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URBANFLUXES

URBAN ANTHROPOGENIC HEAT FLUX FROM EARTH OBSERVATION SATELLITES

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1 INTRODUCTION

1.1 Purpose of the document

This document provides the proceedings of URBANFLUXES Demonstration Event 2 that took place on 6 December 2017 in London. This demonstration event aimed to discuss the relevance of the findings in the project for the planning and management of cities. The outcomes of the project are relevant for the development of tools and strategies to reduce urban heat, improve thermal comfort and increase energy efficiency. Especially in relation to global climate change, cities play a major role considering the impacts of extreme heat waves on the population. For urban planners, it is important to know which types of urban structures are beneficial for a comfortable urban climate and which actions can be taken to improve urban climate conditions. The increase in monitoring frequency by the ESA Sentinels also allow for monitoring of the effectiveness of measures to reduce urban heat and energy losses.

1.2 Project overview

H2020-Space project URBANFLUXES (URBan ANthrpogenic heat FLUX from Earth observation Satellites) investigated the potential of Copernicus Sentinels to retrieve the anthropogenic heat flux Q_F, as a key component of the Urban Energy Budget (UEB). URBANFLUXES aimed to advance the current knowledge of the impacts of UEB fluxes on the urban heat island effect and consequently on energy consumption in cities. In URBANFLUXES, the anthropogenic heat flux is estimated as a residual of UEB. Therefore, other UEB components, such as the net all-wave radiation, the net change in heat storage and the turbulent sensible and latent heat fluxes, are independently estimated from Earth Observation (EO). The European Space Agency (ESA) launched new Earth Observation satellites in 2015, 2016 and 2017. The project exploits observations from Copernicus Sentinels 2 and 3, which provide improved data quality, coverage and revisit times and increase the value of EO data for scientific work and future emerging applications.

1.3 Definitions and acronyms

3D	Three Dimensional
ARUP	Arup Group Limited, a multinational professional services firm headquartered in London
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer, a device on board the Terra satellite
BRIDGE	sustainaBle uRban plannIng Decision support accountinG for urban mEtabolism, an EU FP7 project (2008-2011)

CESBIO	Centre d'Etudes Spatiales de la BIOsphère/ Center for the Study of the Biosphere from Space, located in Toulouse, France
CoP	Community of Practice
DART	Discrete Anisotropic Radiative Transfer, a model run by Cesbio that simulates measurements of passive and active satellite/plane sensors, as well as the radiative budget, for urban and natural landscapes
DLR	Deutsches Zentrum für Luft- und Raumfahrt/ German Aerospace Center
DSS	Decision Support System
EEA	European Environment Agency
EO	Earth Observation
ESA	European Space Agency
ESTM	Element Surface Temperature Method, a model to calculate the storage heat flux
EU	European Union
FORTH	Foundation for Research & Technology – Hellas, Heraklion, Crete
FP7	Seventh Framework Programme, research programme of the European Union (2007-2013)
GDP	Gross Domestic Product
GEO-K	A spin-off company of the Tor Vergata University of Rome to make the know-how developed by the University's Earth Observation Laboratory available in the form of user-oriented applications.
GIS	Geographical Information System, software for making maps
GLA	Greater London Authority
H2020	Horizon 2020 Research programme of the European Union (2014 to 2020)
INFRAS AG	Swiss research organization situated in Zurich and Berne
IPCC	International Panel on Climate Change
Landsat	The Landsat Program is a series of Earth-observing satellites from the United States, providing Earth images since 1972
LCCP	London Climate Change Partnership
LCZ	Local Climate Zones
LIDAR	LIght Detection And Ranging, a surveying method that measures distance to a target by illuminating that target with a pulsed laser light, and measuring the reflected pulses with a sensor
LUCY	Large scale Urban Consumption of energY (LUCY). A model that calculates anthropogenic heat fluxes for cities around the world

MCR Lab	Meteorologie, Klimatologie und Fernerkundung, micrometeorological research unit of the University of Basel
MODIS	Moderate-resolution Imaging Spectroradiometer, a device on board the Terra and Aqua satellites from NASA
MoH	Municipality of Heraklion
NDVI	Normalized Difference Vegetation Index, a graphical indicator that can be used to analyze remote sensing measurements, and assess whether the target being observed contains live green vegetation or not.
NGO	Non- Governmental Organization
Q	Question
Q*	net all-wave radiation flux
ΔQ_A	net advected flux ($\Delta Q_A = Q_{in} - Q_{out}$)
Q_E	turbulent latent heat flux
Q_F	anthropogenic heat flux
Q_H	turbulent sensible heat flux
ΔQ_S	net change in heat storage within the volume (including the flux into the ground)
RoC	Region of Crete
S	all the other sources and sinks
SMS	short message service, a service to receive short messages via GSM
SUEWS	Surface Urban Energy and Water Balance Scheme, a model to simulate the urban radiation, energy and water balances using meteorological variables and information about the surface cover
SVF	Sky View Factor
TPH	Tropical and Health Institute
UEB	Urban Energy Budget
UHI	Urban Heat Island
UK	United Kingdom
UniBas	University of Basel
UoG	University of Gothenburg
UoR	University of Reading
URBANFLUXES	URBan ANthropogenic heat FLUX from Earth observation Satellites
W/m_2	Watts per square metre; a unit of energy
WP	Work Package
WUR	Wageningen University and Research

