The Urban Heat Island – mapping and mitigation

Dr Helen Macintyre[1,2], Dr Clare Heaviside[2,3,4], Dr Jonathon Taylor[5], Dr Phil Symonds[5], Dr Anna Mavrogianni[5], Prof Mike Davies[5]

1. Public Health England, Climate Change Group, Centre for Radiation Chemical & Environmental Hazards
2. School of Geography, Earth and Environmental Science, University of Birmingham
3. Environmental Change Institute, University of Oxford
4. London School of Hygiene and Tropical Medicine
5. University College London

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Introduction

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NIHR Health Protection Research Unit (HPRU) in Environmental Change and Health <u>http://www.hpru-ech.nihr.ac.uk</u>

Project 2.3 – Urban Atmospheric Modelling

- Focus on quantification of the Urban Heat Island phenomenon and its associated effects on health, as well as the potential benefits of specific strategies to reduce heat islands at a city-wide scale.
- These can be considered climate change adaptation. Research and action priorities in the CCRA (2017) on overheating.
- Support PHE in developing its the "Healthy People, Healthy Places" programme.

Outline

- Heat and health – past events
- Urban Heat Island – quantification
- Mapping heat risk
- Assessment of mitigation by cool roofs

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European heatwaves

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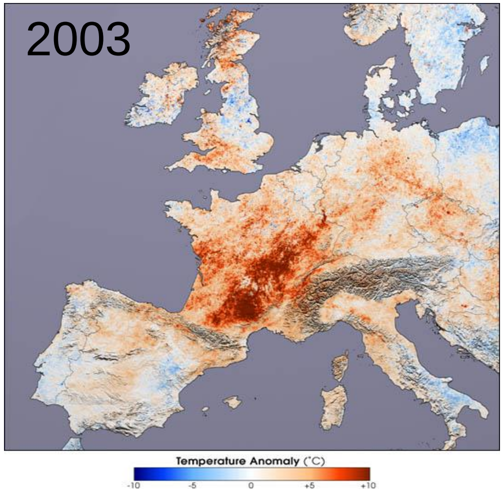
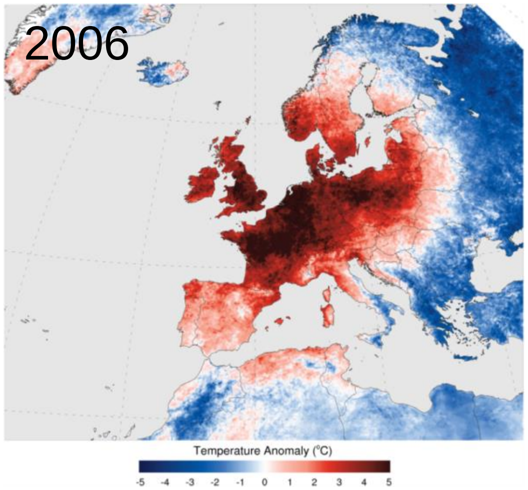
August 2003 and July 2006 heatwaves across Europe. Temperature records broken in most areas of the UK. 70,000 deaths across Europe in 2003 *[Robine et al., 2007]*.

Heatwaves likely to become more frequent and severe in the future (IPCC AR5). UKCP18 projections show increasing temperatures.

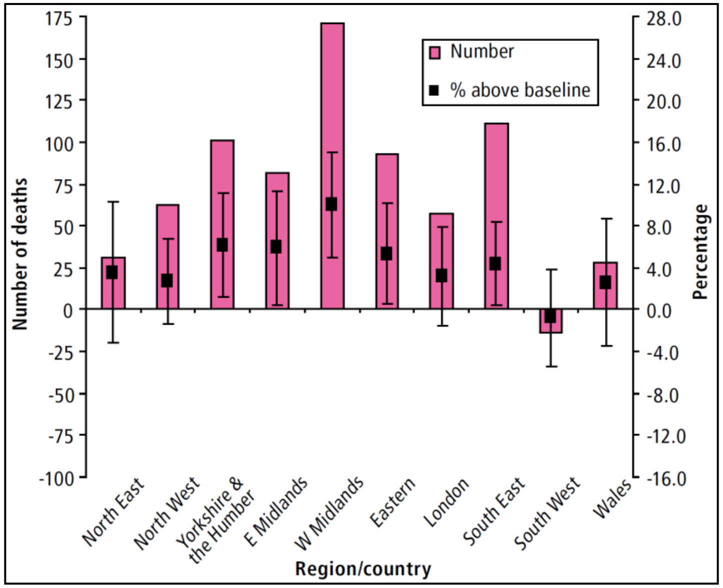
West Midlands strongly affected by July 2006 heatwave.



