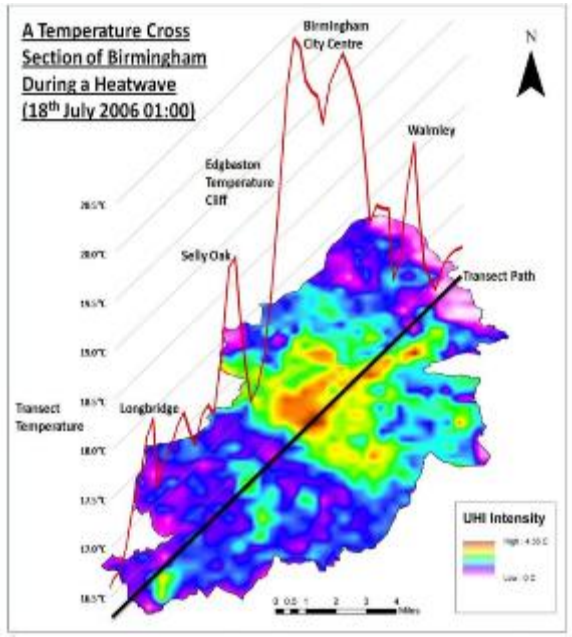
Building Urban Climate Resilience: An Urban Observatory Approach



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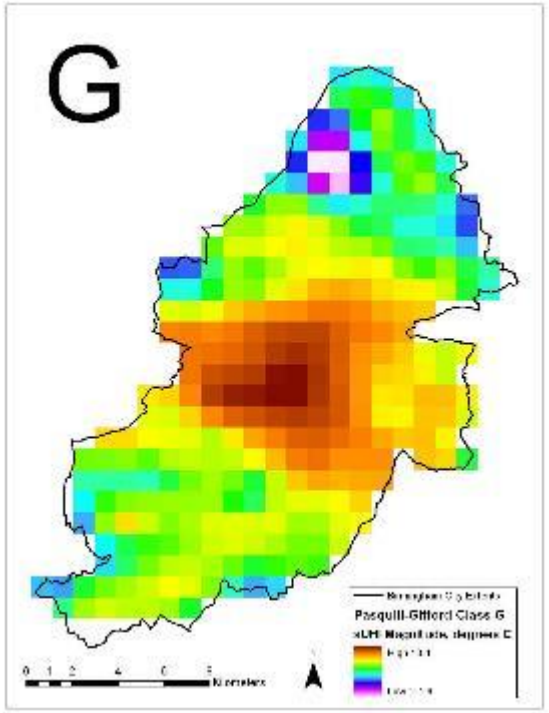
Urban Heat: a perspective

- Urban areas are remarkable concentrations of both people and infrastructure
- Urban heat is a big problem:
  - Cities can be up to 10°C warmer than their surroundings
  - Caused by unintentional climate modification in cities by humans
  - Problems particularly acute during heatwave events and has led to many deaths
- Urban Heat presently not accounted for in climate change models...
- ...but the impact is already far greater than climate change
- Climate change will further exacerbate the issue.
- This has significant implications for the resilience of our urban infrastructure...



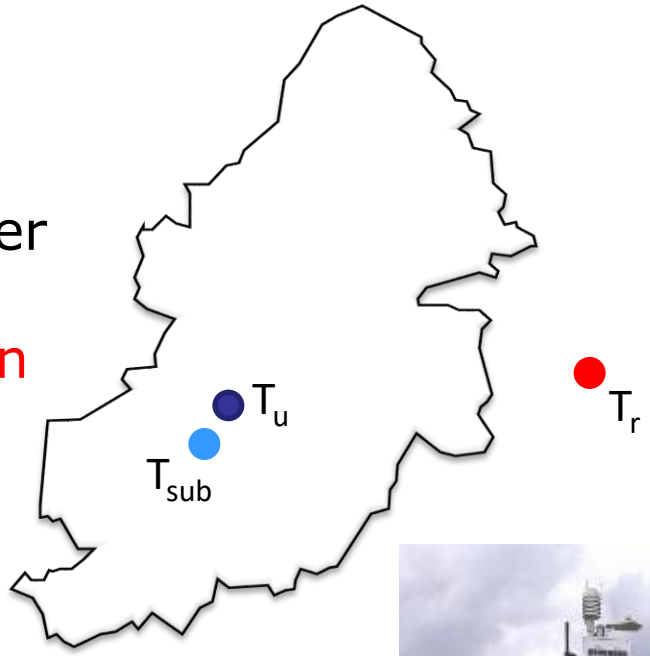
Critical Infrastructure Networks

- Critical Infrastructure can include:
  - Education
  - Healthcare
  - Transport
  - Utilities
  - Communications
- Cities are key nodes for national infrastructure networks.

