Foundation for Research and Technology Hellas
Institute of Applied and Computational Mathematics
Remote Sensing Lab
http://rslab.gr

EO for urban energy exchanges monitoring at local scale

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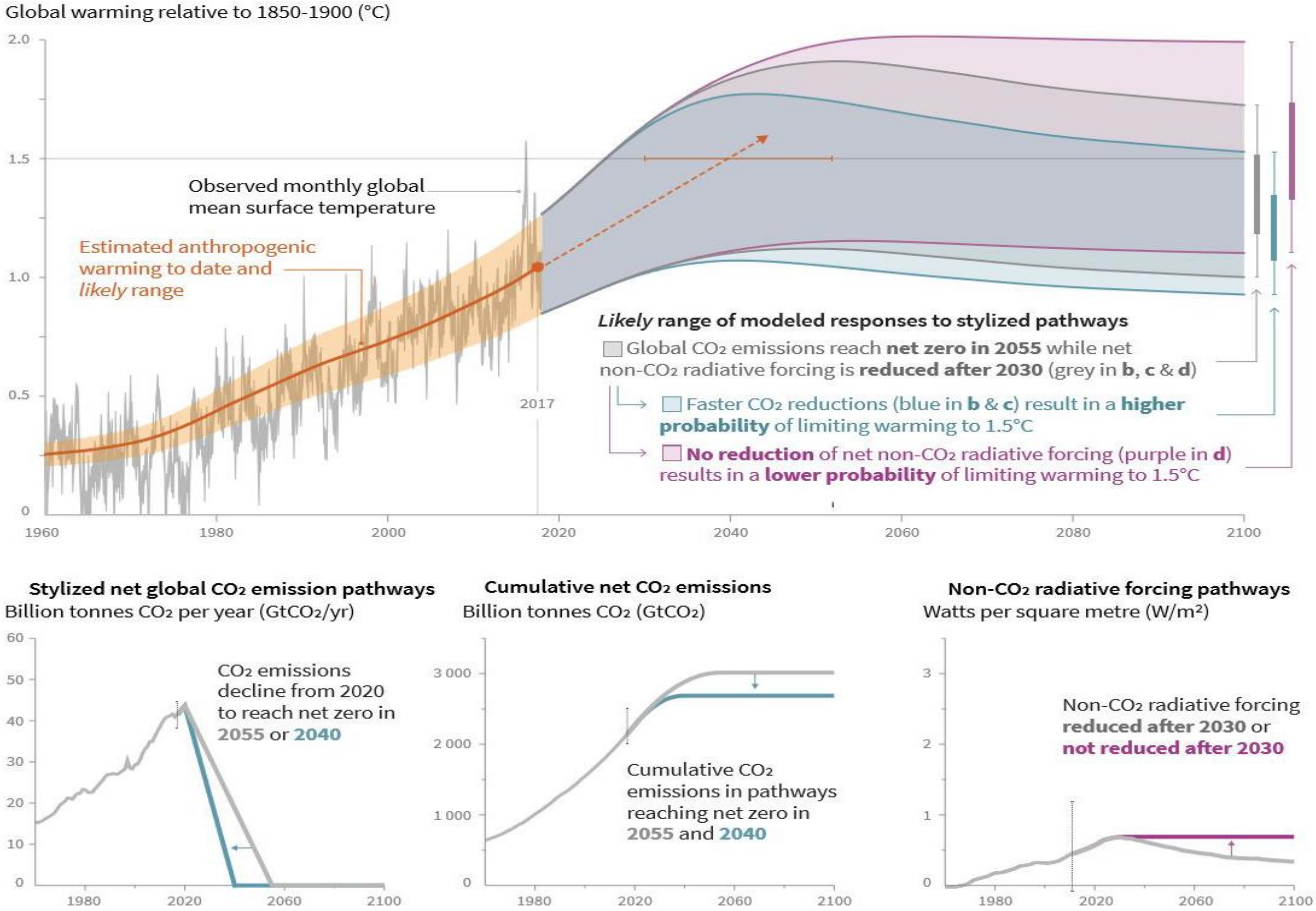
FORTH, *Remote Sensing Lab*