1.4 Document references

Reuter, U. and Kapp, R. (Eds; former editors: Baumüller, J. and Hoffmann. U.), 2012. *Climate Booklet for Urban Development*. Translation by Michael Dempsey (Detroit) and Melanie Vogt (Berglen). Published by the Ministerium für Wirtschaft, Arbeit und Wohnungsbau Baden-Württemberg (Ministry of Economy, Work and Housing of Baden-Württemberg), Stuttgart

https://www.staedtebauliche-klimafibel.de/?p=0.&p2=0.

2 SETUP OF DEMONSTRATION MEETING 1

The demonstration meeting was held on Wednesday 6 December 2017 (13.00-17.00) at the Blue Finn Venue, 110 Southwark Street, London. The demonstration event comprised several presentations that discussed options to influence the Urban Energy Budget, bot through influencing the design of a city and through energy saving measures.

Figure 1: Blue Fin Venue, 10th floor

2.1 Programme

The programme is shown in the table below.

13:00	–	14:00	Welcome - Registration / Lunch Buffet	
14:00	–	14:15	Overview of the URBANFLUXES project	FORTH - Chrysoulakis
14:15	–	14:45	How can urban structures reduce heat? (albedo, greening)	UBAS - Parlow
14:45	–	15:15	Effects of urban structures on heat storage	UoG - Lindberg
15:15	–	15:30	Discussion on options for reducing urban heat	All
15:30	–	16:00	Break	
16:00	–	16:15	Urban Heat Emissions: what are the sources?	UoR - Grimmond
16:15	–	16:30	Future possibilities for monitoring urban energy solutions	FORTH - Chrysoulakis
16:30	–	16:45	Presentation of the URBANFLUXES app	GEO-K - Delfrate
16:45	–	17:00	Discussion on energy losses in cities and monitoring options	All

2.2 Participants

Invitations were sent to the full contacts list of the URBANFLUXES project. Furthermore, for the scientific meeting invitations were sent out to the institutions of which the URBANFLUXES partners were a part. A total of 42 participants subscribed for Demonstration meeting 2.

surname	*first name*	*affiliation*	*country*
Ajmal	Tahmina	University of Bedfordshire	United Kingdom
Aldred	Freya	Met Office	United Kingdom
Browning	Matt	Lambeth Council	United Kingdom
Chrysoulakis	Nektarios	Foundation for Research and Technology - Hellas	Greece
Church	Cecily	Sustainable Homes	United Kingdom
Del Frate	Fabio	GEO-K	Italy
Feigenwinter	Christian	University of Basel	Switzerland
Fleiss	Steven	Royal Borough of Greenwich	United Kingdom
Hemmings	Damian	London Borough of Merton	United Kingdom
Gawuc	Lech	Warsaw University of Technology	Poland
German	Andrew	Innovate UK	United Kingdom
Grimmond	Sue	University of Reading	United Kingdom
Guida	Kristen	London Climate Change Partnership	United Kingdom
Guo	Helen J.W	Sutton Borough	United Kingdom
Hatziyanni	Eleni	Region of Crete	Greece
Hsu	Shih-Che	UCL Energy Institute	United Kingdom
Iannitto	Giuseppe	GEO-K	Italy
Kanawka	Krzysztof	Blue Dot Solutions	Poland
Klostermann	Judith	Wageningen Research	Netherlands
Landier	Lucas	CESBIO	France
Lazuhina	Sabine	Astrosat	United Kingdom
Lietzke	Björn	Statistisches Amt Kanton Basel-Stadt	Switzerland
Lindberg	Fredrik	University of Gothenburg	Sweden
Macintyre	Helen	Public Health England	United Kingdom
Maranesi	Marcello	GEO-K	Italy
Marconcini	Mattia	German Aerospace Center - DLR	Germany
Michelakis	Nikolaos	Municipality of Heraklion	Greece
Mikrakis	Stylianos	Expert Advisor to the Mayor of Heraklion	Greece