- Are the critical infrastructure networks of a major mid-latitude city resilient to the impacts of increasing levels of urban heat?
  - Electricity networks are less efficient at higher temperatures. Life expectancy is reduced and brownouts are increasingly likely.
  - Transport networks have different impacts on different nodes. For example, rail buckling and road deterioration.
  - Telecommunication networks are quite resilient, but not without issues....

What was HiTemp?

- £750k project funded by NERC under the NERC networks of sensors call
- Aim was to provide a high resolution demonstration sensor network initially designed to measure air temperature across the morphologically heterogeneous Birmingham conurbation
- Air temp mapped at a scale not previously possible (previously 1 'urban' station, 1 'sub-urban' and 1 'rural' station).
- The design is a nested network of sensors:
  - 25 full weather stations [coarse array]
  - 84 low cost air temperature sensors located in schools [wide array]



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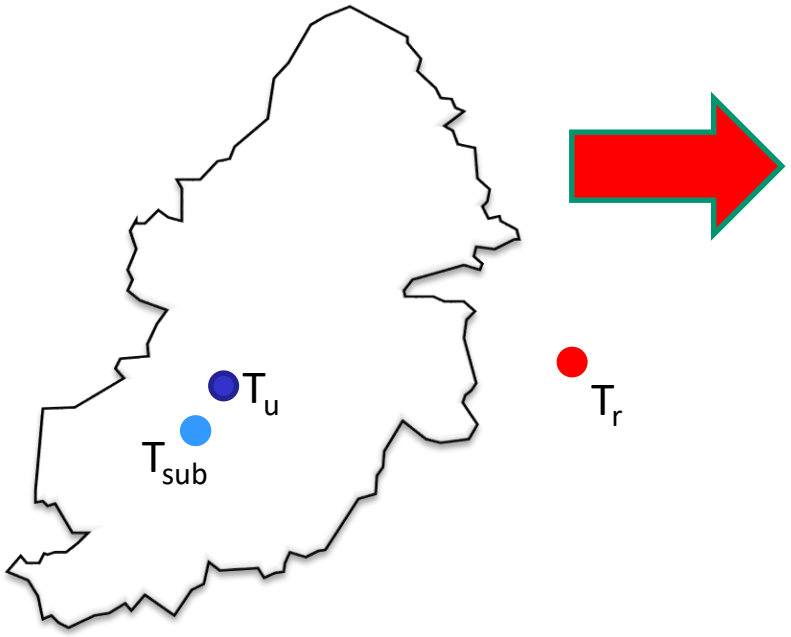
Birmingham Urban Climate Laboratory



