Urban influence
on
atmospheric boundary layer dynamics

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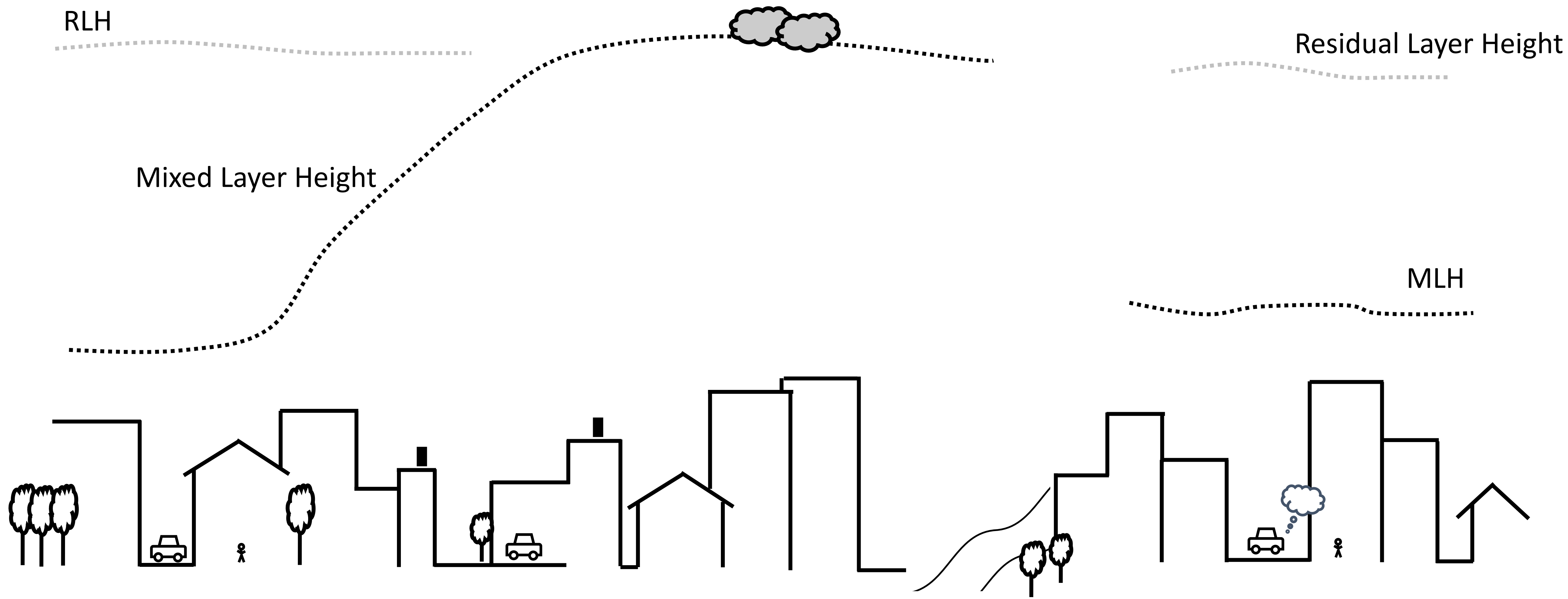
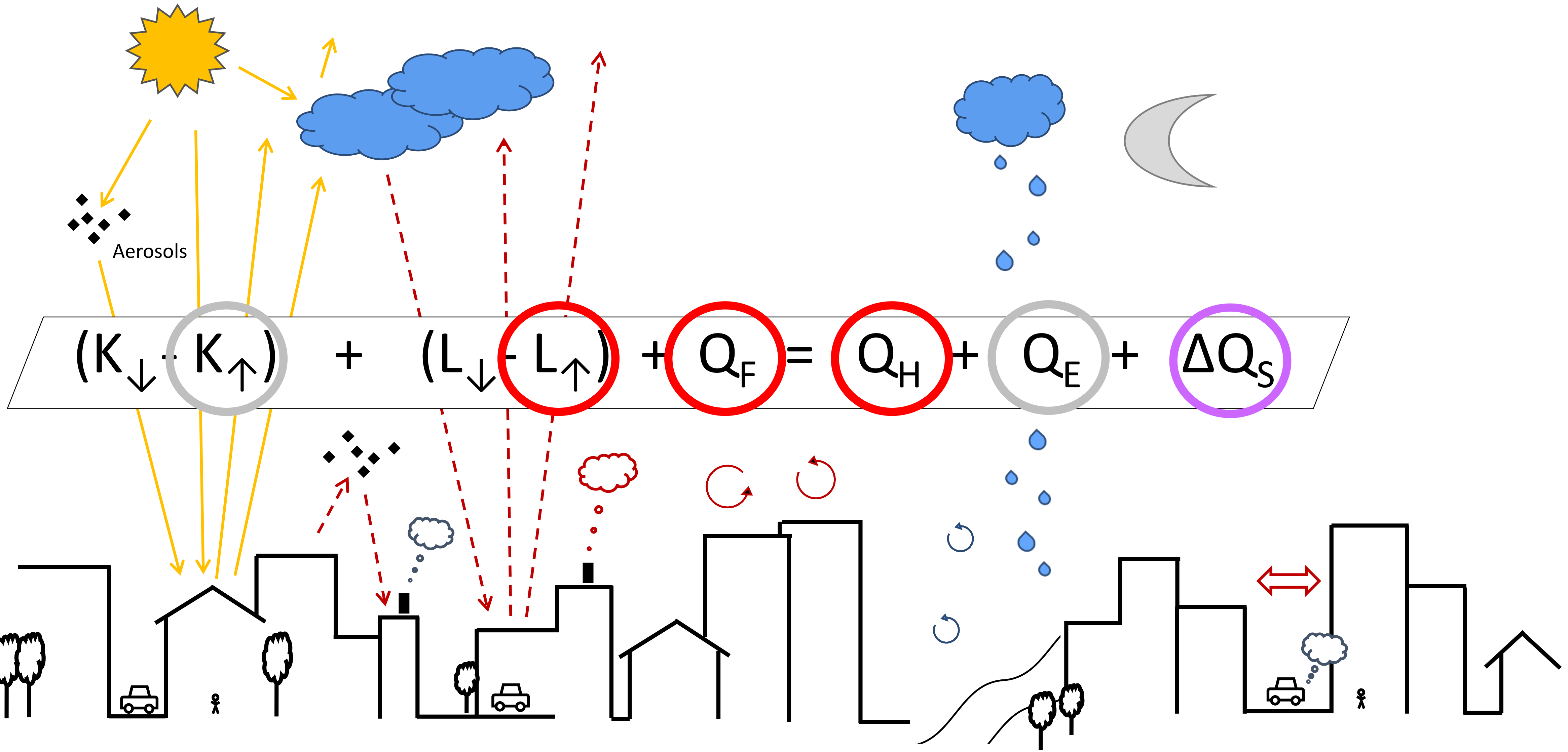
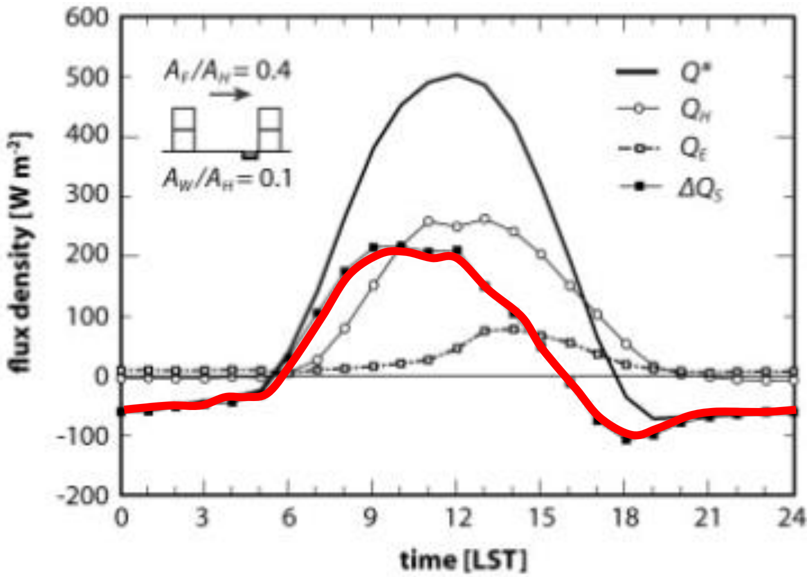

RLH
Residual Layer Height
Mixed Layer Height
MLH



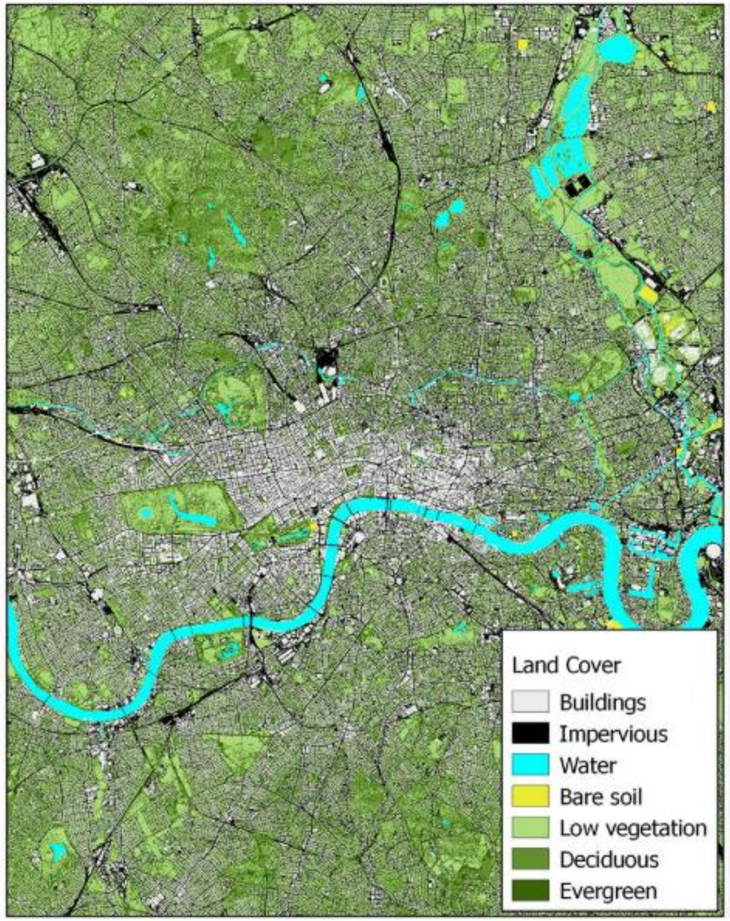
K	short-wave radiation flux	Q_H	turbulent sensible heat flux	Q_F	anthropogenic heat flux
L	long-wave radiation flux	Q_E	turbulent latent heat flux	ΔQ_S	heat storage in urban canopy

