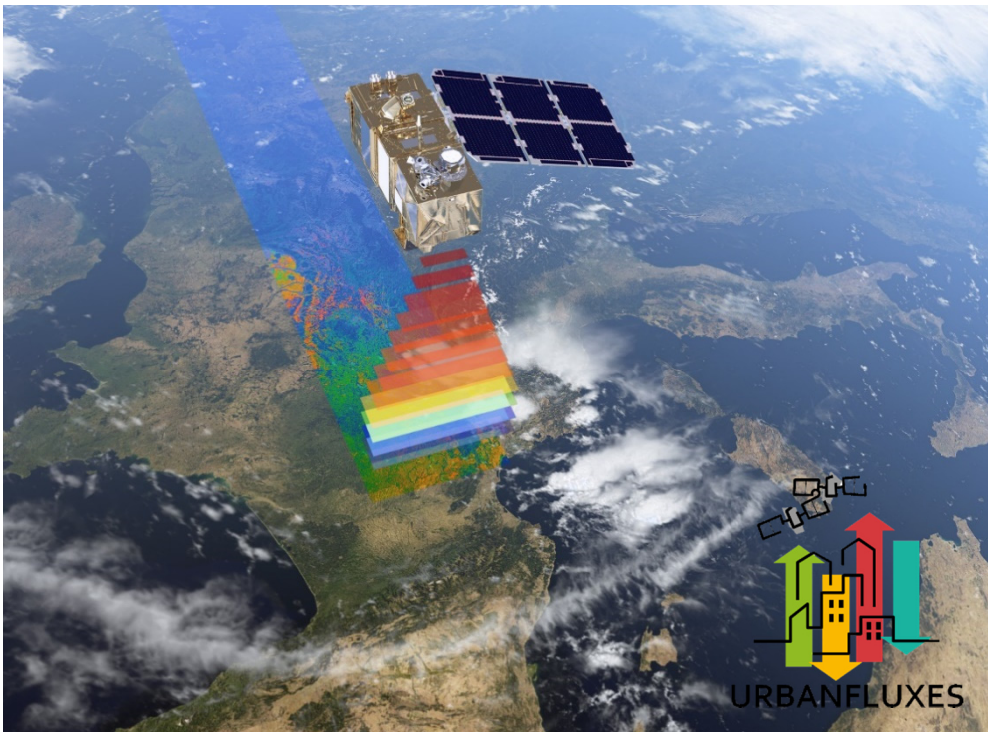

URBANFLUXES Newsletter

January 2016

URBAN ANTHROPOGENIC HEAT FLUX FROM EARTH OBSERVATION SATELLITES

IN THIS ISSUE

Editorial

by Nektarios Chrysoulakis

URBANFLUXES (URBan ANthropogenic heat FLUX from Earth observation Satellites) is one of the five projects that were funded from the H2020-Space call on new ideas for Earth-relevant space applications (H2020-EO-1-2014). It is a joint effort of eight European Organizations aiming to introduce novel ideas on anthropogenic heat flux observation from space, thereby generating new Earth Observation (EO) opportunities of benefit to climate change mitigation/adaptation and civil protection.

Although methods exist for monitoring land-use changes using EO data, a clear link between urban land-use patterns and energy consumption at local scale is missing. Moreover, EO-based methods for determining energy fluxes in urban areas are still under development. Therefore, estimating the spatial patterns of urban energy budget by current EO systems is a challenge. The major challenge, however, is the exploitation of the Copernicus Sentinel satellites' synergistic observations to estimate the spatiotemporal patterns of anthropogenic heat flux. URBANFLUXES was launched in 2015 to meet this challenge.

Knowing what the anthropogenic heat flux patterns are in time and space can be an incentive for cooler urban design. It also creates more support for climate change mitigation and adaptation planning at local scale. The results can lead to a reduced winter and/or summer peak of heat emissions, a reduction in CO2 emissions, improved energy efficiency and better human comfort in the urban areas, since the project results is expected to be easily transferred to other cities.

