High-resolution Modelling of the Boundary Layer and Implications for Urban Air-quality Forecasting

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National Centre for Atmospheric Science
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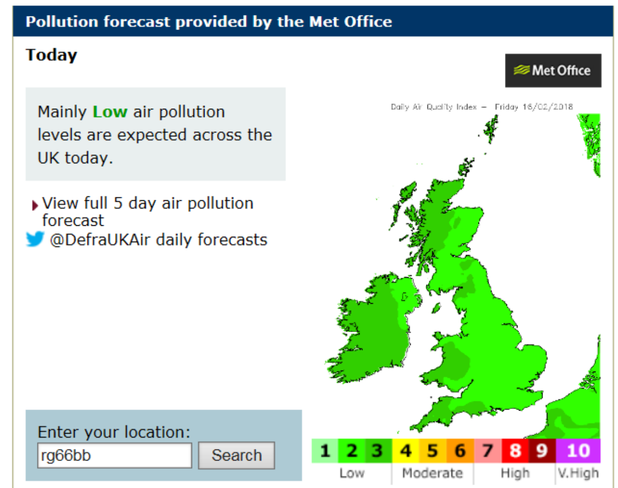
MOTIVATION

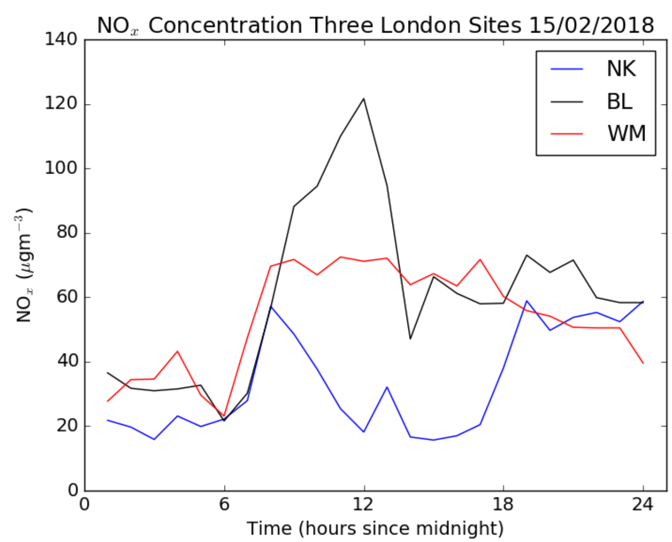
- Current UK Met Office air-quality forecast 12 km resolution

- Urban air quality forecasts at the neighbourhood scale

- Why?
  - Urban planning and air-quality regulation
  - Informed health decisions

