URBANFLUXES

URBAN ANTHRPOGENIC HEAT FLUX FROM EARTH OBSERVATION SATELLITES

Heat Flux Estimations from Space: the URBANFLUXES Products

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ESA LPVE 2018

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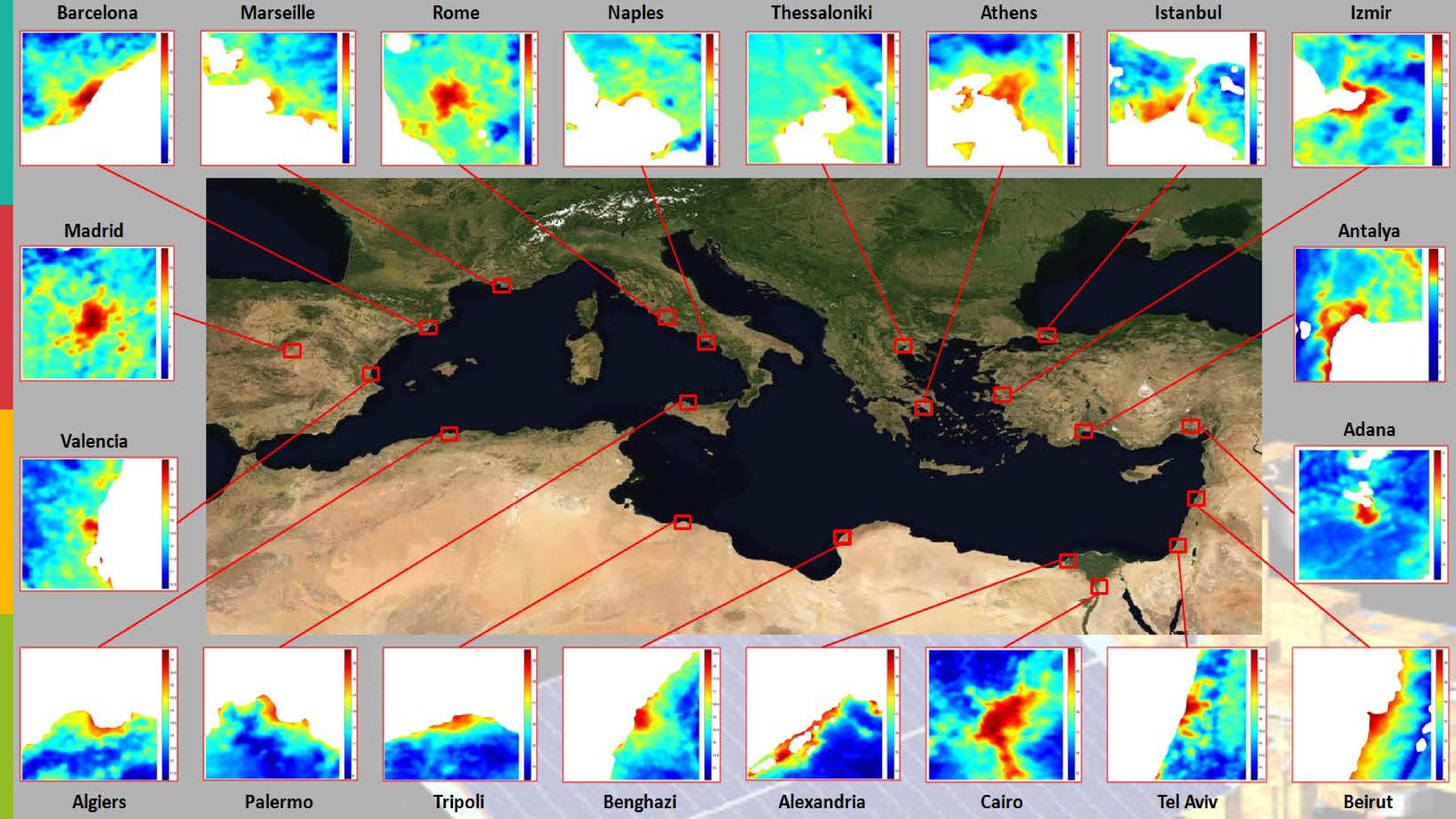
Barcelona
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Tripoli
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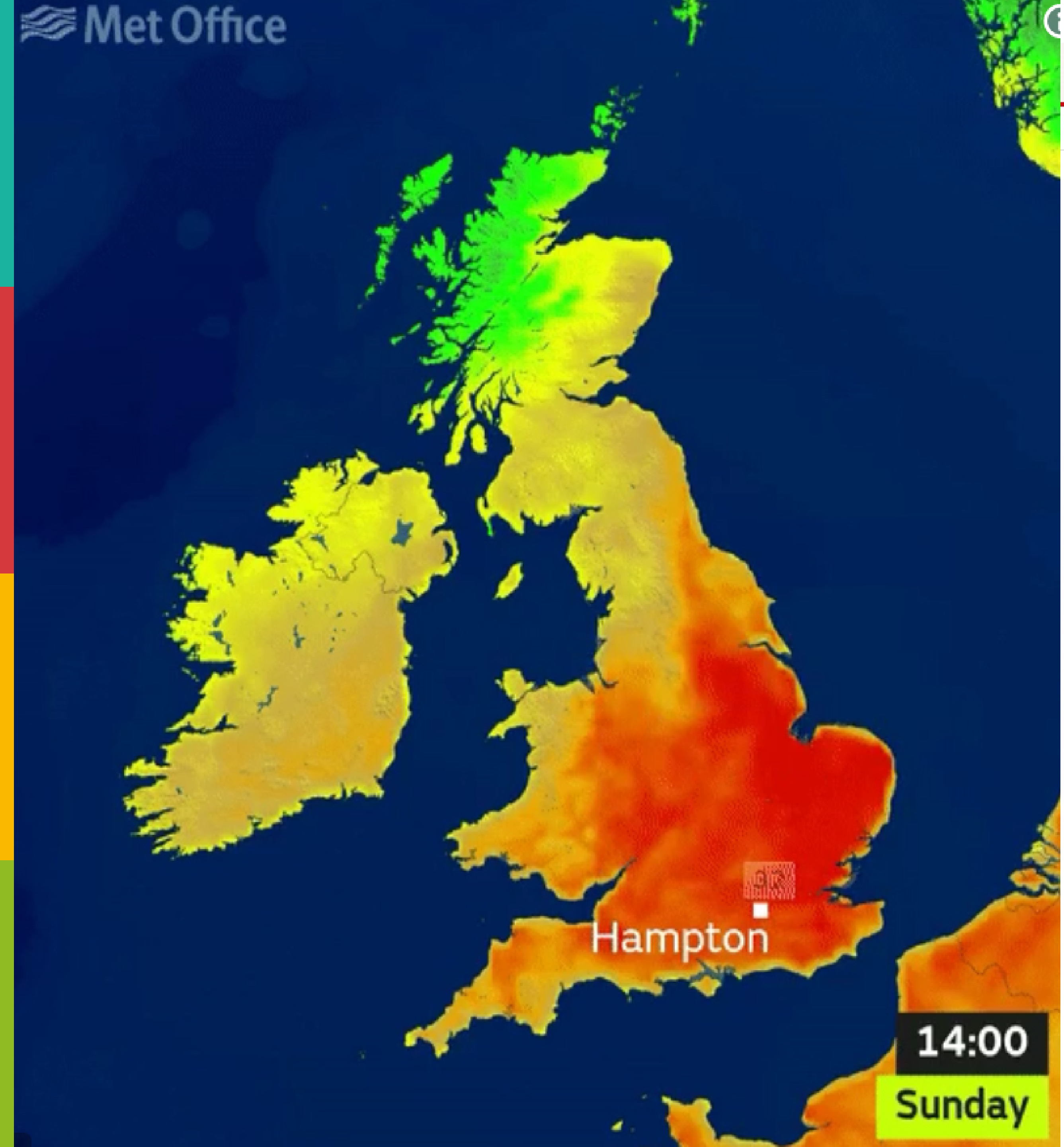


UK weather: Health warning issued as rising temperatures could see Britain bask in hottest June day since 1976

share

Sunseekers enjoy the hot weather on Brighton b

By Telegraph Reporters

19 JUNE 2017 • 12:37AM

The heatwave could bring the ho
the drought of 1976, the Met Off

A health warning has been issued by Pu
who have urged families to keep an eye
sweltering conditions.

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 **Urban Energy Budget (UEB) spatiotemporal patterns**.

Urban Energy Budget (UEB)

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

Q^*: Net all-wave radiation balance

Q_F : Anthropogenic heat flux

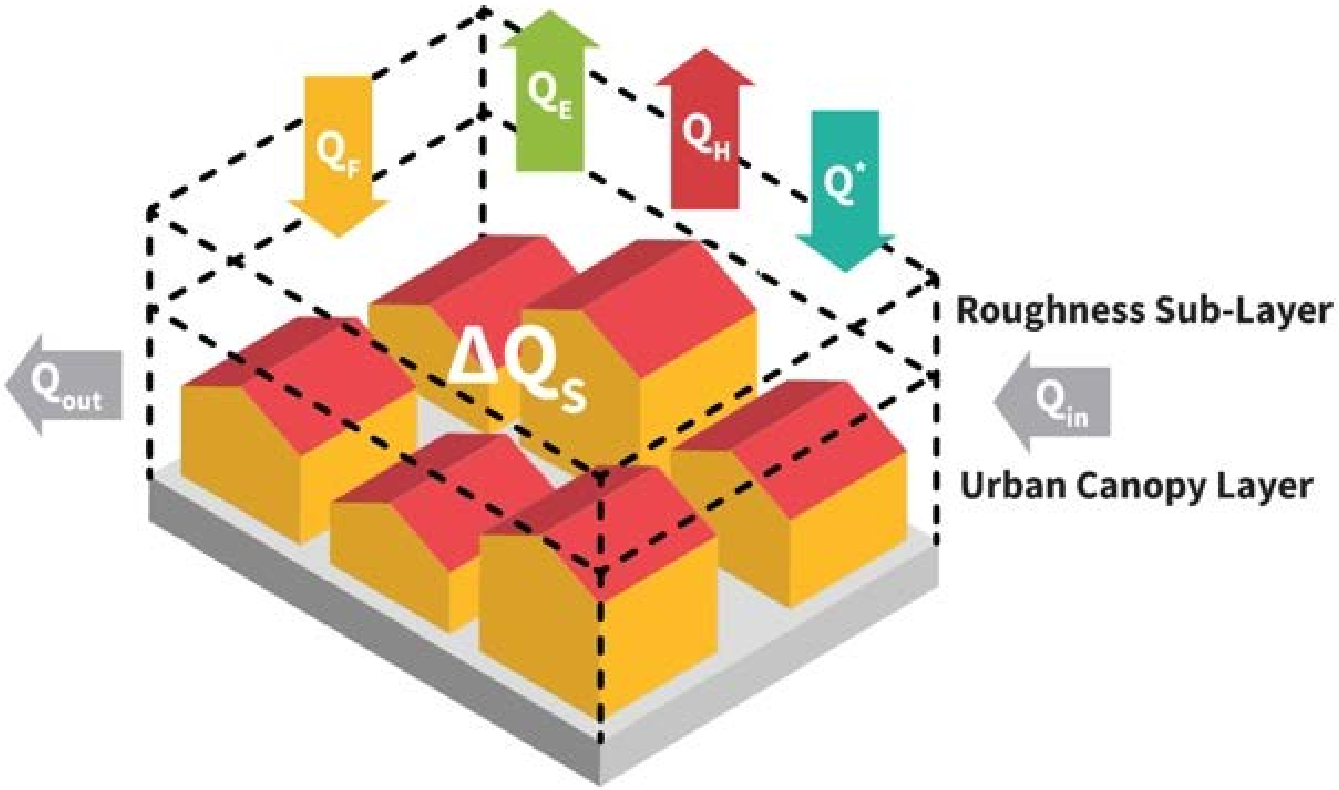
Q_H : Turbulent sensible heat flux

Q_E : Turbulent latent heat flux

ΔQ_S : Net change in heat storage

$\Delta Q_A = Q_{in} - Q_{out}$: Advective heat flux

S: All other sources and sinks



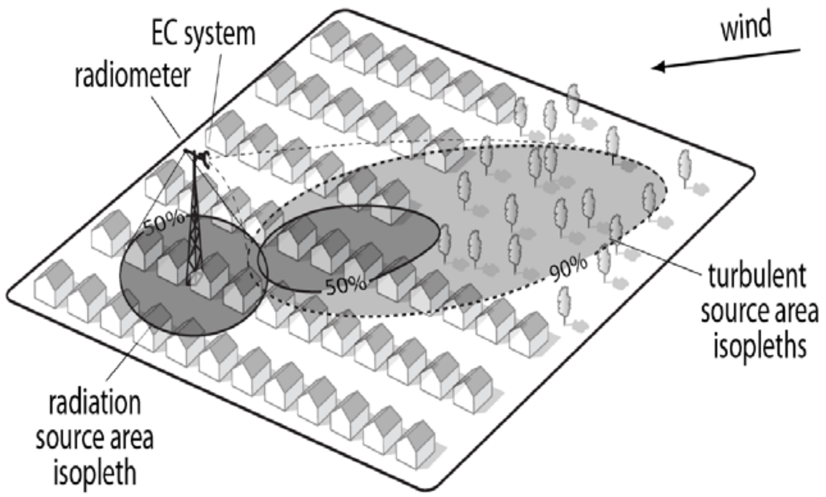
Case Studies

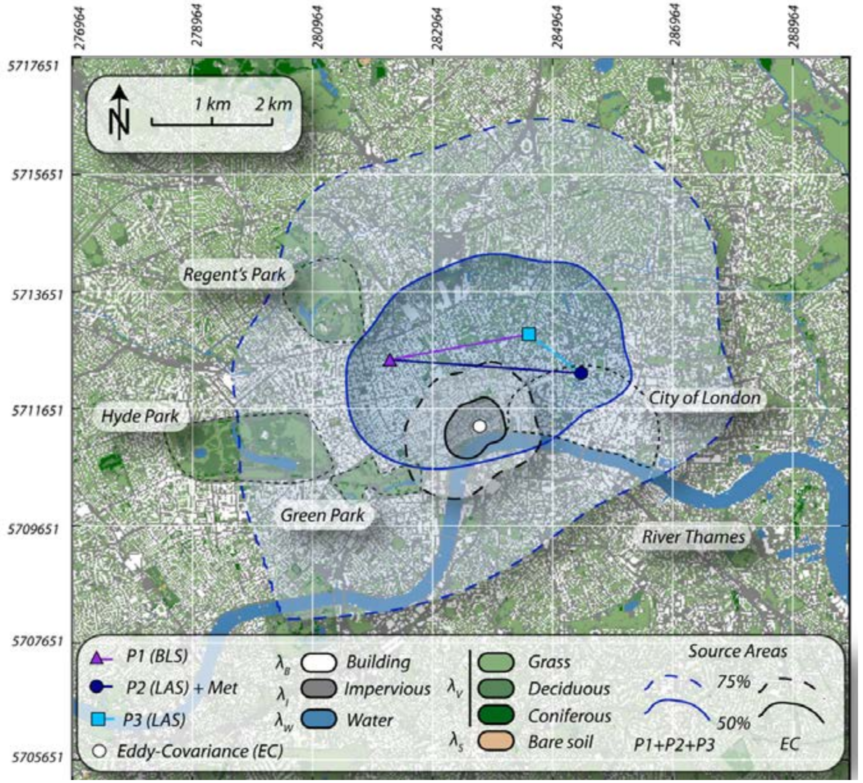
In-situ

Flux towers, Meteorological Sensors Networks

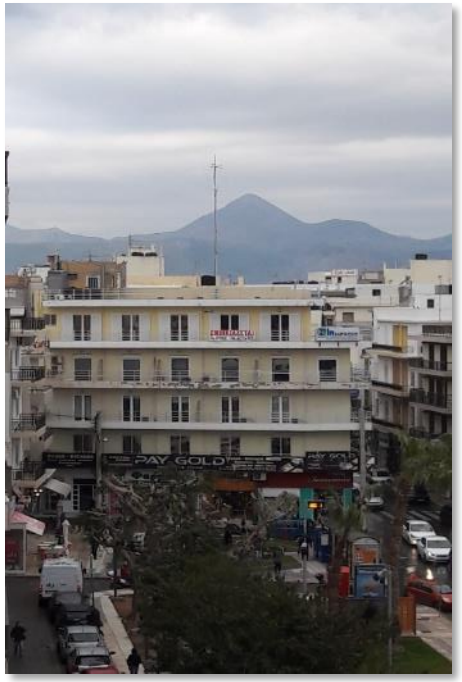
In-situ Observations

- Flux measurements
  - Eddy Covariance flux towers
  - Large-aperture scintillometers



