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NIHR | Health Protection Research Unit in Environmental Change and Health at London School of Hygiene and Tropical Medicine

Potential benefits of cool roofs in reducing heat-related mortality during heatwaves in a European city

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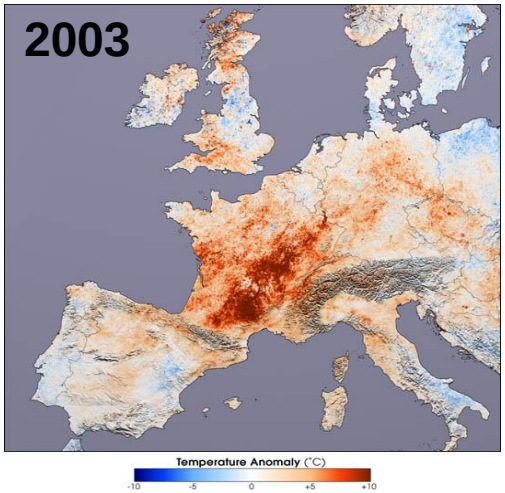
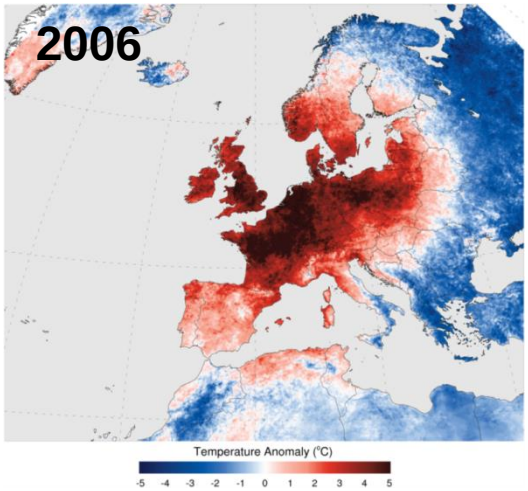
European heatwaves

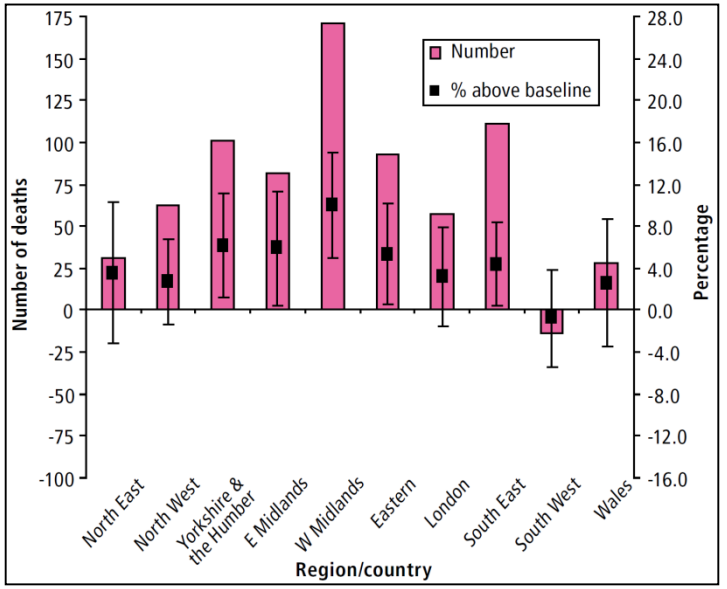
- August 2003 and July 2006 heatwaves across Europe. Temperature records broken in most areas of the UK. 70,000 deaths across Europe in 2003 *[Robine et al., 2007]*.
- Heatwaves likely to become more frequent and severe in the future (IPCC AR5, UKCP18 projections).
- West Midlands strongly affected by 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]*

