Urban Climate News

Quarterly Newsletter of the IAUC

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From the IAUC President

Colleagues, welcome to the Spring 2017 edition of the *Urban Climate News*.

I open this issue's column by drawing to your attention the recently released IAUC Board Statement on the US Travel Ban. The statement is included in this edition of the newsletter under IAUC Board business and is also available on our website. For any international organization, and especially academic organizations, the recent US Executive Order – now in its second version – that affects travel to the United States from some countries, is of particular concern given its negative consequences for the collaborative international nature of research. In the case of the IAUC, there are potential impacts to the broad range of academic activities our members undertake that may involve travel to the US, including the upcoming ICUC-10, should the current order, or a successor, remain in effect. Thanks are due to Alberto Martilli and Negin Nazarian for their efforts to help bring this to the Board's attention.

In my own Department, there was much discussion surrounding the first version of the Executive Order, especially with respect to the upcoming American Association of Geographers' Annual Meeting, set to be held in Boston in about a week. The AAG meeting has substantial international participation and was faced with responding to these challenges in the midst of the conference organization process where abstracts had already been accepted, registration fees paid, and travel plans arranged. The AAG response to date has included refunding conference registration fees to those affected, providing a list of resources for international travellers arriving in the host city, providing facilities to allow for remote participation, and allowing for the presentation of papers and posters by a designate.

To help formulate an IAUC response, a subcommittee led by Alberto Martilli and including Negin Nazarian, representatives from the IAUC Board and ICUC-10 organizers is planning to generate discussion amongst the members on what actions we might take. To this end, we have set up a discussion forum on our website at www.urban-climate.org (see "IAUC and US Travel Restrictions" under Group Activity on the right hand side of the page) that members may join. I encourage everyone to participate so that we can provide the best response to be inclusive of all our members.

In this issue of the *Urban Climate News*, you will find the first in a new series of "special news pieces" by Paul Alexander on the 11 cities that received the 2016 C40 Cities Award for addressing climate change. The series starts by featuring the cities of Portland, USA and Melbourne-Sydney, Australia. Also included in this issue: a Feature article by Anna Mavrogianni (University College London) and co-authors on "Linking indoor climates to weather, human behaviour and building design"; two urban project reports: Martins (Université de Toulouse) et al. on "The effects of Urban Cool Island measures on outdoor climate" and Pawlak (University of Łódź) et al. "On the intensity of methane exchange between the urban surface and atmosphere"; special reports on the recent AGU and AMS conferences, a report on Tony Brazel's (ASU) lifetime achievement award along with our regular newsletter features. Thanks to David Pearlmutter and the newsletter team: Paul Alexander, Helen Ward, Joe McFadden, Matthias Demuzere and the Bibliography committee, and to all our contributors for their efforts in putting this issue together.

– James Voogt,
IAUC President

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Inside the Spring issue...

Cities are tackling climate change: let's see how

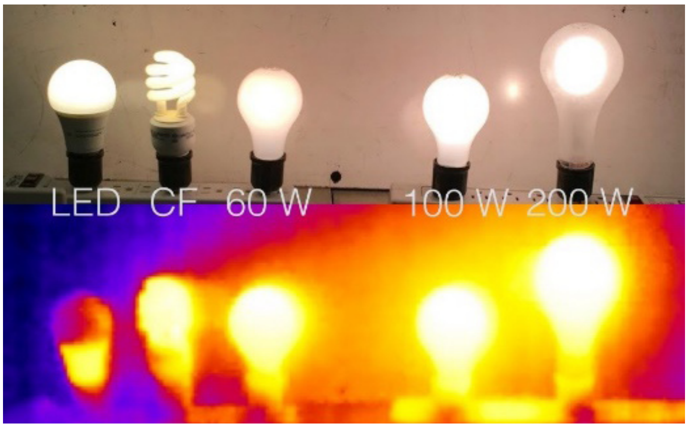
*As promised in the last edition of UCN, News Editor Paul Alexander embarks on a special series profiling the eleven winners of the **C40 Cities Award** for addressing climate change in 2016*

Category:	**Building Energy Efficiency**
Entrants (2016):	• Guangzhou, China • Melbourne & Sydney, Australia • San Francisco, USA
Winning City:	**Melbourne & Sydney** *CitySwitch Green Offices* http://www.cityswitch.net.au/

With ever increasing sophistication in modeling and observational systems, there is growing recognition within the urban climate community that the **anthropogenic heat flux** can be a significant source of energy for the urban system. Though temporally and spatially restricted, emissions of heat from buildings can be staggering. Primarily related to solar access, building materials and occupancy (specifically in relation to human thermal comfort), HVAC systems regulate the indoor climate, are a feature of most modern commercial buildings and are responsible for much waste heat production. However, when a building is owned by one entity, and occupied by another, who is responsible for monitoring and reducing waste heat emissions and energy use? How can environmentally conscious businesses who are "tenants" in commercial offices play their part to reduce waste heat emissions and improve their energy expenditure, without modifying the **physical form** of the building they occupy? This was the problem that motivated the establishment of *CitySwitch* in 2005 – a program designed to empower office "tenants" to undertake bottom-up building energy efficiency initiatives and reduce the impact of their business on the climate. A joint entry from the cities of Melbourne and Sydney won the C40 Award for Building Energy Efficiency.

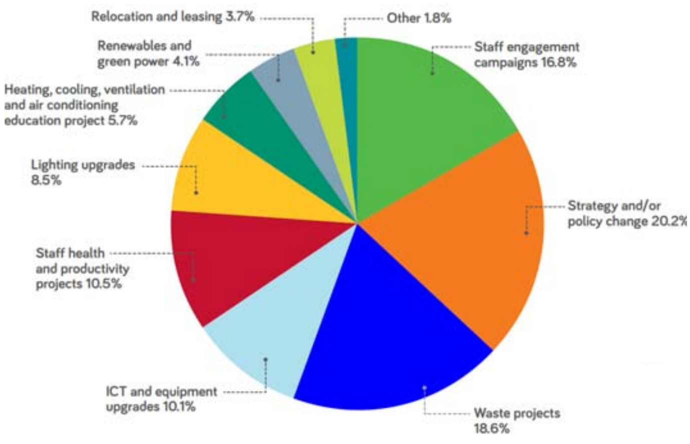
Members of the CitySwitch program have saved a combined AUS$34 million in electricity expenditure since 2011, reducing energy usage across commercial buildings in both cities, without modifying the physical form of buildings they occupy. Overall, 15% of commercial spaces across Australia have engaged with CitySwitch to date. The program is designed as a high-value no-cost service supporting commercial office tenants to improve office energy and waste efficiency through the provision of a range of services, including education, providing free online resources which deliver practical toolkits for energy and waste auditing, workbooks, case studies and engagement tools.

CitySwitch Green Offices offers a structured methodology for quantification and accounting of real, measured energy usage and waste production as well as methods for monitoring project impacts and outcomes. Members are



The most efficient bulbs produce less waste heat and more light. CitySwitch provides training and resources for reducing energy waste in office buildings in Australian cities.

incentivised and acknowledged through nationally recognised "Green-Office" awards held each year. These innovative information resources and tools, delivered through online and in-person support and training is achieving environmentally beneficial results for commercial buildings, which was recognised by C40. Additionally, finance and advice for access to incentive schemes for energy improvements are available for members, which contributes to about 20% of total energy saving projects in office spaces coordinated by CitySwitch. These **bottom-up projects** include upgrades to office lightening and ICT and equipment upgrades. CitySwitch reports that over 850 of their projects have yielded environmental co-benefits in addition to the core energy goals, specifically in relation to technology, waste and renewables.



Breakdown of projects coordinated by the "CitySwitch" Green Office, aimed at reducing CO_2 generation and energy use in Australian offices.

Category:	**Climate Action Plans & Inventories**
Entrants (2016):	• Buenos Aires, Argentina • Cape Town, South Africa • Paris, France • Portland, USA
Winning City:	**Portland** *Portland's Climate Action Plan (CAP)* https://www.portlandoregon.gov/

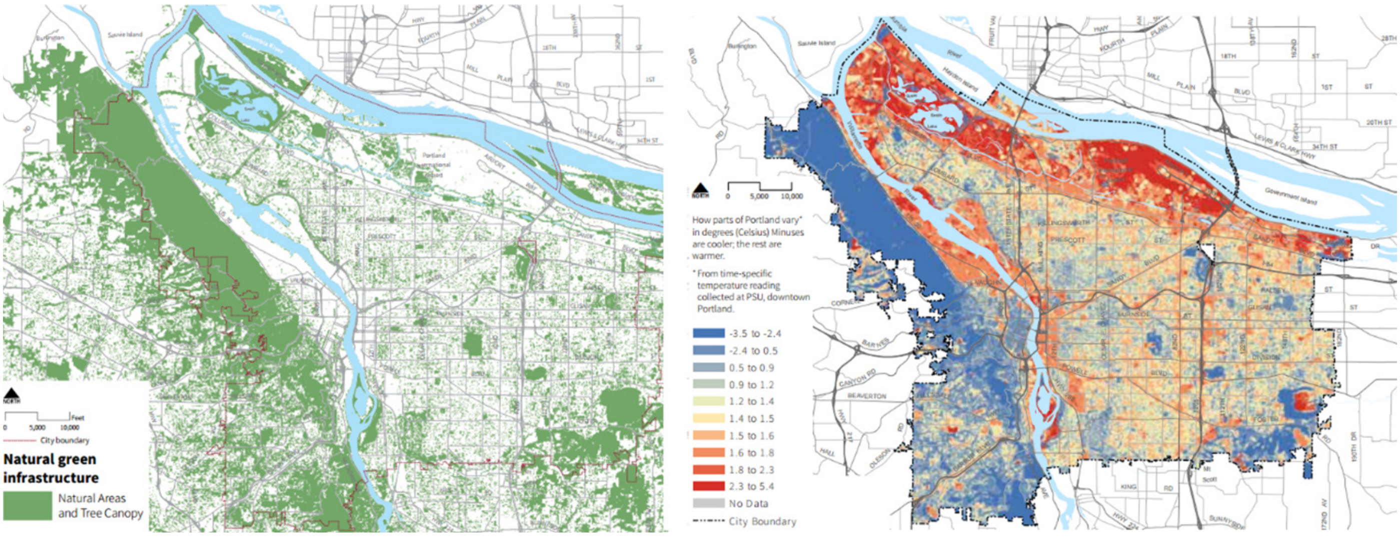
Promotion of Portland CAN! (Climate Action Now), a vision with high-level objectives to mobilise stakeholders.

'Climate Action' is increasingly becoming the preferred term by local agencies, replacing the traditional dichotomy of 'Global Warming' and 'Climate Change' which today have become somewhat politically-charged terms. Essentially, climate action refers to decisions, policies and targeted initiatives relating to preparedness and mitigation with the overarching objective of reducing impacts of climate (either present or anticipated future) on environment, society and economy. A confounding issue that faces many cities relates to responsibilities with respect to climate action: who are the actors? Who pays? What are the priorities of the action? Portland's winning entry for C40 Climate Action Plans & Inventories represents a comprehensive group of stakeholders (over 20), from industry, research institutes, NGOs, local authorities and local residents. The vision of the CAP is one which is agreed by all stakeholders: Portland city will be Prosperous, Connected, Equitable, Healthy & Resilient.

The importance of a climate vision such as this should not be underestimated. It serves to mobilise stakeholders and garners buy-in from wider groups. The CAP sets out twenty objectives to be achieved by 2030, and identifies more than one hundred actions to achieve these objectives. Overall, the principal focus of the Portland CAP is an acceleration in emission reductions from various sectors, underpinned by a comprehensive emission inventory undertaken by the Portland Bureau of Planning and Sustainability.

Actions of note with respect to the urban climate community include those which will change the urban function and are to be undertaken in the short to medium term. For example, residential retrofitting will weatherize 1,000 homes per annum, set new minimum building performance standards and simultaneously seek to repeal the City Charter weatherization prohibition. This prohibition was introduced as it was deemed to impact disproportionately on lower socio-economic groups by placing a higher burden on families with limited economic means seeking to sell their family home.

Additionally, many of the actions will impact on the urban form, for instance in zoning additional car-free portions of the city and de-paving and prioritising cycle and pedestrian routes. Additionally, the CAP heavily promotes urban development on the existing footprint of Portland city (i.e. compactness verses sprawl) and is currently establishing new green-ways (15 miles per annum as an initial target). Portland city will also seek stable funding for their cooling centres which operate during heat waves, alongside continued monitoring of the UHI and seeking to reduce the UHI effect through revegetation, tree preservation planting and maintenance, de-paving and promoting porous pavement. An assessment of population vulnerability underpins much of the CAP, with social and economic equity as a key objective of many of its climate actions.



Taken from the CAP, left: tree canopy and green areas across Portland City; right: UHI intensity (June) as deviations from temperature recorded at Portland State University.

U.S. cities vow to keep fighting climate change under Trump

March 2017 — In St. Petersburg, Florida, city planners are busy mapping out how the low-lying coastal area will cope with sea level rise. In Salt Lake City, officials are working to get 100 percent of the city's electricity from renewable sources. Out in Los Angeles, electric cars are steadily replacing conventional cars in the city-owned fleet.