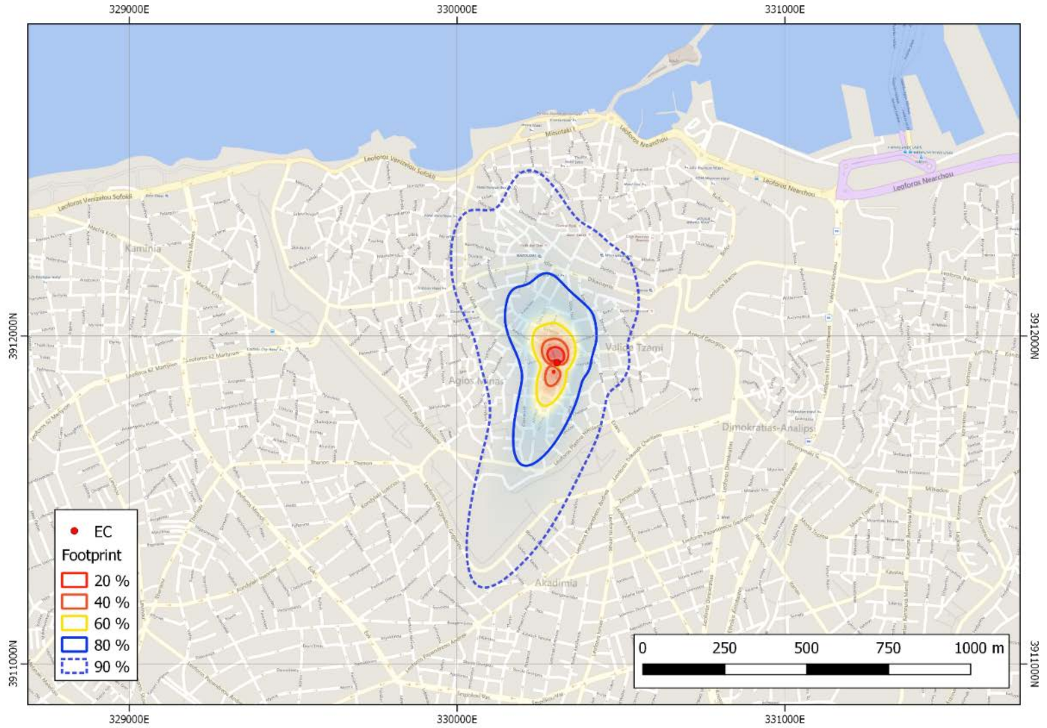


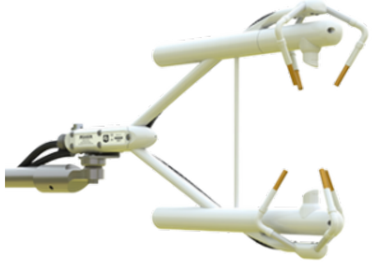
In-situ Observations



$Z = 27$ m, $Z_H = 11$ m

$Z \sim 2.5 \times Z_H$





Sonic Anemometer

- Wind speed 3D
- Temperature

Gas Analyzer

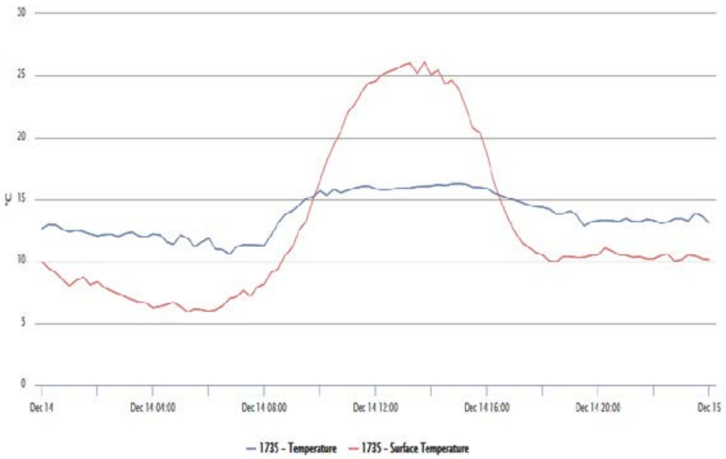
- CO_2 density
- H_2O density

External sensors

- Ambient air temperature
- Ambient air pressure

Maximum frequency:
60 Hz

In-situ Observations



Air temperature, humidity and wind speed

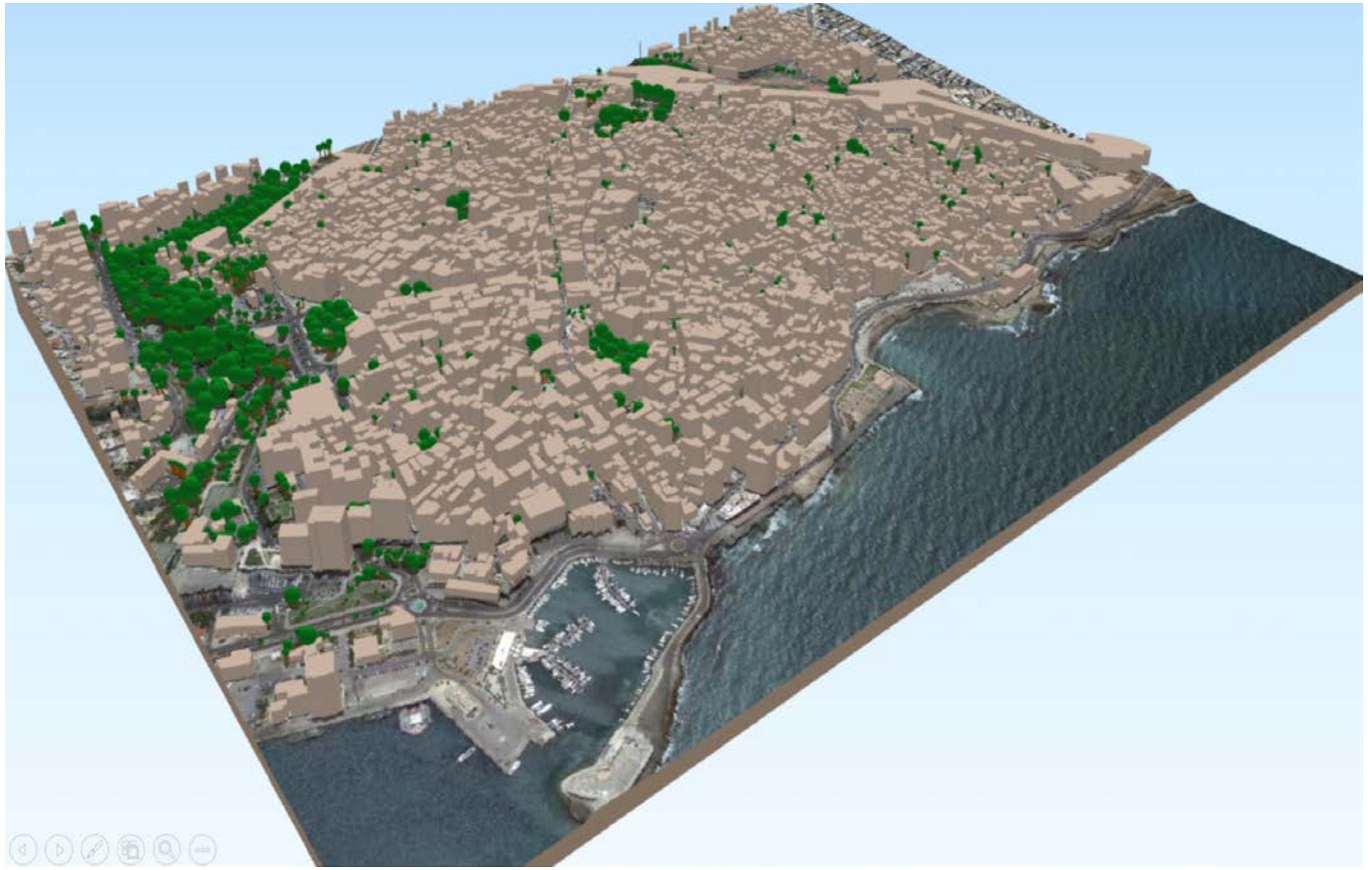
Satellite data products

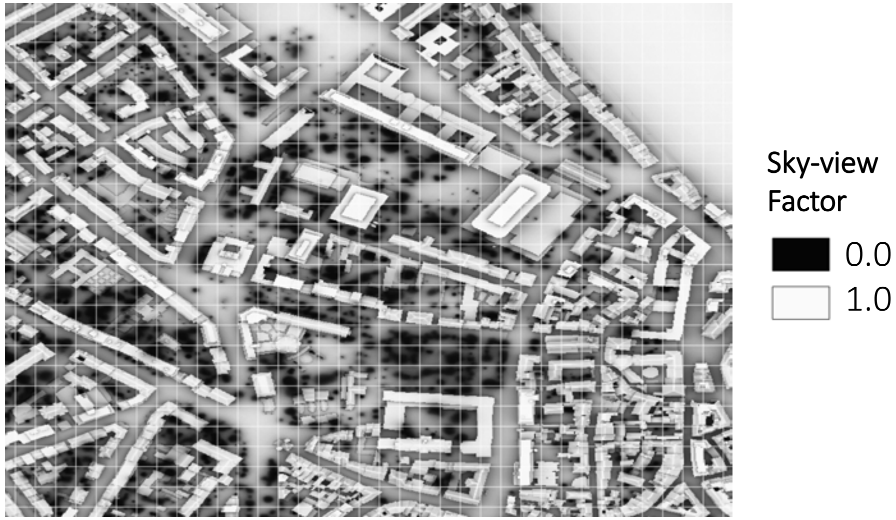
Surface Morphology and Cover

Surface Morphology

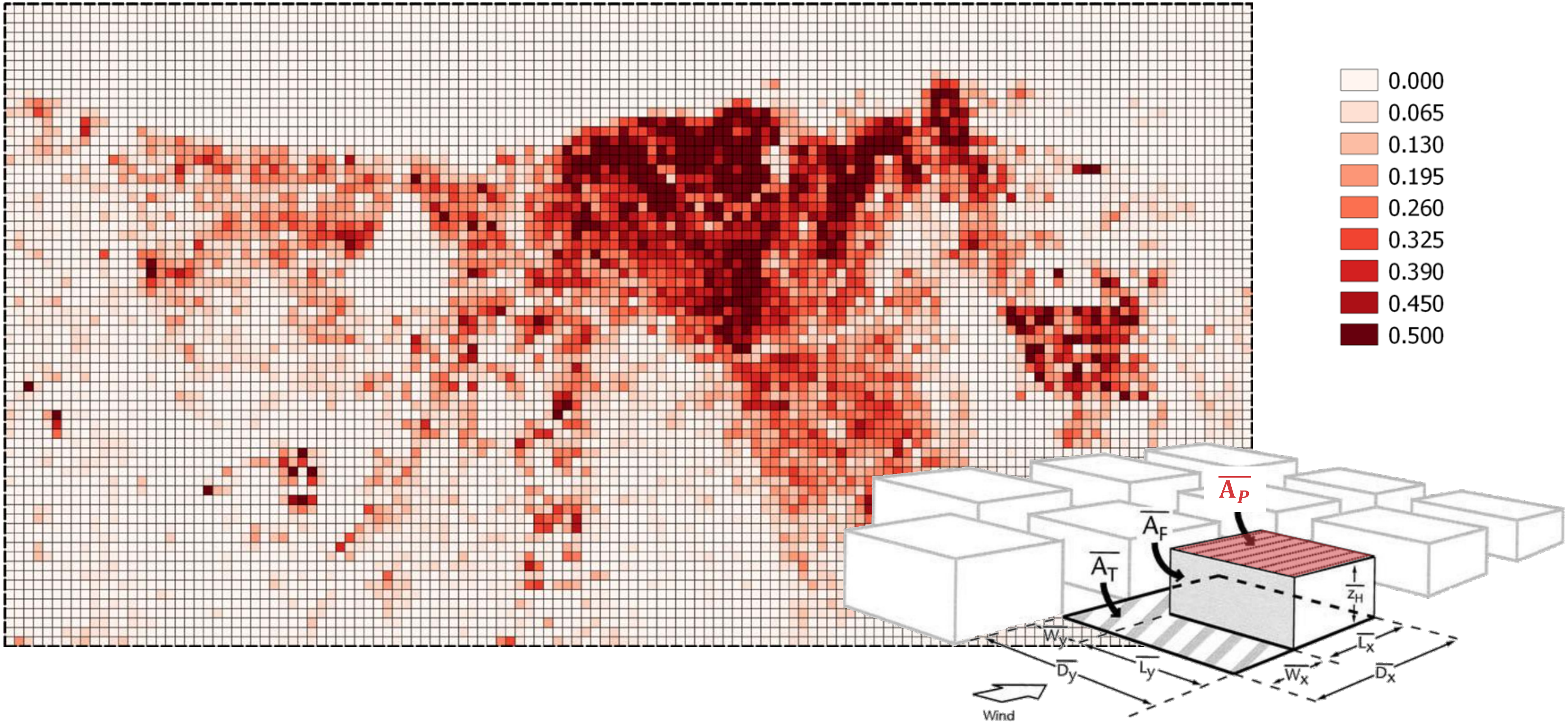
Detailed 3D city representation

Urban objects (buildings and trees) and their height

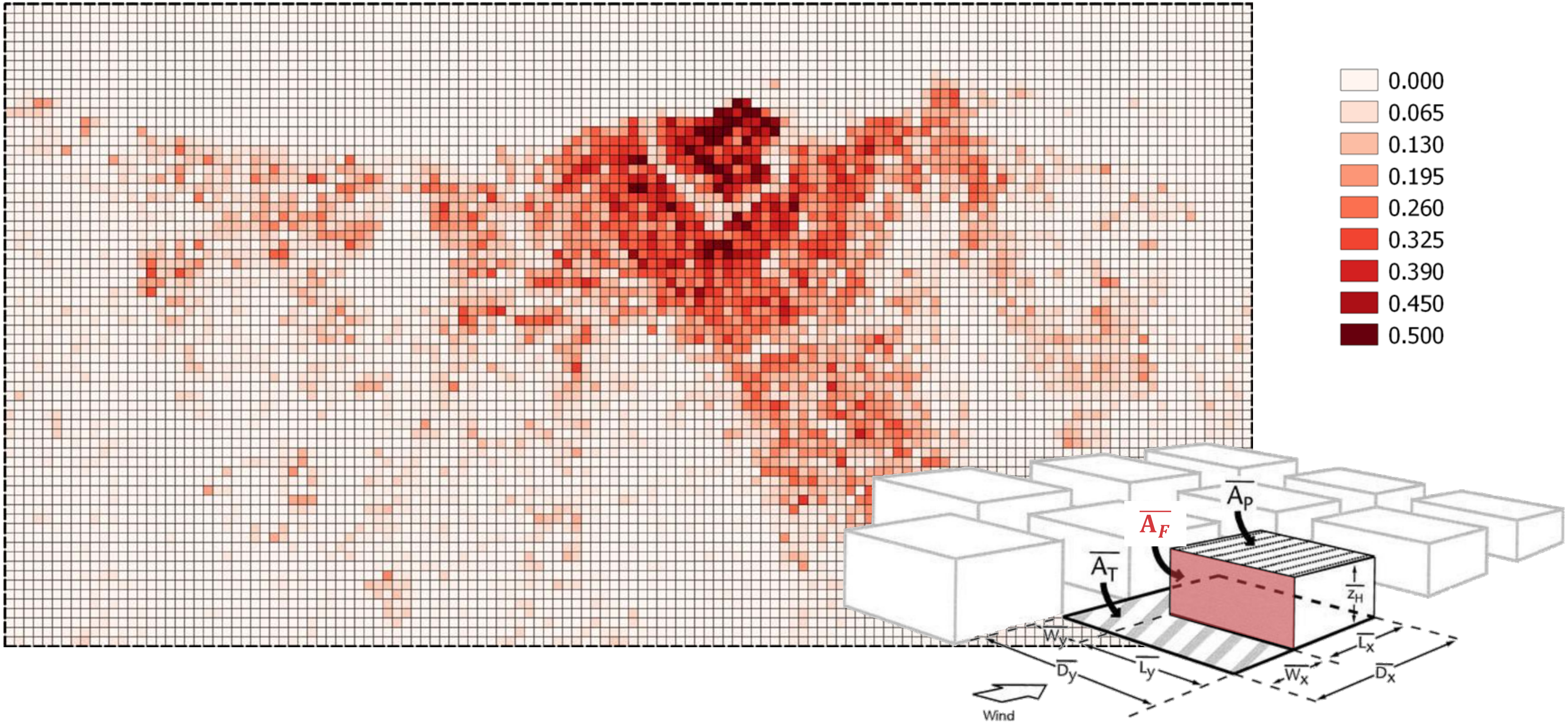




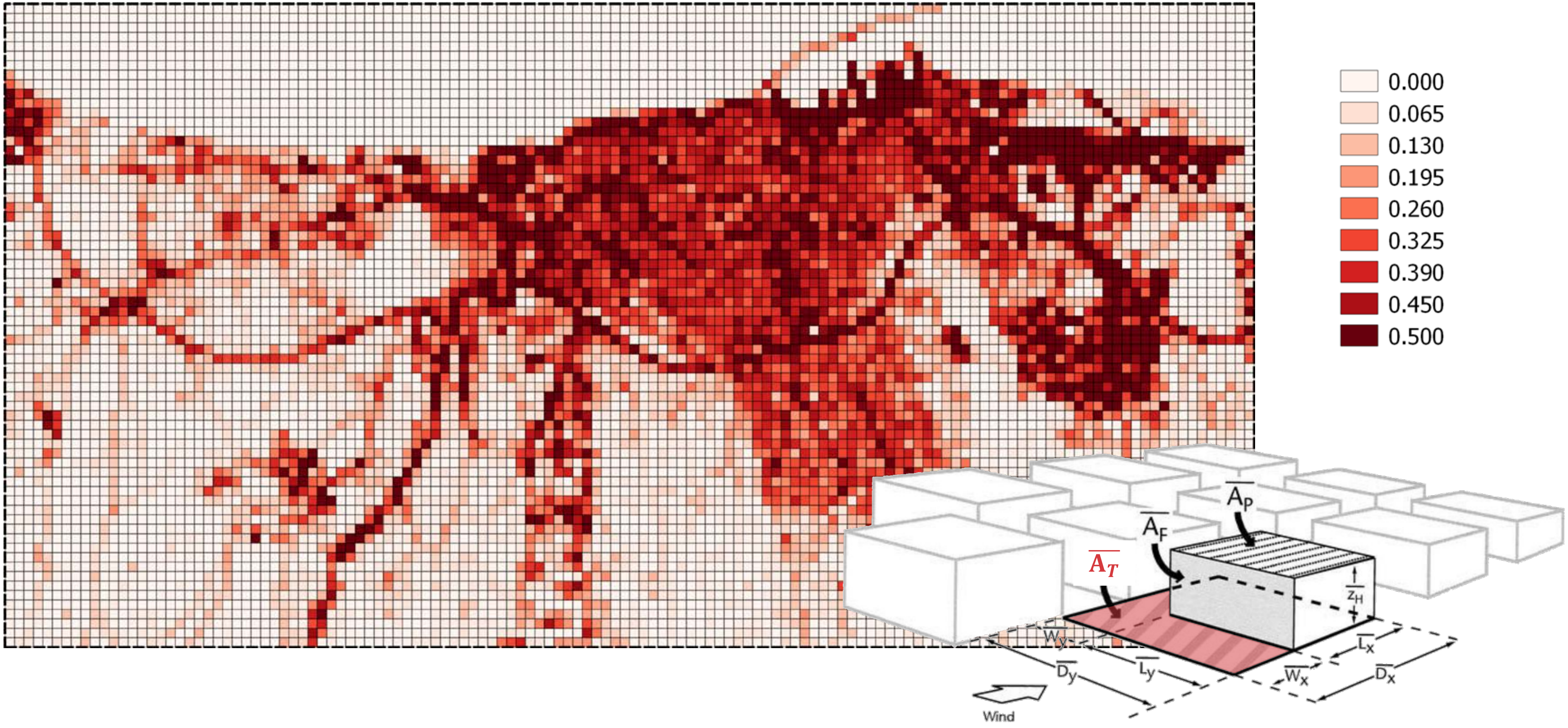
Plan area index



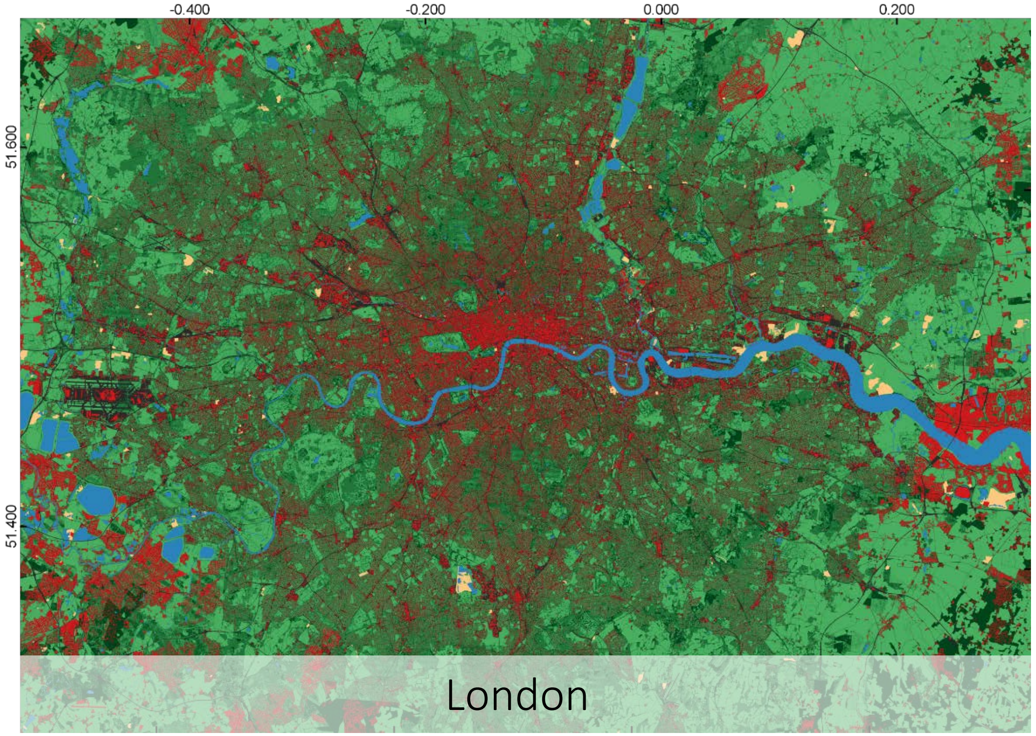
Wall area index

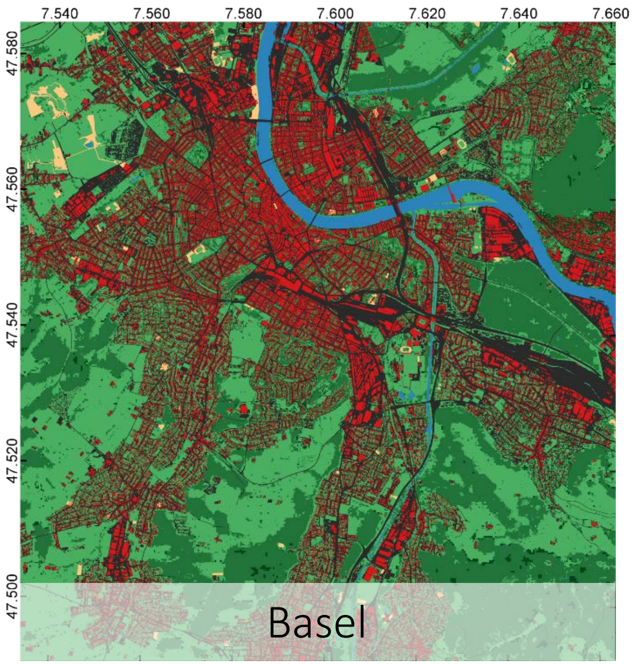


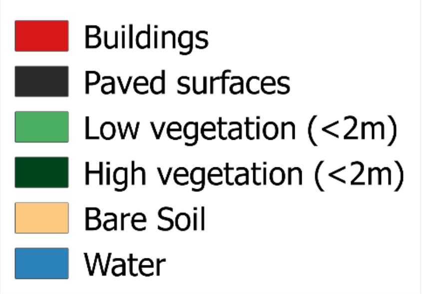
Paved surface fraction

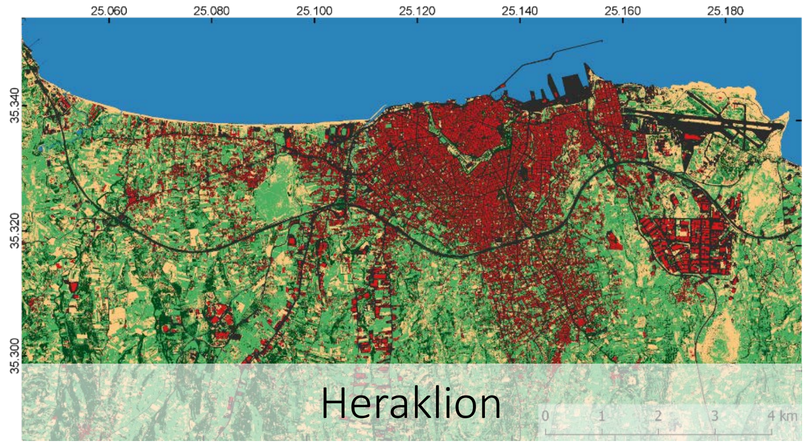


Surface Cover Maps (VHR)