The URBANFLUXES team consists of several leading European organizations in Earth Observation and Urban Climatology – DLR, CESBIO, the University of Basel, the University of Reading, the University of Gothenburg, the Wageningen University – and the industry – a spin-off company of Tor Vergata University, Geo-K s.r.l.

This Newsletter initiates an open dialogue between the URBANFLUXES team and all the potential users from both the scientific and the urban planning communities; and informs about activities, progress and achievements of the project. The Newsletters will be published every 6 months and will be open to articles, news and opinions.

Main Achievements and Upcoming Activities

URBANFLUXES completed one year of activities. The team members meet often, trying to provide answers to the URBANFLUXES scientific questions. To spread the word about the project and its main achievements. The team is presenting the project and its progress to various scientific conferences.

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The URBANFLUXES Data

URBANFLUXES has a database with satellite products for the cities participating in the project, London, United Kingdom, Basel, Switzerland and Heraklion, Greece. The database sis hosted in FORTH and it is constantly updated.

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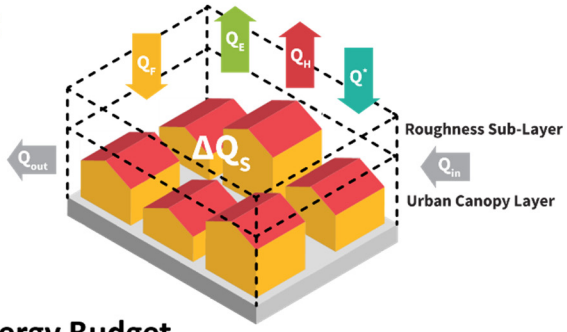
Project Overview

The anthropogenic heat flux (QF) is the heat flux resulting from vehicular emissions, space heating and cooling of buildings, industrial processing and the metabolic heat release by people. Both urban planning and Earth system science communities need spatially disaggregated QF data, at local (neighbourhood, or areas larger than the order of 100 m x 100 m) and city scales. Such information is practically impossible to derive by point in-situ fluxes measurements, while satellite remote sensing is a valuable tool for estimating Urban Energy Budget (UEB) parameters exploiting Earth Observation (EO) data. While the estimation of QF spatial patterns by current EO systems is a scientific challenge, the major challenge lies on the innovative exploitation of the Copernicus Sentinels synergistic observations to estimate the spatiotemporal patterns of QF and all other UEB fluxes.

The main goal of URBANFLUXES is to investigate the potential of EO to retrieve QF, supported by simple meteorological measurements. The main research question addresses whether EO is able to provide reliable estimates of QF for the time of the satellite acquisition. URBANFLUXES answers this question by investigating the potential of EO to retrieve QF spatial patterns, by developing a method capable of deriving QF from current and future EO systems. URBANFLUXES aims to develop an EO-based methodology easily transferable to any urban area and capable of providing QF benchmark data for different applications. URBANFLUXES is expected to increase the value of EO data for scientific analyses and future emerging applications (such as urban planning and local/regional level climate change mitigation/adaptation), by exploiting the improved data quality, coverage and revisit times of the Copernicus Sentinels data. To this end, the specific objectives of the project are:

Anthropogenic Heat Flux (Q_F)

Energy balance residual approach



Urban Surface Energy Budget

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

where $\Delta Q_A = Q_{in} - Q_{out}$ and S represents all other sources and sinks

Sensible Heat Flux (Q_H) – Latent Heat Flux (Q_E)

Adjusted Aerodynamic Resistance Method for EO data

Net all-wave Radiation Flux (Q^*)

Discrete Anisotropic Radiative Transfer (DART) approach

Heat Storage Flux (ΔQ_S)

