Evaluating the urban mixed-layer using a dense observation network (urbisphere-Berlin) and sub-km modelling

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https://images.unsplash.com/photo-1551036746-04a04d0aaa22?ixlib=rb-4.0.3&ixid=M3wxMjA3fDB8MHxzZWFyY2h8MXx8YmVybGluJTIwc2t5bGluZXxlbnwwfHwwfHw%3D&w=1000&q=80

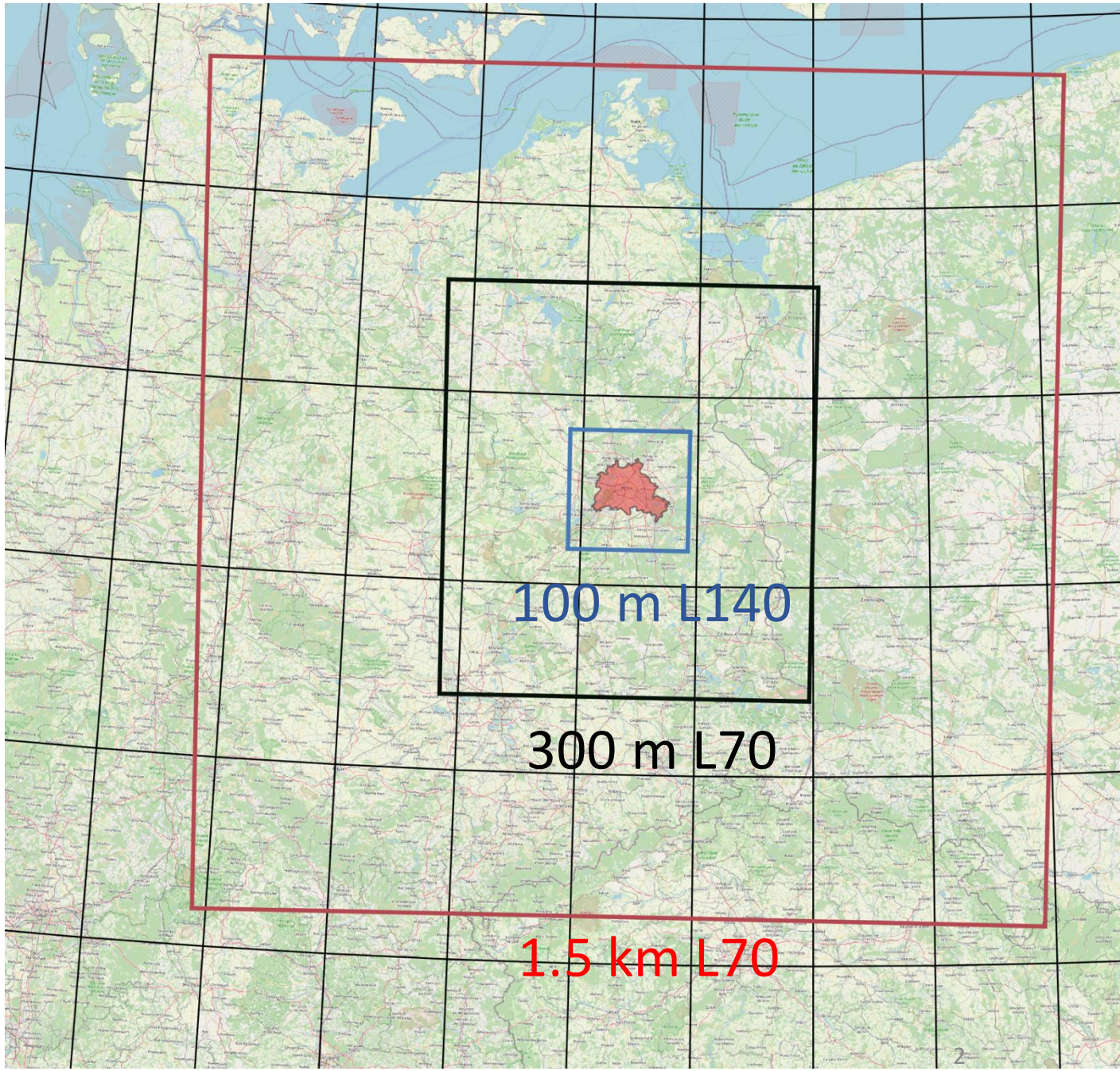
Model Configuration

Met Office Unified Model (UM) RAL3.1

- Scale-aware turbulence scheme (Boutle et al. 2014)
- 3D Smagorinsky-Lilly preferred over 1-D scheme with higher grid-resolution

- 36-h simulation (12 h spin-up)
  - 12 UTC 03 Aug – 00 UTC 5 Aug 2022
  - 12 UTC 17 Apr – 00 UTC 19 Apr 2022

