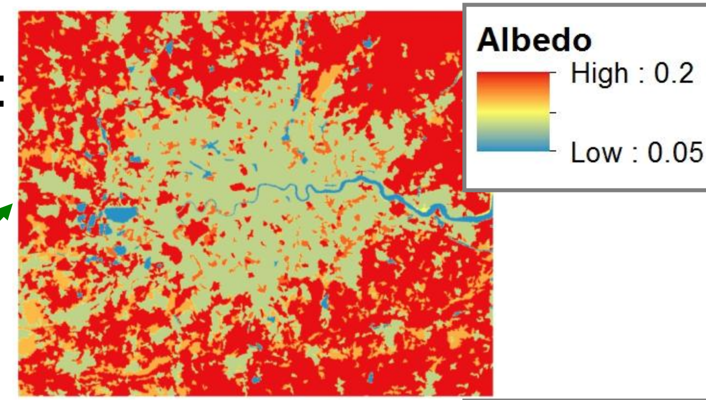
Model configuration: source data

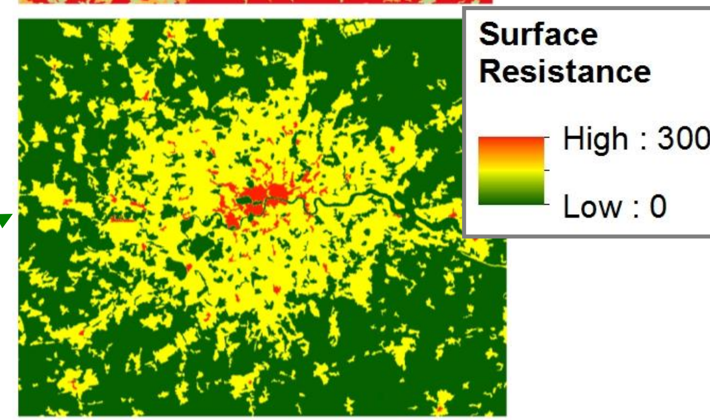
- Input data derived from **land use data**:
  - Albedo
  - Surface resistance to evaporation
  - Thermal admittance

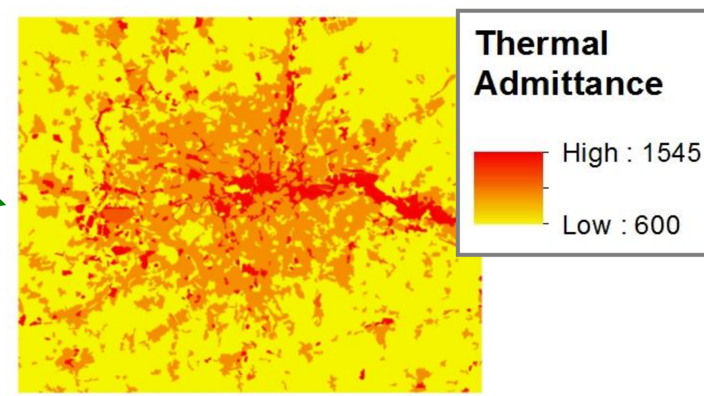
Corine land use data (2006), 100m resolution



Colours represent land use types e.g. urban, woodland, construction







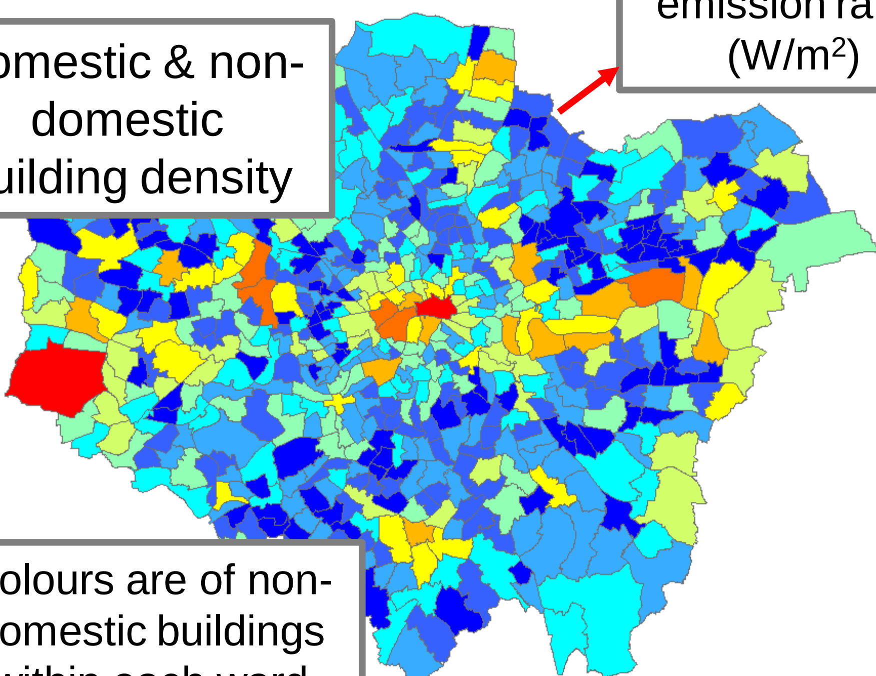
Model configuration: source data

- Input data derived from **buildings data**:
  - Roughness
  - Normalised building volume
  - Buildings anthropogenic heat

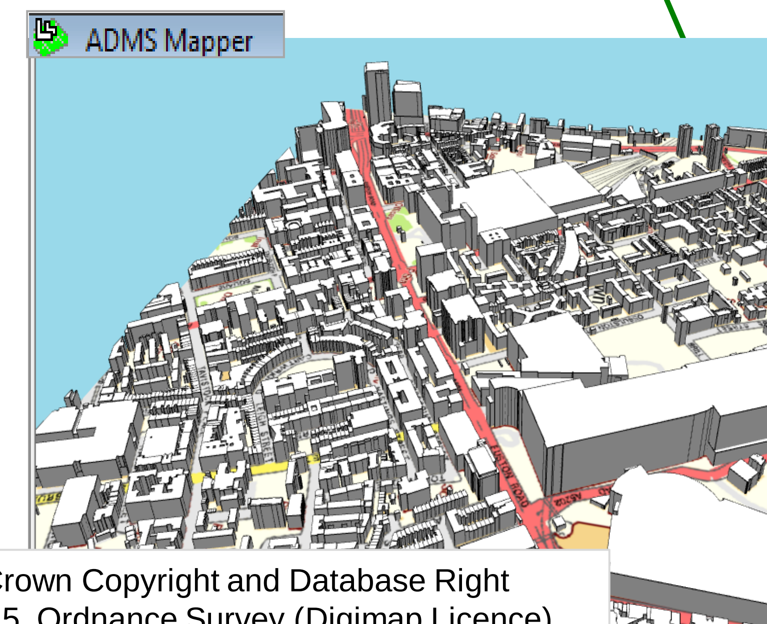
Use 3-D buildings data to calculate parameters λ_p and λ_F (ArcGIS tools)

Use typical heat emission rates (W/m^2)