Element Surface Temperature Method

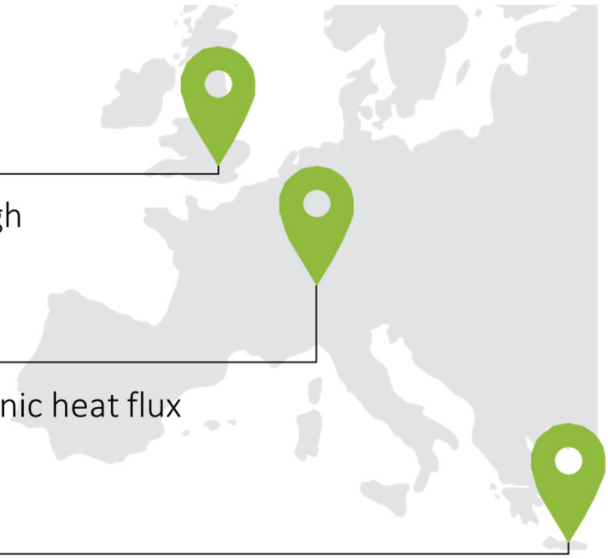
- to improve the accuracy of the radiation balance spatial distribution calculation;
- to develop EO-based methods to estimate the flux of heat storage in the urban fabric, as well as the turbulent sensible and latent heat fluxes at local scale;
- to employ energy budget closure to estimate the anthropogenic heat flux patterns;
- to specify and analyse the uncertainties associated with the derived products;
- to evaluate the products by comparisons with QF estimations by independent methods;
- to improve the understanding of the impact of QF on urban climate; and to communicate this understanding to the urban planning community, which will in turn lead to a better understanding of what new knowledge is needed on the ground;
- to exploit Sentinels 2 and 3 synergistic observations to retrieve UEB fluxes at the local scale, with the frequency of the Sentinel 3 series acquisitions.
- to standardise the resulting products, and by organizing an effective dissemination mechanism, to enhance their use by urban planners and decision makers in cities, as well as by EO scientists, Earth system modellers and urban climatologists.

Three different urban areas are selected in URBANFLUXES as case studies: a highly urbanized mega city (London); a typical central European medium size city, that requires a substantial amount of energy for heating (Basel); and a smaller, low latitude Mediterranean city that requires a substantial amount of energy for cooling (Heraklion). The project uses a Community of Practice (CoP) approach, which means that in the case studies, local stakeholders and scientists meet on a regular basis to learn from each other and to make clear what aspects are important for the future users of the URBANFLUXES products.

URBANFLUXES is expected to generate a novel analysis method for estimation of UEB components from Copernicus data, enabling its integration into applications and operational services; for example to: develop rules of thumb for density and green space ratio, distinguish between insulated and non-insulated buildings and evaluate the implementation of climate change mitigation technologies, such as solar-screening and green-belting.

Despite its local importance, QF is omitted from climate models simulations. Observations of global temperature evolution indicate a pronounced warming over the last 150 years, with an increase in the occurrence of heat waves. The added value and benefit expected to emerge from URBANFLUXES is therefore related to quality of life, because it is expected to improve our understanding of the contribution of QF to heat wave intensity and thus to allow insight into strategies for mitigation. QF estimates are needed for all cities to be able to document the magnitude of the fluxes effects on urban climate so that the impact of QF can be included in climate modelling. URBANFLUXES is therefore expected to advance the current knowledge of the impacts of QF on urban heat island and hence on urban climate, and consequently on energy consumption in cities. This will lead to the development of tools and strategies to mitigate these effects, improving thermal comfort (social benefit) and energy efficiency (economic benefit).

The long term operation of the Sentinels series guarantees the future supply of satellite observations, providing the means for the development and realization of the URBANFLUXES methodology. URBANFLUXES is expected to support sustainable planning strategies relevant to climate change mitigation and adaptation in cities, because knowledge of QF spatio-temporal patterns is important for urban planning (e.g. to reduce or prevent QF hot spots), health (e.g. to estimate the impact on thermal comfort) and future proofing (e.g. to plan and implement interventions towards QF reduction in these areas). Planning tools, such as Urban Climatic Maps and Climatope Maps, should be enriched with information on QF patterns. Mapping provides visualization of assessments of these phenomena to help planners, developers and policy makers make better decisions on mitigation and adaptation.