Storage heat flux

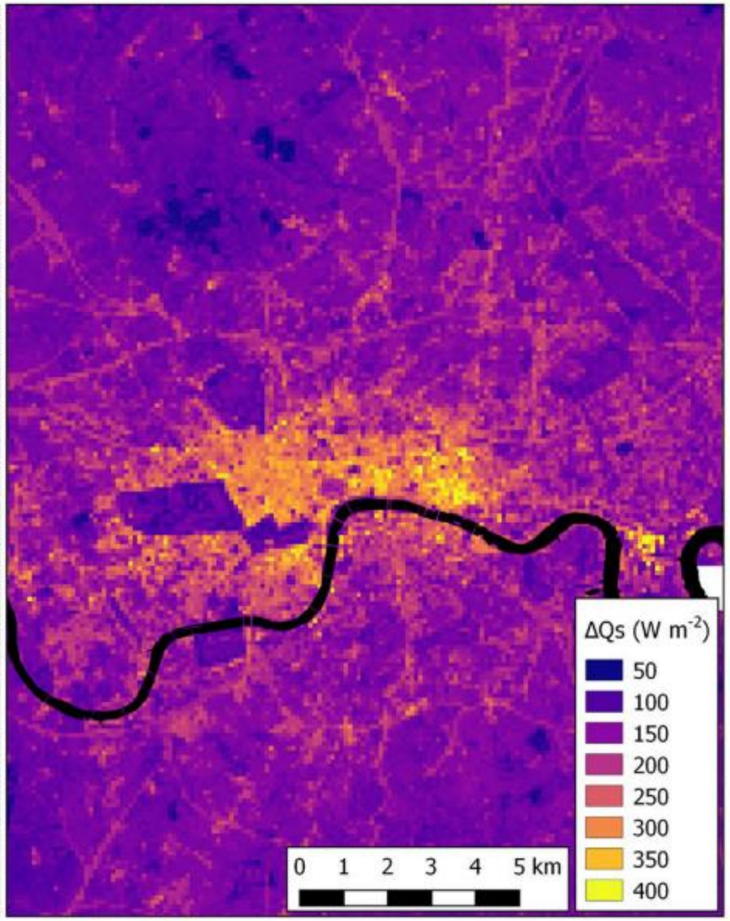
Perlmutter et al. (2012)



Central London



ΔQs (11:00, 19 July 2016)

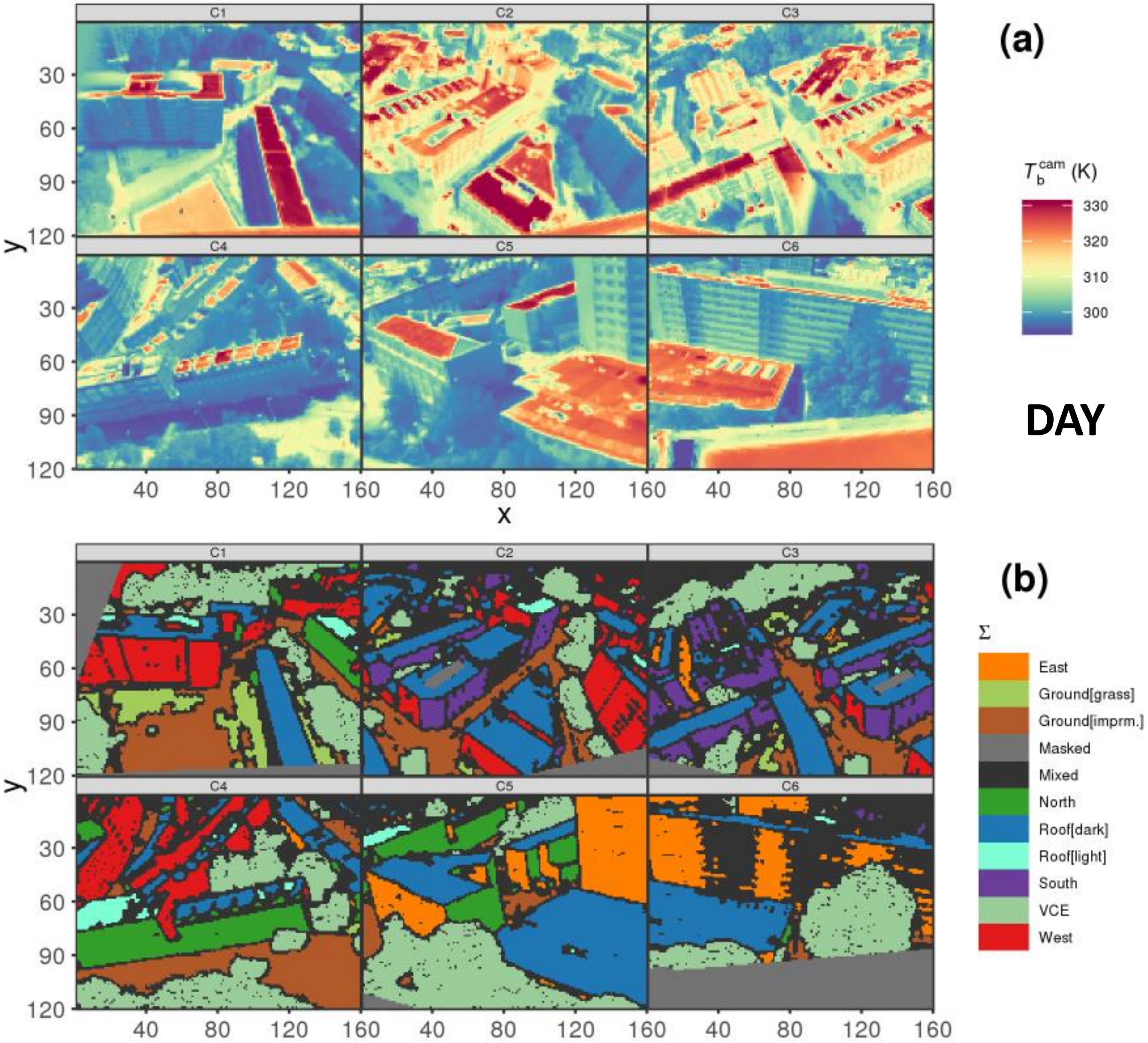


Chrysolakis et al (2018)

- Challenging to measure and model
- Significant contribution to SEB
- Important driver for urban heat island
- Important for indoor thermal comfort and building energy balance

Surface temperatures at building scale

- Surface temperature (Ts) driven by facet orientation, sky-view-factor and materials characteristics (reflectance, emissivity, heat capacity)
- “Radiation trapping” in street canyons increases storage heat flux



Morrison et al., in prep.

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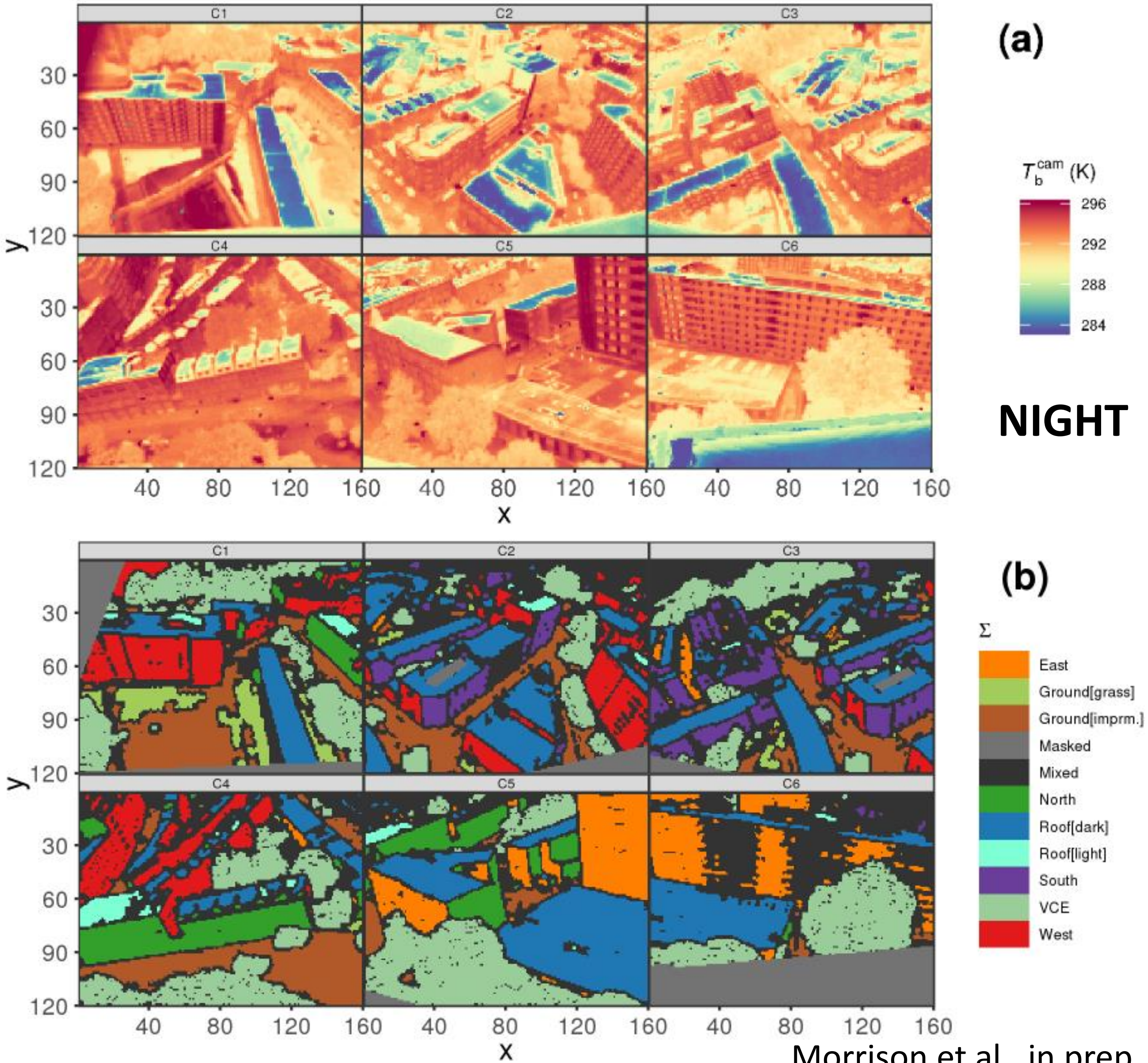
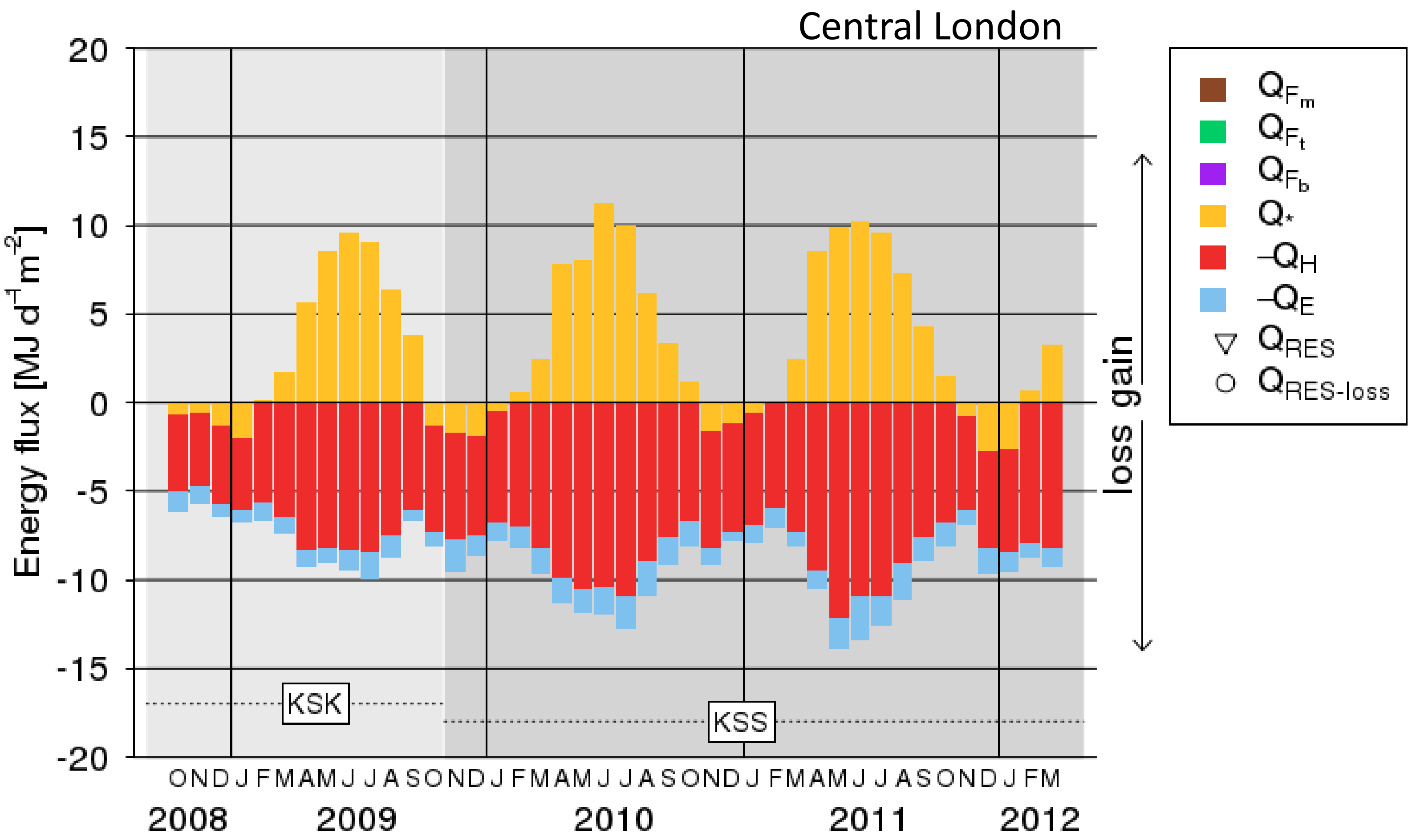


