Public Health England

NHS National Institute for Health Research

UNIVERSITY OF BIRMINGHAM

Heat-related health impacts associated with the urban heat island and climate change in the West Midlands, UK

Dr Clare Heaviside[1,2] Dr Xiaoming Cai[2] Dr Anna Mavrogianni[3], Dr Jonathon Taylor[3], Dr Mike Davies[3], Dr Sotiris Vardoulakis[1,2]

[1]Centre for Radiation, Chemical and Environmental Hazards, Public Health England, Harwell, campus, Oxon
[2]School of Geography, Earth and Environment Sciences, University of Birmingham
[3]Faculty of the Built Environment, University College London

Public Health England

Birmingham and the West Midlands

Urbanisation across the West Midlands

Birmingham is the UK's 2nd most populous city (~1 million)

The West Midlands is the UK's 2nd most populous urban conurbation

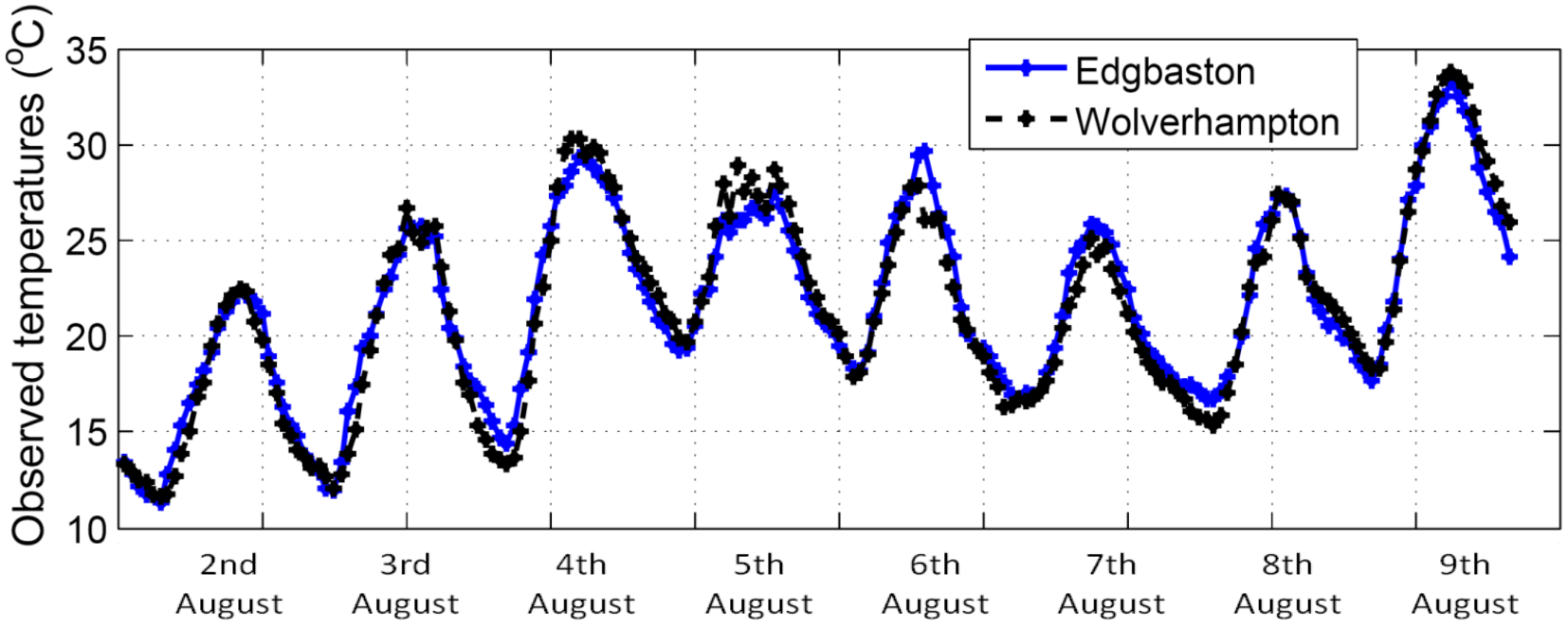
Public Health England

The 2003 European heatwave

Estimates of between 30,000 and 70,000 excess deaths in Europe (Robine *et al.* 2008).

England: >2,000 excess deaths (Johnson *et al*. 2005).