Domestic & non-domestic building density



Colours are of non-domestic buildings within each ward



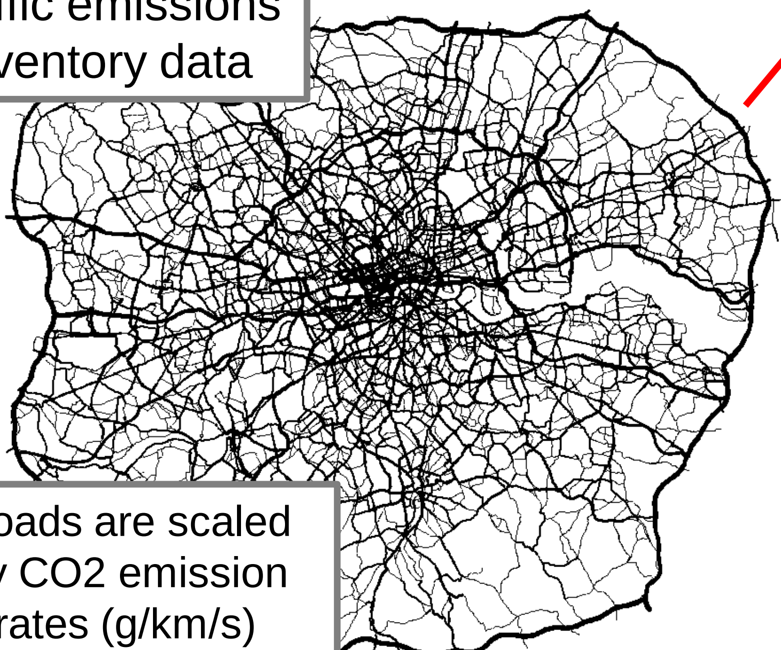
Case Study: London

Model configuration: source data

- Input data derived from **road traffic data**:
  - Road traffic anthropogenic heat

Model converts CO_2 emission rates to heat energy emission rates (W/km)

Traffic emissions inventory data

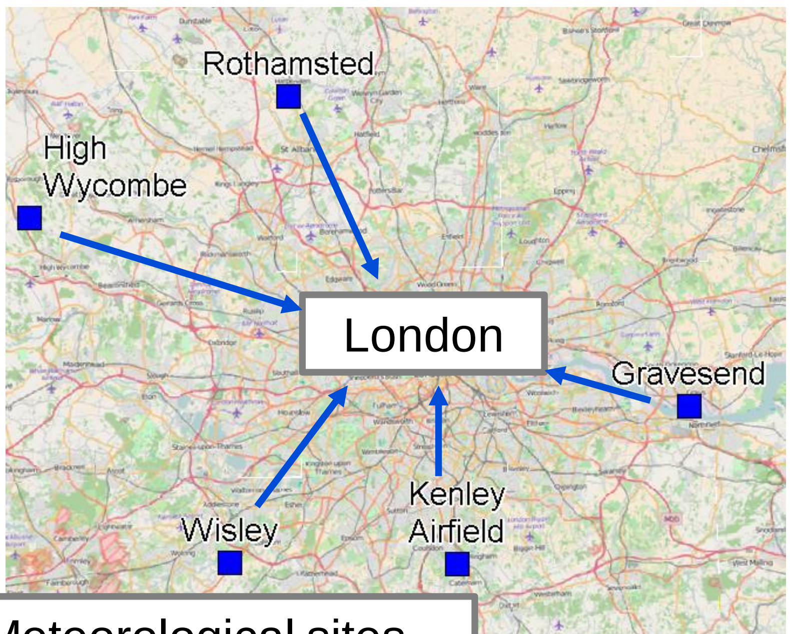


Roads are scaled by CO2 emission rates (g/km/s)

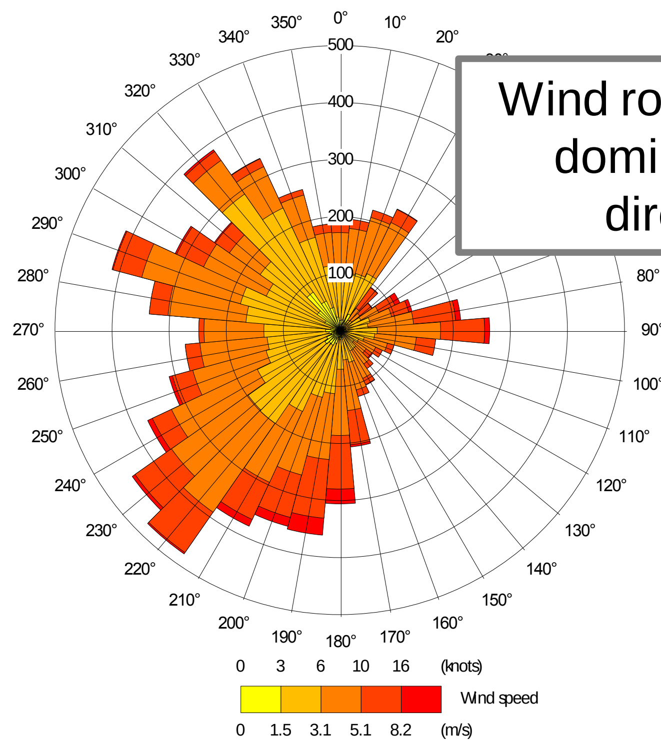
Case Study: London

Model configuration: source data

- **Meteorological data**:
  - Standard ADMS met data parameters
  - Temperature & humidity values must be upwind (cf. pollutant background data)
  - Upwind measurement heights above sea level required as input
  - London: 5 stations used