These local initiatives and thousands of others were already underway when President Donald Trump took office in January. Today, local leaders say they feel even more compelled to take climate action as Trump vows to cut funding and policies related to energy and environmental protection.

"We have both an economic opportunity and a responsibility to act — no matter what President Trump does," said Matt Petersen, the chief sustainability officer of Los Angeles, the second-largest U.S. city.

"That's what we're doing now and intend to do in the future," he added. "And hopefully we'll have some partnership in Washington."

Scott Pruitt, the newly appointed head of the Environmental Protection Agency (EPA), recently said he aimed to be a "good partner" with mayors and local officials.

"Protecting the health of our citizens... is absolutely essential, and we have to do that with a keen interest to jobs and growth as well," Pruitt said at a March 2 meeting with the U.S. Conference of Mayors in Washington.

The former Oklahoma attorney general also vowed to defend certain EPA state grant programs from looming budget cuts, including those for Superfund sites and brownfields, both of which affect cities.

But he didn't mention climate change or clean energy once during the brief meeting — even though it's EPA's job to regulate greenhouse gas emissions. Pruitt, like Trump, doubts the mainstream scientific conclusion that human activity is driving global warming.

The White House's budget proposal would slice the EPA's overall budget by 25 percent to $6.1 billion and reduce staffing by 20 percent, to 12,400 employees, the Washington Post reported.

Meanwhile, on the opposite U.S. coast, Los Angeles is still carrying out its citywide sustainability plan. The city aims to bring $100 million in clean energy investments to the area by fostering startups and attracting developers, and it's seen a rapid rise in rooftop solar projects and electric-car charging stations, Petersen said.

Los Angeles is also a leading member of groups to help officials collaborate on climate policies.

It's among 12 U.S. cities involved in C40, a global network of megacities that work on everything from mass transit networks and microgrids to energy-efficient buildings and climate adaptation. Los Angeles is also

Waves caused by Hurricane Matthew pound boat docks on Cocoa Beach, Florida. *Source:* mashable.com

studying how it could reach 100 percent renewable energy, a goal that two dozen other cities have already set through a campaign driven by the Sierra Club.

Brendan Shane, C40's regional director for North America, said Trump's election sparked a "rallying cry" among mayors who were gathered at C40's Mexico City summit in late November.

"There was a pretty immediate response that we needed to maintain this whole range of actions that are going to protect people," he said. "The federal government was never going to solve this [climate] problem."

That's not to say cities and states won't be affected by deep budget cuts at the Department of Energy or sweeping policy reversals at the EPA – two changes Trump is in the process of implementing.

Many local governments have benefited from federal support. The Obama administration provided billions of dollars' worth of grants, tax credits, training and other incentives to make communities cleaner and more resilient to climate change.

While Trump could scrap funding for local climate programs, there's one thing he can't so easily reverse: the low-carbon economy.

Over the last decade, cities and states have steadily lowered their greenhouse gas emissions by making buildings more energy-efficient and supporting the growth of solar arrays, wind farms, zero-emissions vehicles and other clean technologies. States in particular have enacted standards to require utilities to get a specific portion of their supplies from cleaner sources.

Solar and wind prices have plummeted in recent years as technology improves and projects reach a massive scale. Some major utilities are expanding to include rooftop solar panels and energy-efficiency initiatives, both of which will reduce demand for coal-fired power plants.

Meanwhile, automakers are rolling out more models, at less exorbitant prices, of vehicles that don't run on diesel or petroleum. Consumers are increasingly ditching personal cars in favor of mass transit networks, carpooling services and ride-hailing apps.

These trends will help maintain some of the momentum on climate action at the local level, said Charlie Hales, who until recently was mayor of Portland, Oregon.

"I am bullish on the prospects of cities continuing to get real things done," he said.

Hales noted that Portland has cut its carbon emissions by 21 percent from 1990 levels — even as its population swelled — by encouraging residents and companies to use energy-efficient appliances, install rooftop solar systems, plant carbon-absorbing trees and avoid food waste.

As Portland's mayor at the time, Hales was among the more than 70 U.S. mayors who penned a Nov. 22 letter urging then-president-elect Trump to confront the climate crisis head-on.

"While we are prepared to forge ahead even in the absence of federal support, we know that if we stand united on this issue, we can make change that will resonate for generations," the mayors wrote.

In February, U.S. governors mailed their own letter to the White House. A bipartisan group of 20 leaders argued the wind and solar sectors are important economic engines for impoverished rural regions — the same areas Trump has vowed to revive through coal mining and oil drilling.

Local climate efforts aren't limited to progressive strongholds, like the state of California or the city of Portland. Take Florida, the political battleground state and one of the most vulnerable areas to rising sea levels and acidifying oceans.

Last fall in St. Petersburg, a waterfront city on the Gulf Coast, leaders set aside $1 million for sustainability and resiliency planning. Part of that money will go toward meeting the city's new goal of getting 100 percent of its electricity from clean energy sources.

Portlanders' preferred mode of transport: the bicycle. ***Source:*** mashable.com

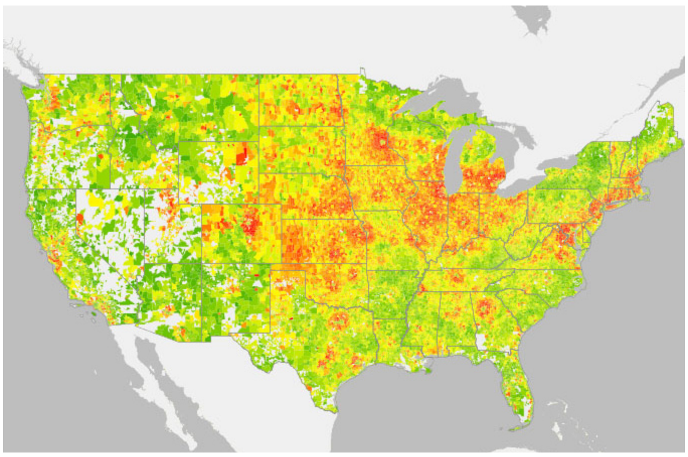
Ironically, the funding was made possible by the 2010 Deepwater Horizon oil spill. BP agreed to pay the city $6.5 million after the deadly disaster upended the region's fishing and tourism sectors and left beaches covered in goopy crude.

"It was devastating to the economy, devastating to the environment, but even more of a blow to my community," said Emily Gorman, a sustainability consultant from St. Petersburg who worked with the Sierra Club to campaign for the 100-percent target.

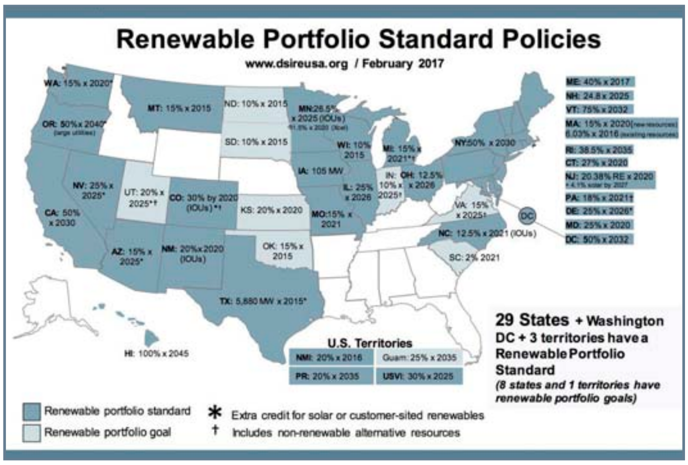
"It's a funny silver lining that we now get to take these meaningful steps to make sure these things never happen again," she said, referring to BP's oil spill.

Such initiatives will continue during the Trump presidency, even as the administration tilts policies in favor of fossil fuel producers. Still, cities and states could take even larger steps to fight climate change if the federal government was walking with them, said Hales, the former Portland mayor. "We will succeed better and faster with the help of national governments," he said.

—Maria Gallucci (http://mashable.com/2017/03/06/cities-climate-change-trump/#pQOrQ8e_wkqy)



Average annual household carbon footprint by zip code. ***Source:*** mashable.com



Renewable portfolio standard policies. ***Source:*** mashable.com

Google concludes nearly 80% of US rooftops suitable for solar

Google's 'Project Sunroof' tool reveals the vast untapped potential for rooftop solar installations in the U.S.

March 2017 — Since 2015, the project has analysed around 60 million buildings across the U.S. concluding that 79 per cent are technically viable for generating solar power.

In sunnier states, including Hawaii, Arizona, New Mexico and Nevada, up to 90 per cent of rooftops are viable, while in states like Pennsylvania, Maine and Minnesota around 60 per cent of rooftops are suitable.

According to the data, Houston in Texas has the most solar panel potential of any U.S. city, with an estimated 18.9 gigawatt hours (GWh) of rooftop solar generation potential per year, just ahead of Los Angeles, Phoenix, San Antonio and New York.

The data suggests that if the top 10 U.S. cities for solar potential installed their full solar photovoltaic (PV) capacity, they would produce enough energy to power eight million homes across the U.S. each year.

The tool uses data from Google Maps and Google Earth, combined with 3D modelling and machine learning for the research, while calculating and taking into account weather patterns and the position of the sun at different parts of the year.

The tool's search function allows users to find the solar electricity potential of individual roofs.

In addition, Project Sunroof advises on the best size solar installation for your property, estimates how much energy it will generate and how much it would cost to buy or lease the panels.

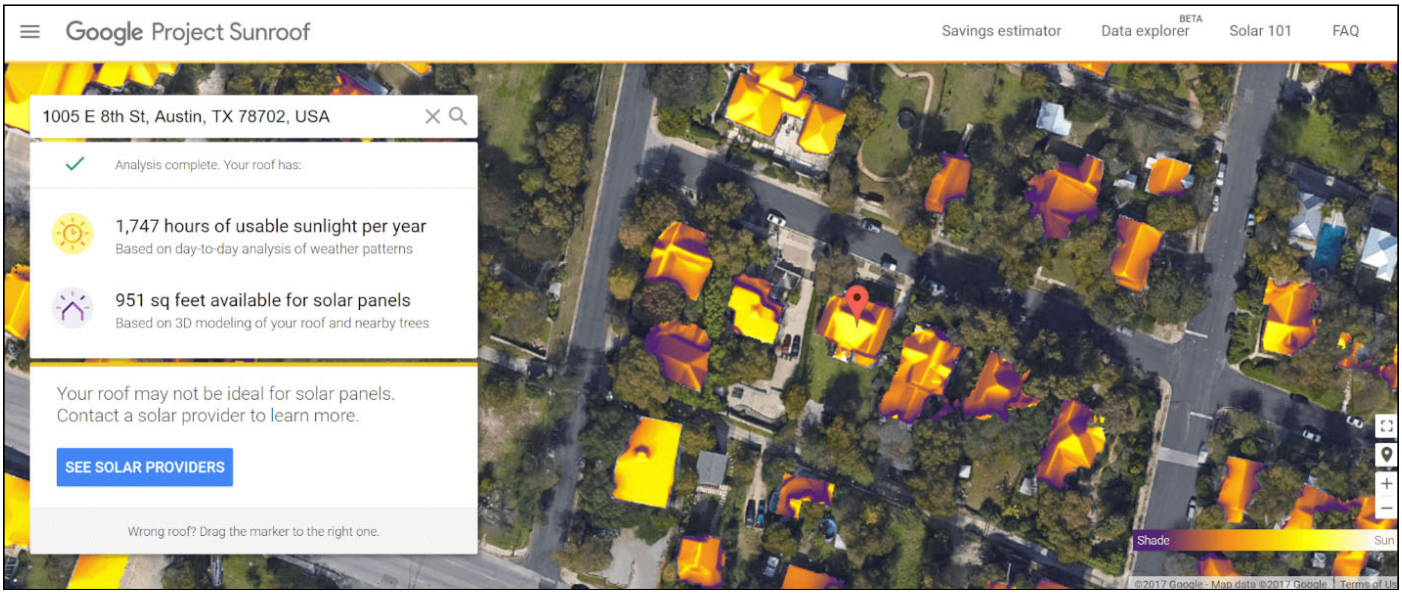
The large amount of data being collected makes the tool useful to not only consumers but also for solar companies looking to attract customers as well as academic researchers.

Google itself is aiming to source 100 per cent renewable energy to power its business and operations this year, making it one of the largest purchasers of renewables in the world.

Furthermore, a growing number of cities are committing to 100 per cent renewable energy targets.

Last month, Pueblo, Colorado, and Moab, Utah, became the 22nd and 23rd cities in the United States to commit to 100 per cent renewable energy targets.

Earlier that month, the state of Massachusetts announced a bill that commits the state to meet all of its energy needs from renewables by 2050. *Source:* http://www.climateactionprogramme.org/news/google_concludes_nearly_80_of_us_rooftops_suitable_for_solar



Screenshot of the Sunroof tool. ***Source:*** http://1u88jj3r4db2x4txp44yqfj1.wpengine.netdna-cdn.com/wp-content/uploads/2017/03/Google-Project-Sunroof-screenshot.png

Species appears to evolve quickly enough to endure city temperatures

Study shows acorn ants rapidly adjust, suggesting the insects may be able to cope with other sources of warming, including climate change

March 2017 — The speed at which a tiny ant evolves to cope with its warming city environment suggests that some species may evolve quickly enough to survive, or even thrive, in the warmer temperatures found within cities, according to a new study by researchers at Case Western Reserve University.

