Semi-idealised urban heat advection simulations using the Weather Research & Forecasting mesoscale model

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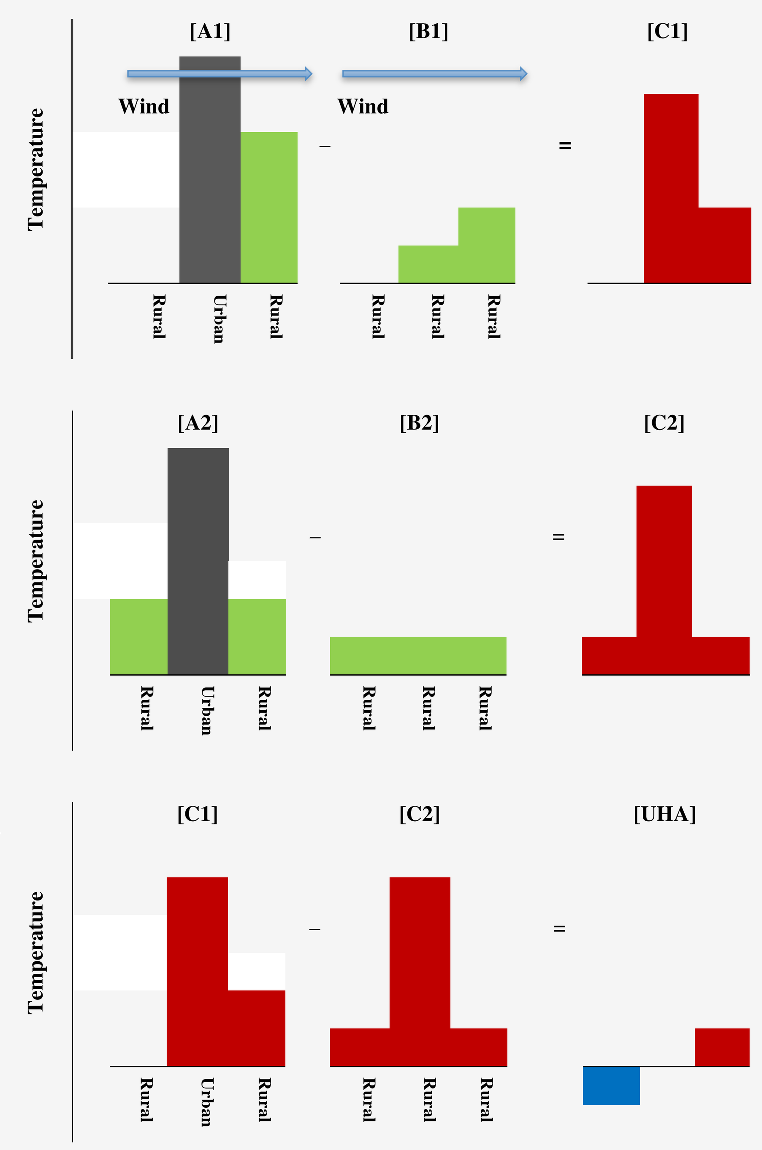
1. Background

- Although urban heat islands (UHI) are a well-studied phenomenon, their dynamic nature, i.e. warm urban air advected downwind, is rarely considered. Urban heat advection (UHA) not only intensifies well-documented heat island impacts on health and infrastructure, but also challenges the representativeness of long-term temperature records taken near urban areas.

