High resolution Numerical Weather Prediction of the urban boundary layer – a comparison with observations for London, UK

ACTUAL

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Thanks to: John Lally, Rosie Wilson, Mark Stringer for technical support

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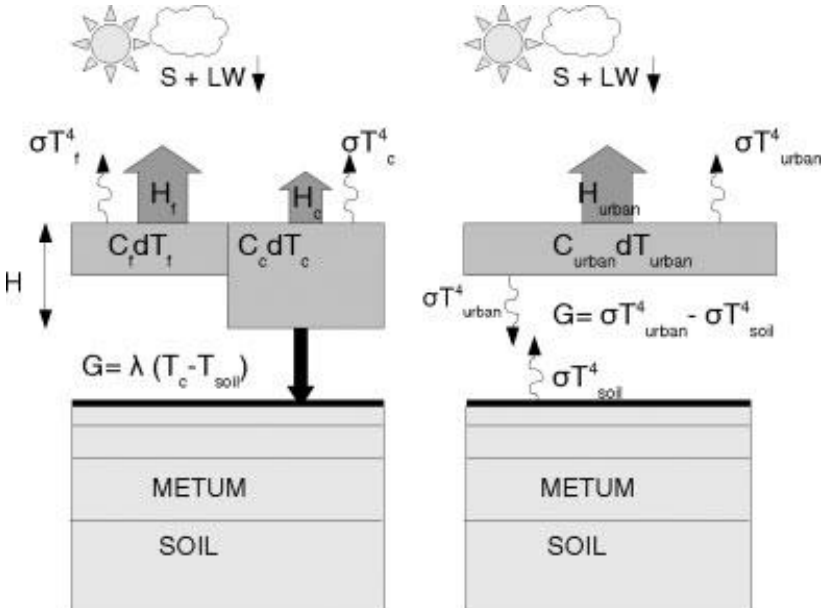
UK Met Office Unified model: representation of urban surfaces in the UKV

- Separate roof and canyon tiles
- Accounts for in-canyon radiation exchange
- Roof thickness and canyon dimensions can be altered to suit local morphology



MORUSES (operational Nov 2015)

(Porson et al. 2010)

Best scheme (operational)

(Best 2005)

- Single 'slab' with defined roughness and heat capacity
- Radiatively coupled with soil (like a vegetation canopy)
- Simpler to implement

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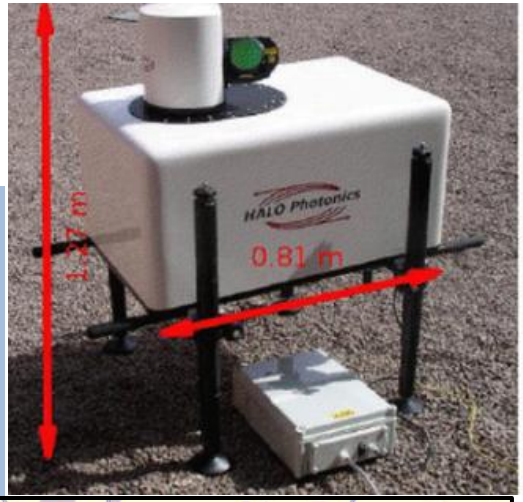
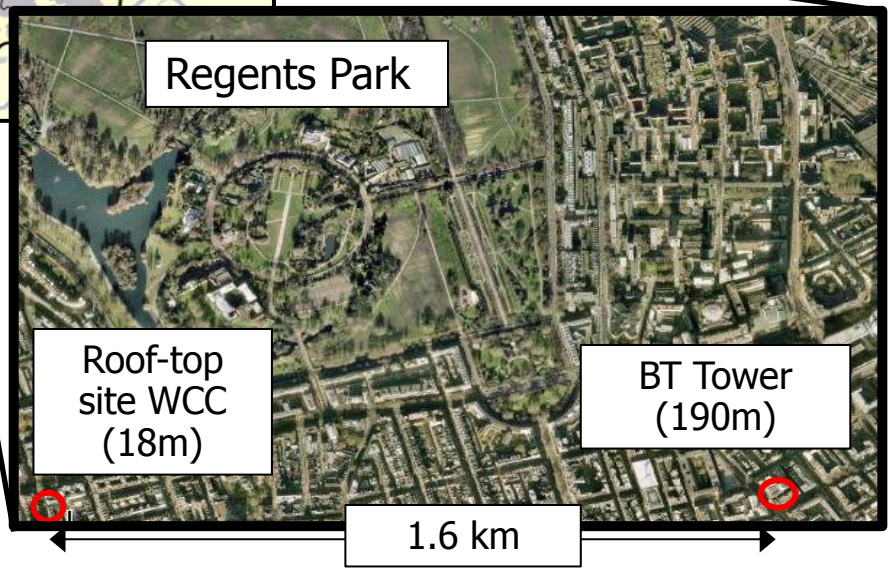
Met Office

ACTUAL Measurements



- Doppler lidar (Halo Photonics) in London and Chilbolton
- Eye-safe (1.5 μm)
- Gate length 30m (36m Ch)
- Integration time: 3.6s (40s Ch)
- Scan pattern (L): vertical stare, Doppler Beam Swinging



- Sonic anemometer (Gill R3-50)
- Weather station (Vaisala WXT520)
- Solar radiation (Kipp and Zonen CNR4)
- Hygrometer/CO_2 (Licor 7500)

Data at **www.actual.ac.uk**

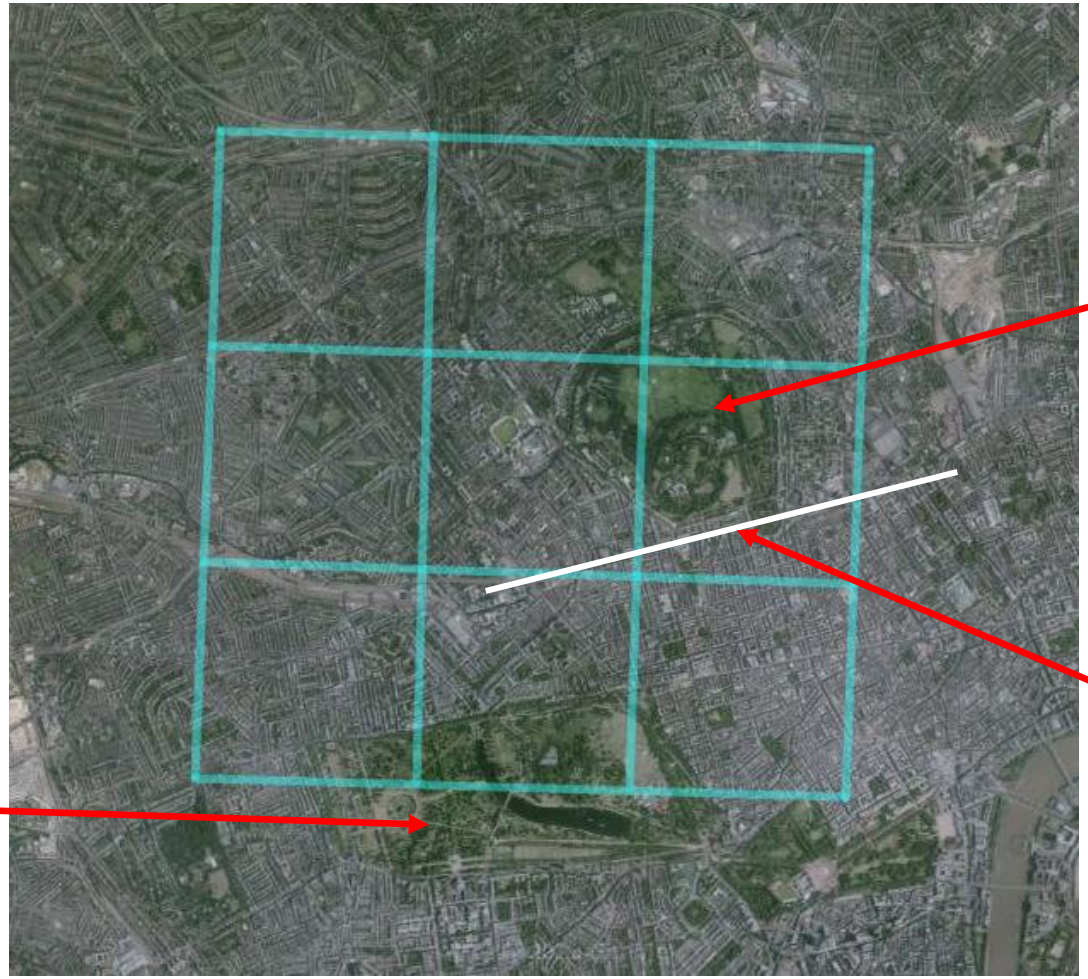
- WCC April 2010 to May 2013
- BT 2010 to present