Evolution is often thought of as a process that takes millennia, but urban acorn ants collected in Cleveland have taken no more than 100 years to adjust to their heat-trapping home of asphalt and concrete steeped with waste heat from cars and buildings -- although their tolerance to cold was reduced.

The researchers' findings are published online in the *Biological Journal of the Linnean Society*.

"Ants are an indicator species, and by comparing the physiologies of urban versus rural ants, we can get an idea of whether ants and other cold-blooded animals will be able to cope with the temperature changes associated with urbanization and other sources of warming like global climate change," said Sarah Diamond, assistant professor of biology at Case Western Reserve and the study's lead author.

Diamond worked with Ryan Martin, assistant professor of biology, research associates Lacy Chick and Stephanie Strickler, and PhD student Abe Perez.

Cities tend to be a couple of degrees warmer than surrounding rural areas. To determine whether animals evolve or simply adjust to added warmth, the research team collected and compared acorn ants from the city and nearby rural land.

The acorn ant (*Temnothorax curvispinosus*) is widespread and important for decomposing organic material in urban and rural environments across the United States. This species of ant is smaller than a cookie crumb; an entire colony of 250 can fit in a single acorn.

The researchers collected colonies from within the city of Cleveland and as far as 28 miles east from the Holden Arboretum in suburban Kirtland, Ohio, to study in Diamond's lab.

To isolate evolutionary change from short-term acclimation, groups of rural and city ants were raised in warmer city temperatures for about 10 weeks. Other groups from both locations were raised in cooler rural temperatures for 10 weeks.Tests of thermal tolerance showed all the ants acclimated.

"They're very plastic," Martin said. "But ants collected from city habitats retained their higher heat tolerance and loss of cold tolerance compared to rural ants, regardless of whether they were born and reared under warm or cool temperatures."

Acorn ants evolve quickly to adjust to living in heat-trapping cities. The capability that may prove essential to enduring other sources of rising temperatures, such as climate change. *Source:* sciencedaily.com

Martin and Diamond believe the Cleveland ants evolved as the city became and remained highly urban during the last 100 years. Because egg-laying queen ants live from five to 15 years, the evolution to heat tolerance likely took no more than 20 generations, the researchers estimated.

With temperatures predicted to rise at least a couple of degrees Celsius over the next century, "Global data suggests that the acclimation response won't be enough to respond to climate change, but some species, like the acorn ants, may evolve quickly enough," Diamond said.

The researchers suggest this experiment can be repeated with other species in cities around the world.

Whether other species can adapt as rapidly to cities and other sources of temperature change is unknown but remains an important question for researchers trying to predict what future biological communities will look like and how they will function, Diamond and Martin said. *Source:* https://www.sciencedaily.com/releases/2017/03/170307130801.htm

More than 100 Chinese cities now above one million people

March 2017 — China now has more than 100 cities of over one million residents, a number that is likely to double in the next decade.

According to the Demographia research group, the world's most populous country boasts 102 cities bigger than 1 million people, many of which are little known outside the country – or even within its borders. Quanzhou, for example, on the south-east coast of China, was one of the most cosmopolitan cities in the world a millennium ago, when it served as a hub for traders from across Asia and the Middle East. It is now home to more than 7 million people, nearly 800,000 more than Madrid.

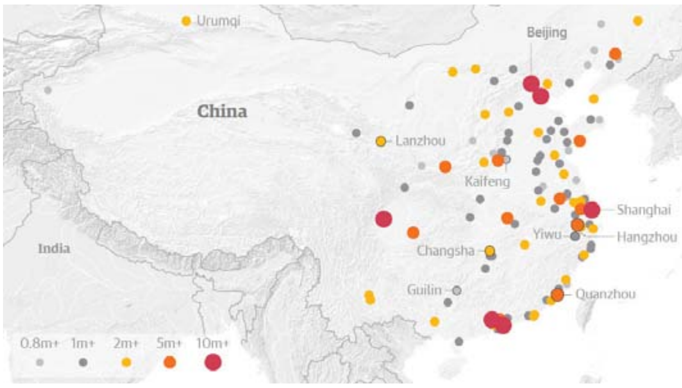
But while Madrid is a cultural powerhouse and the centre of Spanish politics, Quanzhou, with its 1,000-year-old mosque and charming cafes, is rarely discussed even within Chinese media, whereas Beijing, Shanghai and Hong Kong continue to get most of the headlines.Outside China, meanwhile, few will even have heard of Kaifeng, a former imperial capital that was once a terminus on the Silk Road, or Weihai, both cities bigger than Liverpool (estimated population of urban area 880,000).

The scale of China's urban ambitions is staggering: it now has 119 cities bigger than Liverpool. By 2025, according to a report by the McKinsey Global Institute, that number is predicted to have more than doubled.One reason is that the government is actively encouraging rural residents to urbanise. China aims to have 60% of its people living in cities by 2020, up from 56.1% currently, and the World Bank estimates a billion people – or 70% of the country's population – will be living in cities by 2030. Thousands of government officials have campaigned across the country to convince farmers to move to newly built urban districts, turning centuries-old villages into ghost towns.

Another factor? China's centre is moving west. Guiyang, for example, topped a few lists of the best-performing Chinese city last year, as the once-sleepy capital of the country's poorest province saw a boom in cloud computer servers and telecommunications, with e-commerce giant Alibaba a major investor. Factories are moving inland from the coastal regions in droves. Xiangyang and Hengyang, both now home to more than 1 million people, are swelling as low-end manufacturing moves to cities with cheaper labour.

The local government in Zhengzhou, for its part, transformed a dusty patch of land in central China into an industrial park overnight; Foxconn, the world's largest contract electronic manufacturer, now makes about half of all iPhones there and has also built a plant in Hengyang.

Meanwhile, as factories flee the expensive coasts, others have been forced to the traditional manufacturing hub of Guangdong province, especially in industries such as textiles and low-end electronics. This shift to cities is unprecedented in modern Chinese history. For decades, the ruling party wanted to keep rural residents out of cities. They used a household registry system – known as a hukou – that meant people could only receive healthcare, education and other social services in the location where they were registered. Now, however, officials eager to entice farmers into cities are offering them an urban registration with the promise of better benefits.



China has 119 cities with a population above 880,000.
Source: theguardian.com

The result is that urban centres of all sizes are forecast to grow, and by 2025 China will have 221 cities with a population of at least 1 million, according to the consultancy firm McKinsey. That will mean an explosion in construction of buildings, roads and transport systems.Many people worry that many of these newly minted metropolises will lose their character – the Chinese government has set a target for 30% of buildings to be prefabricated in the next 10 years. Newly built apartment blocks already have a cookie-cutter feeling, with identical 30-storey buildings visible from the window of nearly every high-speed train ride. The uniform construction can create an eerie scene, one city indistinguishable from the next.

Measuring the population of a city in China is not an exact science. Chinese cities often administer sizeable rural areas beyond the city centre and surrounding suburbs, and the Chinese word for city – shì or – is typically used to describe a sub-provincial region. Rolling mountains and hundreds of miles of the Great Wall lie within Beijing's official boundary, for instance, and nearly all Chinese municipalities contain at least one rural county within the city limits.

In one extreme example, Chongqing municipality covers an area almost the size of Austria, but the urban area covers only about a quarter of that, according to Demographia. Analysis shows that while the total population living within the city limits is close to 50 million, only about 7.4 million people live in the urban area.

Another issue is that Chinese cities are growing so large that it has become difficult to determine where one begins and another ends. Guangzhou, formerly known as Canton, has an underground line that snakes into the neighbouring city of Foshan. Does that make it one city or two?

The government is currently attempting to tie Beijing with two neighbouring regions, the city of Tianjin and Hebei province, to create the megacity of Jing-Jin-Ji – and recently approved a £29bn railway to improve transport links. The resulting megacity will have a combined population of more than 100 million, and cover an area twice the size of South Korea.

Source: https://www.theguardian.com/cities/2017/mar/20/china-100-cities-populations-bigger-liverpool

Linking indoor climates to weather, human behaviour and building design





By Anna Mavrogianni[1] (a.mavrogianni@ucl.ac.uk) Jonathon Taylor[1], Phil Symonds[1], Mike Davies[1] and Paul Wilkinson[2]

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Introduction

In recent years there has been a growing interest in the effects of indoor environmental conditions on human health and wellbeing. In light of the overwhelming evidence that our climate is warming and the current projections of anthropogenic climate change, there has also been an increasing interest in the potential overheating risk of buildings in previously heating-dominated climates, and the potential synergies between extreme heat and air pollution. This is of particular concern in cities, where the impacts of climate change will be magnified due to the Urban Heat Island effect (UHI).

The influence of indoor environmental quality on human comfort, morbidity and mortality remains a relatively under-researched area to date. There is a wealth of epidemiological studies exploring the relationship between outdoor exposure and health outcomes; however, the link between indoor environmental quality and health is less well understood to date. Taking into consideration that the UK population spends around 90% of their time indoors, it is essential to quantify the impact of building attributes and the occupant's interaction with the building on individual exposure to temperature and pollution-related health risks (Vardoulakis et al. 2015).

This article summarises a series of studies of the interlinkage between the built environment and comfort and health outcomes. In particular, our work quantifies the potential modifying effect of residential building fabric characteristics on occupant thermal comfort and indoor air quality whilst also exploring the relative importance of human behaviour on exposures to indoor heat and air contaminants. These studies form part of ongoing work that aims to enhance our understanding of the links between building design characteristics, human behaviour and indoor climates in the UK from the perspective of human health, comfort and wellbeing.

Methodological approaches

Occupant exposure to air pollution (generated internally as well as coming from outdoors), and excess temperatures (overheating) in domestic settings have been quantified using both modelling and monitoring approaches.

Development of housing stock energy use and indoor environment models – Building stock modelling has been used to explore the variations in indoor environmental conditions across the UK housing stock (Kavgic et al. 2010). From a methodological point of view, this has included the development of both sample (Mavrogianni et al. 2009) and archetype (Taylor et al. 2016, Symonds et al. 2016) models. With regard to modelling scale, citywide models built for London have looked into the impact of local urban temperatures as a result of the UHI effect and building fabric characteristics on domestic space heating demand and overheating (Mavrogianni et al. 2009, Oikonomou et al. 2012, Mavrogianni et al. 2012, Mavrogianni et al. 2014, Taylor et al. 2015a), whereas national models (Taylor et al. 2015b, Taylor et al. 2016, Symonds et al. 2016, 2017) have been designed to evaluate more broadly the impact of urban stock transformations, housing energy retrofit strategies and urban greening on indoor environmental quality and health.

Local urban climate data from the LUCID project (Mavrogianni et al. 2011), which studied the London UHI, was integrated with Geographic Information System (GIS) based building energy modelling. This created a novel localised space heating demand prediction model for UK urban housing that allowed the map-

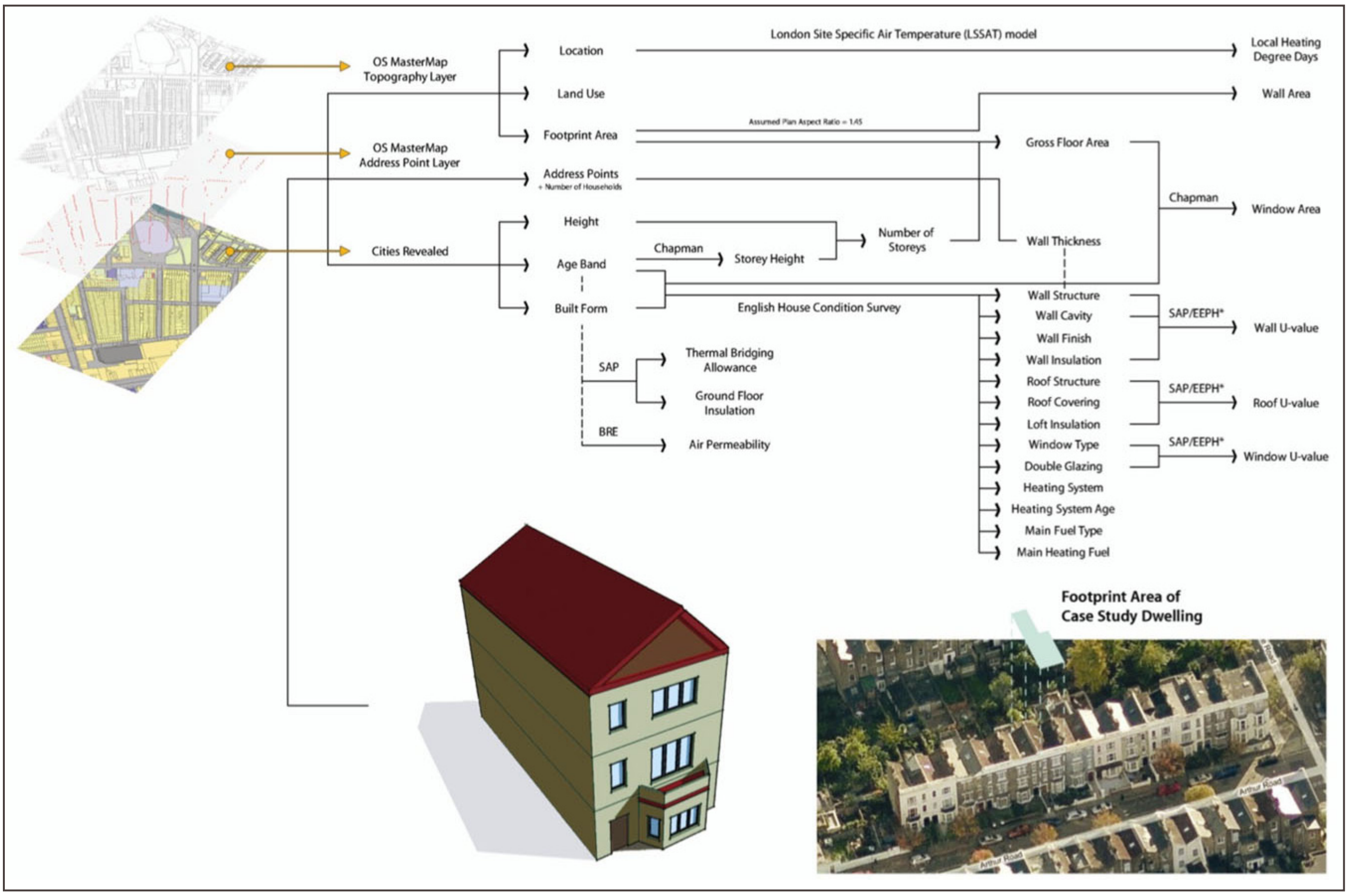


Figure 1. Inference of missing building fabric characteristics.