Mitraka	Zina	Foundation for Research and Technology Hellas	Greece
Mochianakis	Konstantinos	Municipality of Heraklion	Greece
Nash	Begum	Sustainable Homes	United Kingdom
Papadaki	Evangelia	Municipality of Heraklion	Greece
Parlow	Eberhard	University Basel	Switzerland
Schneider dos Santos	Rochelle	UCL - Bartlett	United Kingdom
Sexton	Anna	Public Health England	United Kingdom
Siegrist	Franziska	Frasuk - Umwelt & Kommunikation, Basel	Switzerland
Stagakis	Stavros	Foundation for Research and Technology - Hellas	Greece
Start	Ged	Astrosat	United Kingdom
Thompson	Ross	Public Health England	United Kingdom
Turner	Briony	Space4Climate group	United Kingdom
Wynne	John	FFORM	United Kingdom
Xing	Yangang	Cardiff University	United Kingdom


Figure 2: Participants at Demonstration meeting 2

3 PRESENTATIONS, QUESTIONS AND COMMENTS

3.1 Overview of the URBANFLUXES project (FORTH – N. Chrysoulakis)

Cities accumulate heat which is called the urban heat island effect. We also face an increasing frequency of heat waves. To be able to address these problems we started the URBANFLUXES project. In this project we study the urban energy budget. We focus on all components of this budget and try to calculate the residual Q_F. For each component you would have to do different things to mitigate the heat. For example, for less heat storage and less sensible heat you have to increase albedo, and for Q_F you need to insulate buildings and reduce heat emissions from traffic.

We use different in situ measurements such as meteo stations and Eddy Covariance towers. Then we have models for urban structures such as urban morphology maps from which we can deduce, for example, the sky view factor. Our input scale is fine and our output scale is 100x100m. Data from satellites are either low spatial or low temporal resolution so we need algorithms to extrapolate to time series.

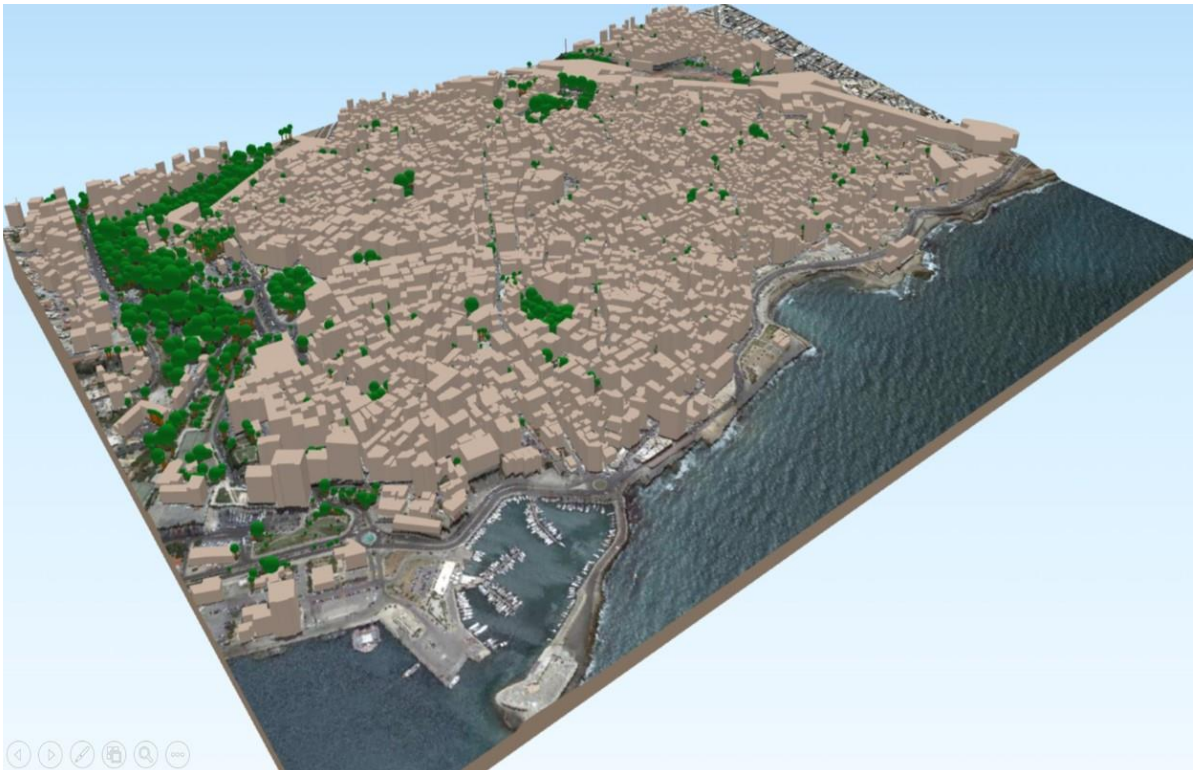

Figure: Surface morphology map of Heraklion

We use the DART model to calculate the net radiance and albedo at a fine scale. We combine different factors to derive at the Q* factor.