Testing different model configurations

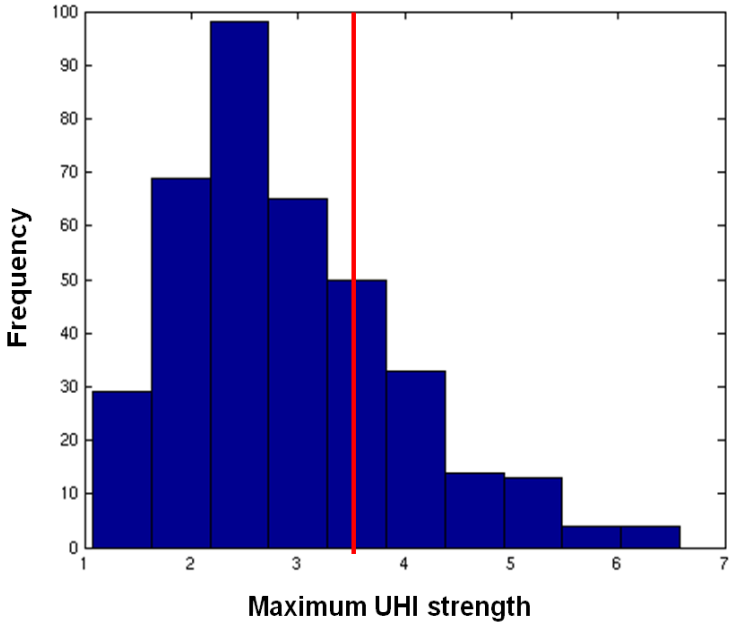
- UK Met Office **Unified Model** 5.2 onwards
- Non-hydrostatic, deep atmosphere dynamics; semi-implicit, semi-Lagrangian numerical scheme (Davies et al. 2005)
- 76 vertical levels up to 40km, 16 up to 1 km (quadratic distribution)
- JULES tiled surface scheme (Best et al. 2011), **1D boundary layer scheme** (Lock et al. 2000), mixed phase cloud microphysics (Wilson and Ballard 1999)

(1) Operational model (1.5 km) with urban slab model
(2) Operational model (1.5 km) with street canyon urban scheme
(3) High resolution simulation (100 m) with urban slab model

(1) Operational model
Met Office UKV 1.5 km model grid



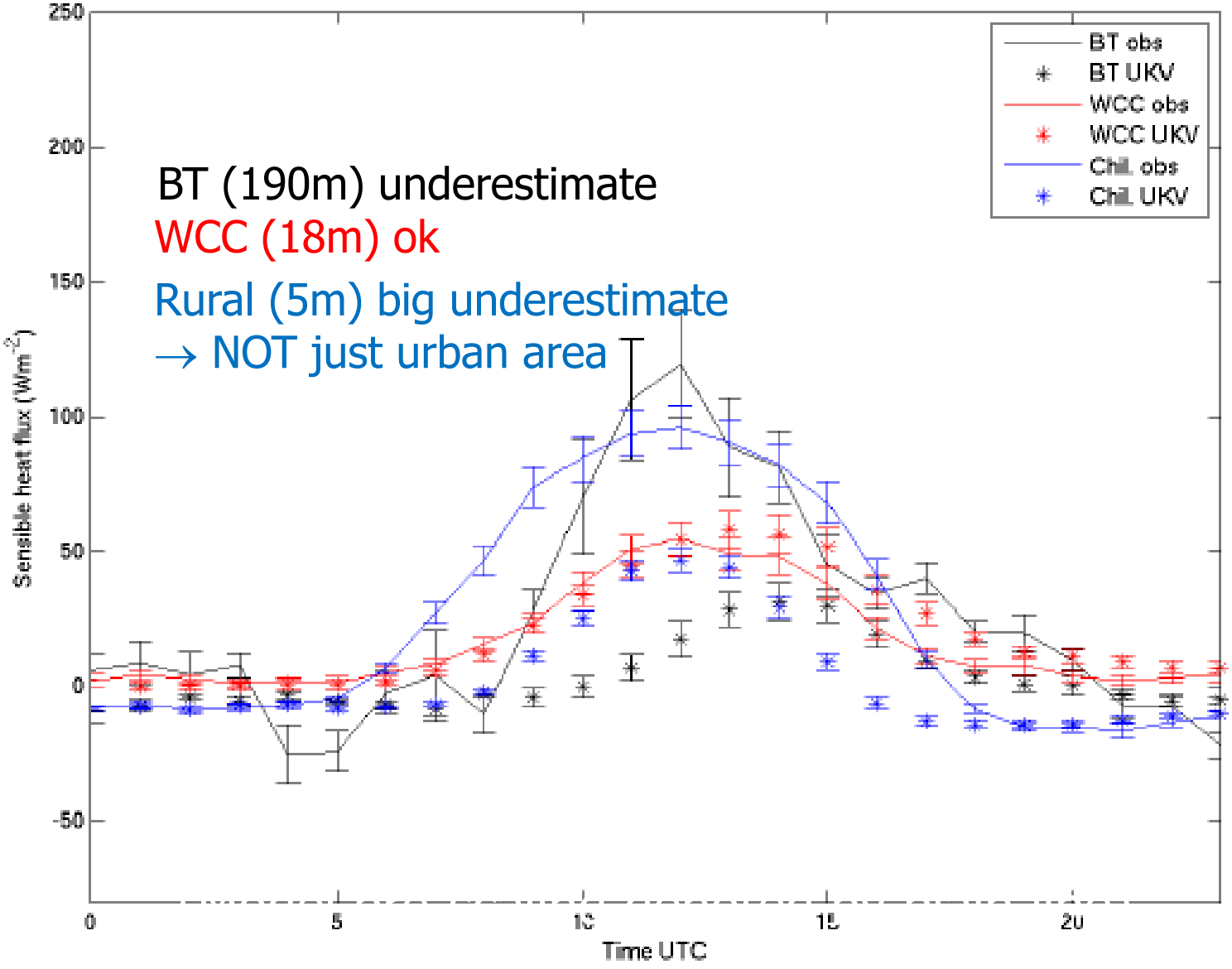
Use UHI to stratify model data



- UHI index defined as difference between WCC urban site, and average over 9 rural sites, T_{WCC} - T_{rural}
- Nov 2011 to March 2013
- Select model data based on daily max UHI strength

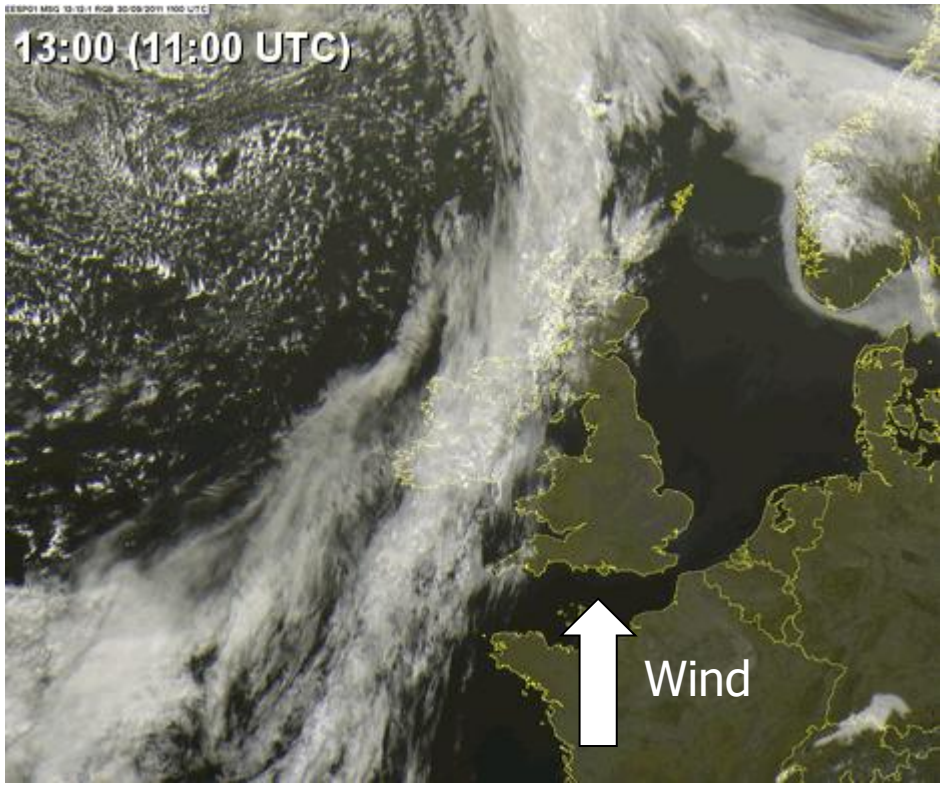
- Select ONLY upper quartile UHI days for model-obs comparison

Strong UHI comparison: sensible heat flux



Sian Lane, PhD thesis 2014

Case study (30/09 – 01/10 2011)



- Clear skies over London

→ strong UHI

Barlow et al. 2014, Environmental Fluid Mechanics
Boundary layer lidar observations