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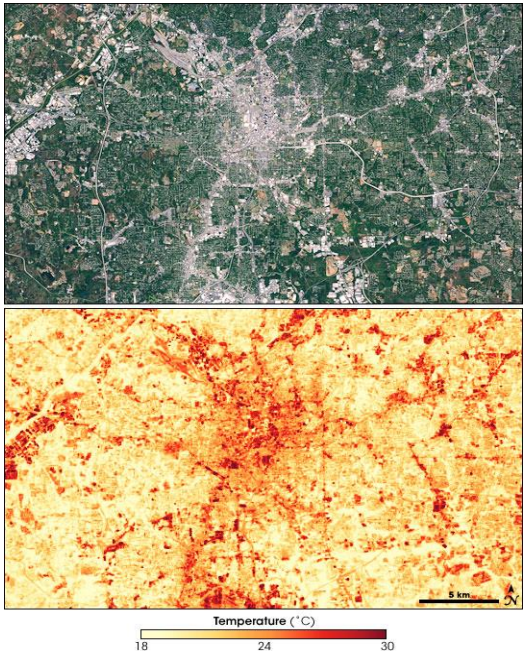
Urban Heat Island (UHI)

- 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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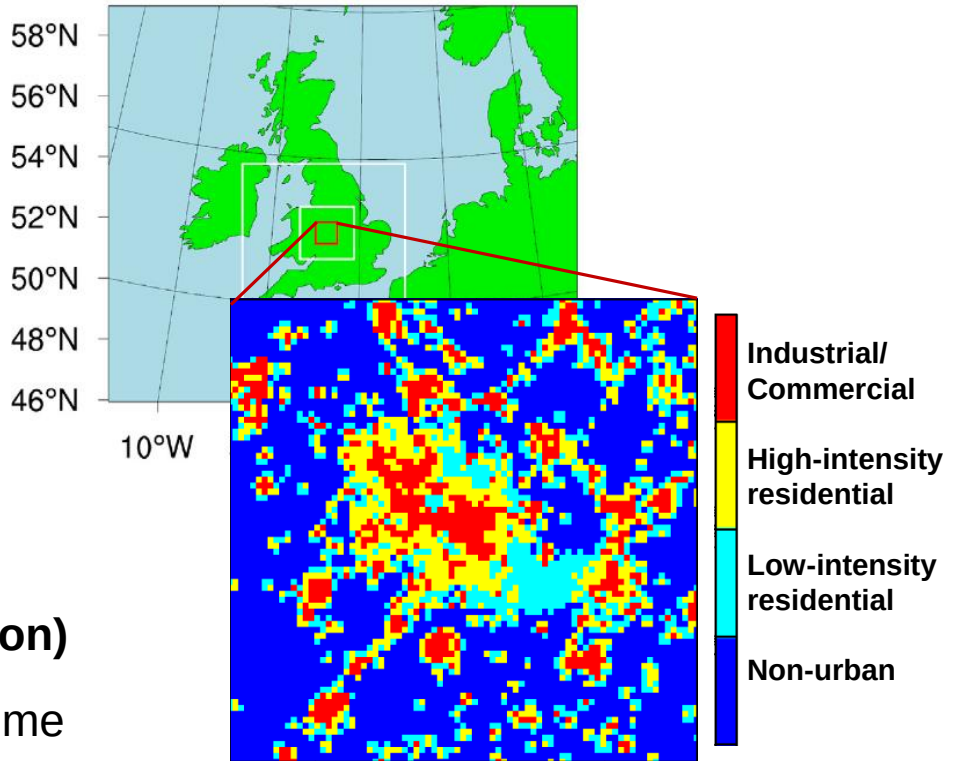
WRF atmospheric model

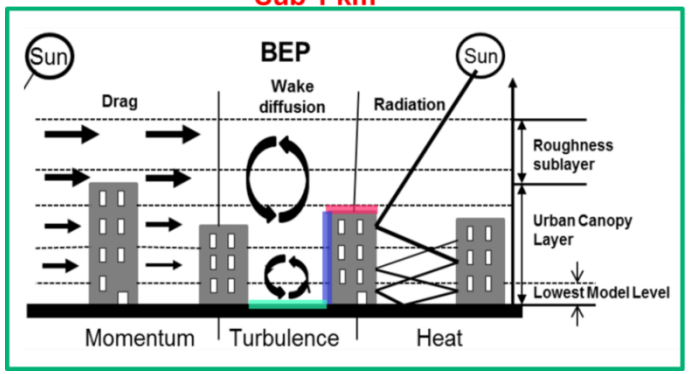
Weather Research and Forecasting (WRF) model

