URBANFLUXES

URBAN ANTHROPOGENIC HEAT FLUX FROM EARTH OBSERVATION SATELLITES

A novel approach for anthropogenic heat flux estimation from space

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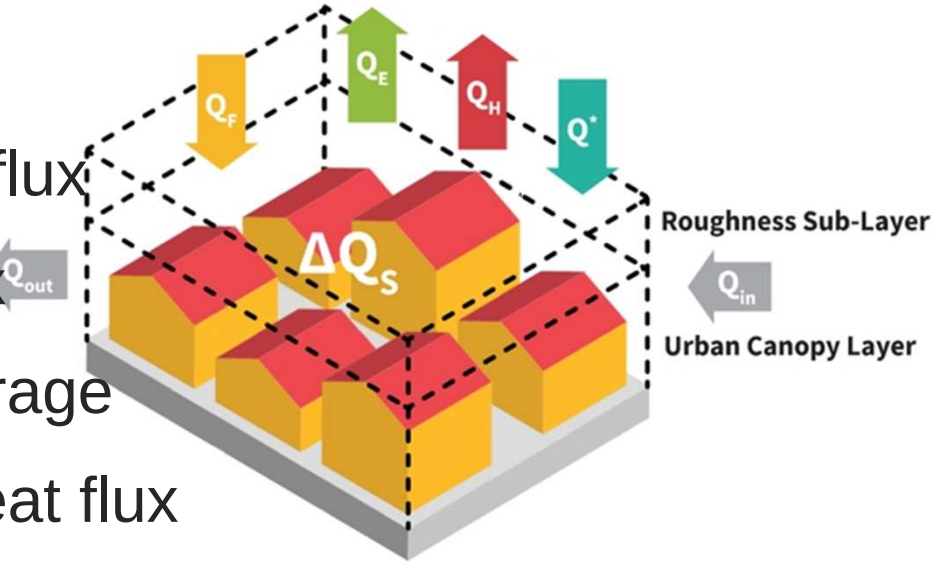
http://urbanfluxes.eu

ICUC9, Toulouse, July 24, 2015

Urban energy balance

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

- **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
- **ΔQ_A** = Q_{in} - Q_{out}*:* Advective heat flux
- ***S:*** All other sources and sinks

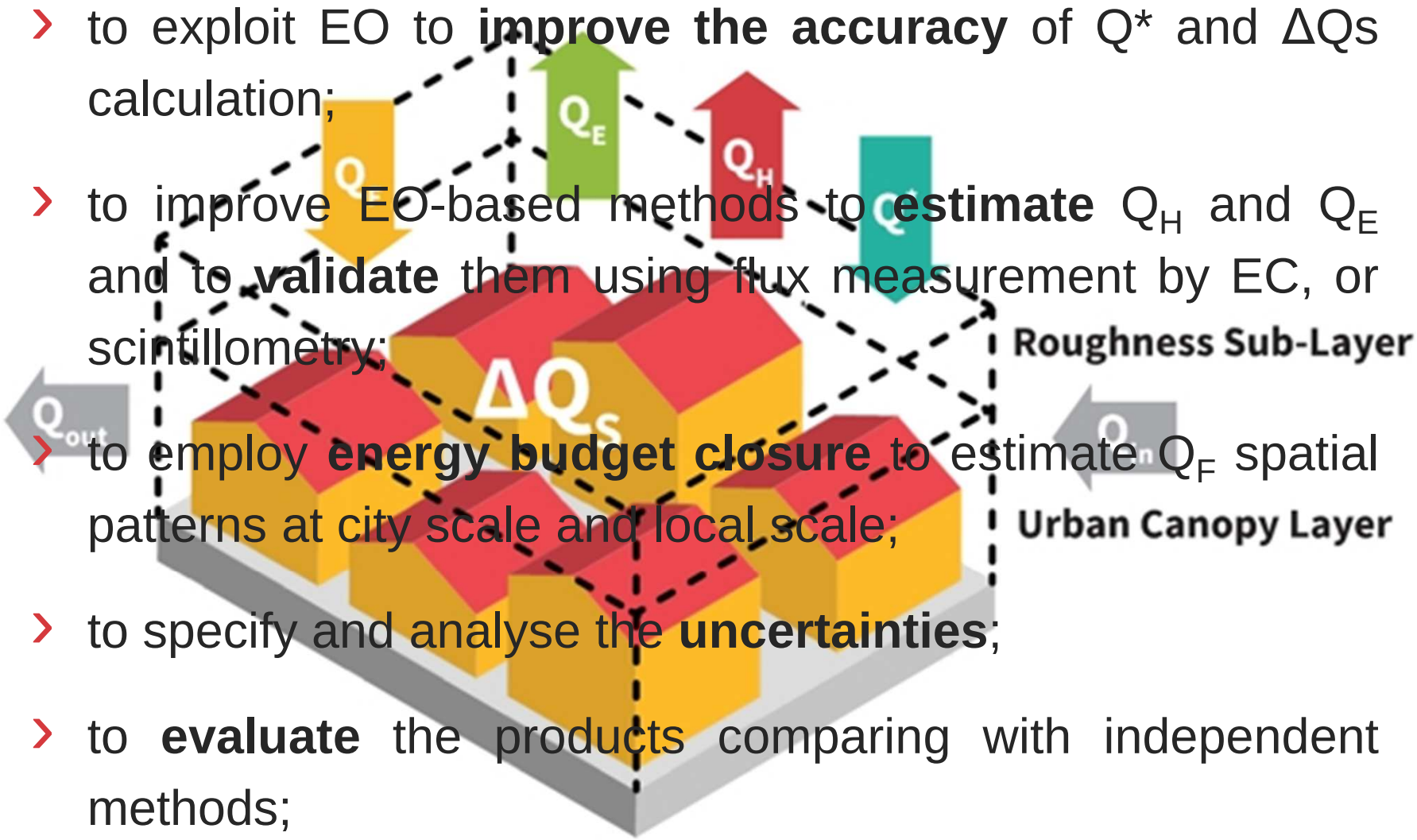


Why URBANFLUXES?