Maximum temperature in UK: 38.5^{o}C in Kent



Public Health England

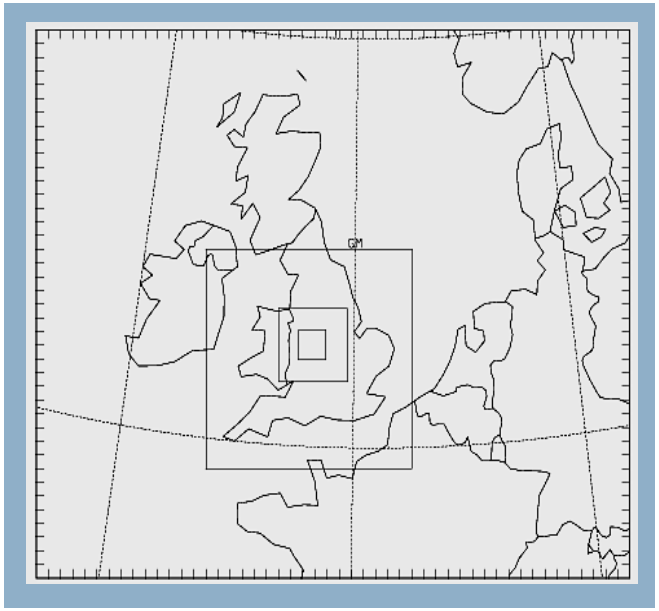
Modelling configuration

WRF (Weather Research and Forecasting) ARW (Advanced Research WRF) model

4 nested domains
(36 km^2, 12 km^2, 3 km^2 and 1 km^2 resolution)

Meteorology: ECMWF ERA-interim reanalysis at 1.5^o every 6 hours

Land surface data: USGS (United States Geological Survey) land use categories



(Heaviside *et al.* 2015)

BEP (Building Energy Parameterization) scheme

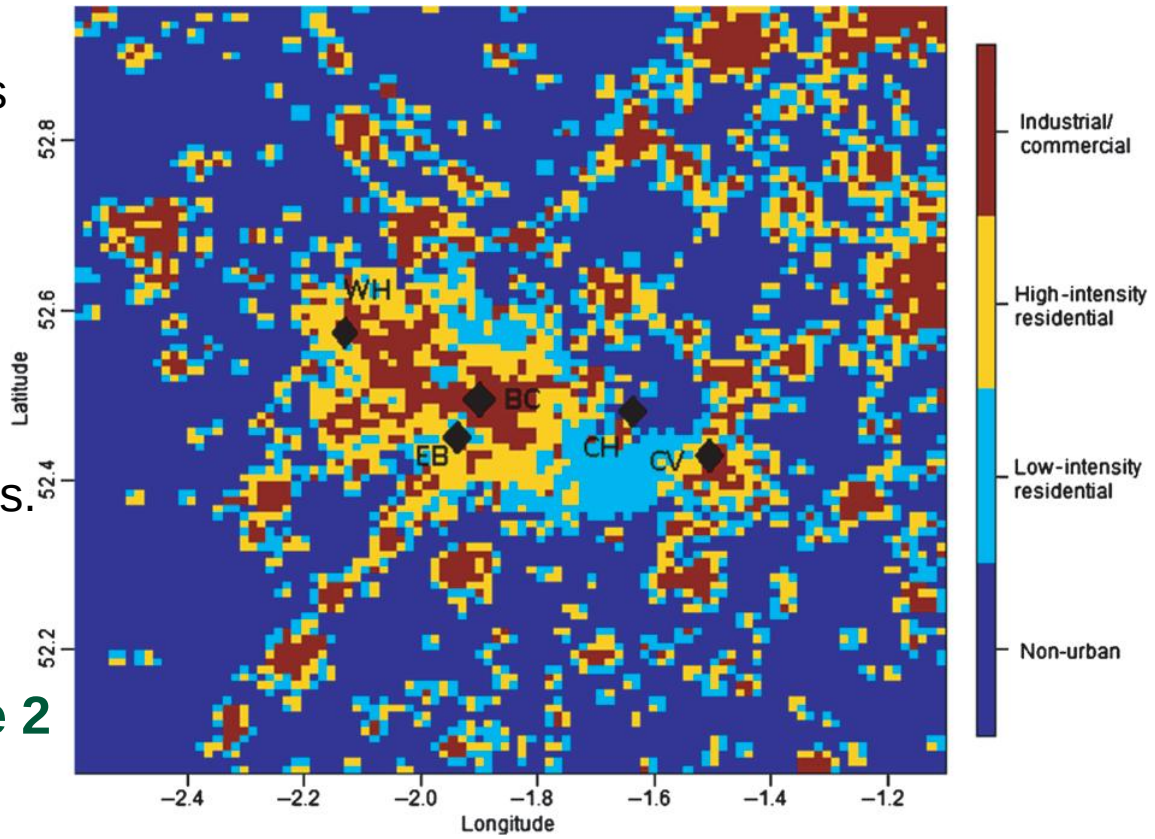
- Multilayer surface urban physics scheme
- 3 types of urban classes
- Urban classes specially adapted for Birmingham and the West Midlands
- Simulates the effects of the vertical distribution of heat, momentum and turbulent kinetic energy throughout the urban canopy layer.