Morrison et al., in prep.

Anthropogenic heat flux Qf

- "Impossible" to measure
- Bottom-up/top-down modelling approaches based on energy consumption etc.
- Significant contribution to SEB
- Important driver for urban heat island
- Building energy balance drives Qf in response to human behaviour



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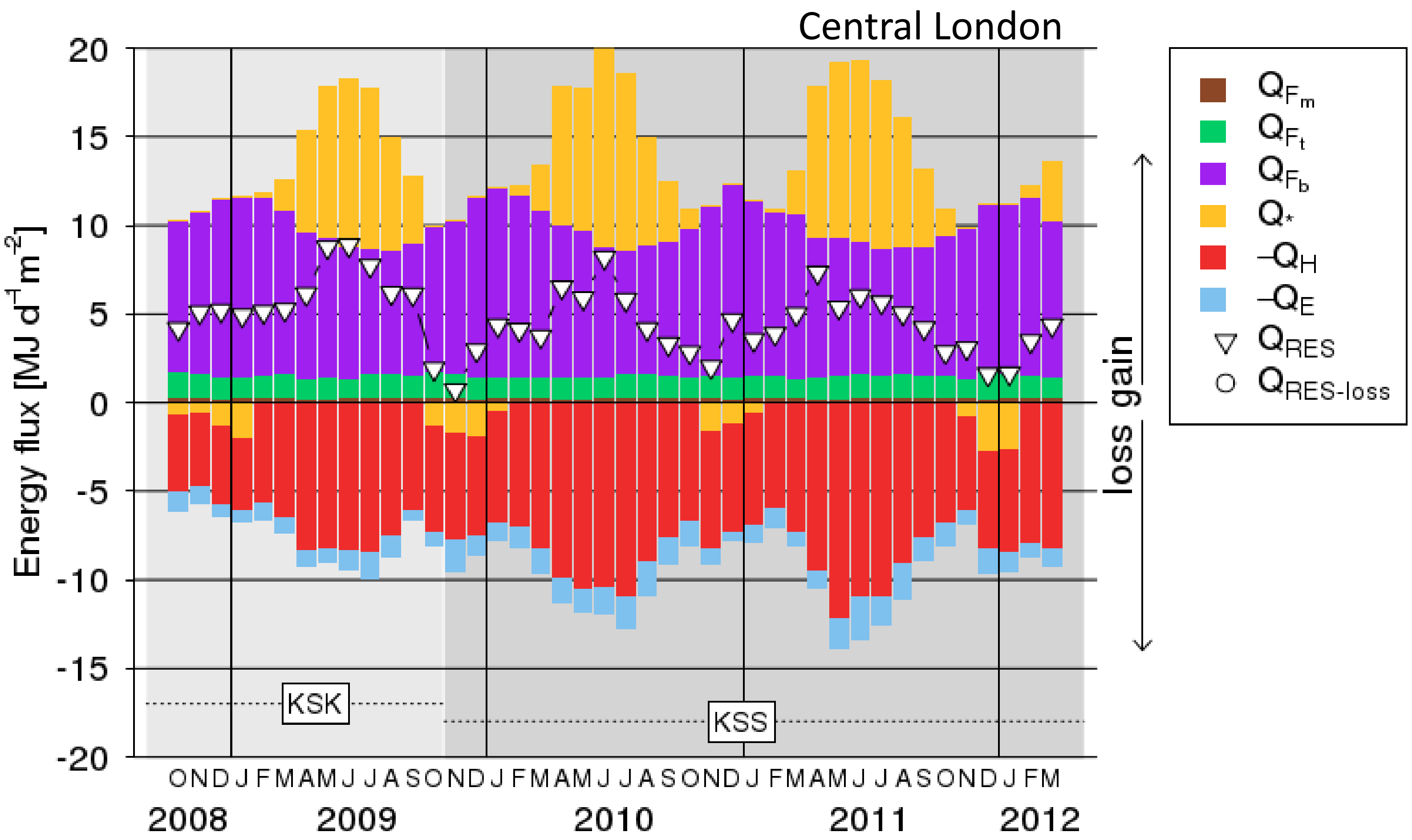