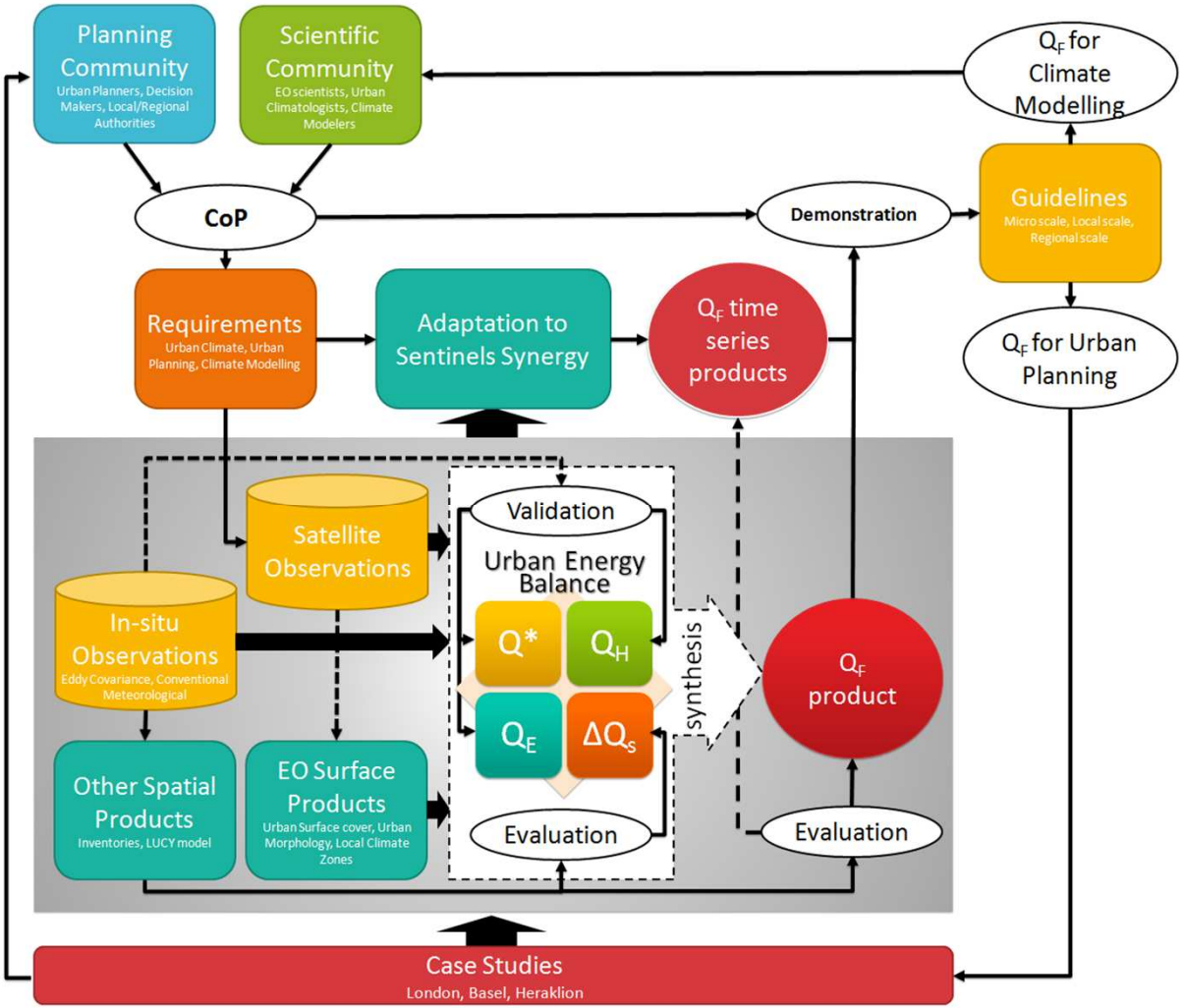
- EO-1-2014: **New ideas** for Earth-relevant space applications
- Urban planning and Earth system science communities need **spatially disaggregated Q_F** .
- **Not possible** to derive it by *in-situ* flux measurements.
- The estimation of **Q_F spatial patterns** by current EO systems is a **challenge.**
- **Major challenge:** the innovative exploitation of the Copernicus Sentinels **synergistic observations** to estimate **Q**

The objectives

- to exploit EO to **improve the accuracy** of Q* and ΔQs calculation;
- to improve EO-based methods to **estimate** Q_H and Q_E and to **validate** them using flux measurement by EC, or scintillometry;
- to employ **energy budget closure** to estimate Q_F spatial patterns at city scale and local scale;
- to specify and analyse the **uncertainties**;
- to **evaluate** the products comparing with independent methods;



The approach



The approach

- In-situ measurements:

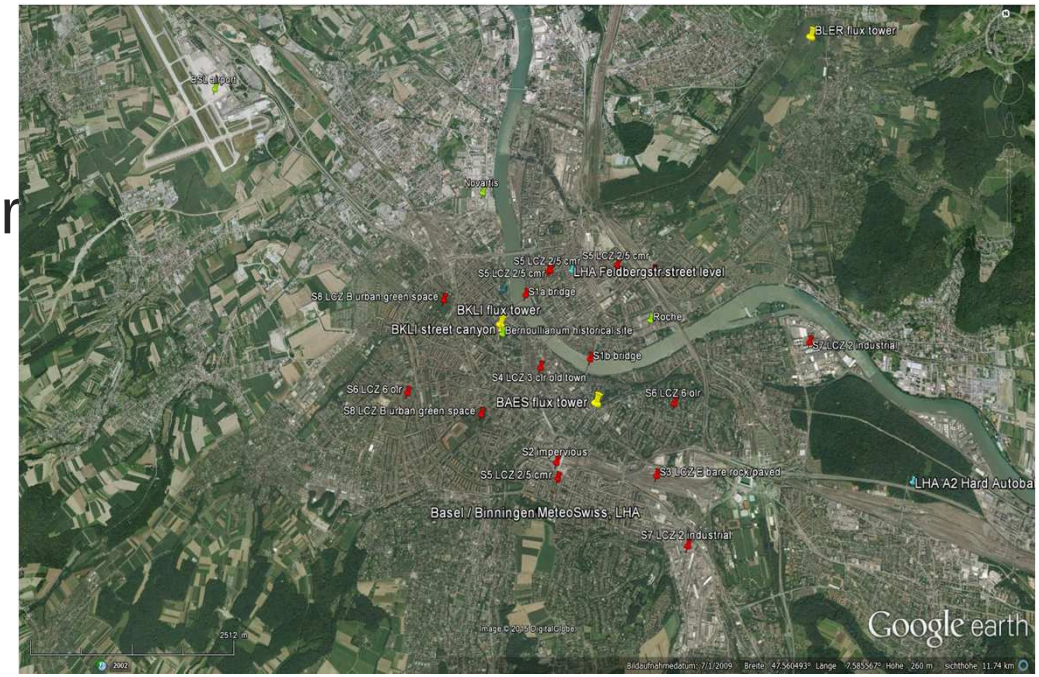
Wireless network for high spatial resolution measurements of:

Surface temperature

Air temperature

Relative humidity

Soil moisture/temperatur



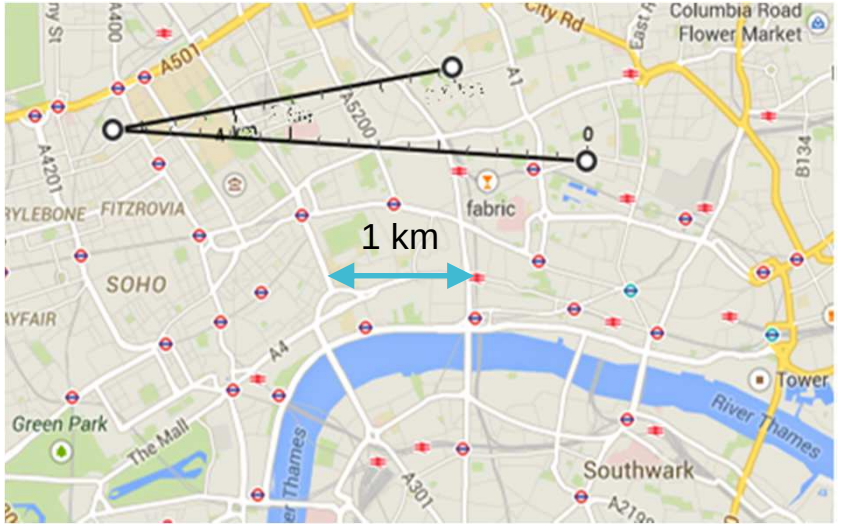
The approach

- In-situ measurements:

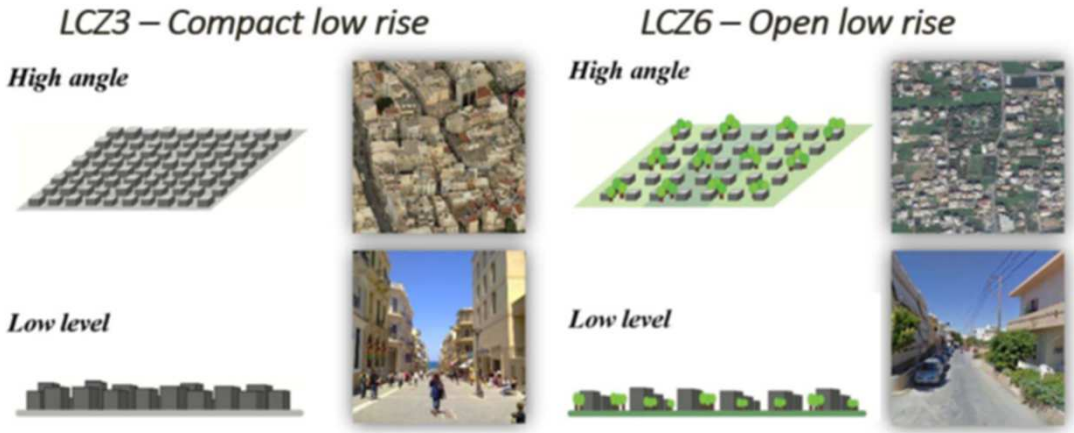
Independent measurements of Q_E and Q_H

Eddy covariance from flux towers

Large-aperture scintillometers

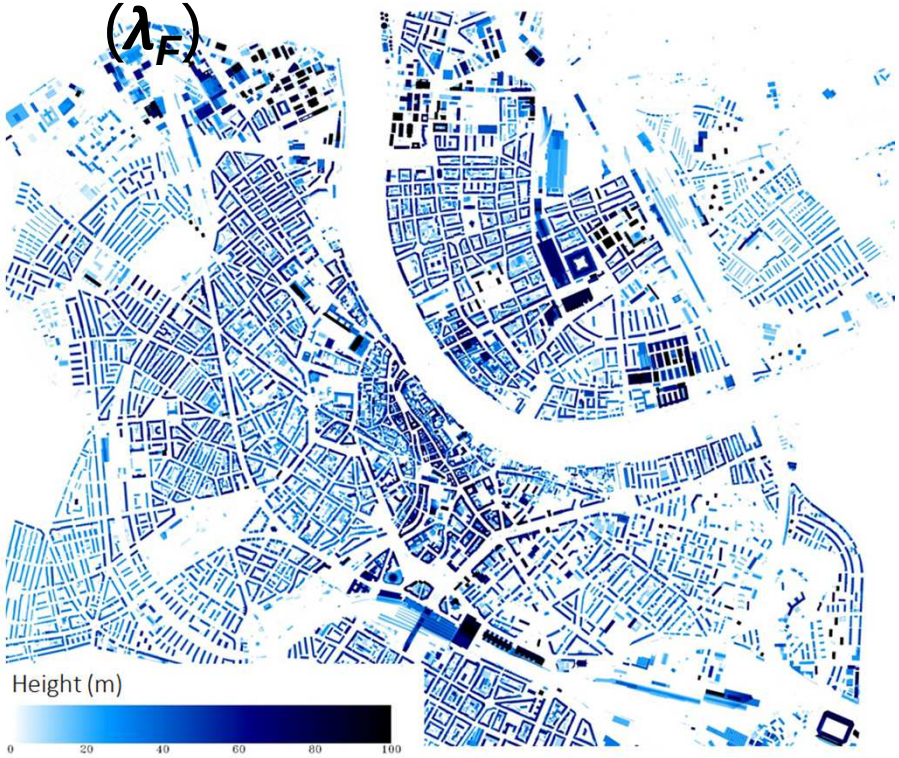


Local Climate Zones

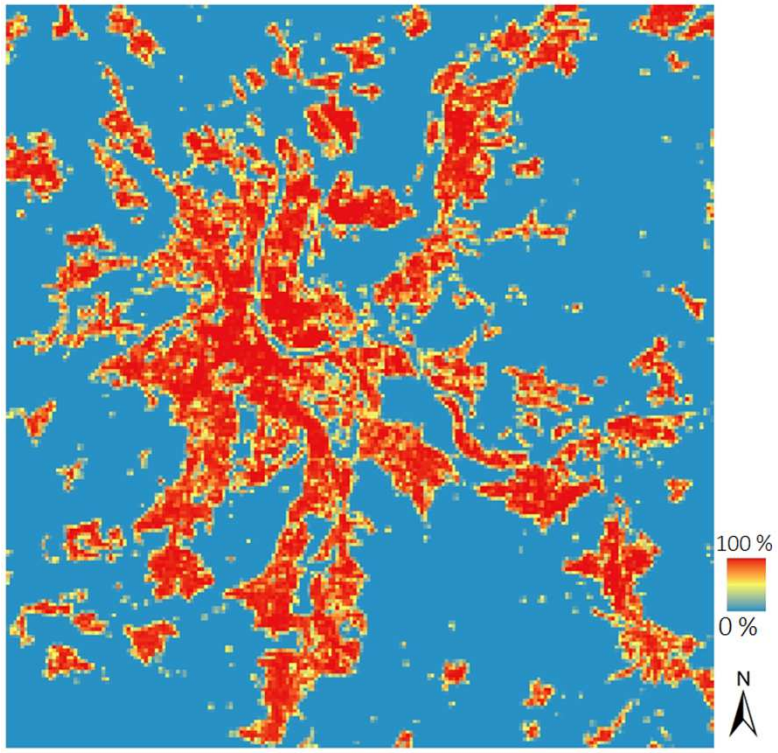


Urban morphology

- **Relevant parameters**: Sky View Factor (***SVF***), Building and vegetation heights (z_H, $z_{H(SD)}$, $z_{H(max)}$), Plan area index (λ_P), Frontal area index (λ_F)