Copernicus for Cities Workshop

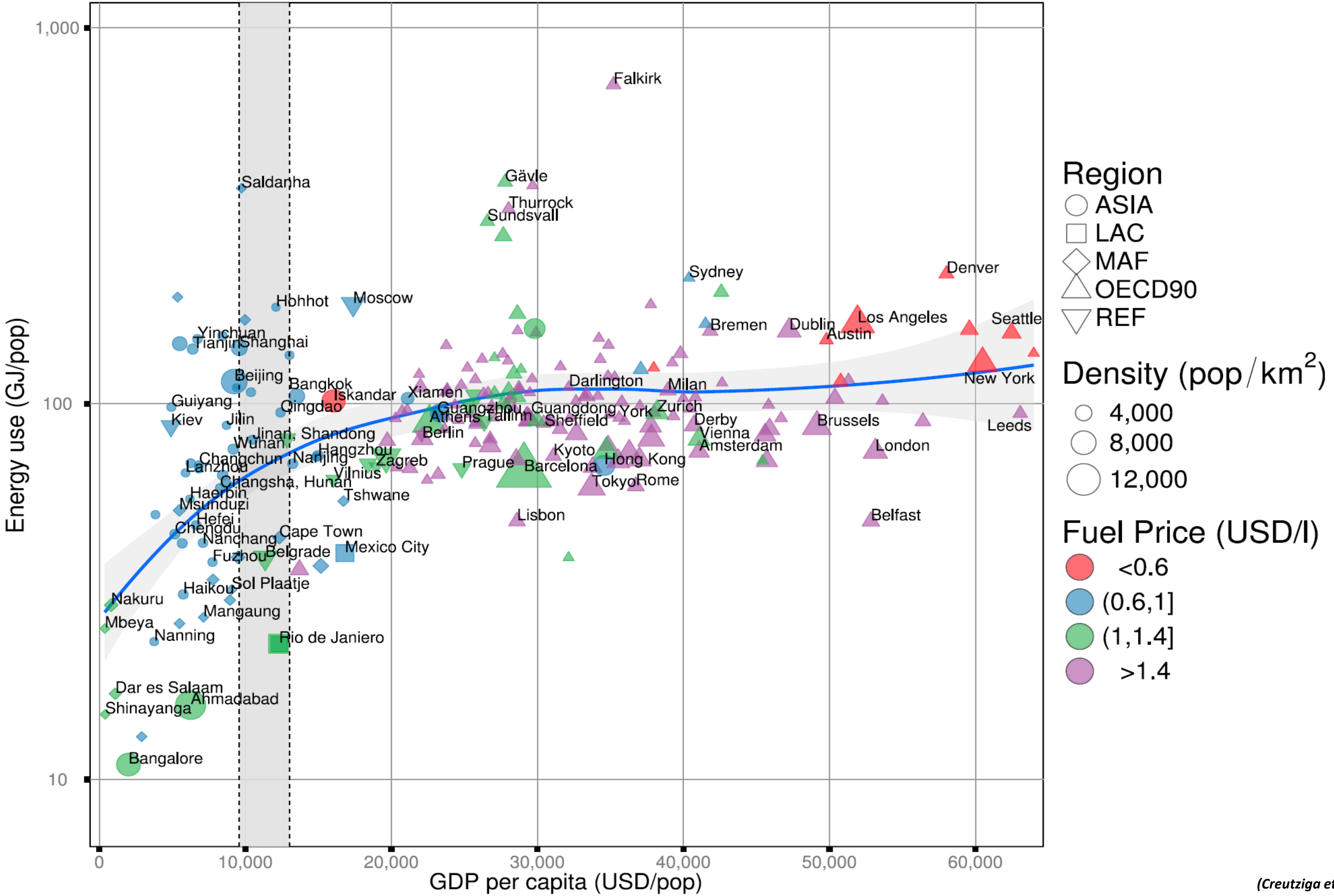
Brussels, November 9, 2018

FORTH
FOUNDATION FOR RESEARCH AND TECHNOLOGY - HELLAS

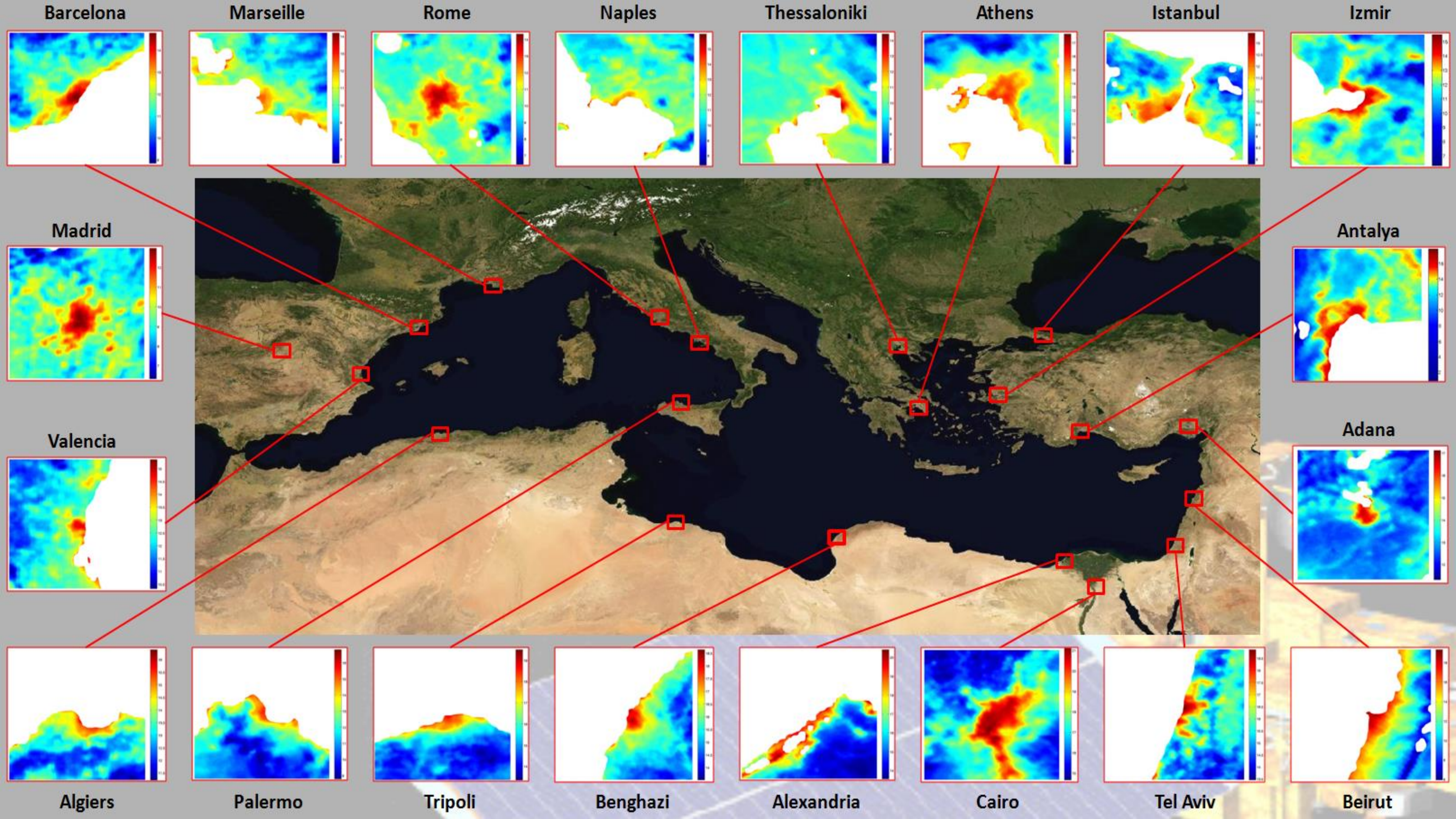

Highest
predicted
temperatures
UK
36°C
France
40°C
Spain &
Portugal
48°C


Global warming relative to 1850-1900 (°C)
2.0
1.5
1.0
0.5
0
Observed monthly global mean surface temperature
Estimated anthropogenic warming to date and *likely* range
2017
Likely range of modeled responses to stylized pathways
Global CO2 emissions reach **net zero in 2055** while net non-CO2 radiative forcing is **reduced after 2030** (grey in **b**, **c** & **d**)
Faster CO2 reductions (blue in **b** & **c**) result in a **higher probability** of limiting warming to 1.5°C
No reduction of net non-CO2 radiative forcing (purple in **d**) results in a **lower probability** of limiting warming to 1.5°C
1960
1980
2000
2020
2040
2060
2080
2100
Stylized net global CO2 emission pathways
Billion tonnes CO2 per year (GtCO2/yr)
60
50
40
30
20
10
0
CO2 emissions decline from 2020 to reach net zero in **2055** or **2040**
1980
2020
2060
2100
Cumulative net CO2 emissions
Billion tonnes CO2 (GtCO2)
3 000
2 000
1 000
0
Cumulative CO2 emissions in pathways reaching net zero in **2055** and **2040**
1980
2020
2060
2100
Non-CO2 radiative forcing pathways
Watts per square metre (W/m²)
3
2
1
0
Non-CO2 radiative forcing **reduced after 2030** or **not reduced after 2030**
1980
2020
2060
2100

(IPCC 2018)



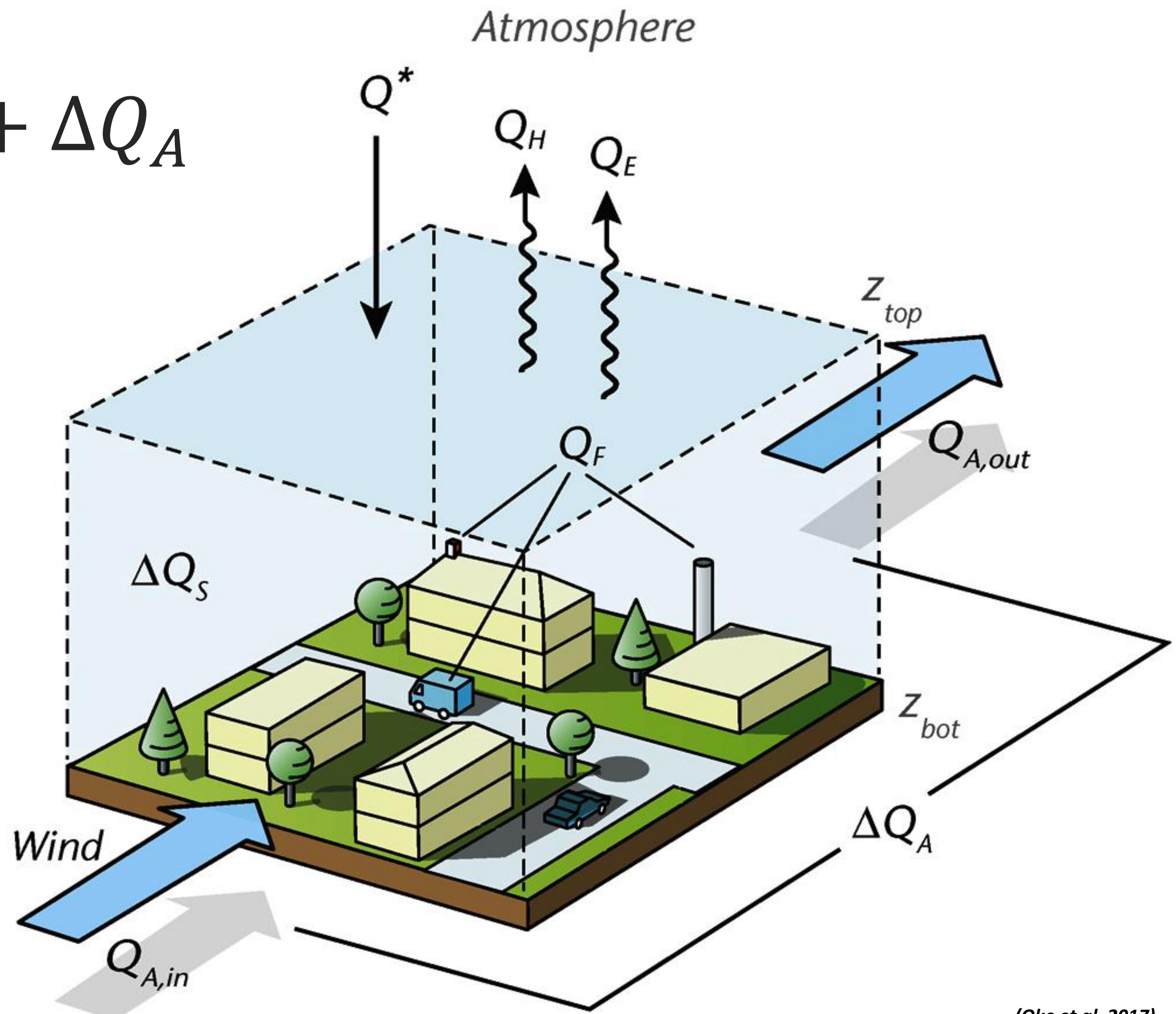
(Creutziga et al. 2015)


Barcelona
Marseille
Rome
Naples
Thessaloniki
Athens
Istanbul
Izmir
Madrid
Antalya
Valencia
Adana
Algiers
Palermo
Tripoli
Benghazi
Alexandria
Cairo
Tel Aviv
Beirut

Urban Energy Balance

$$Q^* + Q_F = Q_H + Q_E + \Delta Q_S + \Delta Q_A$$

- ***Q****: Net all-wave radiation balance
- Q_F : Anthropogenic heat flux
- Q_H : Turbulent sensible heat flux
- Q_E : Turbulent latent heat flux
- ΔQ_S : Net change in heat storage
- $\Delta Q_A = Q_{in} - Q_{out}$: Advective heat flux



(Oke et al. 2017)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NO PARKING


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CARLTON CITY

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Delft: Sand Engine

Antwerp: Old railway yard becomes a park for the 21st century

Porto: Porto's Urban Rooftop Garden

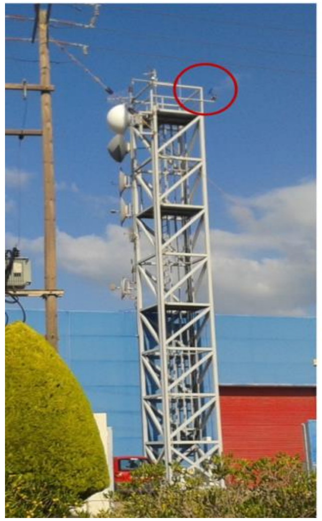
Milan: vertical garden

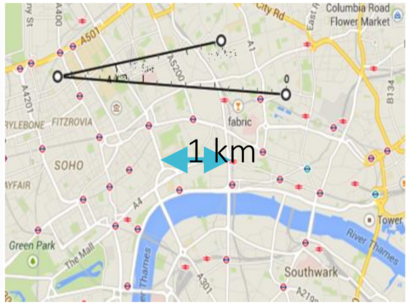
Jinhua City: Yanweizhou Wetland Park - A resilient landscape