London

highly urbanized megacity | anthropogenic heat flux high throughout the year

Basel

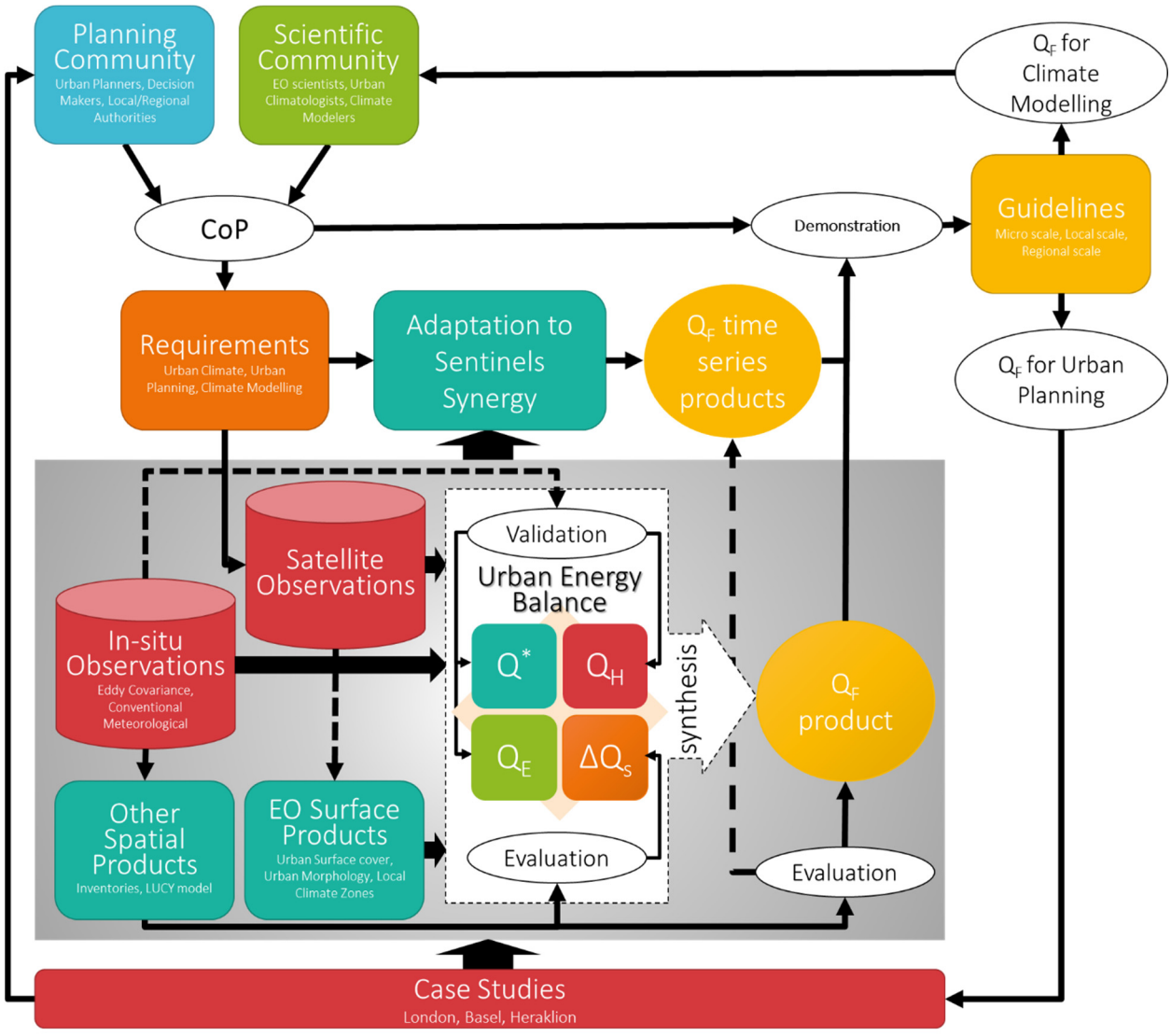
typical central European medium size city | anthropogenic heat flux high throughout the year