For heat storage we use the ESTM model to include walls as well as roofs, even though satellites only see roofs. Heat storage increases with building density and building volumes.

For the turbulent heat fluxes we use Land Surface Temperature (LST), air temperature and resistance factors to calculate the sensible heat flux.

As a result we see Q_F maps that are correlated with the presence of buildings.

Main achievements of URBANFLUXES:

- EO-based estimation of UEB fluxes and exploitation of Copernicus Sentinels in urban planning.
- Advancement of the current knowledge of the impacts of UEB fluxes on UHI and hence on urban climate and energy consumption.
- Development of tools capable of supporting strategies to mitigate these effects, improving thermal comfort and energy efficiency.
- Development of tools for monitoring and valuation of the implementation of climate change mitigation technologies, including nature based solutions.
- Support the development of Sentinels-based downstream services towards informing policy-making.

3.2 How can urban structures reduce heat? (UNIBAS – E. Parlow)

How to reduce heat in a city? Some people are investigating geo-engineering options. These efforts are ridiculous and sometimes they are also dangerous. For example, the idea to release SO_2 to reduce incoming sunlight - this is the acid rain killing our forests that we tried to get rid of a few decades ago.

What else can we do? Climate change is not proven, we can only say if it happened in 2100. But the probability is high. We may not have a Tuscan climate in London; instead it could be the London climate with more extreme events. In German cities you can clearly see the increase of heat waves, especially in inland cities like in Frankfurt and Munich it occurs every three years now. What happens in heat waves: the daily maximum temperature and the night temperature are above a threshold for a number of days. There is human stress when the night temperature is above 20 degrees. In a heat wave mortality increases, especially for elderly people. This does not include the economic impact of a heat wave yet, for example in human productivity.

The urban energy budget is like a bank account. It is not only about the income but also about spending and in the end the balance is what matters. The income consists of solar radiation. This can be reduced with shadowing, increased albedo, and reduced absorption of radiation. Redirecting the radiation into evaporation is also visible in our maps: forests and parks are cooler, they reduce the surface temperature. The difference can be 15-20 degrees between pixels. Shadowing by trees is very effective; and the tree roots can get enough water for evaporation; this is not possible with green roofs because they dry out is a week. Shadowing with canvas is sometimes done in Japan: you get less radiation but also reduced ventilation and thus an increase of air pollution; so it is only an option for pedestrian areas.

In Greece they are painting walls and roofs white: this increases the albedo. In dense areas the albedo is 75% and in outskirts it is less. For cool roofs you can paint them white; but the roof area is small. People do not want white roofs, they prefer red roofs. Now there are also innovative coatings with the same reflectivity in the visible spectrum (looking red), and in high wavelengths it is reflecting 80%.

A negative example for the effect of albedo is a neighbourhood built in the seventies in Germany (Heidelberg Emmertsgrund). The houses had green walls. This increased the albedo, and inside the temperature rose with 7 degrees, and it took a lot of time to release this heat again. Everyone left these houses after six months because it was unbearable.

How to reduce heat storage: in the day energy is stored in a city but we do not feel the difference because it adds only a few degrees. In the night the buildings release the energy, adding significantly to the air temperature while the surrounding rural areas cool off fast, and this difference is the urban heat island effect.