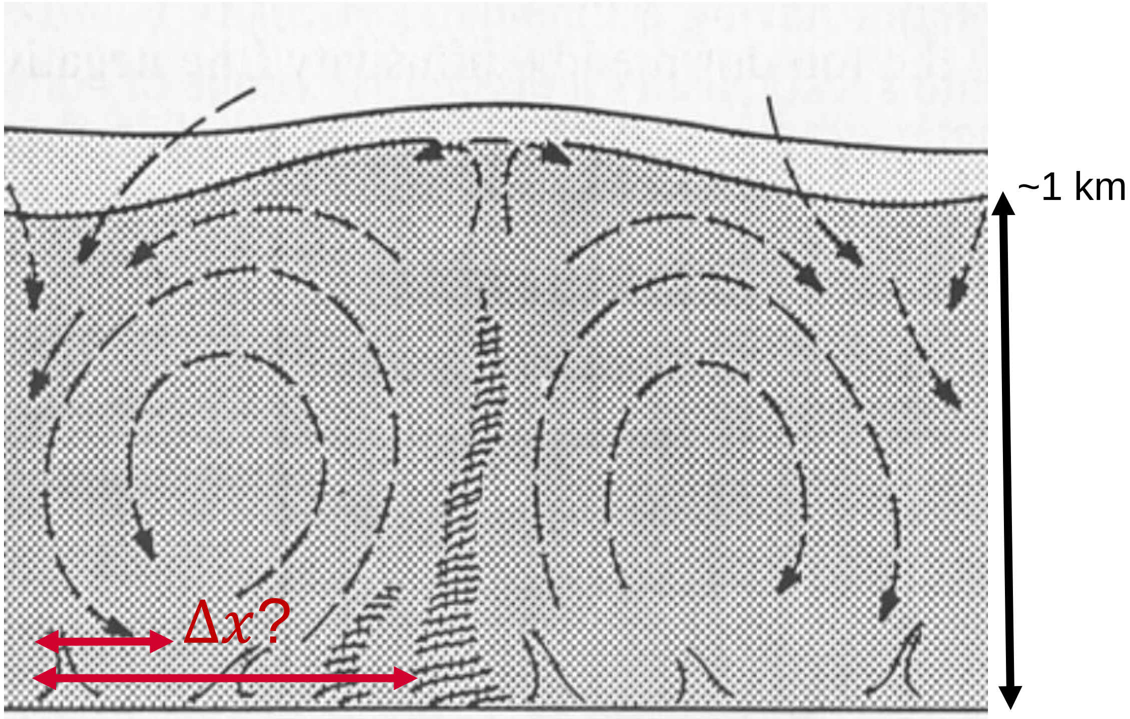


https://uk-air.defra.gov.uk/



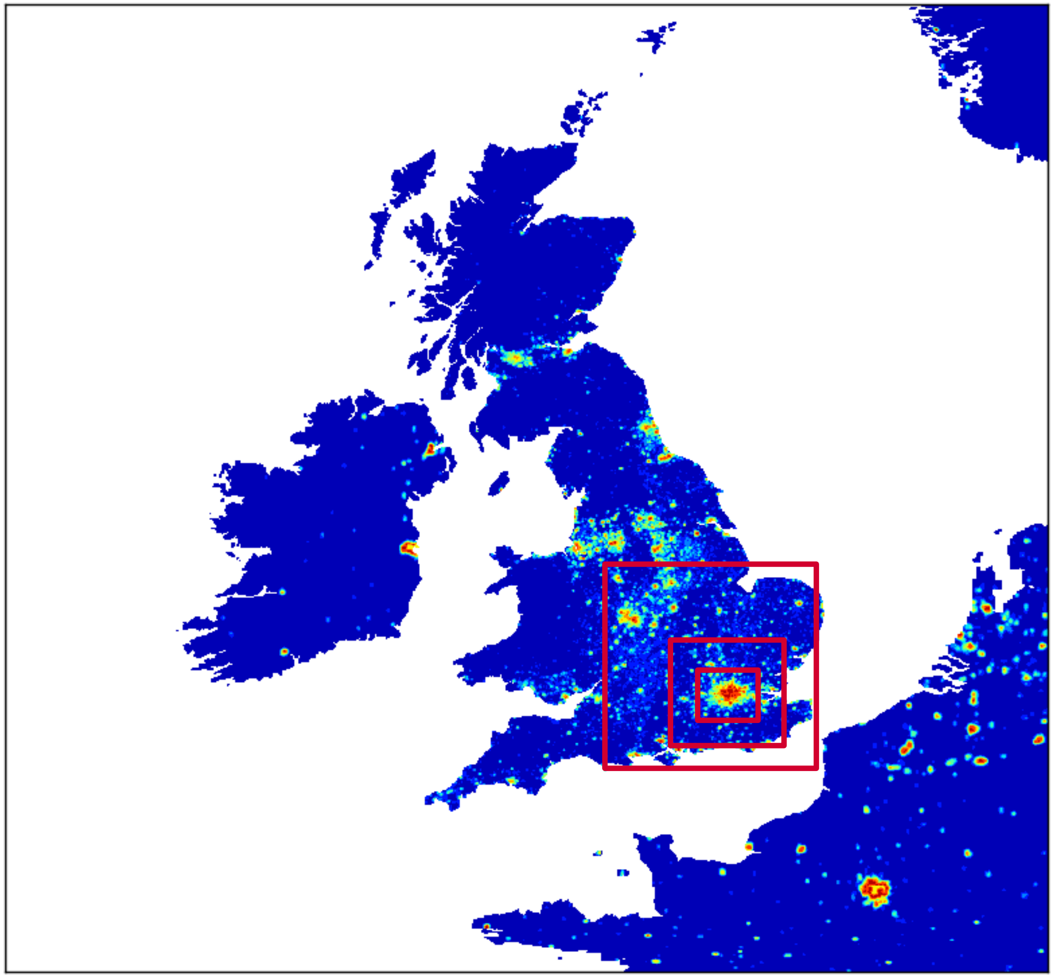
QUESTION

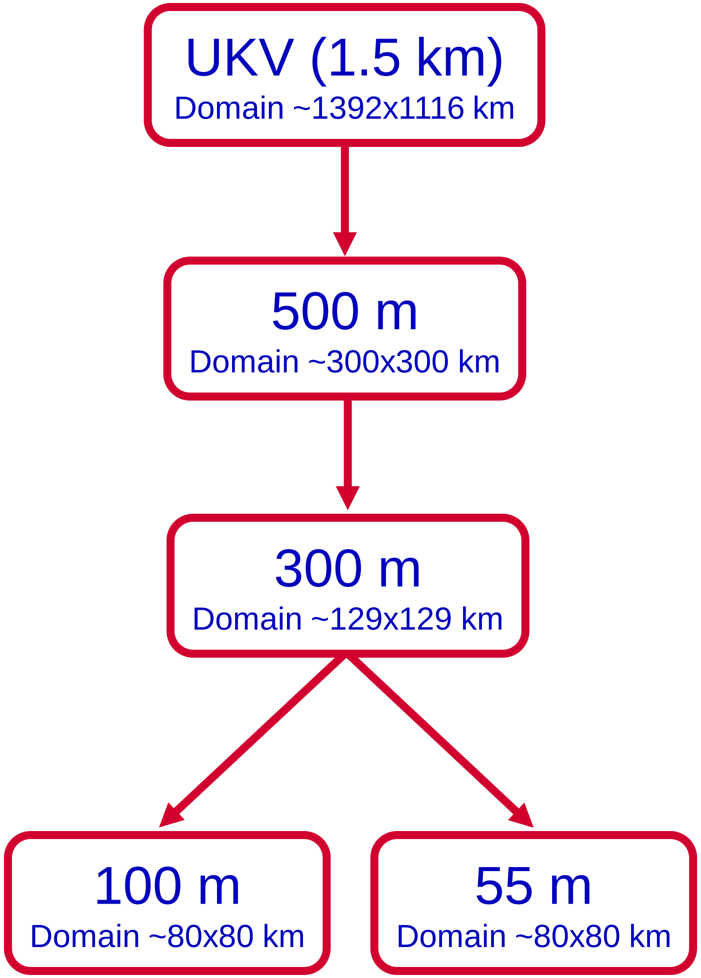
- How does model resolution in “the greyzone” O(100 m – 1 km) affect representation of