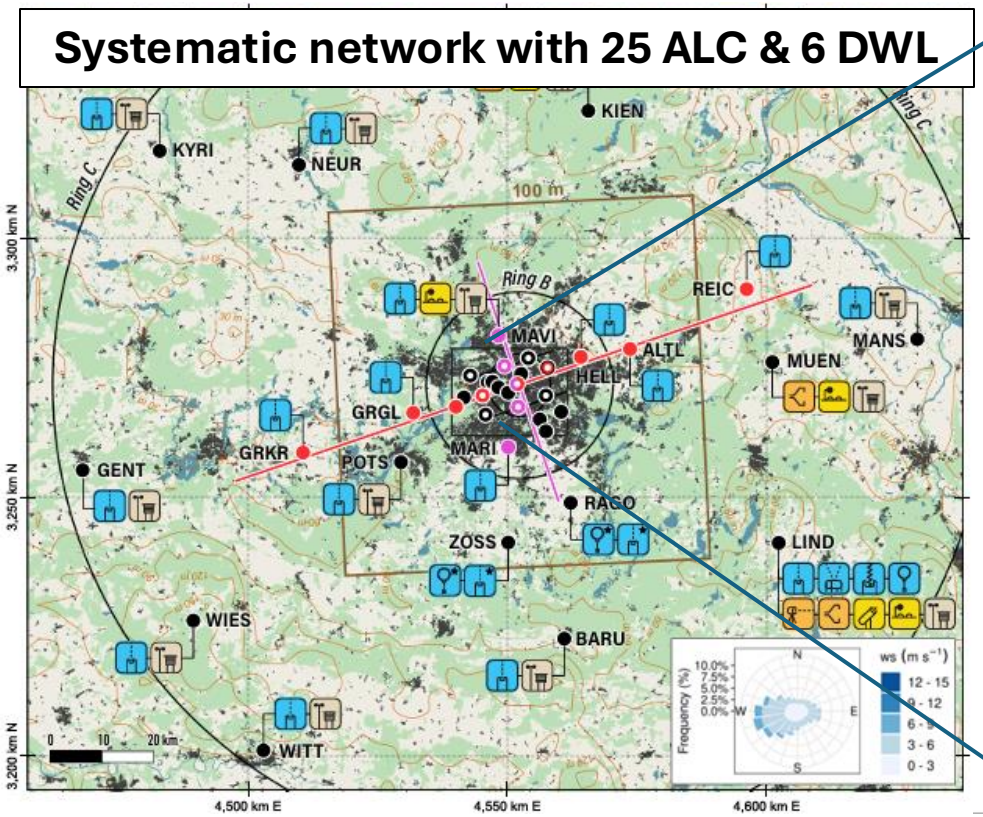
- Model forcing:
  UM global (~10 km) – 1-way nested
- JULES
  - MORUSES – urban 2-tile scheme
    - Roof and street canyon
  - Land cover: CCIv1

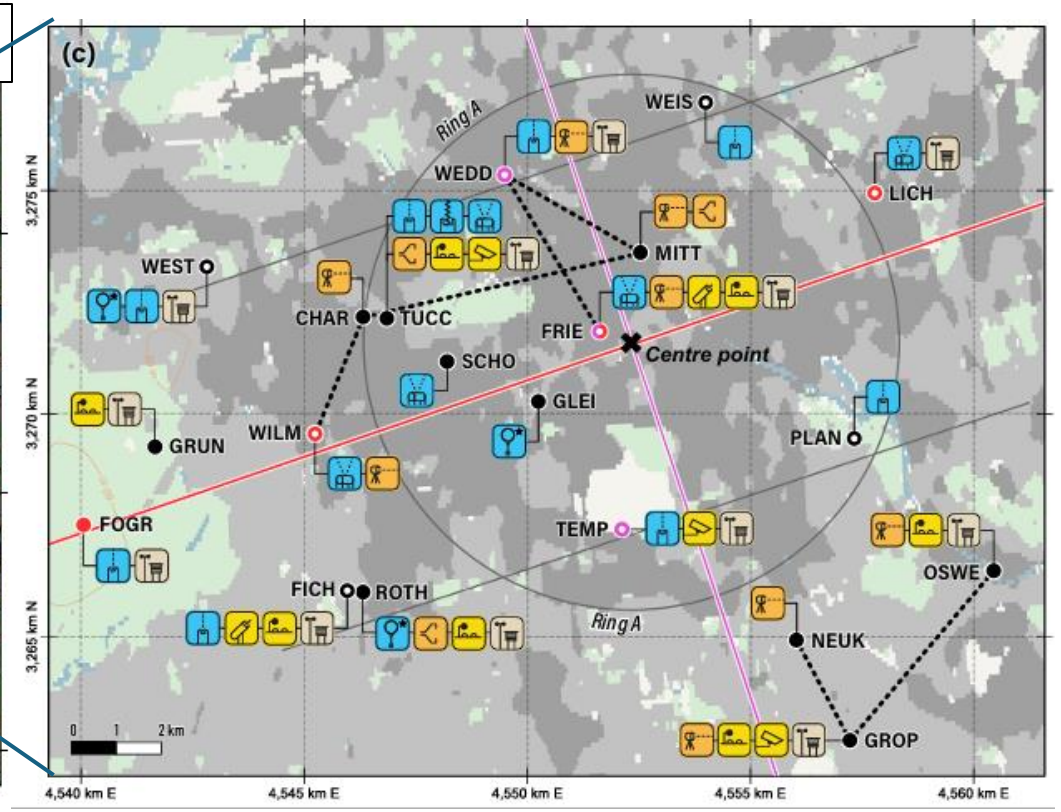


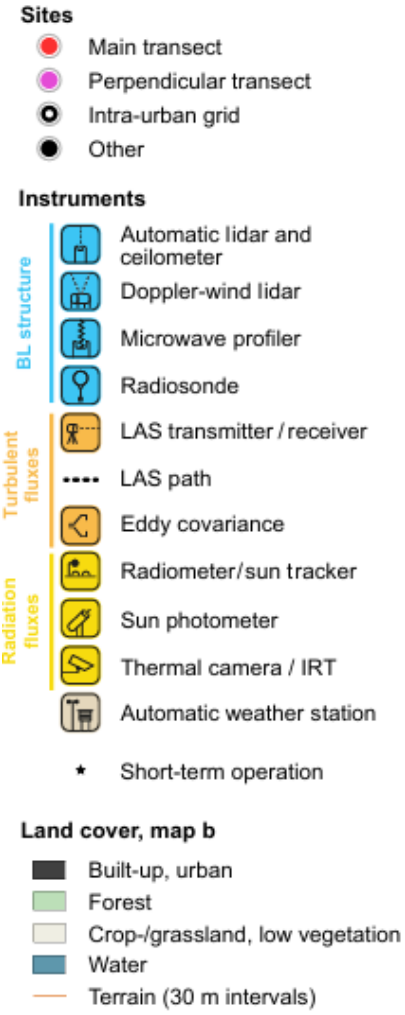
urbisphere-Berlin (2021-22)