Heraklion

typical Mediterranean medium size city with dynamic urbanization process requires a substantial amount of energy for cooling

The URBANFLUXES approach

The URBANFLUXES approach is presented below. The cross cutting process of the CoP, which facilitates the continuous interaction with the users is clear. In the framework of the CoP the Q_F related user requirements were captured and the demonstration of URBANFLUXES method and products will be performed. The duration of the project is three years and it is divided into two main phases: during the 1st Phase an analysis method is being developed to estimate Q_F spatial patterns using currently available satellite data; during the 2nd Phase the developed method will be adapted to Sentinels synergy to derive Q_F spatiotemporal patterns. A network of simple meteorological stations has been deployed in all cities, whereas Eddy Covariance (EC) systems and scintillometrs are also be used. Satellite data are analyzed to map urban surface morphology and cover, whereas a new method is being developed to define UEB meaningful local zones. The Discrete Anisotropic Radiative Transfer (DART) model is employed to improve the estimation of the net all-wave radiation balance, whereas the Element Surface Temperature Method (ESTM), adjusted to satellite observations is used to improve the estimation the estimation of the net change in heat storage. Furthermore the estimation of the turbulent sensible and latent heat fluxes is based on the Aerodynamic Resistance Method (ARM). Based on these outcomes, Q_F is estimated by regressing the sum of the turbulent heat fluxes versus the available energy. Finally, the whole approach will be adapted to Sentinels synergy to derive Q_F spatiotemporal patterns.



1ST ROUND OF COP MEETINGS

Poster session aim to present the work performed in the project directly to city planners. Participants in the CoP meeting have the chance to talk to the URBANFLUXES scientist and ask questions.

The participant are welcome to see the instrumentation and discuss its usability and applications directly with the staff responsible.

Round tables in CoP meetings, allow thorough discussions and close interaction between scientists and the city planners.

The team compiled a video to quickly introduce the project and ask for local authorities to participate in CoPs https://youtu.be/hxS6FqwrvIA

Communities of Practice

A CoP is characterized by three core dimensions: the domain, the community and the practice. If a group of people develops these three elements in parallel it constitutes a Community of Practice. CoPs have been formed within URBANFLUXES by bringing urban stakeholders and scientists together to talk and exchange knowledge and expertise. People involved in the communities meet on a regular basis to learn from each other and make clear what the important criteria are for URBANFLUXES outcomes.

The first round of CoP meetings organized in URBANFLUXES case studies as follow:

London

January 21, 2015

participants of the meeting included representatives of the Greater London Authority, the London Climate Change Partnership and the London First - Security and Resilience. The likely benefits of URBANFLUXES for London were discussed, focusing on the role of the anthropogenic heat flux on urban heat island and heat waves, as well as on the related policies.