meteorological processes in the urban boundary layer?
  - Turbulence
  - Pollution concentration



Adapted from Wyngaard (1990)

UM NESTING SUITE

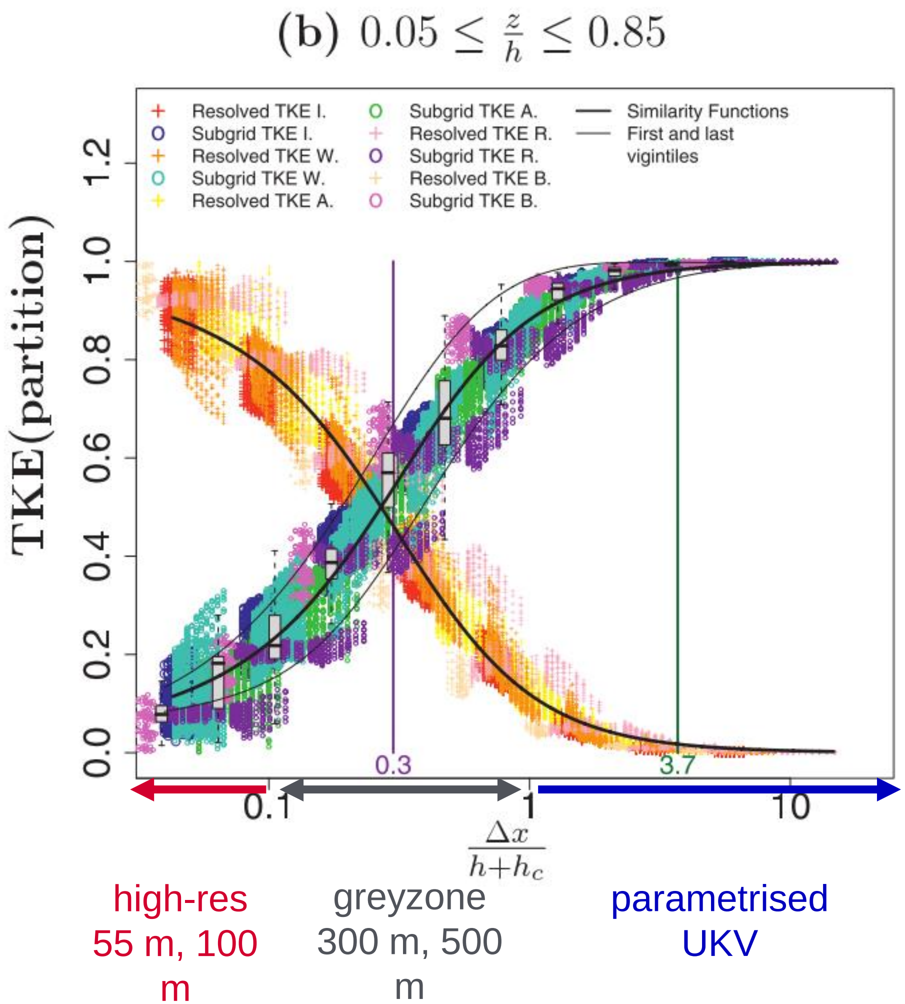




All nests run with MORUSES urban surface scheme (Porson et al. 2010)