Public Health England

Modelled Simulations

'Urban':
Model is run using 3 detailed urban land surface categories to best capture the UHI effect using the BEP scheme.

'Rural':
Model is run by replacing all urban categories with rural (grassland/pasture) categories.



A comparison of temperature between the 2 simulations gives an indication of the UHI intensity

Public Health England

Health Impact Assessment (HIA) methodology I

Aims:

Quantify the effect of the UHI on mortality, and investigate sensitivity of mortality burdens to population weighting of temperature.

Estimate the full potential health impacts of climate change, by including the UHI intensity as well as the UKCP09 temperature projections.

Calculations:

- Mortality associated with heat during the 2003 heatwave period
- The effect of population weighting of temperature on mortality burden
- Mortality associated with the UHI during this period
- Mortality associated with Climate Change and UHI for future decades

Public Health England

Health Impact Assessment (HIA) methodology II

Input data for HIA

Exposure data based on 1x1 km modelled 2m air temperature, including urban surfaces for West Midlands domain – 'urban' run and with no urban surfaces – 'rural' run.

Gridded population dataset.

Time period: 1st – 10th August 2003

Dose-response relationship: ~2% increase in mortality for WM region for a 1°C increase in temperature, with threshold at 17.7°C (Hajat *et al.* 2014)