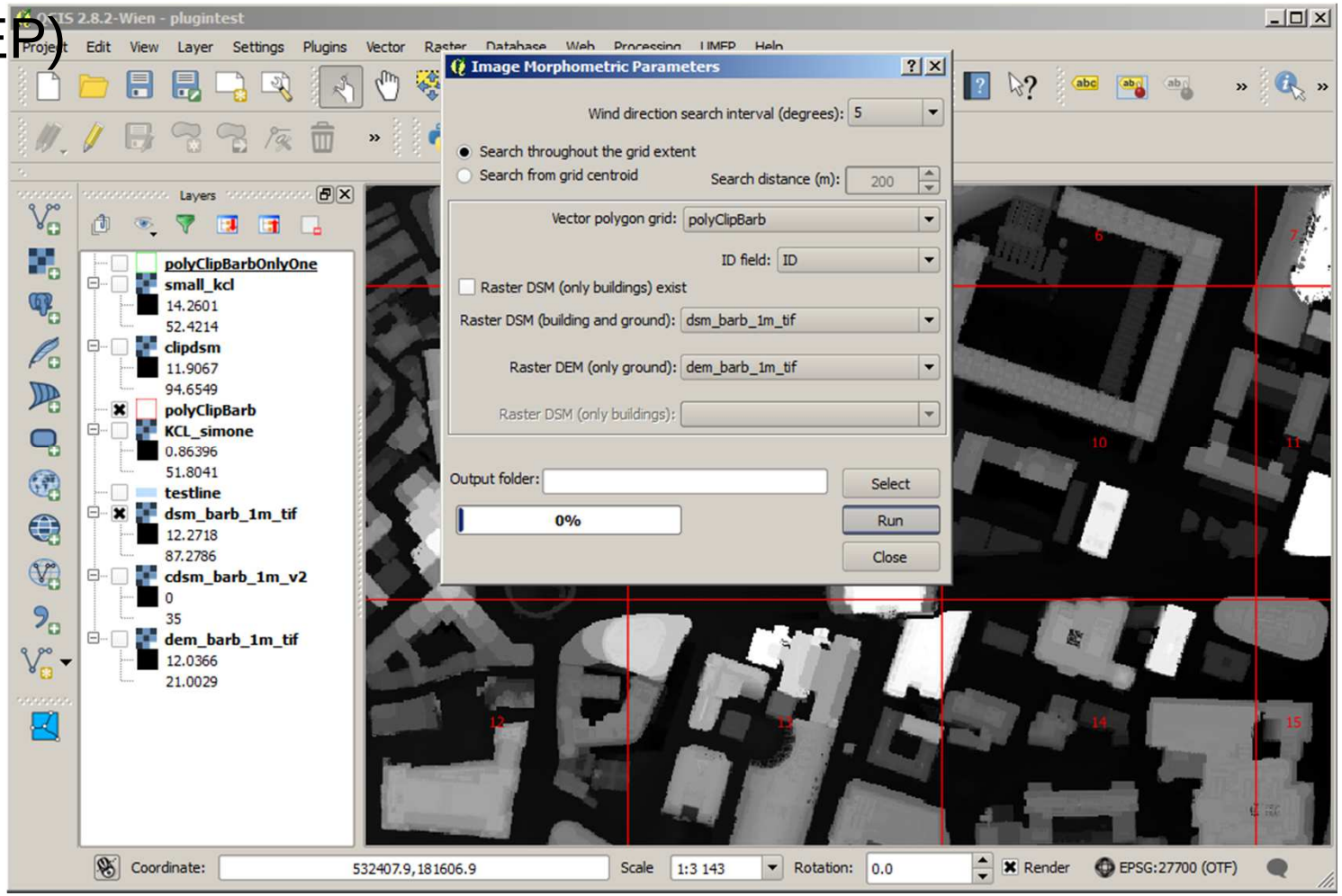
Digital surface model (DSM) of Basel



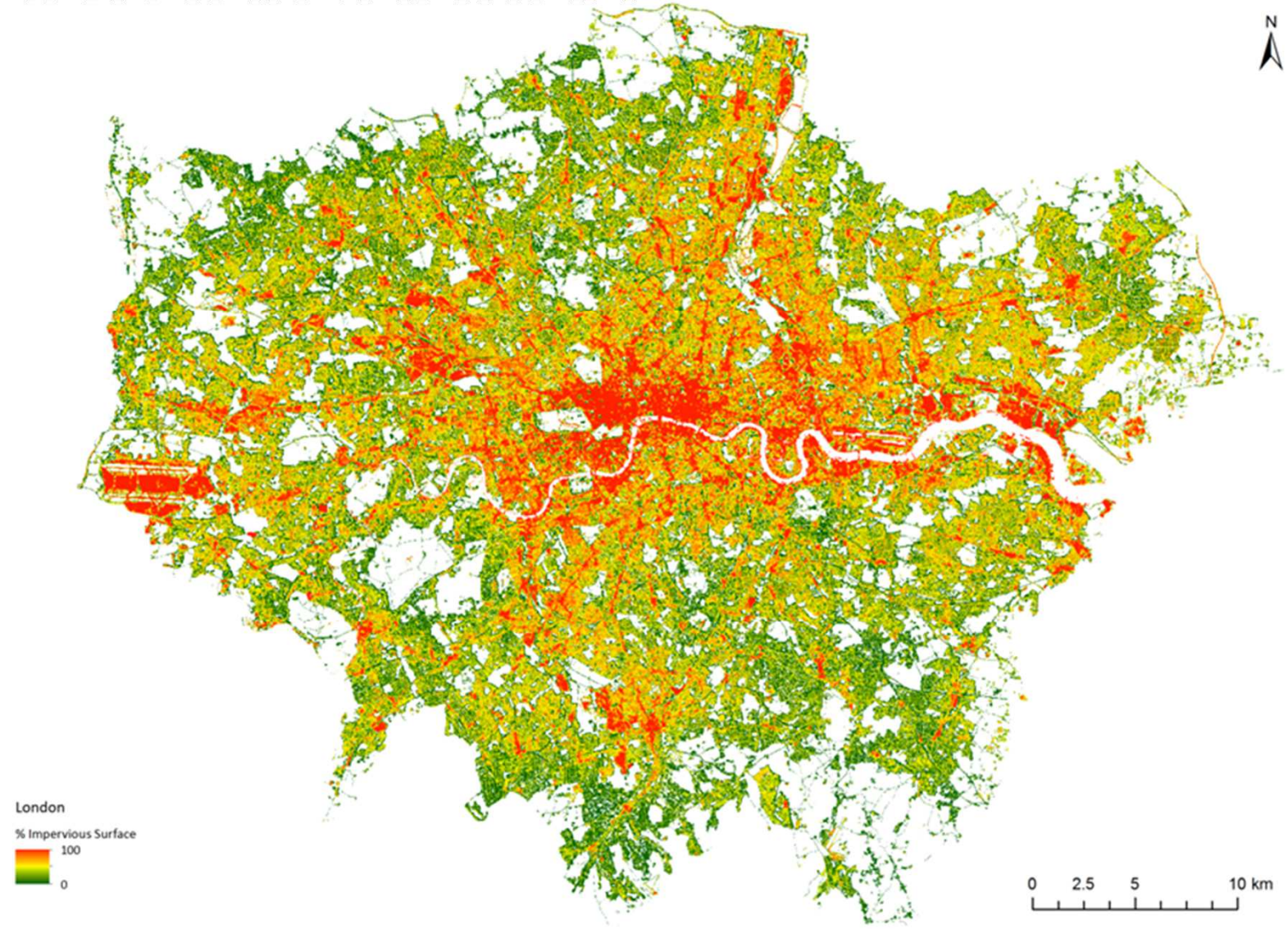
Building density of Basel based on GUF data (100 m grid)

Urban morphology

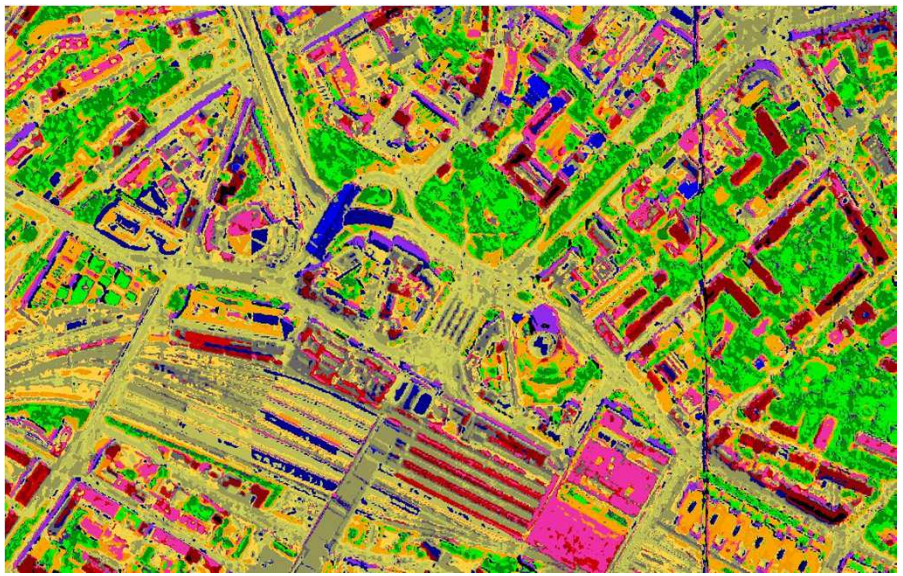
- Urban Multi-scale Environmental Predictor (UMEP)