Land surface temperature anomaly for 20 July – 20 August 2003, compared with the average of the same period in 2000, 2001, 2002, 2004. *(Image courtesy Reto Stöckli and Robert Simmon, Derived from MODIS Terra Data, http://earthobservatory.nasa.gov)*



Land surface temperature anomaly for July 2006 (c.f. 2000-2012). *(Derived from MODIS Terra Data, http://lpdaac.usgs.gov)*



Excess deaths 16-28 July 2006 in England and Wales. *[Health Statistics Quarterly 32, Winter 2006, statistics.gov.uk]*

Urban Heat Island (UHI)

54% of the world's population live in urban areas; expected to rise to 66% by 2050 [*UN (2014) World Urbanization Prospects*]. In the UK this is **82%** *[Census 2011]*

Future population will be more exposed to urban environmental factors. **Climate projections often don't account for the effect of the UHI.**

Visible (top) and surface temperature (bottom) images of Atlanta, GA, 28 Sept 2000.
(NASA images by Marit Jentoft-Nilsen, based on Landsat-7 data.)

Causes of UHI

- Urban materials retain heat
- Buildings reduce heat radiated to the sky
- Lack of moisture and vegetation
- Temperatures up to +10^{o}C. Larger for low-wind, cloud free conditions, and usually more pronounced at night.

Effects of UHI:

- Health – respiratory, stroke, heat exhaustion, death
- Increased energy consumption for cooling/ reduced in winter
- Increased greenhouse gases and air pollutant emissions

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WRF atmospheric model

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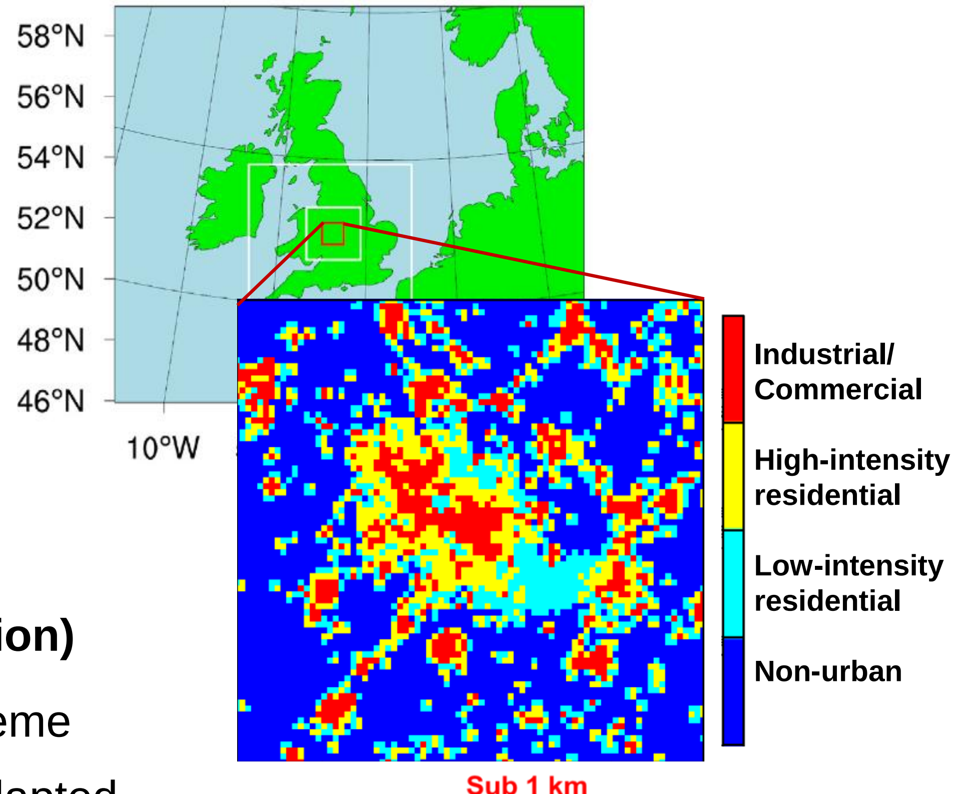
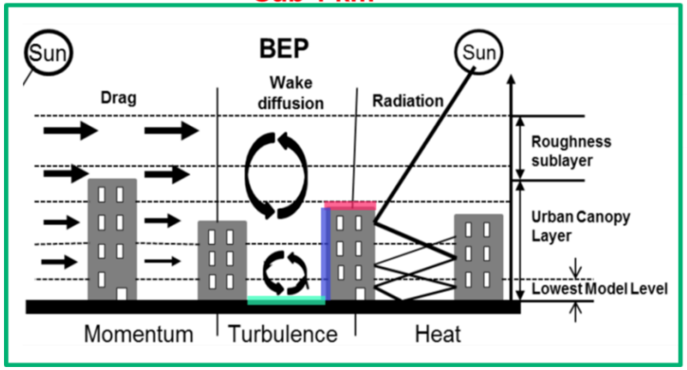
Weather Research and Forecasting (WRF) model

- Regional weather simulation.
- Four nested domains (36km, 12km, 3km, **1km** resolution).
- 2 metre air temperature modelled at $1km^2$ resolution across the West Midlands.



BEP (Building Energy Parameterization)

- Multilayer surface urban physics scheme
- 3 types of urban classes; specially adapted for Birmingham and the West Midlands
- Simulates the effects of the vertical distribution of heat, momentum and turbulent kinetic energy throughout the urban canopy layer.