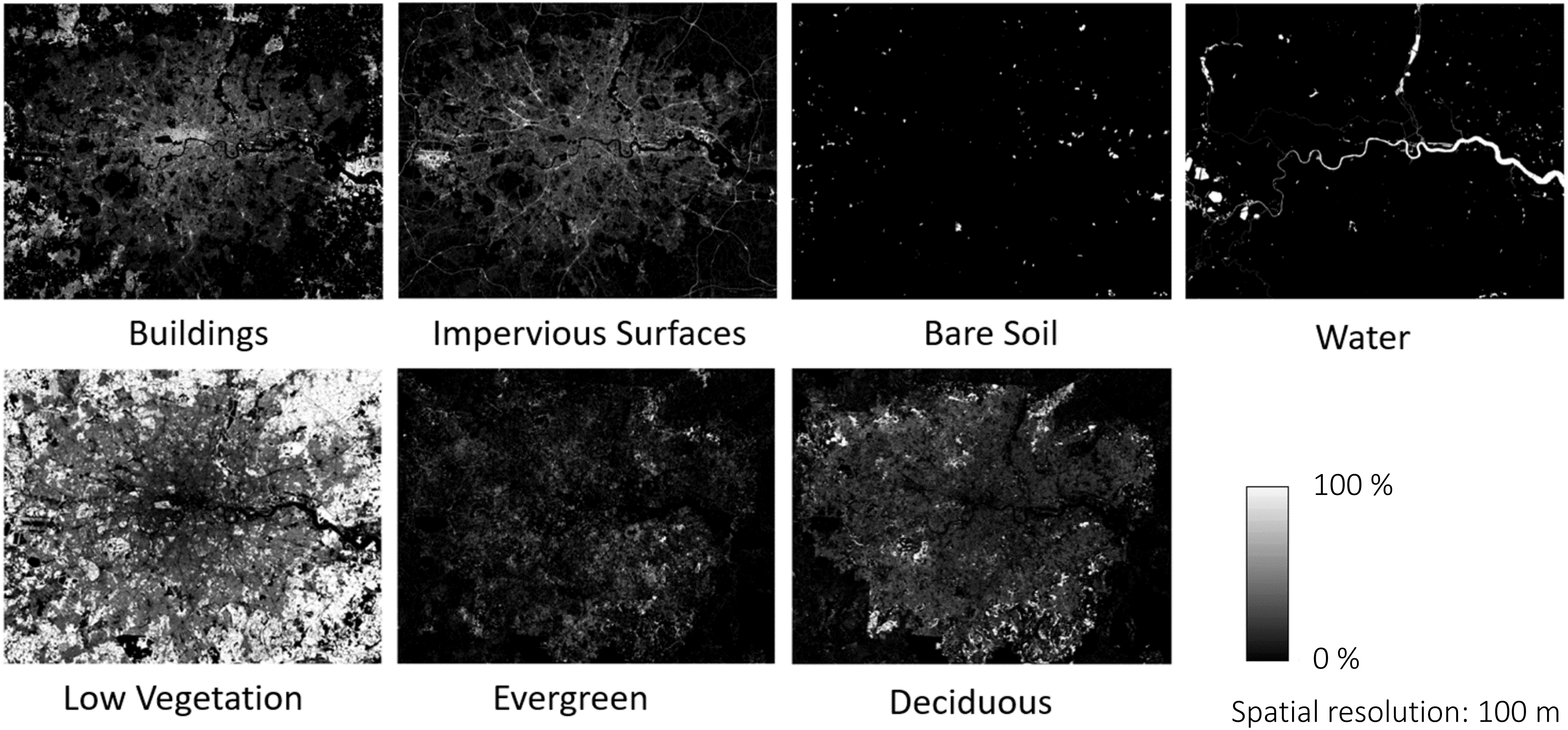




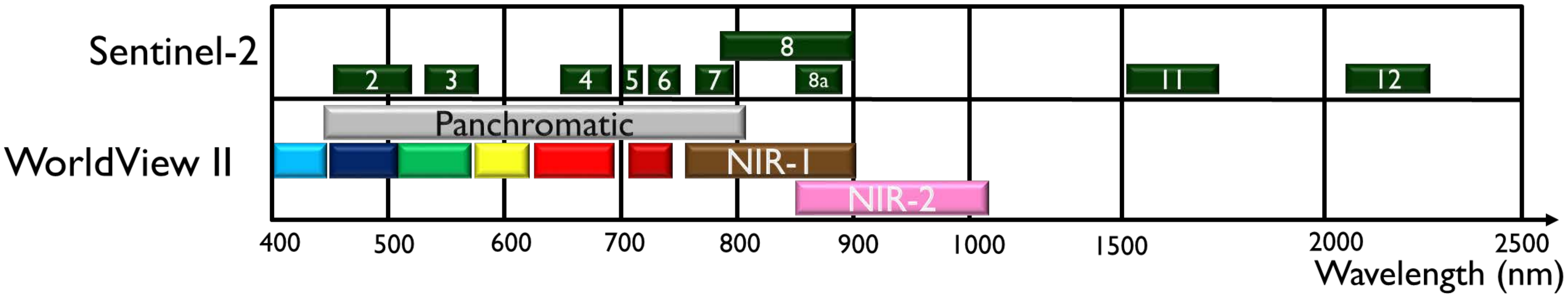


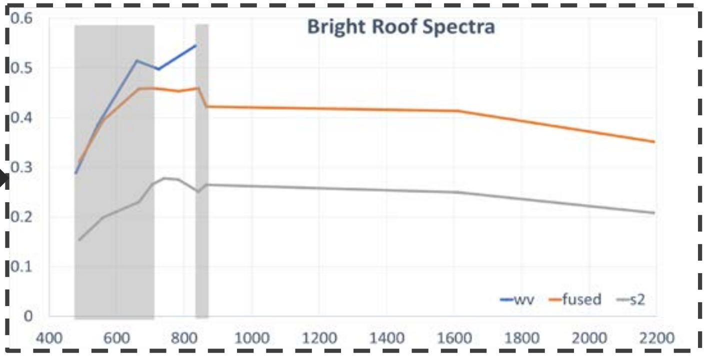
Spatial resolution: 2.5 m

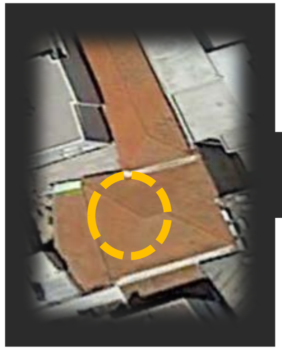
Surface Cover Fractions

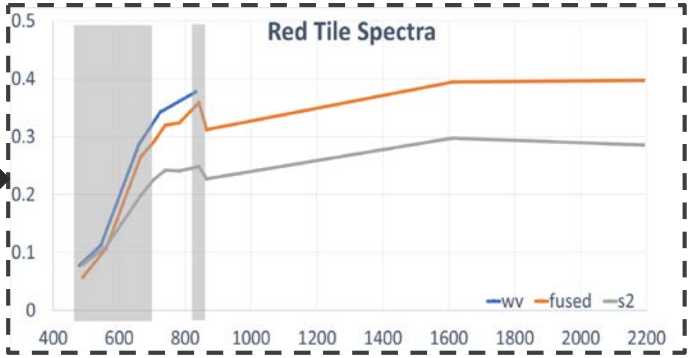


Material Endmembers

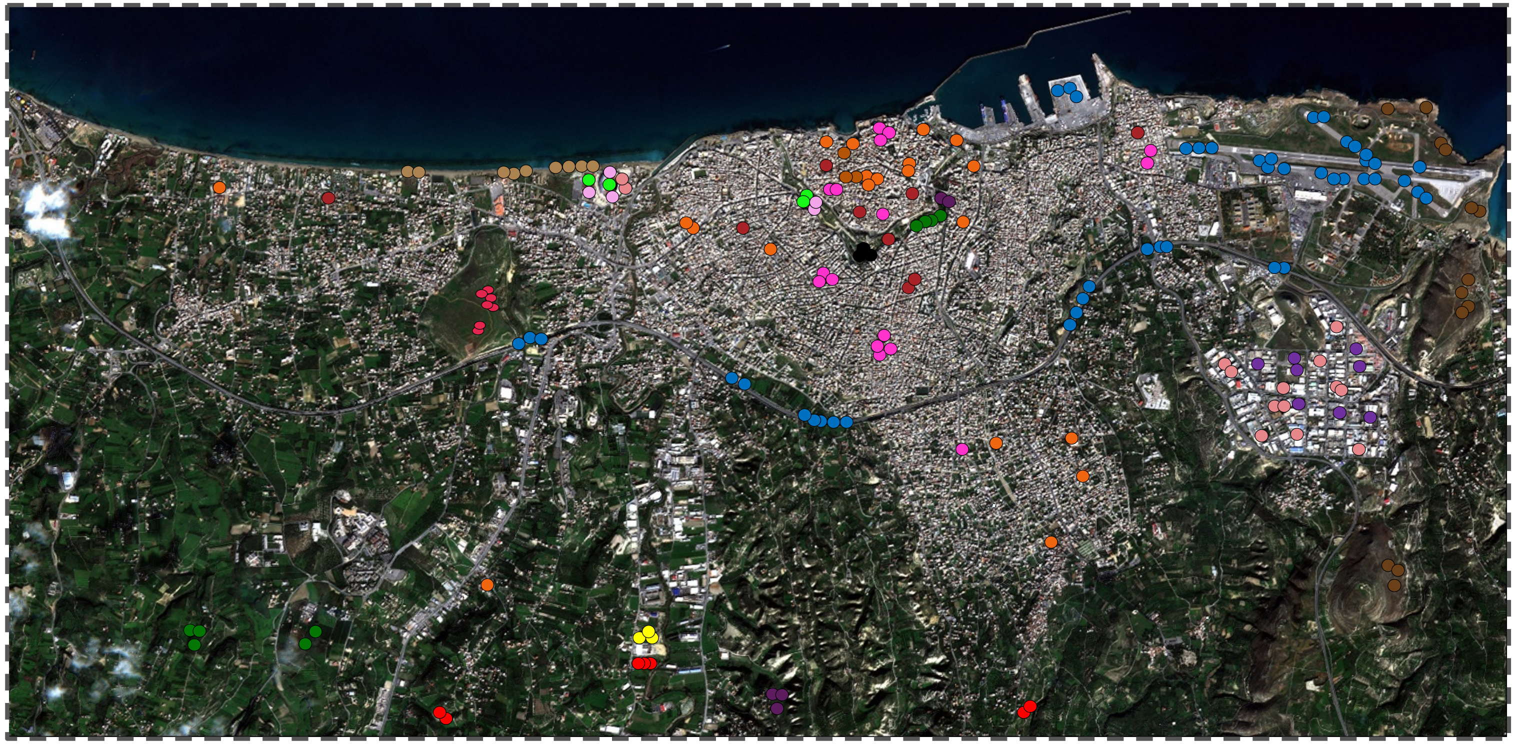








Material Endmembers



Bright Roof
Dark Roof
Red Tiles
Grey Tiles

Bright Metal
Metal
Greenhouse
Asbestos/Amianthus

Boardleave
Conifers
Low Vegetation
Grass

Bare Soil
Sand
Asphalt
Artificial
Sport Area Tartan

Surface Cover Materials

Spectral Library of Urban Materials (London)

74 samples, 10 categories,

New and weathered materials

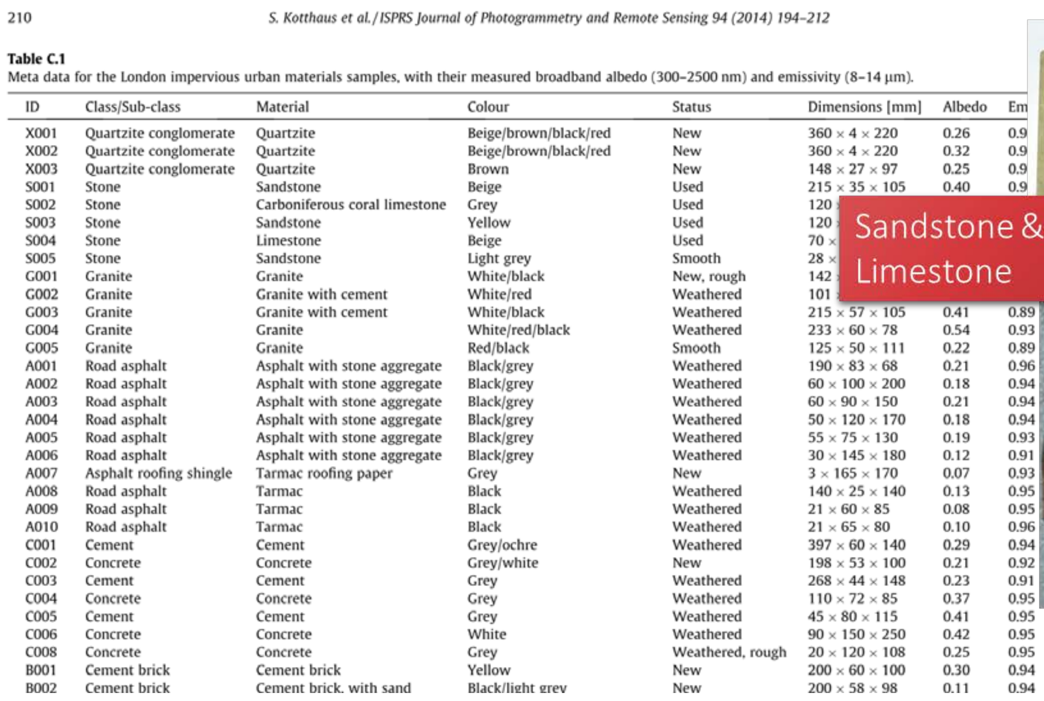


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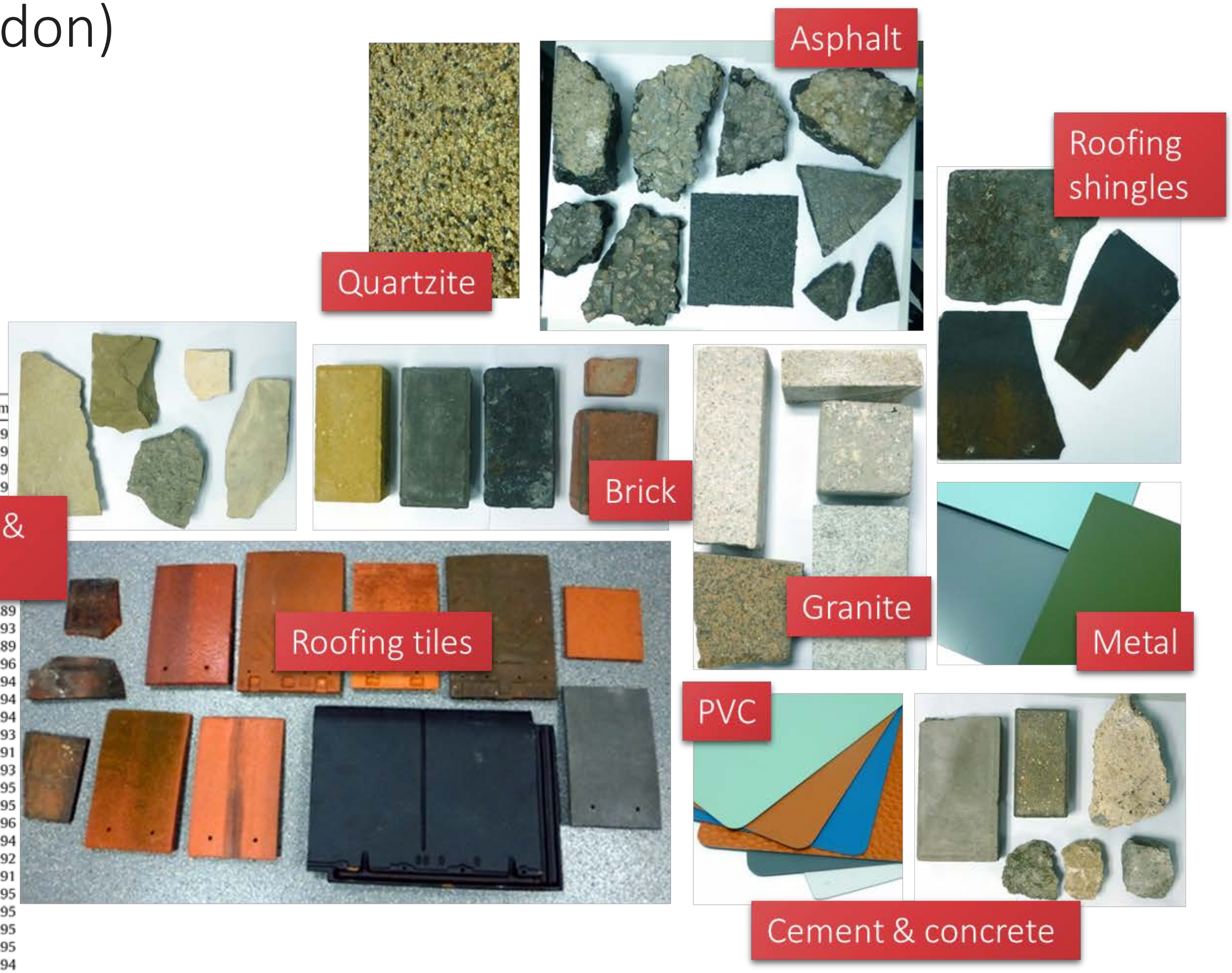
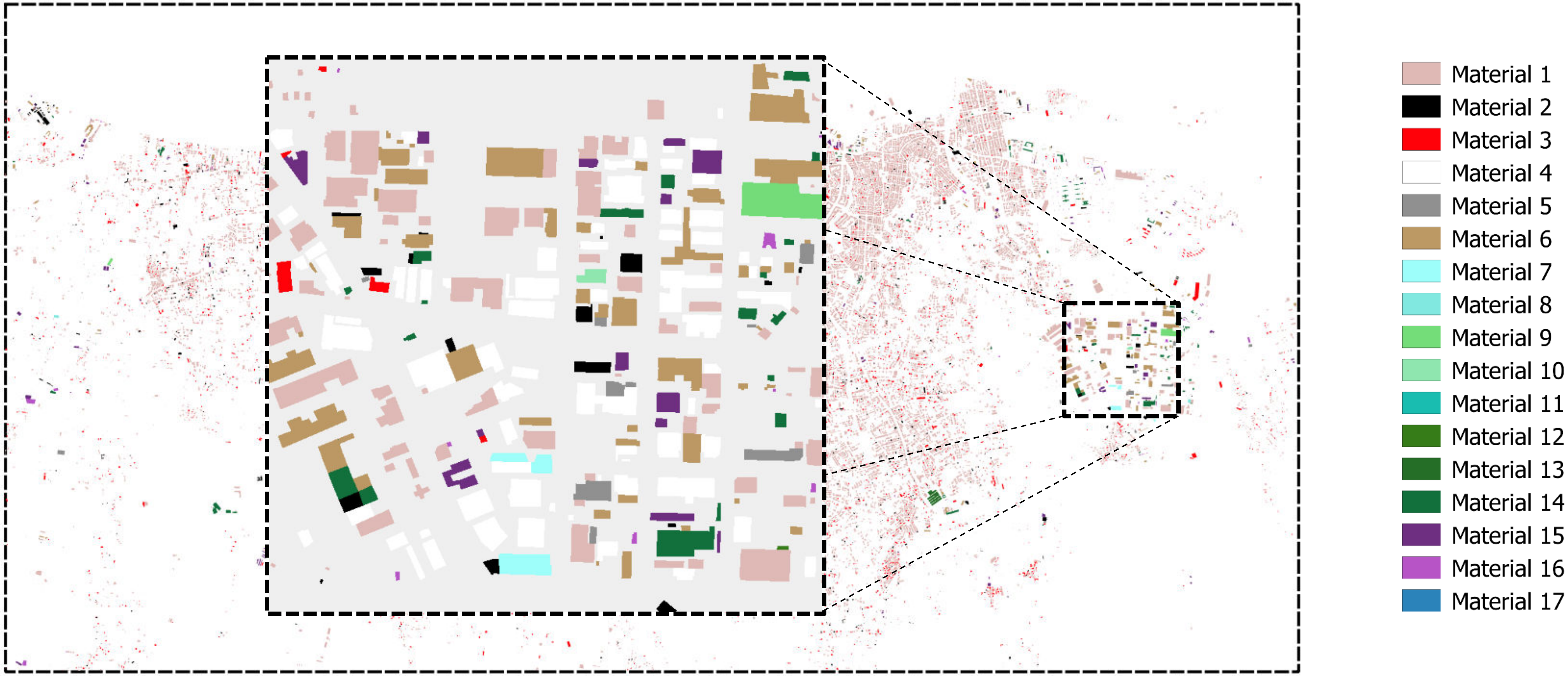
Table C.1
Meta data for the London impervious urban materials samples, with their measured broadband albedo (300–2500 nm) and emissivity (8–14 μm).

ID	Class/Sub-class	Material	Colour	Status	Dimensions [mm]	Albedo	Em
X001	Quartzite conglomerate	Quartzite	Beige/brown/black/red	New	360 × 4 × 220	0.26	0.9
X002	Quartzite conglomerate	Quartzite	Beige/brown/black/red	New	360 × 4 × 220	0.32	0.9
X003	Quartzite conglomerate	Quartzite	Brown	New	148 × 27 × 97	0.25	0.9
S001	Stone	Sandstone	Beige	Used	215 × 35 × 105	0.40	0.9
S002	Stone	Carboniferous coral limestone	Grey	Used	120 [illegible]	[illegible]	[illegible]
S003	Stone	Sandstone	Yellow	Used	120 [illegible]	[illegible]	[illegible]
S004	Stone	Limestone	Beige	Used	70 × [illegible]	[illegible]	[illegible]
S005	Stone	Sandstone	Light grey	Smooth	28 × [illegible]	[illegible]	[illegible]
G001	Granite	Granite	White/black	New, rough	142 [illegible]	[illegible]	[illegible]
G002	Granite	Granite with cement	White/red	Weathered	101 [illegible]	[illegible]	[illegible]
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



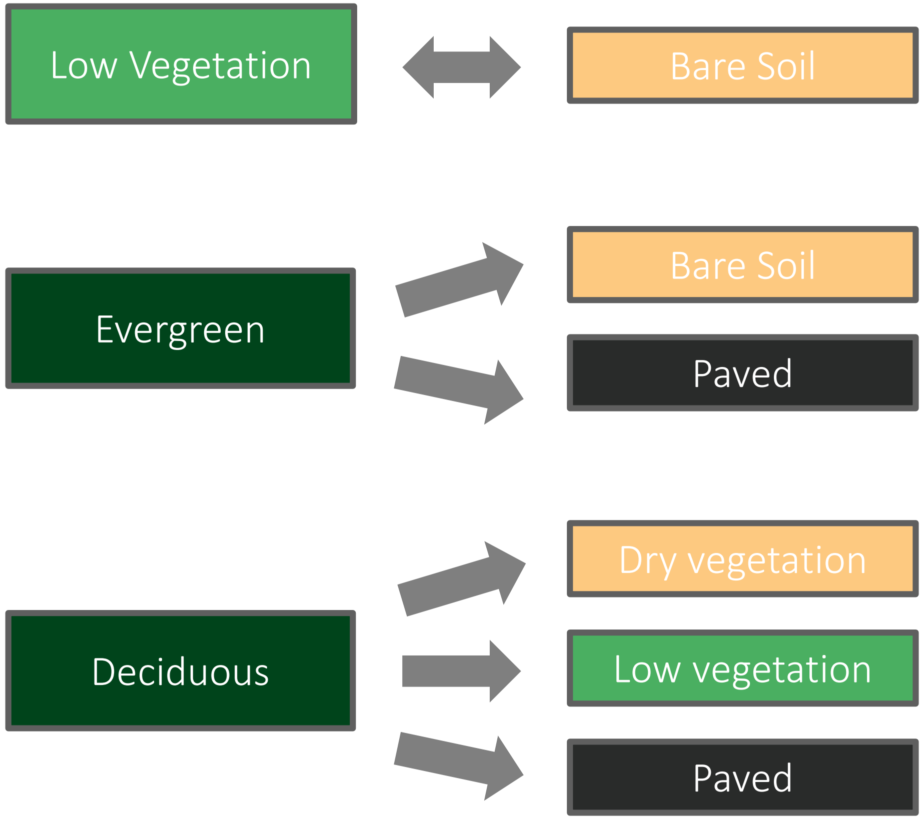
http://www.met.reading.ac.uk/micromet/LUMA/SLUM.html