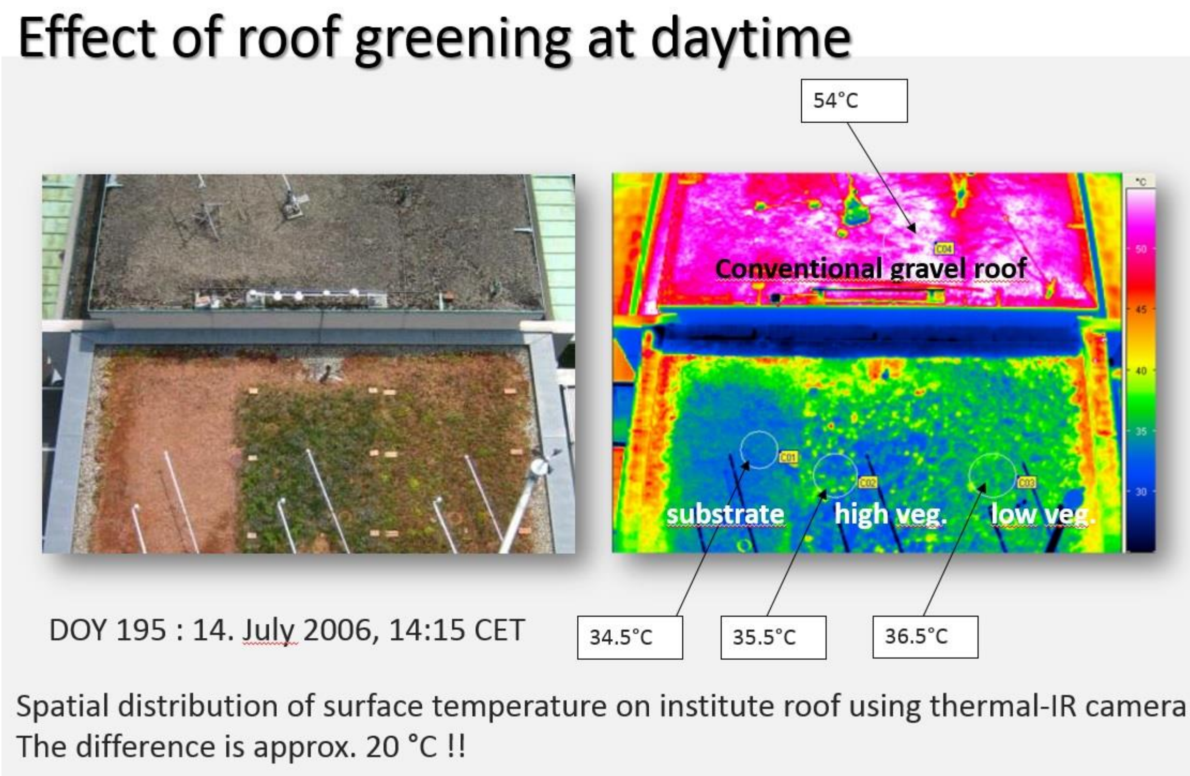

Figure: effect of green roofs on surface temperature

How can we increase the latent heat flux: with green roofs? The latent heat increase only stays when green roofs are irrigated. Green facades create shadowing, and can be helpful especially when they are rooted in the soil. Trees have a much better capacity of maintaining the latent heat because of their root system. If arid plants are used there is not much difference between green and gravel roofs. Xerophytic plants can survive in the Sahara. We compared different types of green roofs with a gravel roof. We measured availability of water and temperatures. The gravel roofs were the hottest and the green roof was cooler, even with only substrate. In the night the gravel cools quickly. The substrate also cools quickly. What is the net effect: green roofs are worse if they are not irrigated. There is only half a meter of substrate which dries out within a week. So green roofs are 'not going to change the needle'.

In Stuttgart a new regulation was made for buildings: you only get permission for a building if it functions equivalent to green roofs with irrigation.

Q: Would heat exchange with only substrate work?

I agree, irrigation of green roofs is not the solution; they reduce albedo and if there is a lack of water, it becomes a sedum desert. Irrigation costs a lot of money. Green roofs only works on flat roofs as well. Trees and parks are better.

3.3 Effects of urban structures on heat storage (UoG – F. Lindberg)

More people are living in urban areas, adding Q_F. Other main factors are the heat storage, reduced radiative cooling. In the future two-thirds of the EU population will be affected by weather related hazards. We are now already naming heat waves: the heat wave of summer 2017 in the Mediterranean was called Lucifer, and UK tourists were warned to stay off the beach. Thermal comfort is a significant factor: there are more deaths if a heat wave lasts longer.

Stone stores heat, which is based on storage capacity and conductivity of the material. Brick and stone and concrete have high values for both. Considering building materials may help to reduce the storage heat. Another factor is the amount of material: the volume of the building. During the burning man festival in the US an experiment with temperature measurements was done, Thousands of people stayed in the desert for a few weeks, with people and cars and tents and campers. But there was no urban heat island effect; there was no storage in the materials they brought: fabric, thin metal etc. The anthropogenic heat increased but you could not see any effect in the local temperature.

We did a modelling study: a change of vegetation and a change of reflectivity. In a heat wave the wind speed is decisive so without wind there is no way to conduct the heat away. There is an effect of vegetation on daytime thermal comfort: shadowing is a main effect. Less radiation makes you feel less hot. Painting the city white, however, is not a solution for pedestrians. The reflection of white surfaces on people also has a heating effect, even if the walls are cooler. White roofs are good to increase thermal comfort but white wall and ground are not.