Meteorological sites upwind of model domain

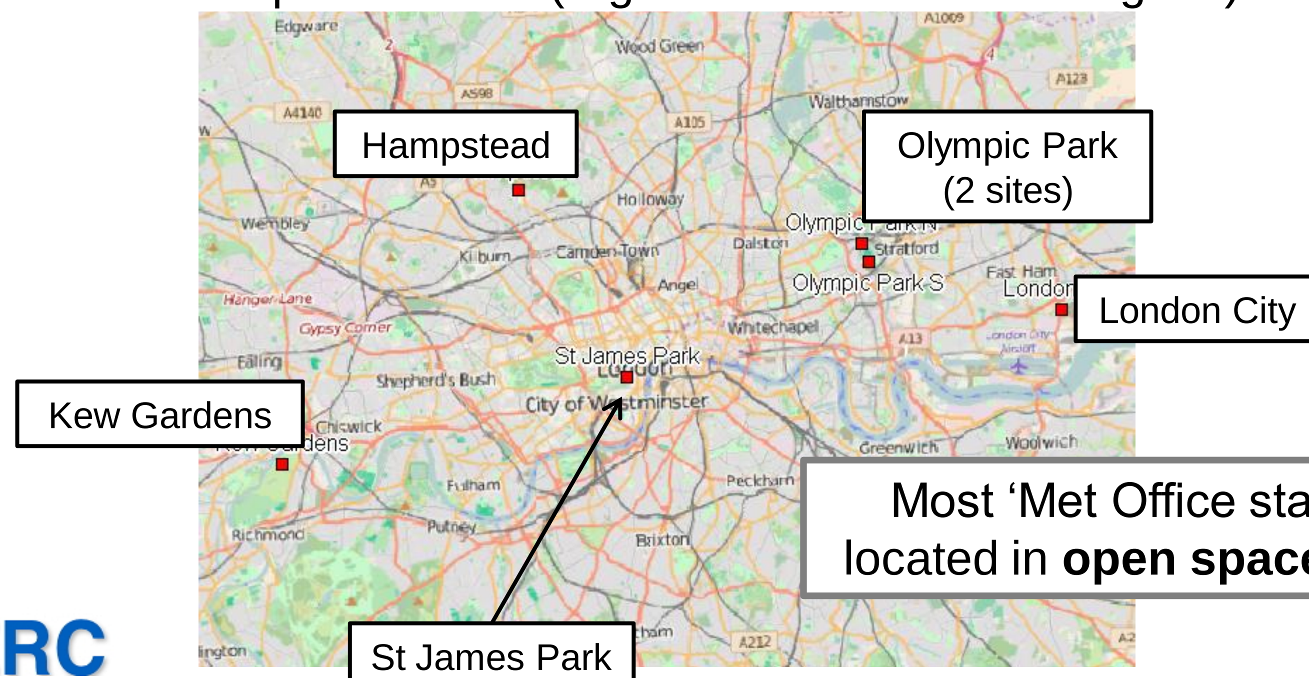


Wind rose indicates dominant wind directions

Case Study: London

Model configuration: model domain & receptor network

- **Model domain**:
  - 80 km x 65 km, Greater London
  - Land-use calculations use ‘FLOWSTAR’ internal grid (e.g. 256 x 256 → 312 m x 234 m)
- **Receptor network:**
  - Measurement sites
  - Full receptor network (regular & source-oriented grids)



Most ‘Met Office standard’ sites are located in **open spaces, usually parks**

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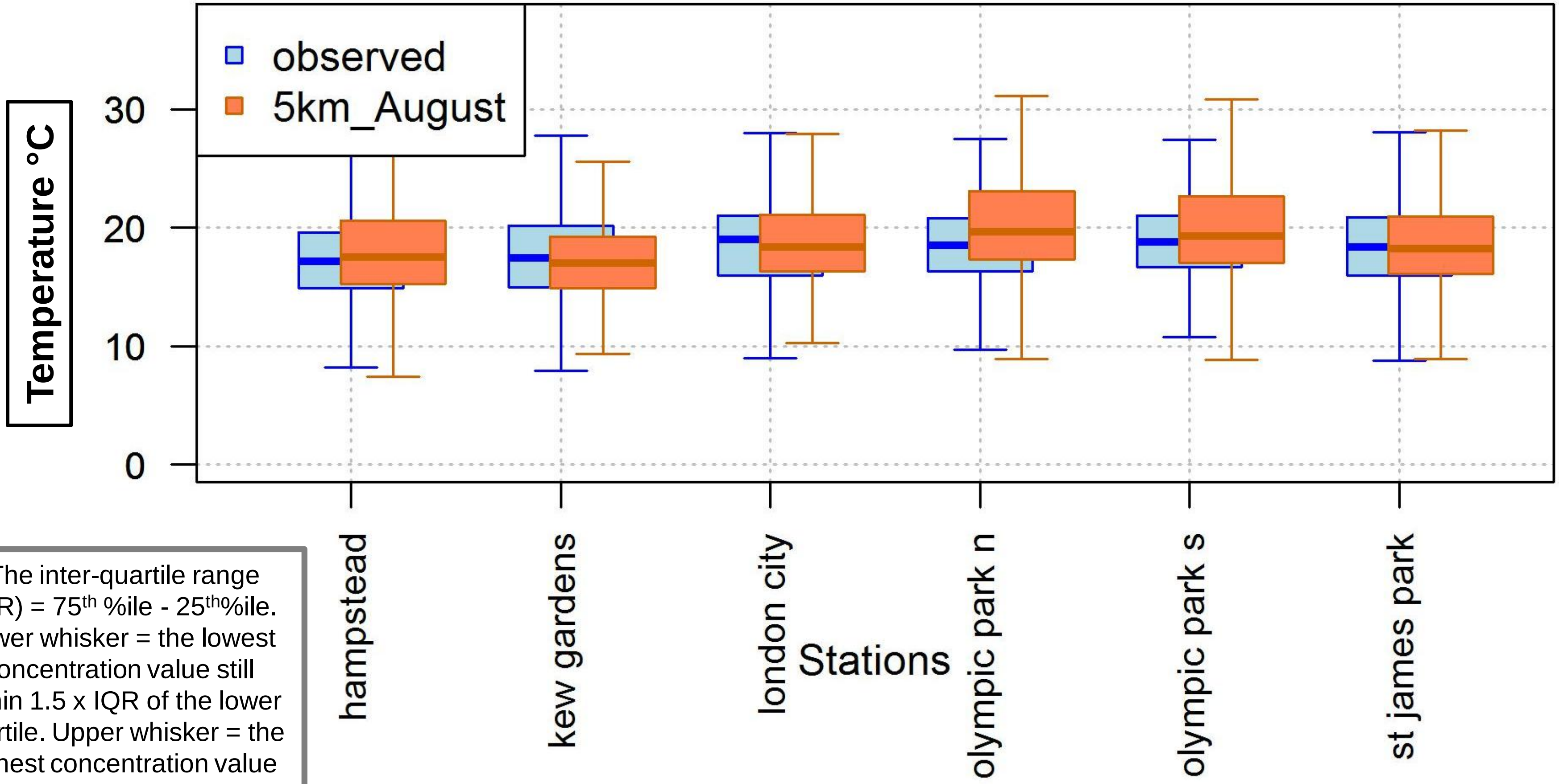
Model results

- Absolute temperatures:
  - Box and whisker plot
  - Frequency scatter plots
- Temperatures perturbations
  - Box and whisker plot
  - Average diurnal profiles
- August and January 2012

- Note
  - Calculation grid resolution may not resolve land use inputs
  - Unrefined receptor locations

Case Study: London
Model results: absolute temperatures

- Absolute temperatures (August 2012)
  - Box and whisker plot
  - The ‘box’ shows the 25th, 50th and 75th percentiles*