Public Health England

Calculation of heat related mortality

$$M = \sum_{i=1}^{N} DM_i\left(1 - e^{(-b\Delta T_i)}\right)$$

M = heat related mortality during heatwave

N = number of days in heatwave

DM_i = recorded daily all-cause mortality for West Midlands on day i

b = slope of exposure response relationship for temperature for West Midlands

ΔT_i = temperature above a threshold on day I

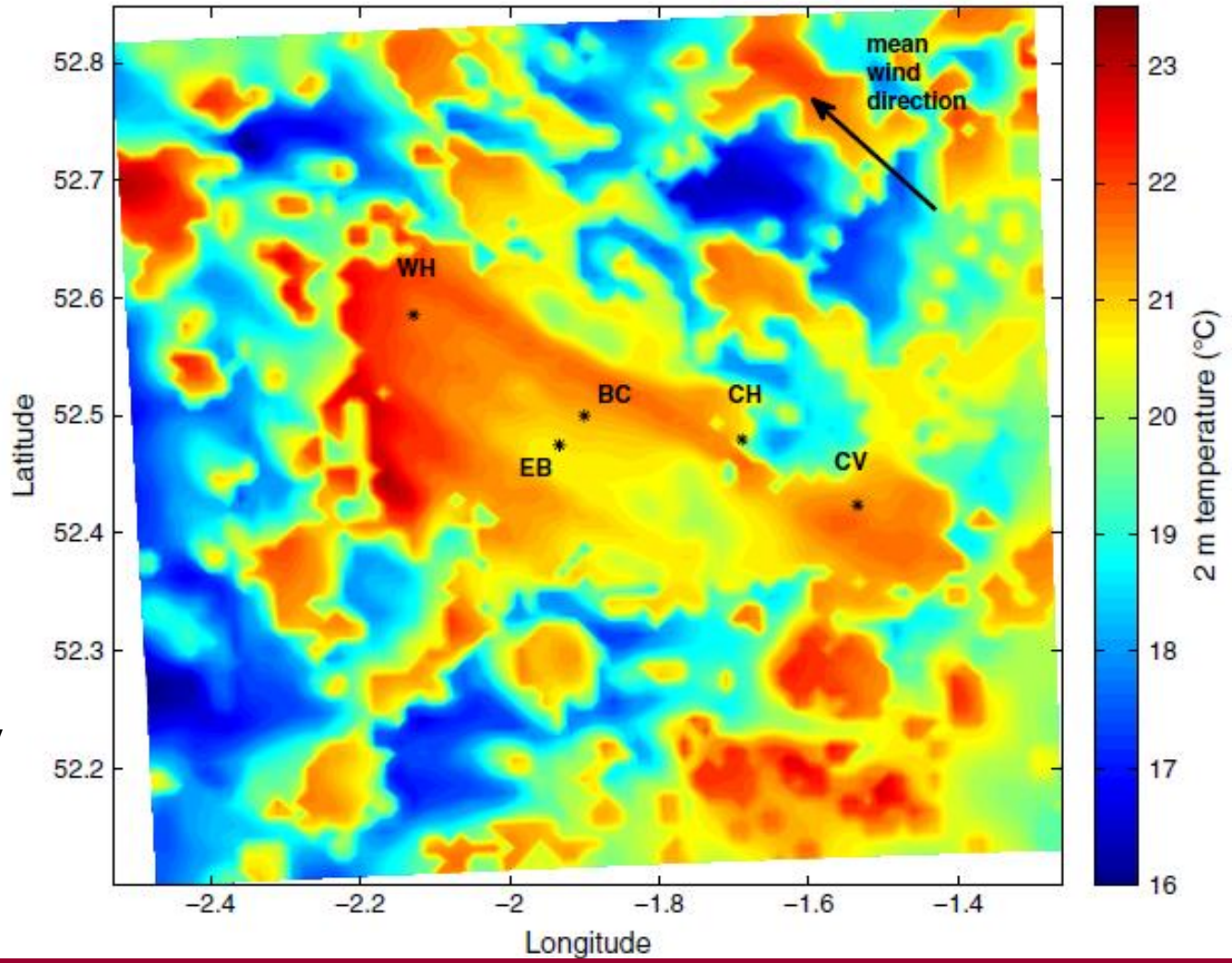
Geographical mean T = mean of all cells within domain (no pop info)