Fenner et al. (2024) – just published in *BAMS*
https://doi.org/10.1175/BAMS-D-23-0030.1

Systematic network with 25 ALC & 6 DWL







2 Case study days:

1) 18 April 2022: dry clear sky, wind from northwest
2) 4 August 2022: heatwave, clear sky, wind from south

MURK Mixed Layer Height (MMLH) algorithm

Morning
Levels: < 700 m
z_{MLH} = max(ΔMURK) + 1 level

Growth period
Levels: $\uparrow_{surf}$
z_{MLH} = $MURK_{lev} < 10\%\ MURK_{z=surf}$

Afternoon
Levels: $\downarrow^{top}$
z_{MLH} = $MURK_{lev} > 10\%\ MURK_{z=surf}$

Evening/night
Levels: < 700 m
z_{MLH} = max(ΔMURK) + 1 level

Time

Use ΔMLH to determine transitions timings

Sunset

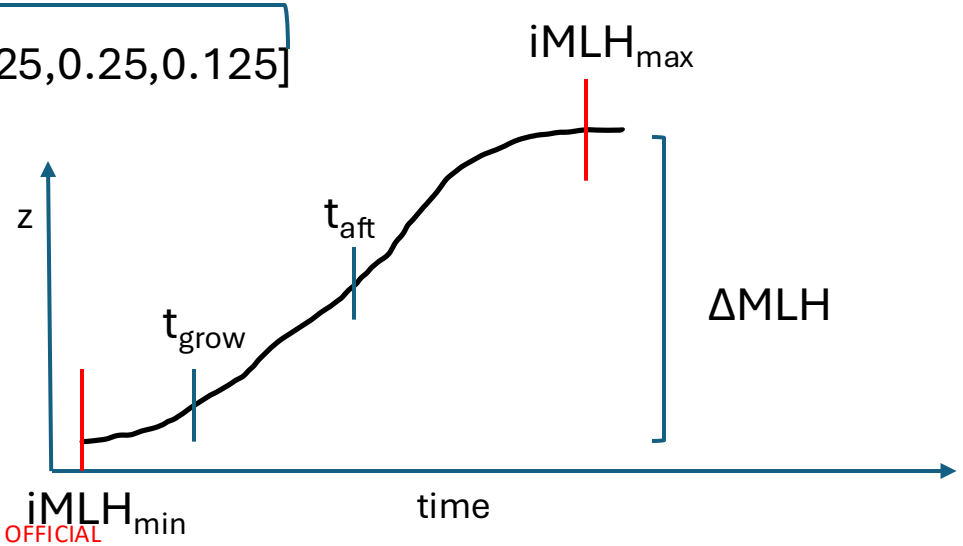
1.25 hours

- temporal smoothing of MURK: [0.125,0.25,0.25,0.25,0.125]
- Initial(i) iteration to determine
  - $iMLH_{min}$ morning 0Z to SR
  - $iMLH_{max}$ afternoon SN to SS

$\Delta MLH = iMLH_{max} - iMLH_{min}$

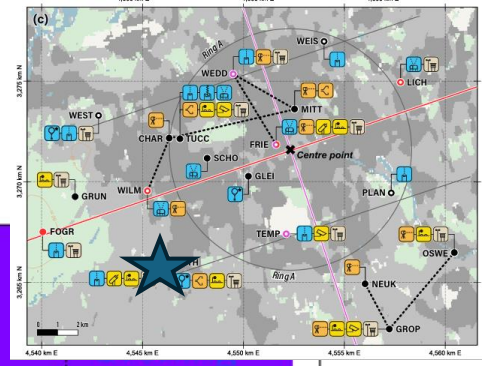
t_{grow} when $z_{MMLH} > \Delta MLH * 0.05 + iMLH_{min}$