Urban surface characteristics

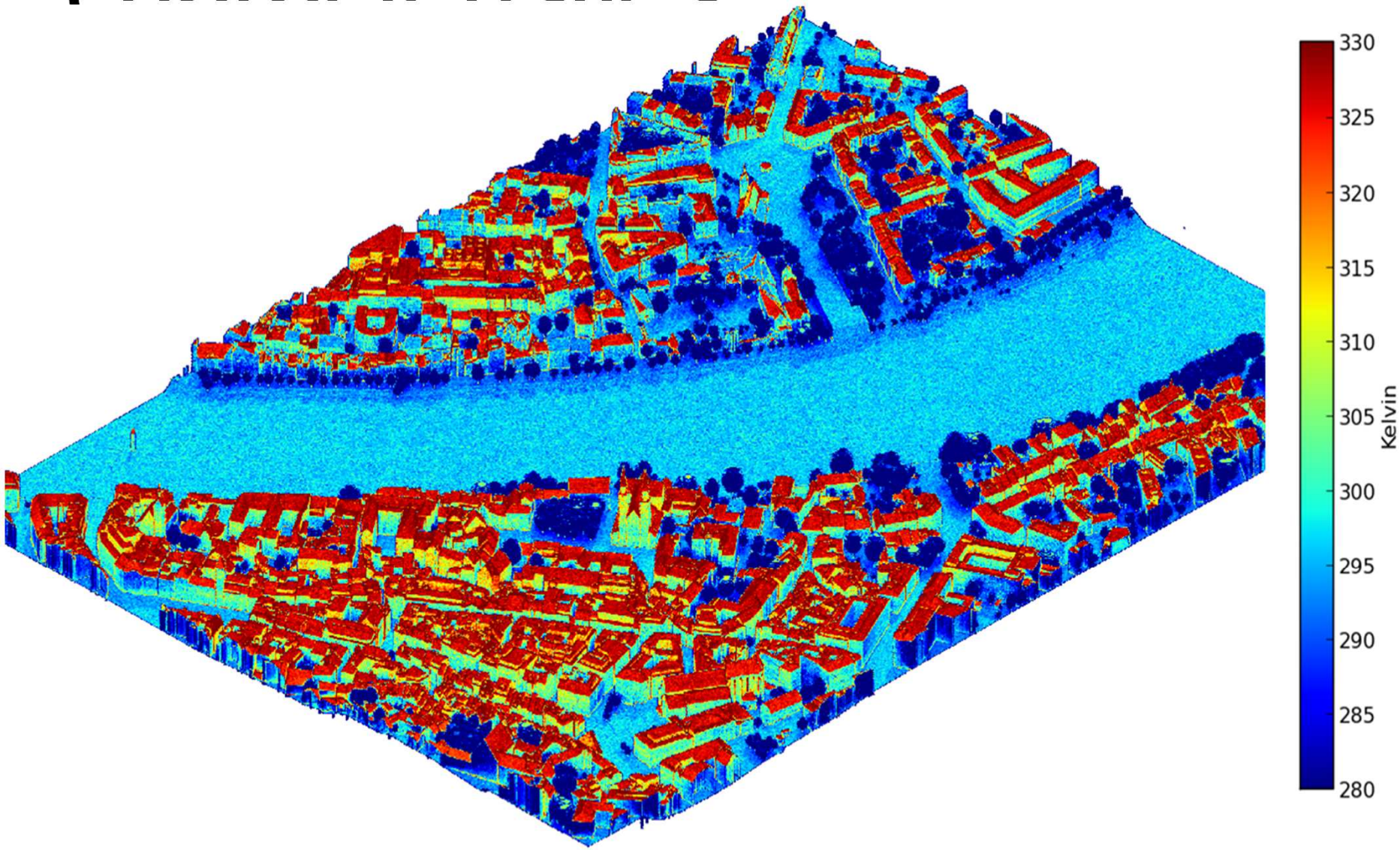


Urban surface characteristics

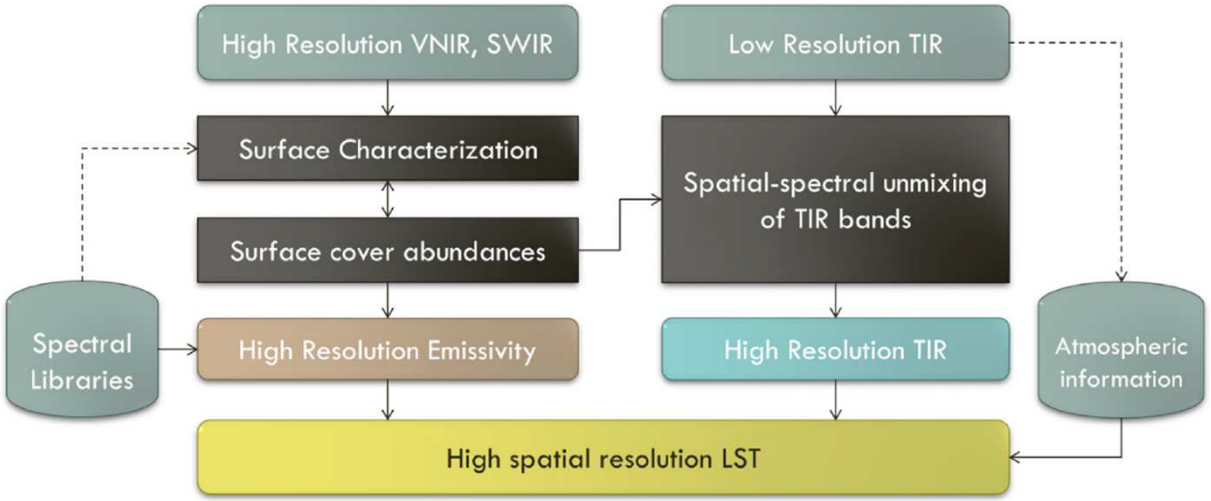


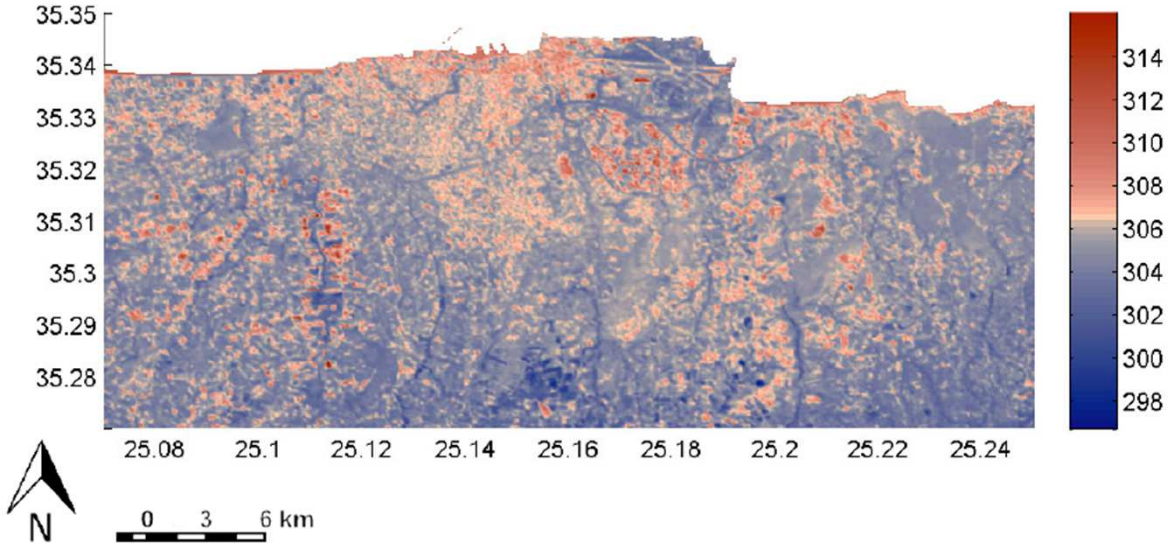
bright tiles	metal I	asphalt I	lawn/meadow	clay	gravel
red tiles	metal II	asphalt II	trees I	sandy soil	tar
dark red tiles	metal III	asphalt III	trees II	bare soil	concrete