Population weighted T = summed (pop per cell x cell temp) / total domain pop

Public Health England

Urban Temperature: 'urban' model simulation

Snapshot:
11pm, 5th August 2003

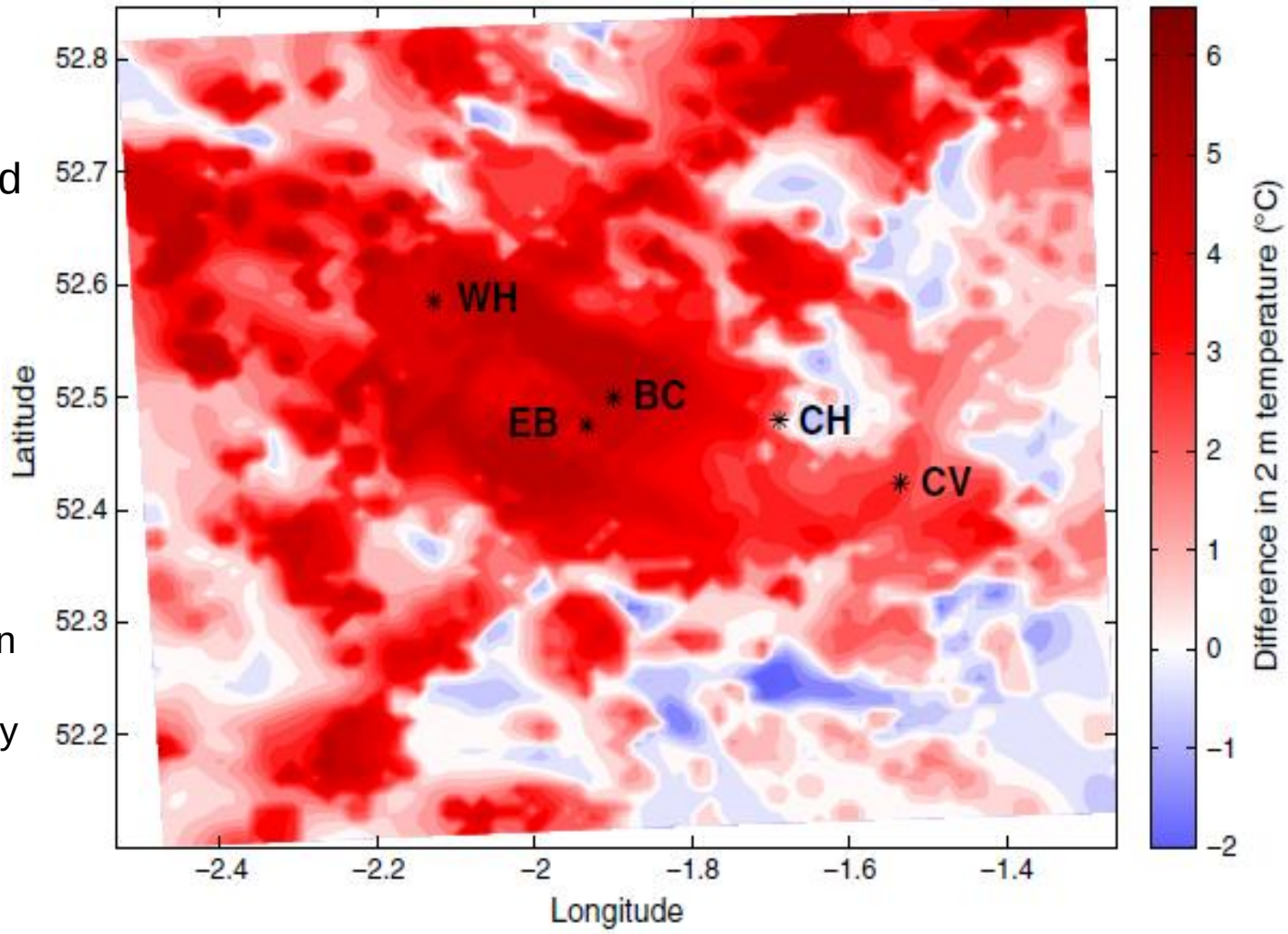


WH – Wolverhampton
EB – Edgbaston
BC – Birmingham City Centre
CH – Coleshill
CV – Coventry

Public Health England

UHI Intensity: urban – rural experiment

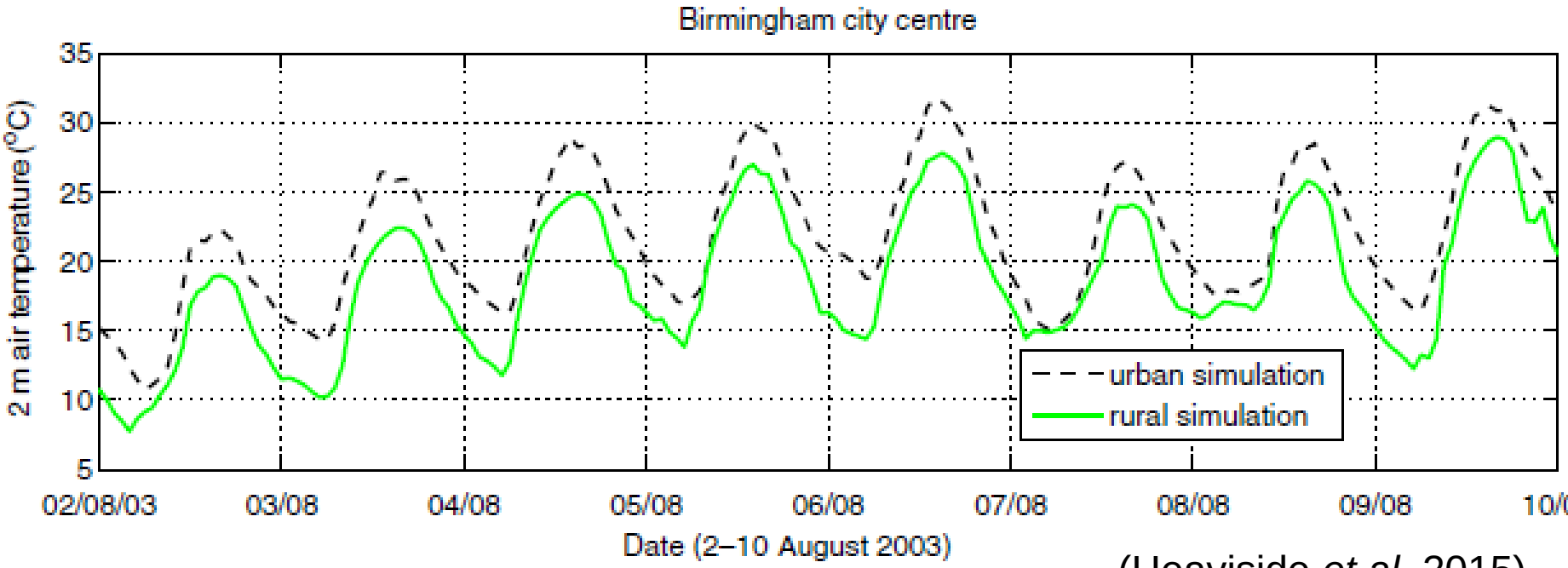
Difference in temperature between urban and rural model runs, 11pm, 5th August 2003