Surface Cover Materials

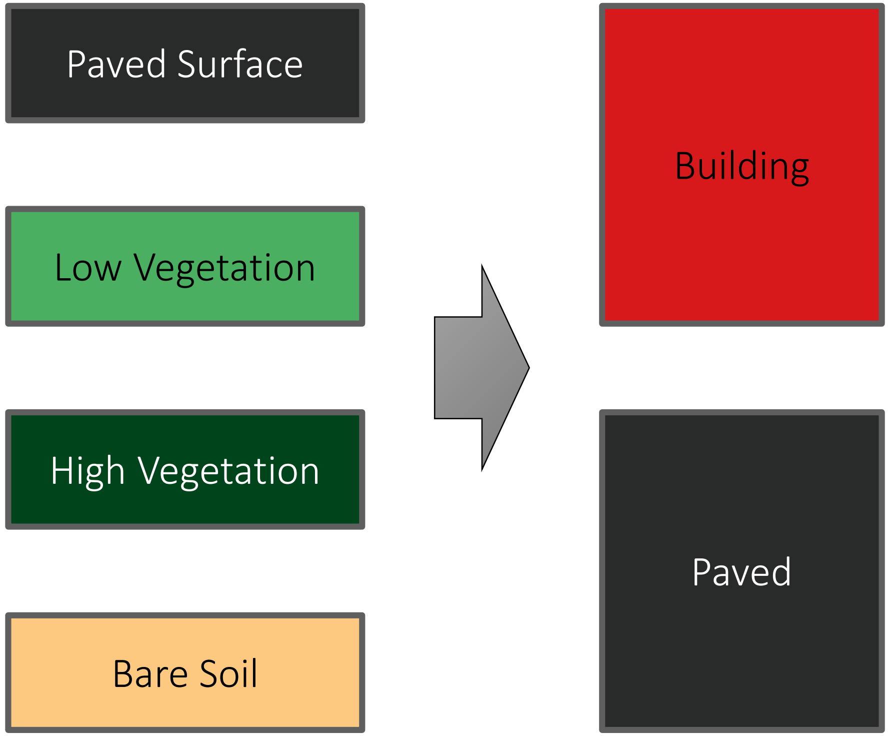


Surface Cover Monitoring

VEGETATION CLASS INTERCHANGEABILITY



URBAN CLASS INTERCHANGEABILITY

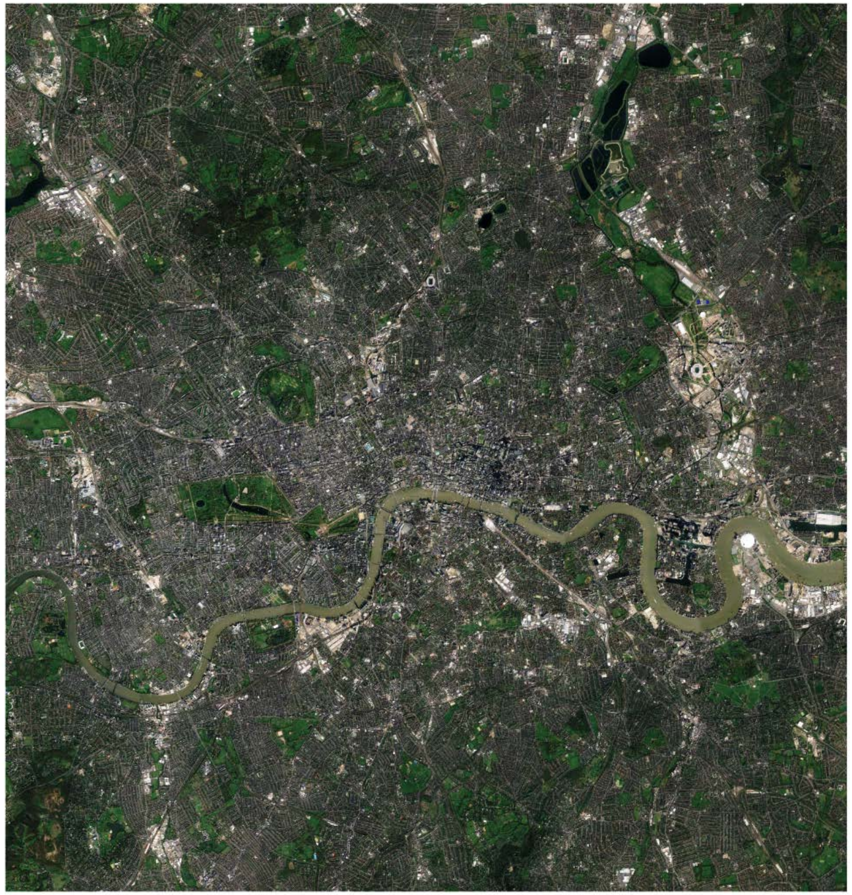


Satellite data products

Land Surface Temperature

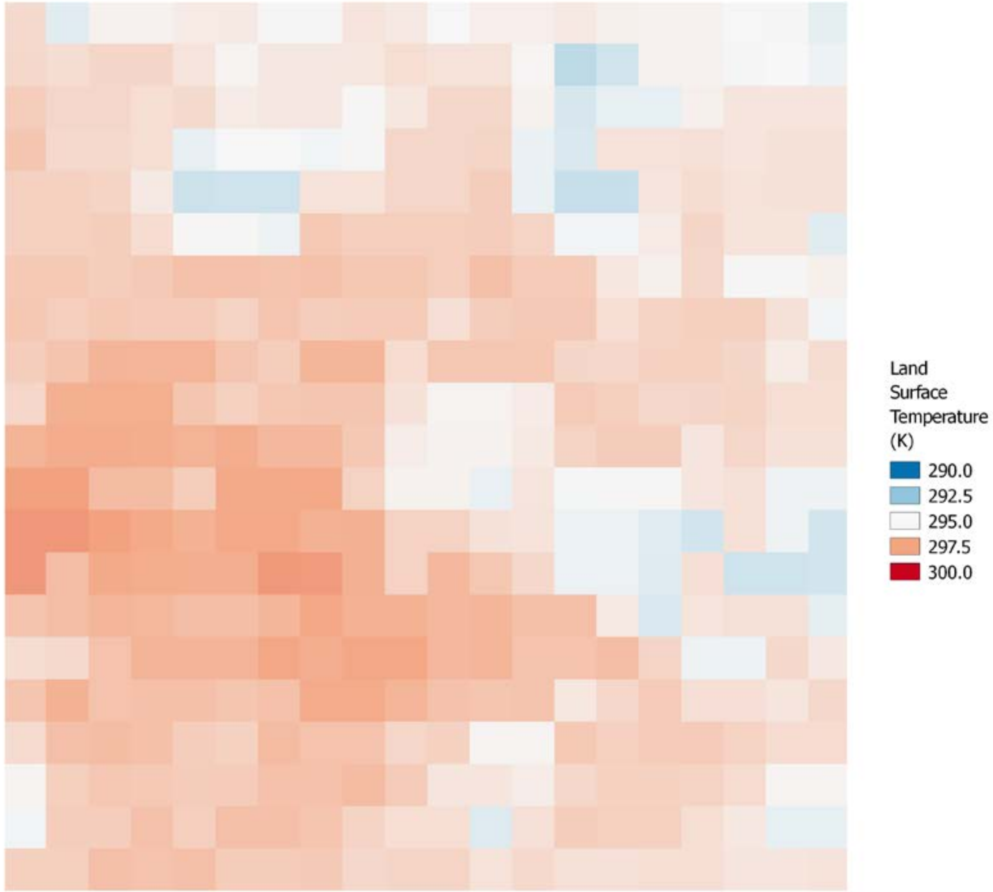
Land Surface Temperature

London



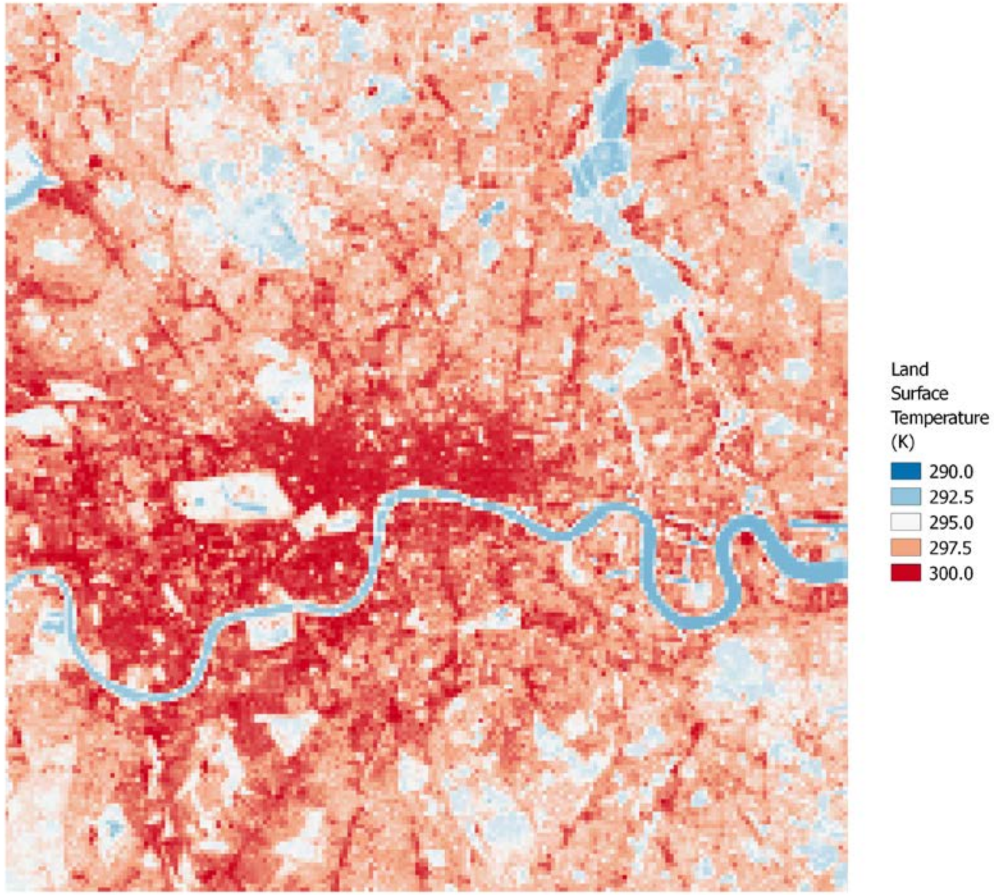
Land Surface Temperature

London – 19 July 2016, 22:05 – MODIS LST product (K) – Resolution 1 km

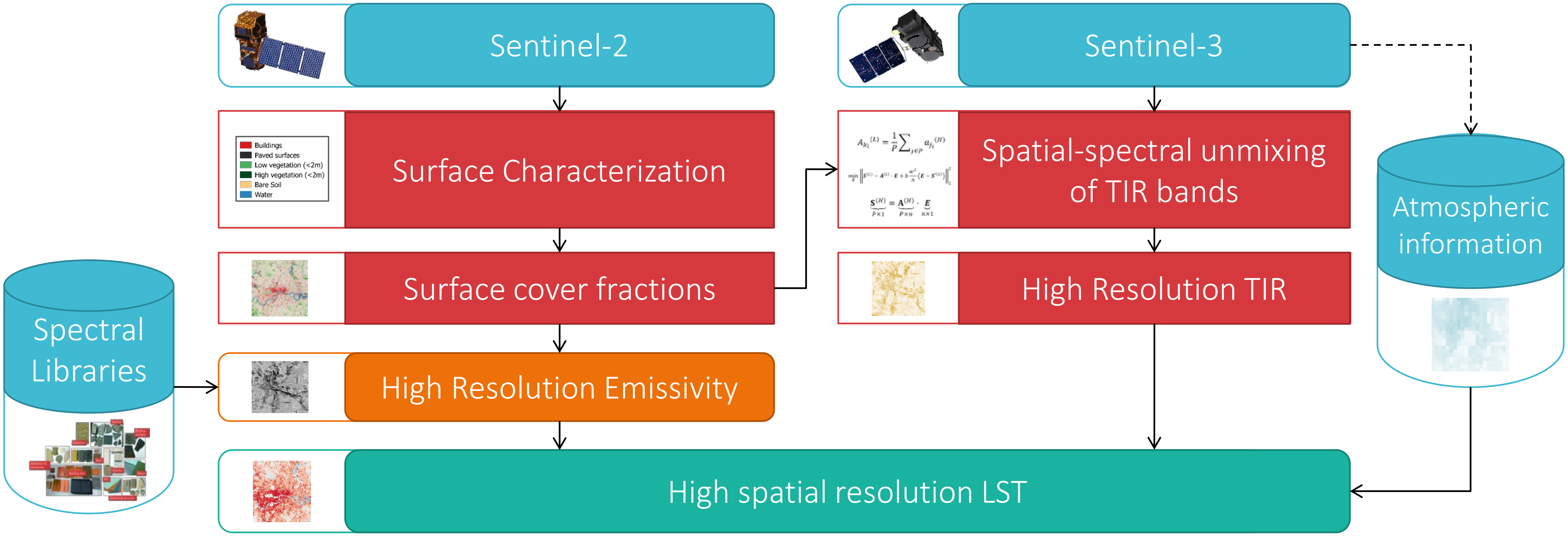


Land Surface Temperature

London – 19 July 2016, 22:05 – Downscaled LST product (K) – Resolution 100 m



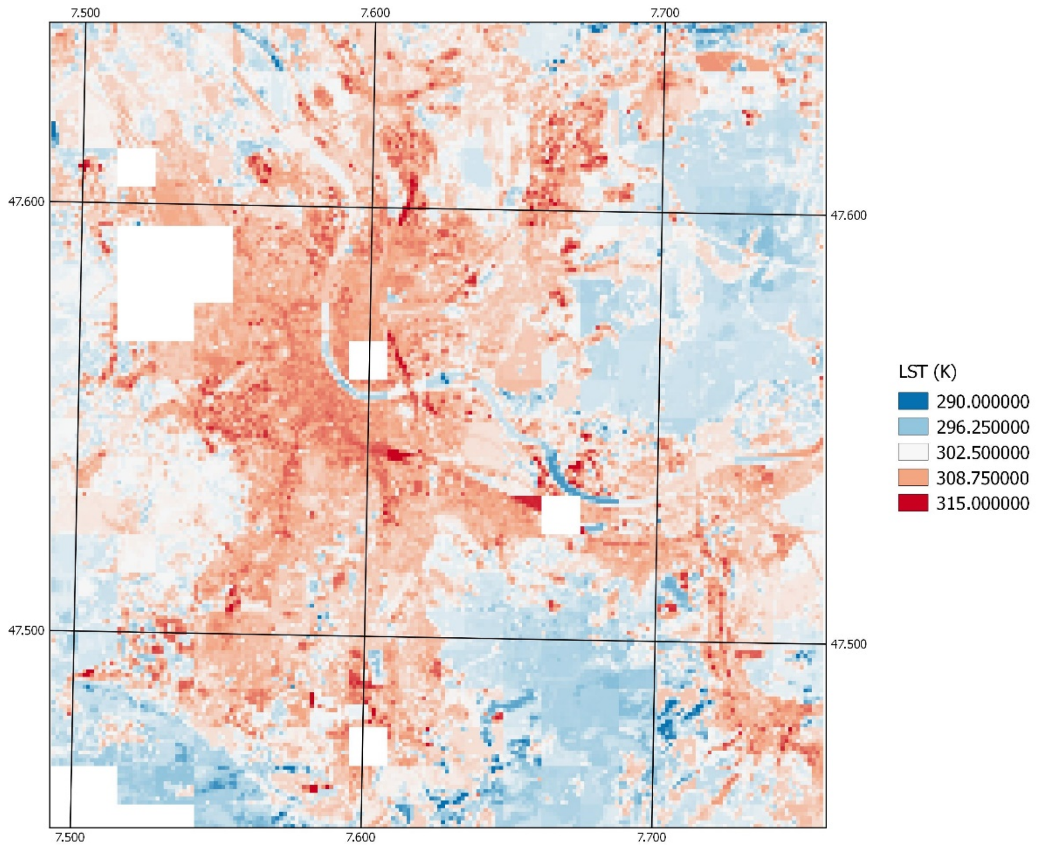
Land Surface Temperature



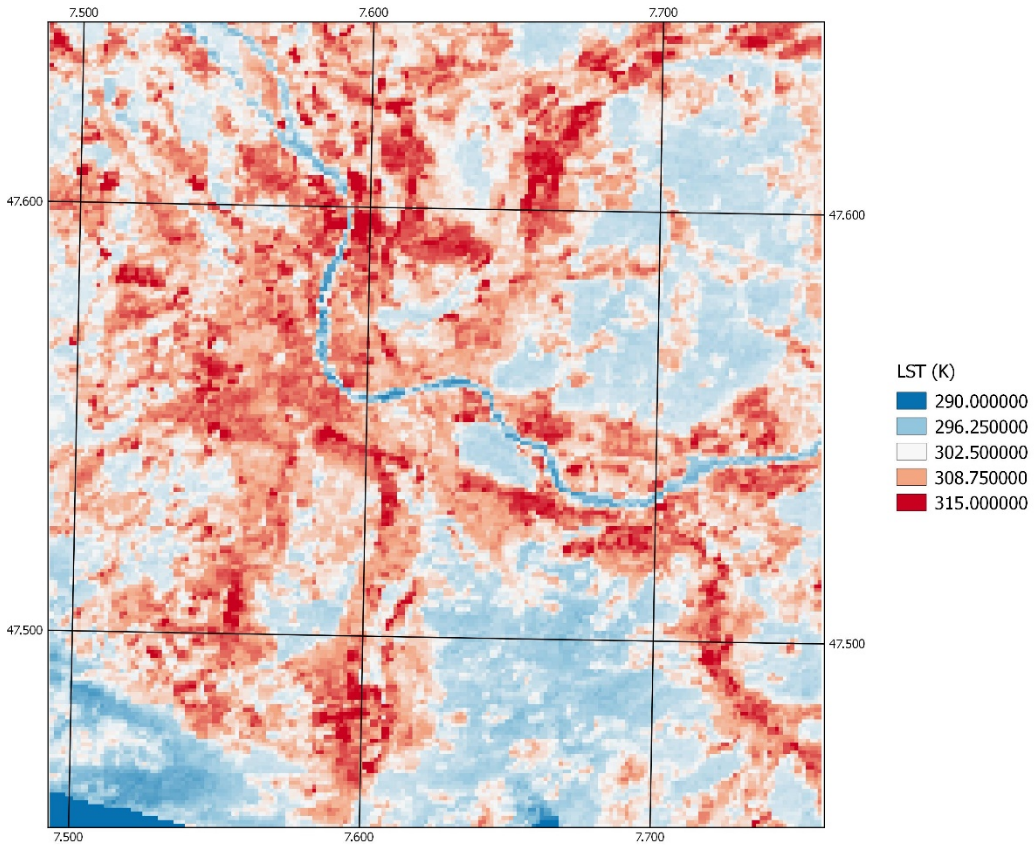
LST Evaluation with ASTER LST Products

› 2 August 2011 10.39

UF Downscaled LST



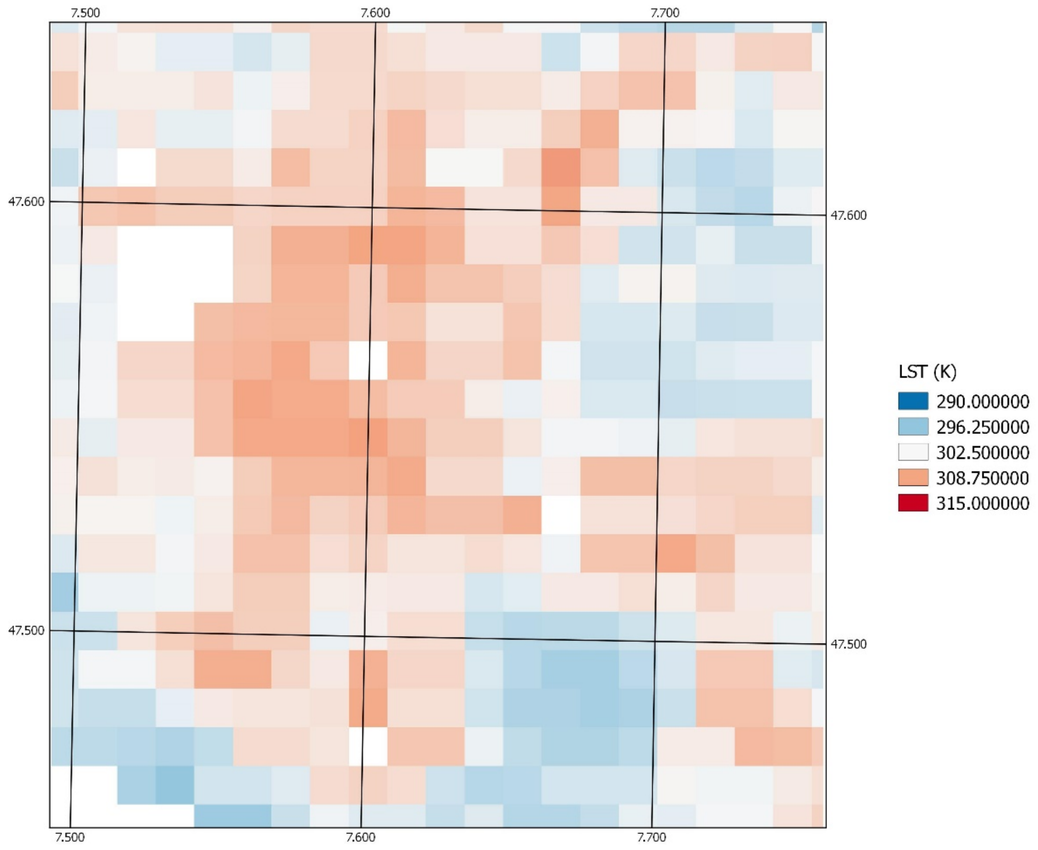
ASTER LST



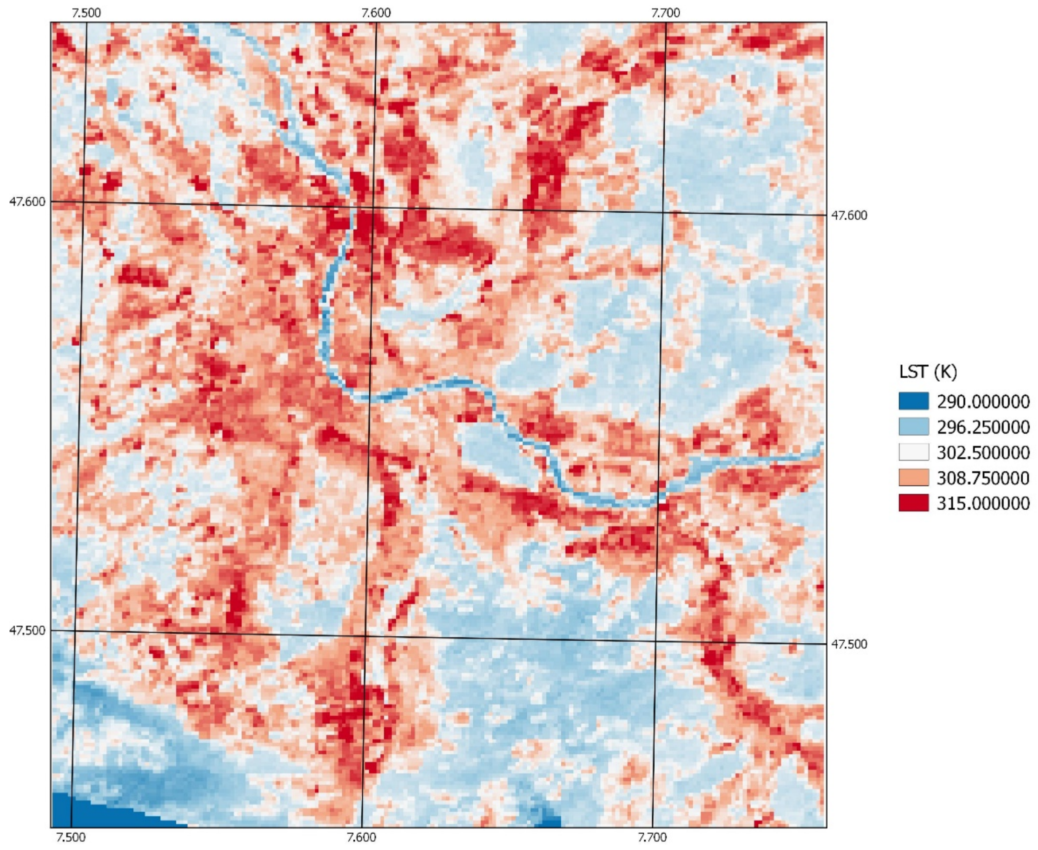
LST Evaluation with ASTER LST Products

- 2 August 2011 10.39

MODIS LST



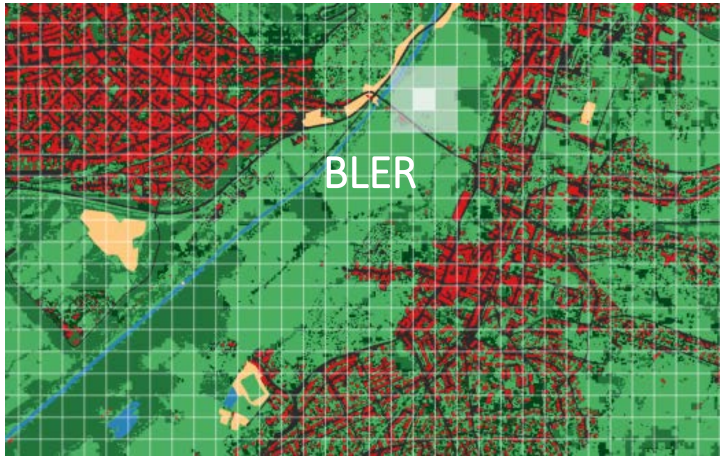
ASTER LST

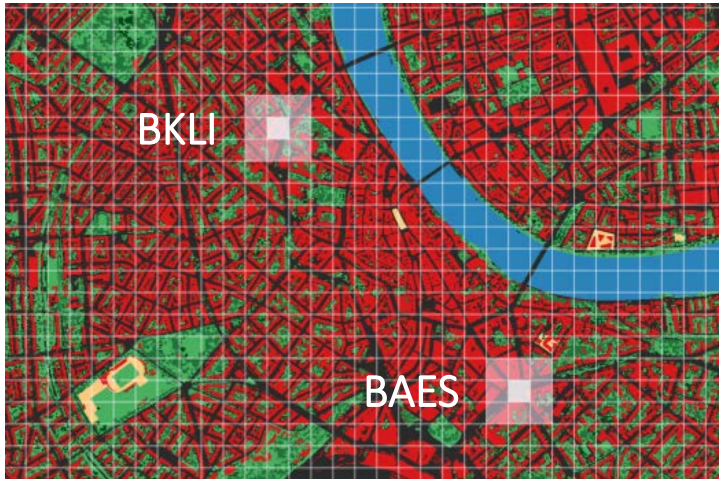


LST Evaluation with ASTER LST Products

Day/Night	Date	Root Mean Square Error (RMSE)	Bias	Mean Absolute Error (MAE)	Median Absolute Error (MdAE)	Quantile .25	Quantile .75
Day	2011.03.20	1.310	0.050	0.607	1.656	-1.475	1.763
Day	2011.08.02	1.340	0.193	0.667	1.650	-0.889	2.127
Day	2011.09.28	2.057	0.782	1.389	1.987	-0.223	2.871
Day	2012.03.22	2.521	0.658	1.362	2.566	-1.220	4.094
Day	2012.06.17	2.173	0.456	1.408	1.945	-1.219	2.631
Day	2014.03.28	1.795	0.584	0.847	2.245	-0.112	3.647
Day	2015.09.07	1.569	0.745	1.040	1.417	0.072	2.354
Day	2015.09.30	1.396	0.414	0.664	1.684	-0.229	2.735
Night	2013.10.30	0.757	-0.146	0.457	0.809	-1.121	0.381
Night	2015.02.22	1.448	0.803	1.000	1.510	0.390	2.295
Night	2015.08.17	0.907	0.209	0.581	0.971	-0.515	1.285