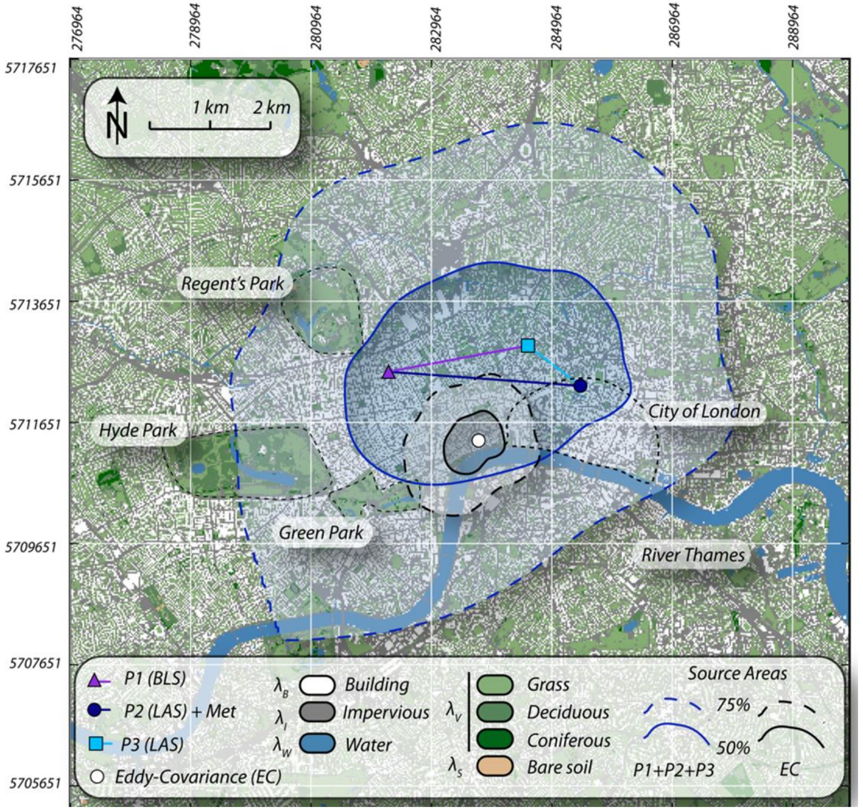
Why URBANFLUXES?

- Urban planners and Earth System scientists need **spatially disaggregated information** on urban heat.
- **Not possible** to derive it by *in-situ* flux measurements.
- **Major challenge:** innovative exploitation of Copernicus Sentinels **synergistic observations** to estimate **UEB spatiotemporal patterns**.

In-situ Observations

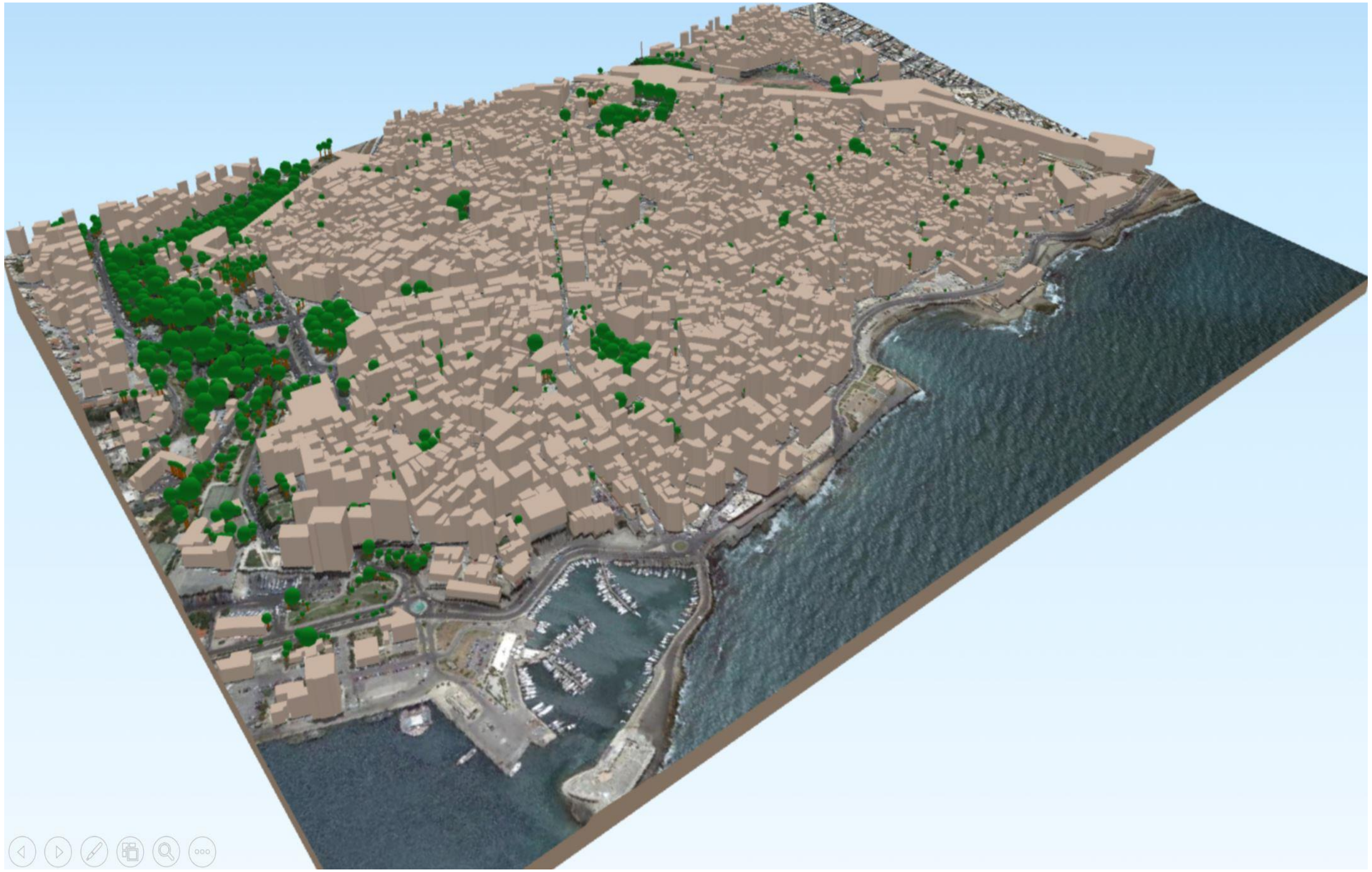


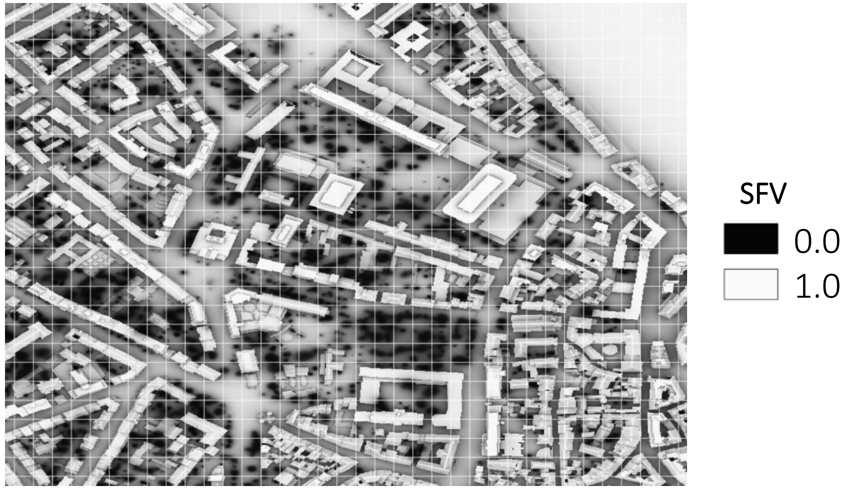




Surface Structure and Morphology

- Relevant parameters: SVF, λ_P, λ_f, z_d & z_0:



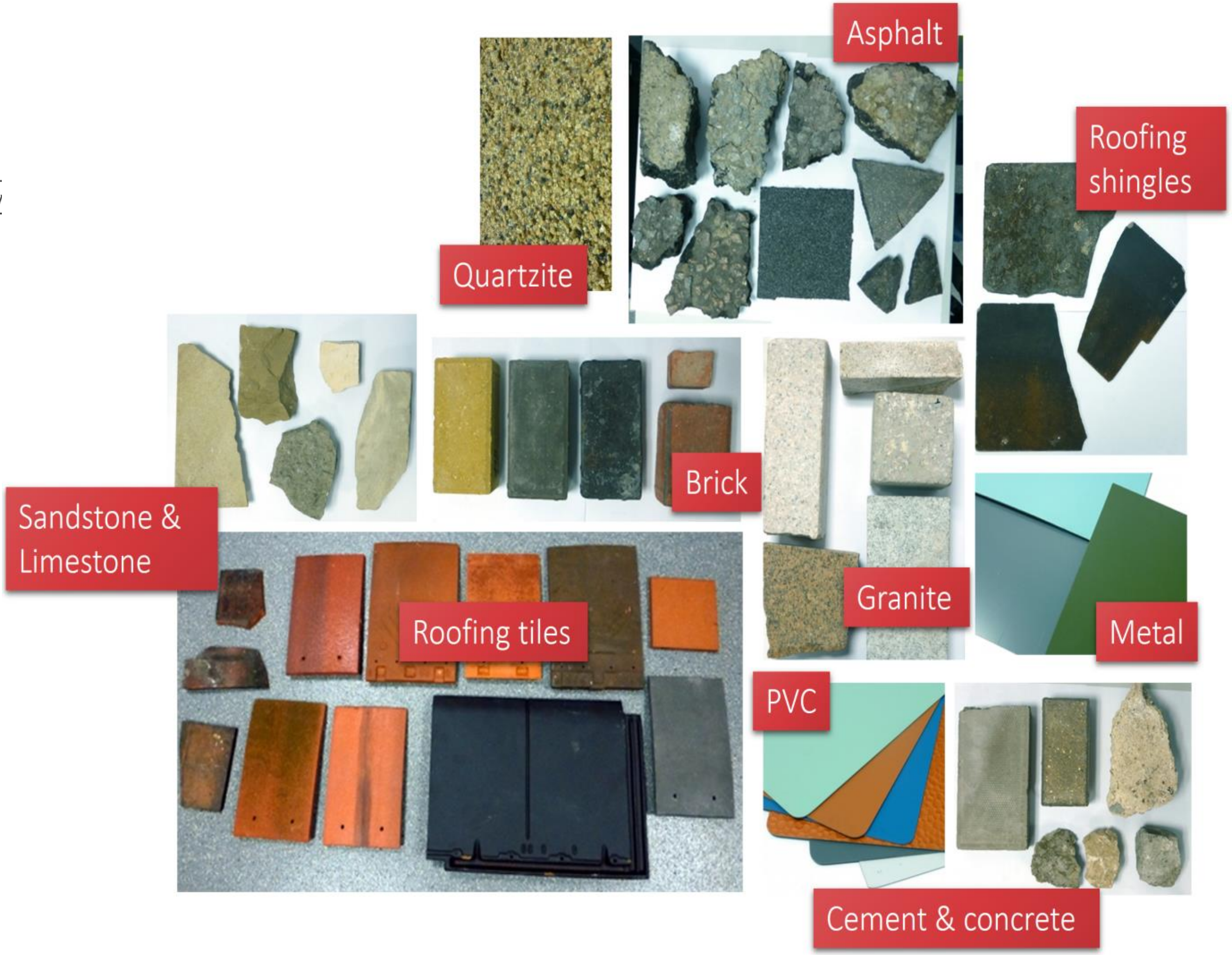


Surface Fabric

› Spectral Libraries (SLUM)

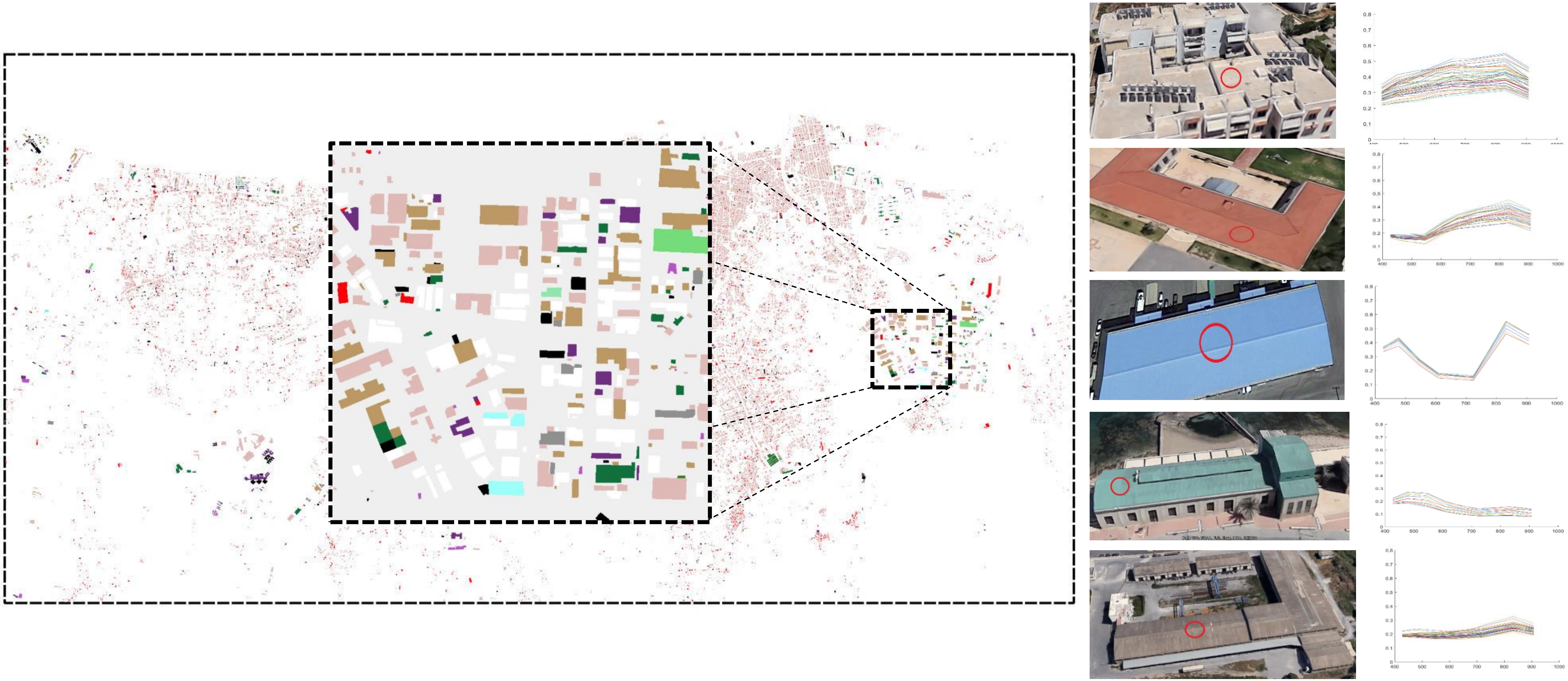
Table C.1
Meta data for the London impervious urban materials samples, with their measured broadband albedo (300–2500 nm) and emissivity (8–14 μm).

ID	Class/Sub-class	Material	Colour	Status	Dimensions [mm]	Albedo	Emissiv
X001	Quartzite conglomerate	Quartzite	Beige/brown/black/red	New	360 × 4 × 220	0.26	0.92
X002	Quartzite conglomerate	Quartzite	Beige/brown/black/red	New	360 × 4 × 220	0.32	0.96
X003	Quartzite conglomerate	Quartzite	Brown	New	148 × 27 × 97	0.25	0.97
S001	Stone	Sandstone	Beige	Used	215 × 35 × 105	0.40	0.90
S002	Stone	Carboniferous coral limestone	Grey	Used	120 × 19 × 90	0.20	0.94
S003	Stone	Sandstone	Yellow	Used	120 × 80 × 27	0.26	0.93
S004	Stone	Limestone	Beige	Used	70 × 55 × 25	0.68	0.93
S005	Stone	Sandstone	Light grey	Smooth	28 × 75 × 180	0.46	0.92
G001	Granite	Granite	White/black	New, rough	142 × 56 × 52	0.48	0.92
G002	Granite	Granite with cement	White/red	Weathered	101 × 95 × 88	0.34	0.93
G003	Granite	Granite with cement	White/black	Weathered	215 × 57 × 105	0.41	0.89
G004	Granite	Granite	White/red/black	Weathered	233 × 60 × 78	0.54	0.93
G005	Granite	Granite	Red/black	Smooth	125 × 50 × 111	0.22	0.89
A001	Road asphalt	Asphalt with stone aggregate	Black/grey	Weathered	190 × 83 × 68	0.21	0.96
A002	Road asphalt	Asphalt with stone aggregate	Black/grey	Weathered	60 × 100 × 200	0.18	0.94
A003	Road asphalt	Asphalt with stone aggregate	Black/grey	Weathered	60 × 90 × 150	0.21	0.94
A004	Road asphalt	Asphalt with stone aggregate	Black/grey	Weathered	50 × 120 × 170	0.18	0.94
A005	Road asphalt	Asphalt with stone aggregate	Black/grey	Weathered	55 × 75 × 130	0.19	0.93
A006	Road asphalt	Asphalt with stone aggregate	Black/grey	Weathered	30 × 145 × 180	0.12	0.91
A007	Asphalt roofing shingle	Tarmac roofing paper	Grey	New	3 × 165 × 170	0.07	0.93
A008	Road asphalt	Tarmac	Black	Weathered	140 × 25 × 140	0.13	0.95
A009	Road asphalt	Tarmac	Black	Weathered	21 × 60 × 85	0.08	0.95
A010	Road asphalt	Tarmac	Black	Weathered	21 × 65 × 80	0.10	0.96
C001	Cement	Cement	Grey/ochre	Weathered	397 × 60 × 140	0.29	0.94
C002	Concrete	Concrete	Grey/white	New	198 × 53 × 100	0.21	0.92
C003	Cement	Cement	Grey	Weathered	268 × 44 × 148	0.23	0.91
C004	Concrete	Concrete	Grey	Weathered	110 × 72 × 85	0.37	0.95
C005	Cement	Cement	Grey	Weathered	45 × 80 × 115	0.41	0.95
C006	Concrete	Concrete	White	Weathered	90 × 150 × 250	0.42	0.95
C008	Concrete	Concrete	Grey	Weathered, rough	20 × 120 × 108	0.25	0.95
B001	Cement brick	Cement brick	Yellow	New	200 × 60 × 100	0.30	0.94
B002	Cement brick	Cement brick, with sand	Black/light grey	New	200 × 58 × 98	0.11	0.94