ping of energy demand variation across London (Mavrogianni et al. 2009). This GIS model used a sample approach to electronically visit individual dwellings in a map and infer their physical properties by interrogating a combination of housing survey databases (Figure 1). Subsequent London housing models used the archetype approach by creating a notional stock comprising 3,456 combinations of building geometry, orientations, urban patterns, fabric retrofit and external weather. These archetypes are shown in Figure 2 and were generated based on the literature describing representative dwelling types of different British architectural eras, as discussed in Oikonomou et al. (2012). Building on these archetypes, a set of nationally representative dwellings were created by statistically analysing national housing surveys and databases (Taylor et al. 2016, Symonds et al. 2016).

A combination of GIS databases, housing surveys and other sources were synthesised for the purposes of the model development outlined above, mainly including:

- The Ordnance Survey (OS) MasterMap Topography and Address Point layers
- The GeoInformation Group Building Class dataset
- The English Housing Survey (EHS)
- The Energy Saving Trust (EST) Home Energy Efficiency Database (HEED)
- The Office for National Statistics (ONS) Census and mortality data
- The Department for Environment, Food and Rural Affairs (DEFRA) Rural Urban Classification
- The Government's Reduced Standard Assessment Procedure for the Energy Rating of Dwellings (RdSAP)

The core calculation engine for these models is the building performance simulation software EnergyPlus, and for the sample model described in Mavrogianni et al. (2009), the RdSAP algorithm. Metamodelling frameworks based on the analysis of a large number of EnergyPlus runs were developed using multiple linear regression analysis (Mavrogianni et al. 2017) and Artificial Neural Networks (ANN, Symonds et al. 2016). These meta-models facilitate the rapid calculation of occupant exposures to indoor overheating or pollutants by using a small number of inputs. The workflow diagram of the model described in Symonds et al. (2016) is shown in Figure 3.

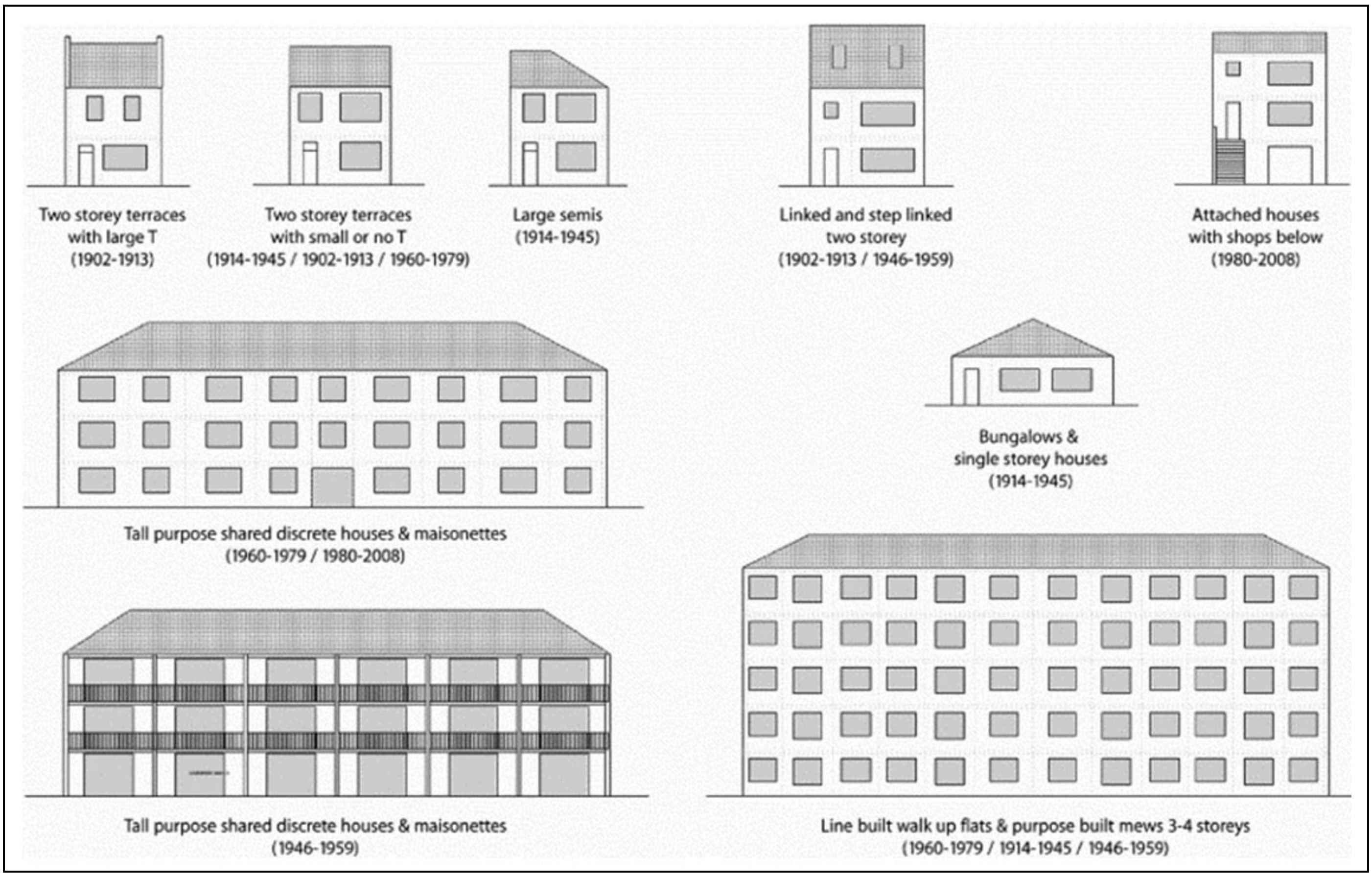


Figure 2. London dwelling archetypes. (Source: Oikonomou et al. 2012)

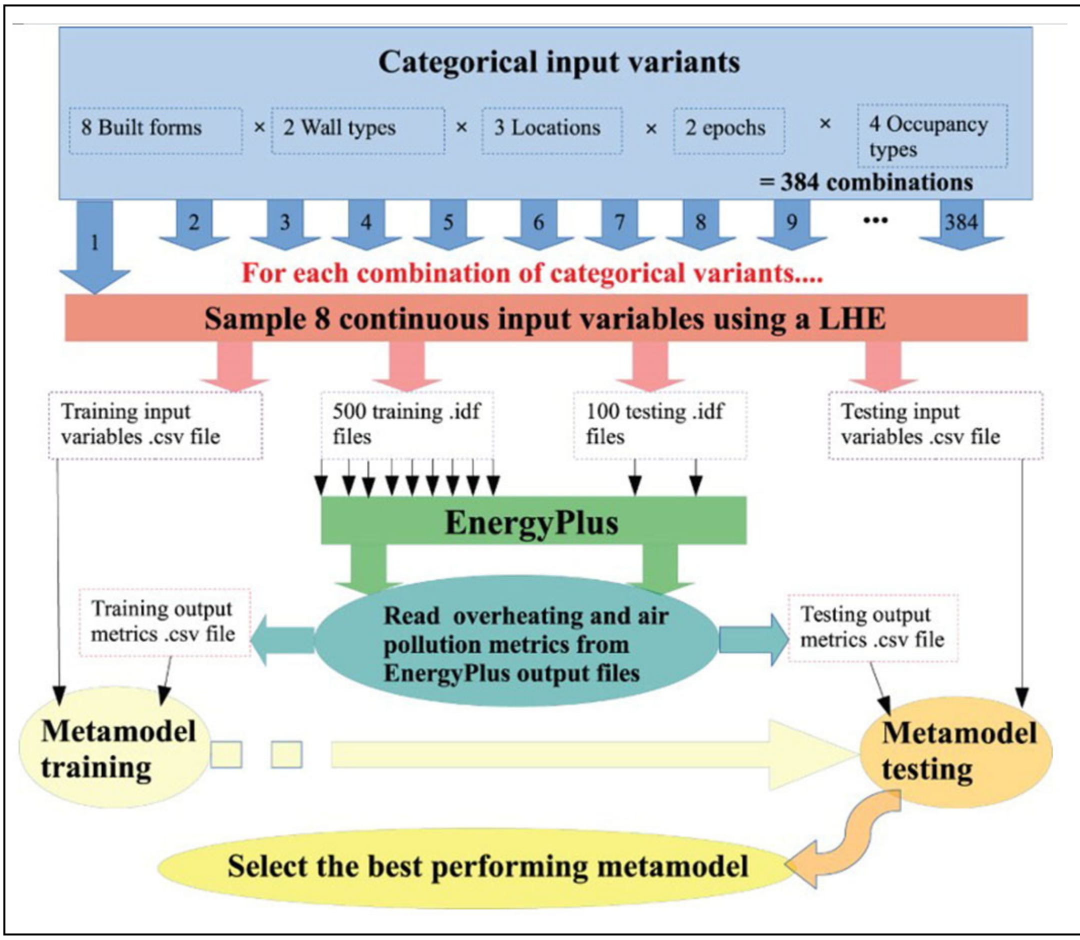
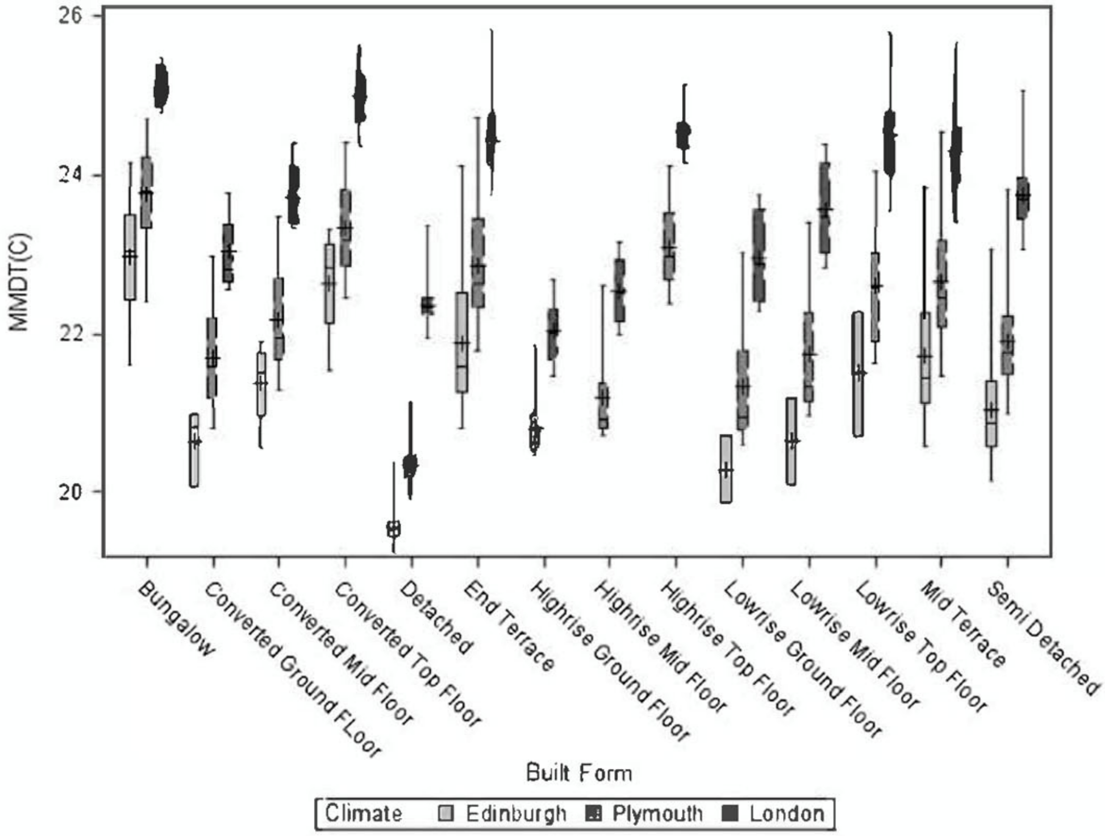
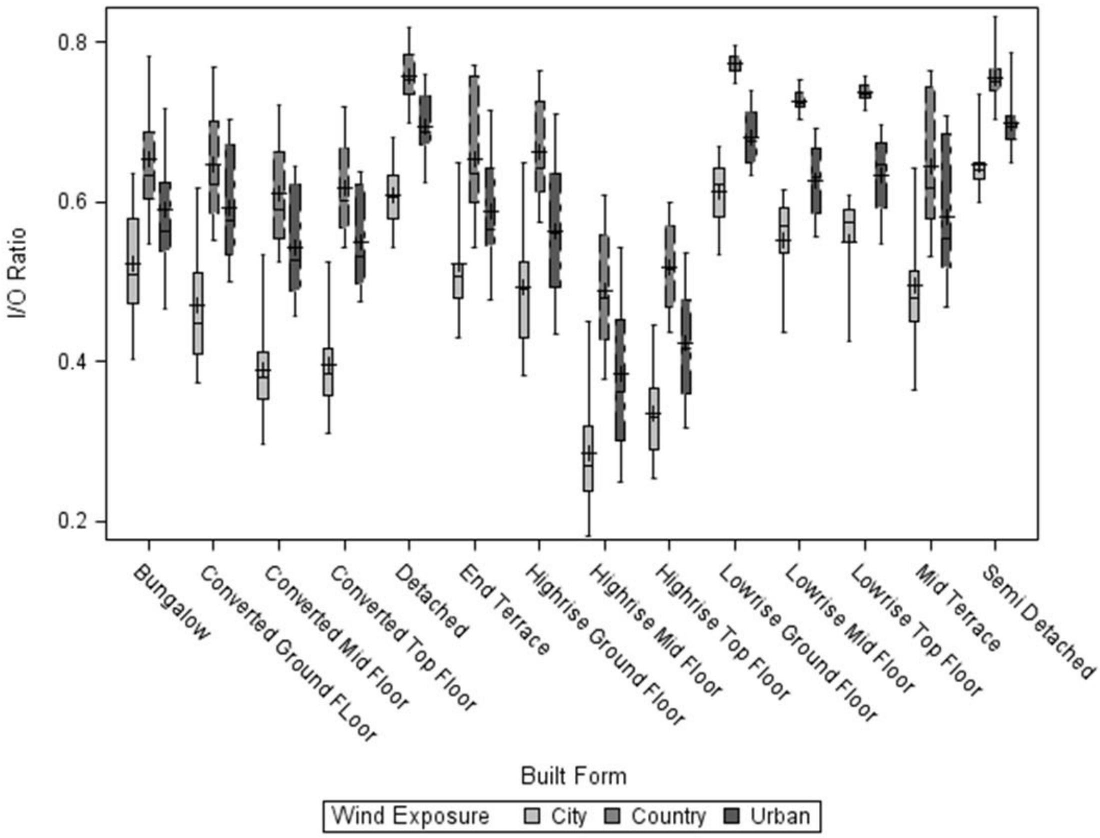