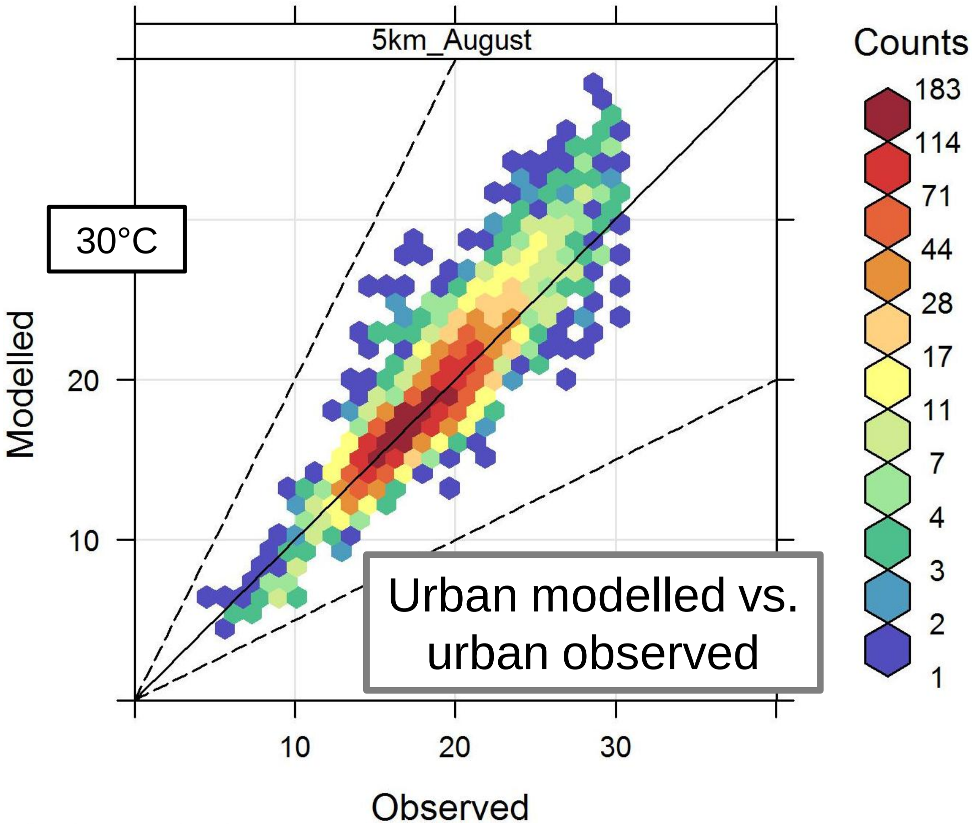


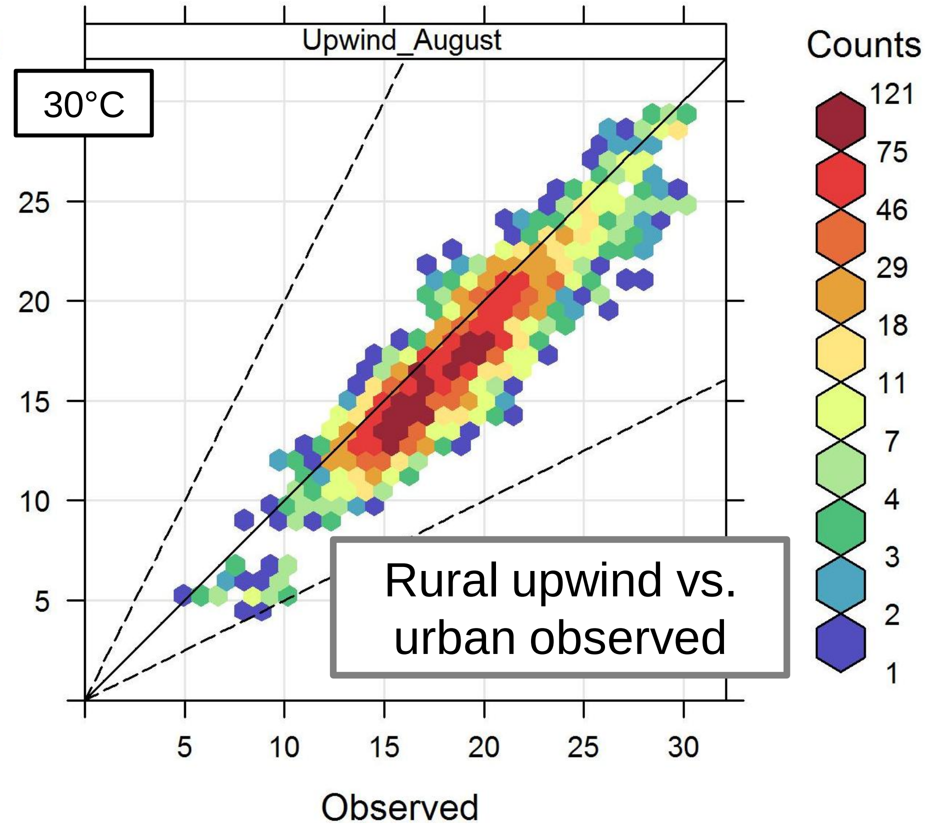
*The inter-quartile range (IQR) = 75th %ile - 25th%ile. Lower whisker = the lowest concentration value still within 1.5 x IQR of the lower quartile. Upper whisker = the highest concentration value still within 1.5 x IQR of the upper quartile.

Case Study: London

Model results: absolute temperatures

- Absolute temperatures (August 2012):
  - Frequency scatter plots of hourly temperatures
  - How does it compare to just using upwind temperatures?





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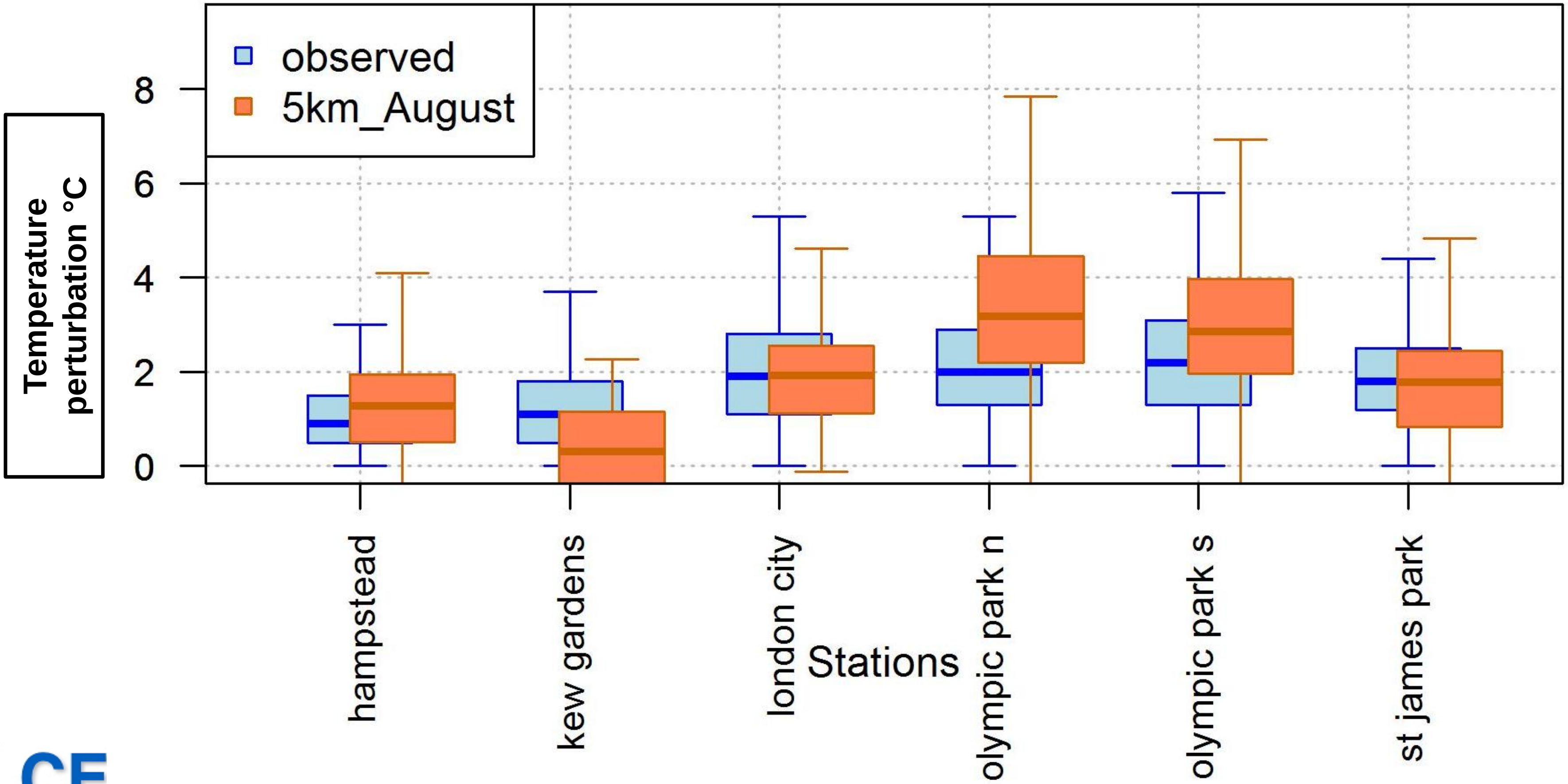
Model results: temperature perturbations