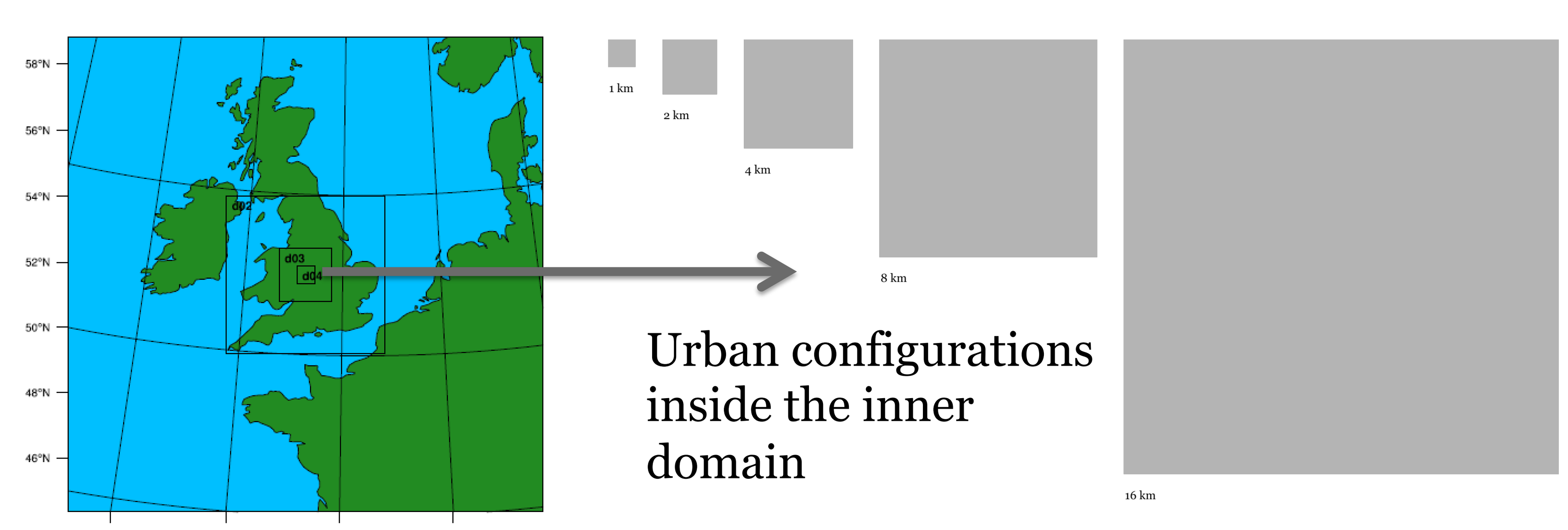
2. Hypothetical UHA calculation

- A methodology to separate UHA from background temperatures has been developed (Heaviside et al. 2015; Bassett et al. 2016).Here the time-mean UHI field is subtracted from the time-mean UHI field for a particular wind direction.
- Diagrams named with [A] relate to the idealised urban simulations and [B] rural.
- In the top diagram the directional (wind left to right) heat pattern from the urban simulation is subtracted from the rural simulation. This leaves the directional UHI pattern [A1 – A2 = A3].
- The middle diagram presents the same calculation but considering the mean of all wind directions (i.e. wind from left and right) [A2 – B2 = C2].
- The bottom diagram shows the results from the top and middle diagrams subtracted from one another, and the resulting pattern is this the UHA, free from any local and regional effects [C1 – C2 = UHA].