WH – Wolverhampton
EB – Edgbaston
BC – Birmingham City Centre
CH – Coleshill
CV – Coventry

Public Health England

Urban – rural experiment: UHI intensity in city centre



(Heaviside *et al.* 2015)

Birmingham City Centre:
ΔT (urban-rural) = 3.2°C (mean UHI intensity)
ΔT (urban-rural) = 5.6°C (max UHI intensity)

Public Health England

Health Impact Assessment results

HIA based on modelled 'urban' and 'rural' WRF simulations

Population weighted temperature is 1^{o}C higher than geog mean temperature

The UHI contributed around half (54%) of the total heat related mortality in the West Midlands during the heatwave of 2003. Heaviside *et al.* (in review)

	'Current' climate
	2003 heatwave mortality
'Urban' pop weighted	80
'Urban' geog mean	64
'Rural'	37

Public Health England

Health Impact Assessment results

HIA based on modelled 'urban' and 'rural' WRF simulations, plus climate change projections

Population weighted temperature is 1°C higher than geog mean temperature

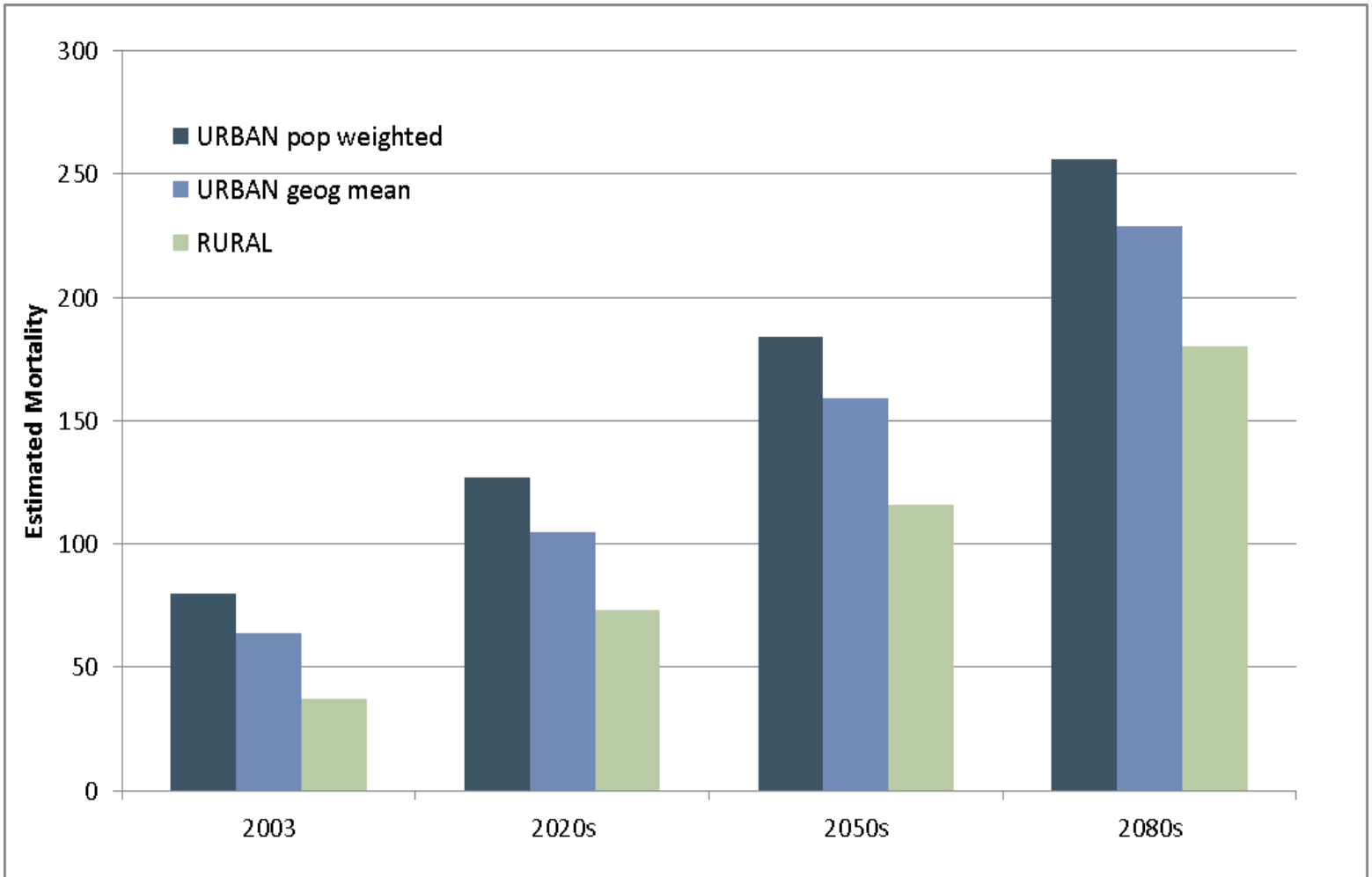
The UHI contributed around half (54%) of the total heat related mortality in the West Midlands during the heatwave of 2003. Heaviside *et al.* (in review)