- 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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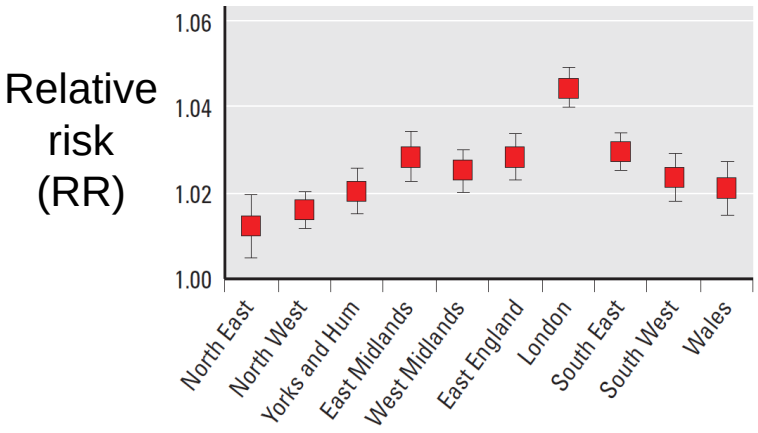
Heat and health

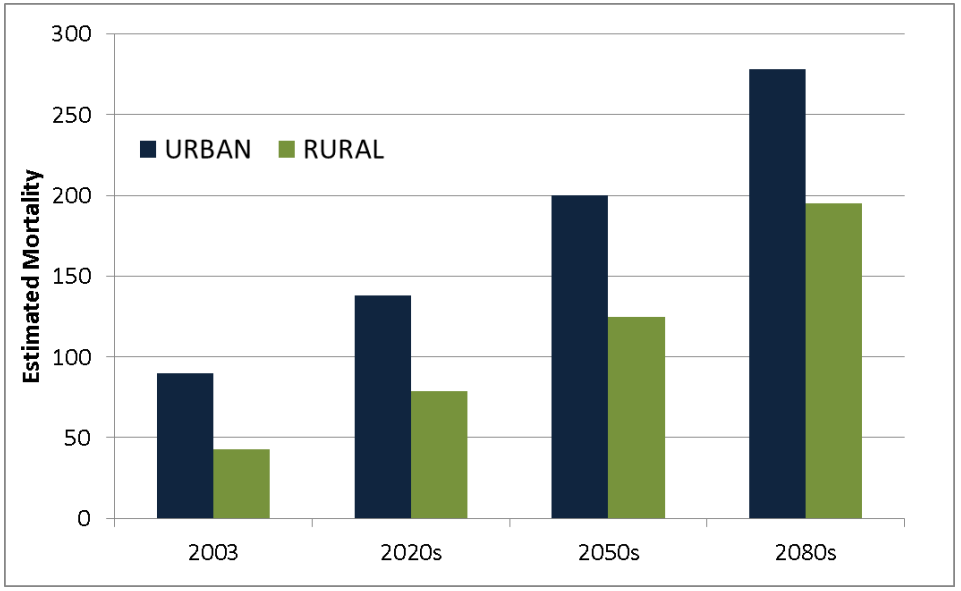
Health Impact Assessment

- In the West Midlands mortality increases by 2.5% for every 1°C increase above 17.7°C *[Vardoulakis et al. 2014, Hajat et al. 2014]*
- Combine with mortality counts and simulated temperatures ('URBAN' and 'RURAL') to estimate impact of UHI on heat-related mortality.



Vardoulakis et al. 2014

Results show around half of heat-related mortality due to the UHI effect for 2003 heatwave in West Midlands



Heaviside et al. (2016) **Attribution of mortality to the Urban Heat Island during heatwaves in the West Midlands, UK**. *Environmental Health* 15 Suppl 1:27.

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Mitigation of the UHI effect

Why cool roofs?

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

Test effect of cool roofs on heat-related mortality:

Repeat urban simulation, but increase roof albedo from 20% to 70%.