Figure 3. Workflow for the development of a national indoor overheating, air quality and energy use model. (Source: Symonds et al. 2016)



(a)



b)

Figure 4. a) Mean Maximum Daytime living room Temperature (MMDT, °C) by location, and b) I/O ratios (the ratio of the indoor concentration of air pollution from outdoor sources to the concentration of outdoor air pollution) for $PM_{2.5}$ by terrain, for the pensioners' occupancy assumption in the different dwelling types. Average values are represented by a +.

Monitoring of the indoor environment – Monitoring data of indoor environmental conditions has been used to test and calibrate the housing stock models described in the previous section. For example, measured daily indoor temperatures from the EHS Energy Follow-Up Survey (EFUS) for 823 nationally representative dwellings were compared with the predictions of the Taylor et al. (2016) and the Symonds et al. (2016) model. A monitoring study of internal overheating in 122 London dwellings was also undertaken during the summers of 2009 and 2010 (Mavrogianni et al. 2016, Pathan et al. 2017). Whilst the participating dwellings were a convenience sample of University College London (UCL) staff and students, a wide range of different dwelling types (detached, semi-detached, mid-terraced house and purpose-built flat) and a large spread of locations across the Greater London Area (GLA) was achieved. Two data loggers (HOBO U12-012) were installed in each dwelling measuring Dry Bulb Temperature (DBT, °C) and Relative Humidity (RH, %) at 10-min intervals in the main living and sleeping areas. Part of this dataset was used to test the prediction of the Mavrogianni et al. (2016) multiple linear regression model of overheating risk.

Study of human behaviour – Occupant interactions with building systems and components were also studied alongside the monitoring of the indoor environment outlined above. A questionnaire survey investigated the occupants' interaction with passive and active ventilation, cooling and shading systems in the London monitored homes (Mavrogianni et al. 2017).

Key findings

Modelling occupant exposure to indoor overheating and air contaminants across Britain – The modelling of the London dwelling archetypes in Figure 2 showed that the housing types most prone to overheating are top-floor flats, buildings with only one external façade, no shading, and very high or very low insulation levels. It was also found that internal wall insulation may increase indoor temperatures if the property is not sufficiently ventilated (Mavrogianni et al. 2012) and that indoor overheating is determined more by the characteristics of a dwelling than its location within the UHI (Oikonomou et al. 2012). The modelling framework outlined above has also allowed the mapping of relative excess indoor heat and air pollutant exposure levels for domestic environments in Britain (Figures 4 and 5, Taylor et al. 2016). By examining air pollution levels across

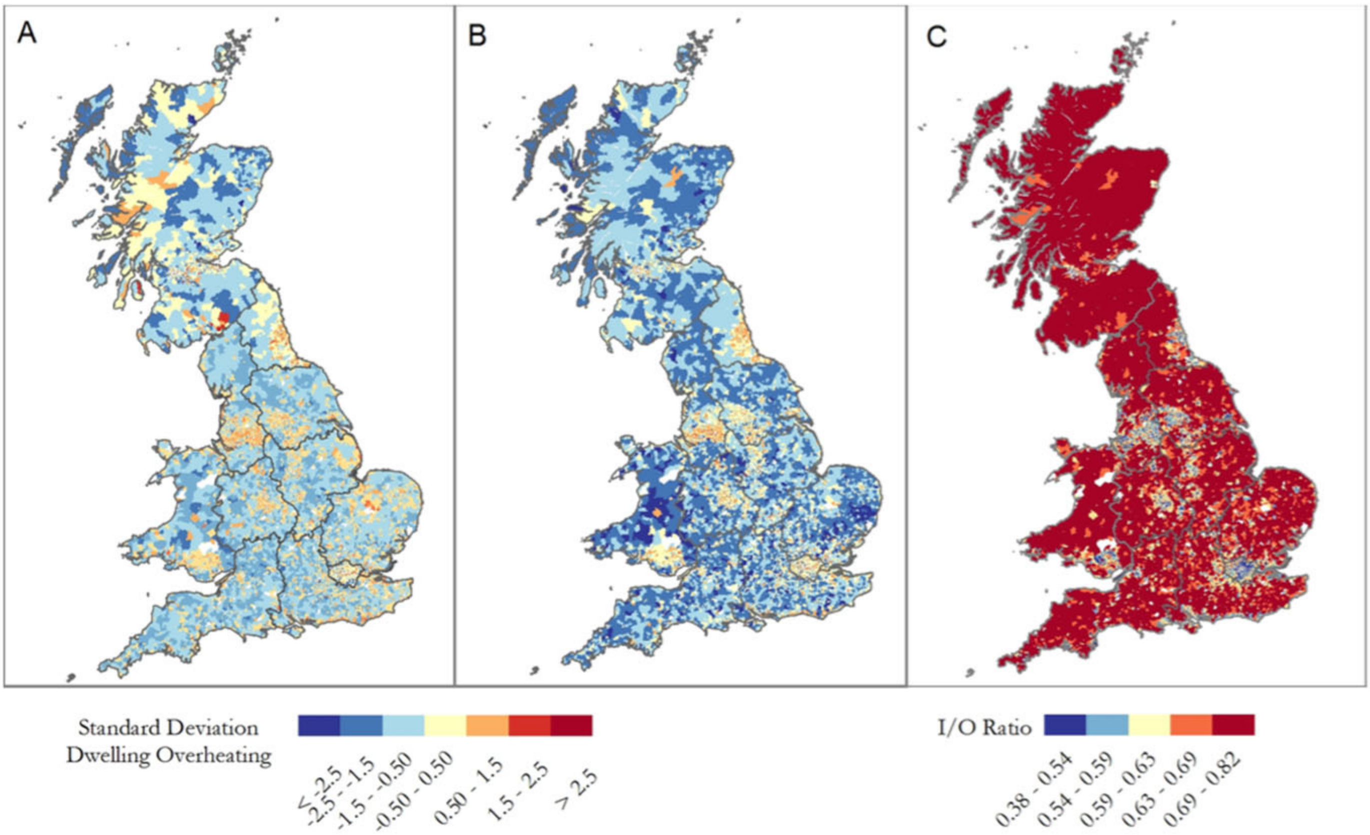


Figure 5. A) Standard deviation of Mean Maximum Daytime living room Temperature (MMDT, °C) from the Government Office Region (GOR) average, B) Standard deviation of Mean Maximum Night- time bedroom Temperature (MMNT, °C) from the Government Office Region (GOR) average, and C) I/O ratios for $PM_{2.5}$, for the pensioners' occupancy assumption aggregated at the Lower Super Output Area (LSOA) level.

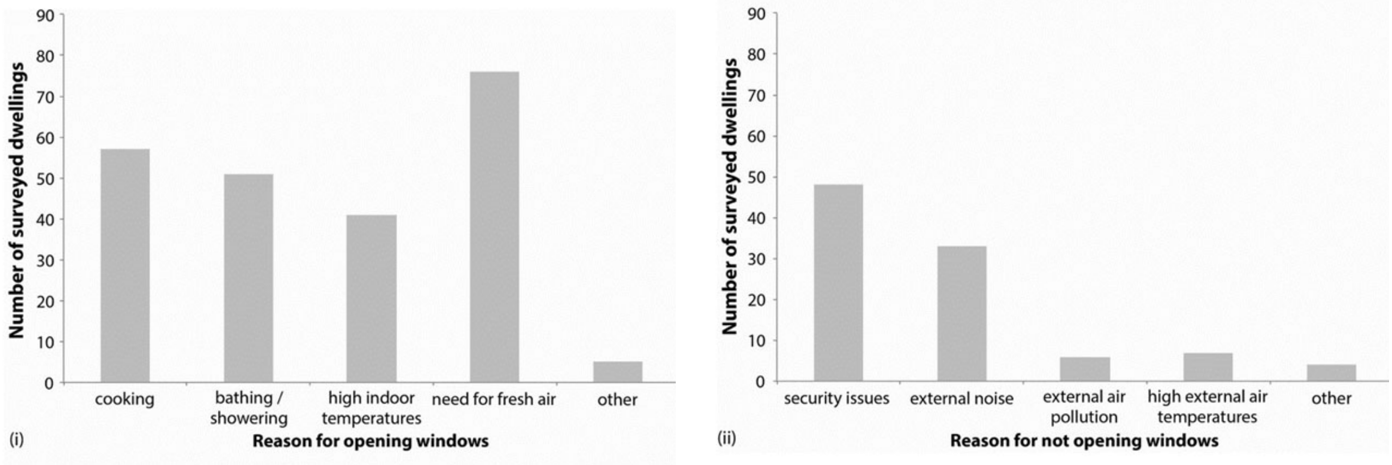


Figure 6. Drivers (i) and barriers (ii) to summertime natural ventilation in the surveyed dwellings.

different structure types, it was found that people living in flats and newly built properties are exposed to lower indoor air pollution from outdoor sources, but higher air pollution from indoor sources. In terms of indoor overheating risk, flats, bungalows and more recently constructed, highly airtight dwellings were amongst the building types that were most at risk. As a result, people living in cities are on average exposed to higher levels of overheating and indoor air pollutants due to the higher number of flats in urban areas.

Monitoring of summer indoor temperatures in London dwellings – The modelling results were corroborated by the findings of the monitoring study. It was demonstrated that London homes and, in particular, bedrooms are already at risk of overheating during periods of hot weather even under the current climate (Pathan et al. 2017, Mavrogianni et al. 2017). The monitored data was analysed using the ASHRAE Standard 55 adaptive thermal comfort criteria, which uses outdoor temperature to derive the optimum indoor comfort temperature. It was shown that 37% of all living rooms and around half of all bedrooms monitored during 2010 had more than 1% of summertime occupied hours outside the comfort zone recommended by the standard to achieve 90% acceptability. However, comparing the Taylor et al. (2016) and Symonds et al. (2016) model against the EHS Energy Follow-Up Survey (EFUS) datasets demonstrated that as a result of the lack of detailed information on the characteristics of individual dwellings and occupant behaviour, the models are not capable of accurately predicting maximum temperatures and are, therefore, less reliable on very hot days. As shown in previous modelling work (Mavrogianni et al. 2014), occupant behaviour, in particular ventilation habits, is a determinant factor of overheating risk.