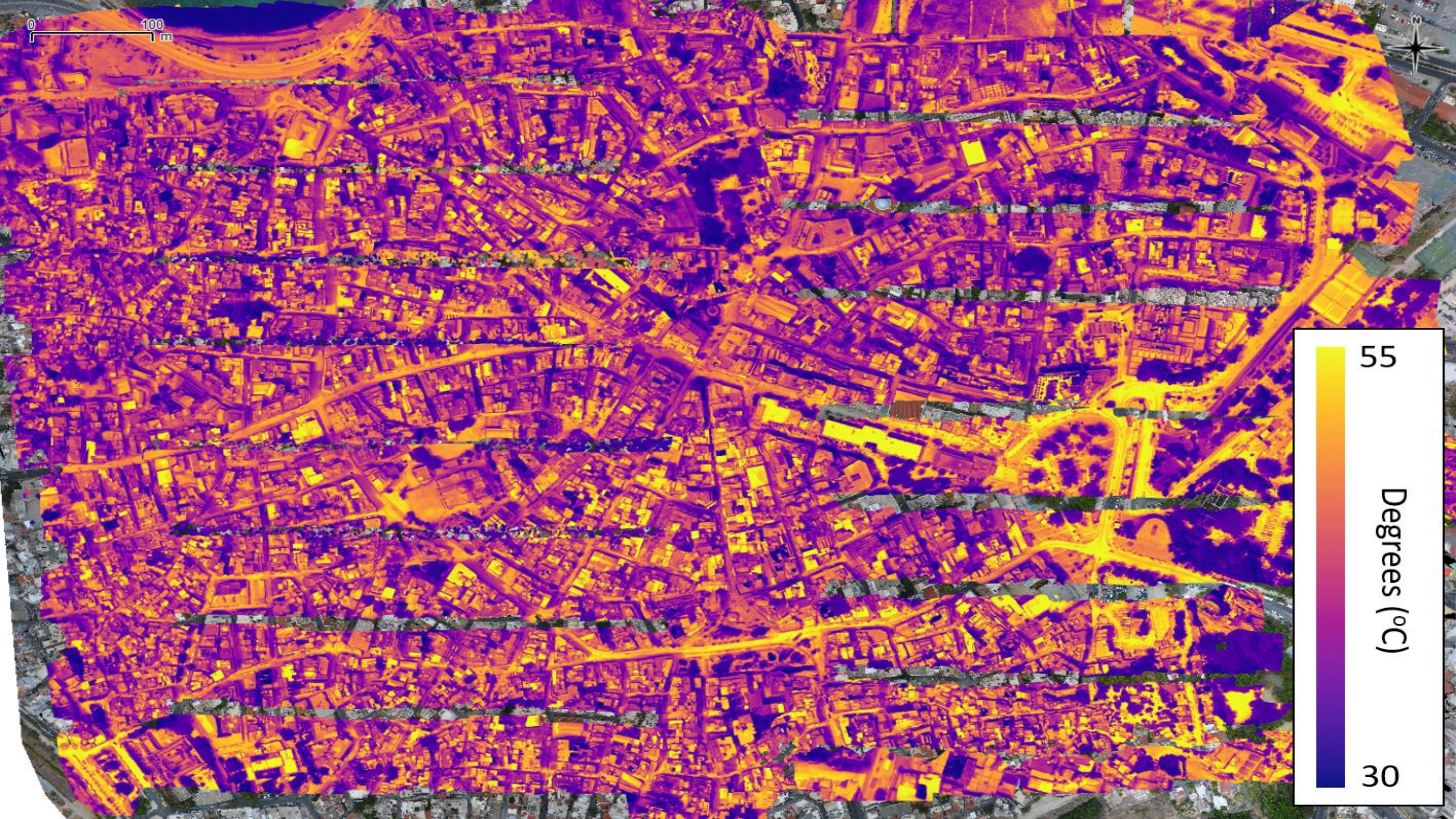


(Kotthaus et al. 2014)

Surface Fabric



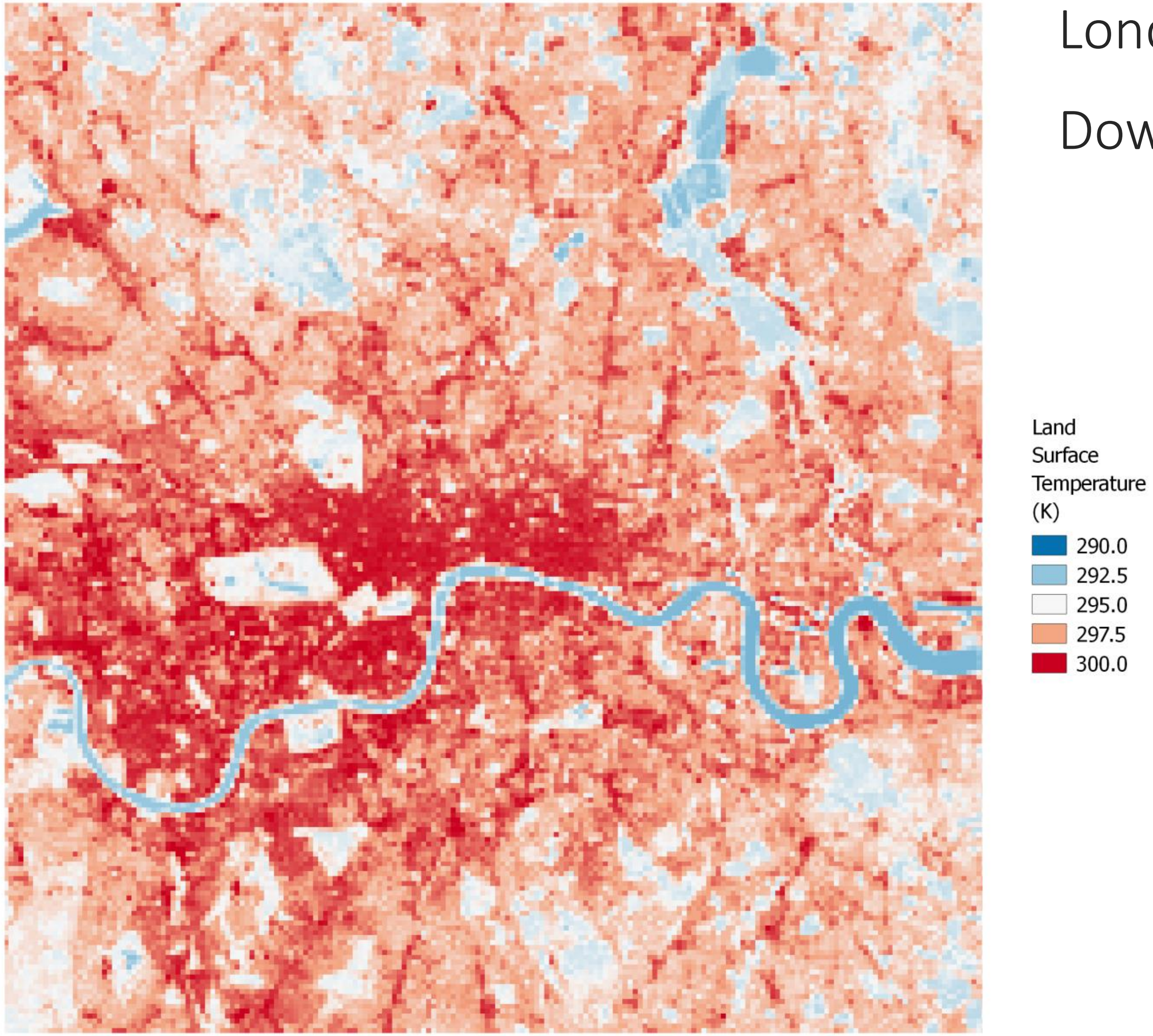
(Lantzanakis et al. 2018)