- Temperature perturbations (August 2012)
  - Very good performance at some sites
  - Negative temperatures not displayed



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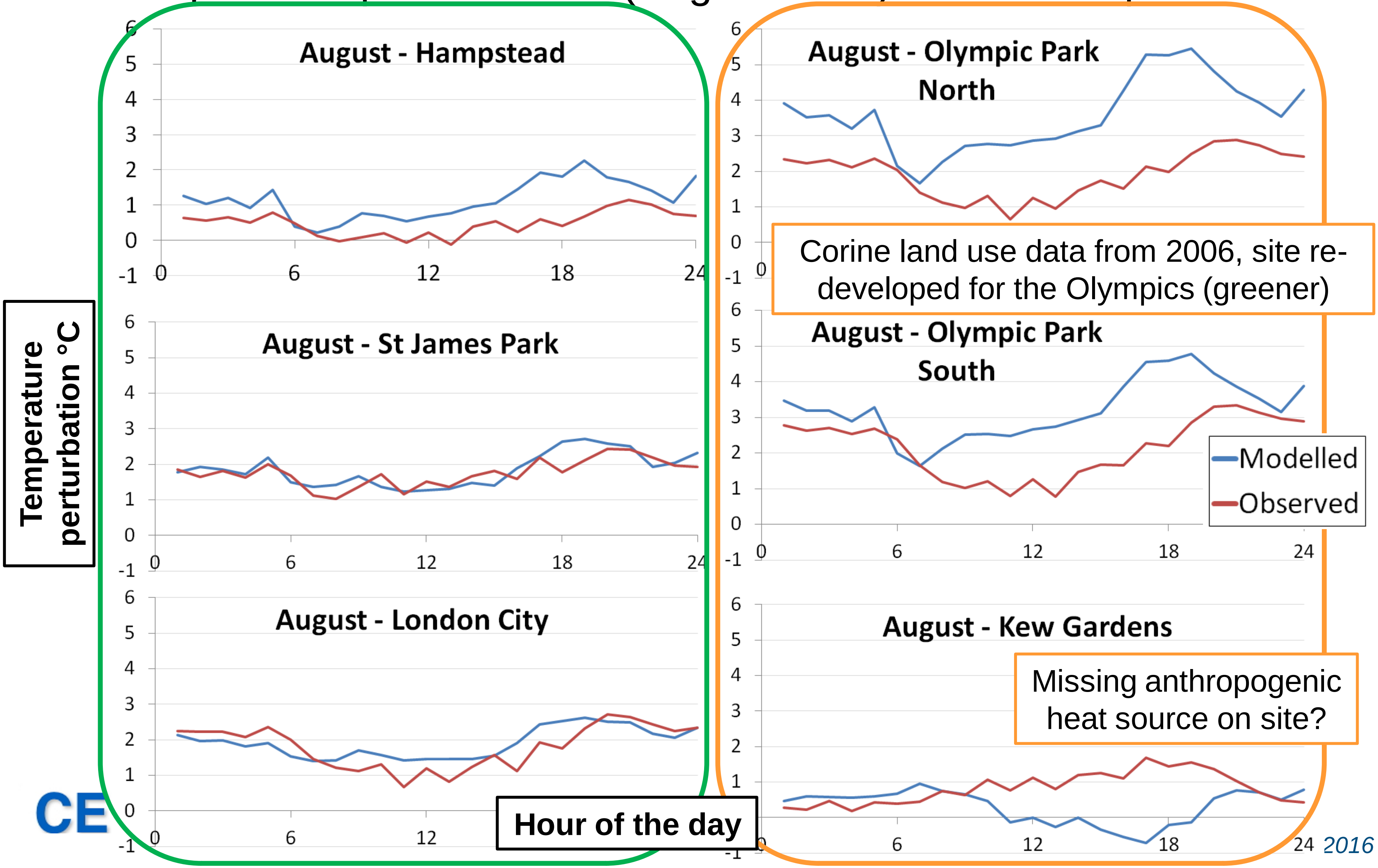
Case Study: London

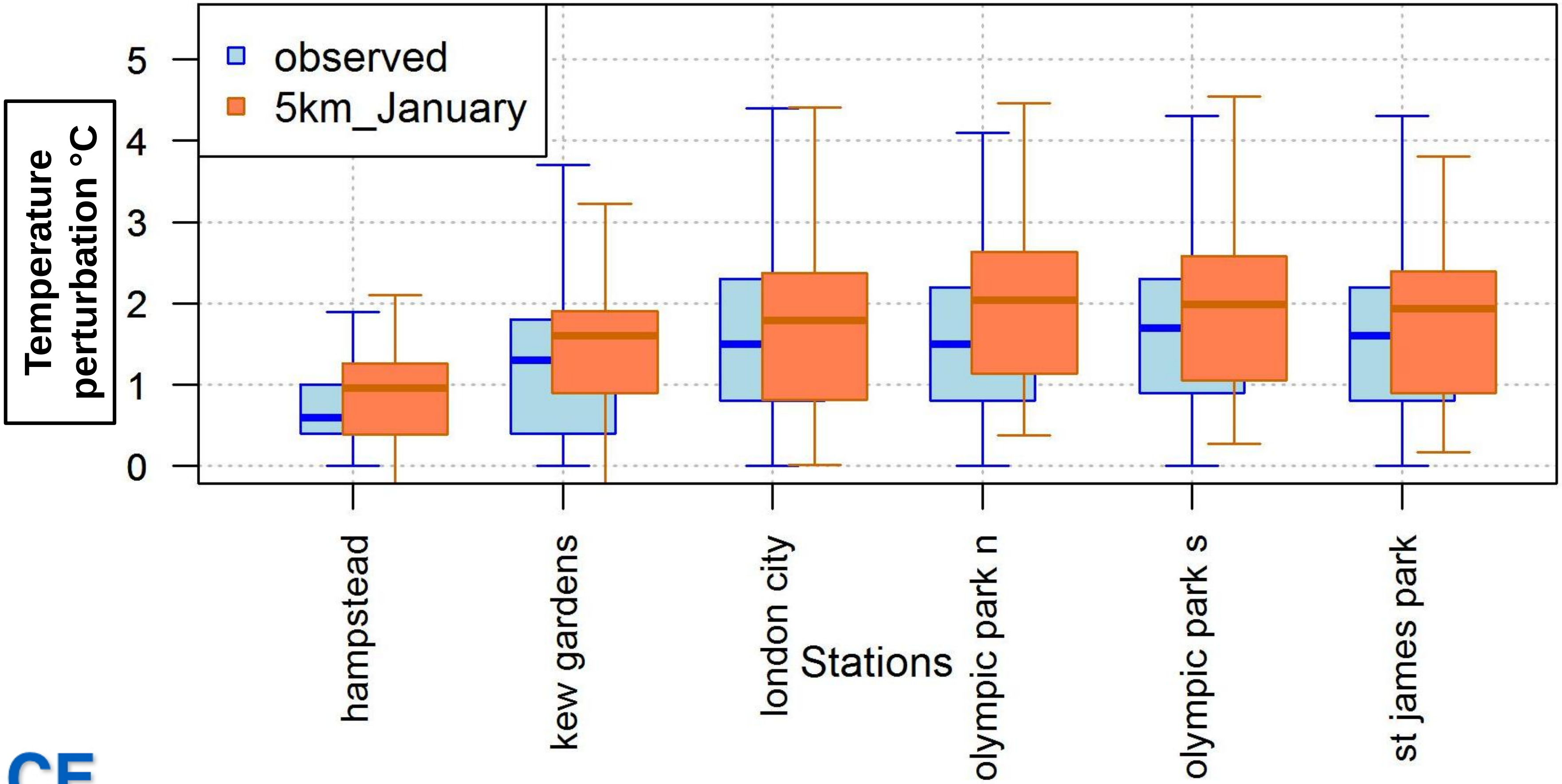
Model results: temperature perturbations