Basel

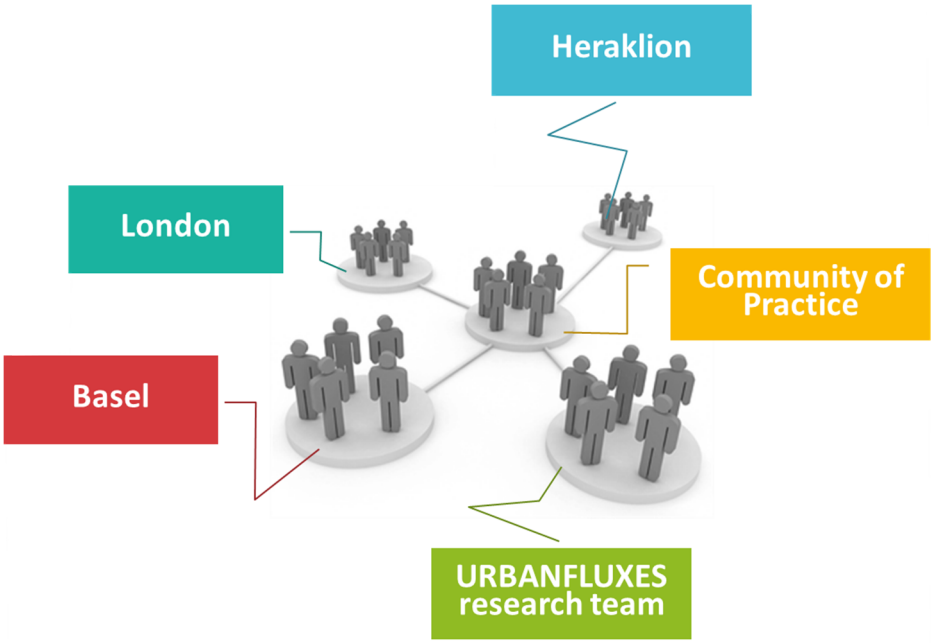
June 23, 2015

participants of the meeting included representatives of the Statistisches Amt Basel-Stadt, Lufthygieneamt beider Basel, the Umwelt und Klimaschutz of Stadt Lörrach, the Swiss TPH, Planungsamt and Raumentwicklung Basel-Stadt and FRASUK Environment and Communication Agency. The problem of urban heat in the city of Basel was explored focusing on the research that has already been done by the research team and the plans for the future.

Heraklion

December 17, 2015

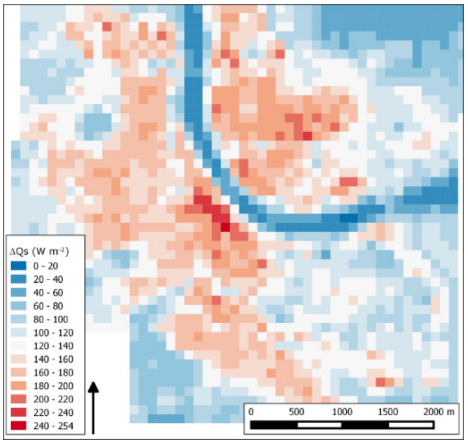
participants of the meeting included representatives of the Region of Crete and of the Municipality of Heraklion. The discussion was focused on how URBANFLUXES can support the climate change mitigation planning for the city of Heraklion. Furthermore, the new wireless sensors network that has been deployed by FORTH in the city of Heraklion was demonstrated.



Main achievements and upcoming activities

The URBANFLUXES kick-off meeting held in Heraklion on February 3-4, 2015, defining the work plan for the first semester of the project. The 1st progress meeting was held in Basel on June 23-24, 2015, reviewing the outcomes of the first semester and defined the work plan for the second semester of 2015. Besides, these meetings, four Management Board internet meetings were held to guarantee the smooth progress of the project actives and to resolve any technical or administrative problems. The operation of the web-server of the project from the very beginning supported the communication and the data exchange among the partners. Besides the web-site, a leaflet and a demonstration video were developed to facilitate the communication with both the scientific and the planning communities and to act as the means for the broader dissemination of the project outcomes. The communication with the potential users was further supported by the CoP meetings in all case study cities.

Concerning the main scientific achievements, a database containing satellite-derived urban surface morphology and cover characteristics, for the three case study cities, as well as a database containing the preliminary local zones for UEB mapping, have been developed; a database containing local scale multi-dimensional normalization functions of directional reflectance and brightness temperature, for any sun direction has been also developed, capable of being used in net all-wave radiation balance estimation. Furthermore, the ESTM has been adjusted to EO-derived surface morphology and characteristics and has been implemented for Basel and a test area in London. Finally, wireless sensors networks have been deployed in all case study cities, providing the appropriate in-situ air temperature and humidity measurements that are needed to estimate the respective gradients by the ARM, which has been implemented for Basel and for a test area in London. The estimated turbulent fluxes have been validated via direct comparisons versus the EC measurements.