t_{aft} when $z_{MMLH} > \Delta MLH * 0.5 + iMLH_{min}$

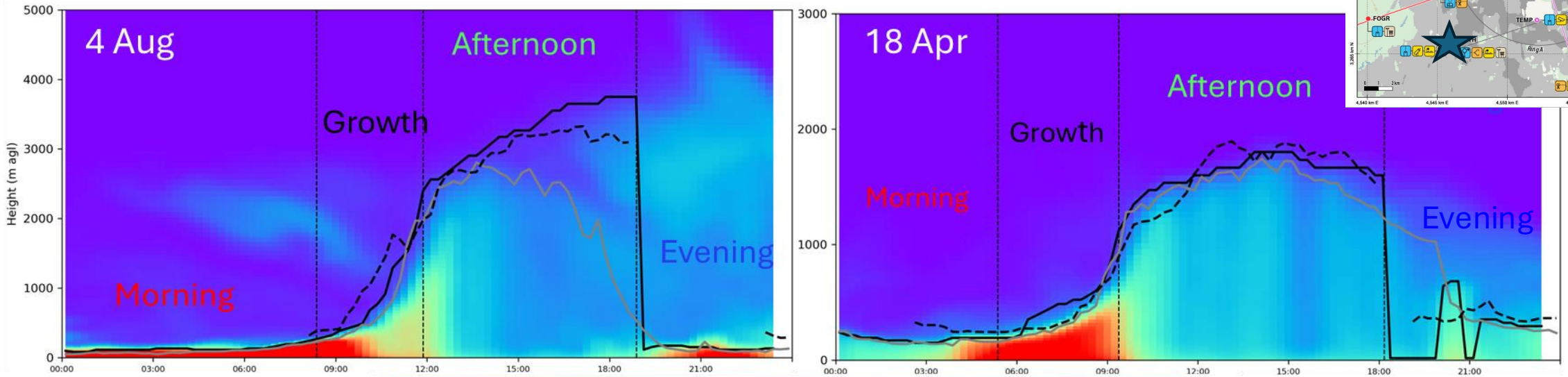


Timeseries at FICH

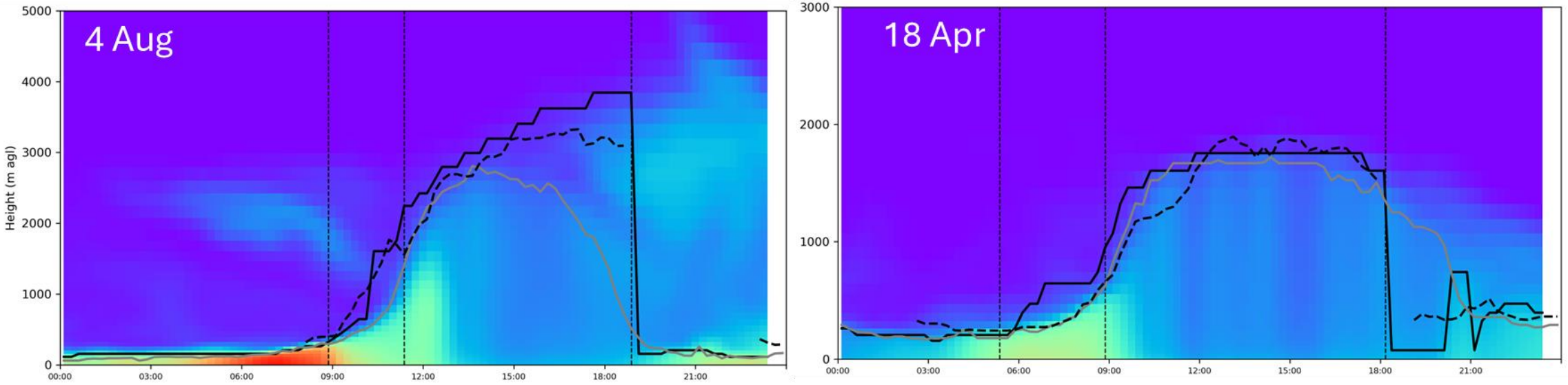
Model BLD diagnostic
MMLH
Ceilometer