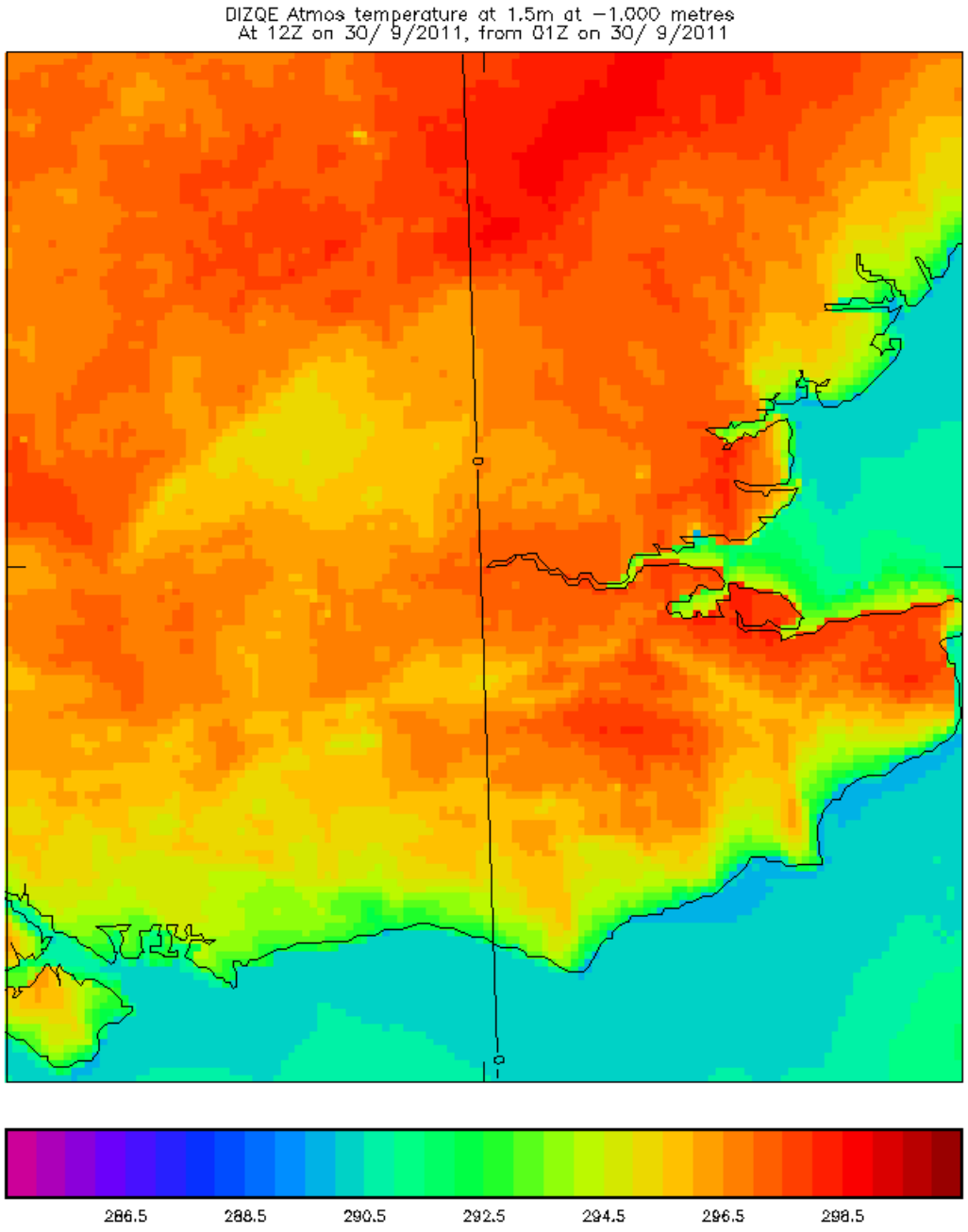
ACTUAL

Case study:

30th Sep 2011

(1) Operational model with slab scheme, resolution 1.5 km

T at 1.5m



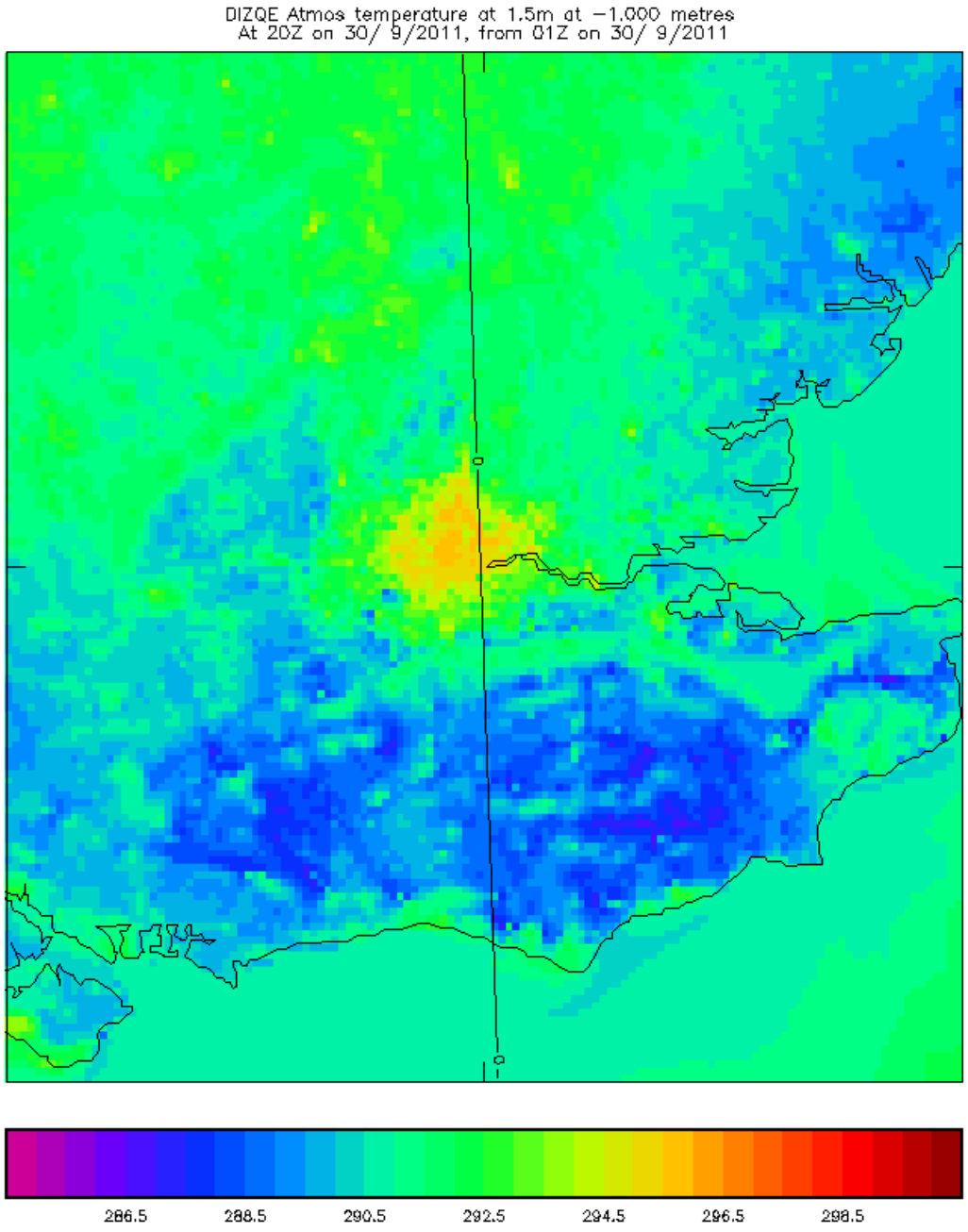
12:00

Case study:

30th Sep 2011

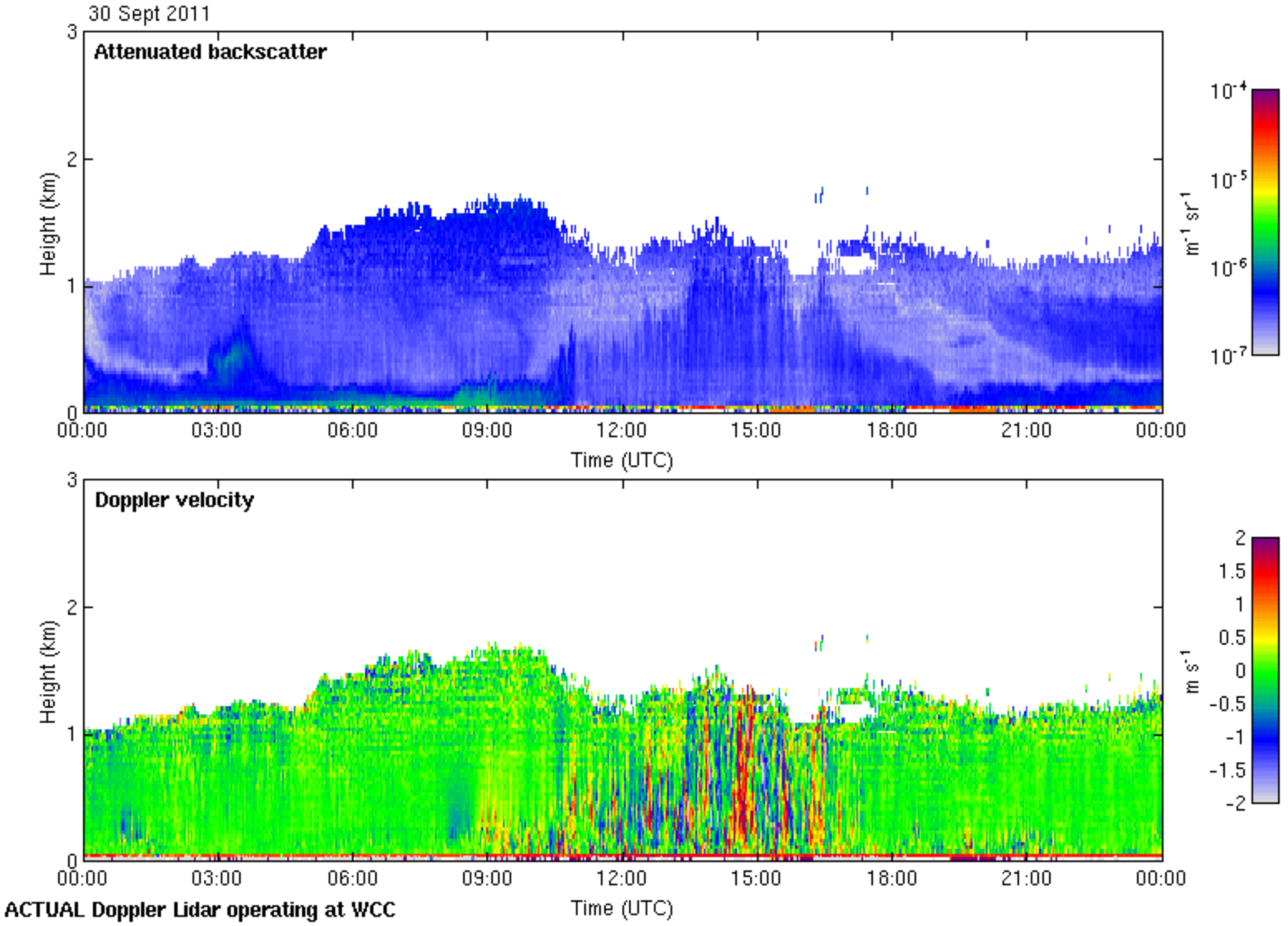
Strong urban heat island

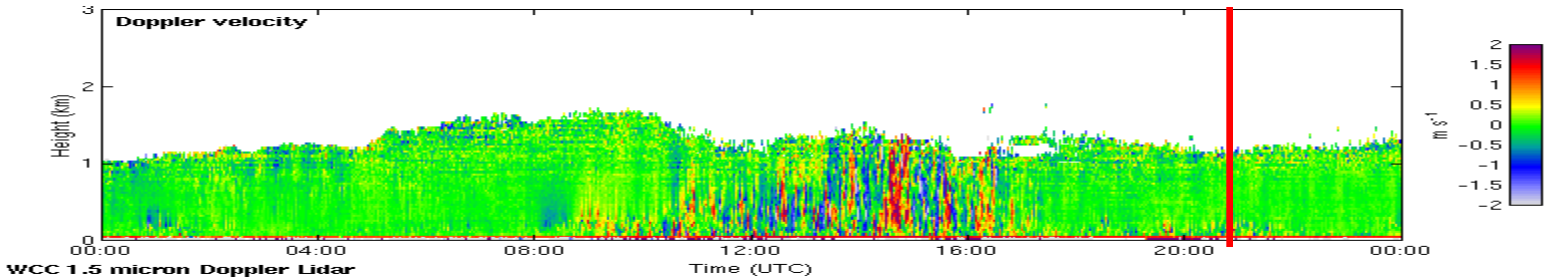
~ 5 degC



20:00

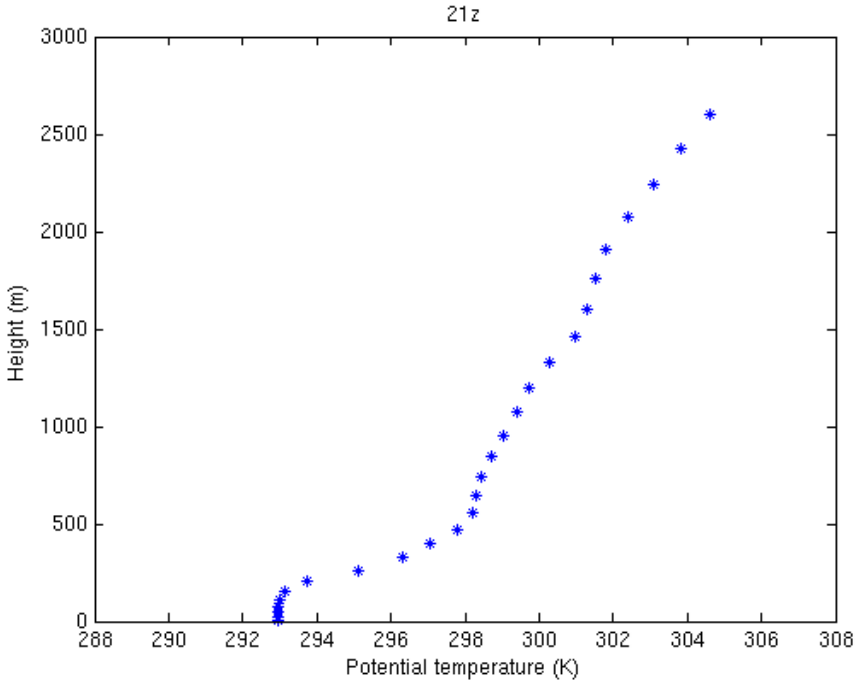
Doppler lidar observations 30 Sep 2011



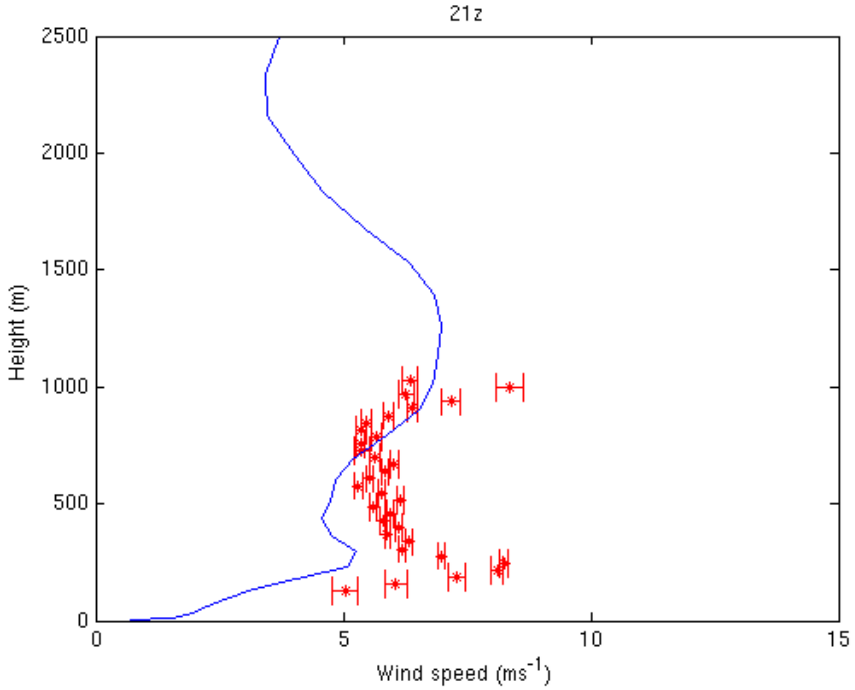


21:00

Potential temperature