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UHI Intensity

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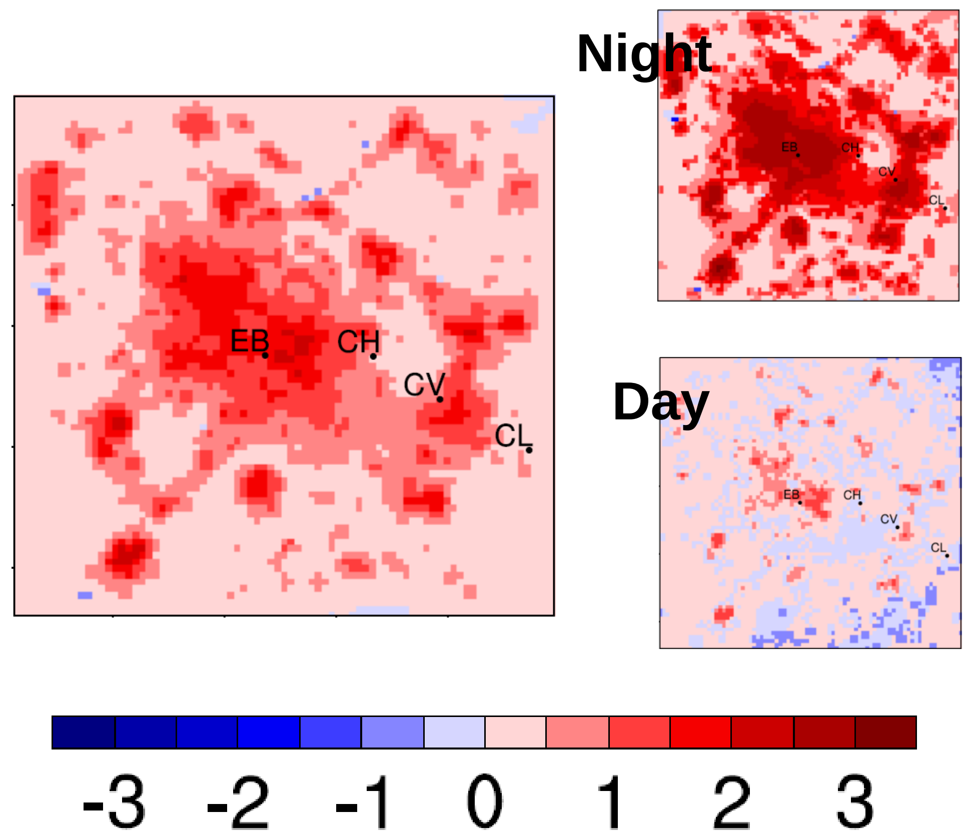
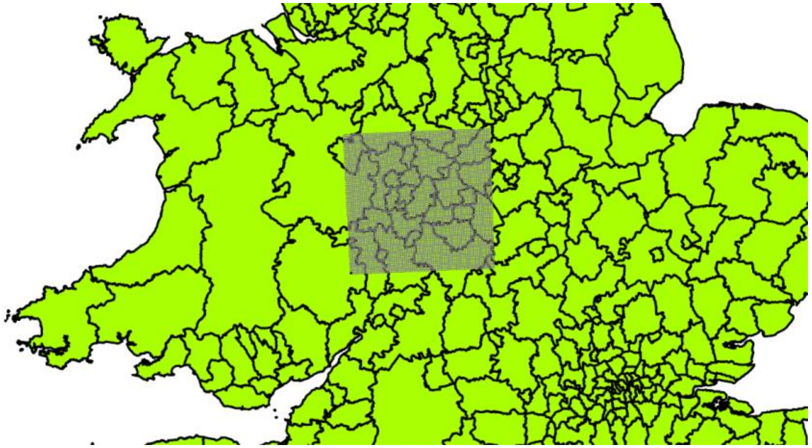
- Difference in temperature between **urban** and **rural** land cover simulations.
- Averaged over 16 – 27 July 2006 (all times of day), the whole region is +0.6°C warmer.
- City centre is +2°C warmer (+3.1°C at night)
- Maximum UHI intensity, reaching **+9.4°C** (11pm, July 17th).
- UHI contributes ~40% of heat-related mortality in summer period.

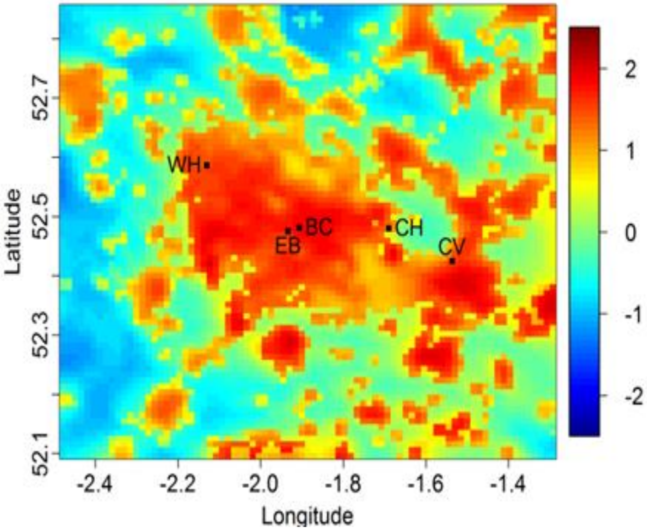


2m air temperature difference between urban and rural model simulations.