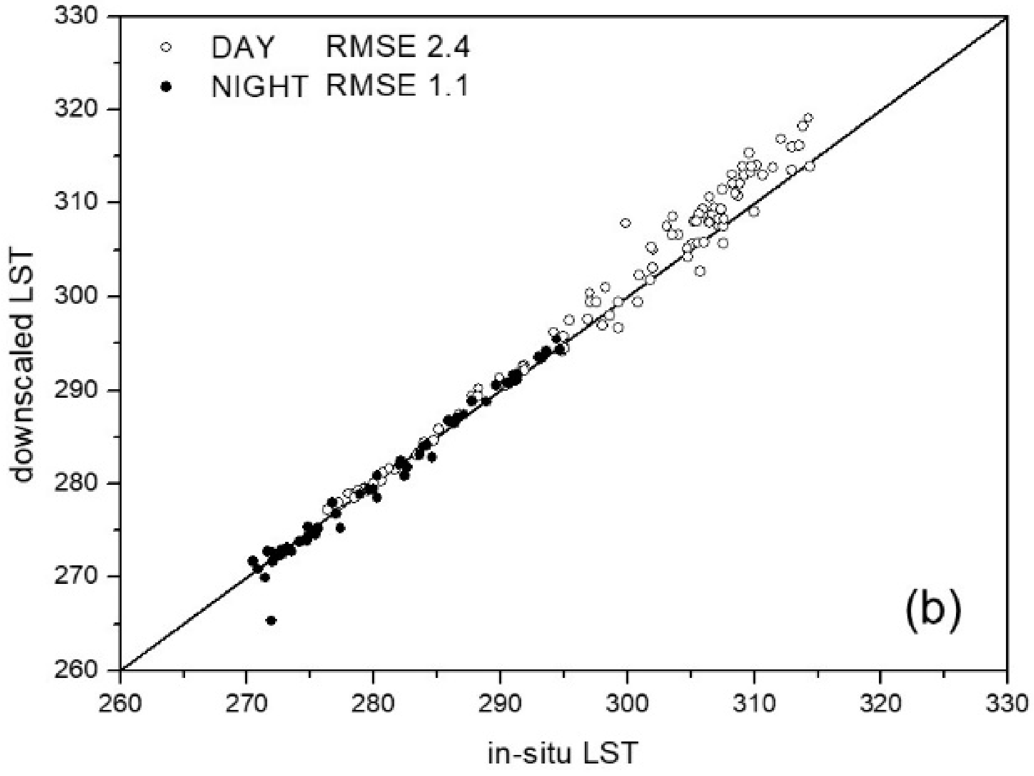
Urban LST *in-situ*



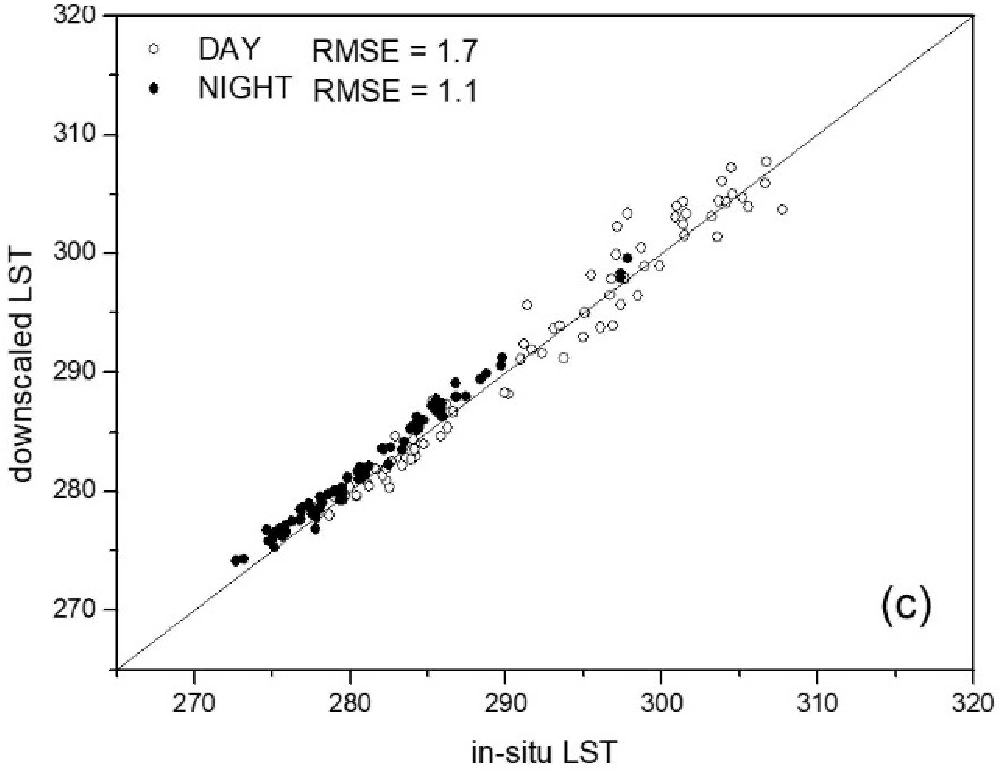


Downscaled LST validation

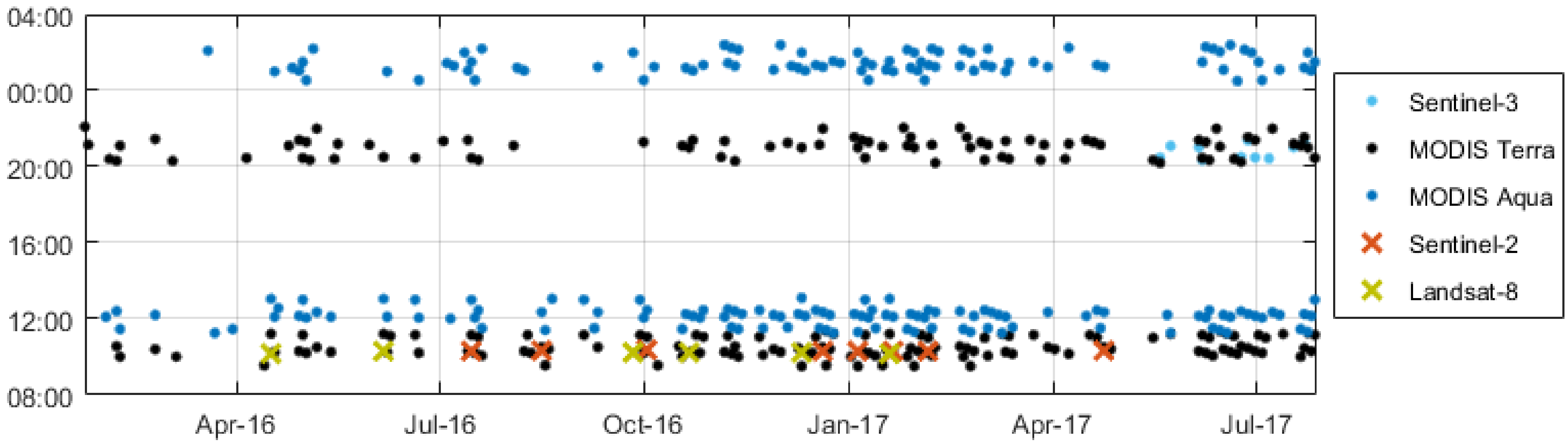
Basel



London



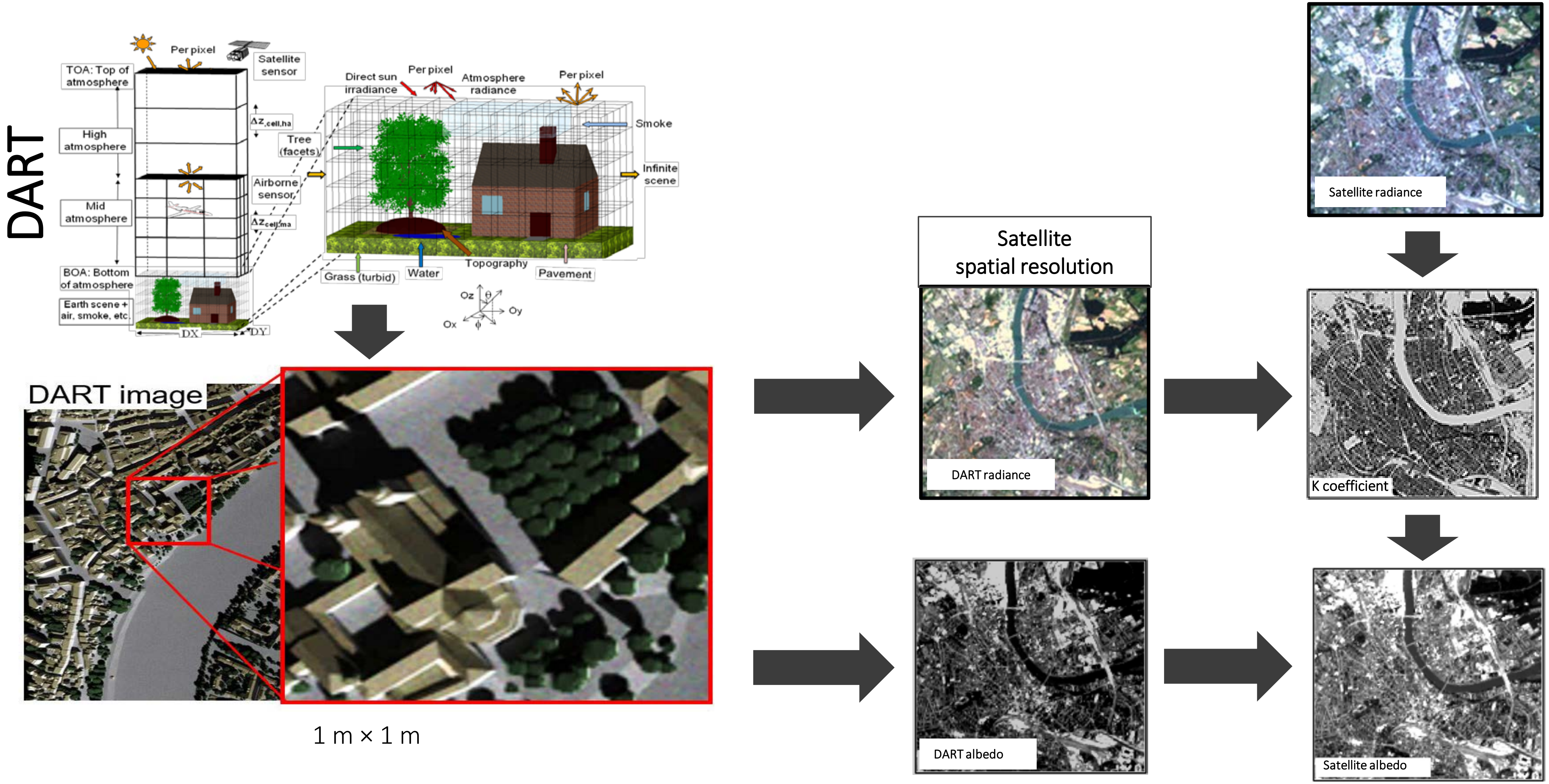
Satellite acquisition times (Basel)



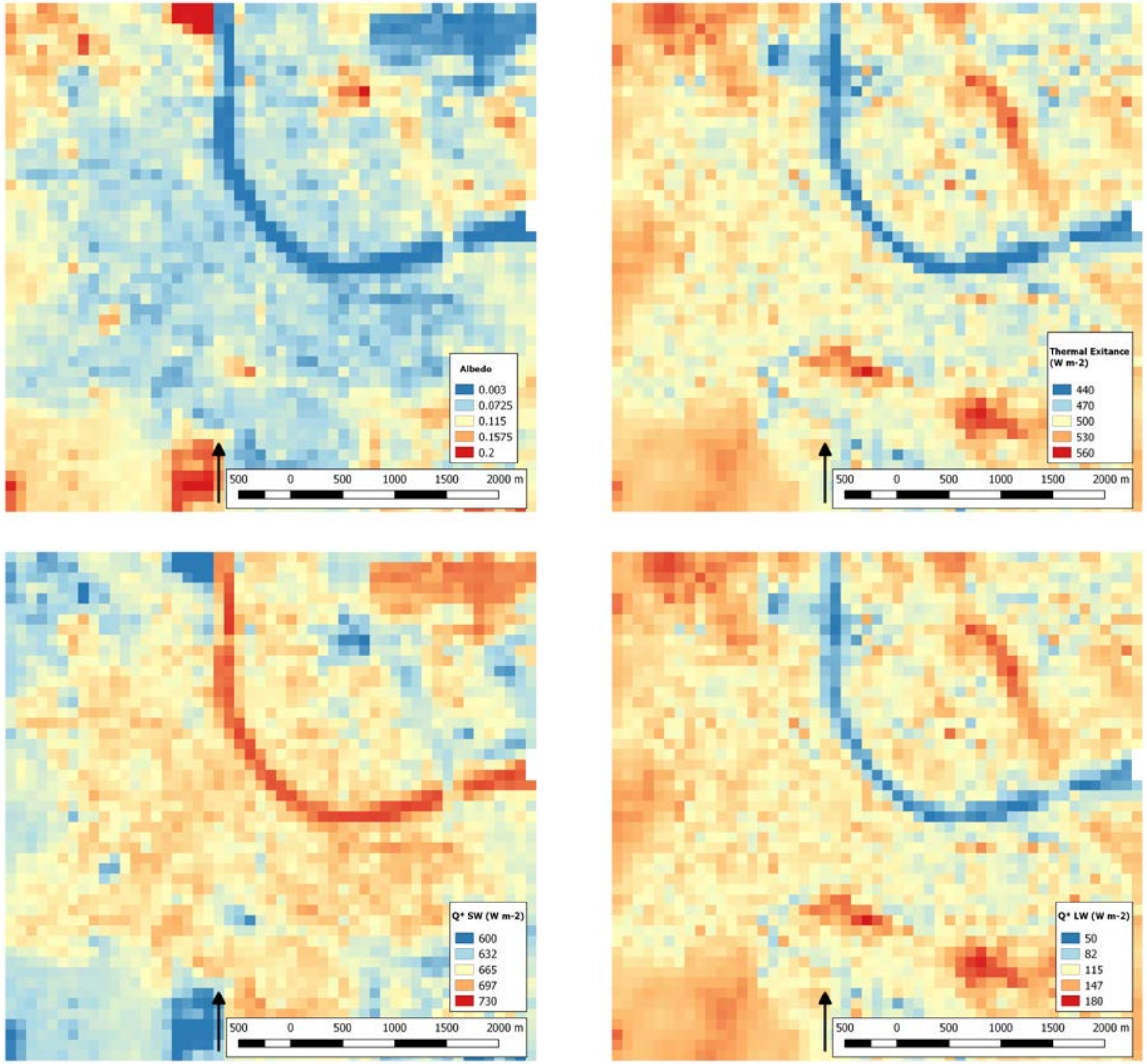
Fluxes

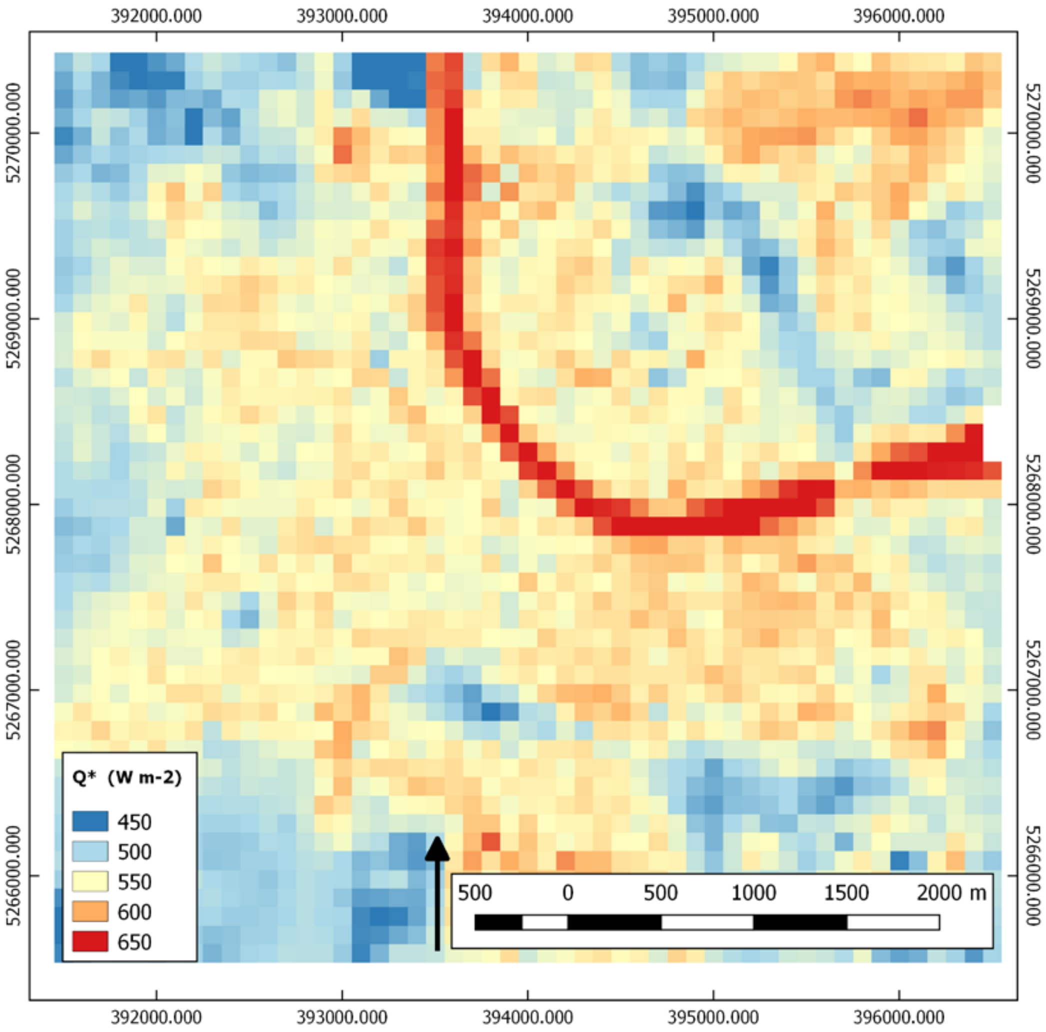
Q^*, Q_H, Q_E, ΔQ_S

Net Radiation (Q*)



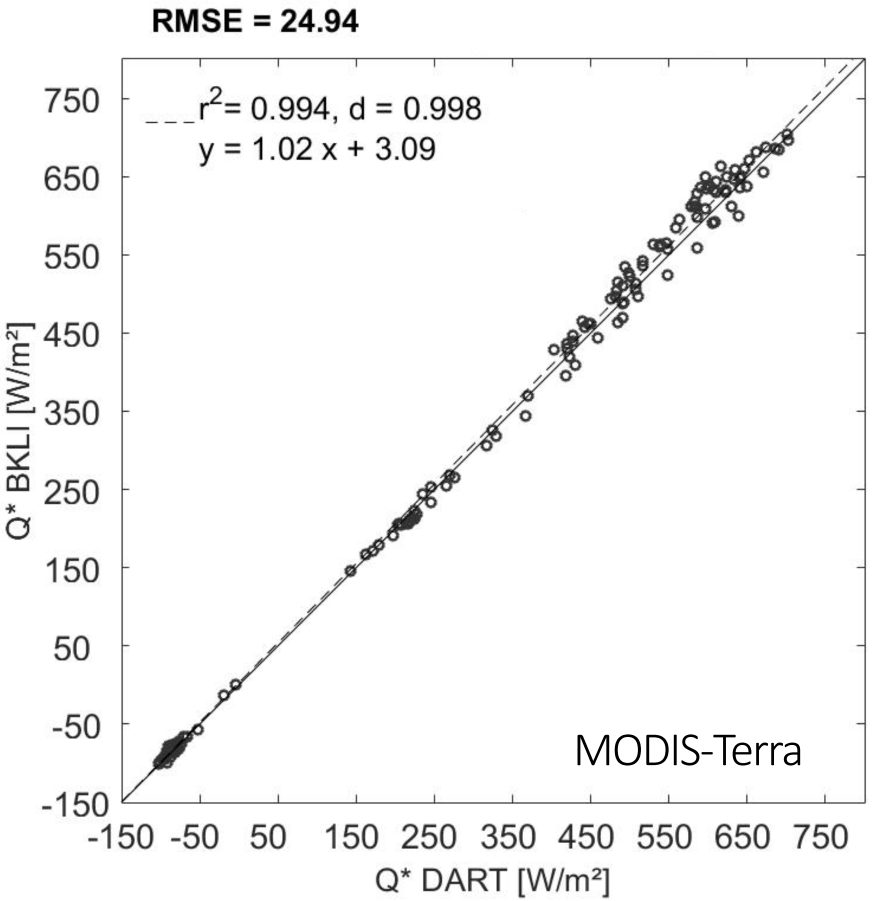
Net Radiation (Q*)

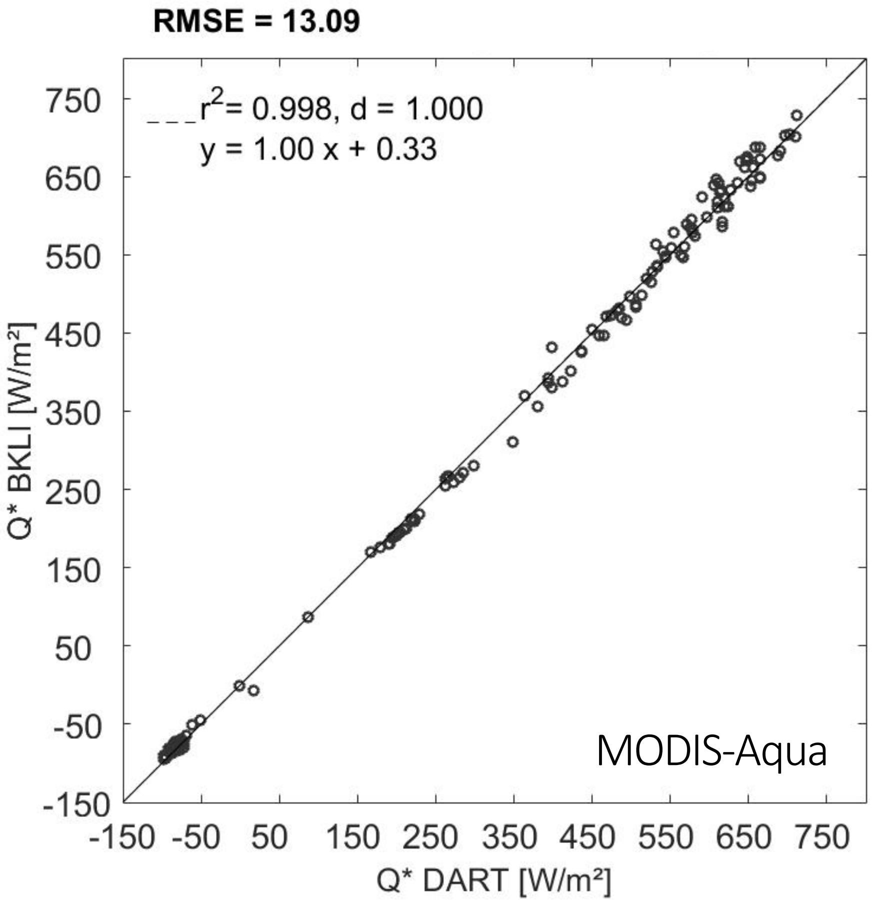




Net Radiation (Q*)