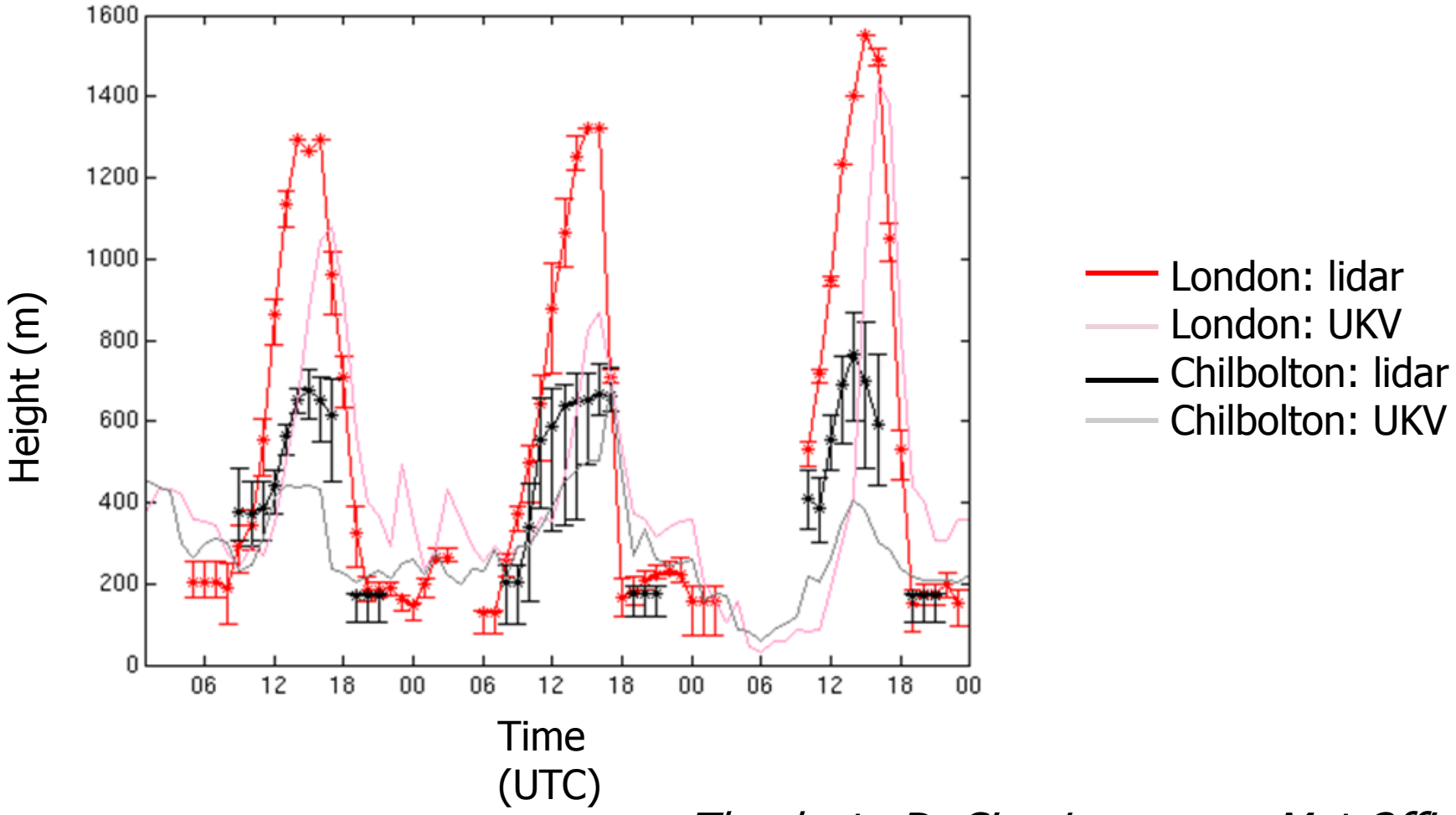


Wind-speed



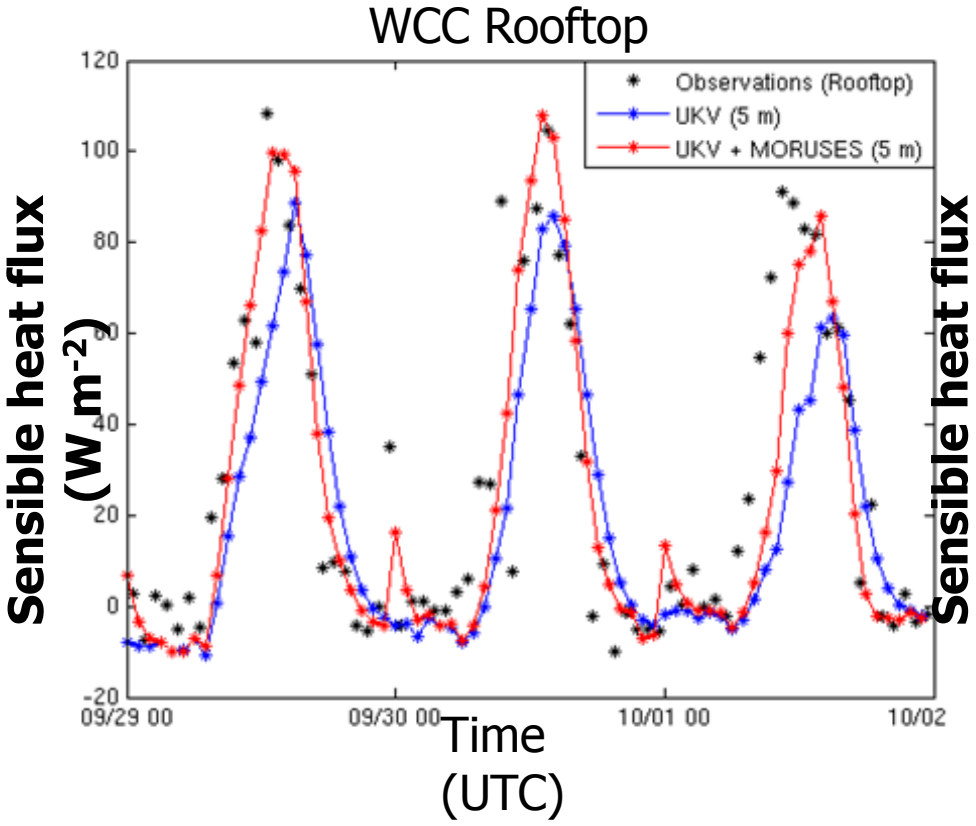
Barlow et al. 2014, Environmental Fluid Mechanics
Nocturnal jet over convective UHI

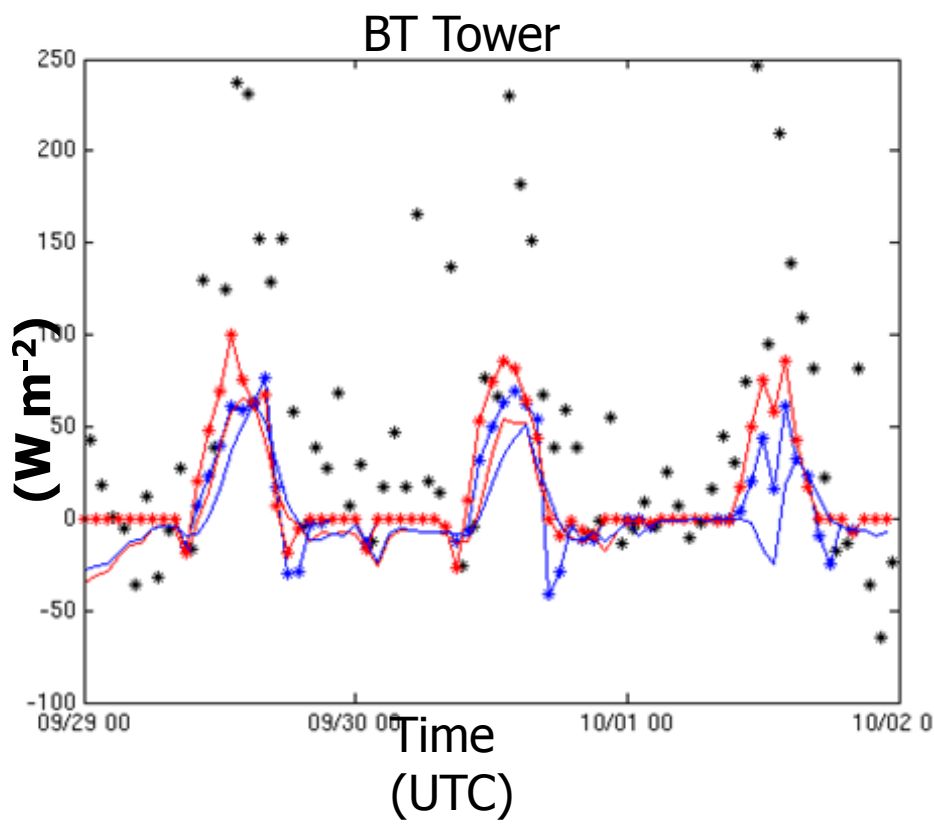
Model underestimates BL depth at urban and rural site 29.10 to 1.11