Urban surface characteristics



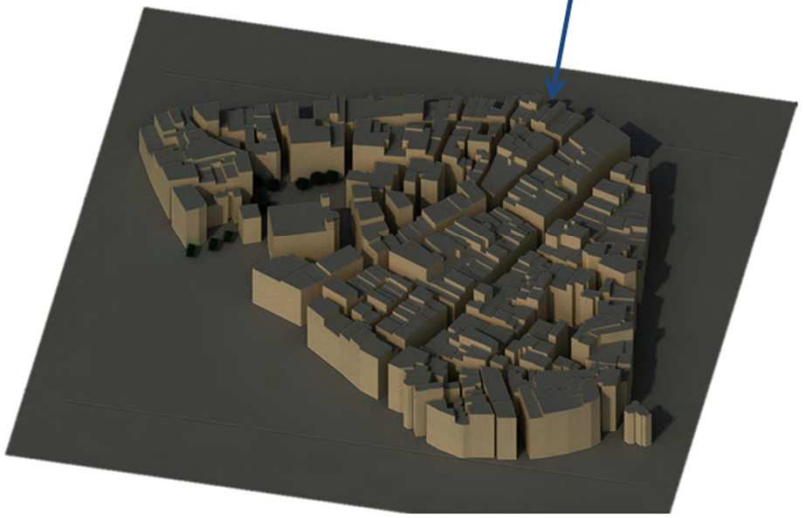
Urban surface temperature



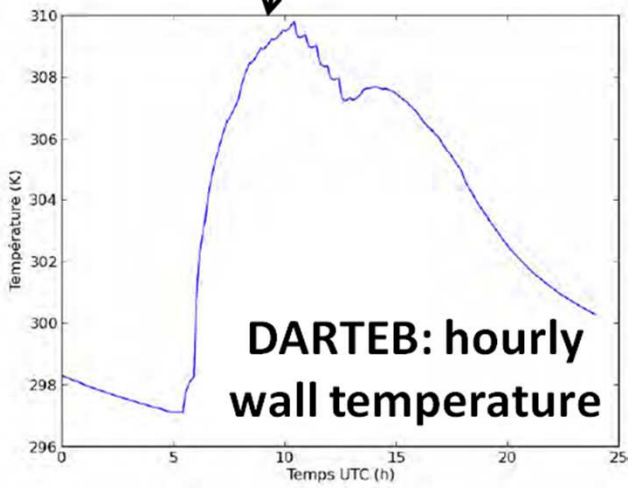


(Mitraka et al. 2015)

Radiation balance (Q*)



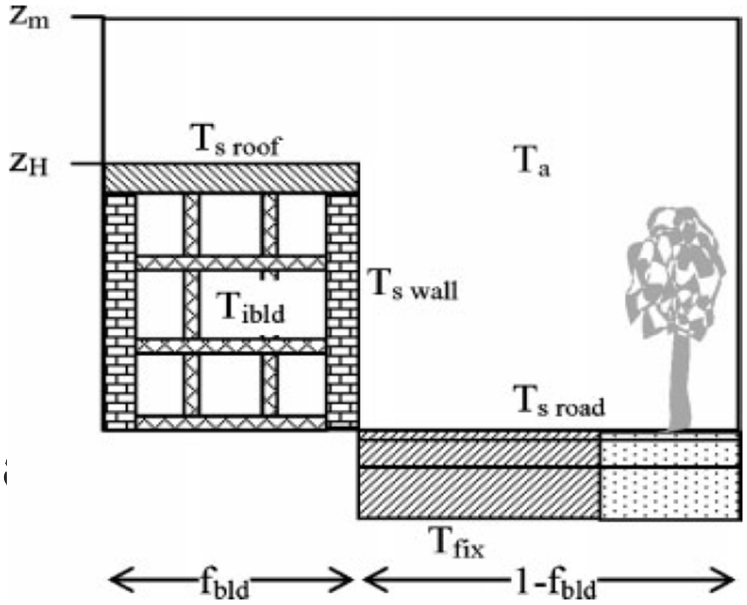
DART: color composite reflectance image



Heat storage change (ΔQ_s)

ESTM (Element Surface Temperature Method):

- Based on facet areas.
- Incorporates heat transfer between the different elements.
- Estimated ΔQ_S represents unit plan are



$$\Delta Q_S = \sum_i \frac{\Delta T_i}{\Delta t}(\rho C)_i \Delta x_i \lambda_{pi}$$

$$\rho C \frac{\partial T}{\partial t} = -\frac{\partial Q}{\partial x} = -\frac{\partial}{\partial x}\left(-k\frac{\partial T}{\partial x}\right)$$

Input data

Materials

- Thermal conductivity
- Volumetric heat capacity

Physical arrangement of elements

→ view factors between elements

T_S

T_{air} inside and outside

Soil temperature T_{fix} (where dT/dz = 0)

(Source: Offerle et al., 2005)

Heat storage change (ΔQ_s)

OHM (Objective Hysteresis Model):

- Contributions to ΔQ_S from multiple surface material types
- EO-derived dQ^*/dt (e.g., Yu et al., 2008)