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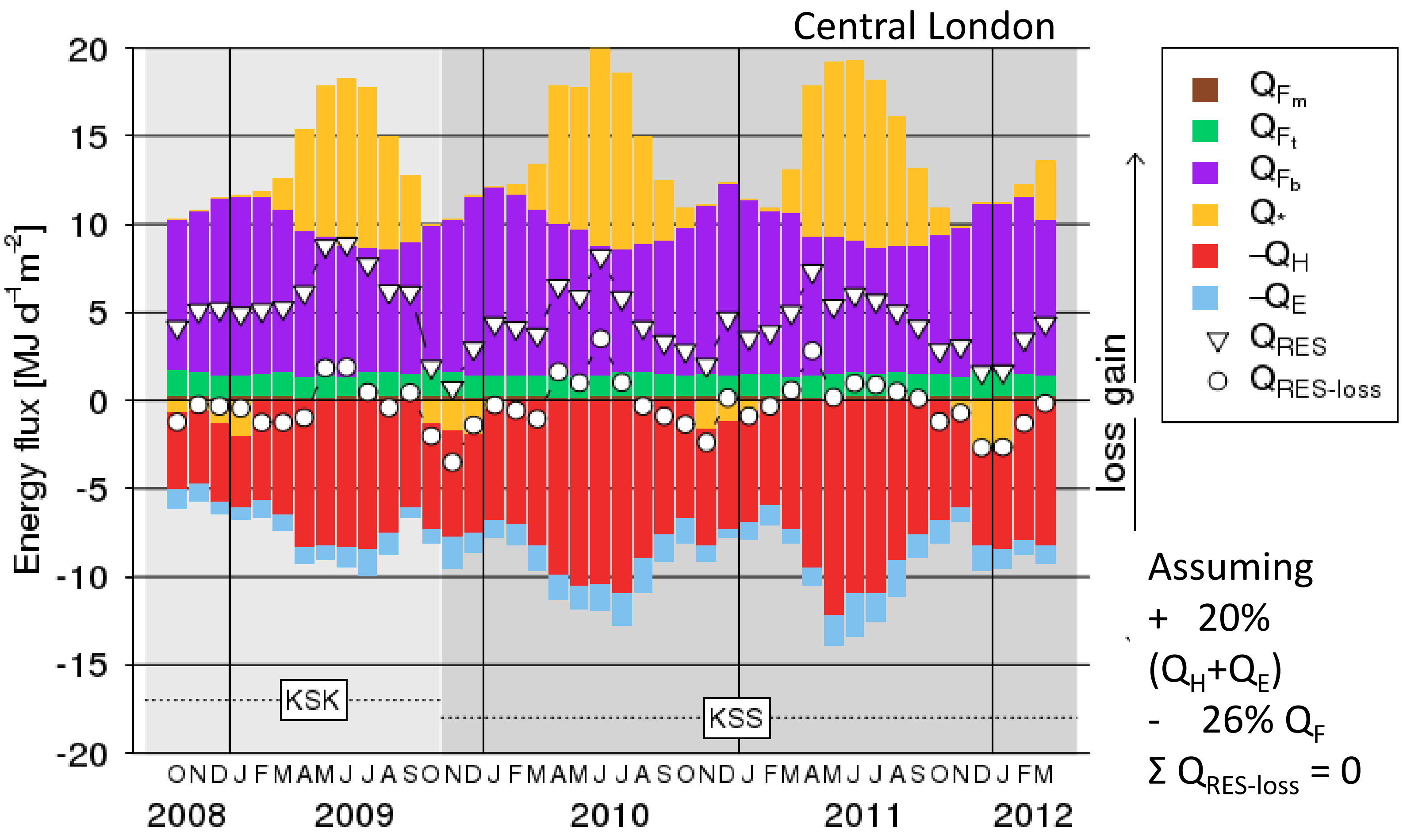
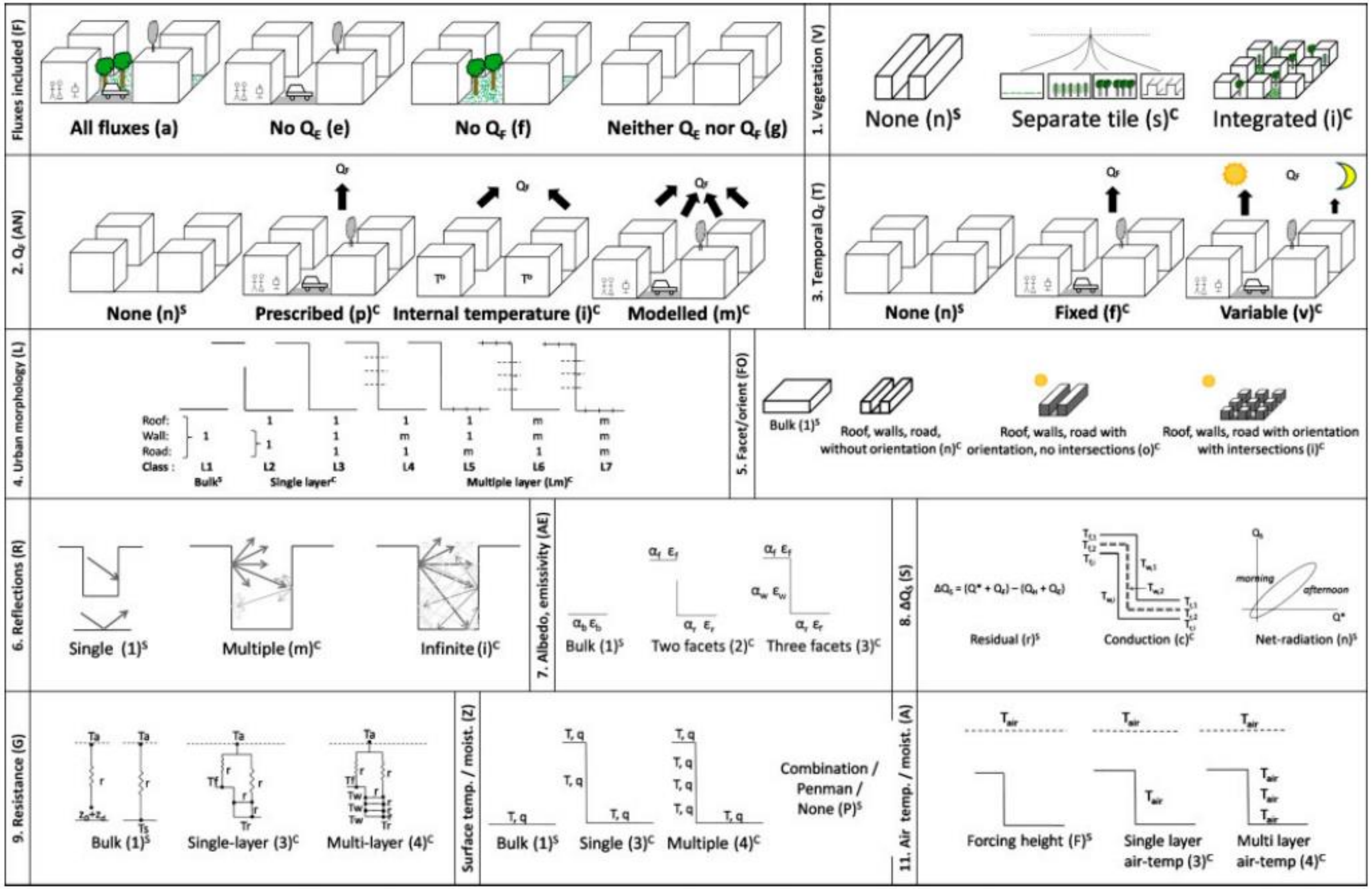


Assuming
\+ 20% (Q_H+Q_E)
\- 26% Q_F
$\Sigma Q_{RES\text{-}loss} = 0$

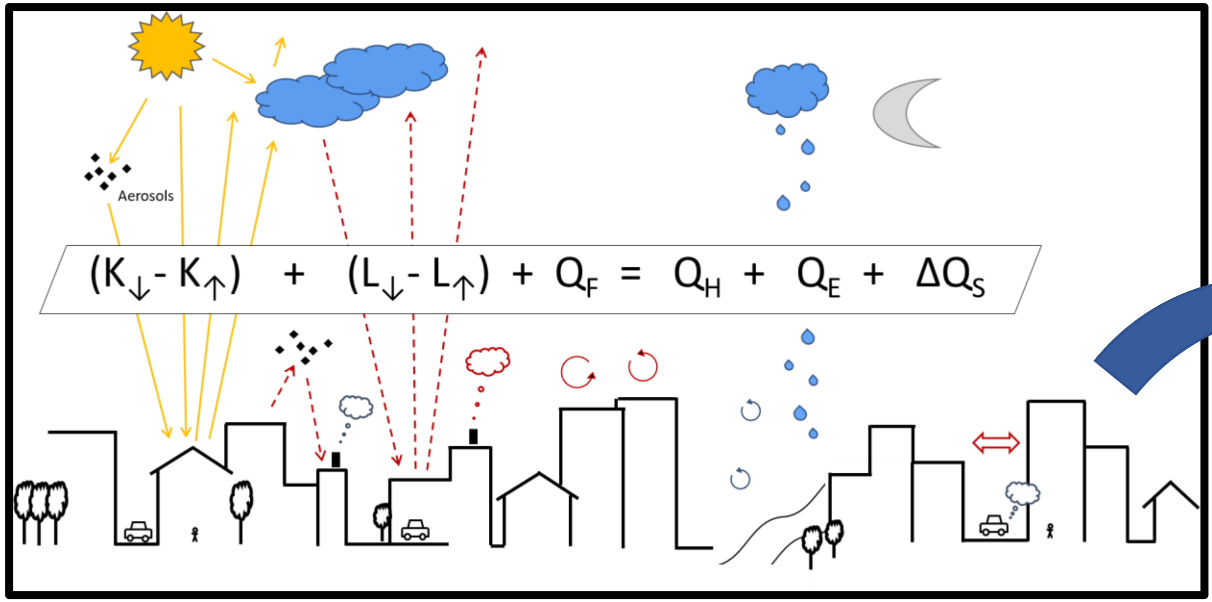
- Q_E restricted due to scarce vegetation
- Rainfall often only moisture source
- Often in order of EC measurement uncertainty

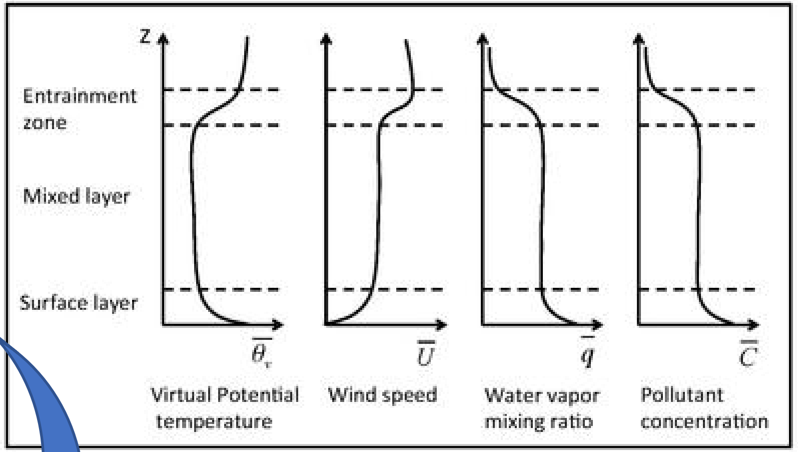
Surface schemes: range of complexity



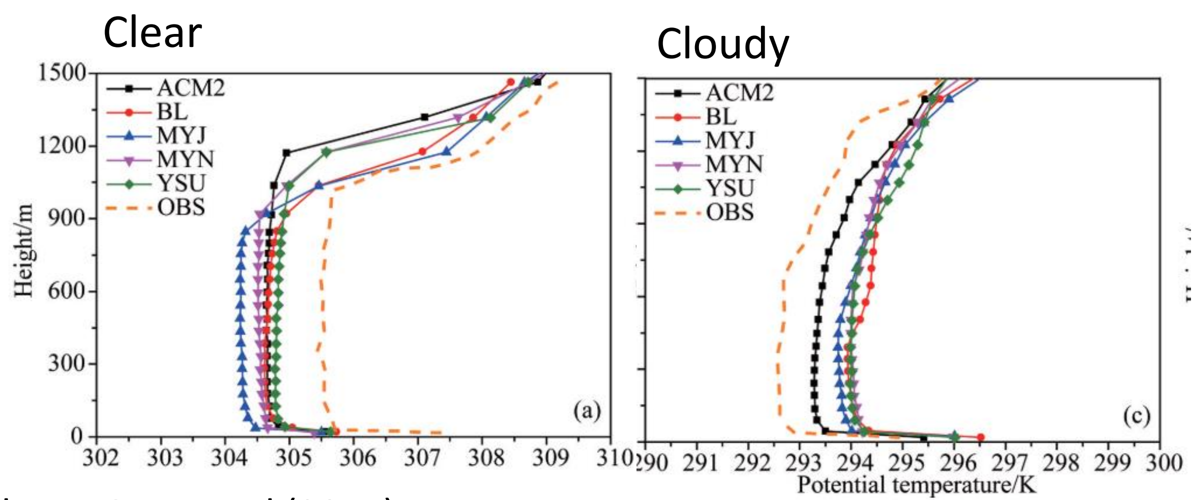
Grimmond et al (2010)

- Meso-scale modelling at increasing resolution: now down to ~100 m
- Implications for representation of
  - Buildings
  - Vegetation
  - Anthropogenic heat
  - Heterogeneity in general
- “Urban” land cover not sufficient
- Implications of surface structure on wind profile – **roughness** parameterisations