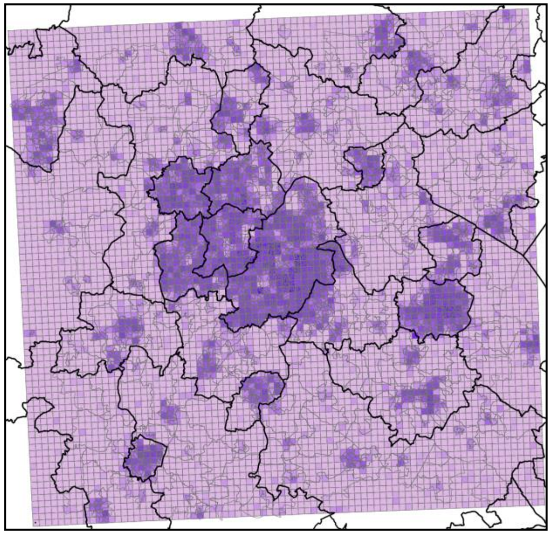
Spatial vulnerability



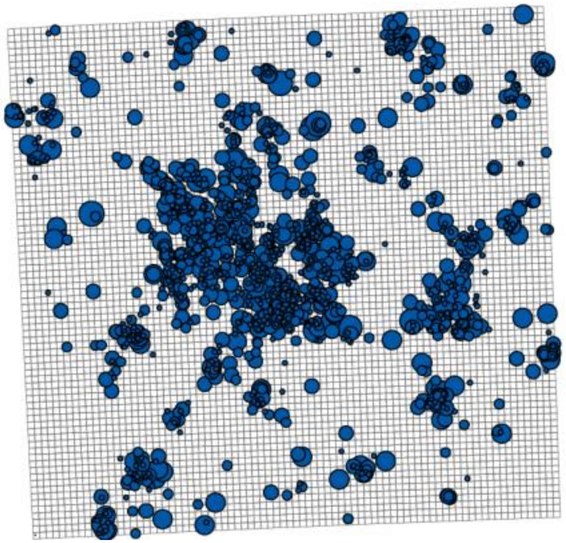
Temperature



Population



Care homes



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Health and care centres

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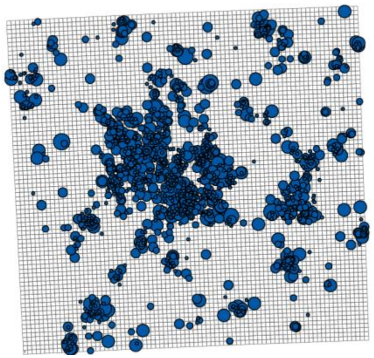
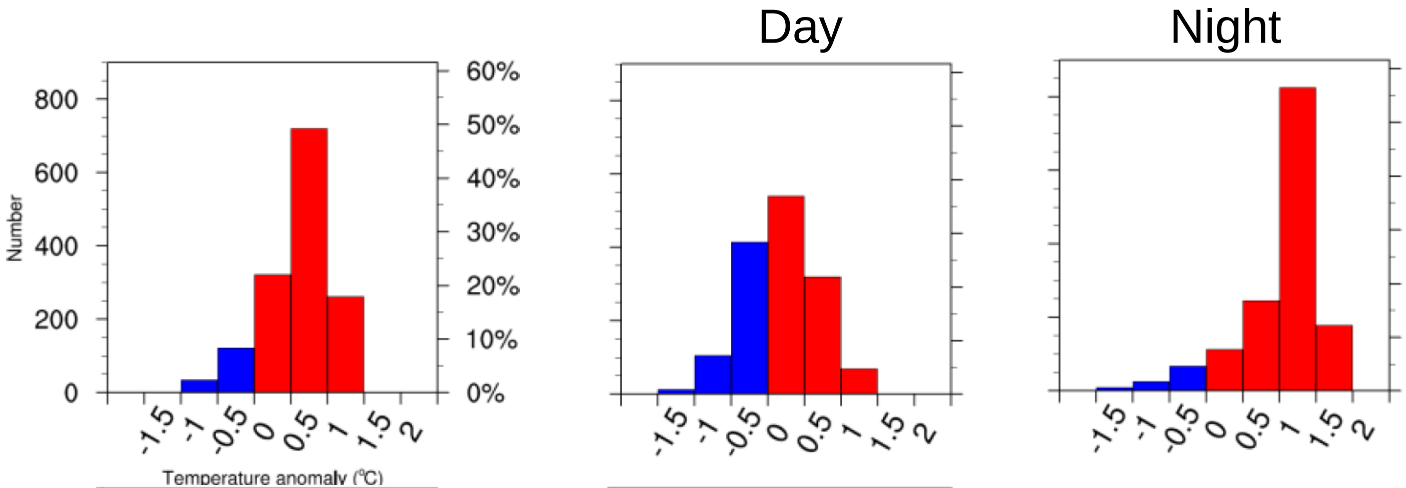
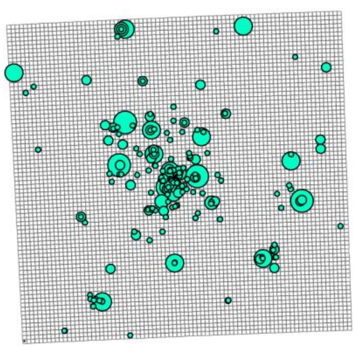
Care Homes