Storage heat flux calculated for central Basel on 30 August, 2015 (11:16 CET).

Concerning upcoming events, the 1st URBANFLUXES review meeting will be held in Reading on February 16, followed by the 2nd progress meeting on February 17, 2016. At least two Management Board meetings will be held to monitor this plan and to adjust it, if needed. The progress of the activities of 1st semester of 2016 will be reviewed in the 3rd progress meeting to be held in the summer of 2016. During the second semester the wireless sensor networks, as well as the EC systems is expected to be fully operational at all case study cities and their measurements to be available via the project's web-site; all the project outputs, maps and other data will be publically available in line with the H2020 Open Data Pilot requirements. The most important expected outcome in the next semester concerns the spatial distributions of the net all-wave radiation, the net change in heat storage, the turbulent sensible and latent heat fluxes, and preliminary anthropogenic heat flux estimations. The results will be presented by the URBANFLUXES researchers in various scientific fora, such as the European Geosciences Union General Assembly, the ESA's Living Planet Symposium, the 36th EARSeL Symposium, the European Space Agency Living Planet Symposium, the Fourth International Conference on Countermeasure to Urban Heat Islands, the IGARSS 2016 and the SPIE Remote Sensing 2016.

The URBANFLUXES Data

The URBANFLUXES team is working on the development of many satellite-derived products towards its final goal, to estimate the spatial distribution of anthropogenic heat flux. FORTH provides the infrastructure to host a data repository.

All URBANFLUXES data products are publically available through the project's web-site, after registration.

During the first year of the project, a great wealth of spatial data related to the urban surface properties have been produced. EO data from various sources, including the Copernicus Contributing Missions, have been used to develop validated urban morphology and surface characteristics products for the three cities considered in the project (Basel, London and Heraklion). Thee product categories can be identified: morphology, land cover and biophysical characteristics.

Morphology products

The morphology products describe various aspects of the urban 3D structure and are derived from high resolution surface models. Surface information on building morphology as well as vegetation is required. Digital Surface Model (DSM) with both ground and object (building) heights needs to accompany a Digital Elevation Model (DEM) to relate all heights to the ground surface. Most of the morphometric parameters are derived using a newly developed tool by the University of Gothenburg, the Urban Multi-scale Environmental Predictor (UMEP). The tool can further be used for a variety of applications related to outdoor thermal comfort, urban energy consumption, climate change mitigation etc.

Land cover products

The land cover products are obtained considering EO data at both high (HR) and very high (VHR) spatial resolutions. For the HR case, with a pixel size of 30 m, the project has taken as reference input Landsat images. SPOT products (2.5 m) and Urban Atlas (http://land.copernicus.eu/local/urban-atlas) have been used for the VHR maps. The generation of land cover classification maps at two different spatial resolutions is motivated by at least a couple of reasons. First of all it is important to evaluate the impact of a coarser spatial resolution of the EO data on the estimation of the anthropogenic heat flux Q_F. Moreover, lower spatial resolutions can be more appropriate for detecting changed areas when the generation of updated products is required. For this task the URBANFLUXES will fully exploit the advantages of the Sentinel missions.

Biophysical products

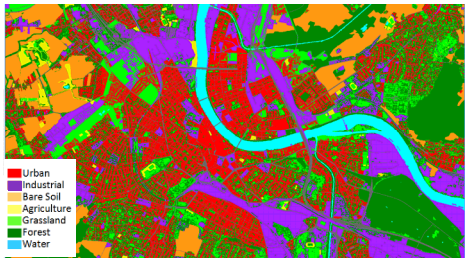
The biophysical products describe the dynamic land surface properties that are required in urban fluxes modelling. Properties such as surface reflectance, albedo, surface temperature and the seasonal vegetation changes are very important parameters of the urban energy budget. Various EO data sources are used for the development of such products and some of them are not in the desired spatial resolution. Thus, novel optimized downscaling techniques are developed from the URBANFLUXES team to enhance the spatial detail of biophysical products.