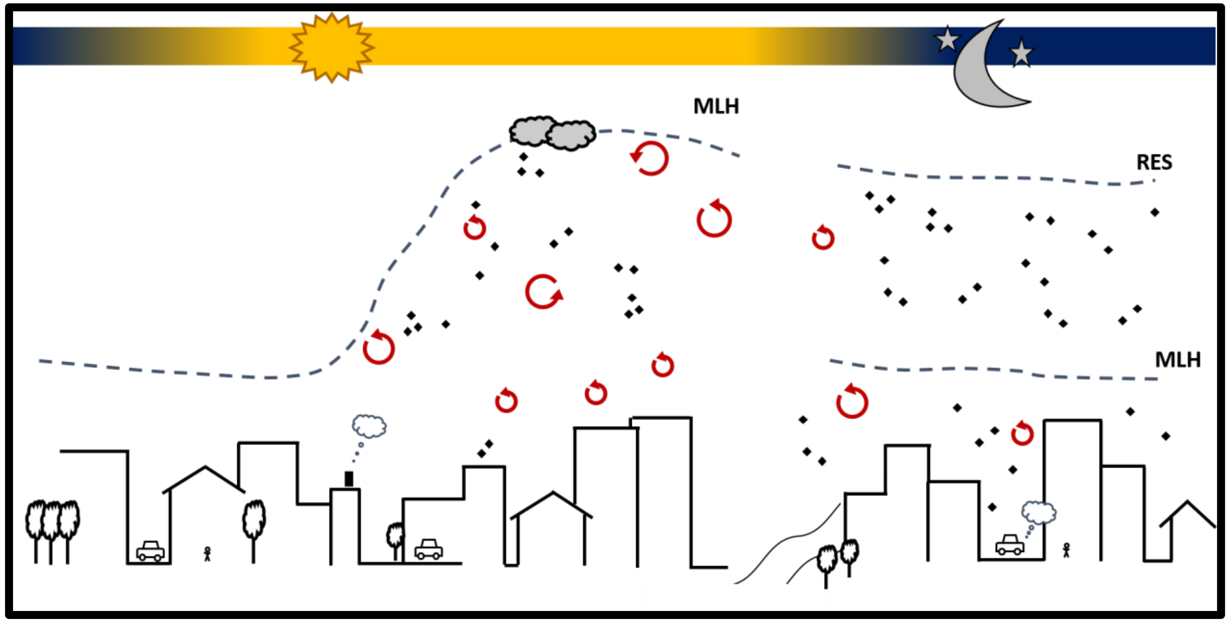




Stull (1988)

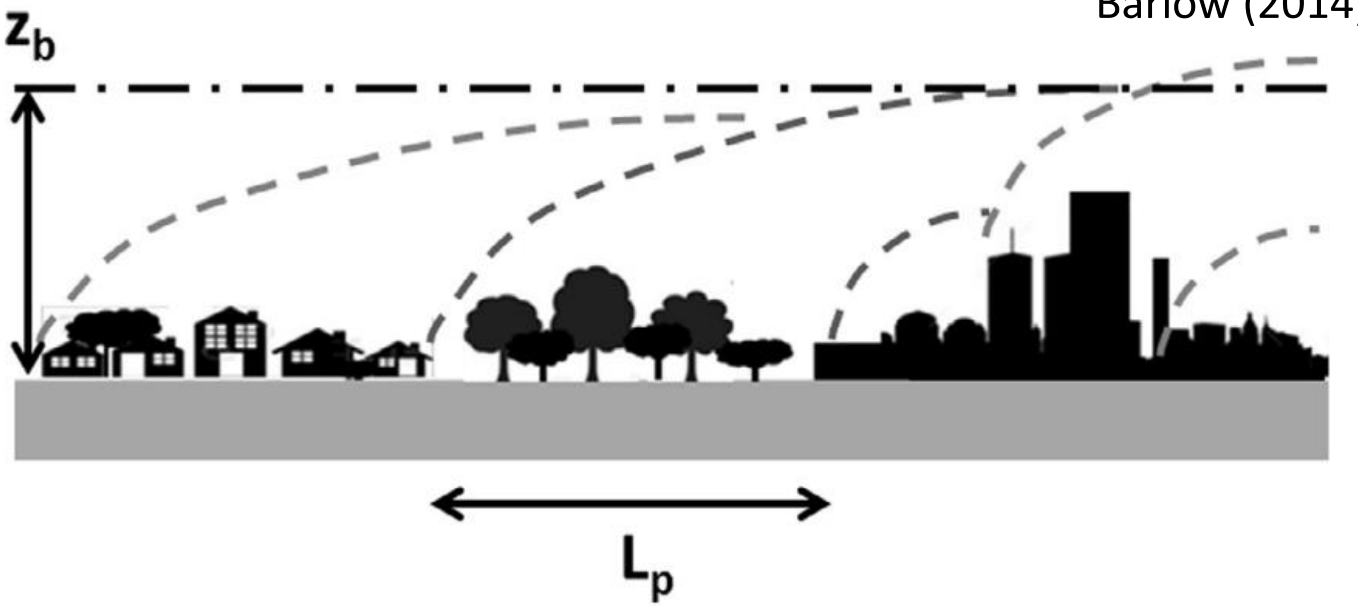


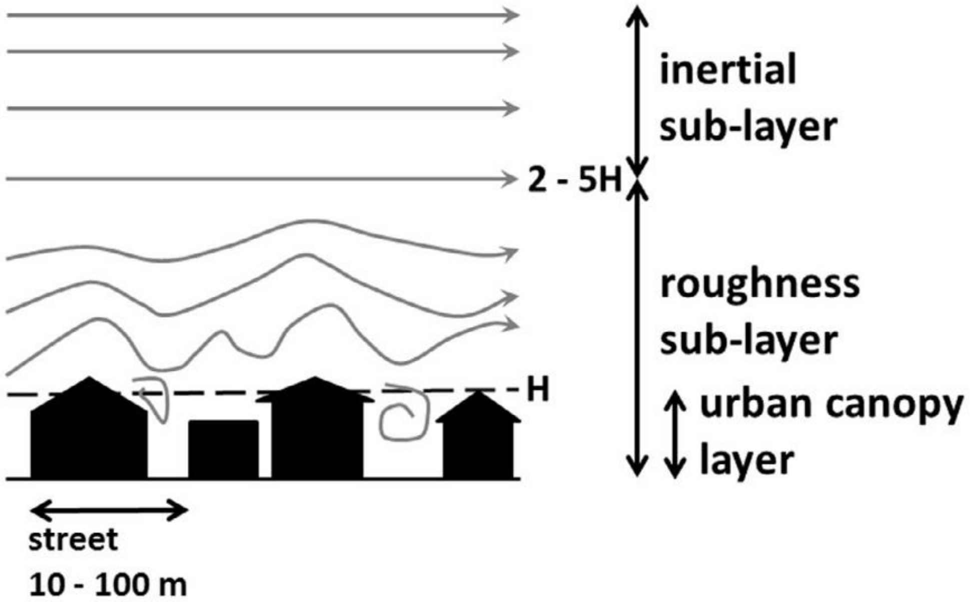
Cheng-Gang et al (2017)

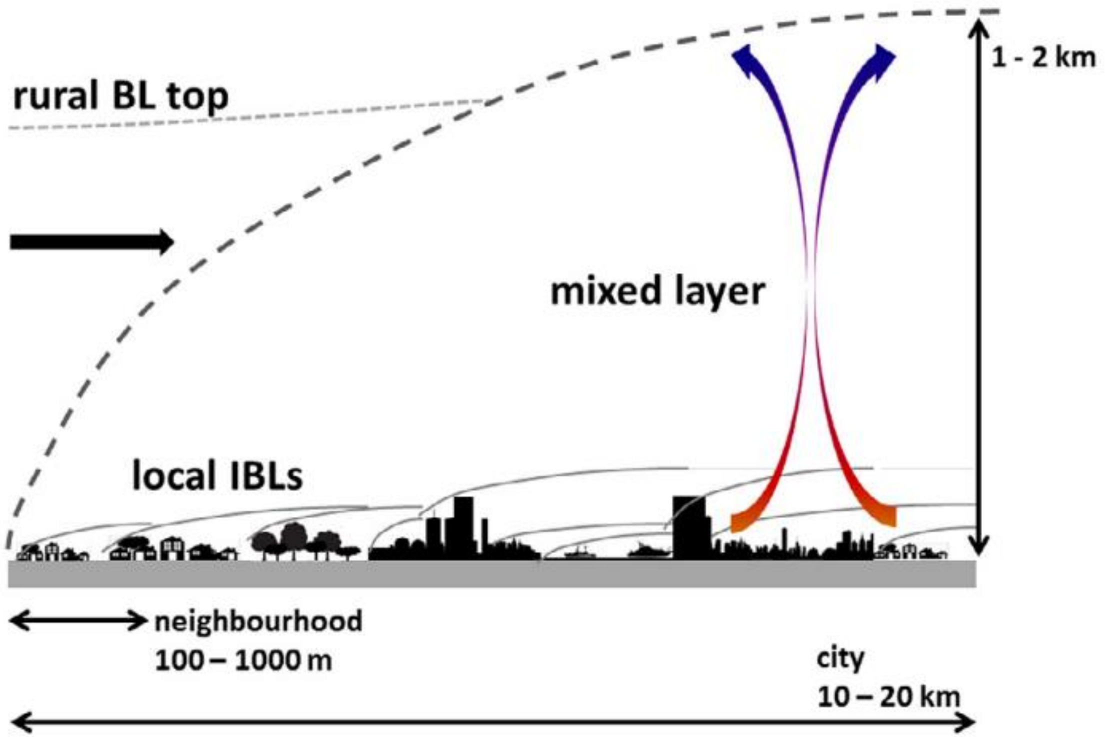


Barlow (2014)

- Reality: blending height z_b depends length scale of heterogeneity
- Model-world: z_b usually assumed to equal first model level
- Model geometry restricts scale of heterogeneity