- Temperature perturbations (August 2012) relative to upwind



Case Study: London
Model results: temperature perturbations

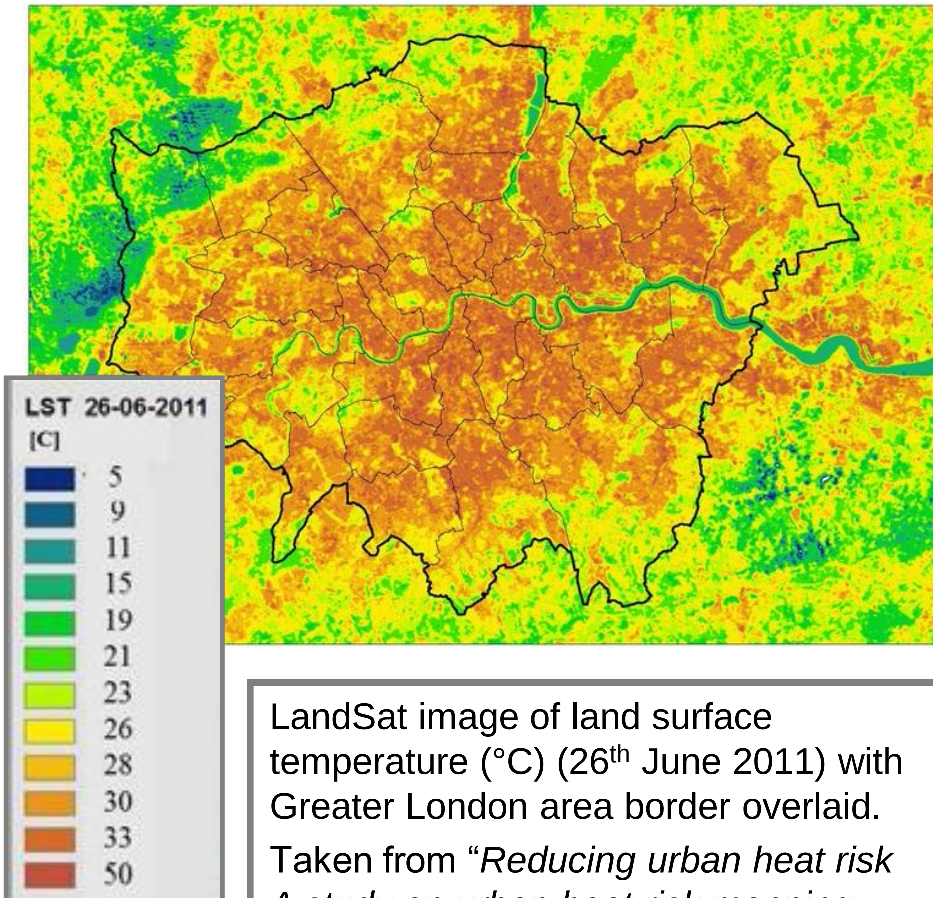
- Temperature perturbations (January 2012)
  - Good performance at all sites
  - Negative temperatures not displayed



CEH

Case Study: London
Model results: heat maps

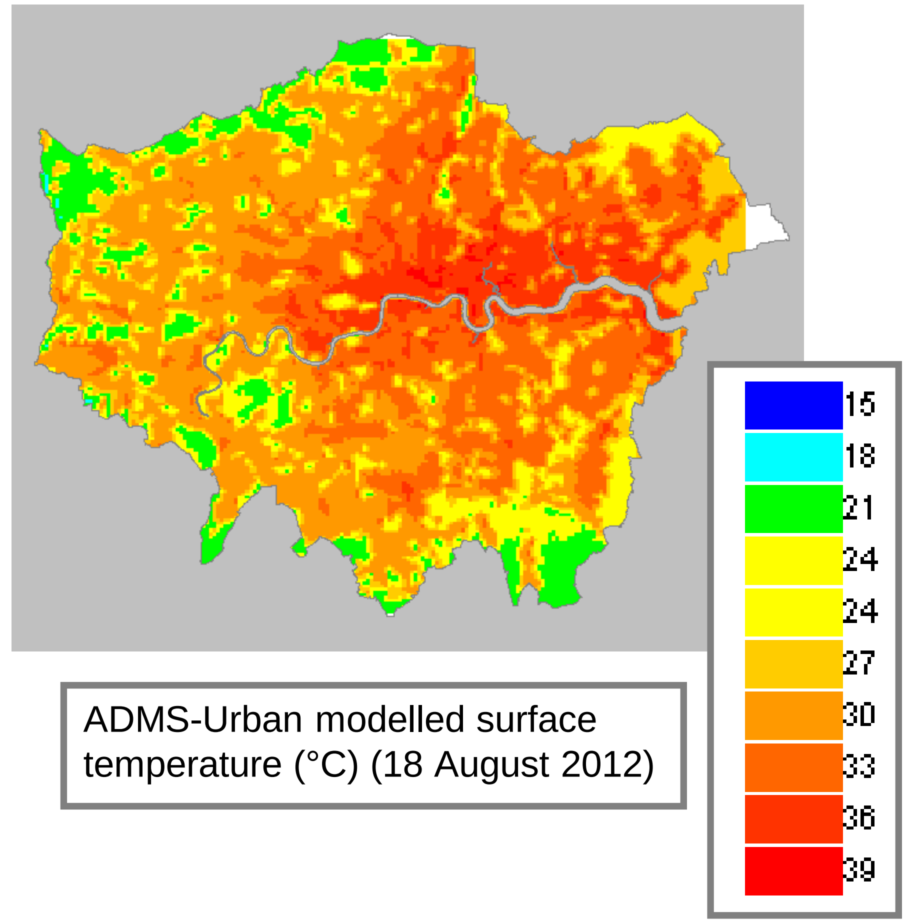
Example satellite image of land surface temperature (June 2011)



LandSat image of land surface temperature (°C) (26th June 2011) with Greater London area border overlaid.