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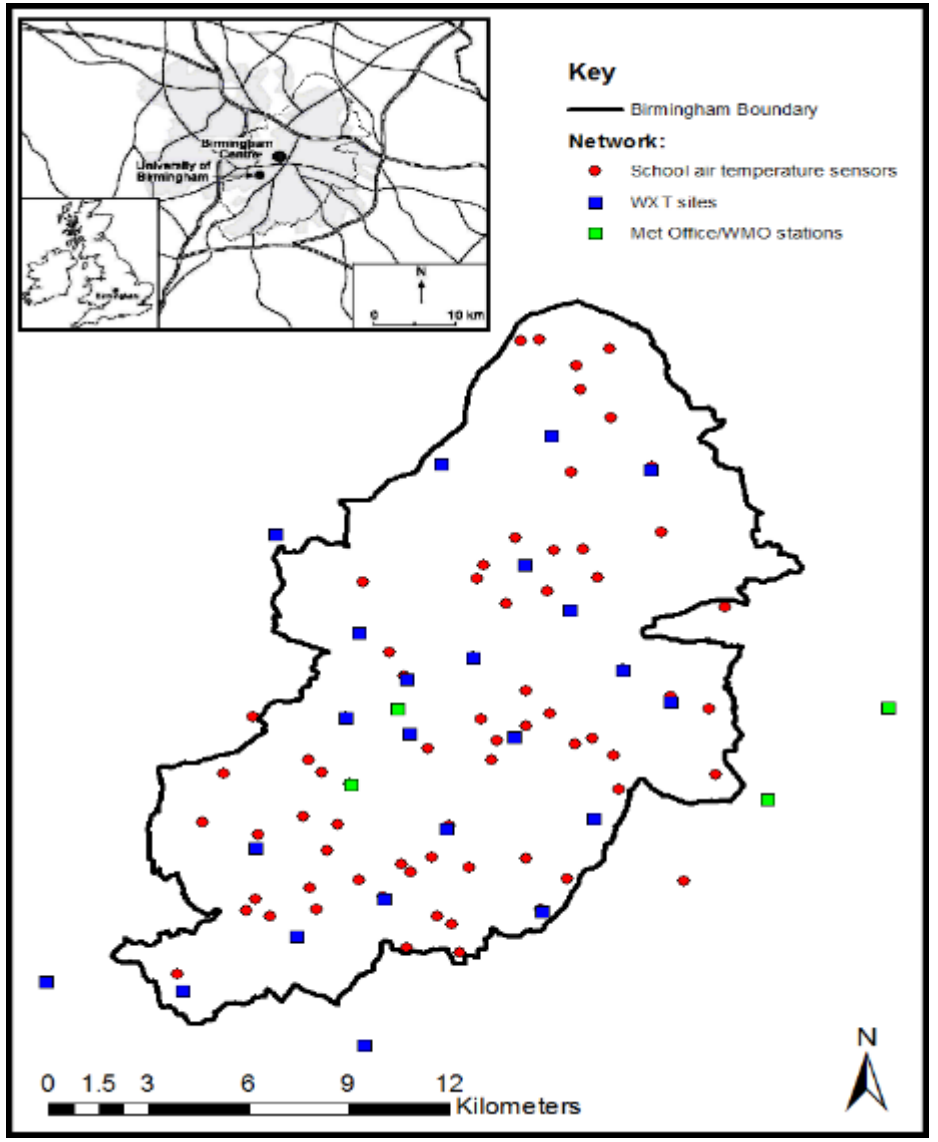

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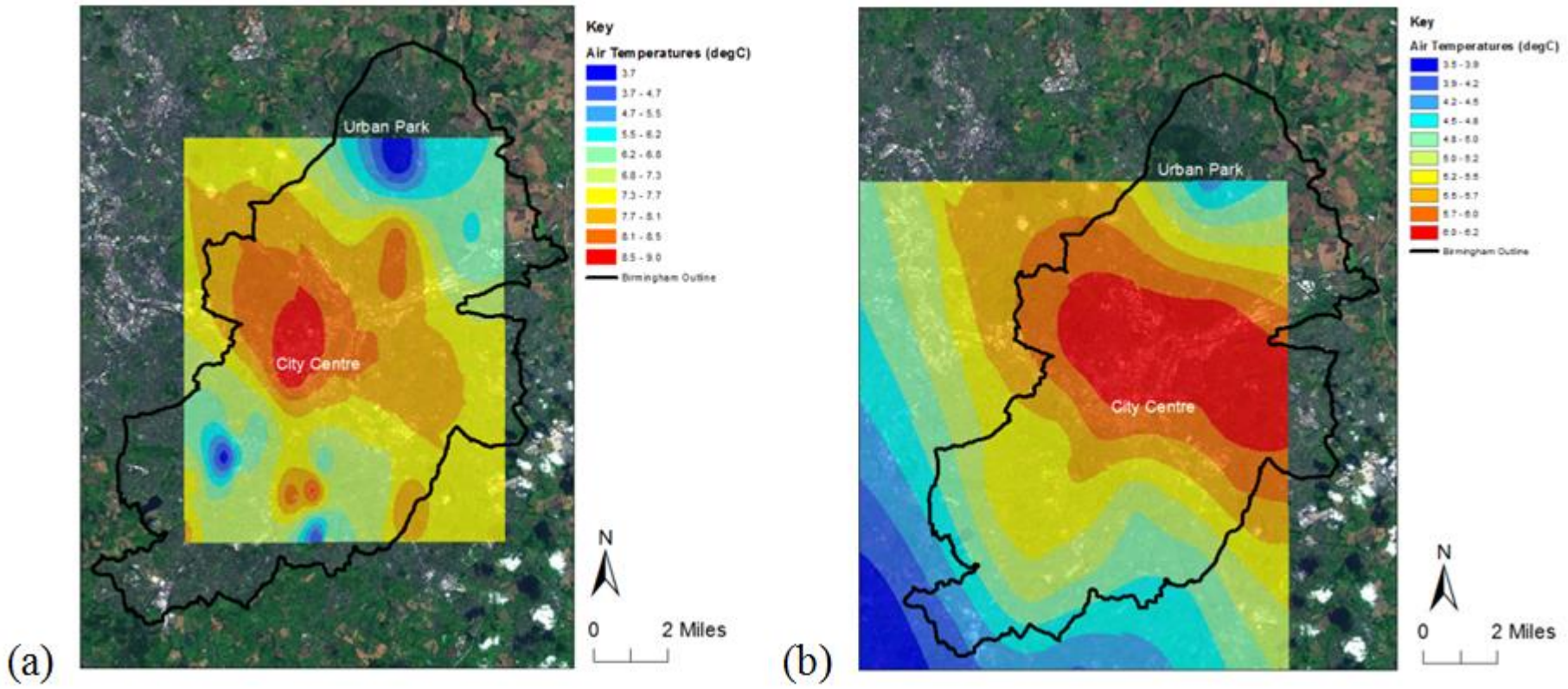