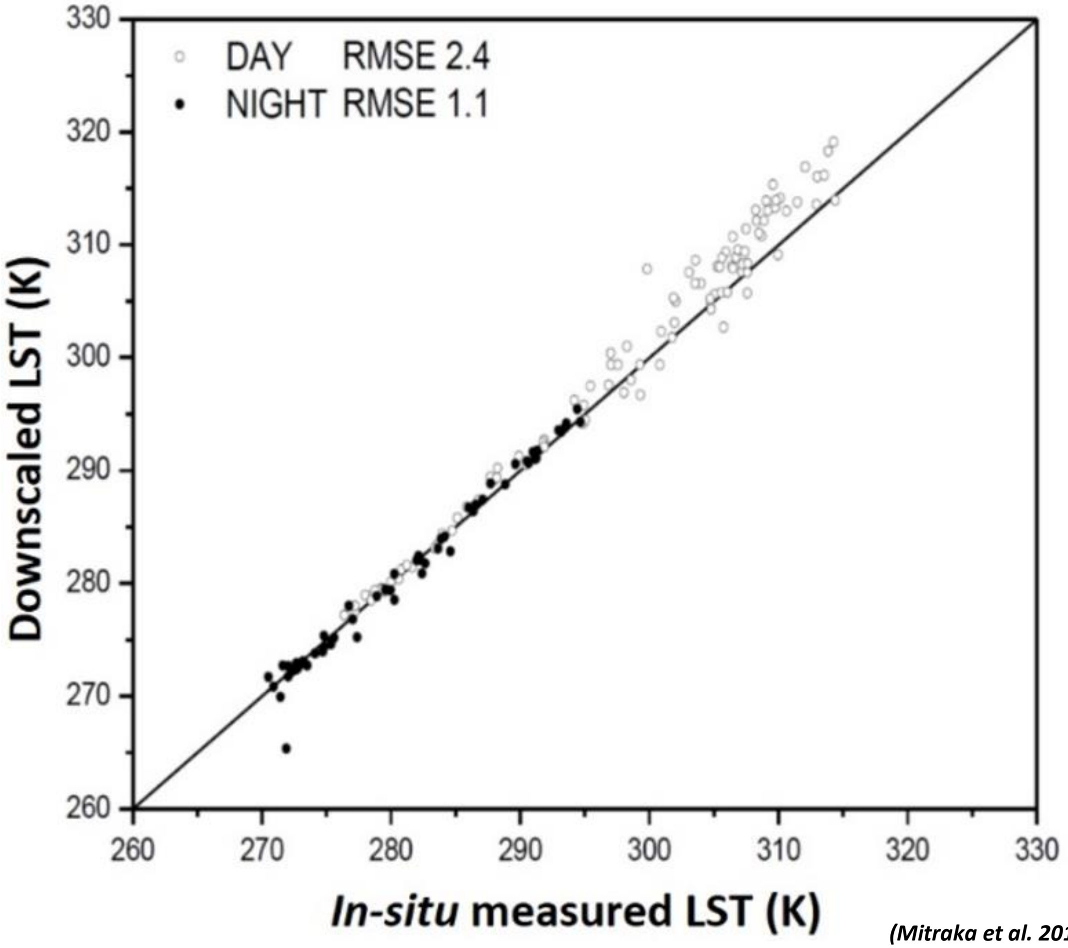

0
100
m
N
55
Degrees (°C)
30

Surface Temperature

London, 19 July 2016, 22:05

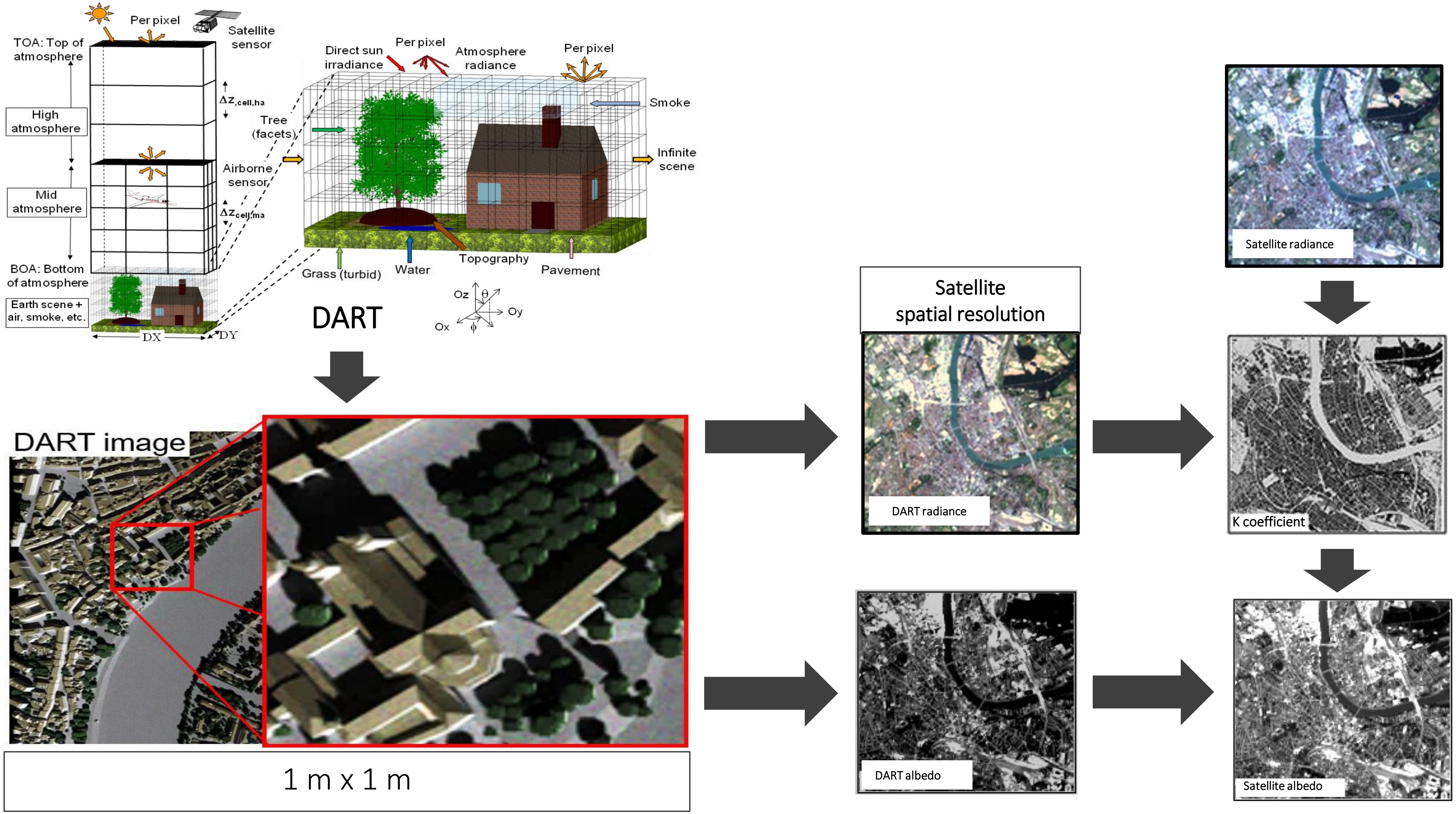
Downscaled LST at 100 m x 100 m





(Mitraka et al. 2015)

Net Radiation (Q*)

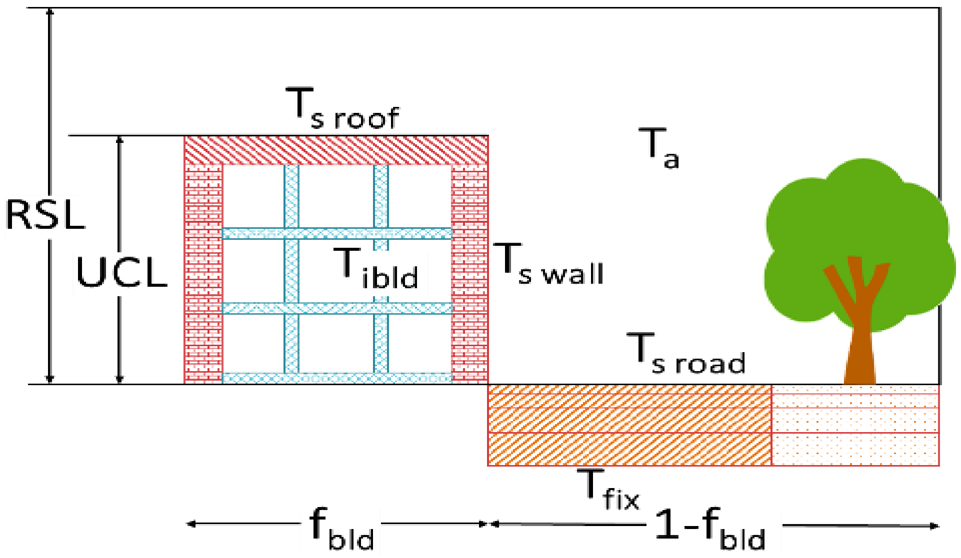


Heat Storage Change (ΔQ_S)

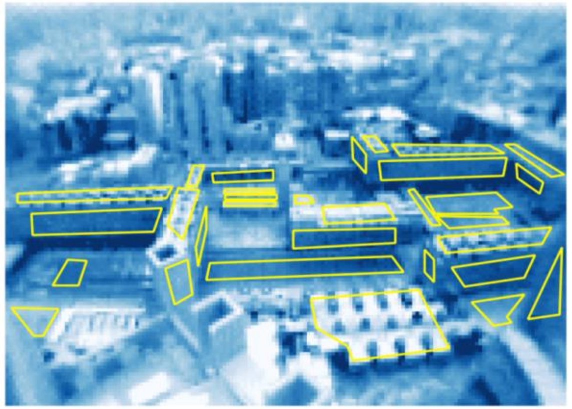
- ESTM: $$\boxed{\Delta Q_S = \sum_i \frac{\Delta T_i}{\Delta t} \varrho c_i \Delta x_i f_i}$$

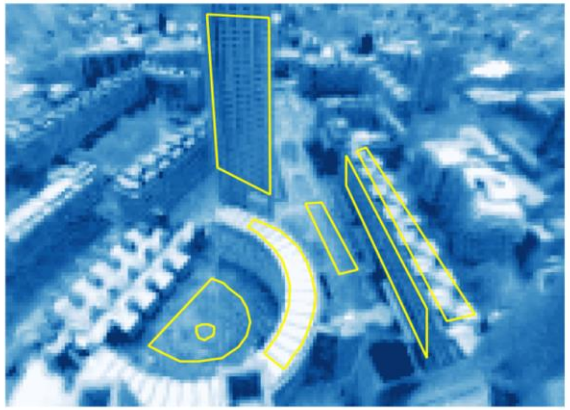
  ✓ Incorporates heat transfer through the different elements.