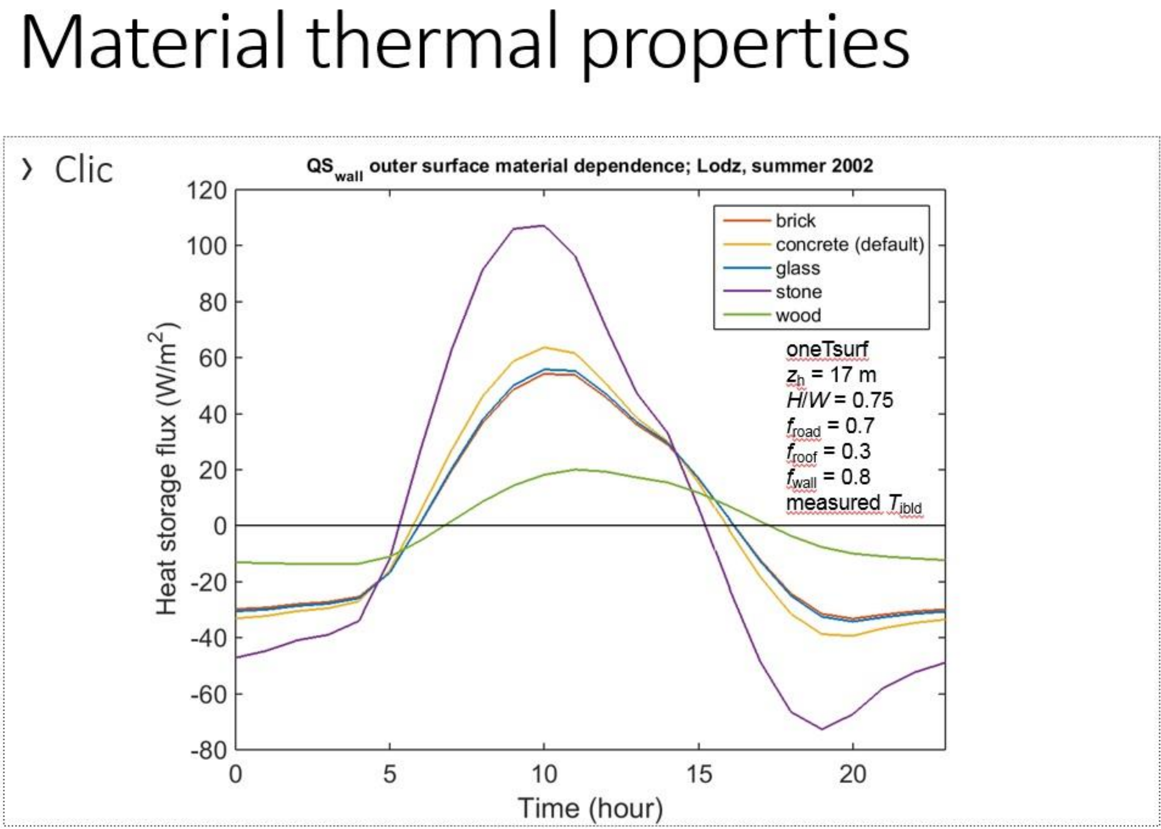

Figure: Materials with different thermal properties

In the URBANFLUXES project we modelled the volume of buildings for the storage. The city centre of London is larger with many high rise buildings and much use of concrete and steel. Streets are also hotter: asphalt can store a lot of heat. If you have parks there is less storage. You can identify hot and cool spots with the storage factor alone.

Summarizing:

- Heat storage is a night time phenomenon.
- Materials and geometry / density are the main factors for heat storage.
- Central business districts have the highest building density.
- Vegetation can be used to reduce heat storage and to increase the latent heat flux.
- Earth Observation is a challenge.

Q: How about heat storage in water?

That is complicated, water is a 3D volume that can store, but it maintains a low surface temperature, and the whole volume also contains heat. Water has a high heat capacity. And it is flowing. In the energy balance water bodies are most important for evaporation.

Q: Architects should reconsider building materials and geometry.

Yes, today many new buildings have glass surfaces which lets in the heat. This fashion should be revised. Glazing is an interesting issue because through glass even floors and inner walls can be heated up. The increase of the total volume exposed to solar radiation. Glazed buildings require more air conditioning. Concrete also has a big heat capacity, we could use lighter materials with more insulation. Bioclimatic architecture could be developed and we need principles for better architecture. The height of the buildings is also a factor: higher ceilings can create passive cooling. You can have balconies all around which also make ventilation or heating up worse. We need guidelines for planning buildings that are resistant to heat. Concerning water evaporation, we could make a system to store rainwater and then it could evaporate in the summer.

Q: Can we deduct a guideline book for architects and engineers?

Our communication about urban climate issues is often difficult to understand. We can communicate better and provide accessible tools. And planners are becoming more interested in heat issues as well. Planning guidelines are also starting to appear: keep more open spaces in municipalities. Nektarios made such a guide with others. In Greece building permit rules have recently changed but microclimate parameters were not included. Guidelines were provided by the scientific community but the ministry did not apply it. The polytechnic university of Athens and FORTH in Crete had contributed to it.