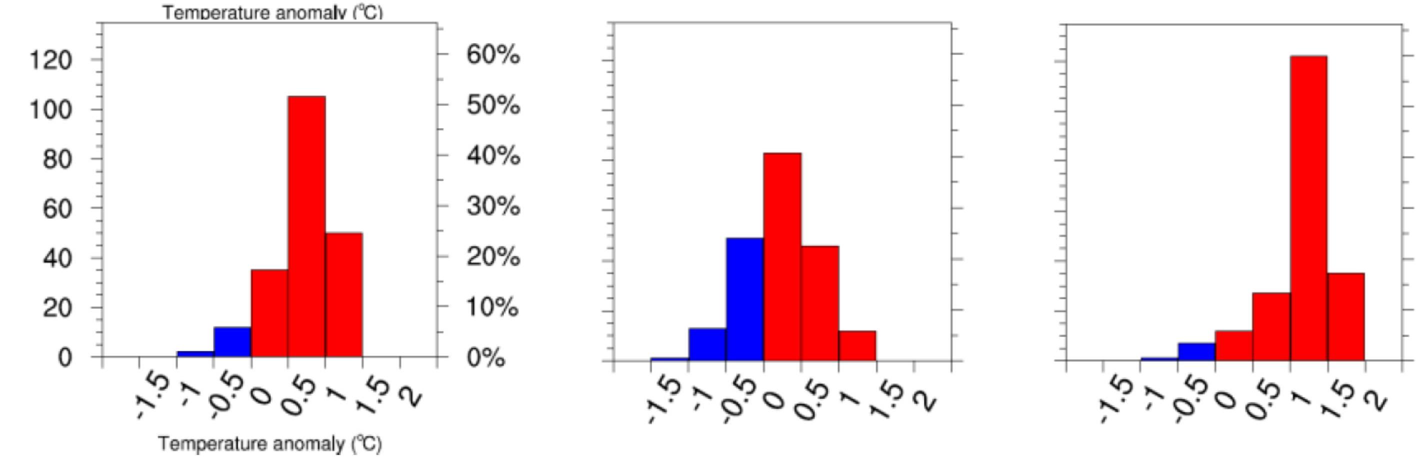
Difference in 2m temperature at care homes and hospitals compared to the average 2m temperature across the whole domain (21.8°C).





Hospitals





Macintyre et al. 2018. Assessing urban population vulnerability and environmental risks across an urban area during heatwaves – Implications for health protection. *Science of The Total Environment* 610–611, 678-690.

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Deprivation Indices

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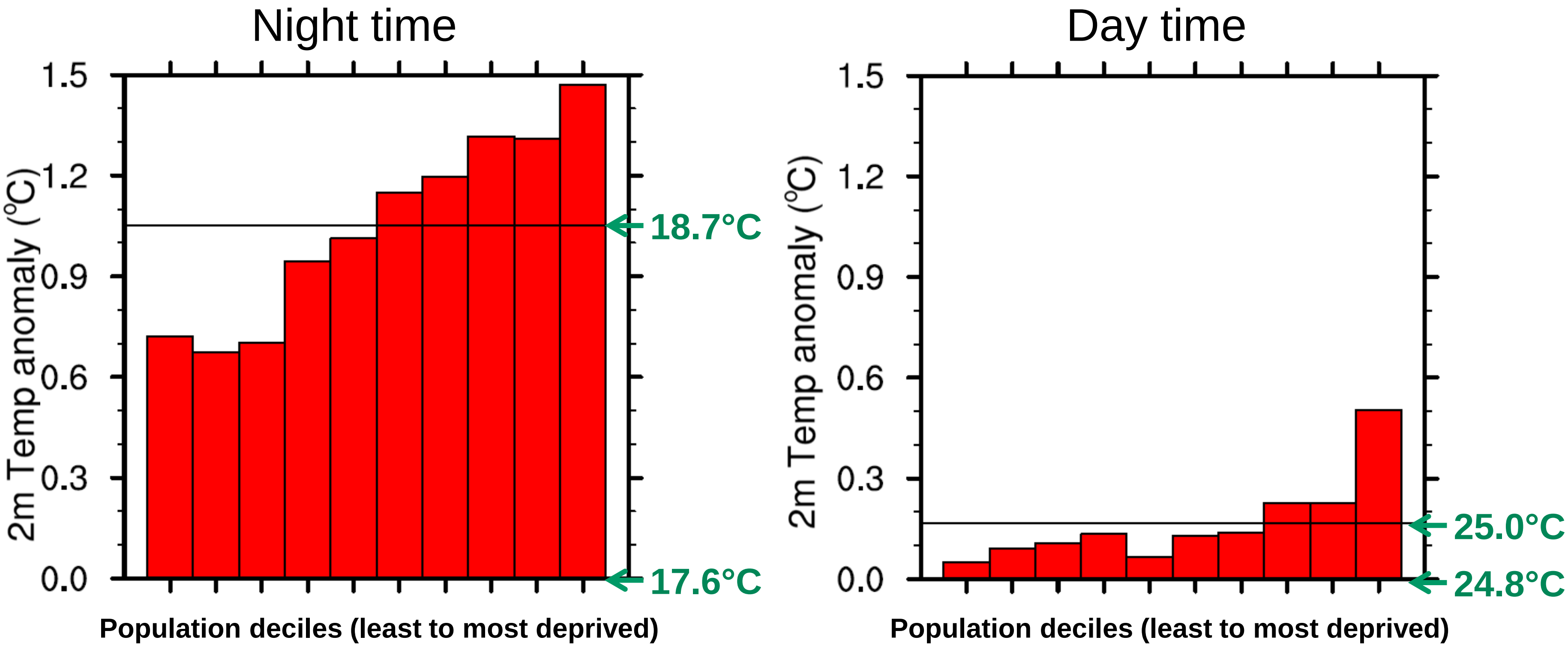
- English Indices of Multiple Deprivation.
- Gridded population at 100 m combined with IMD scores at LSOA level and re-ranked.
- Some relationship with deprivation.