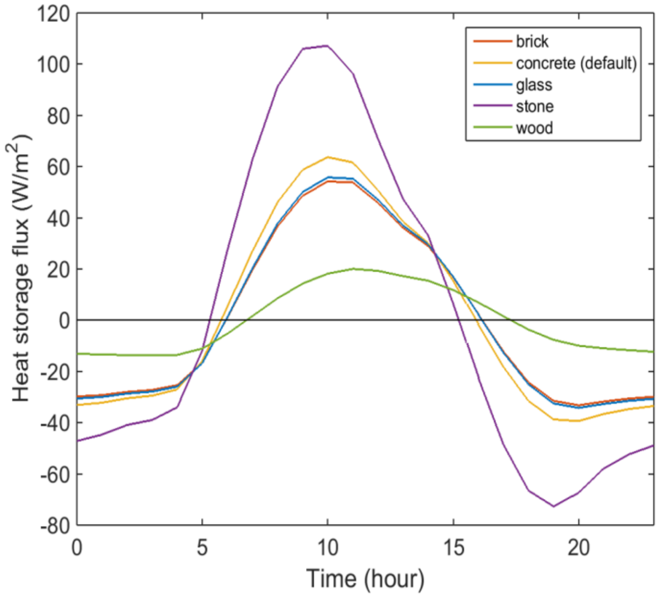
  ✓ Estimated ΔQ_S represents unit plan area.

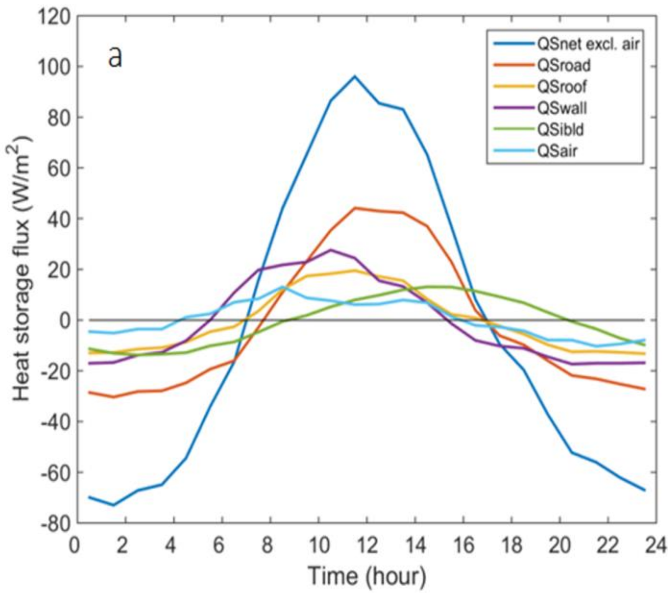


(Offerle et al., 2005)

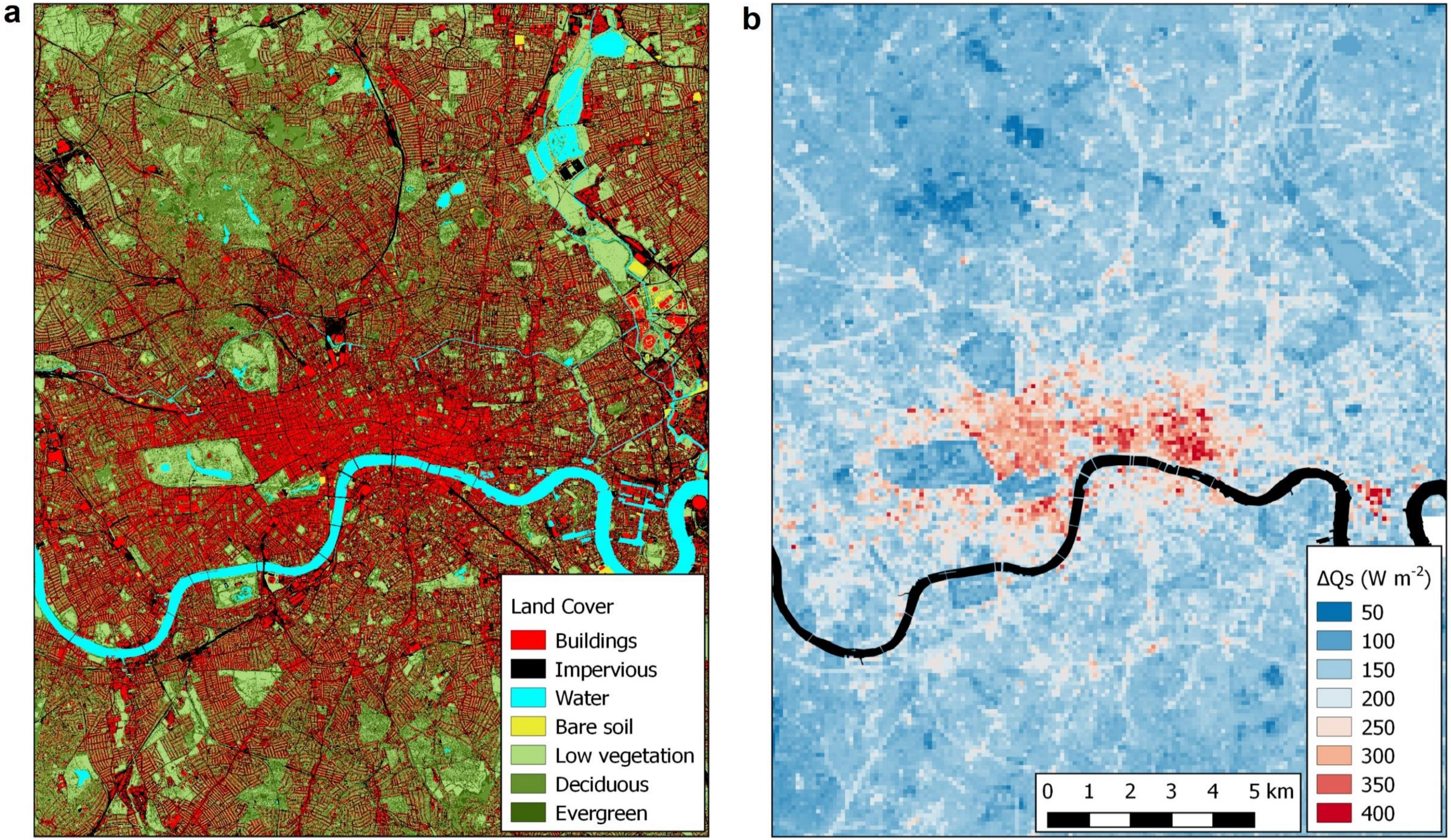








Heat Storage Change (ΔQ_s)



Turbulent Heat Fluxes (Q_H , Q_E)

- Aerodynamic Resistance Method (ARM)

Satellite-based

Measured in-situ

$$Q_H = \rho c_P \frac{T_S - T_{air}}{r_a}$$

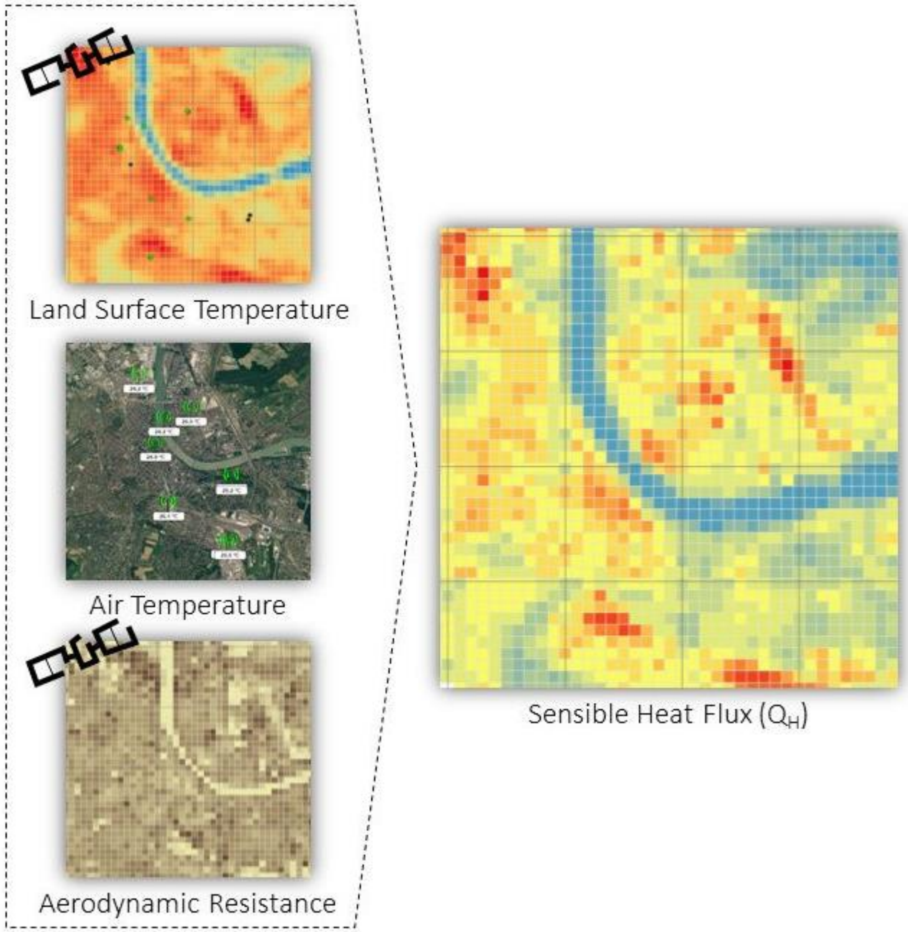
Aerodynamic resistance
from morphometric analysis