3. BEAR simulations

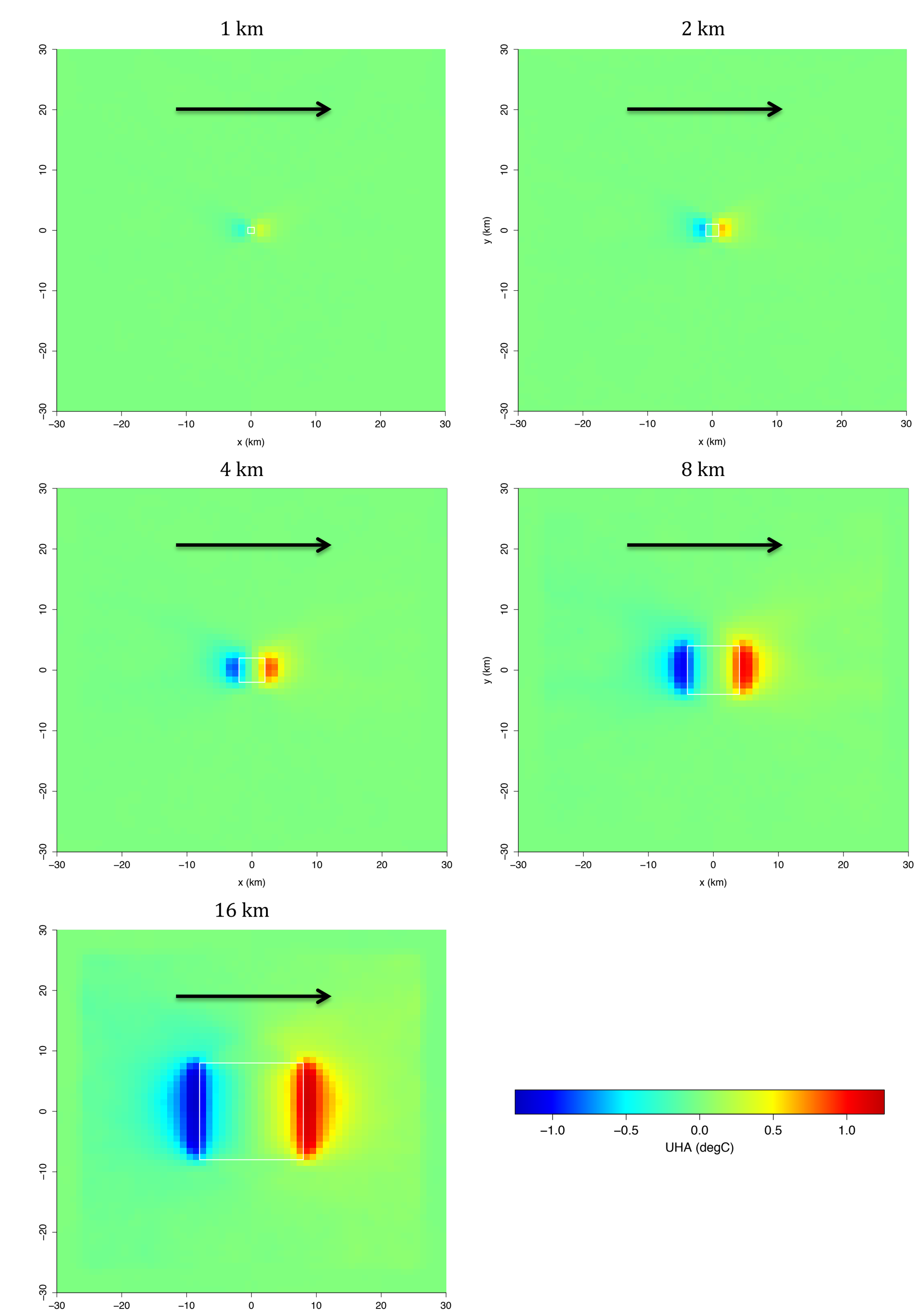
- Weather Research and Forecasting (WRF) version 3.8 coupled with the Building Effect Parameterization (BEP) urban scheme is used to simulate meteorological fields for an idealised range of simple, hypothetical urban areas (1, 2, 4, 8, 16 km) centred in the middle of a 60 x 60 km domain Each urban size is run over 6 case studies of real meteorology in summer 2013 and 2014. (over 1600 hours of stable night-time conditions). Using 16 cores on each of 2 nodes this takes approximately an hour for 24 hours of simulation.