Taken from "*Reducing urban heat risk A study on urban heat risk mapping and visualisation*" July 2014

Example modelled temperature ~ 3.0 m (August 2012)



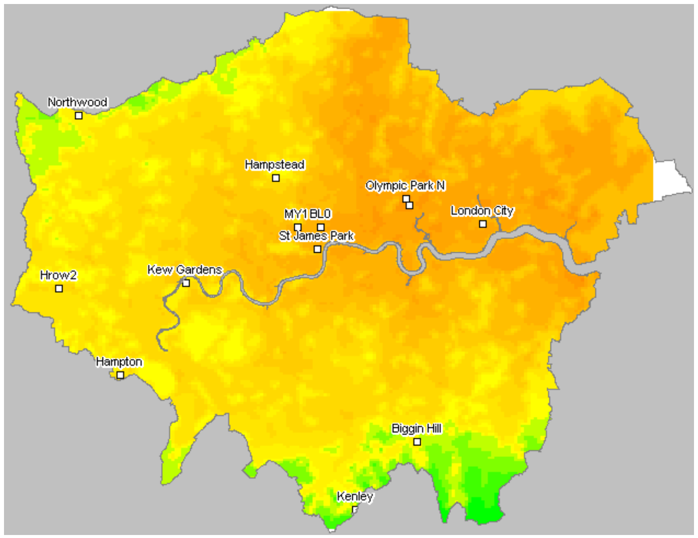
ADMS-Urban modelled surface temperature (°C) (18 August 2012)

Case Study: London

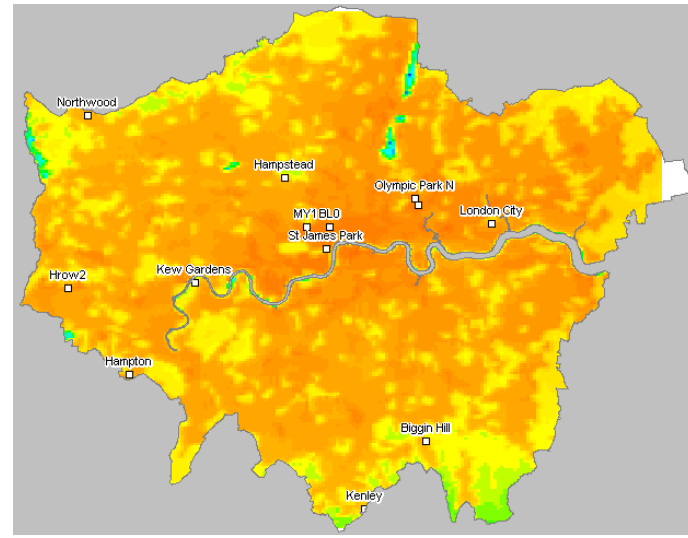
Model results: heat maps

- Example daily variations (August 2012)