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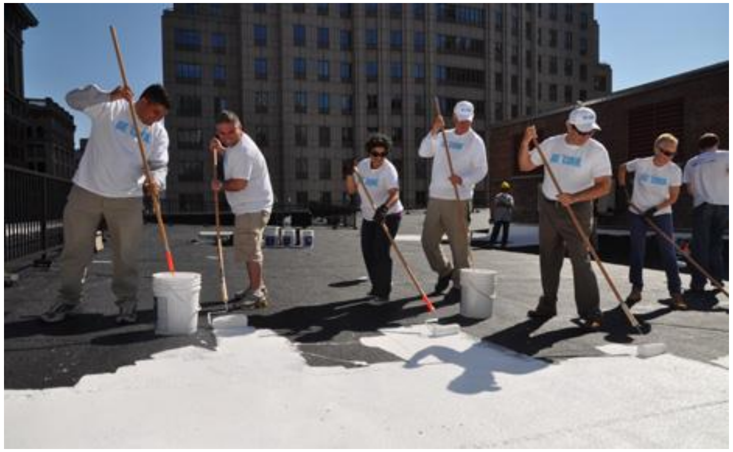
Mitigation of the UHI effect

Modifying urban building properties to reflect more energy from the sun can reduce temperature.

Why cool roofs?

- Cost and ease of deployment impacts favourability of schemes. Easier to retrofit existing buildings (and high-slope roofs).
- Previous studies suggests albedo modification is single most effective strategy.
- Generally more cost effective than other methods (larger area can be covered; lower maintenance costs).



Repeat urban simulation, but make all roofs more reflective. Reflectivity (albedo) is increased to 70% (from 20%).

70% is chosen based on a review by Virk et al. (2014) and A. Mavrogianni, [per. comm.].

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Cool roofs - seasonal

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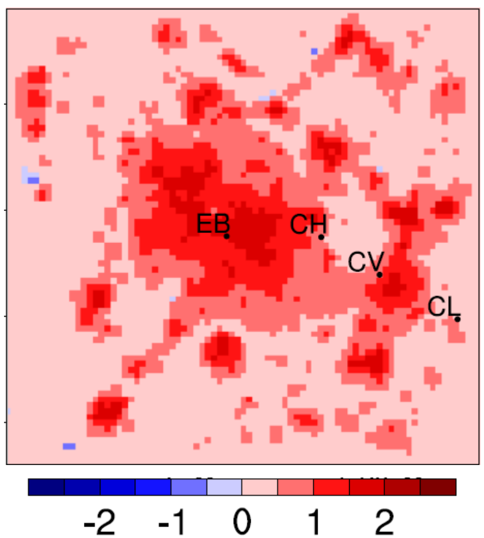
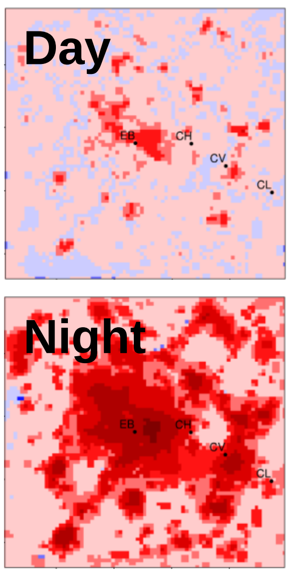
Seasonal simulations run for 1 June – 30 August 2006.