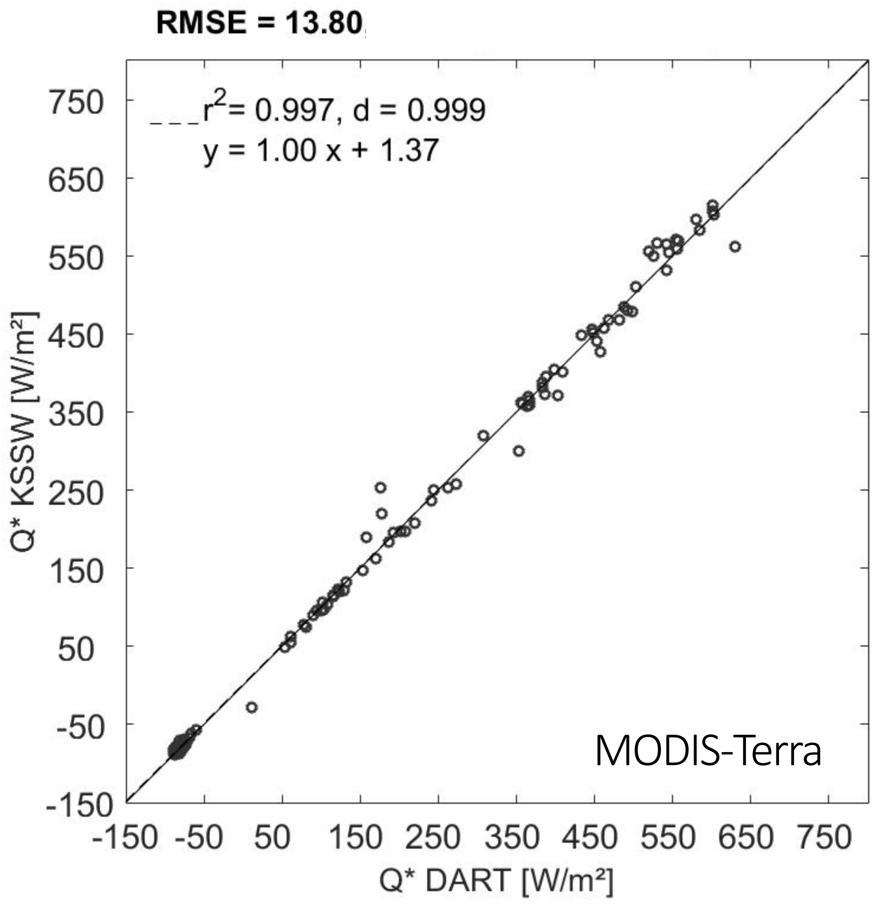
DART/Sentinel-2 Q* vs *in-situ* Q* for Basel

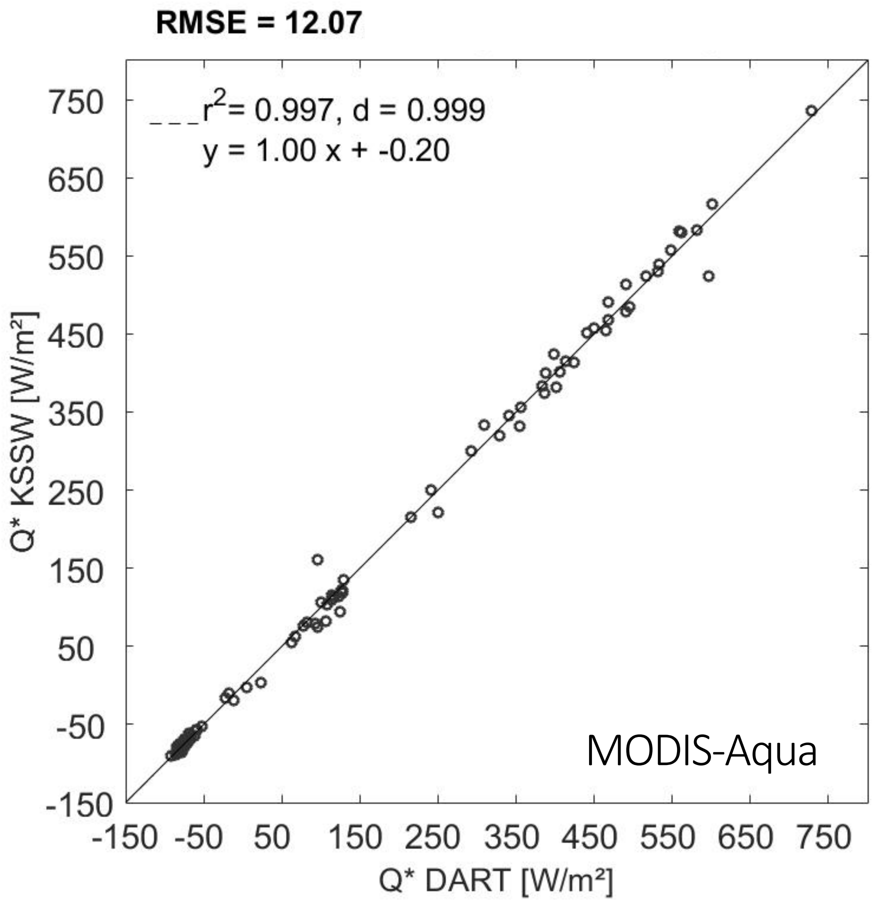




Net Radiation (Q*)

DART/Sentinel-2 Q* vs *in-situ* Q* for London

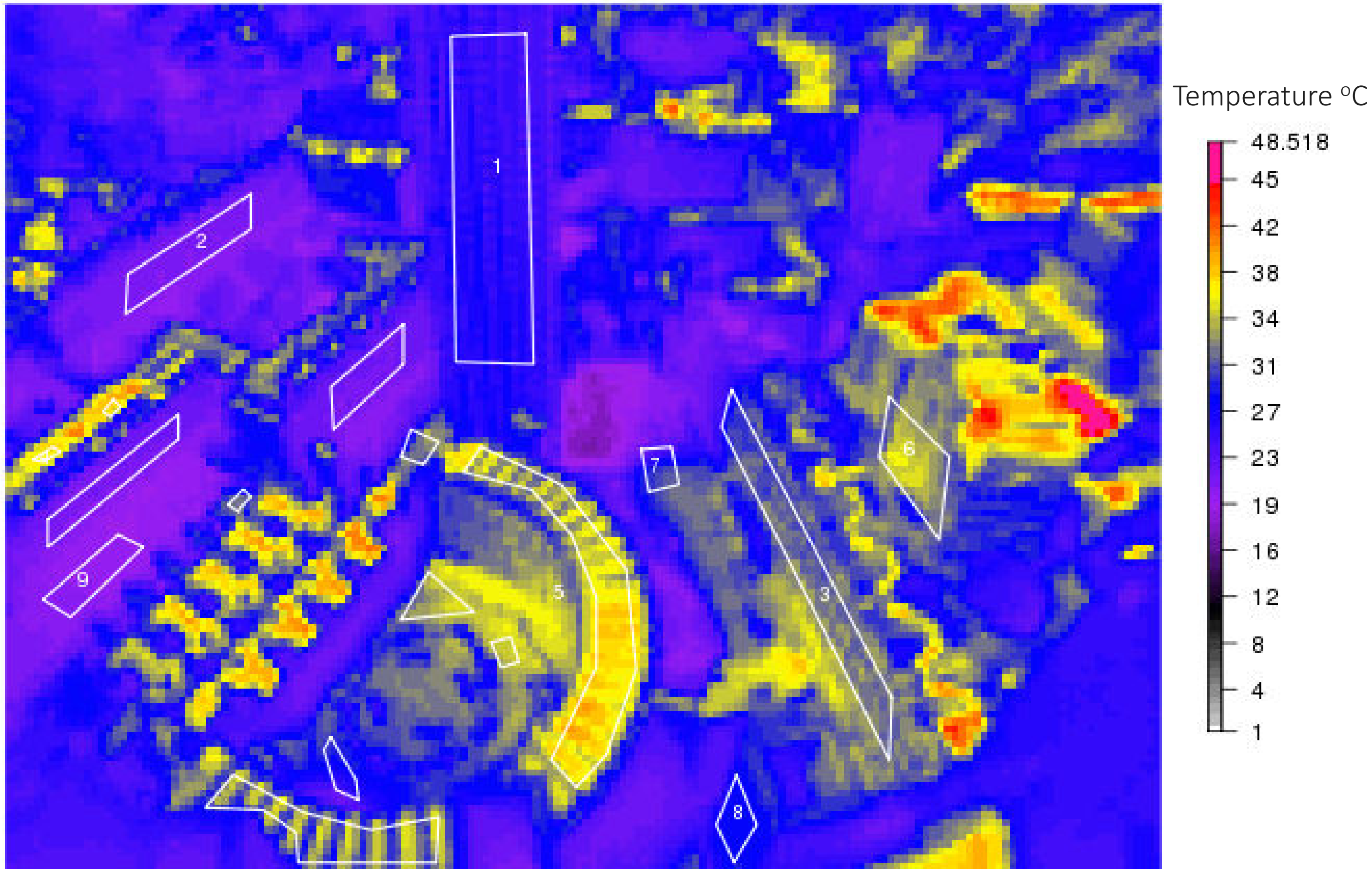




Heat Storage Change (ΔQ_s)

London Barbican

2016-05-05 05.00 – 11.30

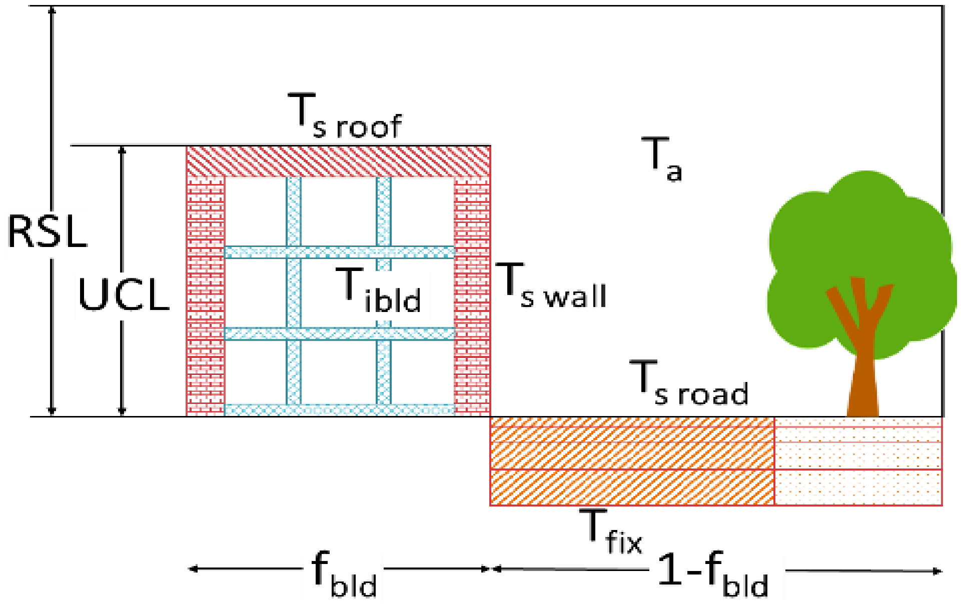


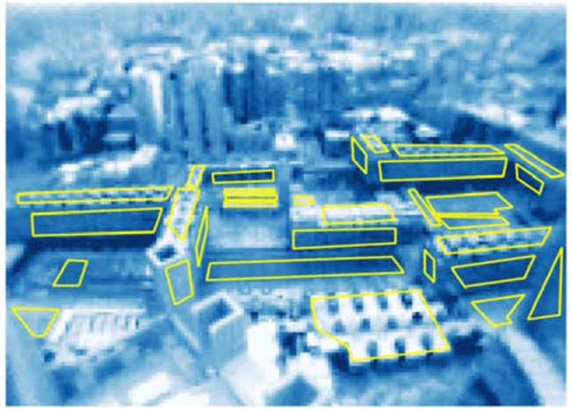
http://www.met.reading.ac.uk/micromet/scripts/plots/OptrisPI/C19/BCT_C19_dailyreport_main.html

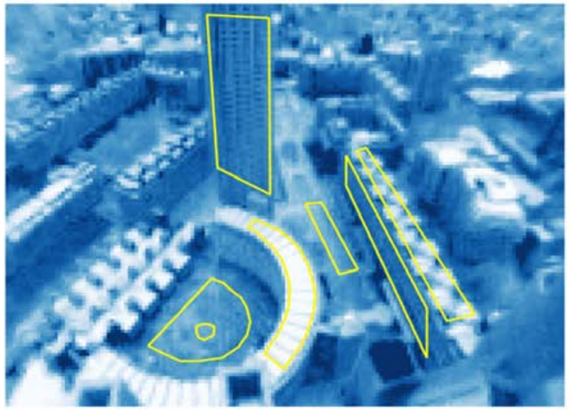
Heat Storage Change (ΔQ_s)

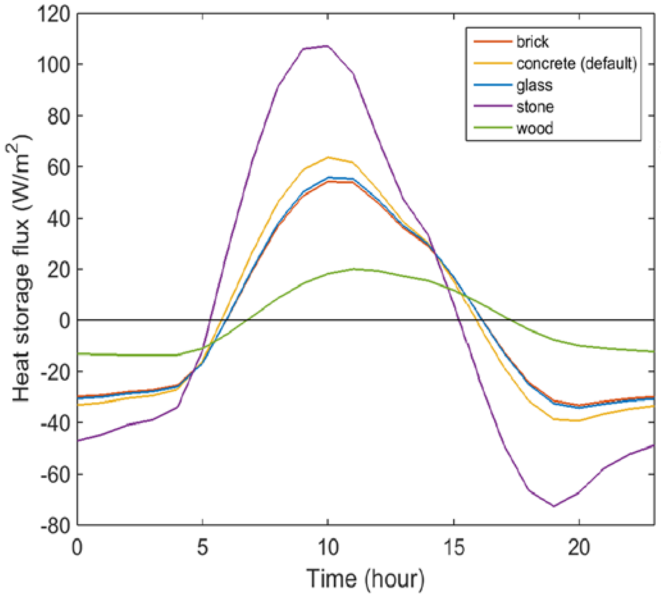
ESTM: $$\boxed{\Delta Q_S = \sum_i \frac{\Delta T_i}{\Delta t} \varrho c_i \Delta x_i f_i}$$

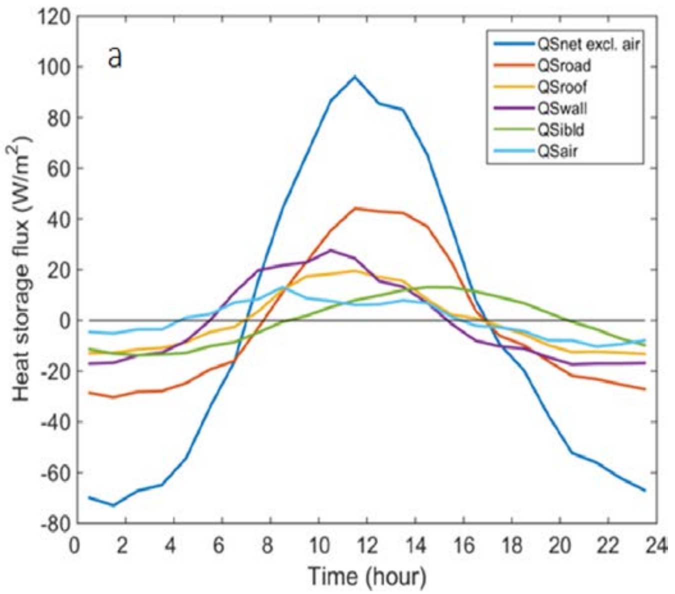
✓ Incorporates heat transfer through the different elements



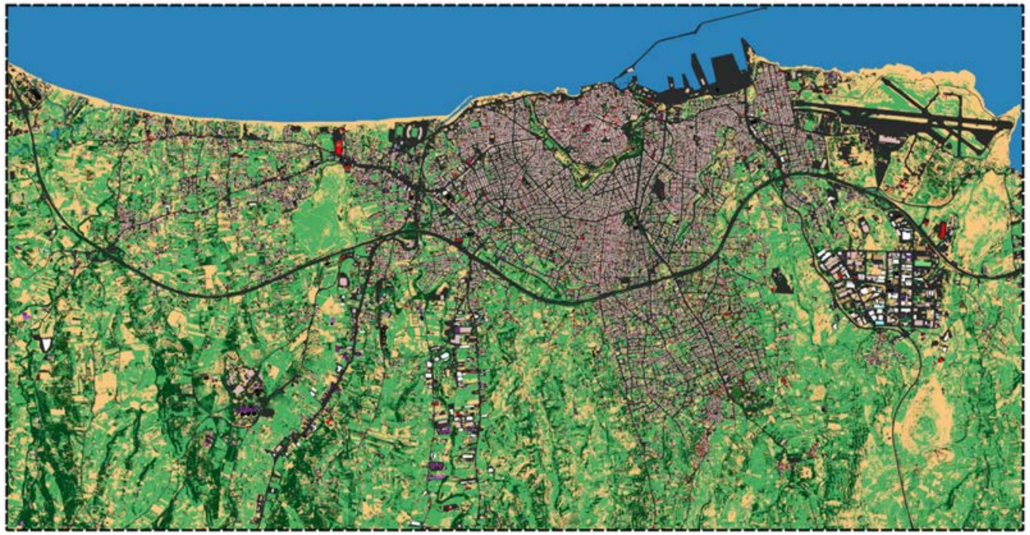


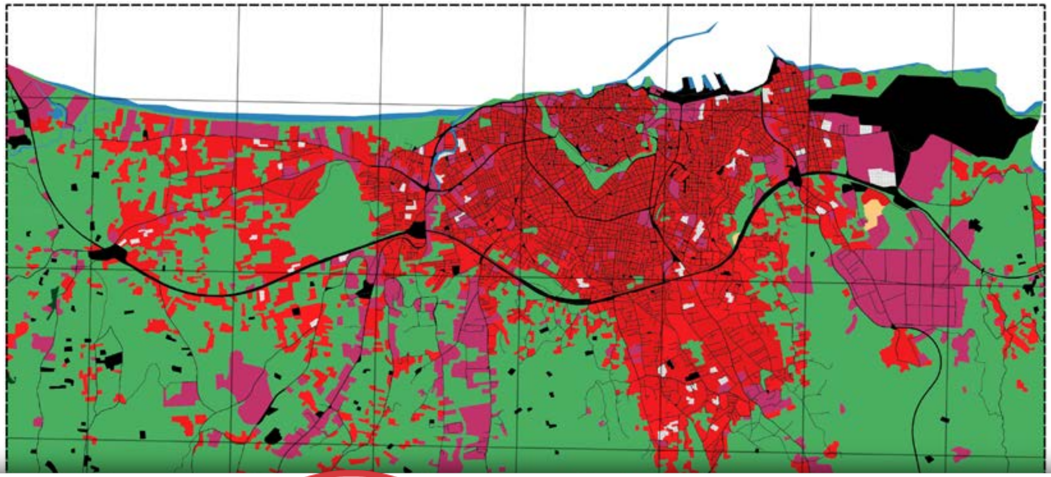


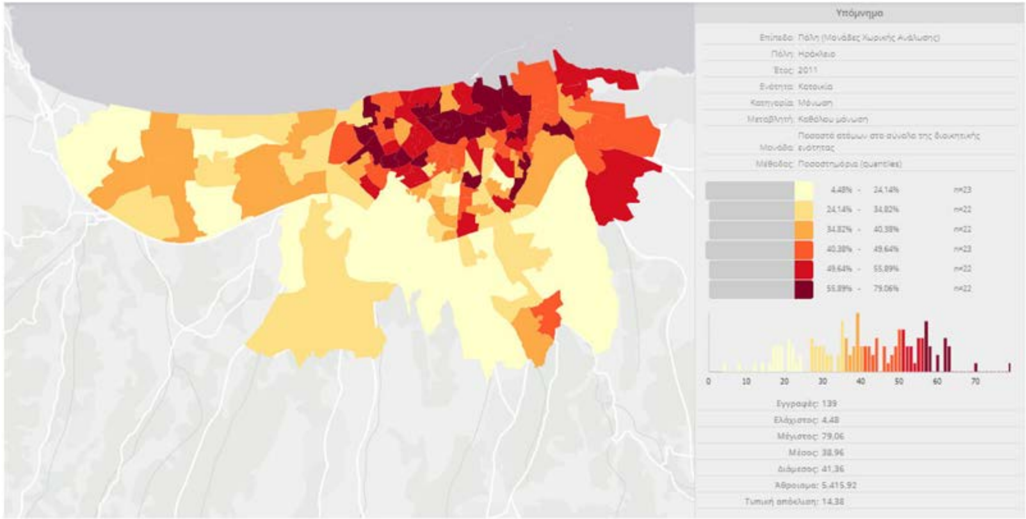




Heat Storage Change (ΔQ_s)