Thanks to Dr Sian Lane, now Met Office

(2) Operational model with street canyon scheme – compare with slab scheme

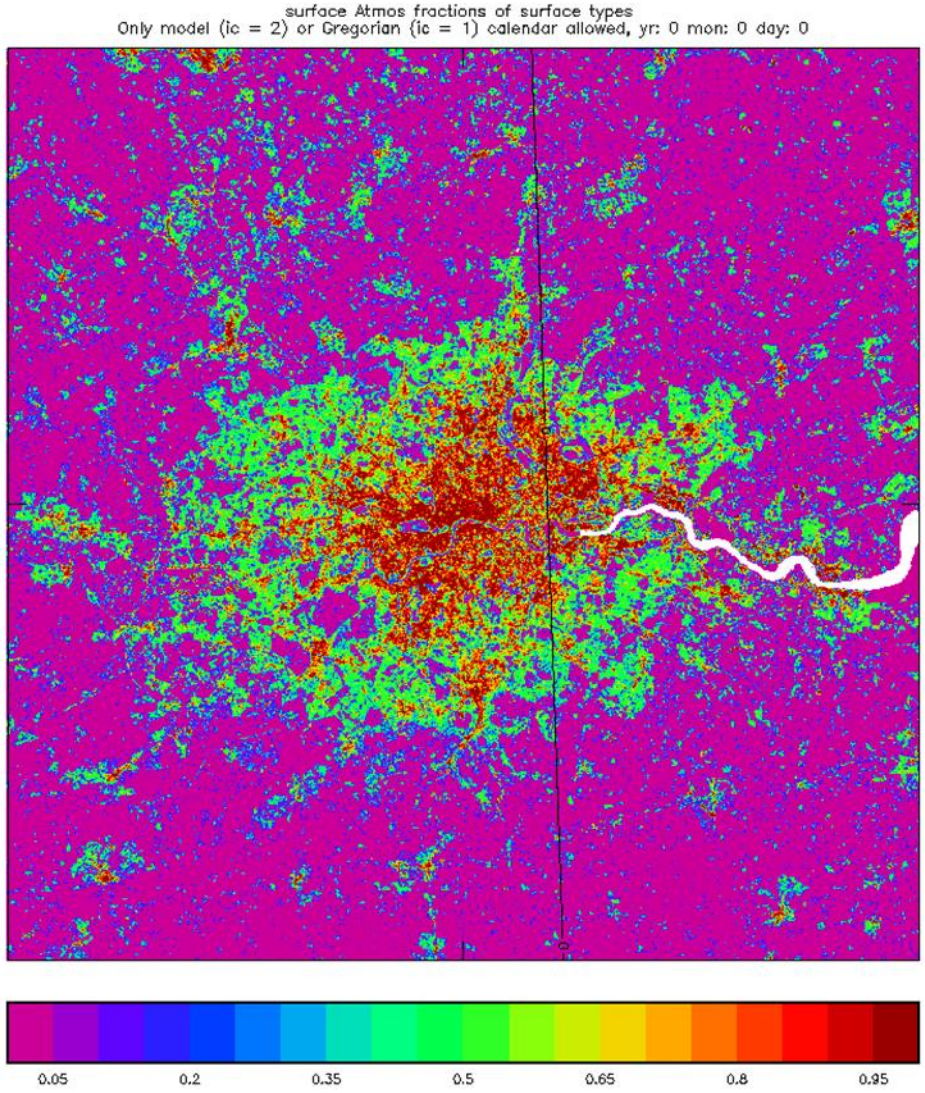




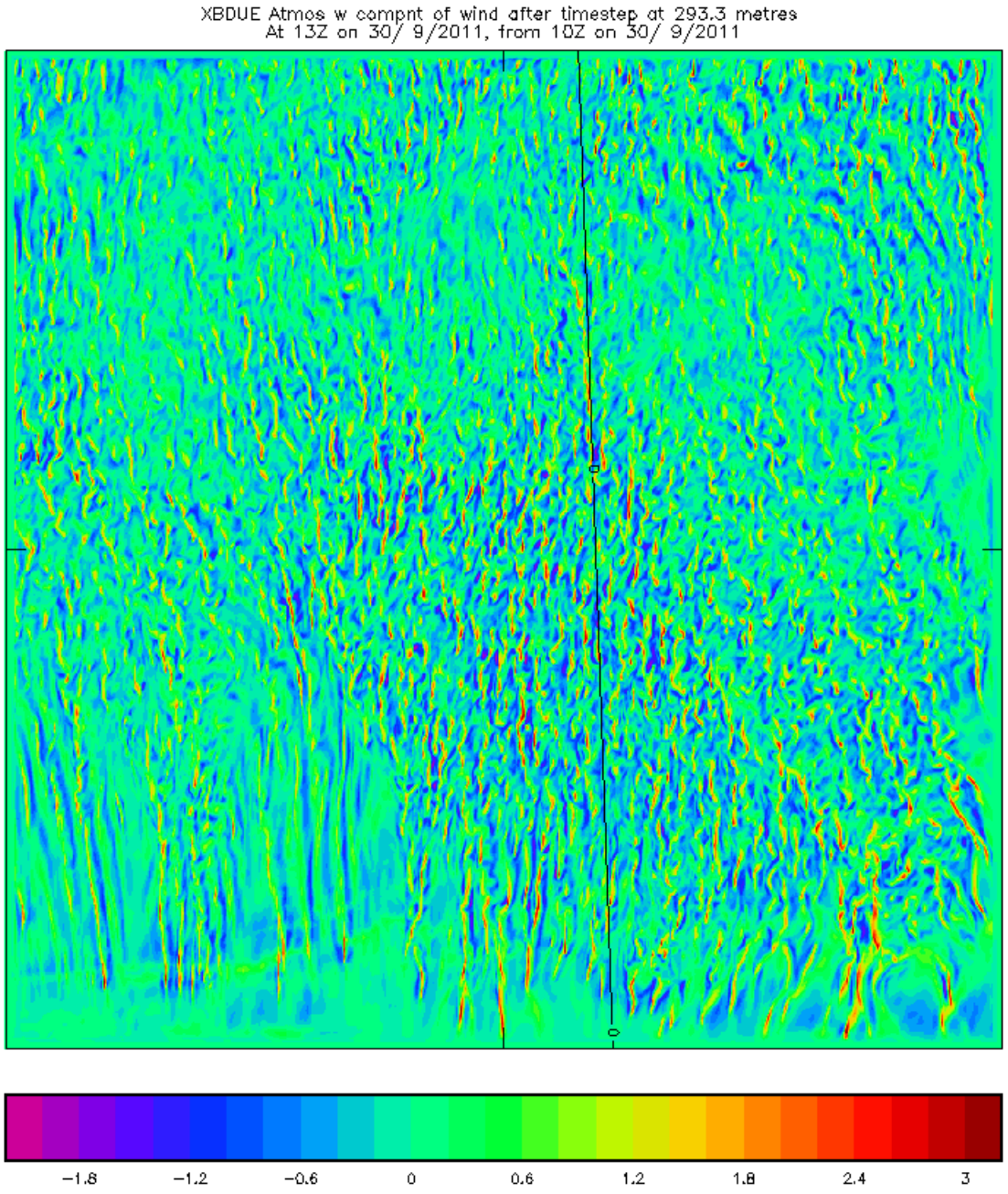
- New MORUSES scheme increases sensible heat flux, reduces time lag

(3) High resolution simulations (30.09.11)

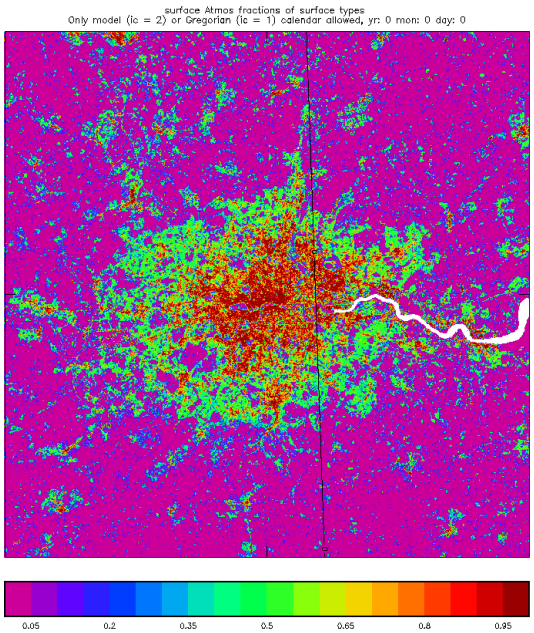
- 80 x 80 km domain
- Resolution **100 m, 55 m**
- Built fraction
- **Slab** scheme
- 140 vertical levels
- Turbulence: change from Lock 1D BL scheme with 2D Smagorinsky mixing to **3D Smagorinsky**