Chapman, L., *Muller, C.L., *Young, D.T., *Warren, E.L., Grimmond, C.S.B, Cai, X-M., *Ferranti, E.J.S. (2015) The Birmingham Urban Climate Laboratory: An open meteorological testbed and challenges of the smart city. *Bulletin of the American Meteorological Society* **96**:1545-1560

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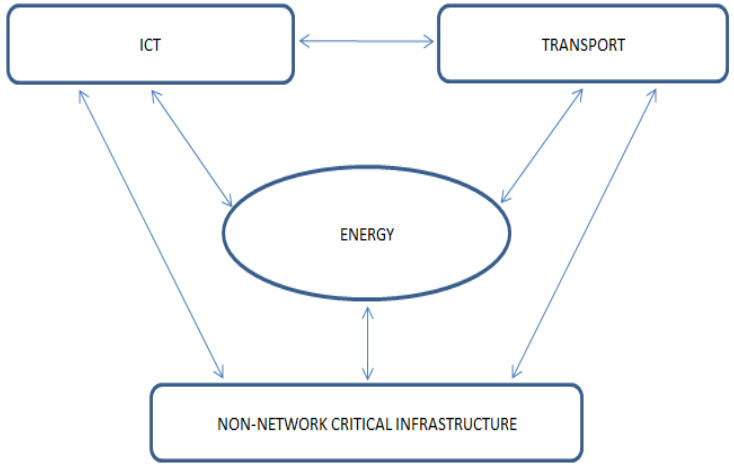
Electricity Network

- Two factors influence transformer temperature and life expectancy:
  - Loading
  - Ambient temperatures
- The IEC standards document states: *"Wind, sunshine and rain may affect the loading capacity of distribution transformers, but their unpredictable nature makes it impracticable to take these factors into account."*

- Climate and technological change are combining to create a perfect storm: Higher temperatures, more refrigeration / air con
  Life expectancy halves for every 6°C increase in transformer temperature above 98°C = rapid decline!
- Due to the age of distribution transformers, work at the University of Birmingham showed all will need replacing by 2050

Critical Infrastructure Networks

- The electricity network is the crucial network as all other networks are becoming increasingly reliant on it to power their networks:
  - Electrification of transport
  - ICT
  - Other (non network) critical infrastructure



- A failure on this network could cascade across all other critical infrastructures...
- Similarly a failure on one of the other networks could quickly cascade onto the energy network (system of systems):
  - Smart Grids (ICT)
- Often local problems - We need more high resolution monitoring on our infrastructure networks