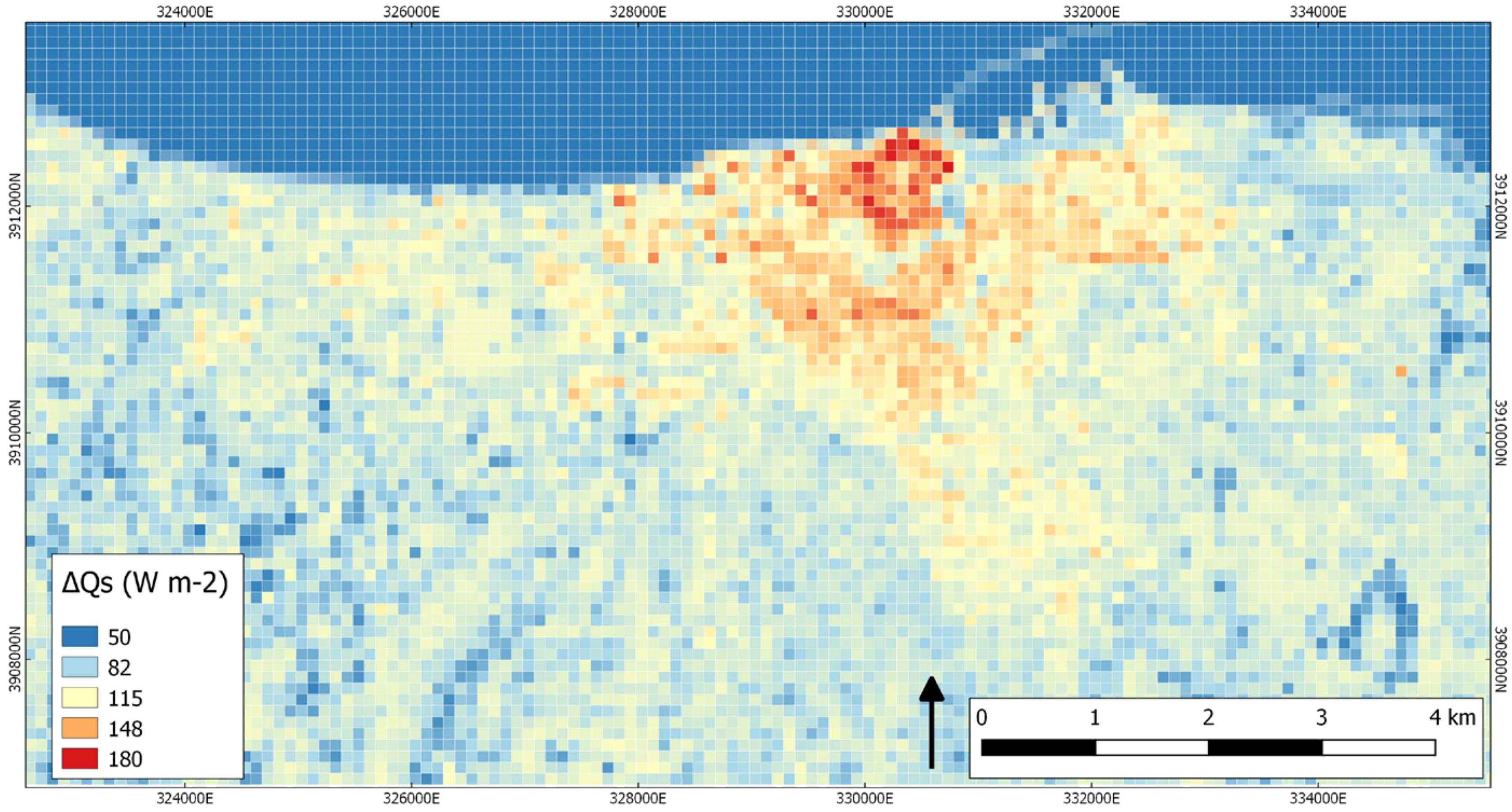




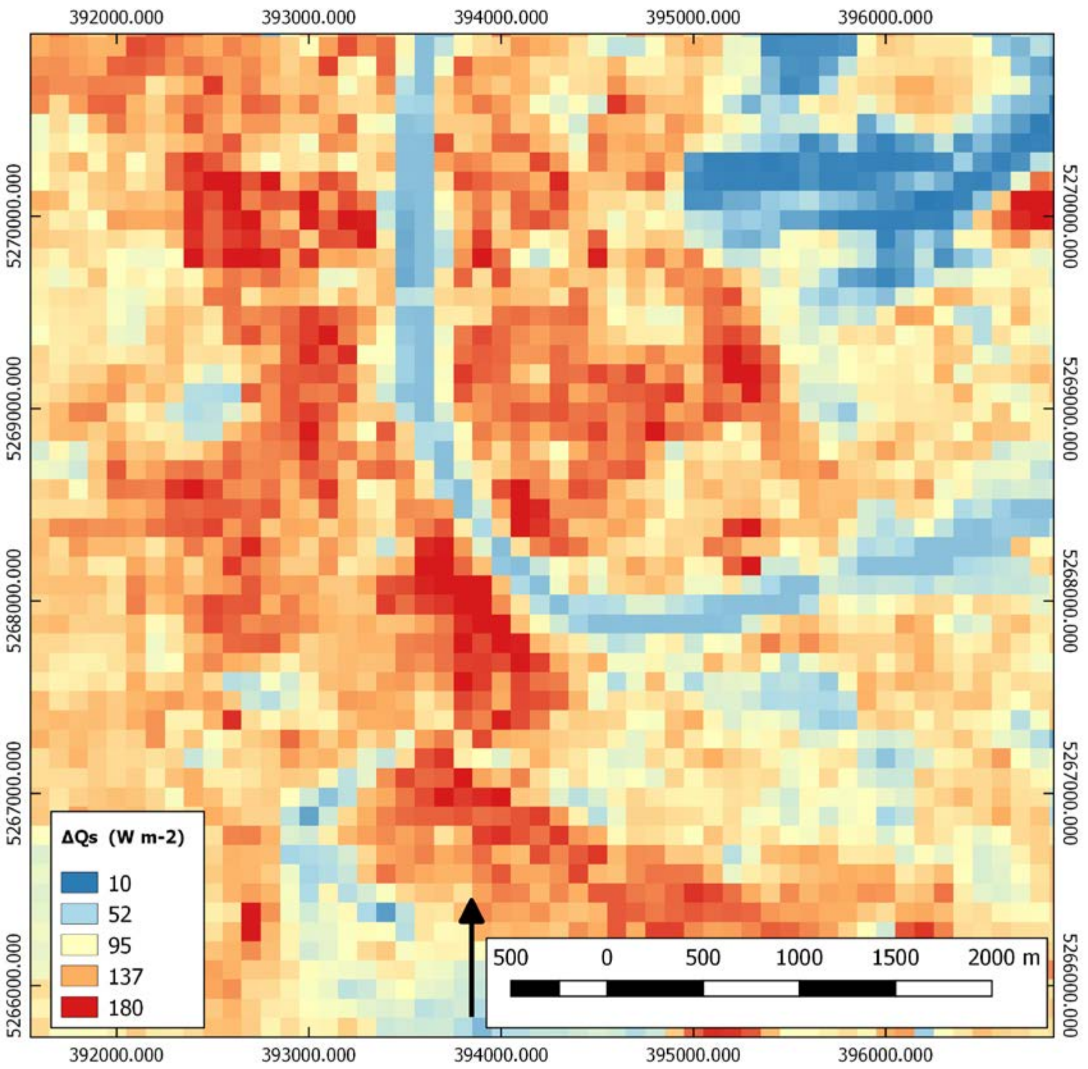


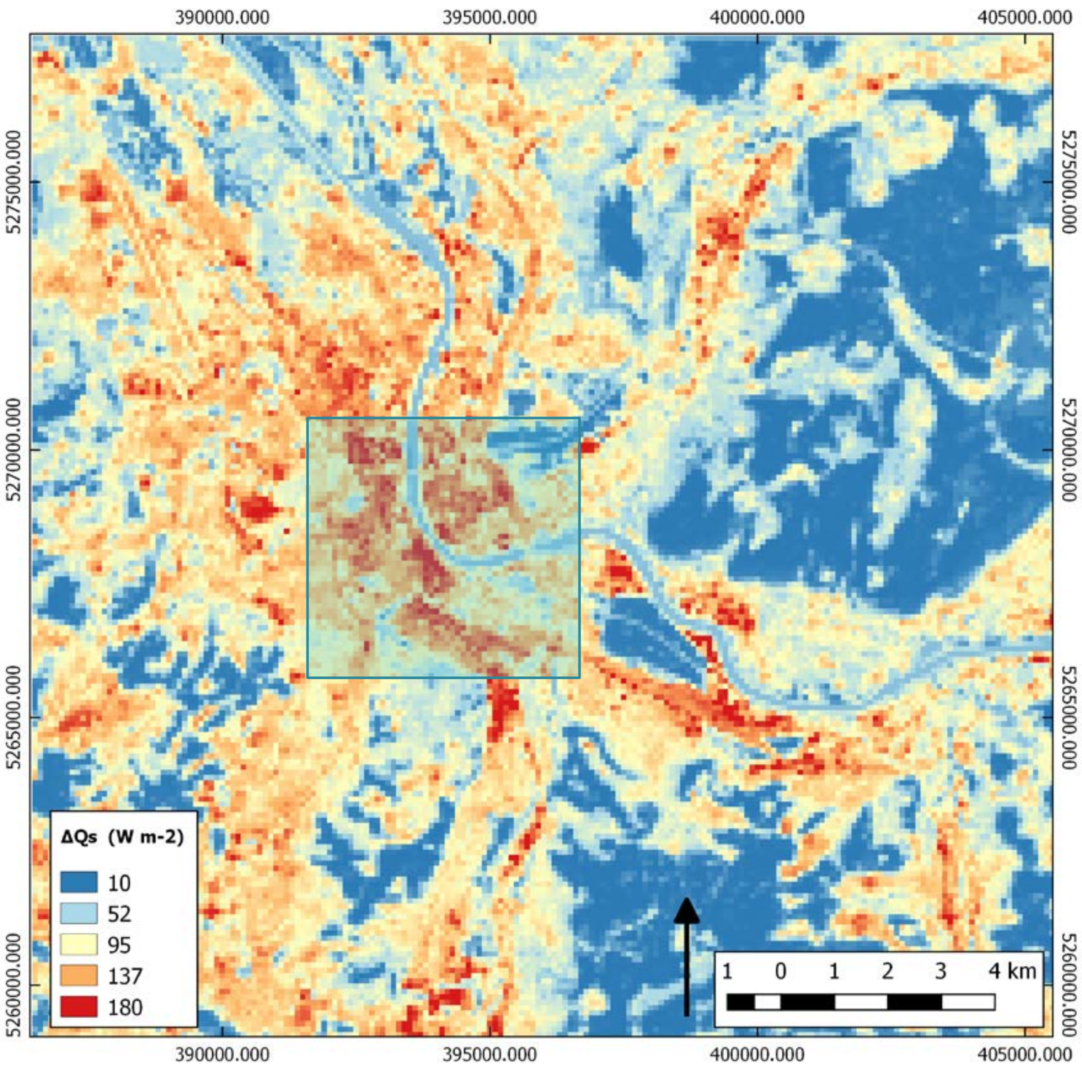
Surface type	Element	k (W m^{-1} K^{-1})	ρc (MJ K^{-1} m^{-3})	Materials and references
Paved #1 (L+B)	ground	0.64	1.23	asphalt[1], concrete[1], gravel[1], lawn[2]
Paved #2 (L+B)	ground	0.63	1.22	asphalt[1], concrete[1], gravel[1]
Paved #3 (L+B)	ground	0.73	1.21	gravel[1], steel[3], wood[4]
Paved (Barb.)	ground	0.97	1.69	concrete[1], ceramic[3], soil[5]
Building #1 (L)	roof	0.63	1.06	ceramic[3], slate[6], concrete[1], insulation[4]
	wall	0.85	1.29	stone[7], concrete[1], brick[3], glass[3]
	internal	0.93	1.5	concrete[1]
Building #2 (L)	roof	0.58	1.02	ceramic[3], concrete[1], insulation[4]
	wall	0.62	1.27	stone[7], concrete[1], brick[3], wood[4], glass[3]
	internal	0.93	1.5	concrete[1]
Building #3 (L)	roof	0.25	1.12	ceramic[3], slate[6], wood[4], insulation[4]
	wall	0.24	0.75	brick[3], wood[4], insulation[4], glass[3]
	internal	0.93	1.5	concrete[1]

Heat Storage Change (ΔQ_s)

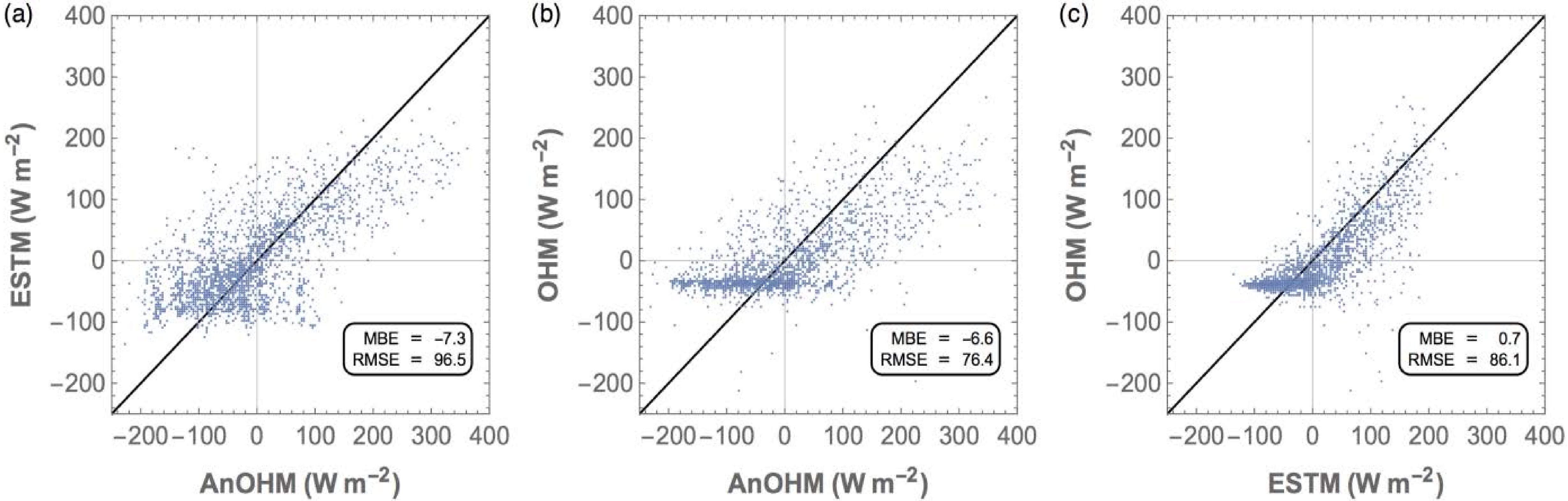


Heat Storage Change (ΔQ_s)





Heat Storage Change (ΔQ_s)



Turbulent Heat Fluxes (Q_H , Q_E)

› Aerodynamic Resistance Method (ARM)

Satellite-based

Measured in-situ

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

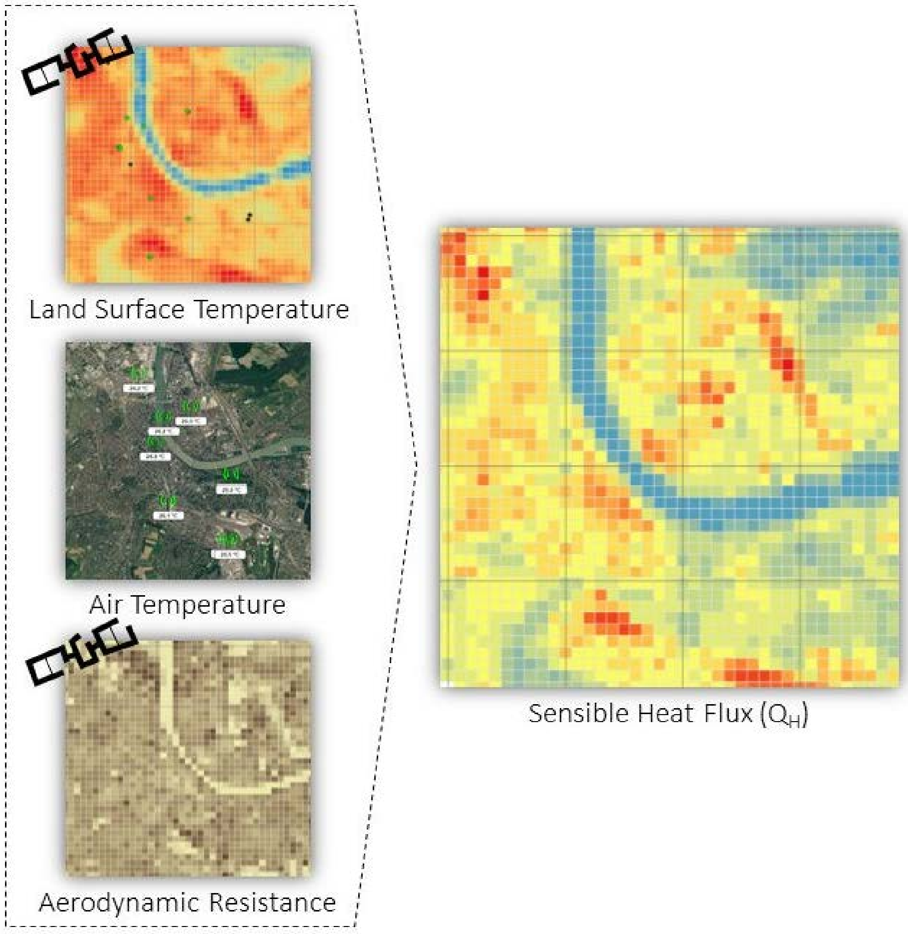
Aerodynamic resistance from morphometric analysis

From T_{air}

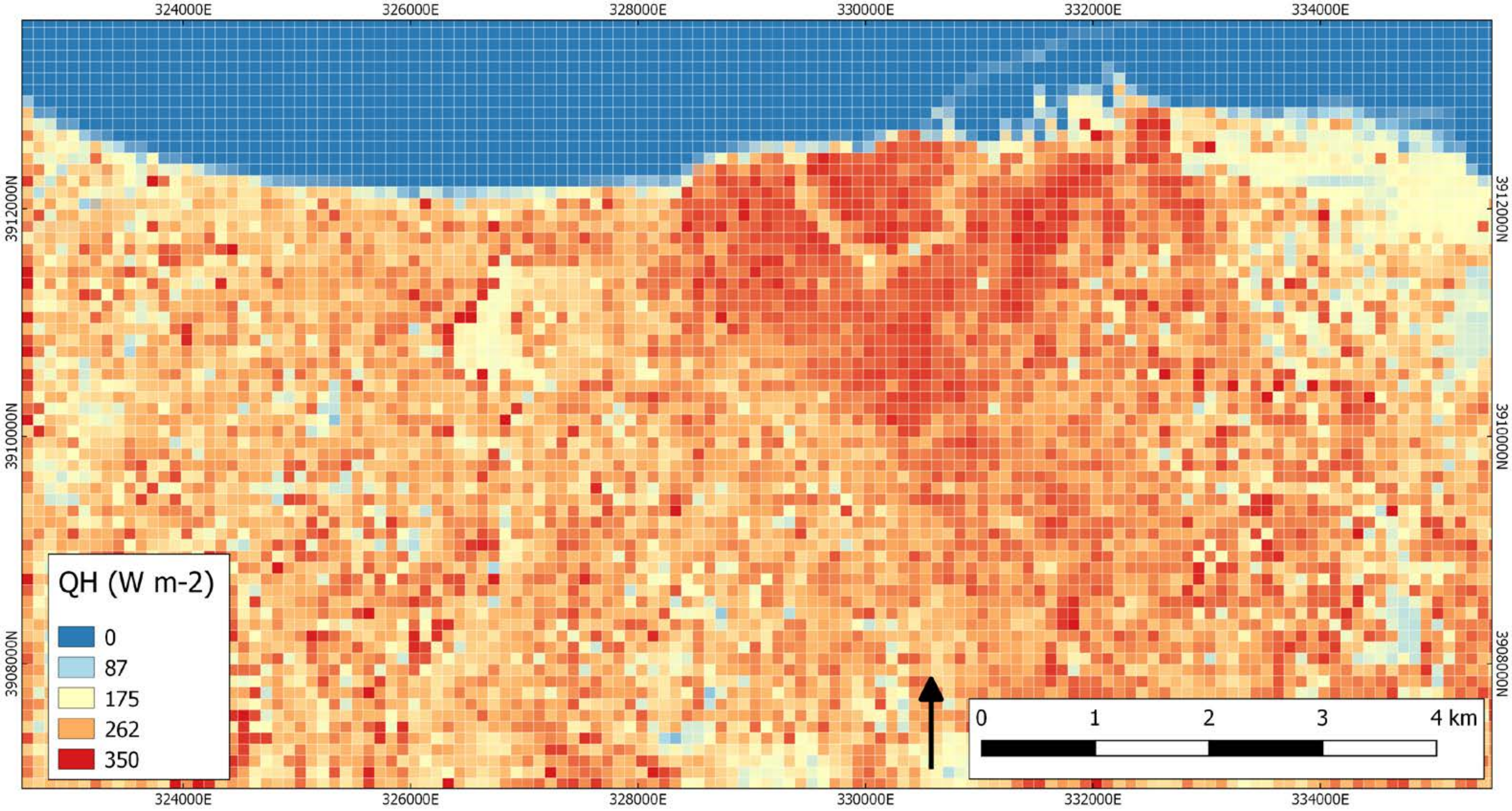
Measured in-situ

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

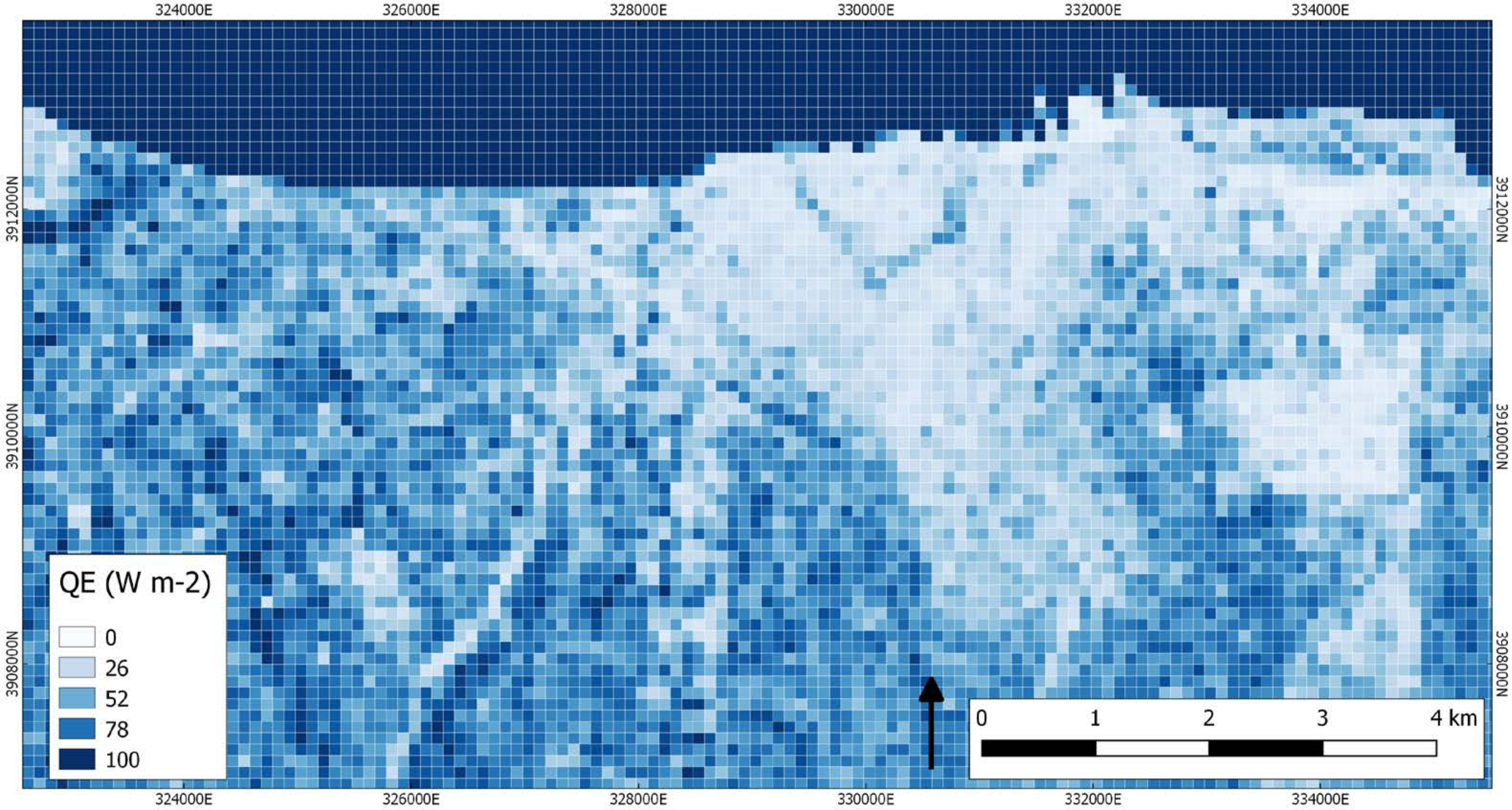
Surface resistance
Depends on vegetation type, moisture conditions