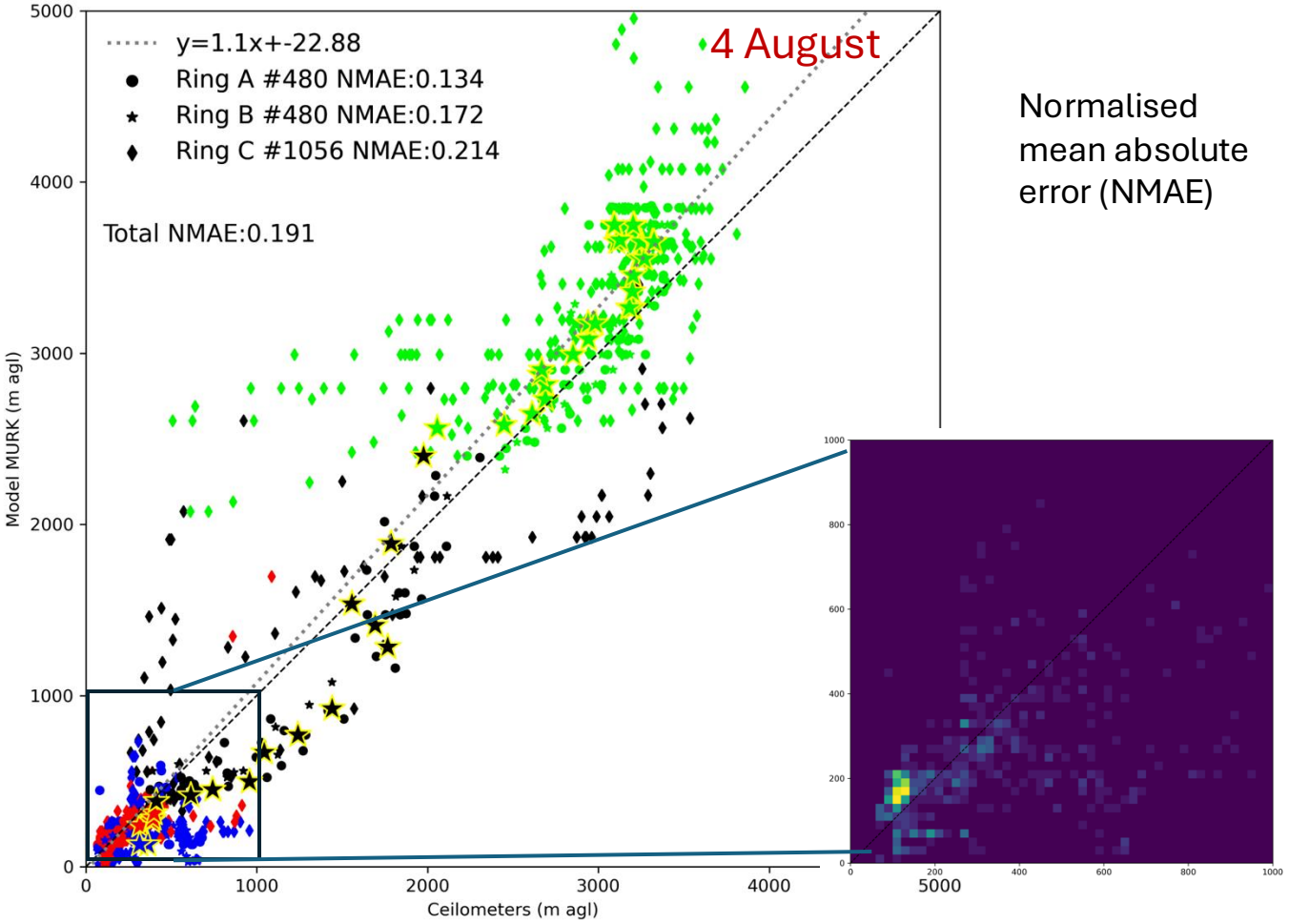
100 m domain



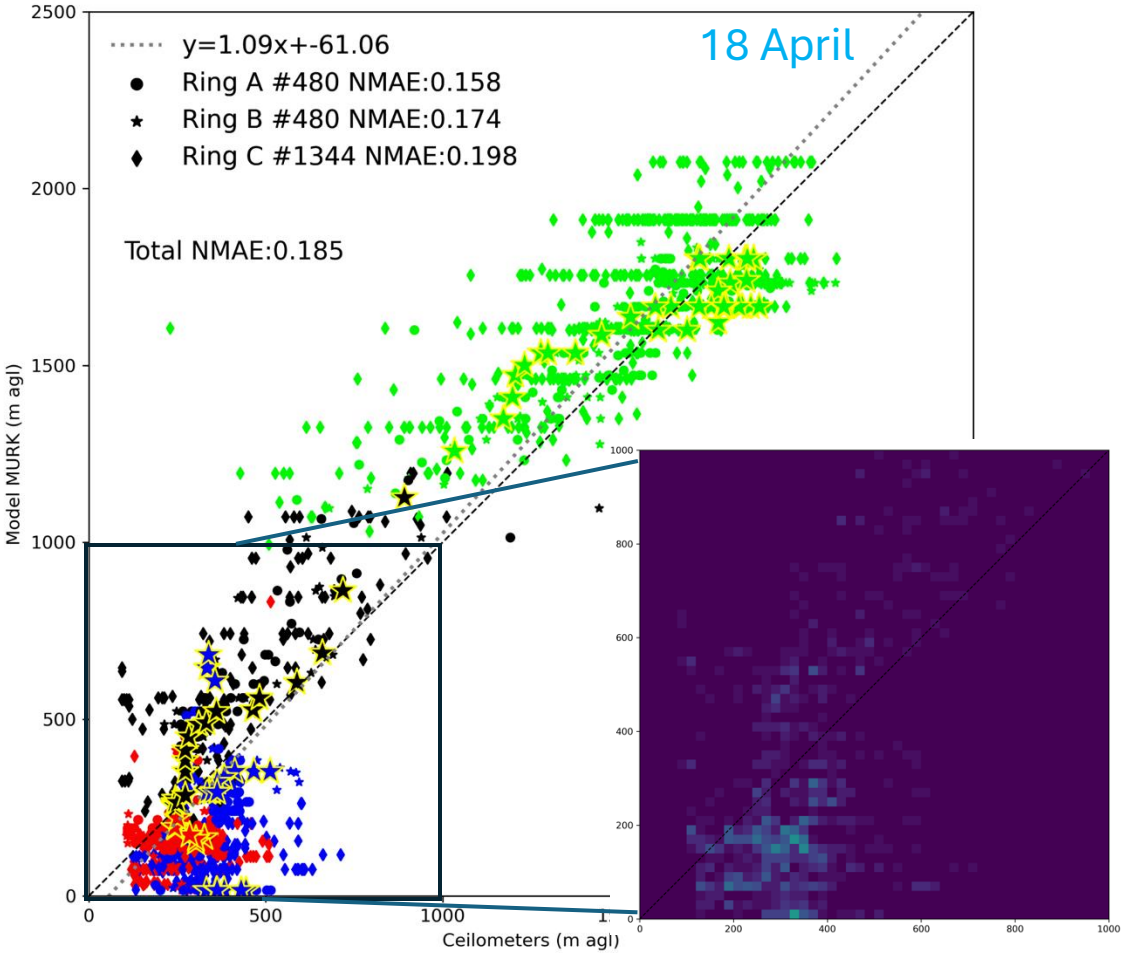
300 m domain



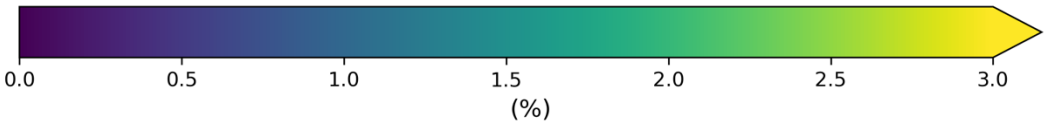
MMLH vs. Ceilometers



Normalised mean absolute error (NMAE)