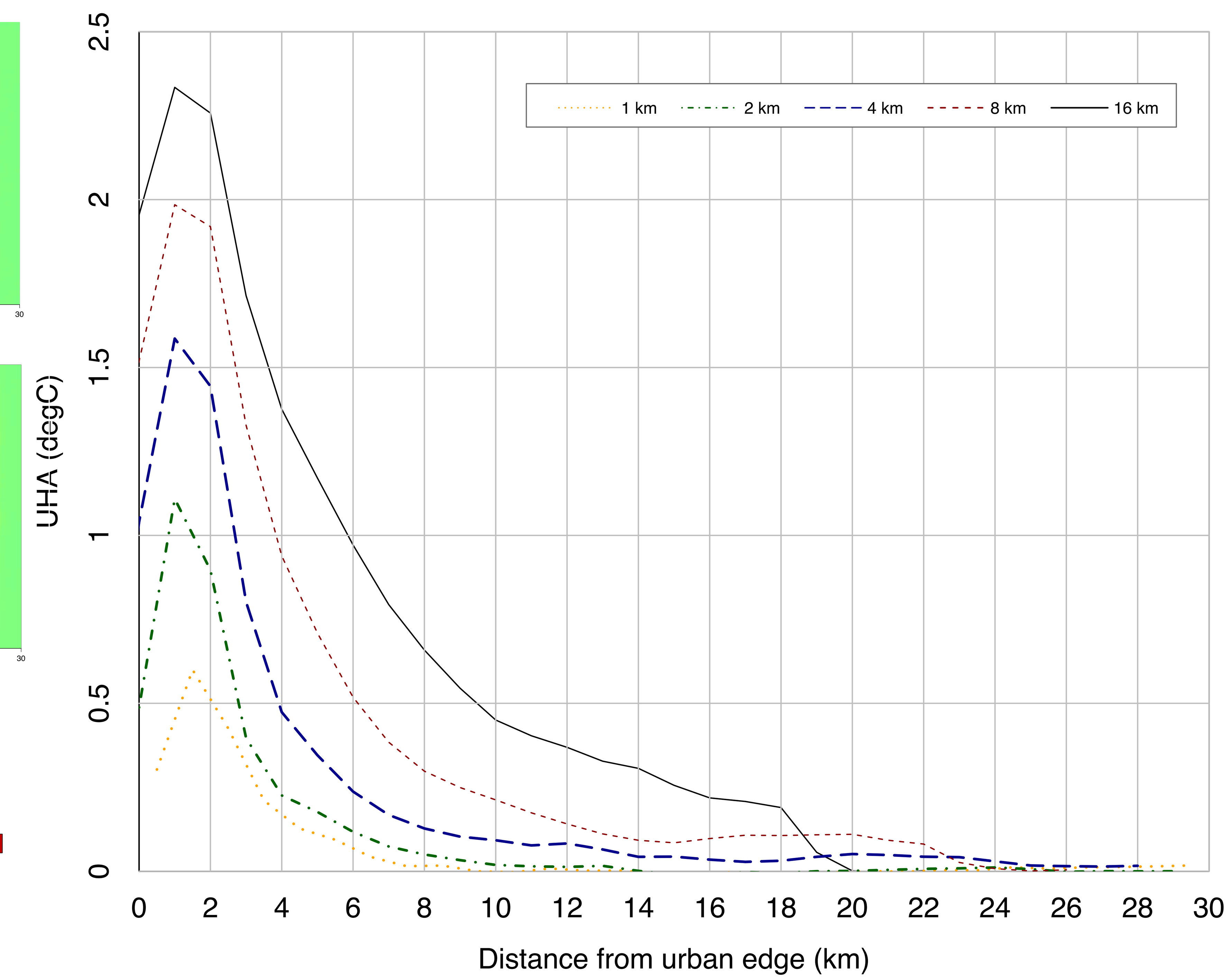


Urban configurations inside the inner domain

4. Results

- Similar to the hypothetical UHA calculation, WRF semi- idealised simulations show a positive downwind and negative upwind temperature anomaly.
- Taking a cross section through each plot UHA plot from the urban edge, UHA is interpreted as the difference between negative and positive values. For a urban size of 16 km, UHA up to 2.3ºC is found in the adjacent rural grid cell, before declining rapidly. However a UHA of 0.5ºC can still be found up to 10 km downwind.





5. Conclusions

- These results offer a significant improvement over existing quantifications of UHA, as complex urban patterns that previously masked and make UHA difficult to interpret have been simplified.
- UHA is related to city size, and even small urban areas have a large UHA signal. Peak UHA (up to 2.3ºC for a 16 km urban size) occurs in the rural grid cell nearest the urban edge.
- Further work is being conducted to create a predictive UHA tool from these results.

6. References

- Bassett R, Cai X, Chapman L, Heaviside C, Thornes JE, Muller CL, Young DT, Warren EL. 2016. Observations of urban heat island advection from a high-density monitoring network. *Quarterly Journal of the Royal Meteorological Society* **142**: 2434 – 2441, doi:10.1002/qj.2836.
- Heaviside C, Cai X-M, Vardoulakis S. 2015. The effects of horizontal advection on the urban heat island in Birmingham and the West Midlands, United Kingdom during a heatwave. *Quarterly Journal of the Royal Meteorological Society* **141**: 1429–1441, doi:10.1007/s10546-012-9705-x.