30th Sep 2011

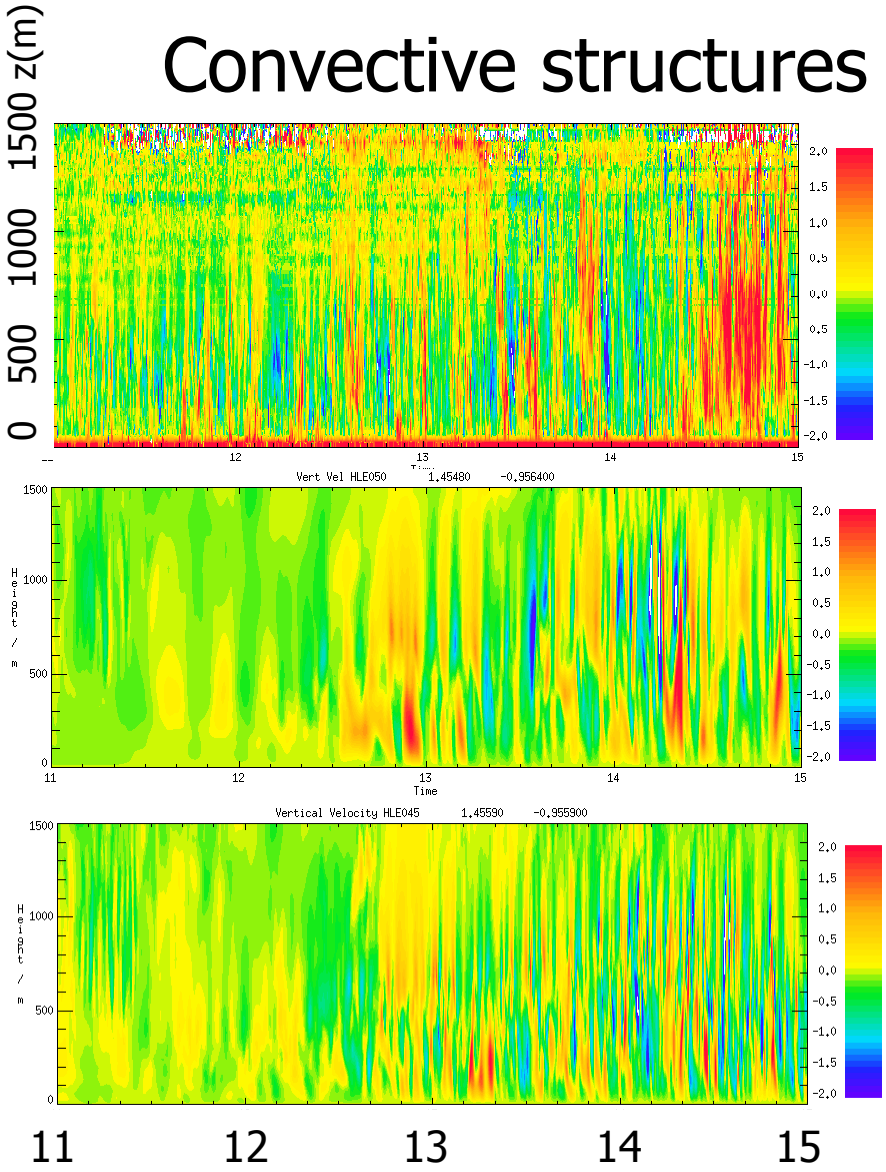


Vertical velocity at 293m



Thanks to Humphrey Lean, UKMO

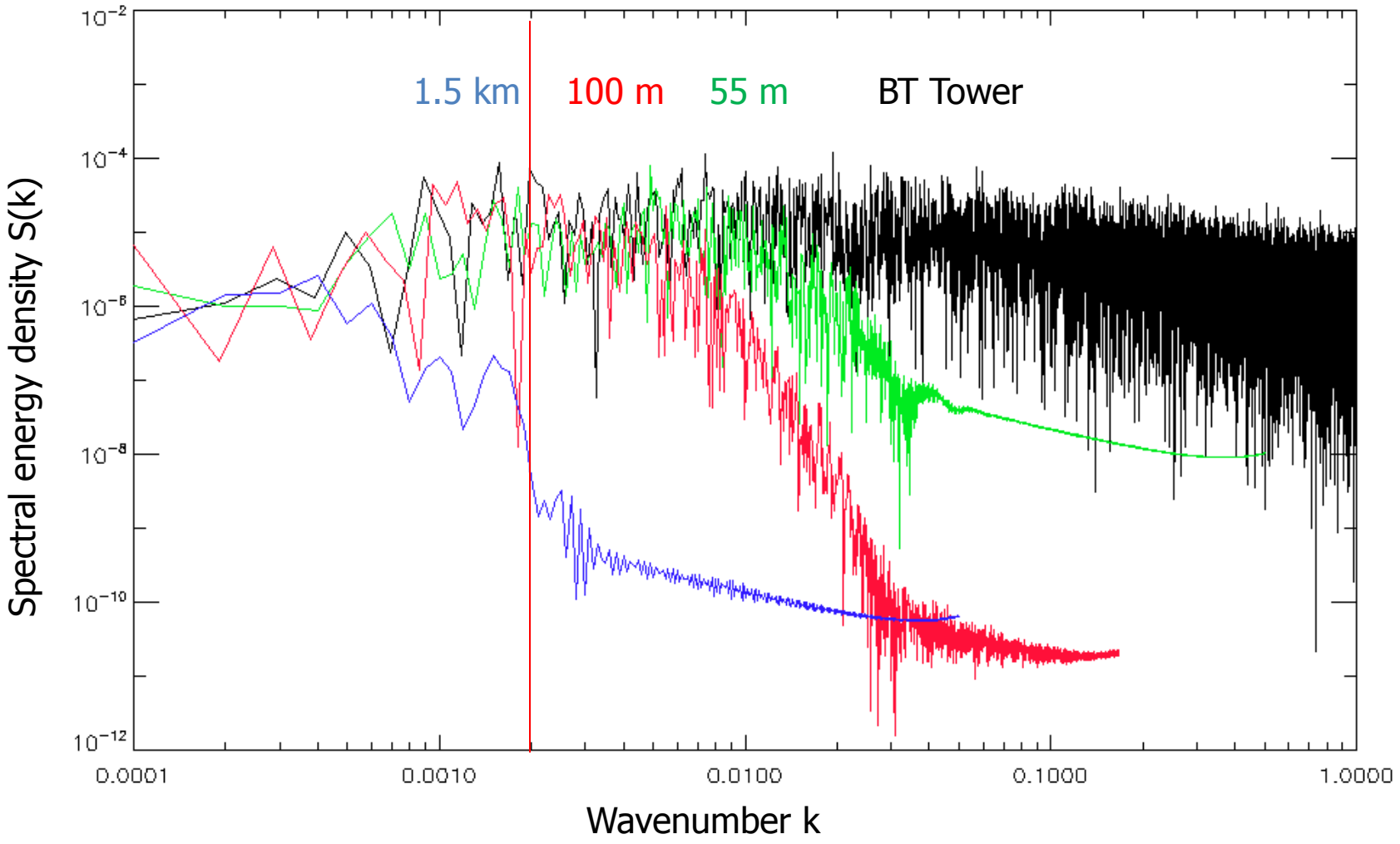
Convective structures – qualitatively similar



- Doppler lidar at WCC
- Model 100 m resolution
- Model 55 m resolution

Lean et al. in preparation

Convective structures – spectral comparison



Peak wavelength ~ 500m

→ semi-Lagrangian advection scheme

"smooths out" some structure

Conclusions

- Operational model with slab scheme underestimates fluxes for strong UHI events; delayed by two hours

- MORUSES canyon scheme reduces delay and underestimation (case study)
  → operational from Nov 2014 (after tests)

- High resolution simulations better resolve convection and entrainment at BL top
  → optimise sub-grid mixing (see Boutle et al. 2014)
  → new dynamical core (ENDGAME) – less smoothing?

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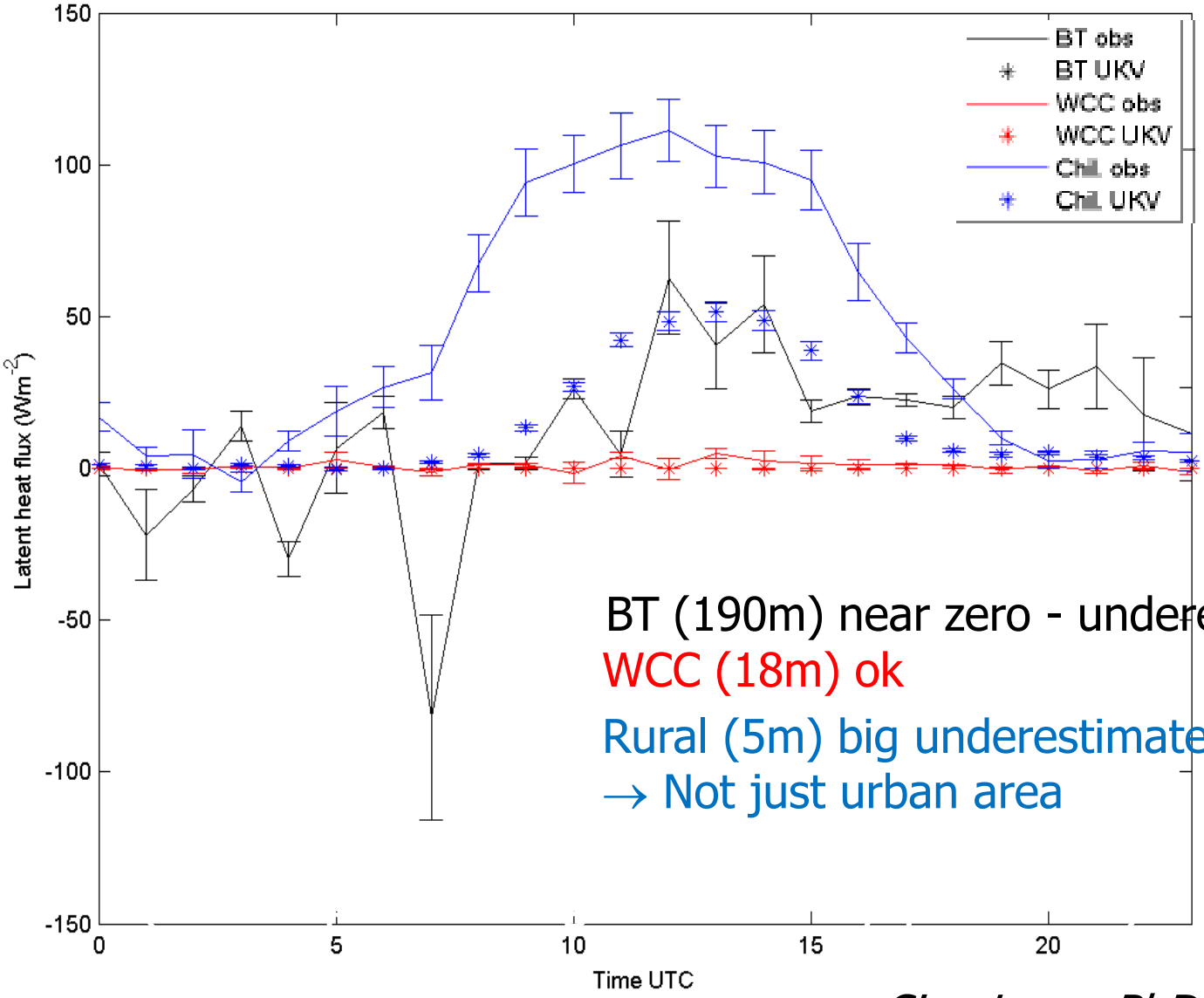
Strong UHI comparison: latent heat flux