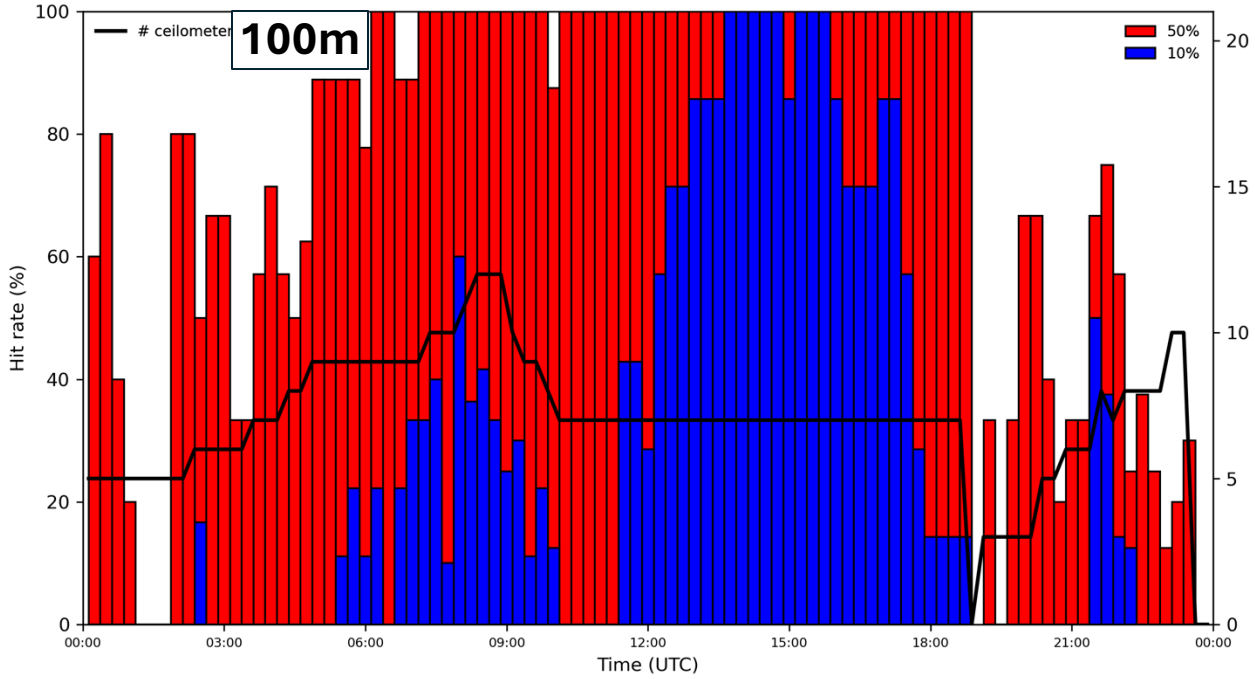
MMLH Period of the day

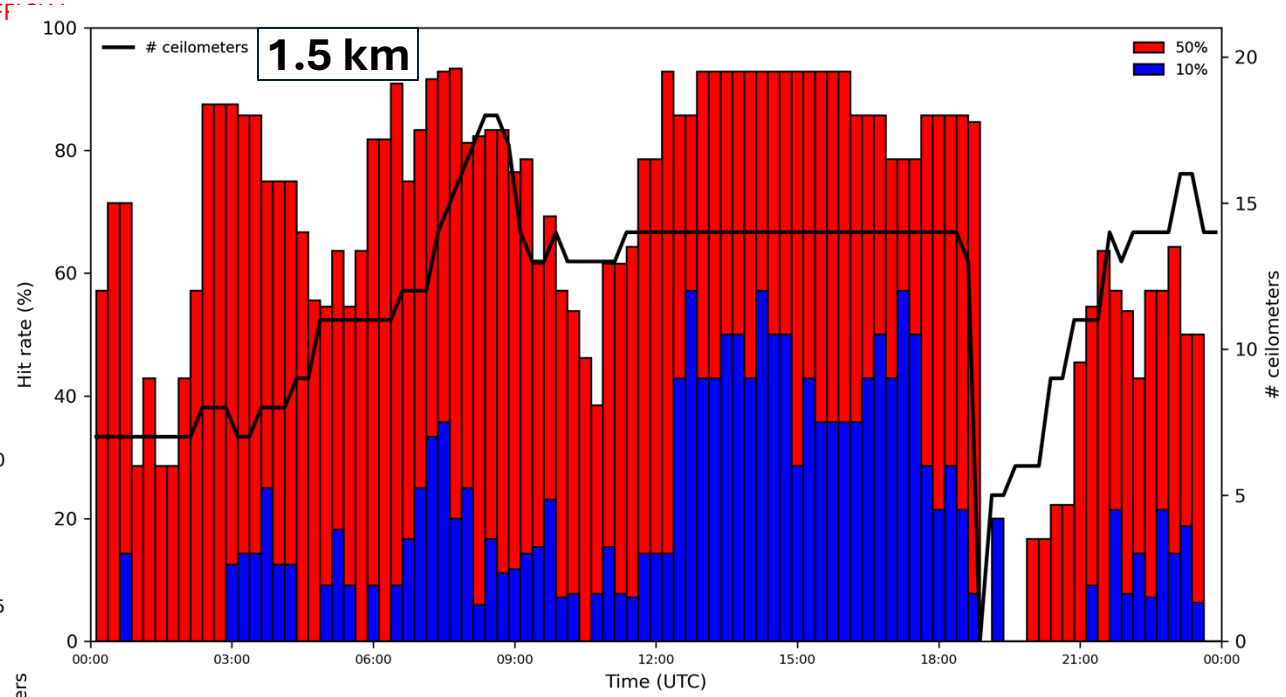


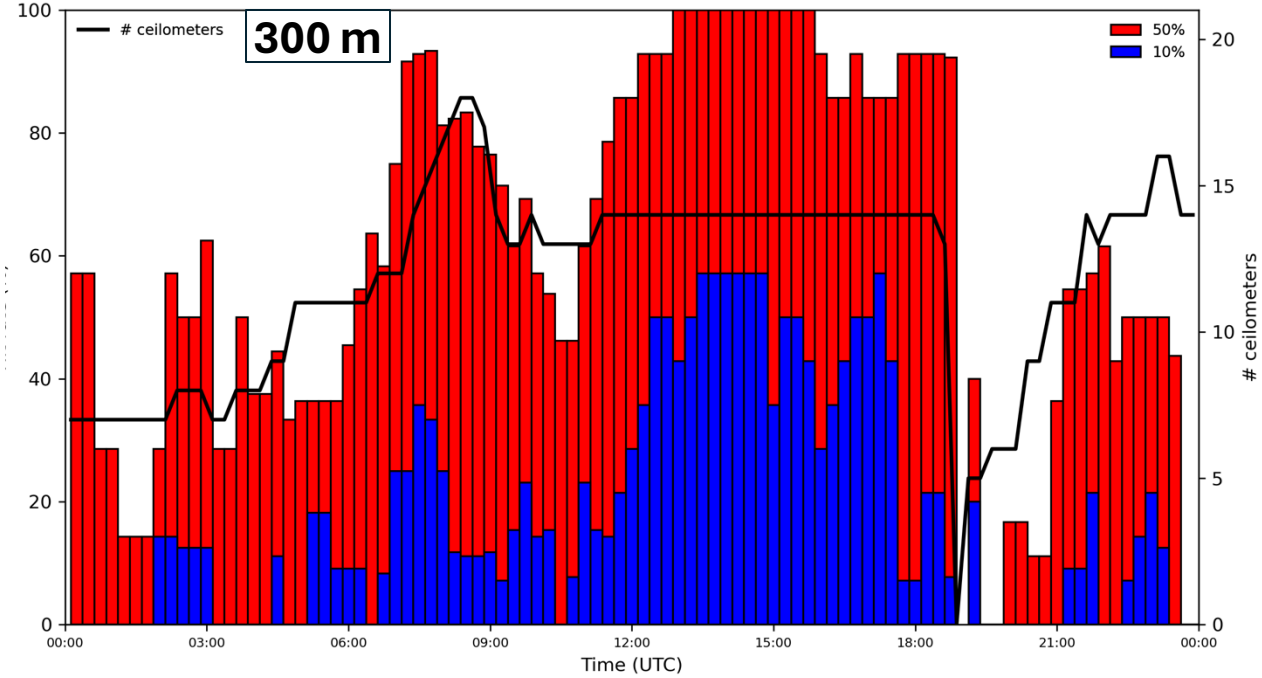
Frequency (PDF)

Hit Rate (10/50%) – 4 Aug.

available ceilometers
sites within +-50% of ceilometer
sites within +-10% of ceilometer