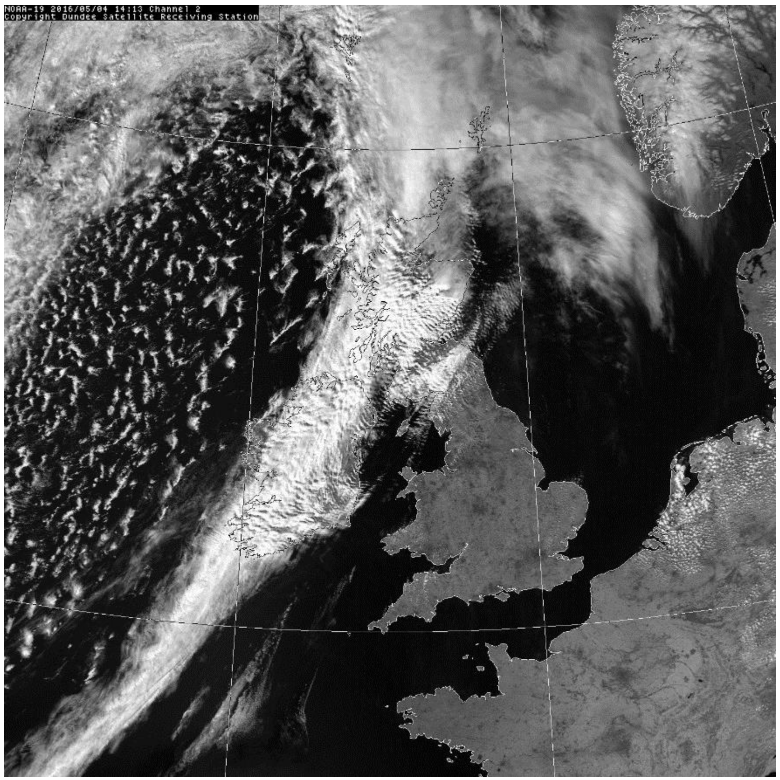
BLENDING SCHEME

- More turbulence becomes resolved with decreasing grid length.
- Fraction of TKE resolved in the mixed layer is used to weight the contribution of parametrised flux.

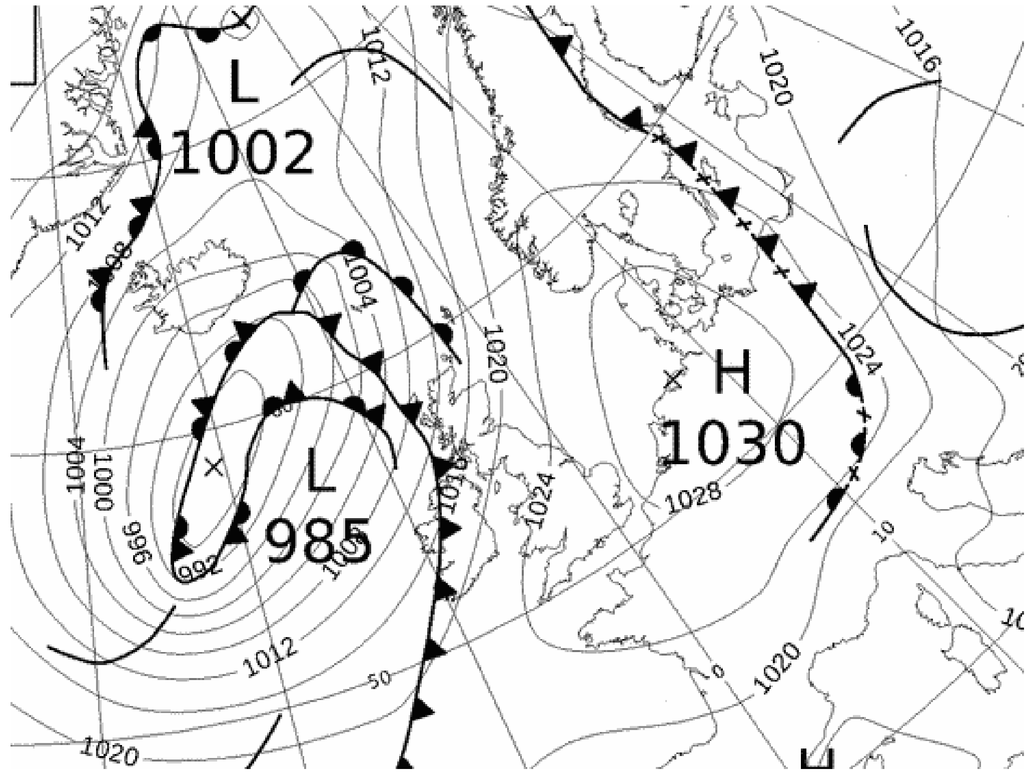


Adapted from Honnert et al. (2011)

CASE STUDY – 04/05/2016



Near infra-red, 0.725-1.10 µm at 14:00 UTC
(Courtesy of Dundee Satellite receiving Station).