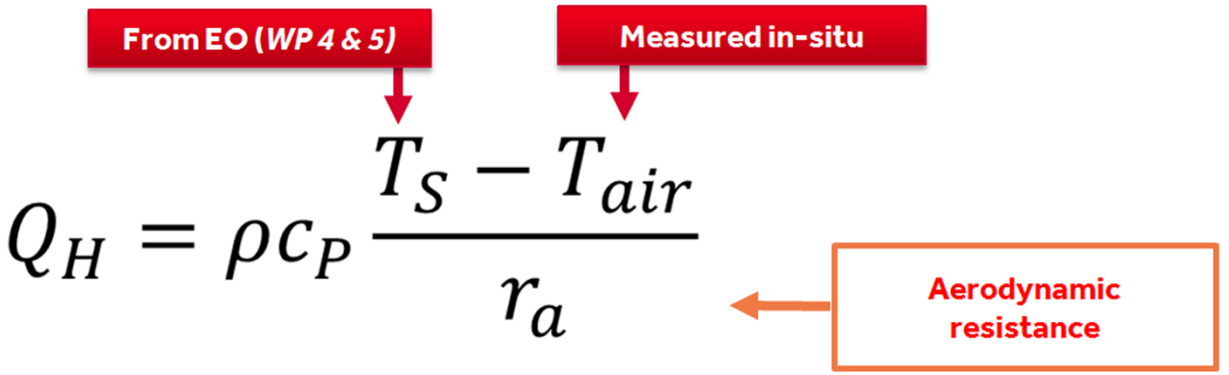
Q* and dQ*/dt measurements from EO

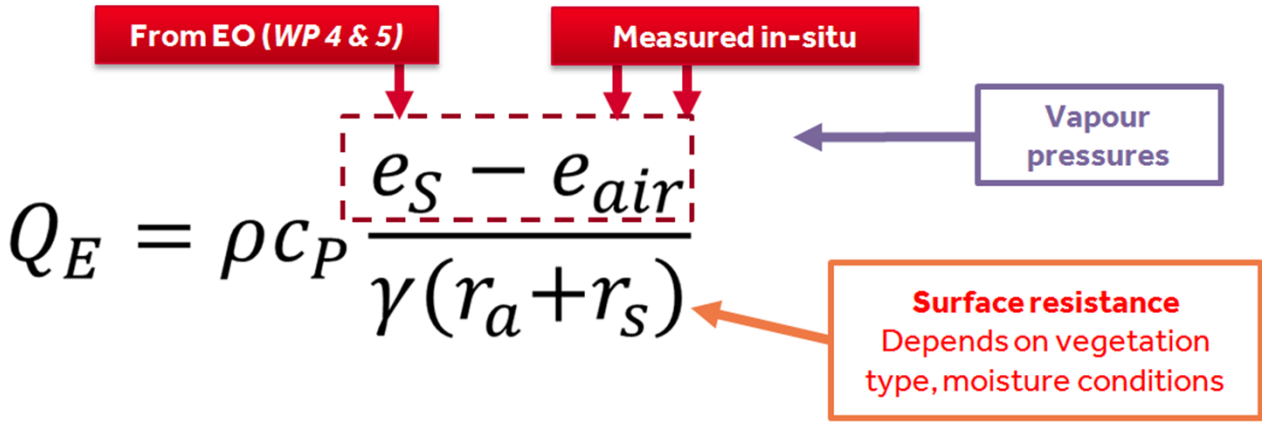
$$\Delta Q_s = \sum f_i a_{1,i} Q^* + f_i a_{2,i} \frac{dQ^*}{dt} + f_i a_{3,i}$$

Parameters specific to land cover class

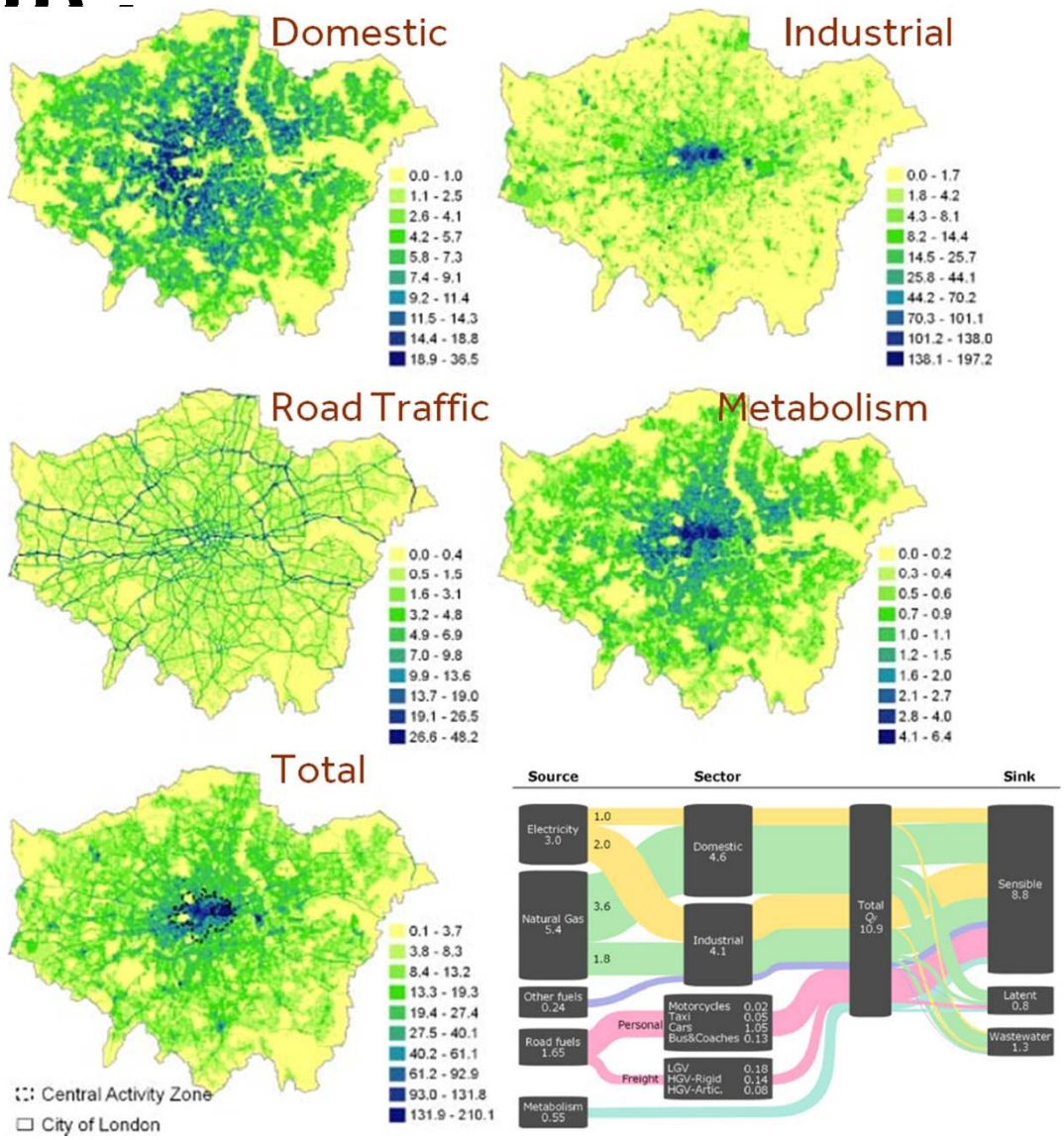
Turbulent Heat Fluxes (Q_H , Q_E)

- Aerodynamic Resistance Method (ARM)