Self-reported occupant behaviour at home during periods of hot weather – Indeed the analysis of the questionnaire survey results demonstrated that actual behaviour can deviate considerably from common modelling occupant behaviour assumptions. Around 70% of participants in the questionnaire survey responded that they tended to open only one or no windows during night-time primarily due to security reasons (Figure 6). Such concerns may hinder the adoption of best practice night purge cooling strategies in dense urban environments such as London.

Perspectives

Monitoring and modelling studies have shown that occupant exposure to excess internal temperatures in urban environments will increase in the future as a result of climate change and UHI effects. It is imperative, therefore, that climate change adaptation strategies are embedded in Building Regulations and best-practice building design and retrofit guidelines. The impacts of energy retrofit decisions, such as increased airtightness, on indoor air quality also need to be considered.

Existing epidemiological studies tend to focus on the impact of external rather than internal environment on health risk. The novel housing stock models outlined above isolate the contribution of the building fabric on indoor overheating and pollution risk and associated health hazards. These models can function at the national level, using sophisticated physics-based modelling frameworks and national housing survey databases. They can be useful tools to local government decision makers and public health policymakers who aim to evaluate the impact of housing, energy, transport and air pollution policies on population health. However, there are high levels of uncertainty associated with the occupant behaviour assumptions of these models. Further research is needed to compile detailed, nationally representative information on the way people in Britain use their homes.

Acknowledgements

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On the intensity of methane exchange between the urban surface and atmosphere: Are cities comparable sources of methane to wetlands?

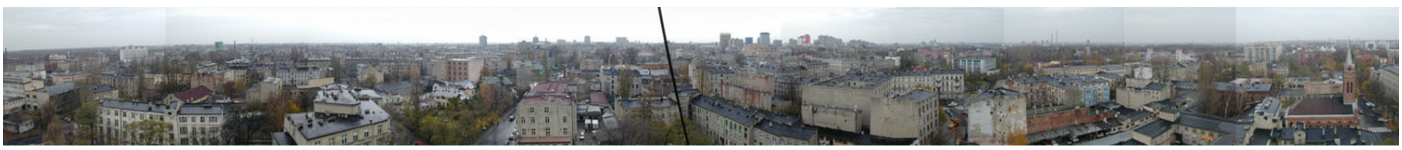
Introduction

Urban climate research in the city of Łódź has been conducted for several decades. Over this period, we have completed a number of research projects relating to, among others, features of the urban heat island, solar radiation distribution within the urbanized area and turbulent exchange of mass, energy and momentum (Kłysik and Fortuniak, 1999; Offerle et al., 2003; 2005; 2006a; 2006b; Podstawczyńska; 2010; Fortuniak et al., 2012; Fortuniak and Pawlak, 2014). Since 2006, we have also measured carbon dioxide fluxes (FCO_2) in the city (Pawlak et al., 2011). Such long-term measurements are carried out in only 10-15 cities around the world and one of the results is determination of the relation between the percentage of artificial surfaces and the intensity of the CO_2 exchange between the urban surface and atmosphere. It is also known that the temporal variability of FCO_2 in urban areas is significantly different in comparison with areas covered with vegetation, both natural and agricultural. In 2013, we started measurements of methane fluxes (FCH_4) in the centre of our city. Since such research is undertaken extremely rarely (Nicolini et al., 2013; Christen, 2014), the main goal was the analysis of the temporal variability of FCH_4 and determination of the annual methane exchange. At the same time we started measurements of methane fluxes on the largest Polish wetland (Biebrza National Park). Wetlands are considered the largest natural source of methane to the atmosphere, therefore, simultaneous measurements allowed to answer the question of whether the centre of Łódź is a source of methane with similar intensity as the wetland. In other words, whether anthropogenic sources of methane (fossil fuels combustion, leaks from pipelines, methane emissions from sewer systems) are as intense as the methanogenesis in the wetland. The results of these studies are described in the three papers: Pawlak and Fortuniak, 2016, Fortuniak et al., 2017 and Pawlak et al., 2016.

Sites description, method and instrumentation

Łódź is the third largest city in Poland in terms of population (about 706,000 residents), and its area is approximately 295 km^2. The centre of Łódź where the measurements were taken (Fig. 1), unlike other large cities in Poland, does not have a standard central sector of very tall buildings, clearly towering over the urban canopy layer. Buildings are structurally homogenous in the study area which enables eddy covariance assumptions of horizontally homogenous flow. The most densely built-up city centre covers an area of 80 km^2 and the altitude differences in this part of town do not exceed 60 m. The measurements of turbulent fluxes of methane were conducted in the western part of the city centre at 81 Lipowa St. (51°47'N, 19°28'E, 204 m a.s.l.) in an area with the highest population density, reaching 17.2 thousand persons per km^2. The measurement site is mostly surrounded by artificial surfaces (62%), and the remaining part is covered with vegetation, mainly lawns, distributed irregularly along the streets. Trees, mainly deciduous, rarely higher than the surrounding buildings, occupy only 10% of the area. The study area in the centre of Łódź is built-up with 3-5 storey buildings and the Local Climate Zone (LCZ) can be described as compact low rise (for more details see: Pawlak et al., 2011; Fortuniak et al, 2012).

The second measurement site was installed in the Biebrza River Valley at the village Kopytkowo (north-eastern Poland, approximately 350 km from Łódź). The study area is part of the Biebrza National Park, which since 1993 has been responsible for protecting the largest Polish, and one of the largest European, complexes of fens and wetlands. The area is known for its ecological value, exceptional on a European



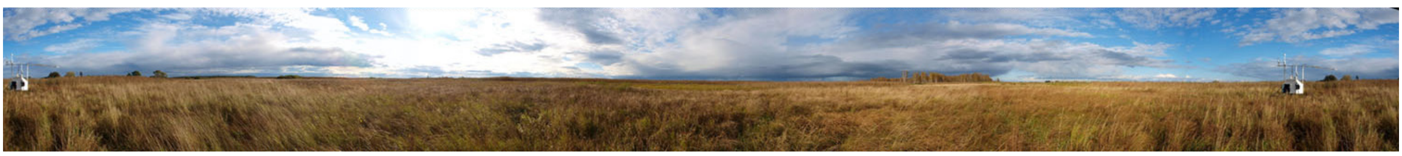


Figure 1. Panoramic view of measurement sites: urban (upper) and wetland (bottom).

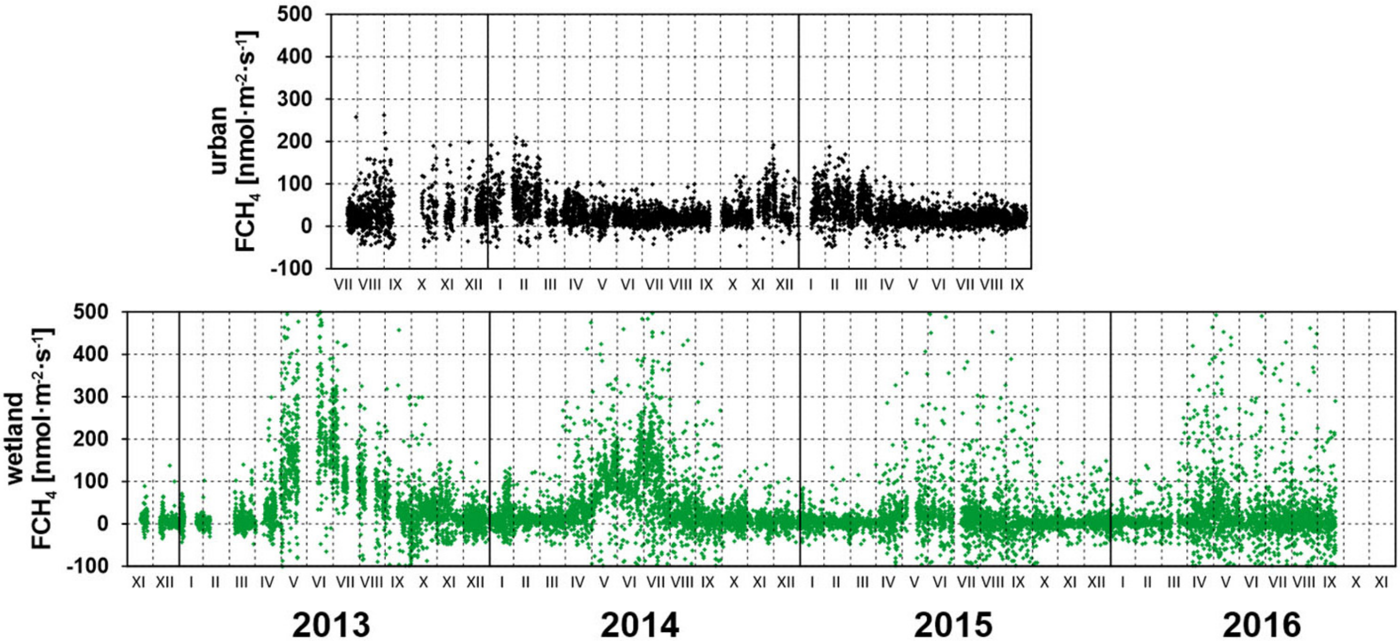


Figure 2. Hourly means of turbulent fluxes of methane (FCH_4) in the centre of Łódź (upper) and wetland (bottom) in the years 2013-2016.

scale, which results from its major deposits of peat, natural annual flooding and the presence of wetland ecosystems constituting habitat for rare plant species and protected animals. The Biebrza Valley wetlands occupy a total area of approximately 250 km^2. The measurement site (53°36'N, 22°53E, 110 m a.s.l.) was located in the Middle Basin (Fig. 1), on flat terrain on the southern edge of the peatland called "Czerwone Bagno" (the Red Marsh). The station is located at a mire area (wetland terrain without forest cover dominated by living, peat-forming plants) surrounded by a mixture of reeds, rushes and sedges. According to different classifications, the place is a fen or a marsh. To the south of the station, there are a few houses and farm buildings at a distance of about 500 m (for more details see Pawlak et al., 2016; Fortuniak et al., 2017).

For the measurements of FCH_4 the same set of devices was used at both sites: ultrasonic anemometers by RMYoung (model 8000, RMYoung, USA) and gas analyzers Li7500 (H_2O and CO_2) and Li7700 (CH_4) produced by Licor (USA). Measurement sets were installed at the height of 37 m in the city (where the urban canopy layer reaches 11 m) and 3.7 m on the wetland, where average height of the surrounding plants ranged from 0.4 to 1 m (depending on season). FCH_4 was determined using the eddy covariance method. The measurements were conducted with a frequency of 10 Hz and a 1-hour averaging period was taken in both cases. During post-processing all appropriate corrections and producers were applied (for more details see Pawlak and Fortuniak, 2016; Fortuniak et al., 2017). A lot of attention has been devoted to the evaluation of data quality (turbulence development, stationarity assessment, etc.).

Results

Both the centre of Łódź and the wetland were characterized by a marked prevalence of positive values of FCH_4. This means that both ecosystems should be regarded as net sources of methane to the atmosphere. Another characteristic of the temporal variability of FCH_4 is a marked annual cycle at both stations (Fig. 2).

In the city, maximum FCH_4 values were observed during the cold time of the year. In the wetlands, maximum FCH_4 values occurred during the warm half of the year. The different times of occurrence of peaks in the annual cycle result from different sources and processes determining methane emissions in the urban and natural areas. In the city in winter, methane emissions can be attributed to anthropogenic processes associated with the combustion of fossil fuels by vehicle engines, the heating of houses, as well as increased emissions through leakages due to increased pressure in natural gas distribution networks. In the wetland, methane release results from a natural process, i.e., methanogenesis, which is much more intense during the warm season, at high water levels in the fen and a relatively high temperature of the soil. The mean values of FCH_4 calculated for the measurement period August 2013 – September 2015 were similar: 31.8 nmol·m^{-2}·s^{-1} in the city and 34.3 nmol·m^{-2}·s^{-1} in the wetland. A characteristic feature of the wetland FCH_4 was