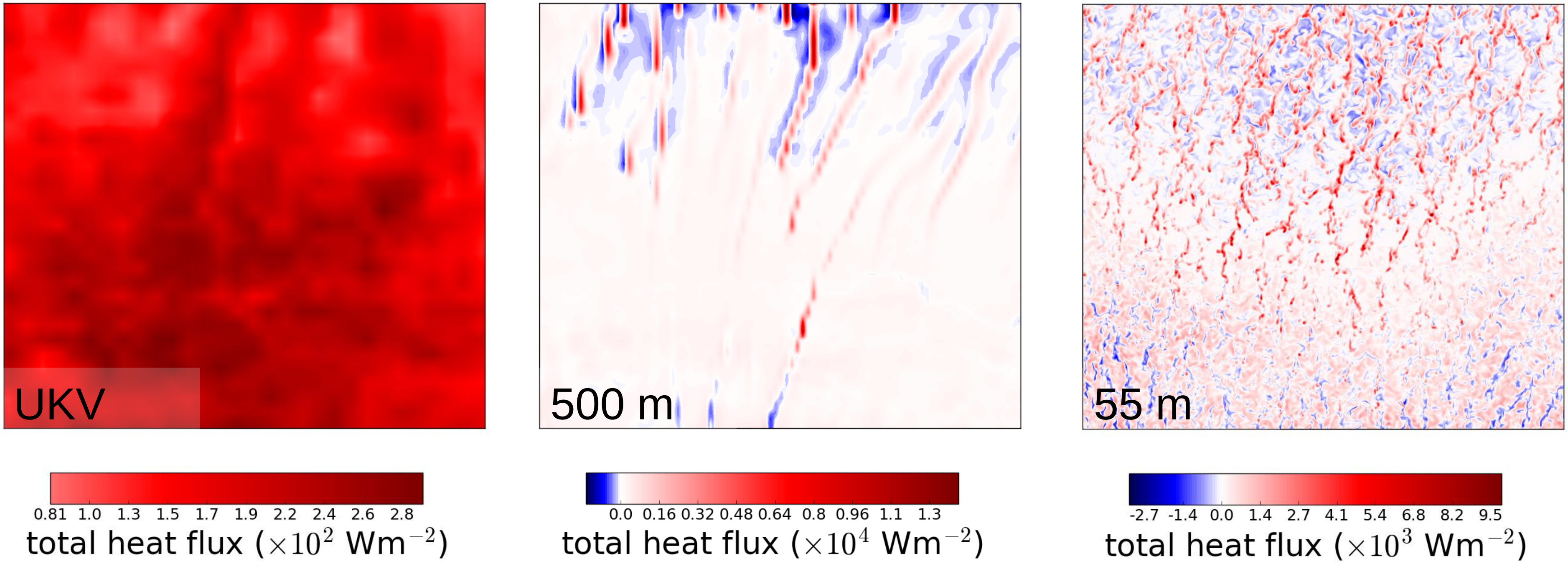
Surface chart at 12:00 UTC
(Courtesy of www.wetter3.de)

10 m wind at Reading Observatory averaged from 09:00 – 17:00 UTC:
2.8 m/s (light breeze)