Simulations:

URBAN	COOL ROOF	RURAL

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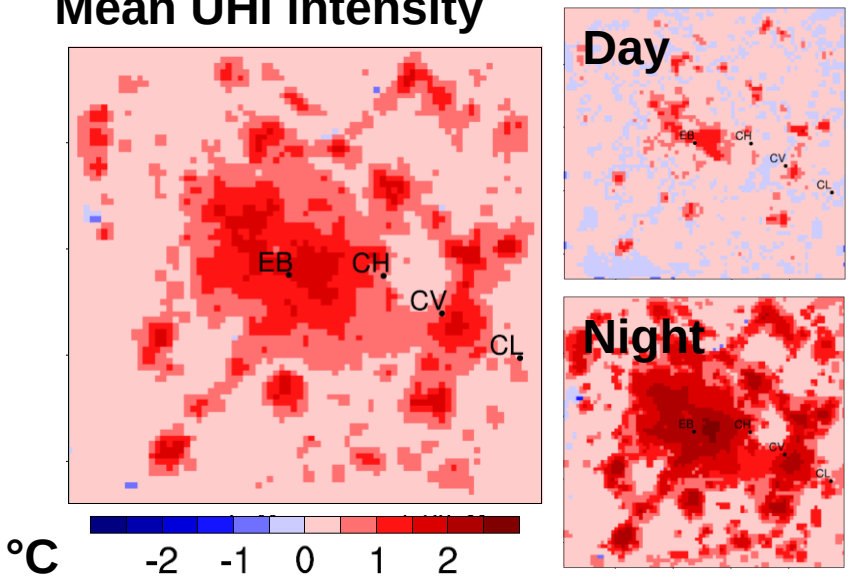
UHI & Cool roofs - seasonal

Seasonal simulations run for 1 June – 30 August 2006.

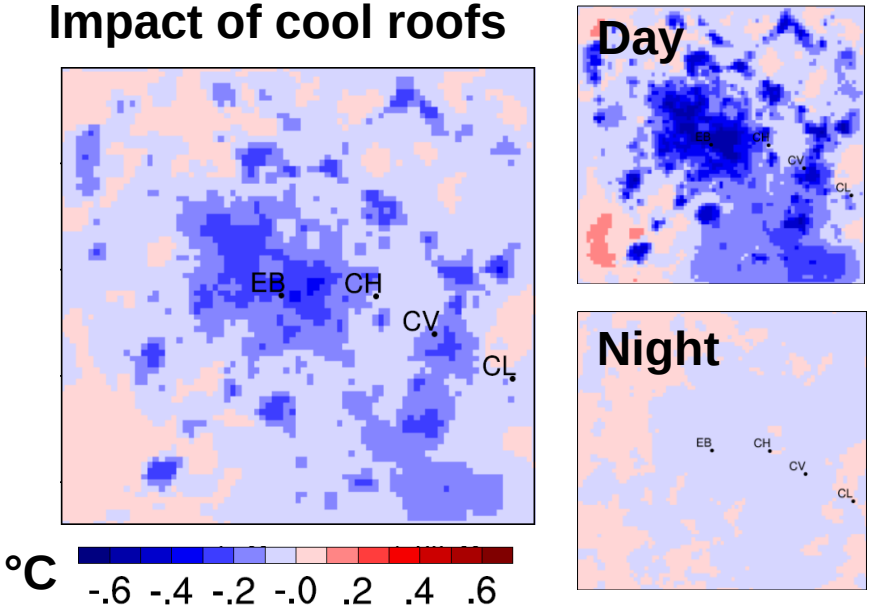
- Mean city UHI: **+2.0°C** (**+2.6°C** night)
- Peaks at **+9°C**.
- **UHI contributes ~40% of heat-related mortality in summer period**.

- Cool roofs: **−0.6°C** (daytime city mean)
- Peaks at **−3°C** in city centre.
- **Offset** up to **18% of seasonal heat related mortality associated with the UHI** (7% of overall heat-related mortality).