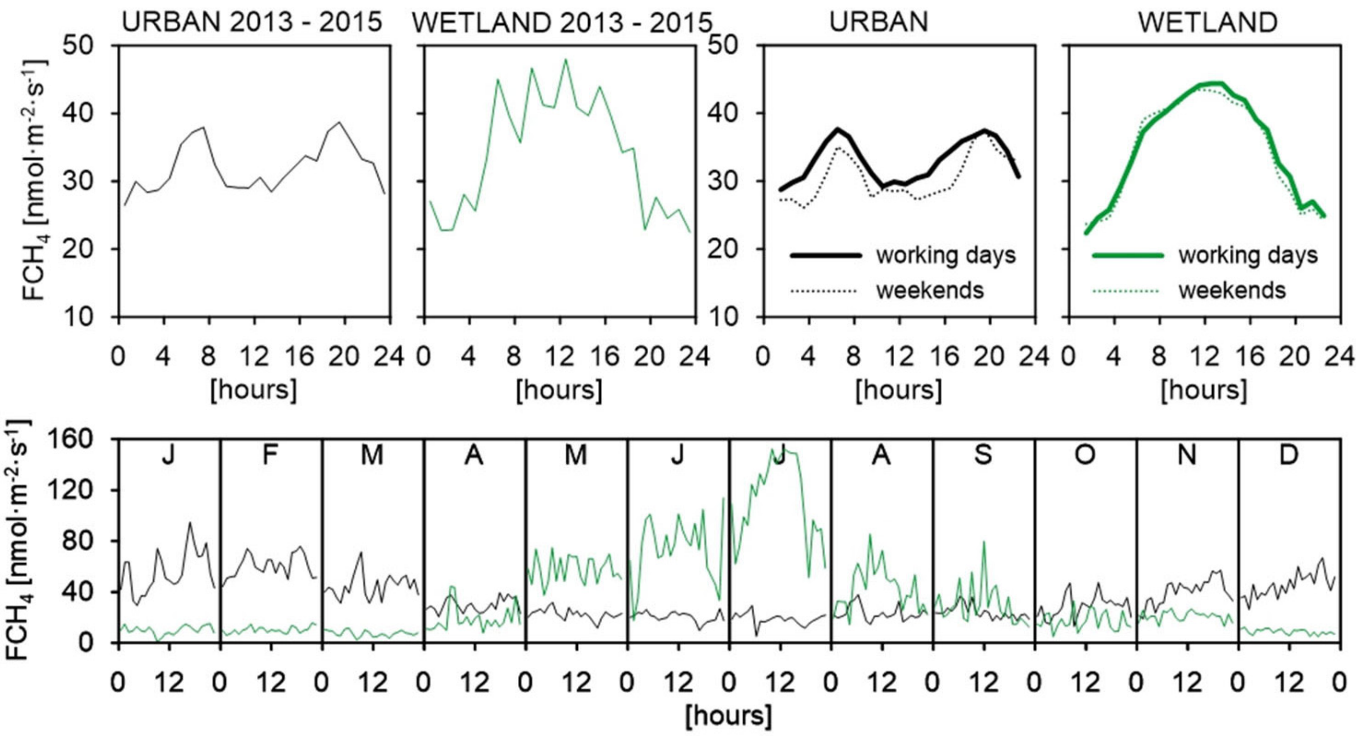


Figure 3. Daily patterns of FCH4 in the center of Łódź (black lines) and wetland (green lines) in the period 2013-2015. Upper plots – daily patterns for a whole period; separate patterns for weekends and working days are smoothed by 3-element running average. Lower plot – daily patterns by month.

significant decrease in 2015 and 2016, which was the result of a prolonged drought in Poland and lowering the groundwater level by more than 1 m.

The mean diurnal patterns calculated for the whole study period are characterized both by similarities and differences (Fig. 3). First of all, on average, regardless of the hour, FCH_4 fluxes were positive whatever the studied surface; their maximum values occurred during the day and the minimum values at night. In the city, the mean values of FCH_4 changed from 26 nmol·m^{-2}·s^{-1} at night to nearly 39 nmol·m^{-2}·s^{-1} in the daytime. In the wetland, the nocturnal minimum values reached 22 nmol·m^{-2}·s^{-1}, whereas during the day they increased to almost 50 nmol·m^{-2}·s^{-1}. However, the crucial difference lies in the number of maxima. In the wetland, the mean diurnal pattern had one maximum in the daytime during the period from 8:00 a.m. to 4:00 p.m. In the urban area, the mean diurnal pattern appeared twice: in the morning (7:00-8:00 a.m.) and in the evening (7:00-8:00 p.m.); maxima and minima values were similar during both periods. Such a pattern seems to confirm the importance of anthropogenic sources of methane to the atmosphere in the city. The morning and evening maxima of FCH_4 reflected increased methane emissions during rush hours, as well as from heating homes and greater consumption of natural gas. Regardless of the season or the time of the day, FCH_4 fluxes had positive values (Fig. 3, bottom), which means a definite prevalence of the emissions of methane over its uptake by the surface of the city. During the warm half of the year, from May to October, the average daily variability of FCH_4 was not too varied and ranged between 10 and 40 nmol·m^{-2}·s^{-1}, while the diurnal maxima were difficult to identify. During the cold half of the year, distinctly higher values of FCH_4 occurred, reaching from 20 to 90 nmol·m^{-2}·s^{-1}. At that time, the double daily maximum was easier to identify. The presence of double maxima during the cold season can be explained by the increased emissions of methane resulting from the increased consumption of natural gas, the combustion of fossil fuels in the morning and afternoon hours (cooking, home heating) and the diurnal variability of motor vehicle traffic, which in winter is often accompanied by traffic jams. During the warm half of the year, the aforementioned sources lost their intensity (decreased motor vehicle, no home heating, decreased consumption of natural gas).

In the wetland, the average diurnal variability of FCH_4 was also characterized by positive values only and, like in the city, the annual cycle of methane fluxes was confirmed. A marked diurnal variability of fluxes was basically observed only in summer when diurnal maxima occurred in the noon hours and reached 110, 150 and 85 nmol·m^{-2}·s^{-1} (in June, July and August, respectively). Such diurnal variability resulted from the natural emissions of methane combined with the

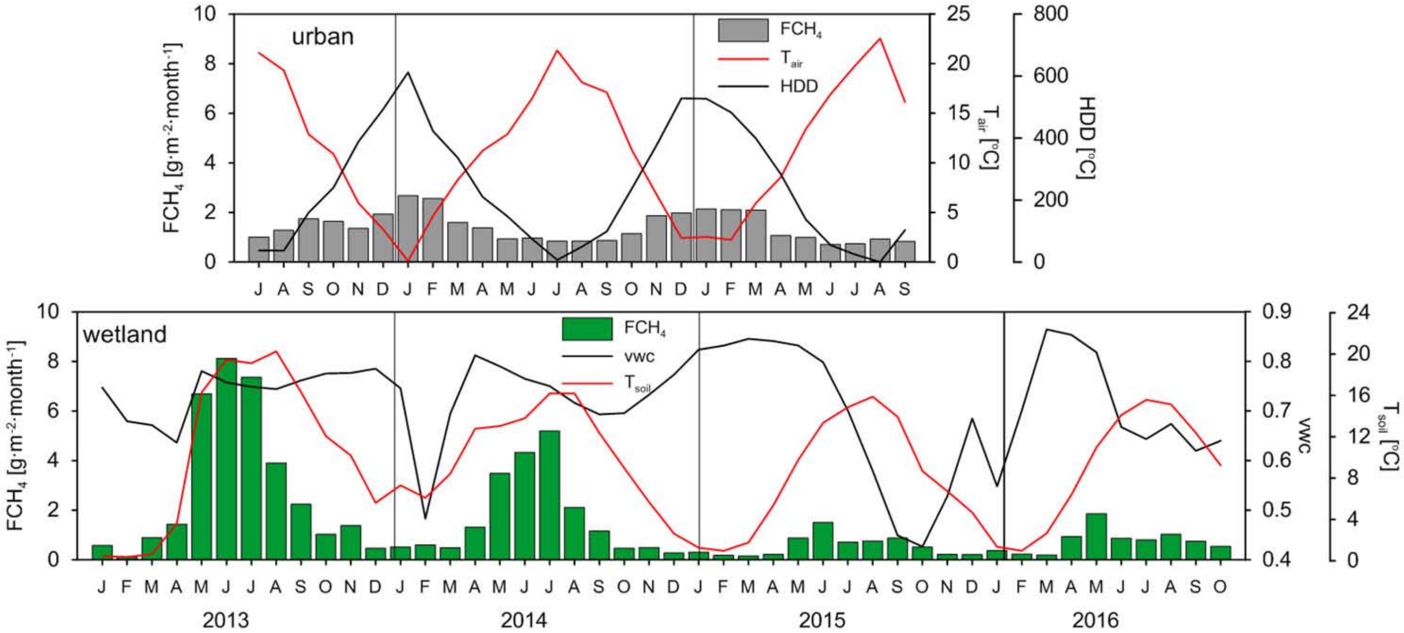


Figure 4. Monthly exchange of methane (FCH4) in the centre of Łódź (upper) and wetland (bottom) in comparison to air temperature (Tair), heating degree days (HDD), volumetric water content (vwc) and soil temperature (T_{soil}) in the period 2013-2016.

diurnal development of turbulence. In six months of the year (from October to March), it was difficult to talk about any diurnal variability of the flux of methane because in those months it remained at a more or less similar level of 10-20 nmol·m^{-2}·s^{-1}. The mean diurnal patterns of FCH_4 (for the entire study period) were also calculated for working days and weekends (Fig. 3). In the centre of the city, fluxes lower by 2-3 nmol·m^{-2}·s^{-1} are clearly visible in all hours except for the evening maximum. In the wetland, such differences were not observed, which confirms the significance of anthropogenic methane sources in the city.

Depending on the type of ecosystem, monthly methane exchanges differ in intensity (Fig. 4). In the case of the city, the differences in monthly exchanges were small and ranged from 0.7 to 0.8 g·m^{-2}·month^{-1} in summer to 2.5-2.6 g·m^{-2}·month^{-1} in winter. Thus, anthropogenic methane sources increase in intensity at low air temperatures, which can be noticed when comparing the results of FCH_4 measurements in successive cold seasons of the year. From November 2013 to January 2014, FCH_4 doubled (from 1.36 to 2.67 g·m^{-2}·month^{-1}), and then decreased until April-May. In contrast, between November 2014 and March 2015 no significant differences were recorded in the monthly exchange of methane in the city, and FCH_4 increased from November 2014 to January 2015 only by 0.27 g·m^{-2}·month^{-1}. The differences resulted from thermal contrasts in the successive winters. During the winter 2014/2015, the mean monthly temperature was at a level of 2.2-2.5°C, while in the previous winter the mean monthly temperature of January fell to 0.1°C. Correlation between monthly average temperature and the FCH_4 can be considered quite strong (R^2 = 0.73), as well as between FCH4 and heating degree days (R^2 = 0.78). The variability of monthly methane exchange in the wetland was much greater. Winter values were at a similar level of 0.3-0.5 g·m^{-2}·month^{-1}, but the summer values changed significantly in the successive years. In the year 2013, which was very warm and wet, in July the monthly exchange exceeded 7 g·m^{-2}·month^{-1}, while in drier 2014 it was a little lower and in July amounted to 5.2 g·m^{-2}·month^{-1}. In the very hot summer of 2015, the wetland water level fell by approximately 1 m. As a result, the maximum exchange of methane was observed in June and it slightly exceeded 1.5 g·m^{-2}·month^{-1} . So, during the warm half of 2015 the monthly methane exchange fell to the level of the exchange observed in the city. In the preceding years, comparable CH_4 fluxes were observed only in the transitional seasons.

Data obtained from both stations between January 2014 and September 2015 enabled an attempt to assess the cumulative annual flux of methane in the centre of the city and in the wetland (Fig. 5). In both

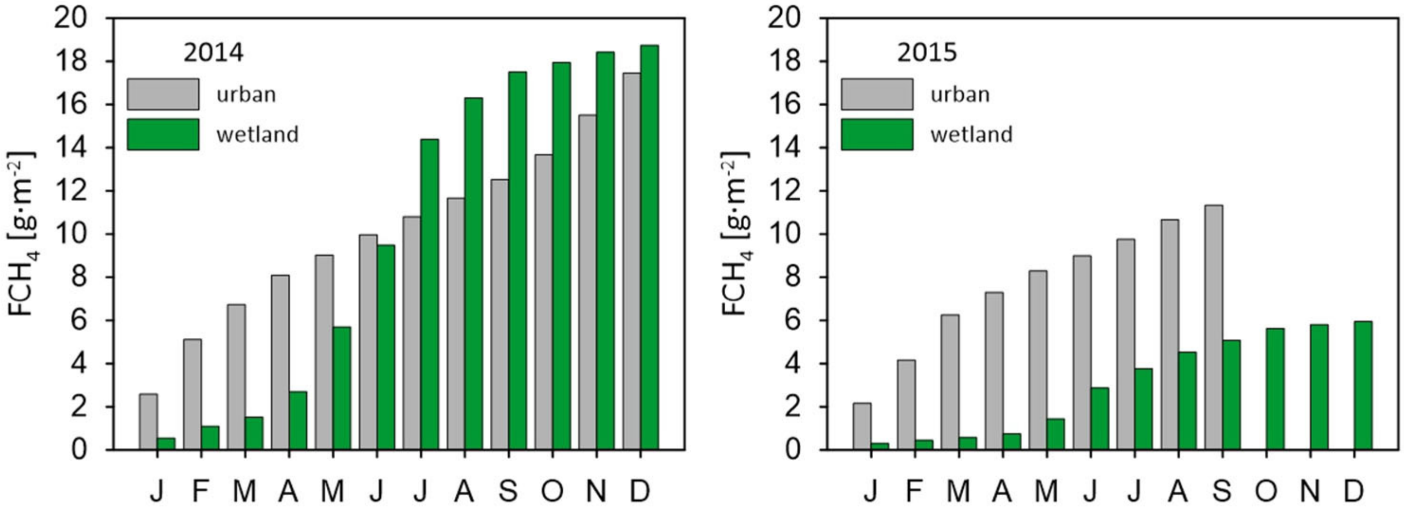


Fig. 5. Cumulative annual exchange of methane in the center of Łódź and wetland in the period 2014-2015.

cases the same simple technique was used of the FCH_4 data series gap filling for estimating the cumulative annual exchange of methane at the two stations. Gaps in the 1-hour series of FCH_4 values were filled in two ways. If a data gap was not longer than three hours, interpolation was used; for longer gaps, data were inserted from the average daily pattern for a given month at a given hour. Having supplemented the data, it can be stated that the annual exchanges in the city and in the wetland in 2014 were similar and amounted to 17.6 $g{\cdot}m^{-2}$ and 18.7 $g{\cdot}m^{-2}$, respectively. In both cases, the graphs show the impact of the annual variability of turbulent methane flux. The cumulative flux of CH_4 in the centre of Łódź grew faster during the cold half of the year, while in the wetland the greatest increase of FCH_4 occurred during the warm season when the mire produced methane most intensely. The cumulative exchange of methane was also calculated for the data recorded between January and September 2015. The exchange in the centre of Łódź was slightly lower in 2015, which resulted from January and February being warmer than in 2014. At the end of September 2015, the cumulative flux was 11.3 $g{\cdot}m^{-2}$, and was lower by 9.2% as compared to September 2014. The difference was much greater in the case of the wetland. The warm season of 2015 was very hot and dry, which resulted in the lowering of the water level in the wetland, thus reducing its methane producing capacity. In September 2015, the cumulative methane flux amounted to only 5.1 $g{\cdot}m^{-2}$ and was lower than in 2014 by as much as 71%.