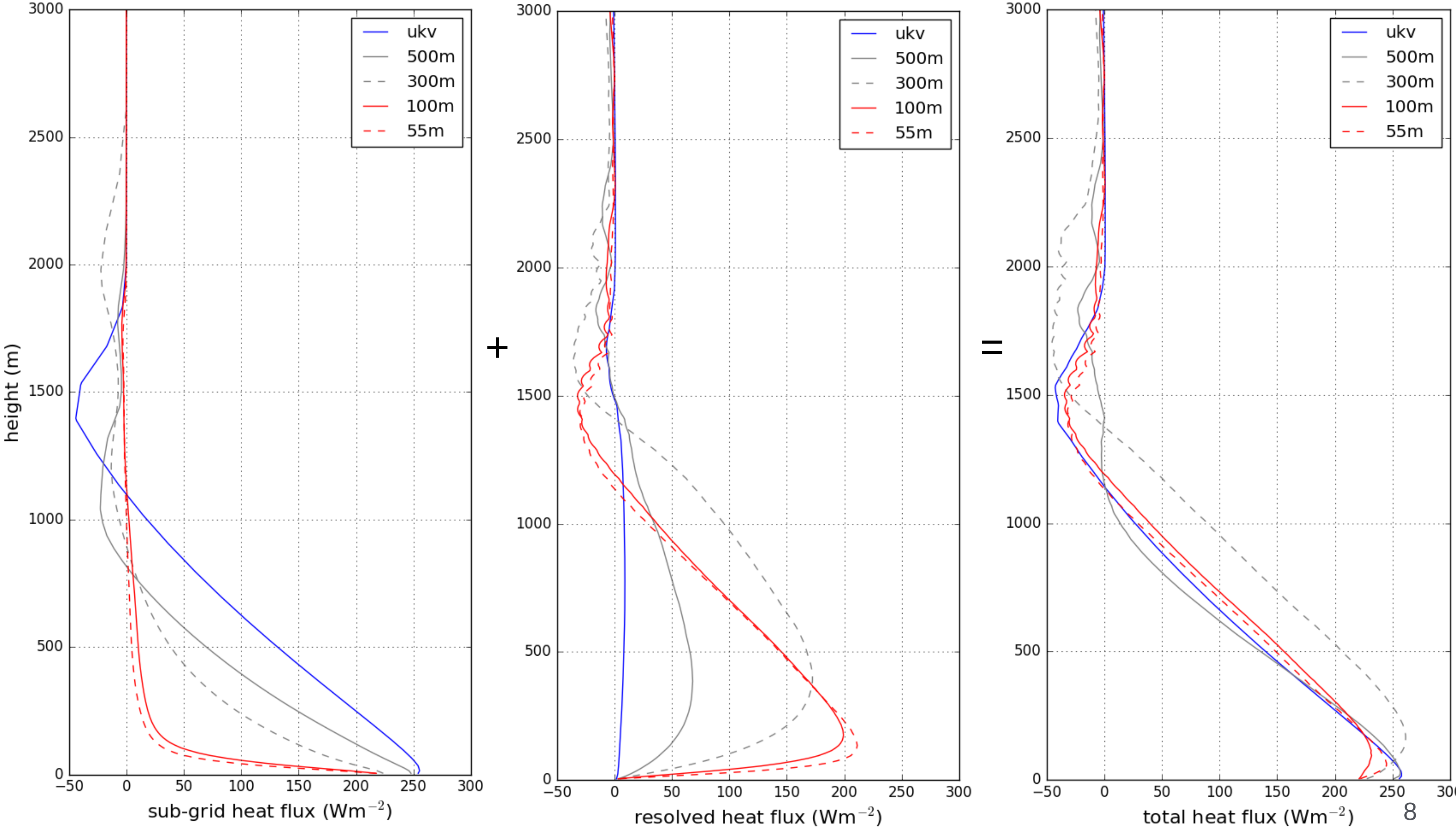
SENSIBLE HEAT FLUX

$$H_{total} = \underbrace{\rho c_p w'\theta'}_{H_{resolved}} + H_{sub-grid}$$

Plots: 14:00 UTC, z = 295 m, area ~ 45 km x 45 km.