From T_{air}

Measured in-situ

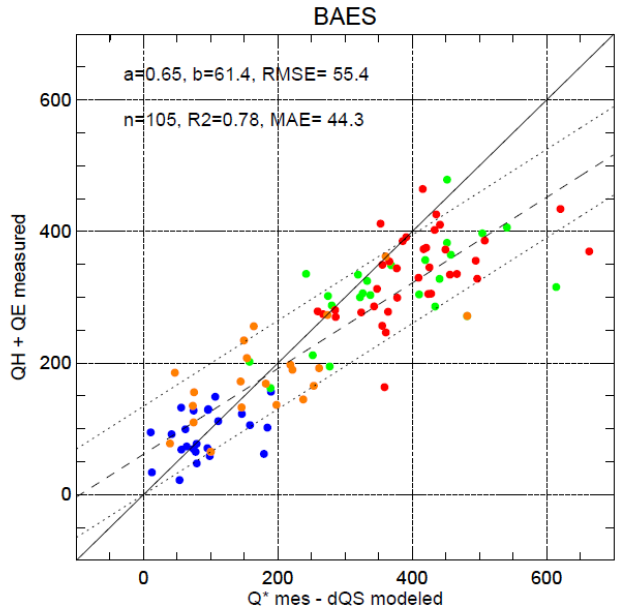
$$Q_E = \rho c_P \frac{\boxed{e_S - e_{air}}}{\gamma(r_a + r_s)}$$

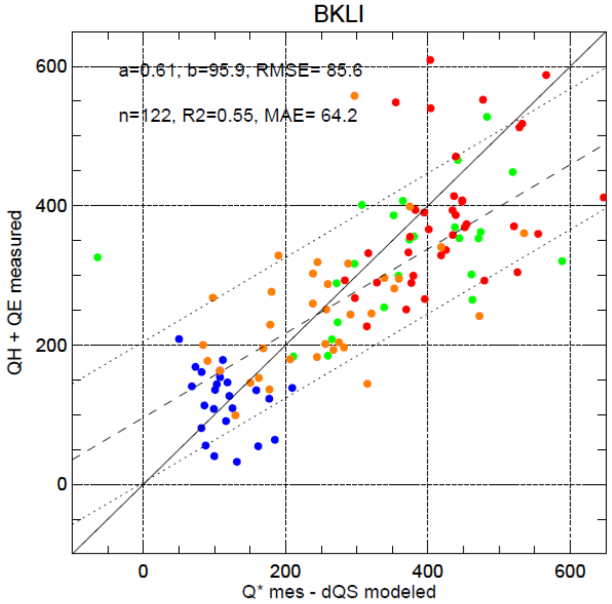
Surface resistance
Depends on vegetation type, moisture conditions

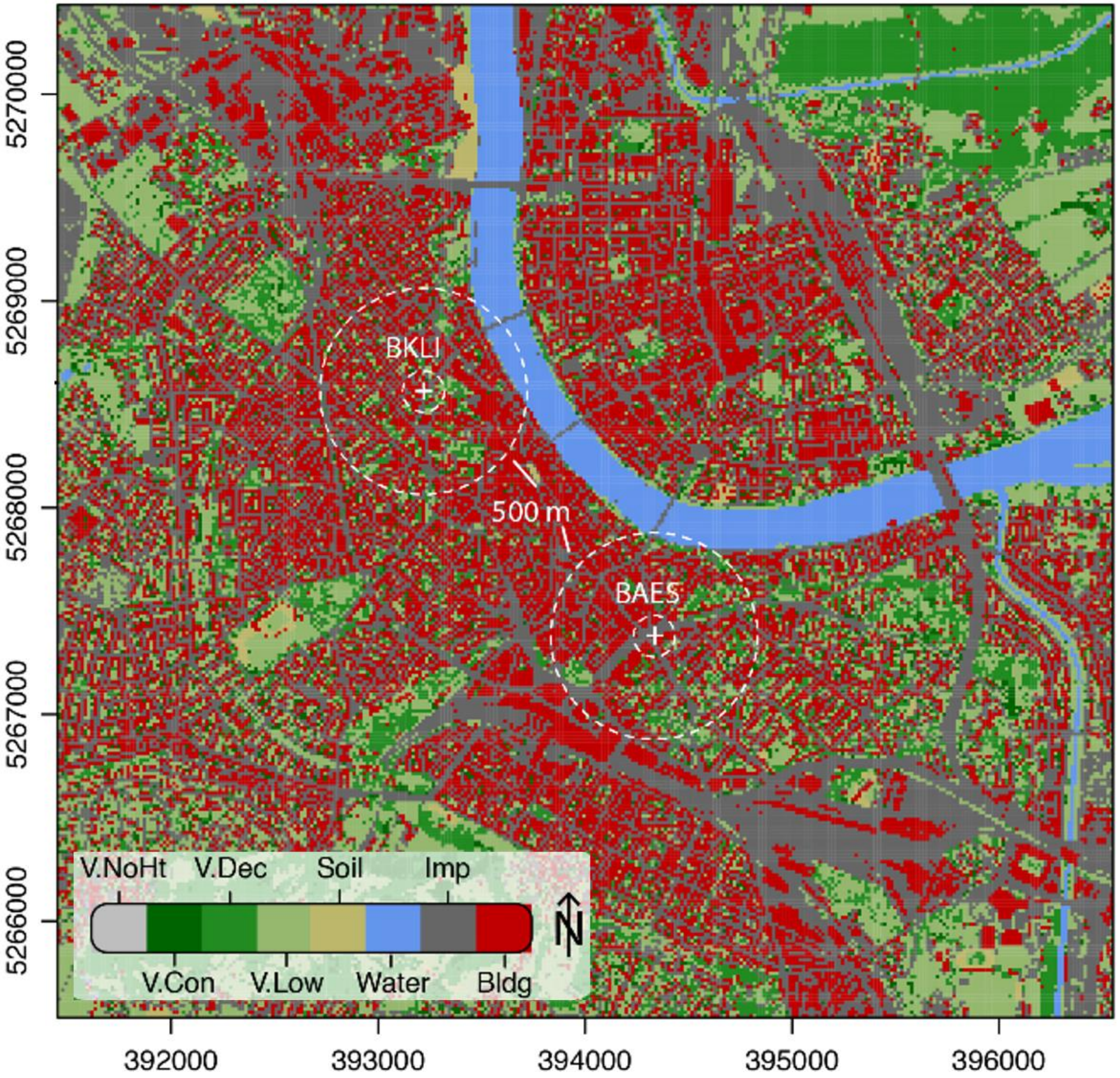


Q_F Results

SON
JJA
MAM
DJF







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SCIENTIFIC REPORTS

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Urban energy exchanges monitoring from space

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One important challenge facing the urbanization and global environmental change community is to understand the relation between urban form, energy use and carbon emissions. Missing from the current literature are scientific assessments that evaluate the impacts of different urban spatial units

Long-term Vision

Exploitation of URBANFLUXES outcomes in analysing observations from forthcoming satellite missions, including future **hyper-spectral** missions and **High Altitude Pseudo-Satellites (HAPS),** for **monitoring urban energy solutions**, having the potential to:

- lead to **new services**, such as the **evaluation** of **NBS implementation**;
- support the climate change **mitigation planning** at Municipality level;
- support the **resilient cities** concept;
- support **sustainable planning strategies** to improve the **quality of life** in cities.

URBANFLUXES

urbisphere

coupling dynamic cities and climate

CURE: *Copernicus for Urban Resilience in Europe*

LC-SPACE-04-EO-2019-2020

- CURE will provide the means to cope with the EO data under-exploitation in the domain of **sustainable urban planning**, towards developing **new services**, based on our projects URBANFLUXES, UrbanTEP, SEN4RUS, DECUMANUS, GEOURBAN, BRIDGE, etc. **and** combining products of different **Copernicus Core Services** (CLMS, CAMS, C3S and CEMS).
- CURE will introduce novel ideas on how applications for urban planning, urban climate, urban air quality and health will be developed **across** Copernicus Core Services.

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Thank you!

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