Chapman, L., *Azevedo, J.A. & *Prieto-Lopez, T. (2013) Urban heat and critical infrastructure networks. *Urban Climate* **3**:7-12

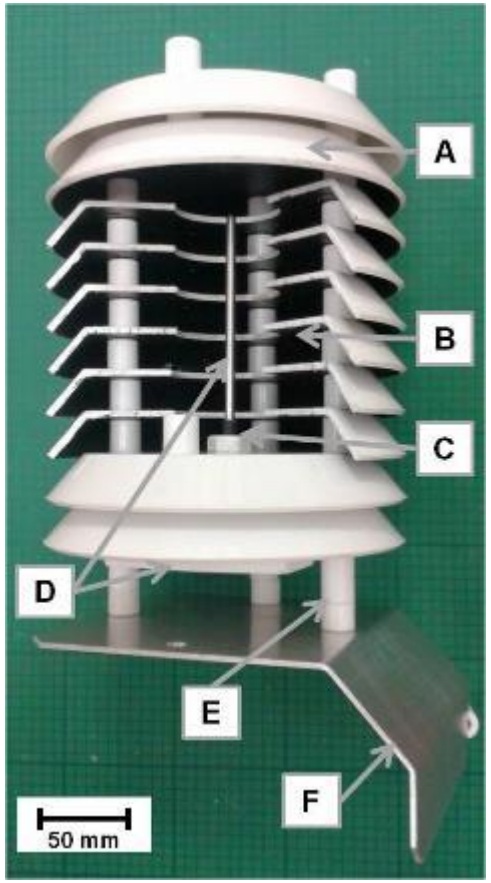
The Internet of Things

- Literally means things that connect to the internet
  - Computers
  - Smart Phones
  - Curtains, lights, central heating...
  - Sensors
- Since 2008, these things now outnumber users online

- Lots of potential via the smart cities agenda
  - Miniaturisation of technology
  - Decreasing cost of sensor networks

Low Cost Air Temperature Sensors

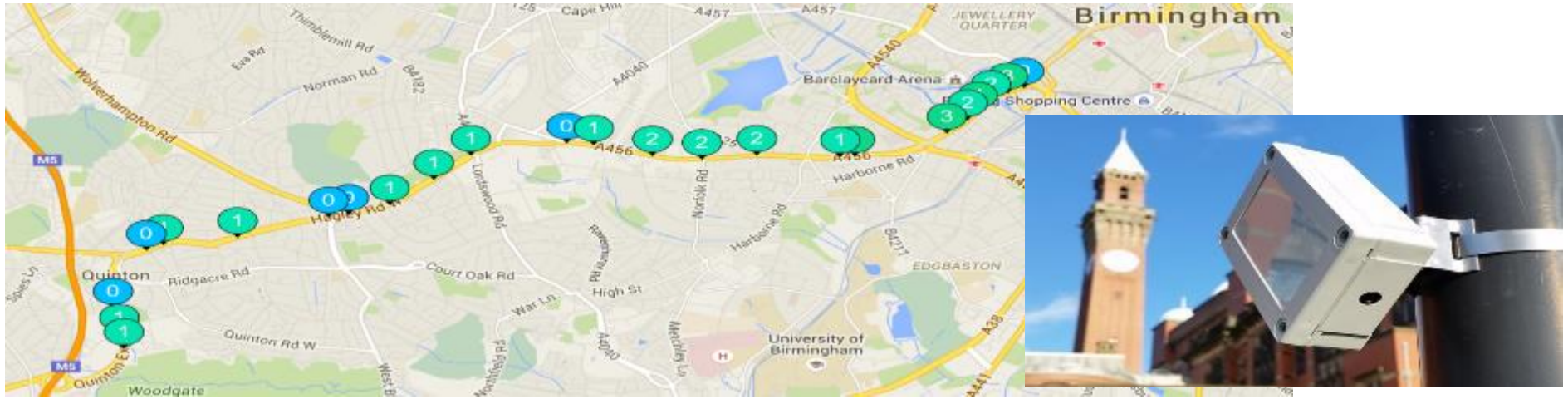
- Bespoke self contained air temperature sensor was designed to produce a high resolution network across Birmingham:
  - 10kΩ Negative Temperature Coefficient Thermistor
  - Bespoke radiation shield
  - Comms provided via a wireless communication card
  - Power provided from a Lithium-Thionyl Chloride battery which last for 3 years under ideal conditions
  - Very cheap - £87!
  - Tested at UKMO calibration lab with an absolute error of ±0.22°C
- Can be deployed anywhere where there is a WiFi network
- A good example of a low cost thing in the IoT
  - No ongoing costs for communication / power
  - Cheap to install in a large network
  - Has led to a number of successful 'spin-off' projects condition monitoring infrastructure