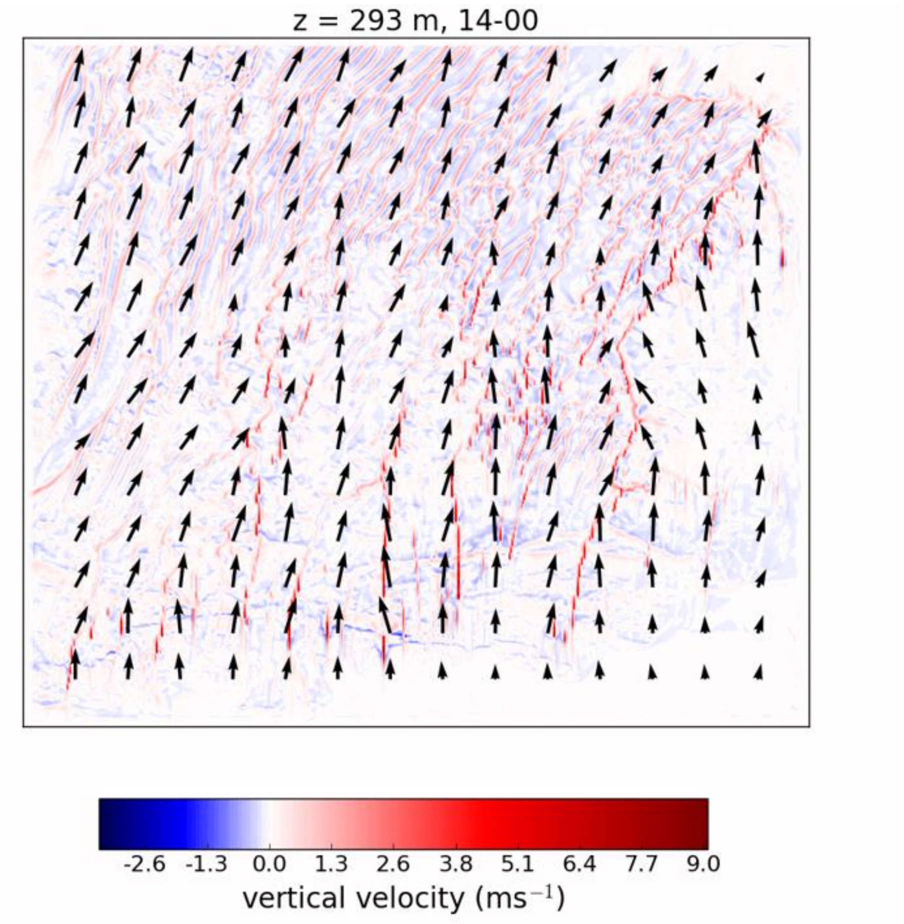
SENSIBLE HEAT FLUX



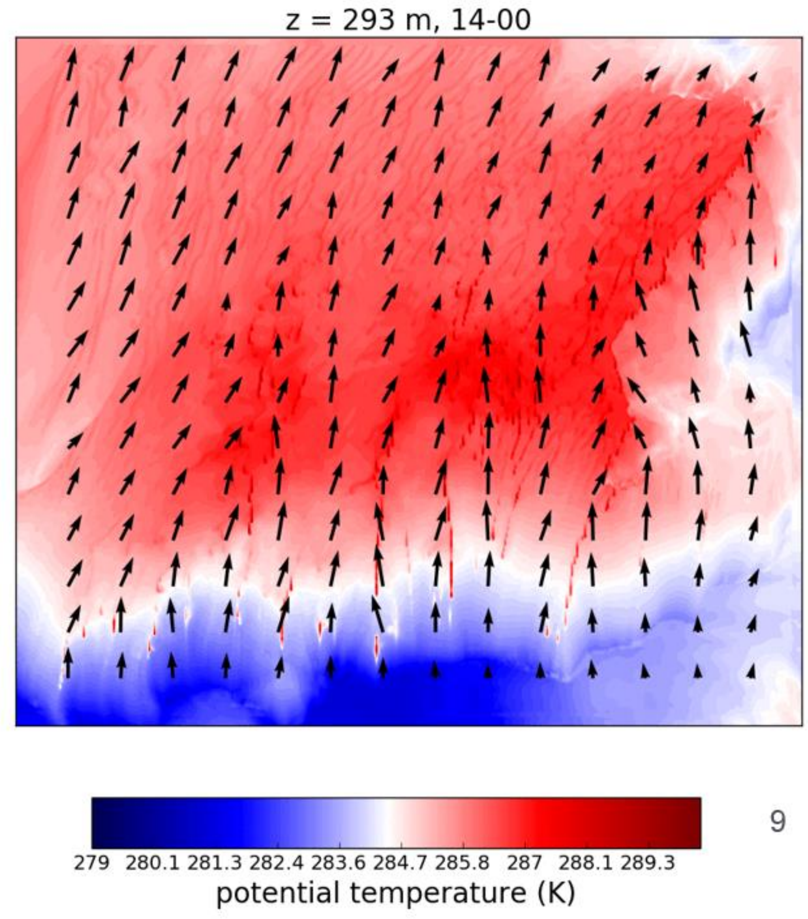
W AND θ FIELDS

Issue in greyzone (300 m, 500 m) with $H_{resolved} = \rho c_p w'\theta'$

500 m grid length:

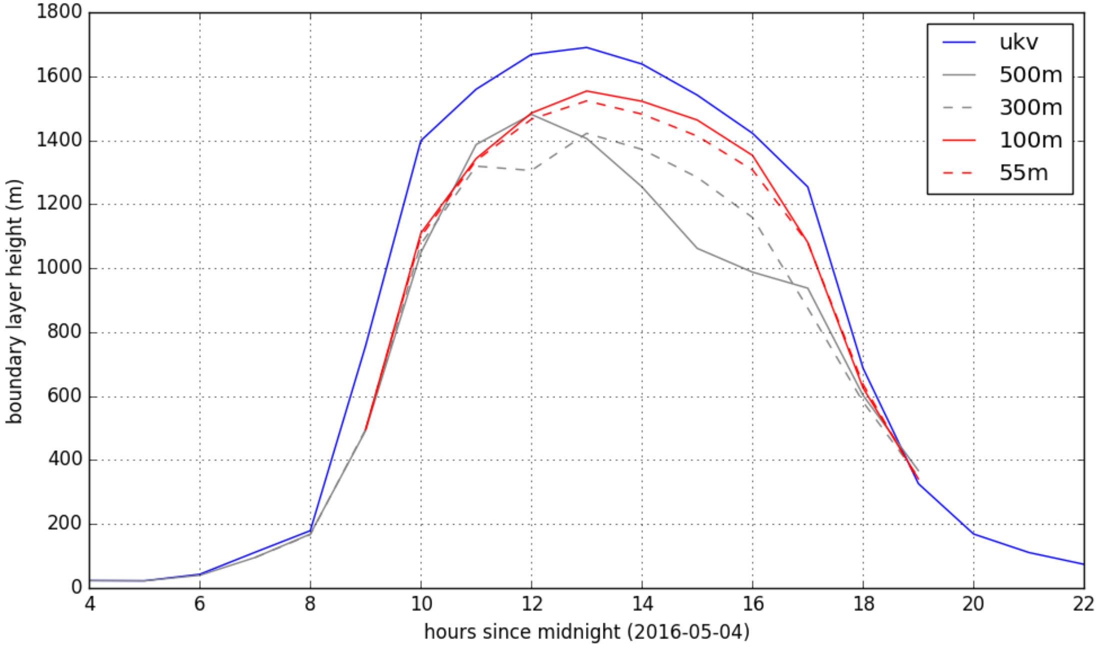


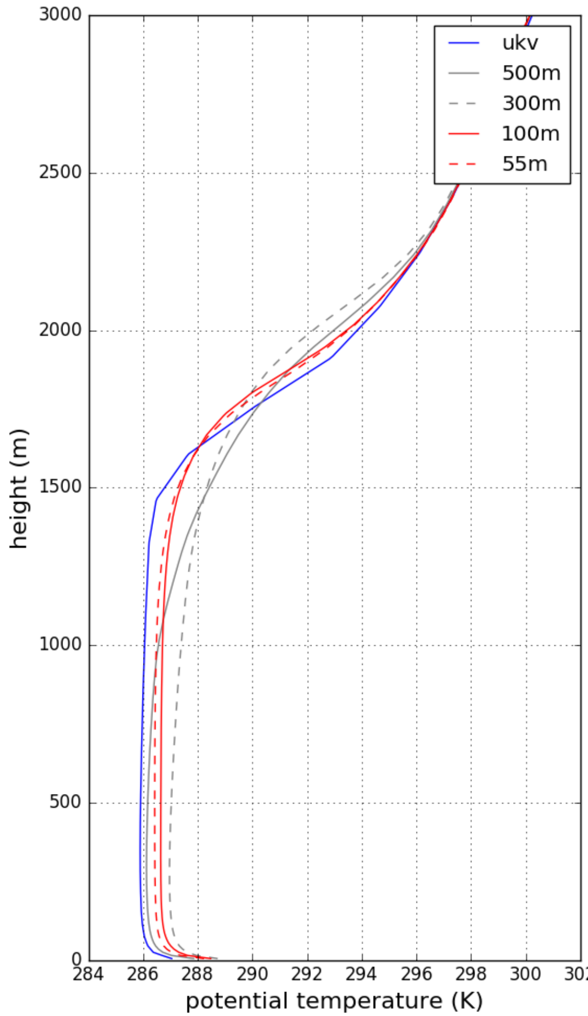
500 m grid length:



BL HEIGHT TIME SERIES AND θ PROFILE

- 10% difference in BL height between UKV and 55 m run
- Greyzone BL heights lower – consistent with potential temperature profiles





CONCLUSIONS

- Advise caution when using greyzone for air quality forecasting
- Recent Met Office “Blobbiness” report has similar findings
- 10% difference in BL heights between 1.5 km (UKV) and 55 m runs
  → Translates to approx. 10% difference in tracer concentration
- Parametrised (UKV) and high-res (55m,100m) sensible heat flux profiles consistent with each other
- Spatial structure of sensible heat flux varies greatly with resolution
  → Pollution fluxes

THANK YOU

References:

- Honnert, R., V. Masson, and F. Couvreux, 2011: A Diagnostic for Evaluating the Representation of Turbulence in Atmospheric Models at the Kilometric Scale. *J. Atmos. Sci.* **68**, 3112–3131.
- Porson, A., P.A. Clark, I.N. Harman, M.J. Best, and S.E. Belcher, 2010: Implementation of a new urban energy budget scheme in the MetUM. Part I: Description and idealized simulations. *Quart. J. Roy. Meteorol. Soc.* **136**, 1514 – 1529.
- Wyngaard, J.C., 1990: Scalar Fluxes in the Planetary Boundary Layer – Theory, Modeling, and Measurement. *Boundary-Layer Meteorology* **50,** 49–75.

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