Q: What is the correlation between heat and pollution?

Pollution is mostly related to traffic, and by the ventilation / the street canyons. In hot areas you also have more pollution problems. Where more people are, you get more pollution. The heat and the pollution both increase, so if you change urban geometry you can reduce both problems.

There should be guidelines for construction of buildings and for urban design. Nektarios wrote information for Greece and it is available. Jürgen Baumüller wrote a booklet about Stuttgart, in German and in English. It is available online here: https://www.staedtebauliche-klimafibel.de/?p=0.&p2=0.. The EU could legislate but often Member States do not want more regulation. EEA publishes voluntary information for cities.

3.4 Urban Heat Emissions: what are the sources? (UoR – Grimmond)

There are three main sources of anthropogenic heat: buildings, transport and human metabolism.

There are several methods to approach anthropogenic heat:

1. Scintillometry: an Eddy Covariance tower providing frequent measurements over a part of the city. We can see more heat in winter due to heating of buildings and we see more heat in rush hour and in the daytime.

2. SUEWS modelling maps: the city centre comes out as hotter and Canary Wharf as well. There is more heat emission in winter than in summer. There are very high values in the city centre during winter compared to the incoming radiation.

3. LQF results: there are less heat fluxes in Heraklion, more in Basel and most in London.

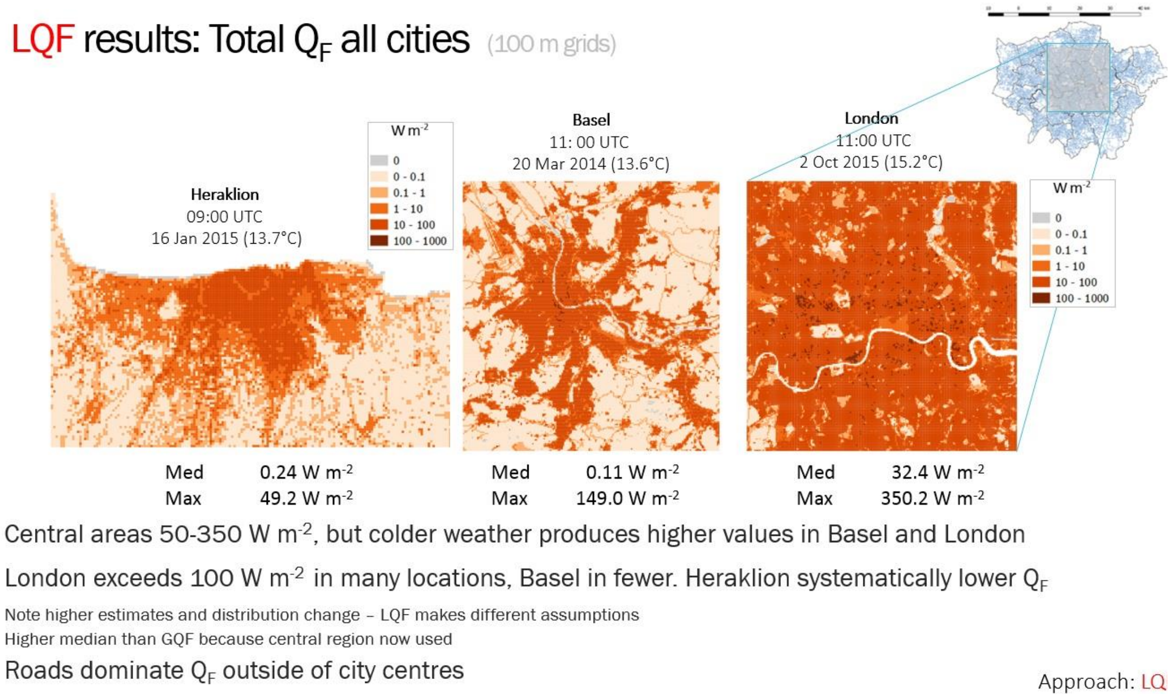

Figure: Q_F Results from LQF modelling for three cities

4. GQF results: GQF is more complete while LQF used less data input. With transport you can clearly pick out the main road. Metabolism shows where people live. In buildings the commercial areas stand out. For all of London buildings are the most important source of anthropogenic heat and domestic uses more energy outside of work hours and vice versa. GQF has the best results for mapping anthropogenic heat fluxes. Buildings most important source; we have modelled the Q_F well but it is a data rich approach. LQF cannot show workforce data. GQF could be used for London, but not for Basel and Heraklion, because of a lack of data, so

we used LQF for the other cities. We compared the outcome of the models in London and tried to improve LQF. At a 500m resolution the results start to look the same. In the centre of London the workforce can be 10x the residential density so this has a big impact on Q_F. Then we used paved surfaces to show the transportation network. It improves the maps but it is not ideal. So LQF works good for buildings apart from the central business district; metabolism results are reasonable but transport results of LQF were still poor.