*Young, D.T., **Chapman, L.,** *Muller, C.L., Grimmond, C.S.B., Cai, X. (2014) Evaluating the performance of a 'low-cost' wireless temperature sensor. *Journal of Atmospheric & Oceanic Technology* **31**:938-944

*winter**sense** is an EPSRC project, co-created with Amey, that is adapting the technology to measure road surface temperatures for gritting applications.*

- Thermistor replaced with a low cost IR thermopile sensor.
- Sensors relay data back to central server using existing city-wide Wi-Fi installed by Amey
- High resolution network quantifies thermal variations around the road network (up to 20°C on a marginal night)
- Save money by selective salting and dynamic routing



Chapman, L. & Bell, S.J. (2016) Low-cost, Road Surface Temperature sensing enabled by the Internet of Things. *Proceedings of the 18th SIRWEC Conference, 28th-30th April 2016, Fort Collins, Colorado*

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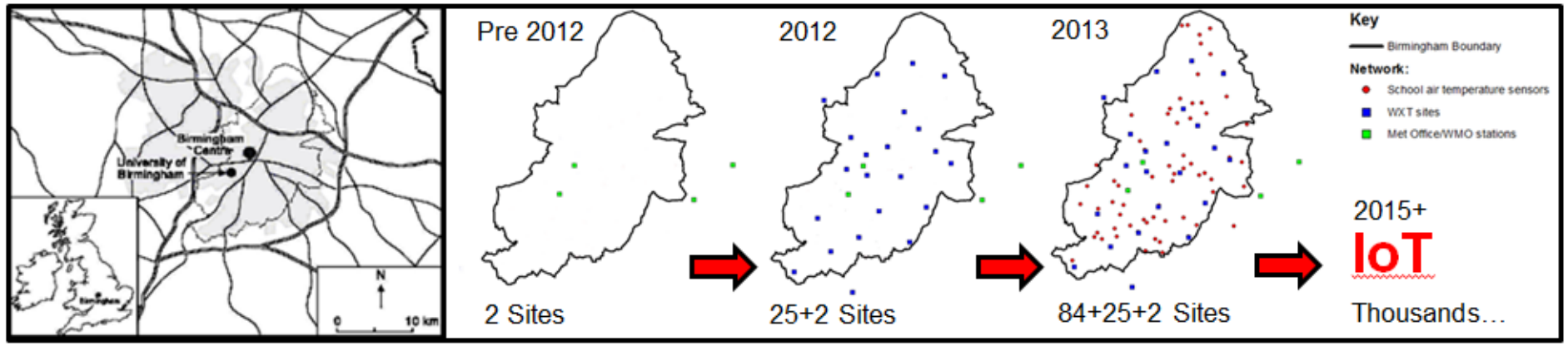
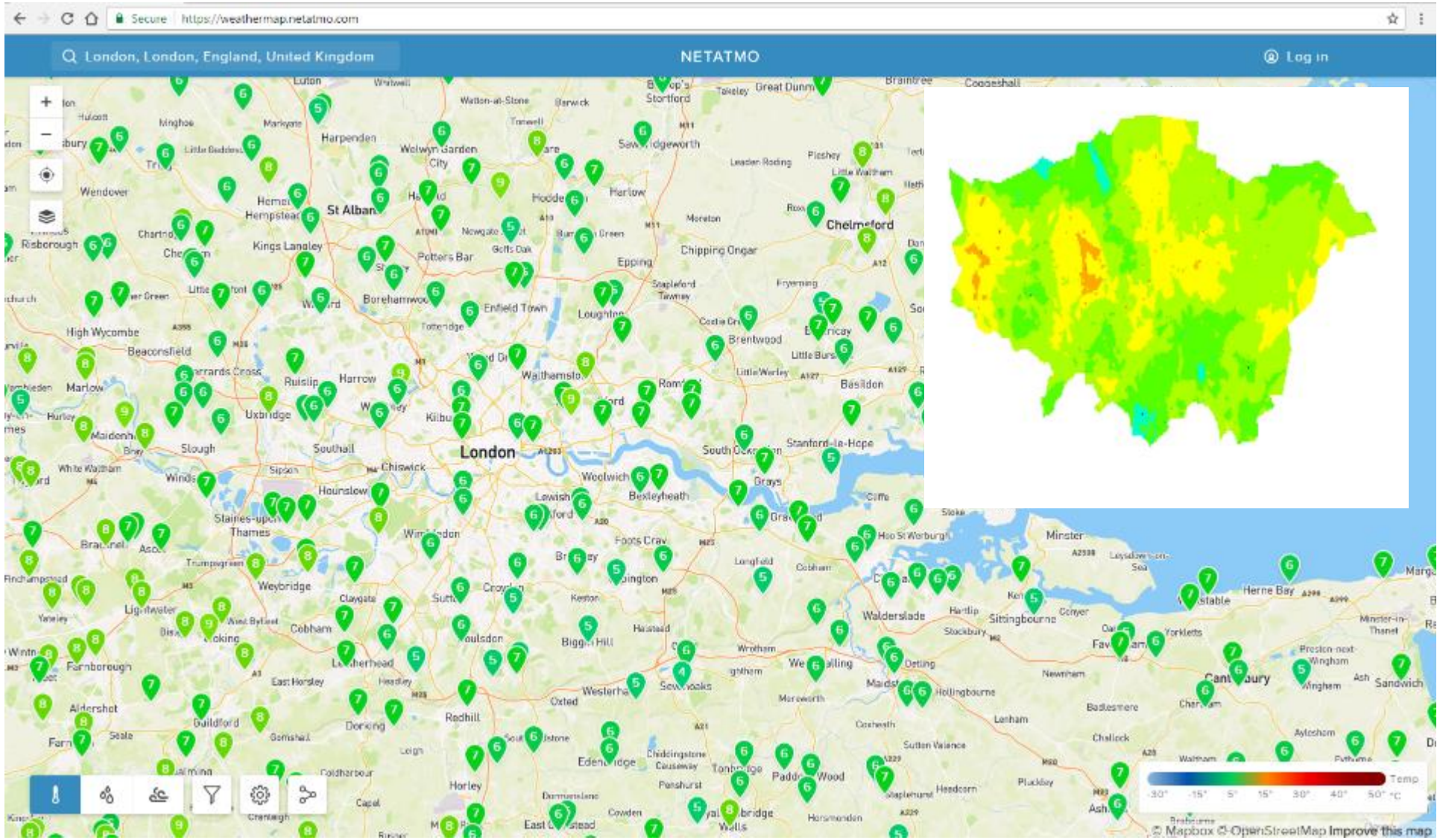
BUCL v2

- Weather monitoring has come a long-way since the use of a single weather site for each urban area
- Birmingham: 1 site > 4 sites > 25+84 > 1000s!?



- Only ran for 2 years. Run out of money and increasing numbers of sensors become quickly unsustainable.
- Some challenges:
  - Technology doesn't stand still (BUCL was built on WiFi!)
  - Which communication network!?
  - Power issues
  - Maintenance and calibration
  - Few users for 'generic' weather data
- What other approaches can we use?