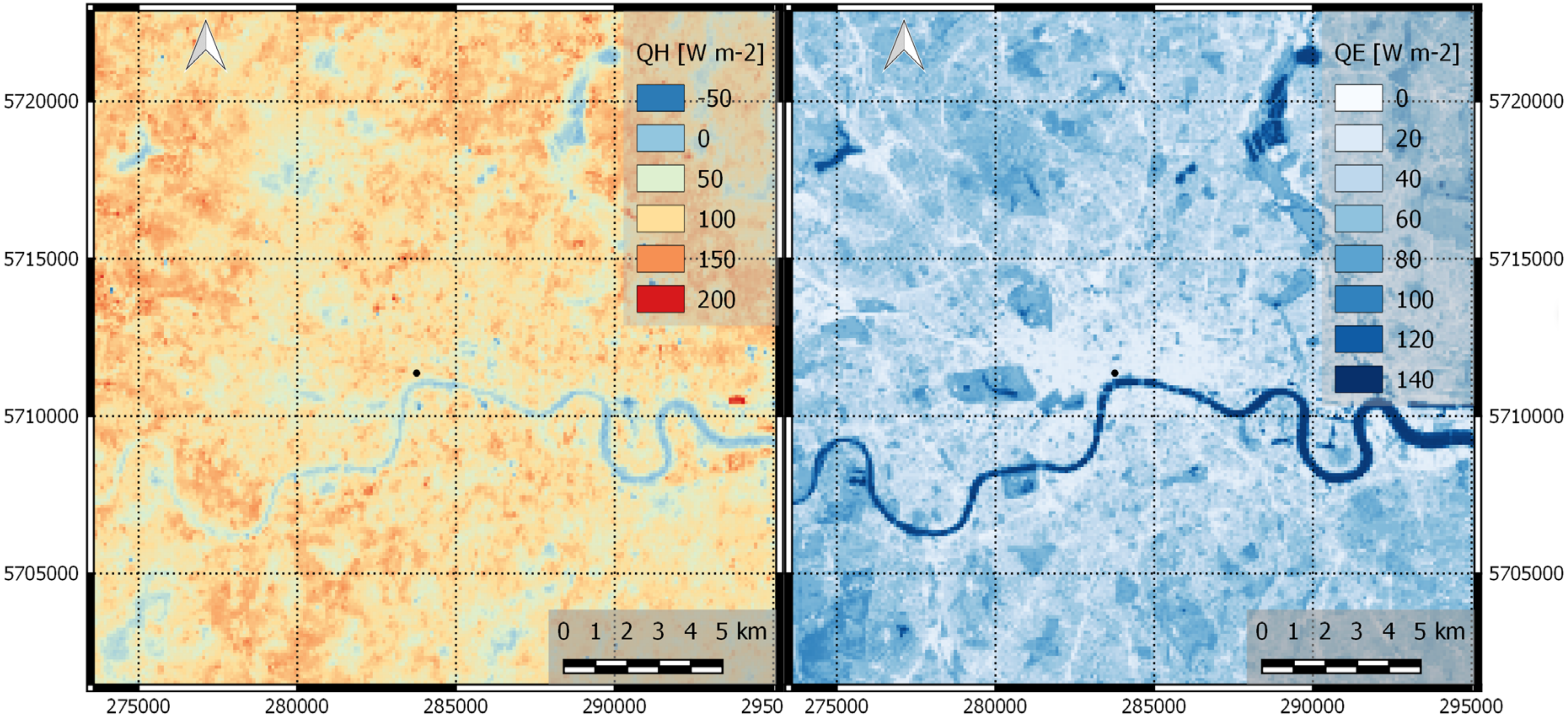
Turbulent Heat Fluxes (Q_H)



Turbulent Heat Fluxes (Q_E)

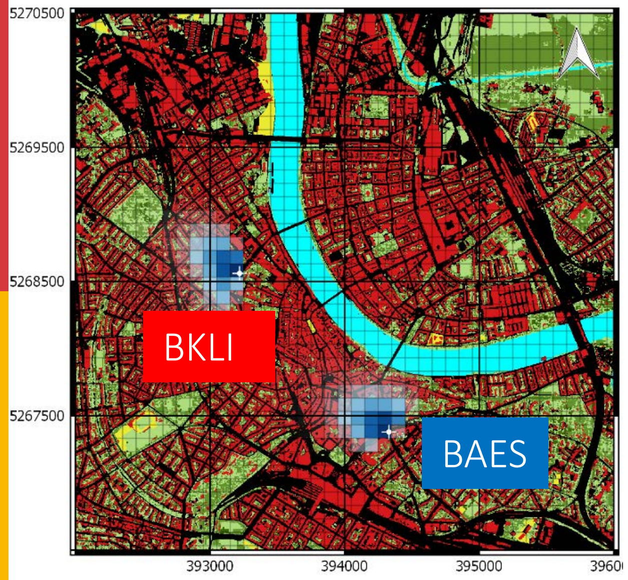


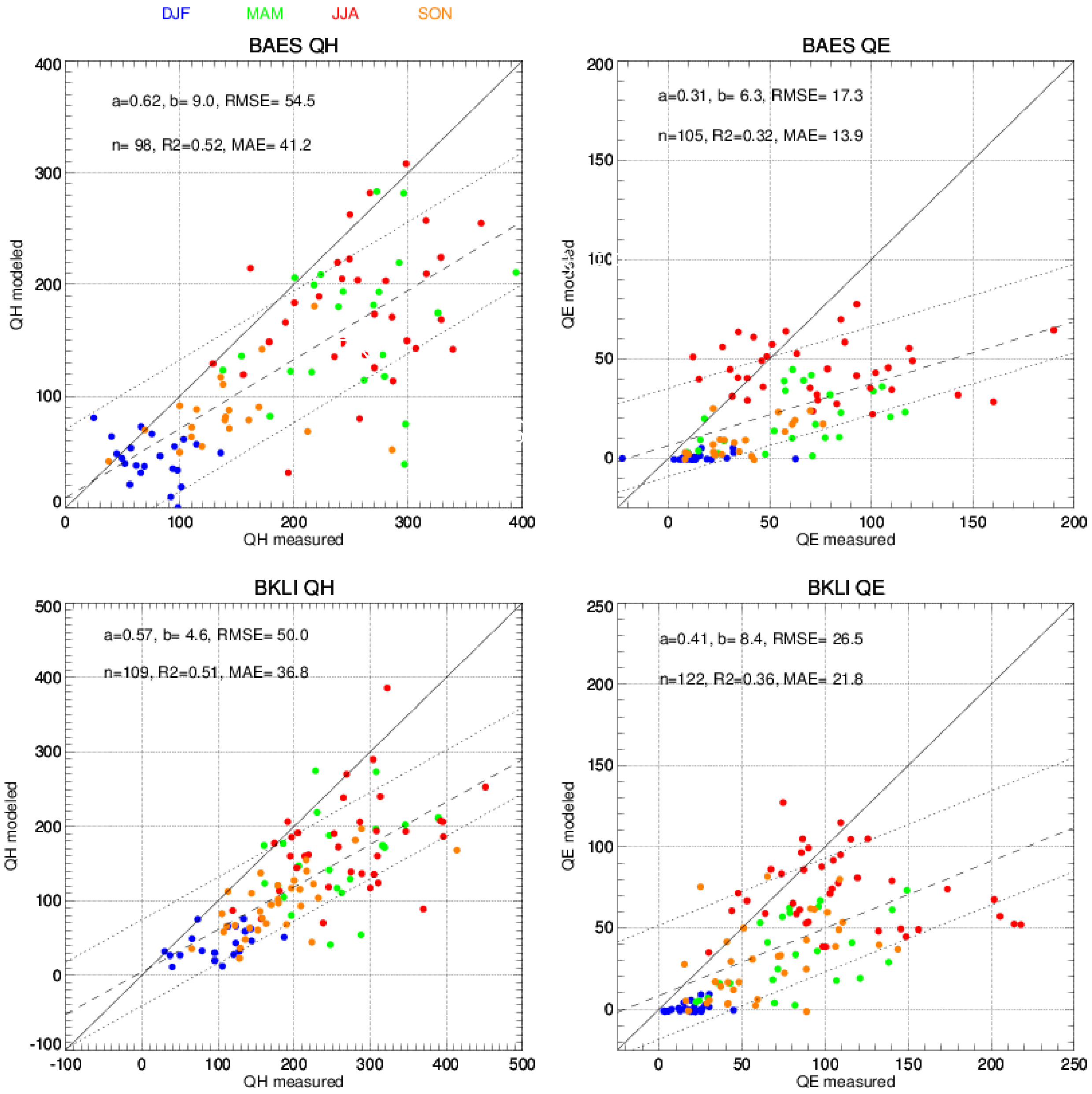
Turbulent Heat Fluxes (Q_H , Q_E)



Turbulent Fluxes: evaluation with flux tower measurements BASEL

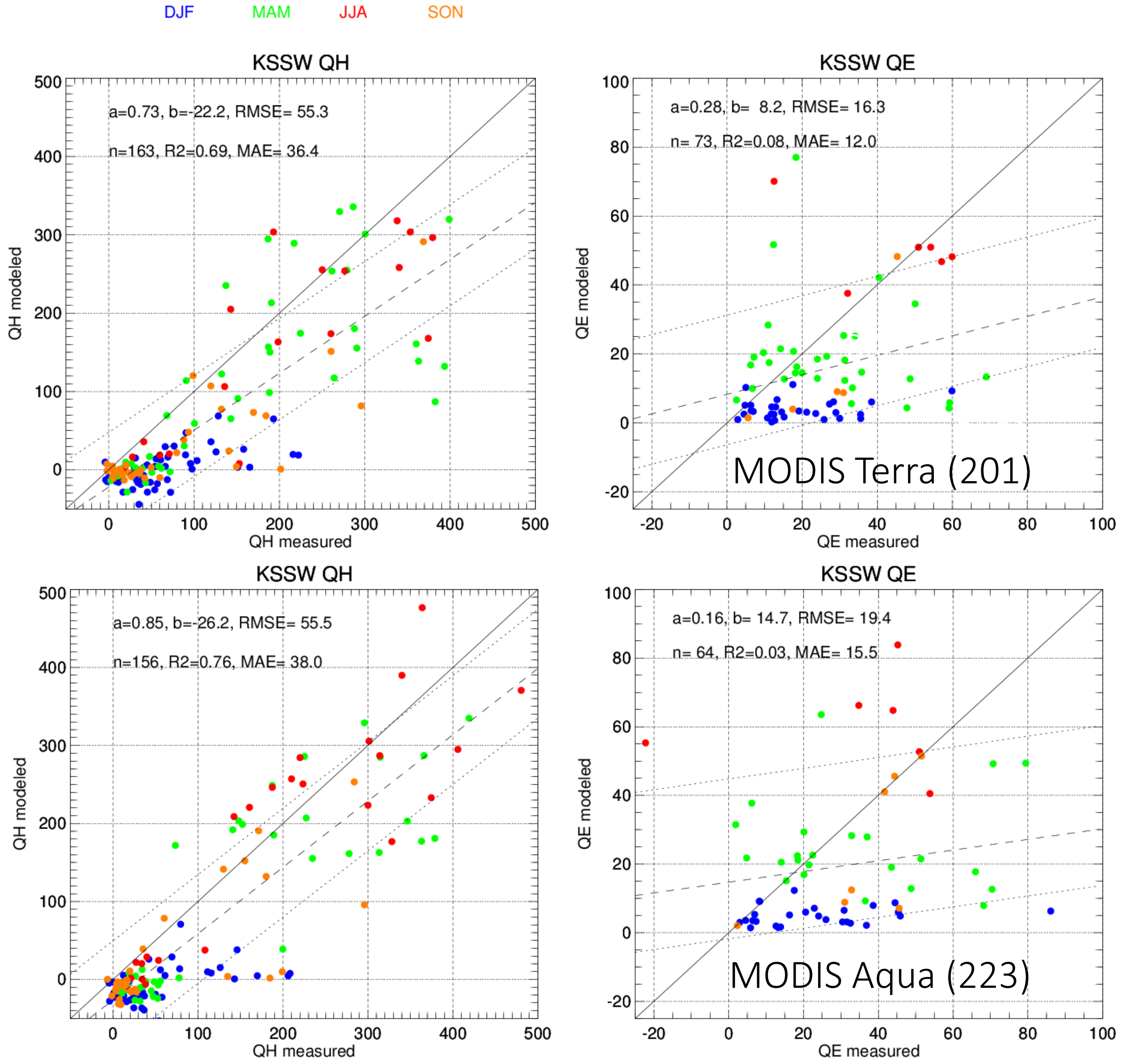
405 MODIS scenes

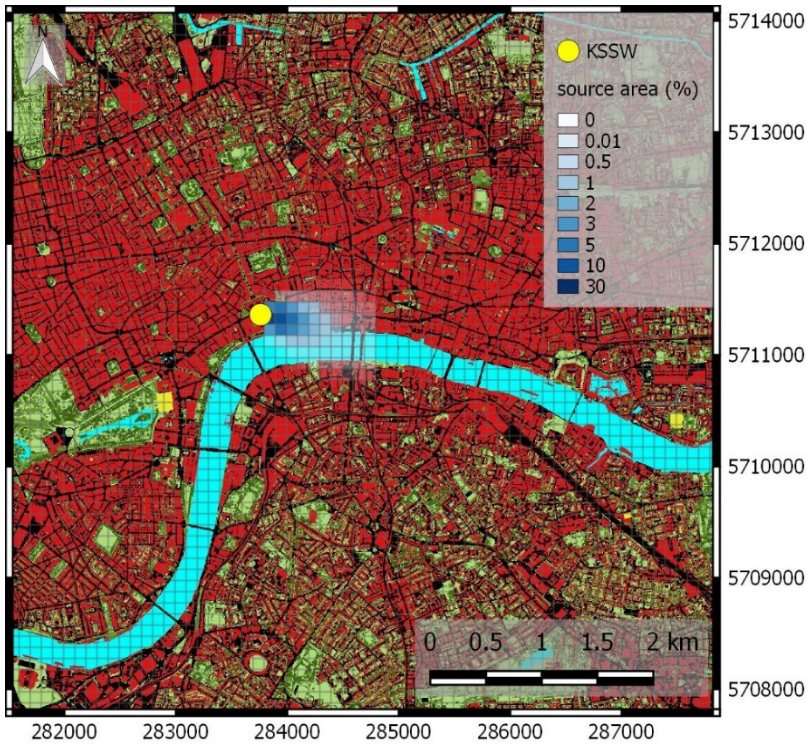




Both fluxes are generally underestimated if compared to measurements. Modeled Q_E in urban areas are small.

Turbulent Fluxes: evaluation with flux tower measurements LONDON

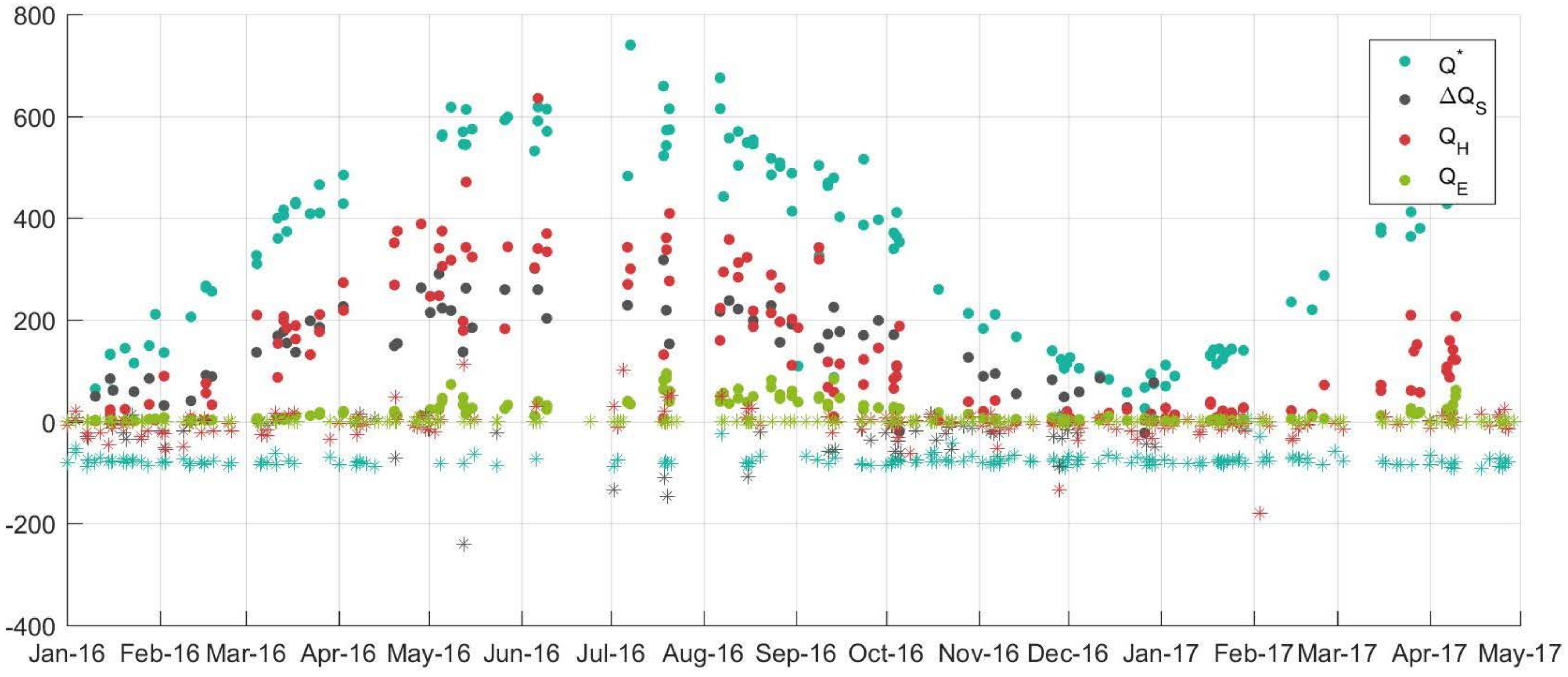




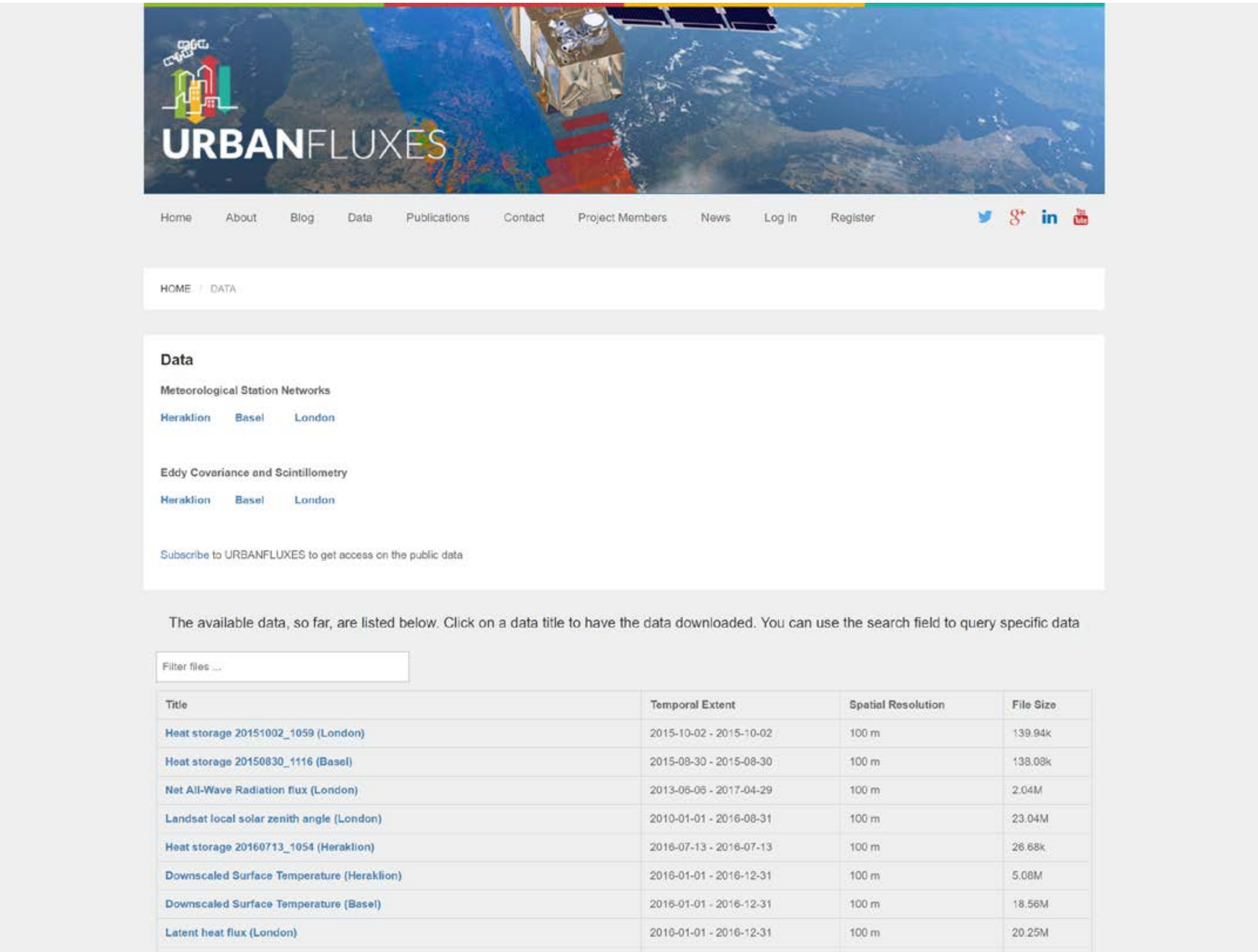
Both fluxes are generally underestimated if compared to measurements. Modeled Q_E in urban areas are small.

UEB Components Time Series

Day (●), night (*) one 100 m x 100 m pixel



Data availability



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Data

Meteorological Station Networks

Heraklion Basel London

Eddy Covariance and Scintillometry

Heraklion Basel London

Subscribe to URBANFLUXES to get access on the public data

The available data, so far, are listed below. Click on a data title to have the data downloaded. You can use the search field to query specific data

Filter files ...

Title	Temporal Extent	Spatial Resolution	File Size
Heat storage 20151002_1059 (London)	2015-10-02 - 2015-10-02	100 m	139.94k
Heat storage 20150830_1116 (Basel)	2015-08-30 - 2015-08-30	100 m	138.08k
Net All-Wave Radiation flux (London)	2013-06-06 - 2017-04-29	100 m	2.04M
Landsat local solar zenith angle (London)	2010-01-01 - 2016-08-31	100 m	23.04M
Heat storage 20160713_1054 (Heraklion)	2016-07-13 - 2016-07-13	100 m	26.68k
Downscaled Surface Temperature (Heraklion)	2016-01-01 - 2016-12-31	100 m	5.08M
Downscaled Surface Temperature (Basel)	2016-01-01 - 2016-12-31	100 m	18.56M
Latent heat flux (London)	2016-01-01 - 2016-12-31	100 m	20.25M

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Conclusions

- URBANFLUXES implemented new urban surface **parameterization schemes**
- Developed new **synergistic algorithms** for analysis of EO data
- Achieved EO-based estimation of **UEB fluxes,** validated in London, Basel and Heraklion
- Uncertainty in measurements impose large **uncertainties in UEB closure**; further research is necessary to further reduce the uncertainties
- URBANFLUXES improved the current knowledge of the **role** of the different UEB fluxes **on UHI** and hence on urban climate and **energy consumption**
- Developed tools for **monitoring and evaluation of** the implementation of climate change mitigation technologies, including Nature-Based Solutions (NBS)
- Results capable of supporting the development of Sentinels-based downstream services towards **informing policy-making**

URBANFLUXES

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