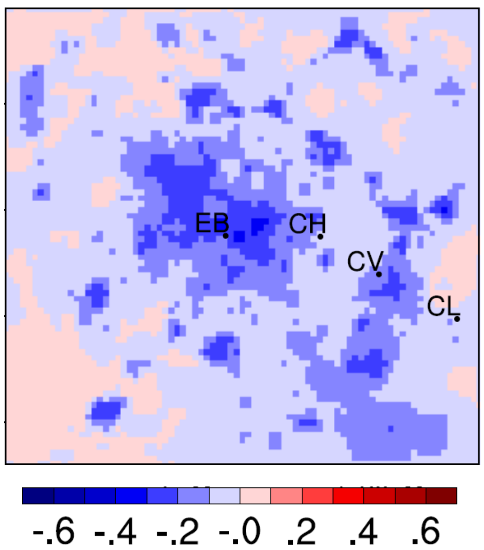
- Population weighted UHI is +1.1°C (+1.8°C at night) – double the geographical mean. Mean city centre UHI is +2.0°C (+2.6°C night). Peaks at +9°C.
- Cool roofs: daytime -0.6°C mean (-3°C max) cooling in city centre when cool roofs most effective, but small effect at night when UHI is largest. Beware percentage results…
- Cool roofs offset up to 18% of seasonal heat related mortality associated with the UHI (7% of overall heat-related mortality).

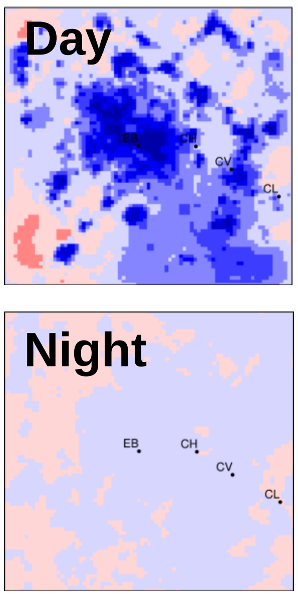
Average UHI intensity





Impact of cool roofs



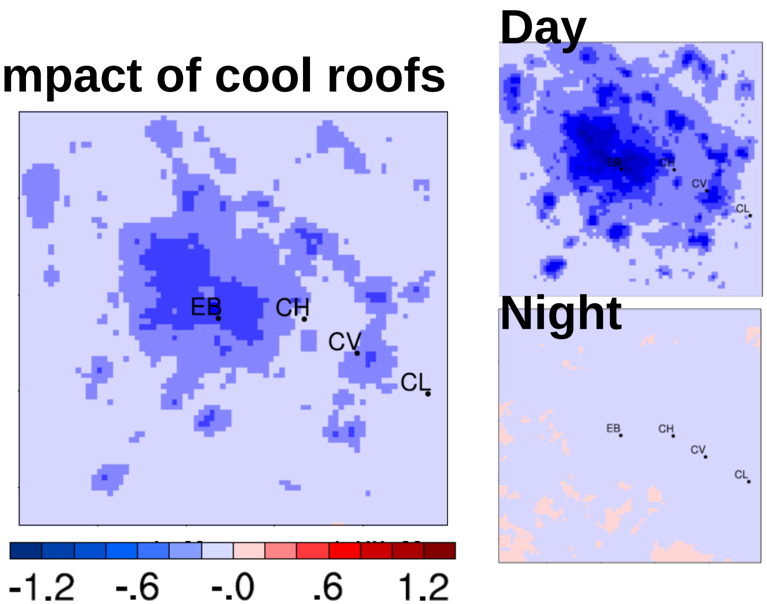


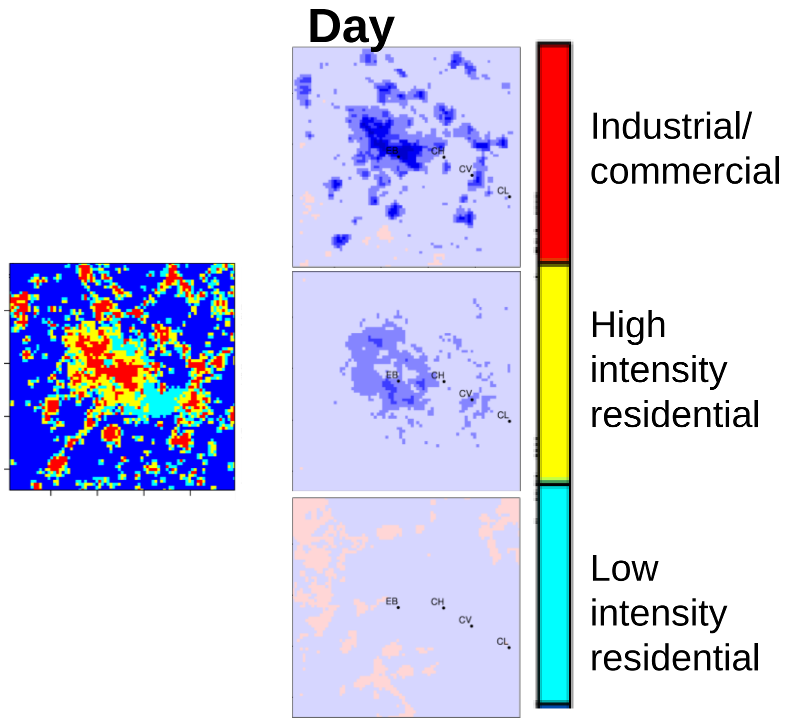
Cool roofs - heatwaves

Heatwave periods: 2-10 Aug 2003, 16-27 July 2006.