Crowdsourcing in London



Chapman, L., *Bell, C., *Bell, S. (2017) Can the crowdsourcing data paradigm take atmospheric science to a new level? A case study of the Urban Heat Island of London quantified using Netatmo weather stations. *International Journal of Climatology*

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The Urban Observatory Approach

UKCRIC

£12m project spanning six cities across the UK:

- Newcastle, Sheffield, Bristol (Phase 1)
- Birmingham, Manchester, Cranfield (Phase 2)

- Broader Approach:
  - Assimilate real-time data (both structured and unstructured) with other live feeds (e.g. mobile phone data, health tracker data)
  - Distributed networks + supersites
  - Focus for Birmingham is weather and air quality
    - Foundation is the Birmingham Urban Climate Lab
    - Other infrastructure monitoring planned
  - System systems thinking: providing the data to balance engineering, natural and social systems

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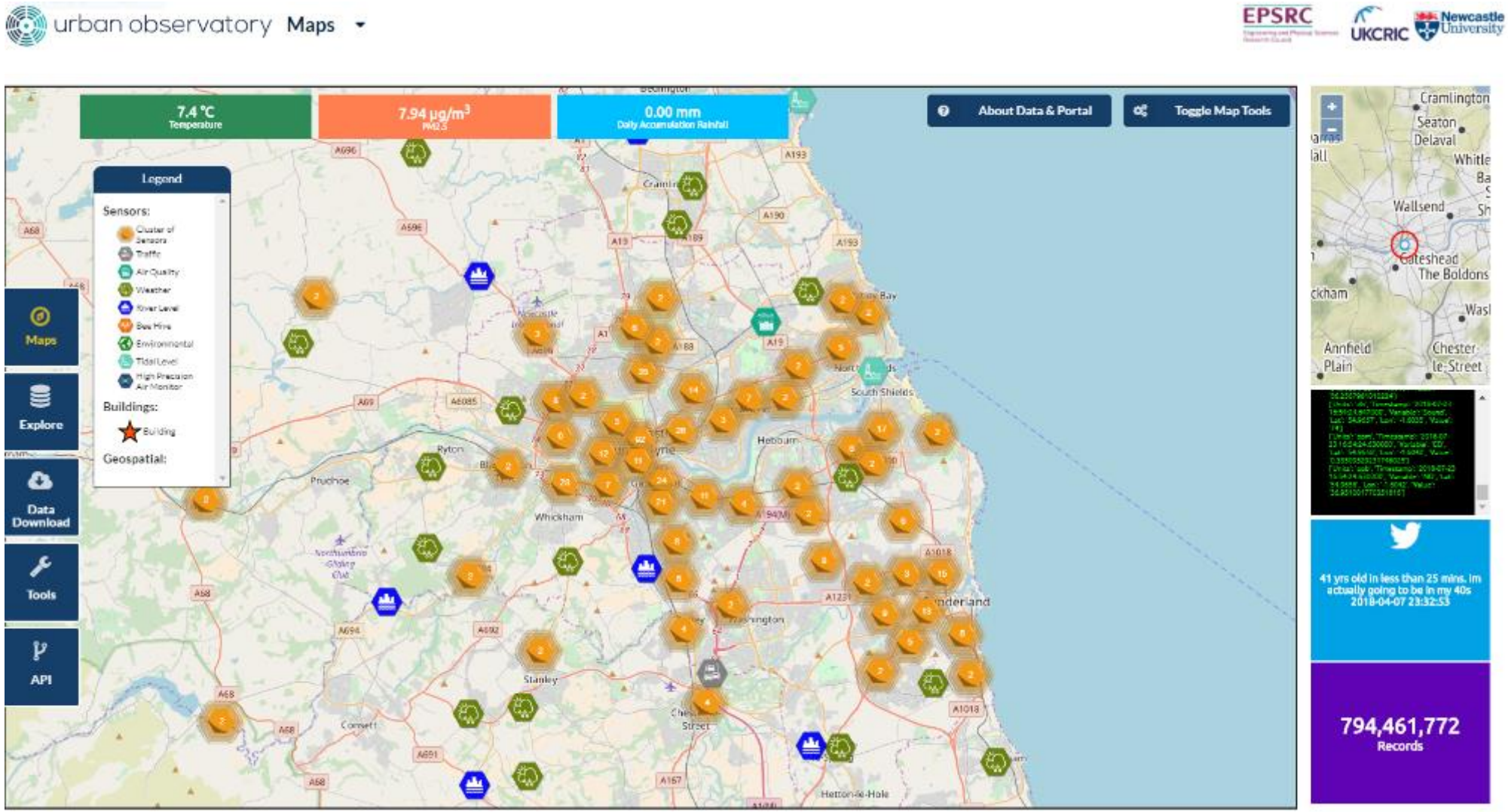
The Urban Observatory Approach



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