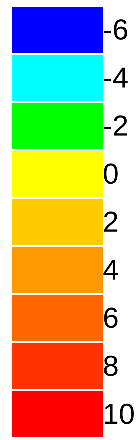
7 am



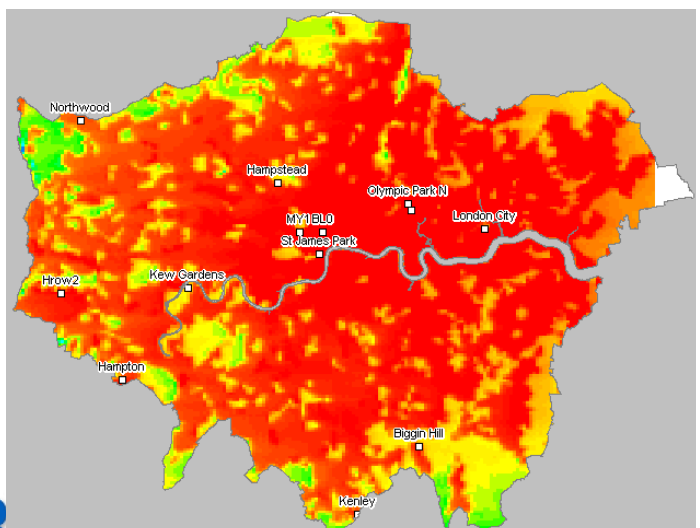
Midday



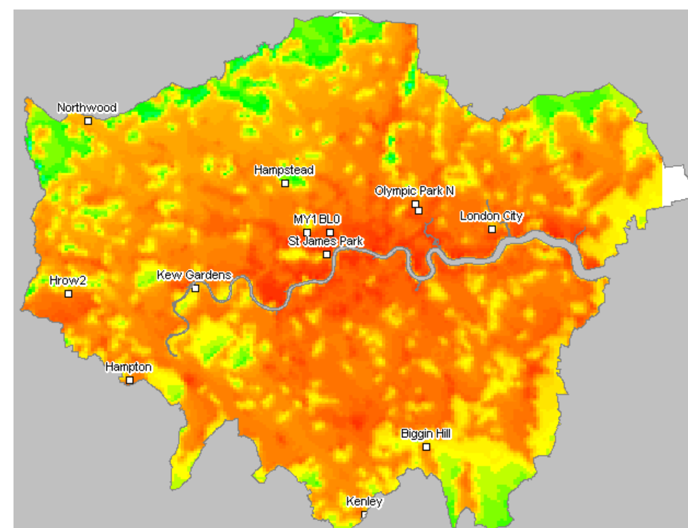
Temperature perturbation °C



7 pm



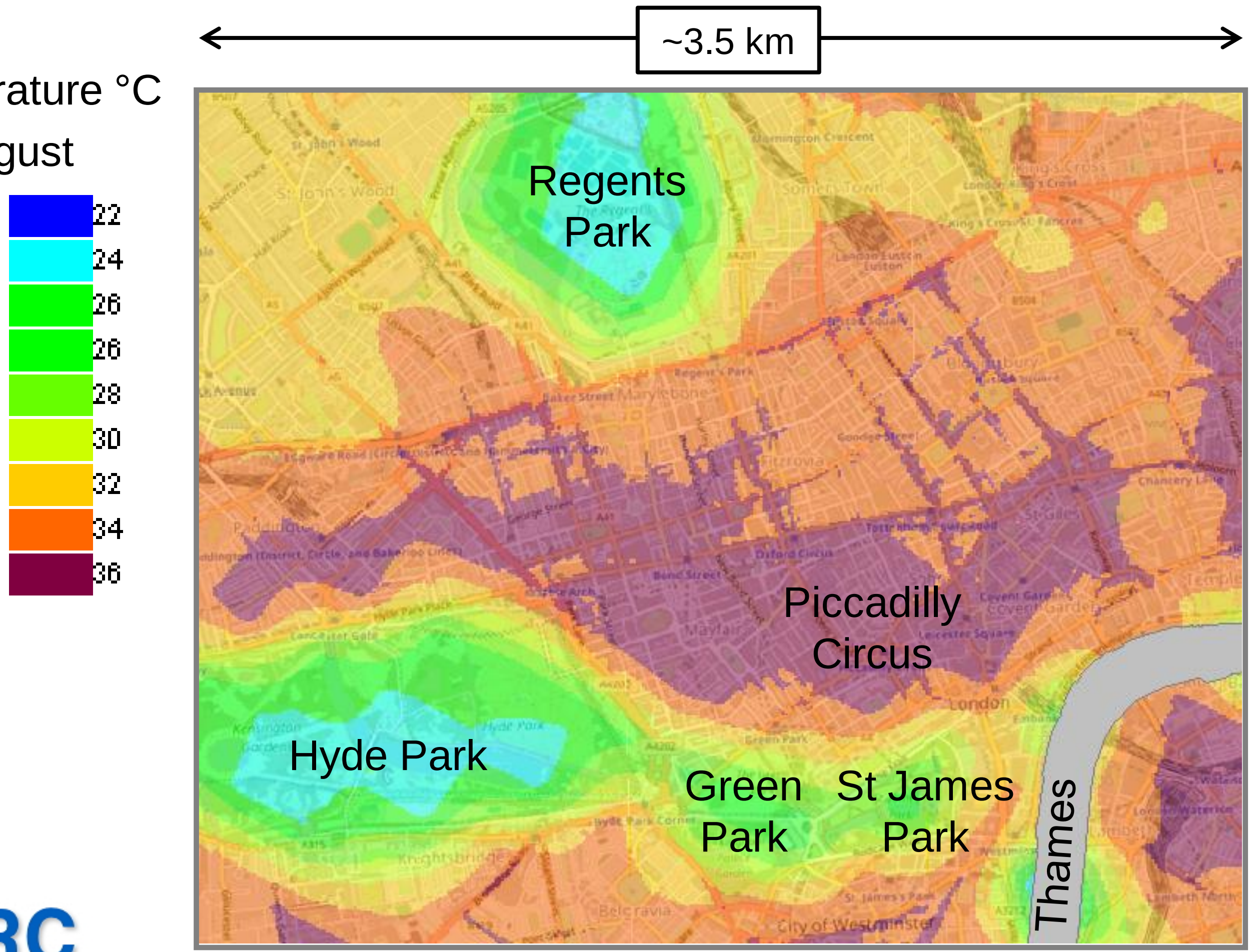
Midnight



Case Study: London
Model results: heat maps

- Example daily UHI variations
- Street-scale resolution contour model output for planning

Temperature °C
18th August
7 pm



Resolution of model inputs for this figure:

Traffic anthropogenic heat ~ street scale

Buildings anthropogenic heat ~ 5 km

Land use ~ 400 m

Higher resolution buildings and land use inputs can be used

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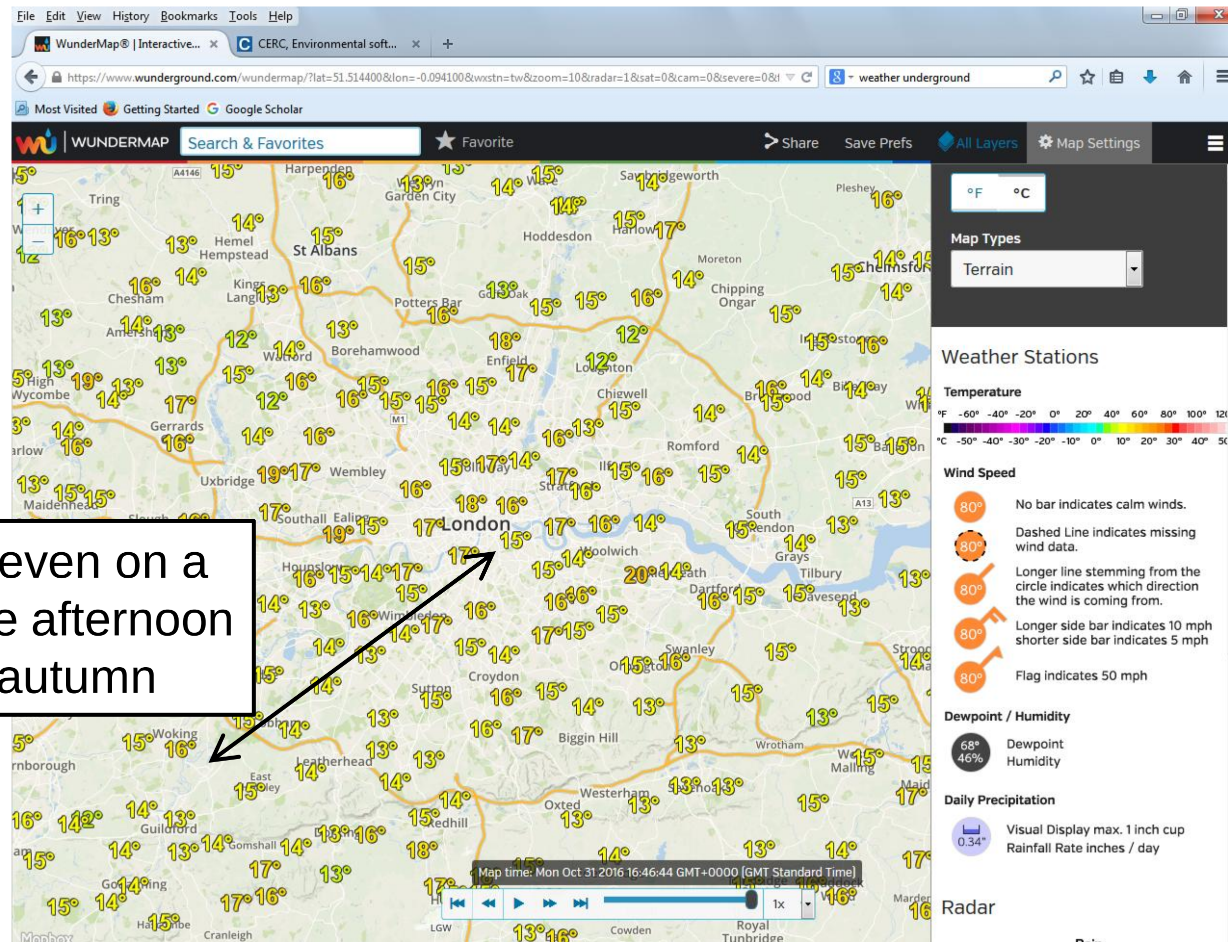
Case Study: London
Model results: heat maps

- Example daily UHI variations
- Street-scale resolution contour model output for planning
- Model validation at all site types e.g. data from wunderground.com



~4° UHI even on a cloudy late afternoon in the autumn

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Summary

- ADMS-Urban 4.1 will include a ‘Temperature & Humidity’ module*
- Good model performance at the city scale
- Ongoing projects to validate at the local scale
- As for air quality, ADMS-Urban is able to model hourly temperature and humidity variations to a high spatial resolution
- Applications include:
  - Planning applications
  - Climate change mitigation scenarios
  - UHI modelling

*extended licence required

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Any questions?

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