Realtime meteorological measurements

The URBANFLUXES project started operation of the Urban Meteorological Station Network (UMSN) in the town of Heraklion and the area of Basel in December 2015. Similar network is also available for London case study. The URBANFLUXES meteorological stations measure air temperature, relative humidity, infrared ground temperature, wind speed and wind direction with very high frequency (4 measurements per minute). The measurements are available realtime at URBANFLUXES website through a user-friendly GIS platform for each case study.

3D view of Basel generated using DART. The Discrete Anisotropic Radiative Transfer (DART) model is a physically based 3D model simulating the Earth-atmosphere radiation interaction from visible to thermal infrared wavelengths.

Sky-view factor for a part of London. The sky-view factor is the fraction of sky visible from the ground level. Varies with height and spacing of buildings and trees and affect the surface radiation heating/cooling.



Land cover classification map at VHR for the city of Basel.

Surface reflectance of Heraklion, derived by Landsat-8

Realtime measurements for the three cities participating in the project are available throught the project's web-site.

Recent Publications

Chrysoulakis, N., Esch, T., Gastellu-Etchegorry, J. P., Grimmond, C. S. B., Parlow, E., Lindberg, F., … Mitraka, Z. (2015). A novel approach for anthropogenic heat flux estimation from space. In *36th International Symposium on remote Sensing of Environment (ISRSE), 11-15 May, Berlin, Germany*.

Chrysoulakis, N., Esch, T., Grimmond, C. S. B., Parlow, E., Lindberg, F., Frate, D., … Feigenwinter, C. (2015). A novel approach for anthropogenic heat flux estimation from space. In *9th International Conference on Urban Climate (ICUC9), 20-24 July, Toulouse, France*.

Chrysoulakis, N., Heldens, W., Gastellu-Etchegorry, J.-P., Grimmond, S., Feigenwinter, C., Lindberg, F., … Olofson, F. (2015). Urban Energy Budget Estimation from Sentinels: The URBANFLUXES Project. In *Mapping Urban Areas from Space Conference, Frascati, Italy, 4-5 November*.

Heldens, W., Del Frate, F., Lindberg, F., Mitraka, Z., Latini, D., Chrysoulakis, N., & Esch, T. (2015). Mapping urban surface characteristics for urban energy flux modelling. In *Mapping Urban Areas from Space Conference, Frascati, Italy, 4-5 November*.

Landier L, Al Bitar A, Gregoire T, Lauret N, Yin T, Gastellu-Etchegorry JP, Aubert S, Mitraka Z, Chrysoulakis N, Feigenwinter , Parlow E, Heldens W, KC, L. F. (2015). Modeling parameters and remote sensing acquisition of urban canopies. In *9th International Conference on Urban Climate (ICUC9), 20-24 July, Toulouse, France*.

Lindberg, F., Grimmond, C. S. B., & Martilli, A. (2015). Sunlit fractions on urban facets – Impact of spatial resolution and approach. *Urban Climate*, *12*, 65–84. http://doi.org/10.1016/j.uclim.2014.11.006

Mitraka, Z., Chrysoulakis, N., Gastellu-Etchegorry, J.-P., Del Frate, F., & Chrysoulakis, N. (2015). Exploiting Earth Observation data products for mapping Local Climate Zones. In *9th International Conference on Urban Climate (ICUC9), 20-24 July, Toulouse, France*. IEEE. http://doi.org/10.1109/JURSE.2015.7120456

Mitraka, Z., Chrysoulakis, N., Heldens, W., Feigenwinter, C., Lindberg, F., Grimmond, S., … Gastellu-Etchegorry, J. P. (2015). Earth Observation for Urban Climate: Mapping the Local Climate Zones. In *Mapping Urban Areas from Space Conference, Frascati, Italy, 4-5 November*.

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All publications are available through the project's web-site: www.urbanfluxes.eu.

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