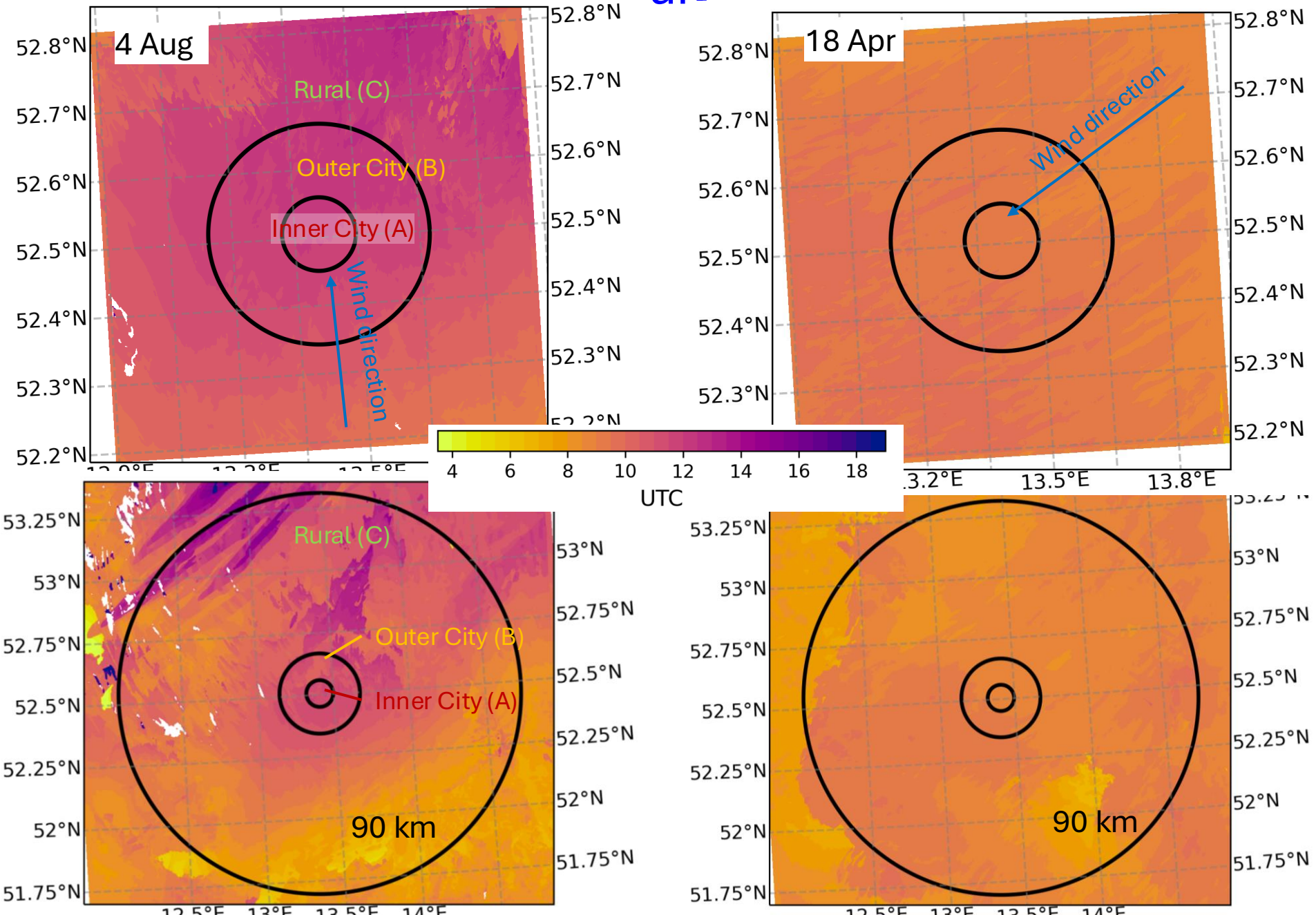


100 m model has added value in the afternoon over 300 m and 1.5 km

MMLH afternoon transition (t_{aft}): urban plume

100 m

300 m



Along wind transect: 18 Apr. evening

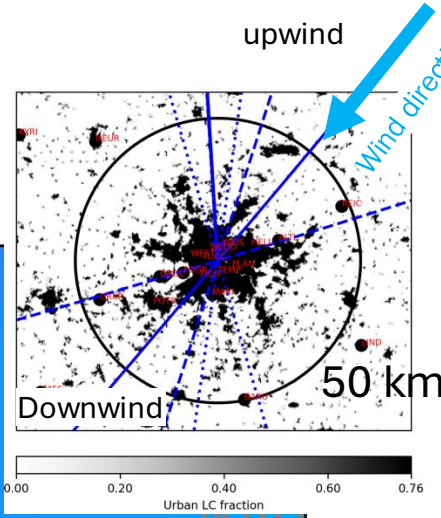
300 m grid

Potential temperature

MURK MLH

Shading – Aerosol concentration

18 April 2022: 20 UTC

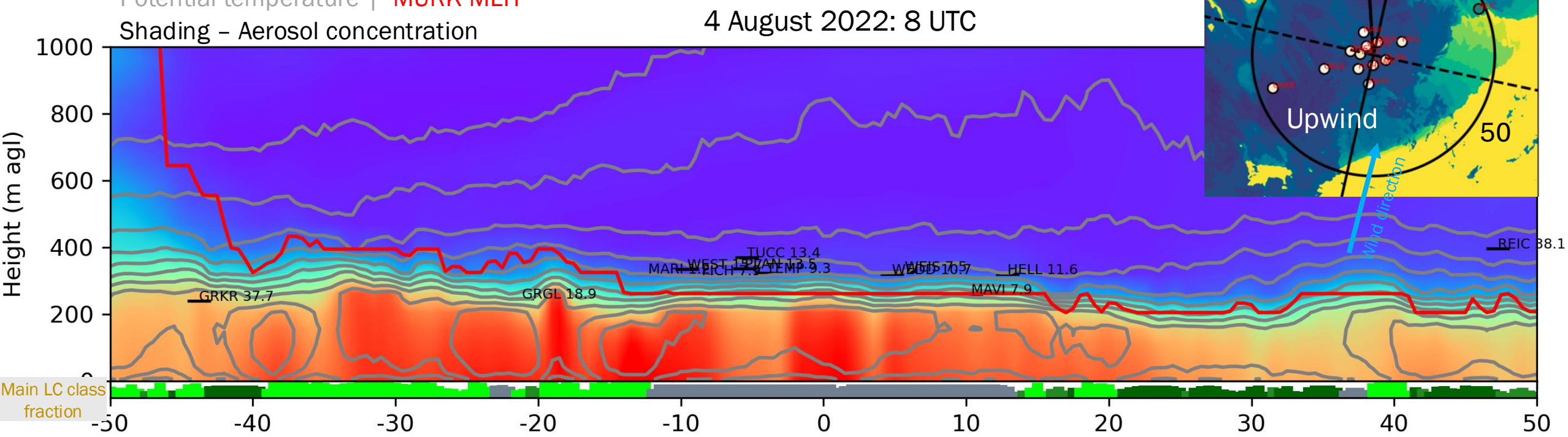


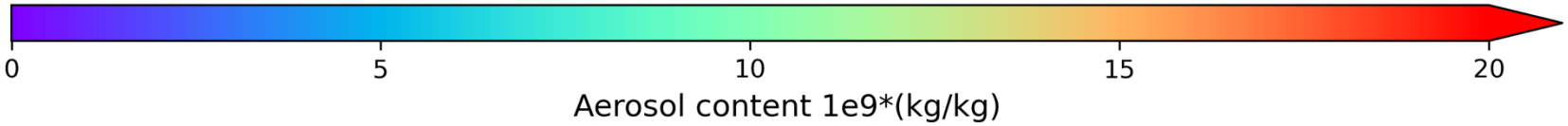
Along wind transect: 4 Aug morning

300 m grid

Potential temperature | MURK MLH

Shading – Aerosol concentration





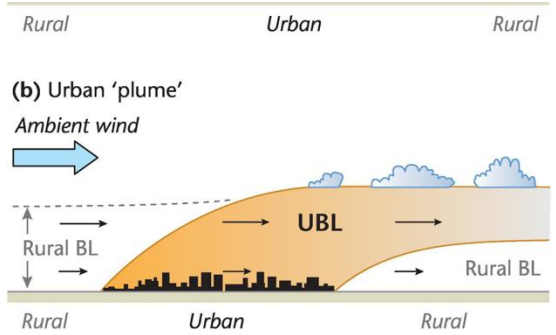
Main LC class fraction

Land cover classes: Broad leaf Tree | Needle leaf Tree | C3 Grass | Water | Buildings+Paved

Glazer et al. in prep

Final Comments

- MMLH algorithm – relativity easy to implement
  - MMLH and ceilometers agree best in afternoon and over the city
- Added value at 100 m resolution comparing to ceilometers
- An urban plume effect is clear in both model case studies (esp. in the evening)
- Mesoscale/synoptic conditions affect this plume:
  - 18 Apr: downwind MLH is shallower, more variability upwind w/ cooler airmass
- Is there a difference in urban plume effects depending on mesoscale conditions? i.e. 18 Apr. vs. 4 Aug.



Oke (2017), *Fig. 2.12*