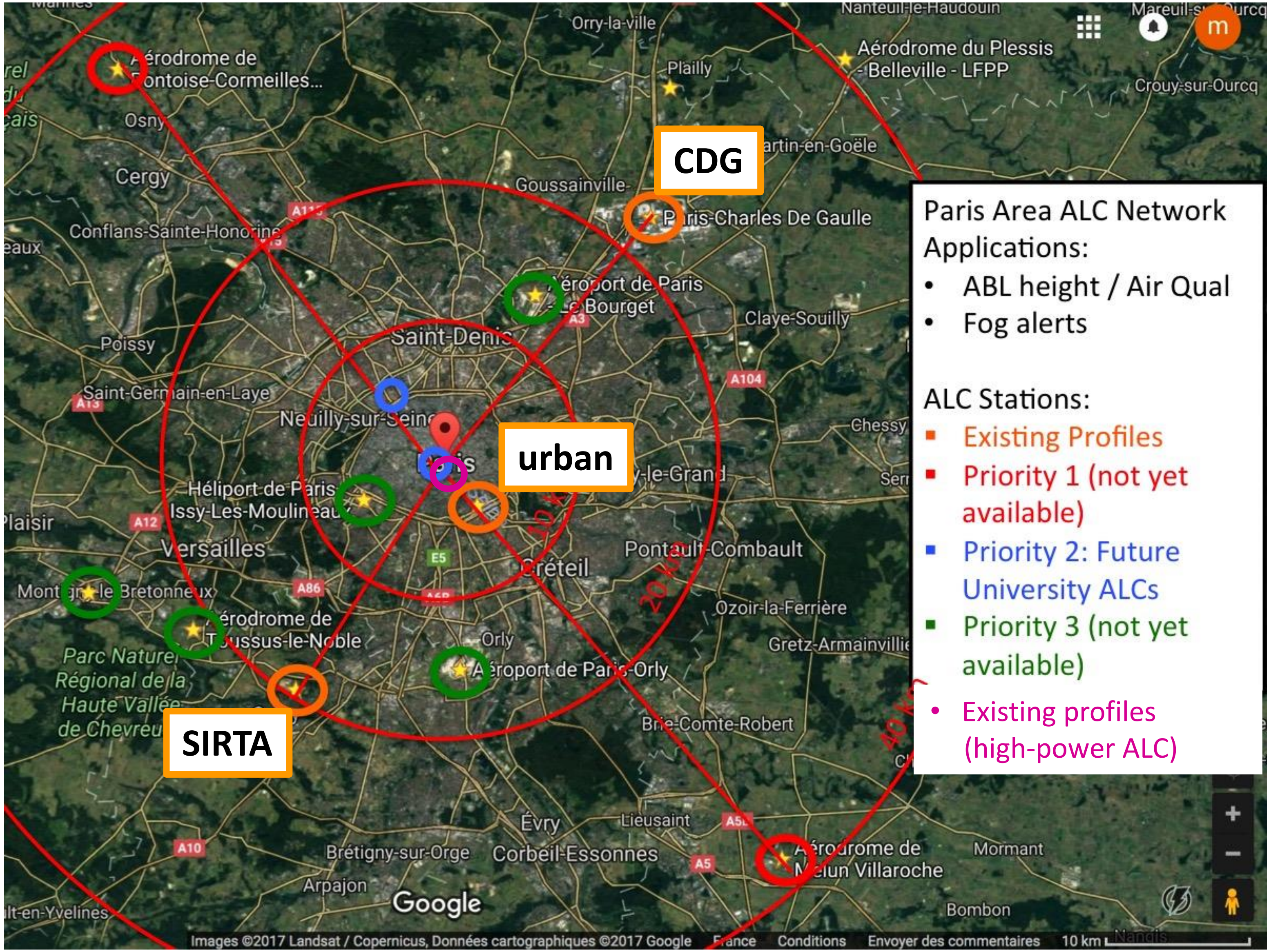






Observations of boundary layer height (few examples)

Spatiotemporal variability of ABL structure



<u>Measurements</u>

Surface air quality

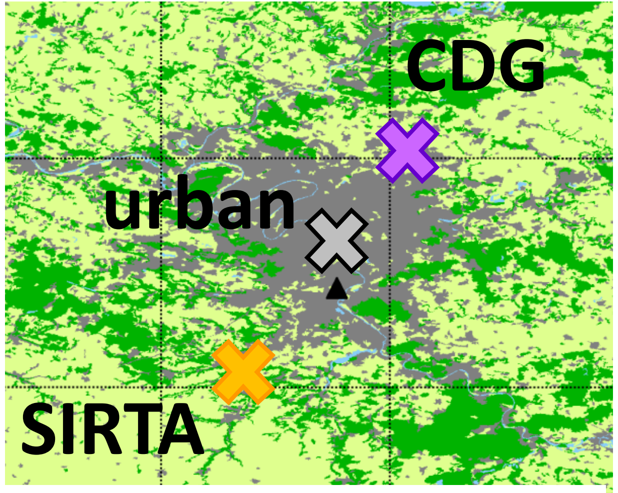
- AirParif
- IPSL laboratories
- INERIS

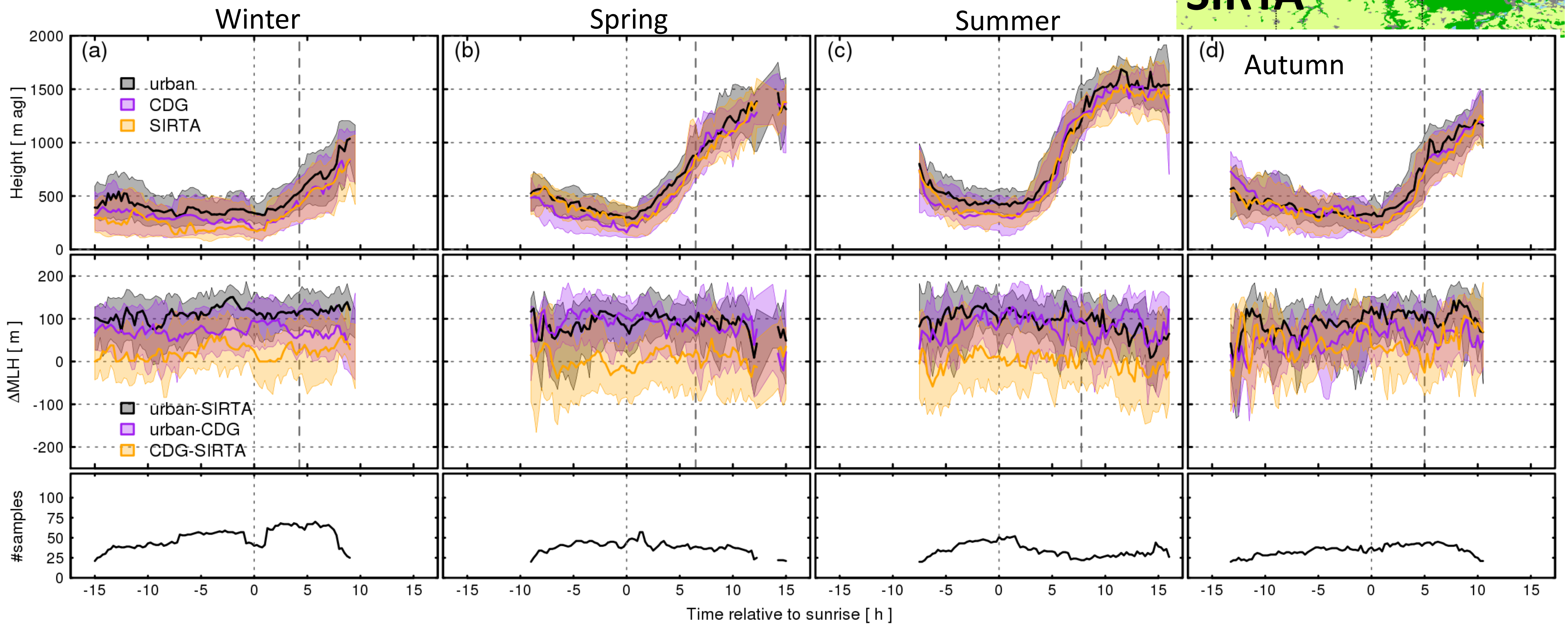
Mixed Layer Height

- Regional network
- Automatic lidars and ceilometers (ALC): **Vaisala CL31**
- Tailored automatic algorithm *CABAM*

Intra-city comparison

- ABLH Paris urban-suburban transect (2017-2018)
- Urban increment vs suburban surroundings ~ 100 m on average
- Now investigating land cover-driven contrasts



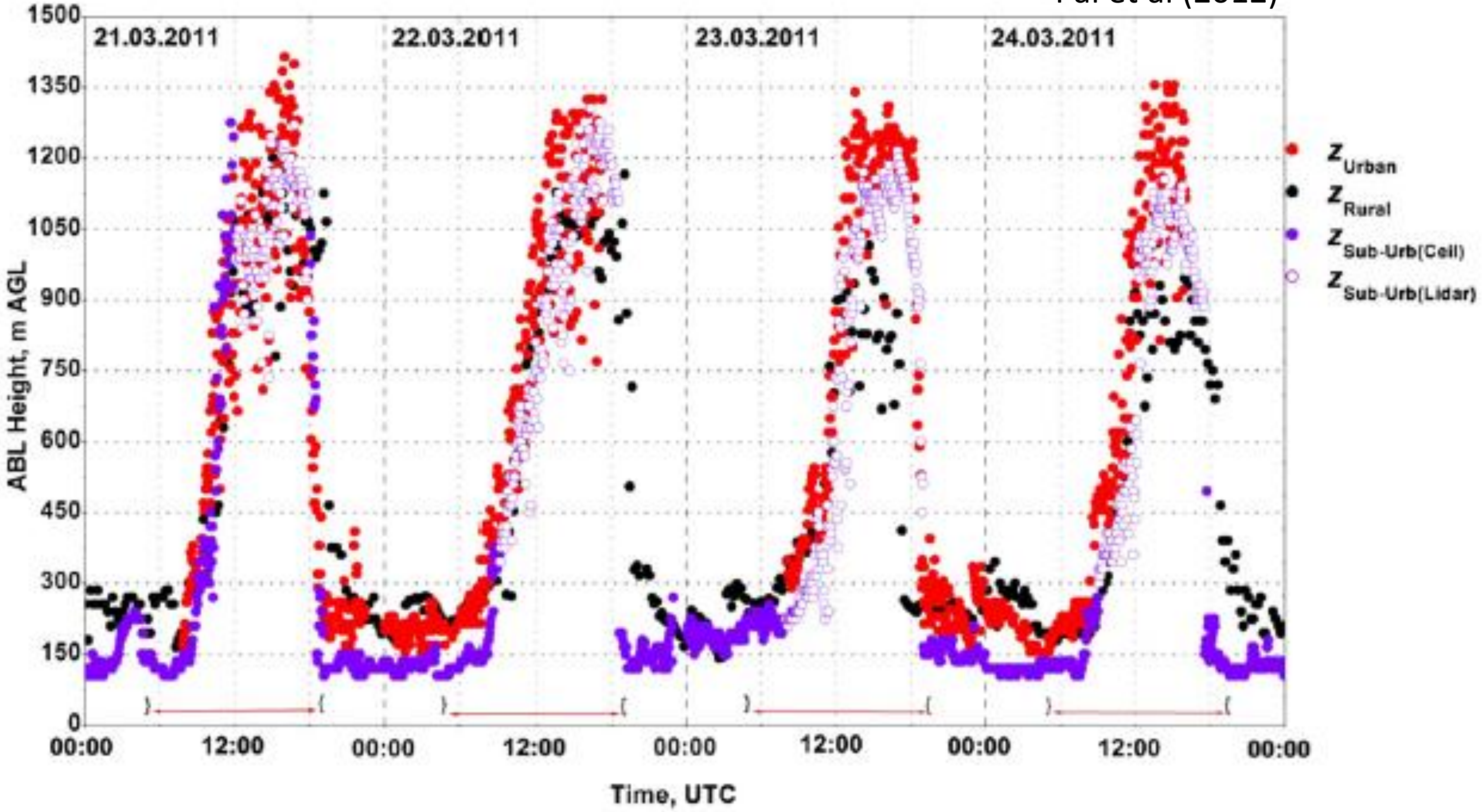


Urban increment in ABLH

ABLH gradient during strong UHI event:

- Urban-rural ~ 500 m
- Urban-suburban ~ 250 m

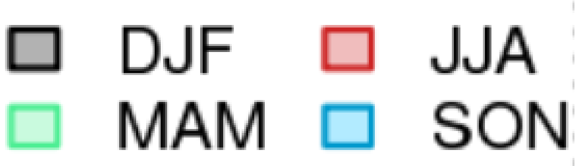
Pal et al (2012)

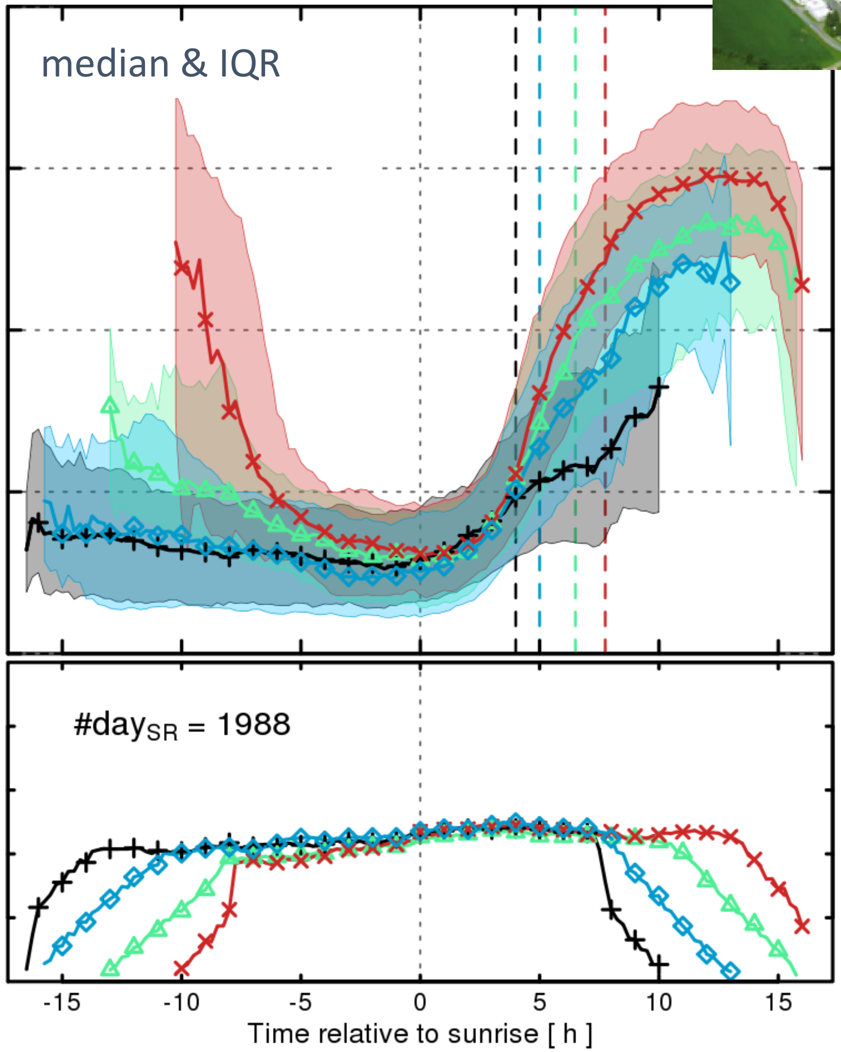


- Quantify spatio-temporal variations in ABL dynamics.
- Links to surface roughness, SEB, land cover characteristics.
- Relation of vertical dilution and horizontal advection (‘urban plume’, ‘urban dome’)

Observed Mixed Layer Height (MLH)

Paris, sub-urban (2010-2017)

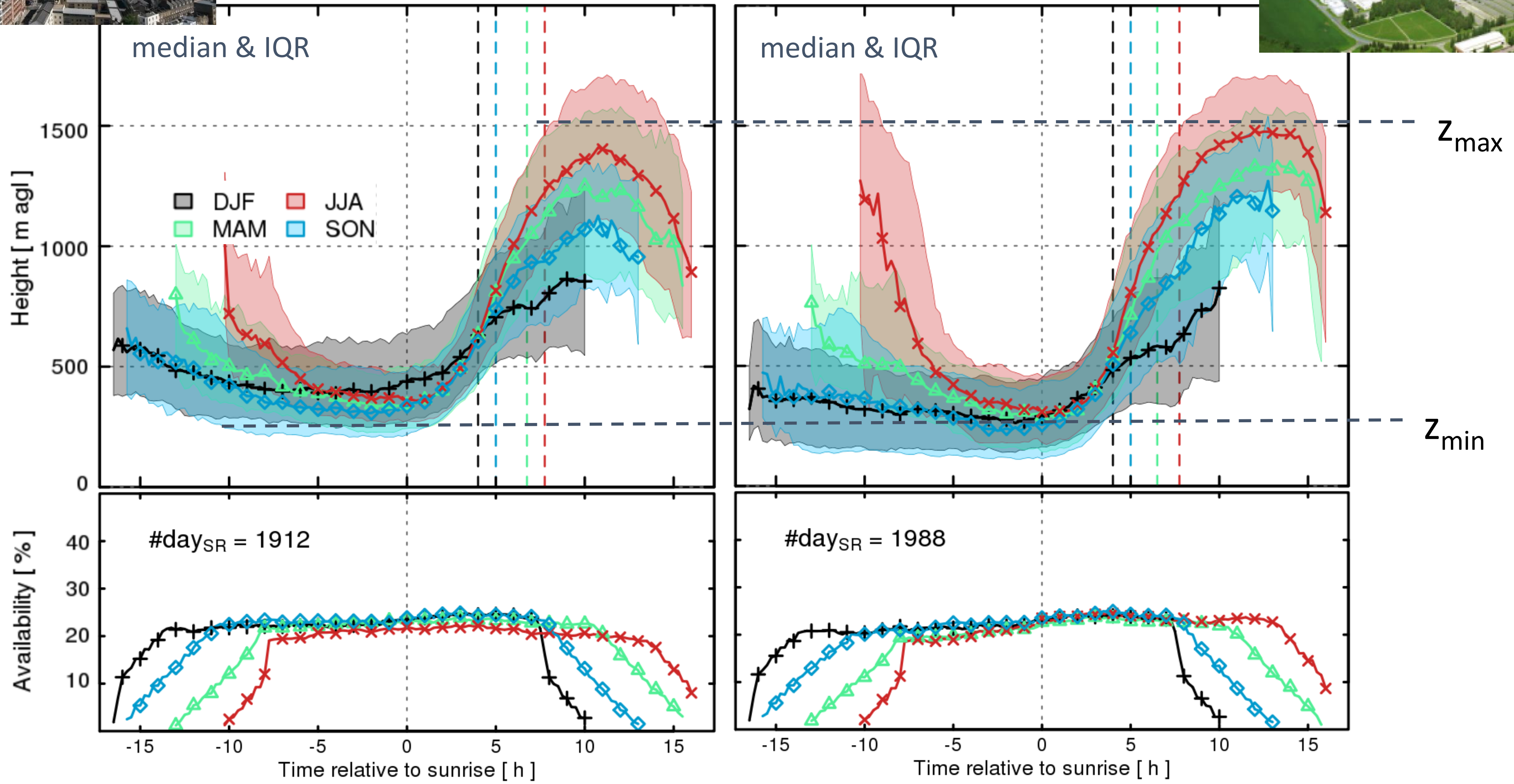




Kotthaus et al., in prep

Observed Mixed Layer Height (MLH)

London, urban (2010-2017) **Paris, sub-urban (2010-2017)**



Kotthaus and Grimmond, 2018b, QJRMS

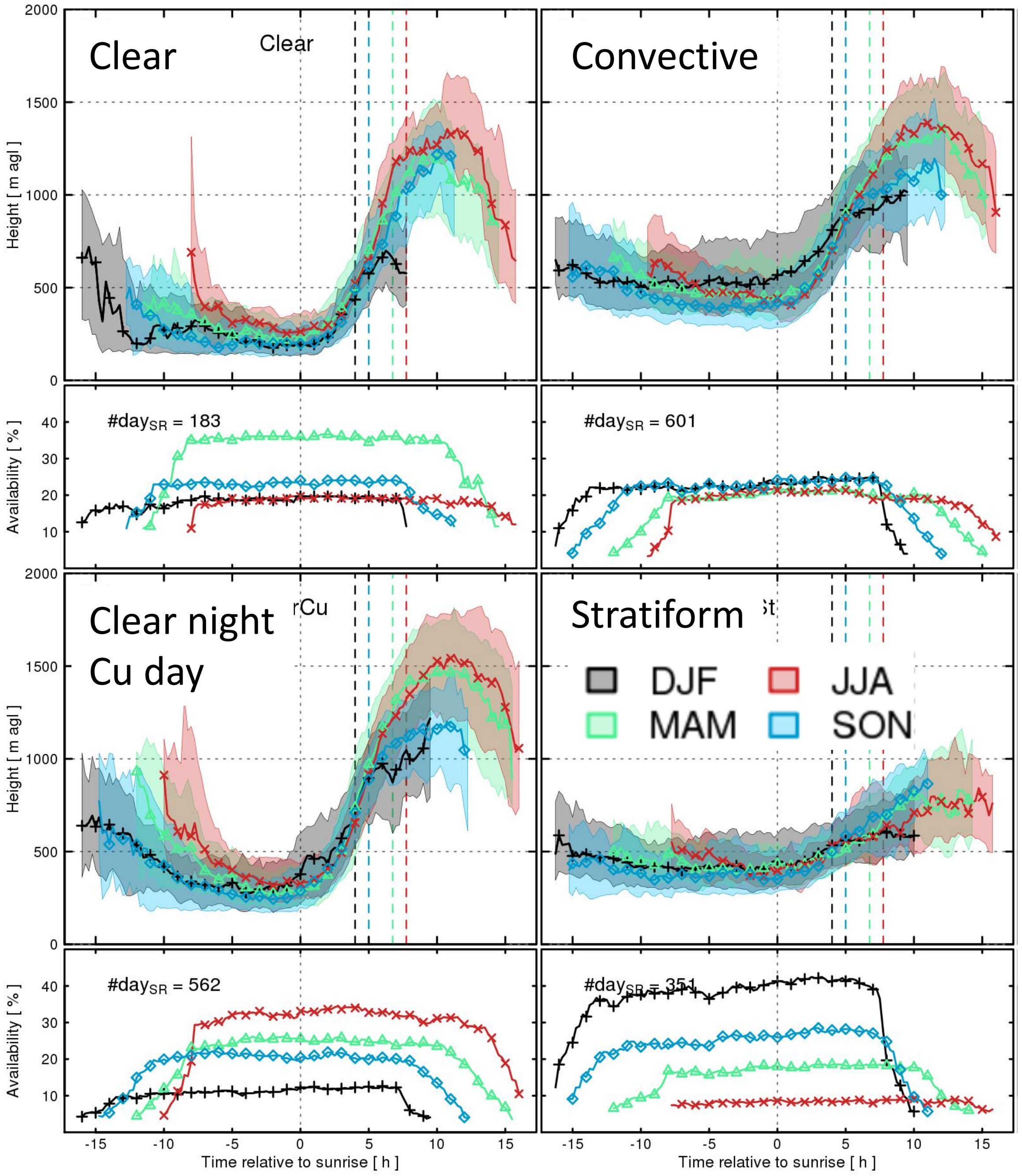
Kotthaus et al., in prep

Cloud type

- MLH closely linked to cloud cover and cloud type
- Clouds impact mixing via regulation of radiation through surface energy balance
- Cloud-induced mixing
- Clear nights: shallow MLH
- Stratiform clouds: low daytime MLH
- Convective Cumulus (Cu) clouds forming on ABL top after clear night → strongest morning growth