Final comments:

- Anthropogenic heat emissions vary with human activity.
- Care needs be taken to compare compatible spatial information.
- Areas with the most intense anthropogenic heat emissions may be missed by a simple model.
- Road heat emissions are predicted poorly by a simple model. The paved area fraction is a poor substitute for road data.
- The simple model performed poorly at spatial resolution finer than ~1 km
- The population shift during a workday led to changes in the spatial structure of emissions.
- Emissions estimates improve with more detailed information.

Q: For areas where it is difficult to get data: could you use Earth Observation data?

LQF uses Earth Observation data and we can model any city.

Q: How can we improve from LQF to GQF? Was it improving the model?

We will get more data in the future. But below a 1km grid the results of LQF are bad and above that we are OK. Q_F varies so much over the urban space. There is a right method for the right scale.

3.5 Future possibilities for monitoring urban energy solutions (FORTH – N. Chrysoulakis)

IPCC reports estimate energy emissions in different mitigation scenarios. Only the most optimistic scenario gets us below the 1,5 degrees average temperature rise. The GDP per capita has a relation with emissions as well as fuel prices. Transformative solutions are better for the long term, even though they cost more in the short term. Many solutions have been made available: green roofs, solar panels, green belting, nature based solutions. Many options are resilient and effective but the final measures should be locally designed. The EU invested a lot in nature based solutions. These solutions also have socio-economic benefits. Can nature based solutions cool a city? A BRIDGE project experiment showed that combining trees and green roofs had the best results. Cool roofs can also help.

Figure: An old railway yard in Antwerp becomes a park for the 21st century

Earth Observation data are available at better resolution over time. Zeppelins, drones and the like can do permanent monitoring from the stratosphere. So there is a high potential. We can even monitor individuals moving with images from space. Better wall data are also under development e.g. for Manhattan. URBANFLUXES developed algorithms for downscaling of maps and material based classifications. If we combine it we can make a thermal image of buildings. The ground measurements will help to monitor fluxes in Heraklion in the future.

Conclusion: the exploitation of EO for monitoring urban energy solution, has the potential to:

- lead to new services which are easily transferable to any city, such as the evaluation of Nature Based Solutions implementation;
- support climate change mitigation planning at municipality level;
- support the smart cities concept towards building resilient cities;
- support sustainable planning strategies to improve the quality of life in cities.

Q: Indeed it is good to look for synergy between projects and extrapolate results to local and regional policies, for example climate change in Crete. We now launched a new survey to launch nature based solutions in the region. So this way projects can have an impact on concrete local and regional policies. Manchester also has interesting initiative that may be relevant for London.

3.6 Presentation of the URBANFLUXES app (GEO-K – Delfrate)

We developed an app that summarizes the result of the URBANFLUXES project. The app is not so scientific but it does provide all the links to original data for who wants it. We also want to relate more to a younger audience. We do not show a final version because interesting products are still being finalized. The app is functional for phones, iPad and laptops. The main sections are background, technology and results. For example, there is information about London. And there is information about the data, and the models used. We also show direct links to the ground measurements websites. We explain the methods used, and if people want to know more we provide links to the website. The results section shows land cover maps. It shows the percentages of land cover. It also shows the lowest and highest values for temperature.

Figure: Start screen of the URBANFLUXES app

Q: Why an app?

Because it works on a mobile phone so it is portable and attractive and easy to use. We can also make a laptop version available.

3.7 Discussion on options for reducing urban heat and energy losses in cities

Q: How can you transfer these results to another city?

We can transfer it but would take some work, for example, a ground validation of air temperature, and we need morphology maps from a city. In any case we would need some meteo data such as air temperature, humidity etc. It is not automatic; it would take some work. We could make something like the app for another city: where does urban planning need to create more ventilation? GQF is too difficult to transfer but LQF can be used anywhere. We sorted out what the best and easiest methods are. You always need to look at the local context. The methods can be applied but we still need some local data.

Q: Can you influence the planners with this? For example the materials they use?

The planners of London are interested but they do not always know what questions to ask. So we are working on it in London.

Final remark: we will make a report of this meeting and you will receive a copy. We will also send you a link to the app and the Stuttgart / Jürgen Baumüller document that Eberhard mentioned can be found here: https://www.staedtebauliche-klimafibel.de/?p=0.&p2=0.