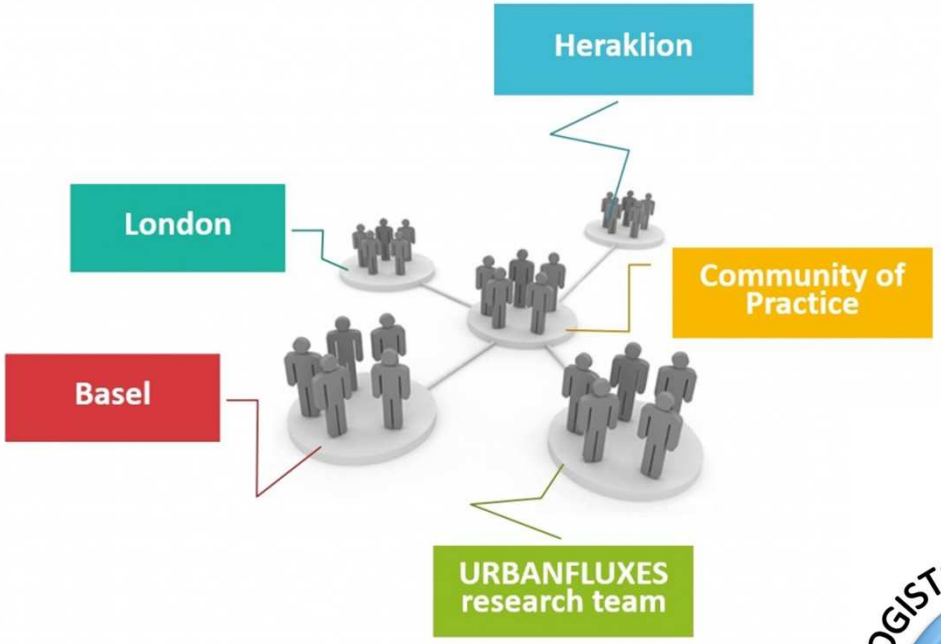


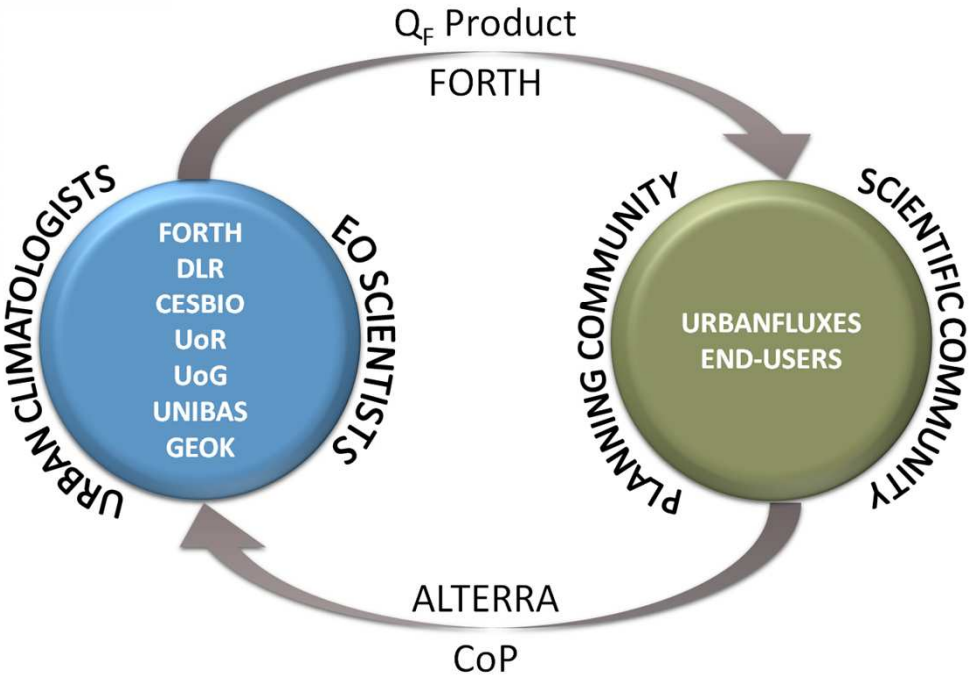
Comparison with non-satellite



(Source: Iamarino et al. 2012)

The involvement of users





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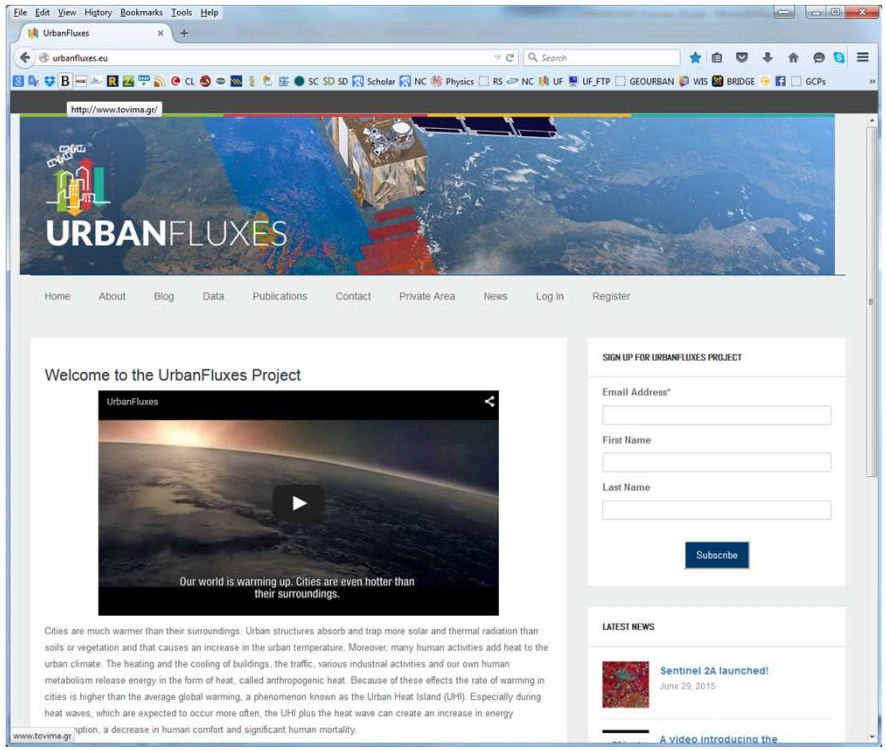

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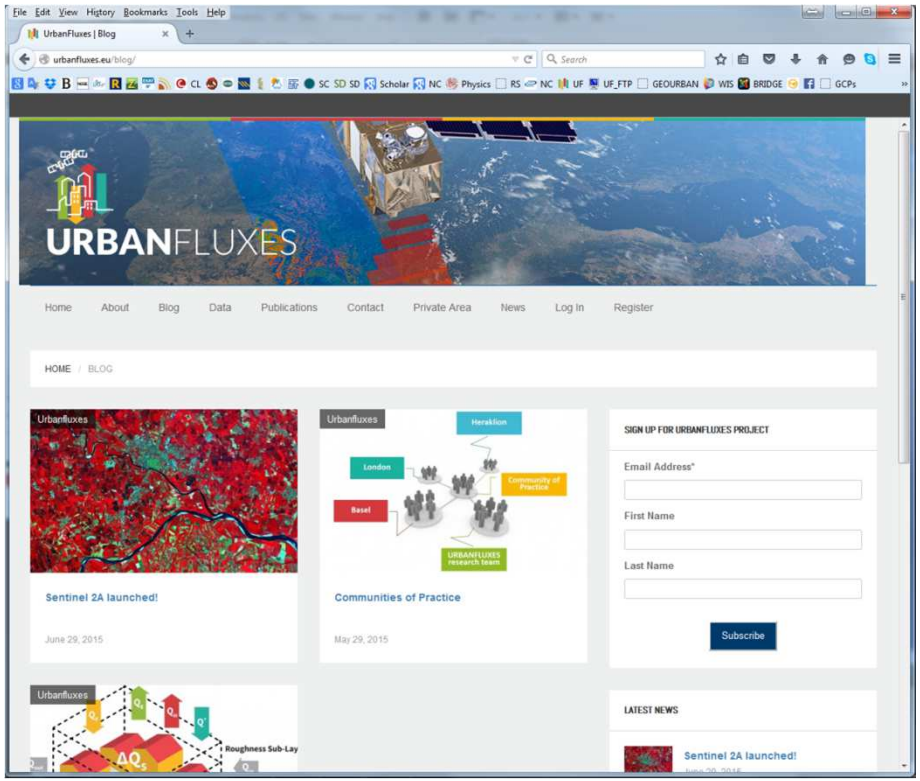

The vision

- To advance the current knowledge of the **impacts** of Q_F **on UHI** and hence on urban climate and **energy consumption**.
- To support the **development of tools** and strategies to mitigate these effects, improving **thermal comfort** and **energy efficiency**.
- To support the establishment of EO as a tool to **help inform policy-making**.
- To develop **EO-based services**.


THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION
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