→ Cloud base height (CBH) closely related to MLH
→ Cloud cover & cloud type important

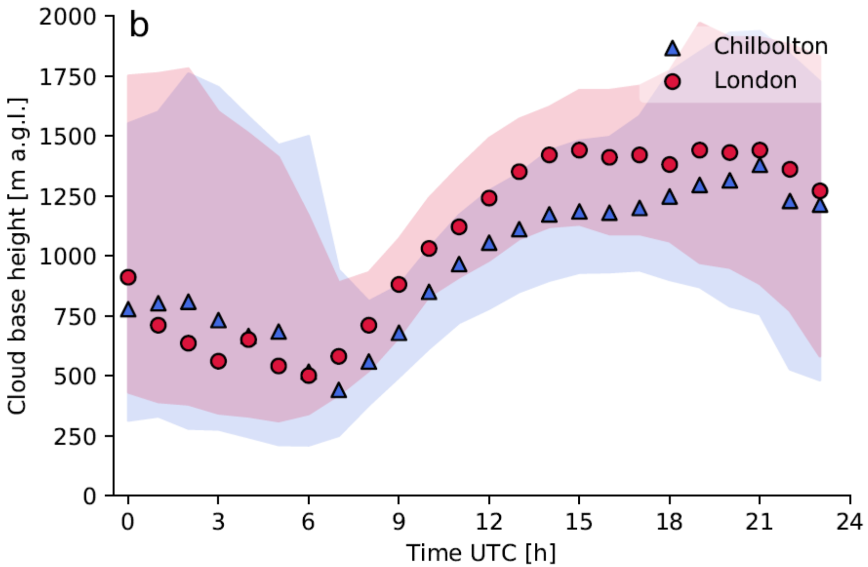
Kotthaus and Grimmond, 2018b, QJRMS



Clouds over cities

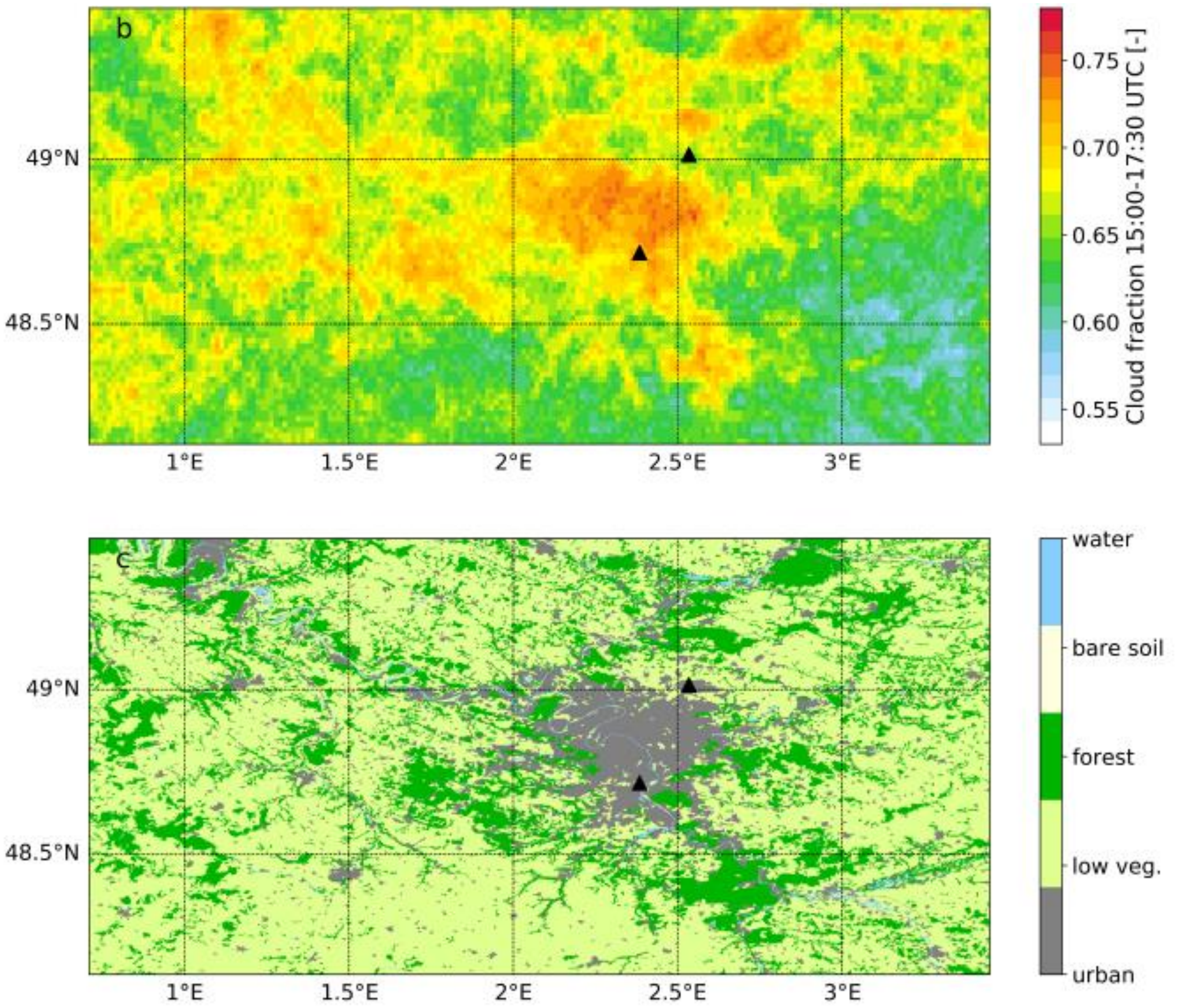
- Convective clouds during summer afternoon more persistent over London and Paris (and forests)

→ Sensible heat flux and urban roughness maintain afternoon convective activities
→ Urban increment in CBH due to drier air above city



Cloud fraction derived from MSG SEVIRI HRV (0.4-1.1 m)

Spring/summer cloud fraction (15-17h)



Theeuwes, Barlow, Teuling, Grimmond and Kotthaus (2019)

Summary

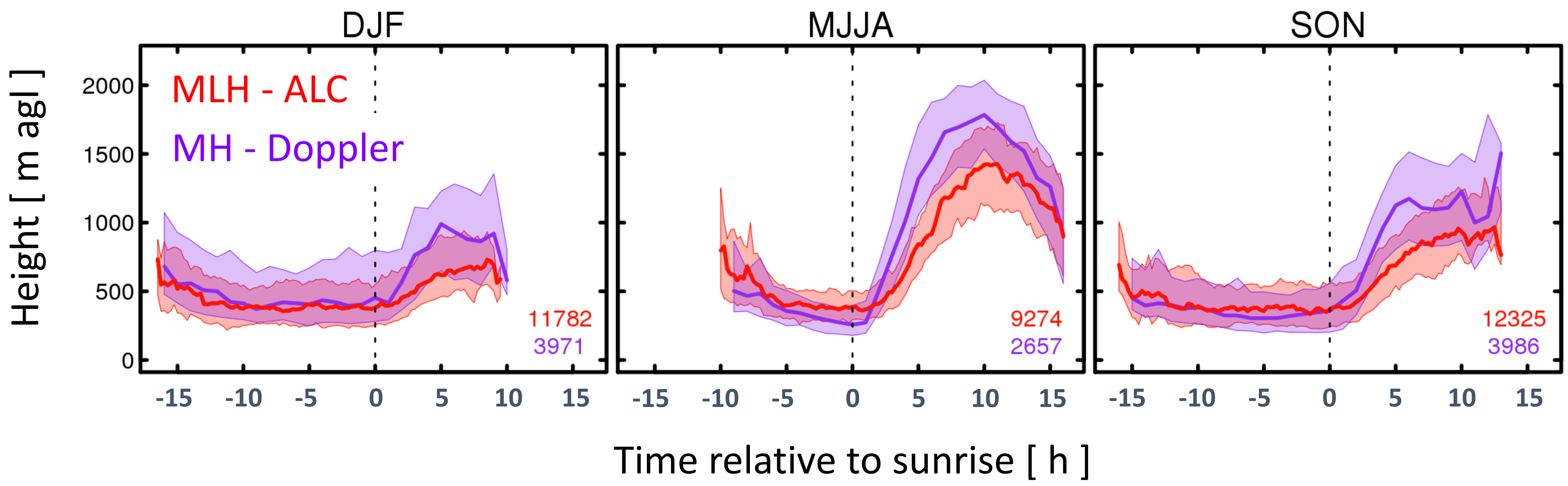
- **Urban surface** and anthropogenic activities greatly impact surface-atmosphere exchanges of energy and momentum
- Access of heat and reduced moisture can maintain afternoon cumulus **clouds** for longer over the city and forest
- Heterogeneity of the urban surface is challenging parameterisations in increasingly **high-resolution modelling**
- **Surface schemes** are becoming increasingly complex (e.g. integrated vegetation) with international efforts towards model improvement and evaluation
- Performance of **boundary layer schemes** (e.g. WRF) also varies significantly, performance may depend on atmospheric stability conditions
- Observations of **boundary layer structure** now becoming available to quantify atmospheric response to differences in land cover

Comparison to Doppler lidar

- Turbulence-derived **mixing height (MH)** from Doppler lidar profiles of vertical velocity variance
- Observations in central London (2010-2012)

→ **MLH ≠ MH**

- Careful processing and advanced algorithms are key
- MH rises ahead of MLH in morning
- Role of clouds is important and needs further investigation



Kotthaus et al. (2018) AE