Mean UHI intensity



Impact of cool roofs



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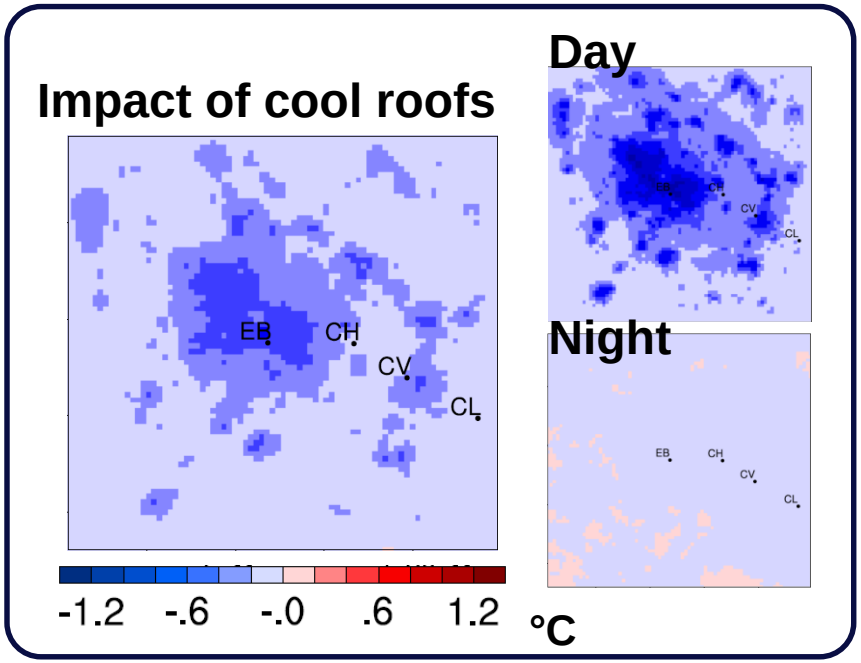
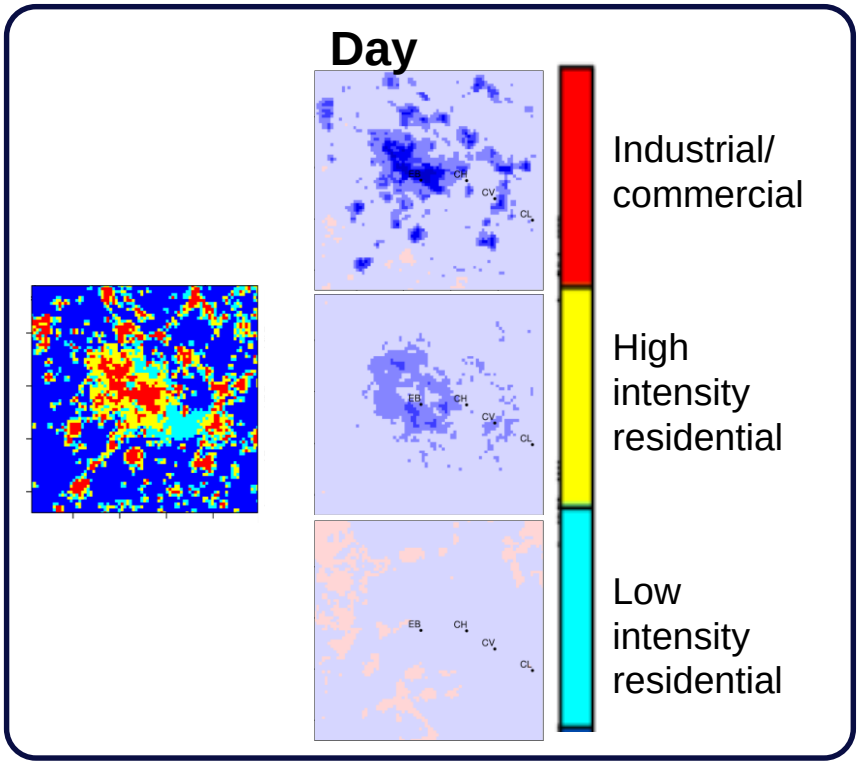
Cool roofs - heatwaves

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

- Mean city UHI is **+2.3°C** (**+3.0°C** night)
- **Cool roofs** offset up to **25%** of heat-related mortality associated with the UHI
  City centre **−1.1°C** cooler during day
- Individual urban categories show commercial have largest impact