- Population weighted UHI is +1.3°C (+2.2°C at night). Mean city centre UHI is +2.3°C (+3.0°C night).
- Cool roofs offset up to 24% of the regional population weighted average UHI. Max -1.1°C cooler in city centre during day.
- Individual urban categories show commercial have largest impact.

Impact of cool roofs





Figures are for the August 2003 heatwave

Health Impact Assessment

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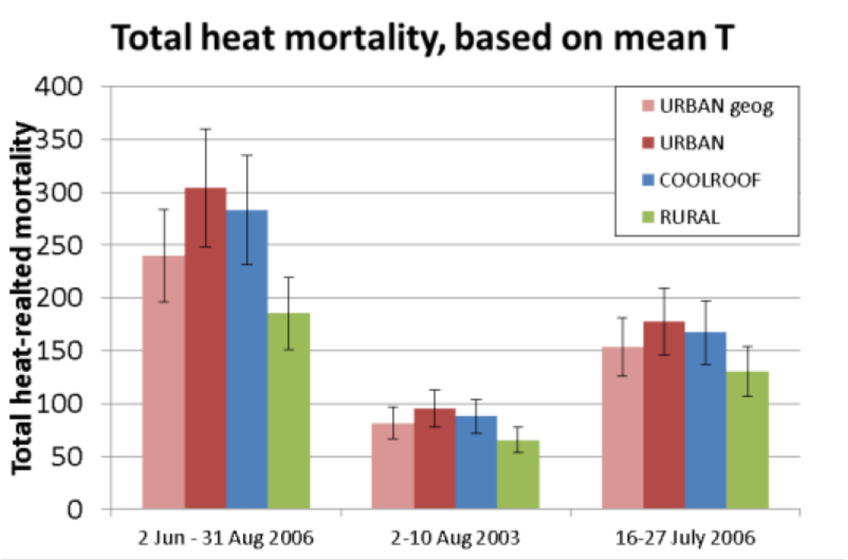
Heat-related mortality for the summer season in 2006, and for heatwave periods in August 2003 and July 2006.				
Dates	**Exposure-response metric**	**URBAN**	**COOL ROOF**	**RURAL**
Jun-Jul-Aug 2006	**Mean T**	**305**	**283**	**185**
	Maximum T	**272**	**240**	**232**
2-10 August 2003	**Mean T**	**96**	**88**	**66**
	Maximum T	**101**	**89**	**83**
16-27 July 2006	**Mean T**	**178**	**167**	**131**
	Maximum T	**188**	**172**	**178**

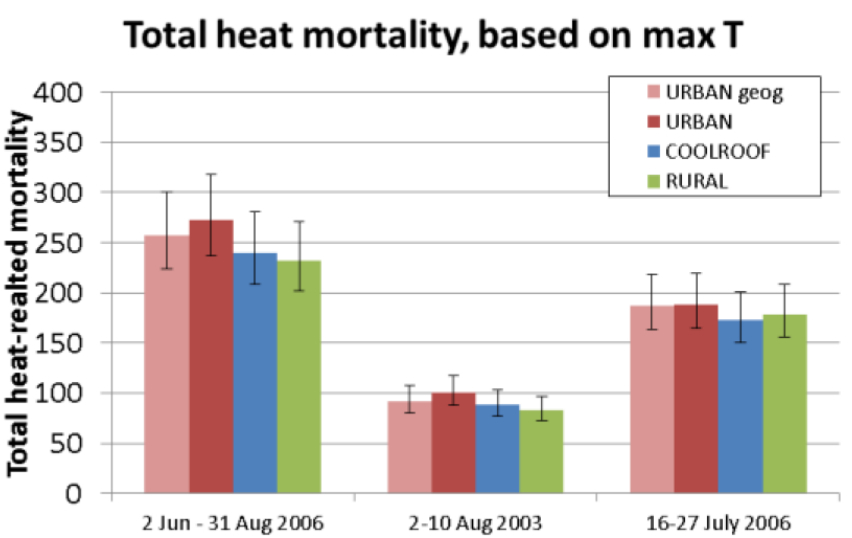
Mean temperature (Vardoulakis et al. 2014):

- **2.5% (95%CI: 2.0% – 3.0%) increase per 1°C > 17.7°C daily mean T.**

Maximum temperature (Armstrong et al. 2011):

- **2.2% (95%CI: 1.9% – 2.6%) increase per 1°C > 23.0°C daily max T.**





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