	'Current' climate	Future Climate Projections (without pop growth)		
	2003 heatwave mortality	2020s	2050s	2080s
'Urban' pop weighted	80	127 (112)	184 (143)	256 (174)
'Urban' geog mean	64	105 (92)	159 (124)	229 (155)
'Rural'	37	73 (64)	116 (90)	180 (122)

Public Health England

HIA results – climate change

Estimated mortality based on HIA for 2003 heatwave, and for potentially similar heatwave events projected for 3 future decades, (medium emissions, with population growth).



Public Health England

Summary of HIA results

- According to simulations, the effect of urbanisation in the West Midlands was on average **~3ºC**, with max ΔT of **7ºC** during the 2003 heatwave (daily mean T)
- Population weighting of temperature data resulted in **+1ºC** for the region
- The 1st-10th August 2003 heatwave was associated with **80 additional deaths** in region
- Around **half (43) of these** were associated with the UHI intensity
- Climate projections suggest a similar heatwave in 2080 could result in **~260 deaths**

Implications for HIA methodology:
A HIA based on geographic mean temperature **underestimated mortality by 20%**

A HIA without urban surfaces (no UHI) **underestimated mortality by 54%**

To account for all future effects:
include population weighting and UHI as well as climate and population projections

Public Health England

Thank you

Clare.heaviside@phe.gov.uk

Public Health England

Bibliography

Hajat, S., Vardoulakis, S., Heaviside, C. and Eggen, B. (2014) Climate change effects on human health: projections of temperature-related mortality for the UK during the 2020s, 2050s, and 2080s. *Journal of Epidemiology & Community Health.* **68** (7), 641-648.

Heaviside C., Cai, X.-M., Vardoulakis, S. (2015). The effects of horizontal advection on the Urban Heat Island in Birmingham and the West Midlands, UK during a heatwave. *Quarterly Journal of the Royal Meteorological Society.* **141**, 1429–1441.

Heaviside C., Cai, X.-M., Vardoulakis, S. (under review) The contribution of the Urban Heat Island to heat related mortality during the 2003 heatwave and for projected future climate in the West Midlands, UK. *Journal of Environmental Health*

Johnson, H., Kovats, R.S., McGregor, G., Stedman, J., Gibbs, M. and Walton, H. (2005) The impact of the 2003 heat wave on daily mortality in England and Wales and the use of rapid weekly mortality estimates. *Euro surveillance : bulletin européen sur les maladies transmissibles. European communicable disease bulletin.* **10**(7), 168-171.

Robine, J.-M., Cheung, S.L.K., Le Roy, S., Van Oyen, H., Griffiths, C., Michel, J.-P. and Herrmann, F.R. (2008) Death toll exceeded 70,000 in Europe during the summer of 2003. *Comptes Rendus Biologies* **331**(2), 171-178.

Vardoulakis, S. and Heaviside, C. [eds.] (2012) *Health Effects of Climate Change in the UK 2012 – Current evidence, public health recommendations and research gaps.* Health Protection Agency, Centre for Radiation, Chemical and Environmental Hazards, UK. ISBN:978-0-85951-723-2.

Public Health England

Title