Figures are for the August 2003 heatwave



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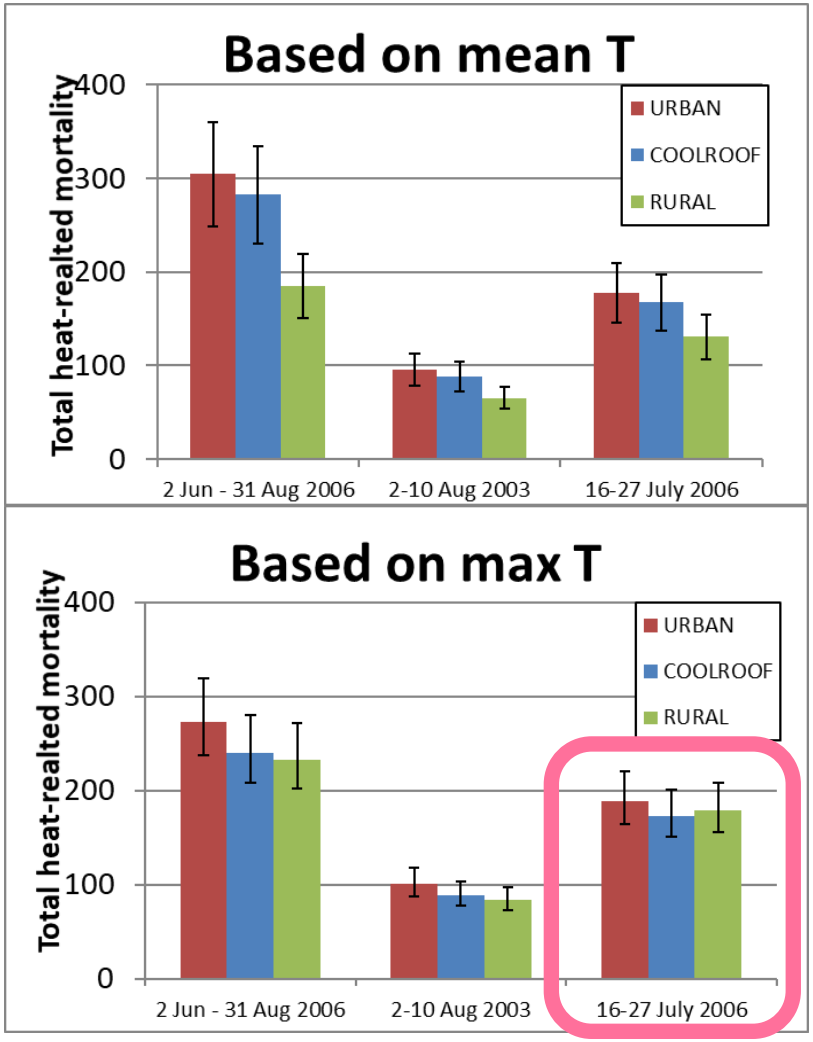
Health Impact Assessment

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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Summary

- Using high-resolution modelling of air temperature allows **quantification of UHI intensity** (difference in temperature between urban and rural areas) across wide spatial area.
- UHI intensity across the West Midlands reached up to +9°C (on **average +2.3°C in city centre during heatwaves**)
- Mitigation techniques (e.g. cool roofs) may reduce the UHI intensity. Results suggest a ~23% reduction in UHI intensity of cool (reflective) roofs are implemented across the region, and **may offset up to 25% of heat-related mortality associated with the UHI**.
- Further work on interventions. Green space. Impact on air quality.

Macintyre & Heaviside (2019): Potential benefits of cool roofs in reducing heat-related mortality during heatwaves in a European city. *Environment International*, 127, 430-441.

Heaviside et al. (2016): Attribution of mortality to the Urban Heat Island during heatwaves in the West Midlands, UK. *Environmental Health* 15 Suppl 1:27.

Macintyre et al. (2018): Assessing urban population vulnerability and environmental risks across the West Midlands during heatwaves - implications for health protection. *Science of the Total Environment*, 610–611, 678-690.

Thank you!

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