BT (190m) near zero - underestimate

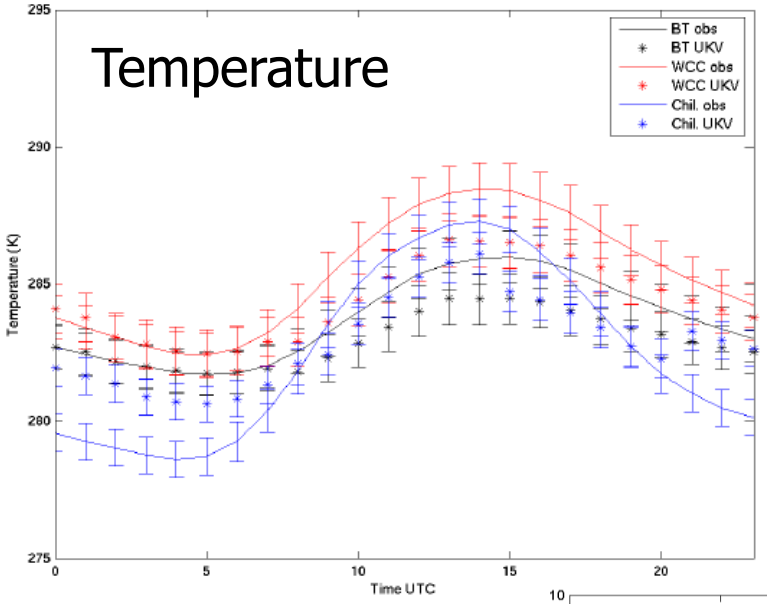
WCC (18m) ok

Rural (5m) big underestimate

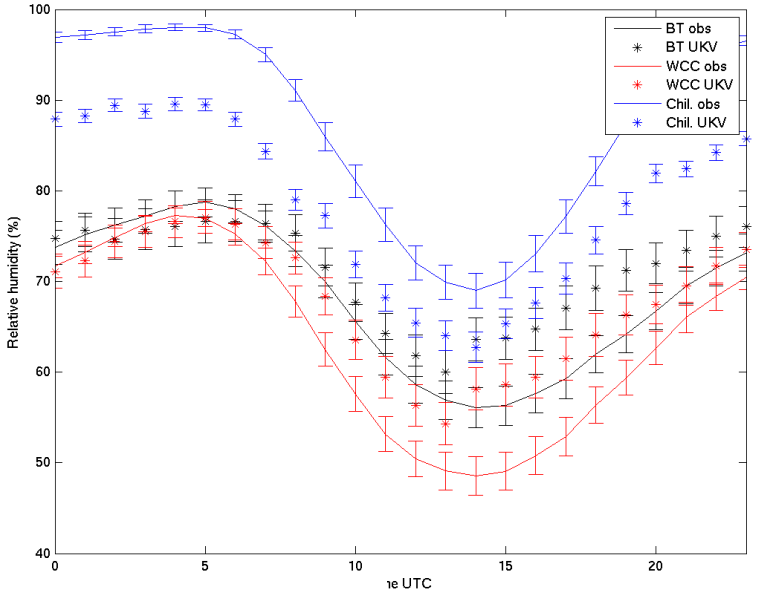
→ Not just urban area

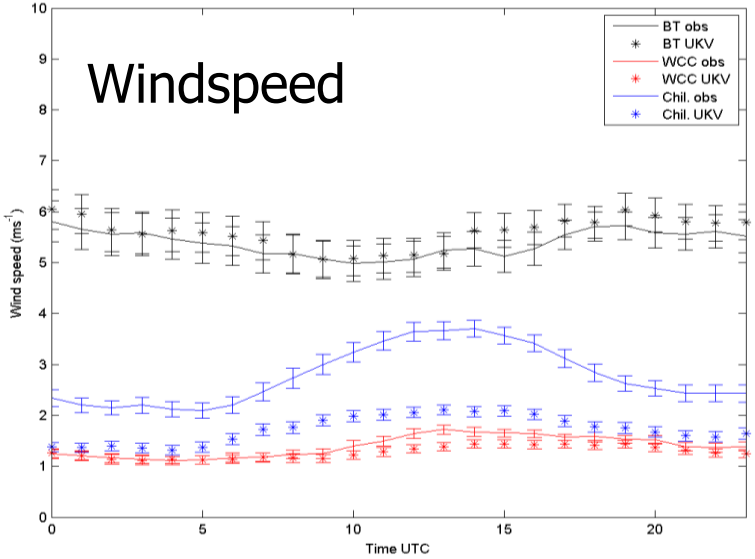
Sian Lane, PhD thesis 2014

Modelled temp, relative humidity, windspeed



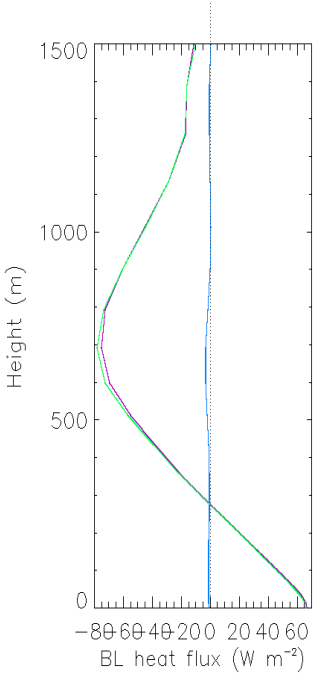
RH



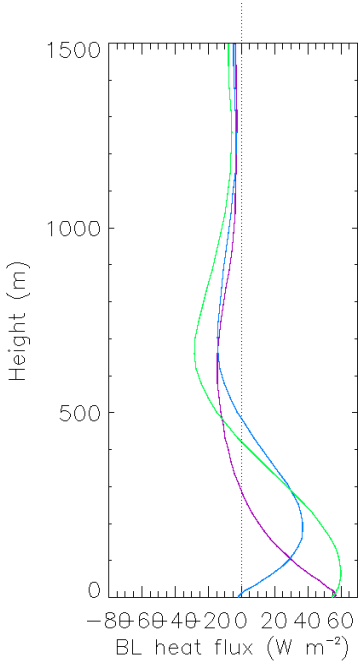


Explicit vs. parametrized fluxes

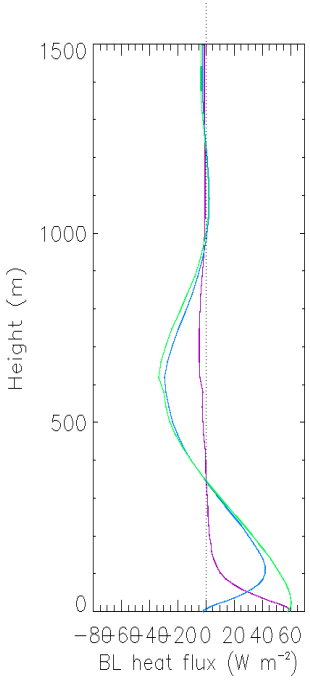
1.5 km

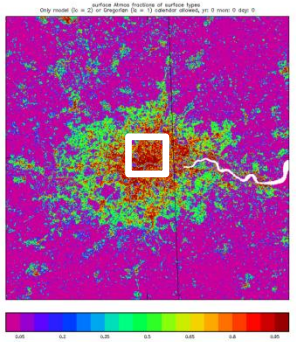


500 m



100 m





- Purple – parametrized, Blue – explicit, Green – total
- Use of 3D Smagorinsky gives smaller entrainment flux over shallower zone
- BL height decreases with increased resolution, 3D Smag