Summary

Several years' measurement campaign of methane fluxes in Łódź and at a wetland has provided a range of relevant information. Thanks to this rare dataset, we could determine the characteristics of FCH_4 variability in the city centre. We also analyzed the annual, monthly and diurnal FCH_4 variability. Moreover, it turned out that as in the case of FCO_2 there is also a weekly cycle of FCH_4 in the city. Another important result of the measurements was the urban/wetland comparison of the FCH_4 variability. Per unit area, the centre of Łódź seems to be a similar source of methane to the atmosphere as wetland. Interestingly, the results of measurements carried out in London (Helfter et al., 2016) and Florence (Gioli et al., 2012) suggest that CH_4 release from urban centres can be much more intense than from the centre of Łódź. Furthermore, measurements have shown that prolonged drought significantly restricts the ability of the wetland for the "production" of methane, while the city centre is far less sensitive to this type of phenomenon.

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Data availability

The data set is available to the community and can be accessed by request to the corresponding author.

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The effects of Urban Cool Island measures on outdoor climate: Simulations for a new district of Toulouse, France

Introduction

Current urbanization is marked by significant changes in natural surfaces and in the built morphology, which alter the thermal, moisture and aerodynamic properties of these environments, leading to a new, human-induced climate. This new urban climate, often characterized by urban heat islands (UHI) (Oke 1988), has several possible causes and effects. Anthropogenic heat emissions, pollution and energy consumption in towns and cities (Chow et al. 2014; Santamouris et al. 2011), intensive land use and high urban density associated with buildings presenting high thermal masses and heat storage properties (Harlan and Ruddell 2011), urban street canyon configurations that result in reduced long-wave radiation emission to the sky during the night (Santamouris et al. 2001), reduced wind speed due to the significant roughness length of urban centres (Santamouris et al. 2001), absence of green areas and presence of low-albedo materials with reduced permeability (Chen et al. 2009) are known to be the most significant causes of UHI.

Nevertheless, UHI can be exacerbated in a climate change context and introduce negative effects on health through heat stress and the stimulation of ground-level ozone, which can cause respiratory problems (Kleerekoper et al. 2012). Furthermore, UHI may also worsen episodes of heat waves, bringing several other consequences such as a reduction of the efficiency of passive cooling modes in buildings, a significant increase in the energy demand of buildings and also the deterioration of climatic quality in public spaces (Colombert 2008).

In France, most of the metropolitan areas have been intensively spreading outwards, which has led more and more residents to move farther away from the city centre. In the city of Toulouse, some new empty areas on the outskirts of the old centre have been entirely planned to accommodate multiple activities, based mostly on functional, social, heritage, and economic aspects.

The UCI project (from "Urban Cool Islands") is a French national research project that has discussed procedures with urban planners and investors with the aim of incorporating a set of reasoned measures for local climate adaptation in a particular new urban area in the city of Toulouse that is expected to become a landmark reference.

This research analyses and compares different suitable, resilient urban design strategies to provide support for their application in the particular real-life case of the Montaudran district of Toulouse, focusing on mitigating UHI effects in summer and including a quantitative assessment of their impacts. Our study approach combines knowledge from theoretical and applied research concerning local city planning decisions, integrating an evaluation of the planners' demands, compatible strategies and microclimate modelling for a certain number of design choices.

Research method

To achieve the objective described above, the following main methodological steps were taken:

(1) Assessment of the proposed urban plan of Montaudran Aerospace campus and discussions with urban planners regarding its design opportunities and constraints relative to its climate adaptation for the summer season;

(2) Definition of a set of reference urban variations to the initial plan, based on the local planning guidelines and on the main microclimate adaptation measures;

(3) Computer modelling of outdoor climate conditions.

Case study – Toulouse is located in the south west of France (43°36′ N 1°26′ W). It lies at an altitude of 263 m, on the banks of the river Garonne. The climate of Toulouse is temperate with oceanic, Mediterranean and continental influences, characterized by very warm, dry summers. Heavy precipitation can occur during mild winters, which are dominated by mid-latitude cyclones. Seasonality is moderate. On a typical summer day, air temperature can fluctuate between 15°C with 90% relative humidity early in the morning and 30°C with 50% relative humidity late in the afternoon. However, the summer season in Toulouse is often marked by extreme heat wave episodes with temperatures that can rise above 40°C. In urban environments, these thermal conditions can be exacerbated by the hard-surfacing of urban surfaces.

This research project integrates the design process of an important urban planning project in Toulouse, France: the Toulouse Montaudran Aerospace Campus. This new district, covering more than 56 ha in southeast Toulouse, will replace the historic Montaudran aerodrome, home of one of the first airmail services in the world. The district of Montaudran currently possesses the emblematic 1.8 km long, 30 m wide runway (Figure 1). This landmark and its surroundings will be refurbished and transformed into a mixed-used urban site, the "Aerospace campus", with residential buildings, and commercial, sports, educational, scientific and cultural activities.

Figure 1. Urban plan and surroundings of Montaudran new district displaying its main activity areas and its emblematic runway to be refurbished (source: Adolphe, 2015).

The Toulouse community also has strong ambitions regarding the environmental quality of this urban district, especially concerning the transport network, rainwater management, bioclimatic design of buildings and renewable energy installations. The Montaudran neighbourhood is located in southeast Toulouse, about 6 km from the downtown area and Blagnac International Airport. Montaudran is bordered by two expressways and is situated at the former airdrome of AirFrance. This site remains the last large-scale buildable zone in the metropolitan area of Toulouse. ZAC Toulouse Montaudran Aerospace will enable the development of a new neighbourhood among existing Montaudran residential and Ormeaux districts, an economic development hub and the Rangueil Campus.

The new Montaudran district links to existing surrounding neighbourhoods and proposes a mixed-use development, with commercial and service activities, technological research laboratories, cultural and sports facilities and residential buildings, located close to the ring road and railway infrastructure.

To cope with the task of adapting the urban plan to face the climate change challenge, the Montaudran district plan presents a few linking points to support the integration of important solutions and strategies to reduce UHI effects:

a) Concerning the planning opportunities:

• It presents a total built density of 0.63, which is a relatively low-density urban site for plans of this magnitude. A large area of potential green surfaces will allow the use of local vegetation to be satisfactorily considered to promote shading and evapotranspiration as cooling strategies for public and private spaces.

• Urban planners wish to design hydraulic urban storm-water systems to cope with the effects of seasonal floods (e.g. floodwater detention systems), and redirect water to permeable spaces where the quality of the soil allows safe percolation down into the water table.

• The possibility of integrating water fountains or sprayers along and at the borders the old runway is also being considered (at the central square and playground square).

• The height of certain buildings bordering the road can still be reasonably modified.

• Montaudran lies within the greenway of the Rangueil University campus.

b) Regarding the planning constraints:

• A large area of asphalt surfaces including the 1.8 km long, 30 m wide old runway (that must not be modified) is likely to produce an important overheating zone.

• The urban form and implementation of buildings previously defined should not be modified.

• Cool paving materials are not primarily envisaged because of their high investment cost.

• There is a large commercial and services building area where the use of air-conditioning is primarily imposed.

To address these issues and explore possible variables concerning climate-adapted scenarios, “it is important that urban climatologists meet the planners demand-driven needs by providing them with good arguments, suitable methods and tools” (Eliasson 2000). Researchers are also encouraged to improve awareness of the importance of urban climate not only among planners but also among decision-makers and the public (Eliasson 2000).

Initially, a top-down approach was adopted to synthesize research knowledge and to support urban planners with information on the main factors influencing the intensity of urban heat islands. For this purpose, summarized documentation called “action sheets” was produced. Then, in a bottom-up approach, these action sheets were presented to planners and investors in several working meetings to determine, with them, the set of constraints (e.g. policy, technical, etc.) and scenarios of opportunities for the future urban site of Montaudran. In fact, the originality of the UCI project lies in the construction of both action sheets and reference scenarios in collaboration between researchers and urban planners (Figure 2).

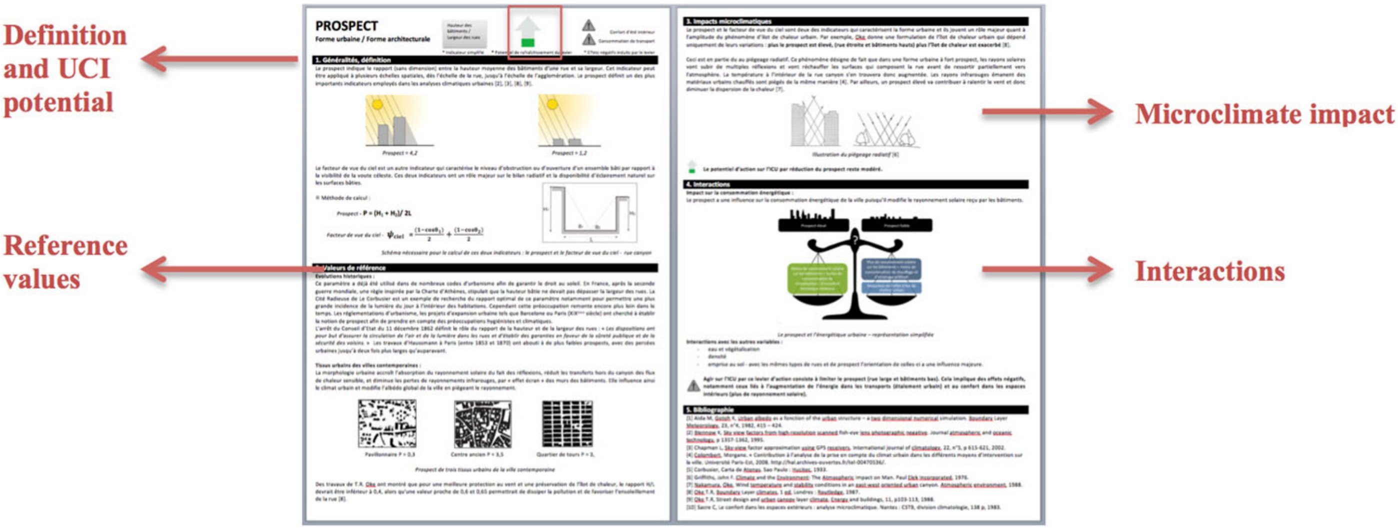

Figure 2. Example of an "action sheet" produced to provide information/results and support for decision-making.

Elaboration of reference urban scenarios – This research proposes various planning strategies that could allow urban cool islands to be created during major heat waves in summer.

To apply and test these strategies for the Montaudran district, a limited number of public spaces presenting stronger potential use in summer season were evaluated. These spaces include the public squares, sports and recreational parks, and the main student residential blocks (Figure 3), for which the use of air-conditioning was not anticipated. The study was conducted for the zone highlighted below.

To propose urban design strategies for climate adaptation, this research focused on the main factors well-known to contribute to UHI in cities.

One of the main reasons for the night-time warming in cities is their extensive soil sealing that changes the thermal properties of surface materials. Generally, dark concrete and asphalt absorb solar energy during the day, and the urban structure makes it difficult for this energy to be released during the night (Solecki et al. 2005).

The lack of vegetation in urban areas reduces shading, evapotranspiration cooling effects and the removal of carbon dioxide.

UHI may also be due to geometric effects. Tall buildings within many urban areas provide multiple reflective and absorptive surfaces, increasing the efficiency with which urban areas are heated: the "urban canyon effect" (Oke 1988).

Thus, this study divides the adaptation strategies for reducing UHI effects into four categories:

1. Vegetation strategies, which consist of establishing green-corridor streets to benefit from the cooling effects of plants.

2. Water strategies, which consist of using ponds and fountains to provide cooling effects through water evaporation.

3. Built form strategies, which consist of altering built density, building height and street width.

4. Material strategies, which involve materials that present greater cooling effects through evaporation, low heat capacity and high solar energy reflectivity.

It can be difficult to transfer a large amount of knowledge and evidence about the combined use of these tools into the urban planning process. However, this study provides an example of how the different Urban Cool Island strategies can be applied together with the aim of adapting to climate change and reducing UHI effects.

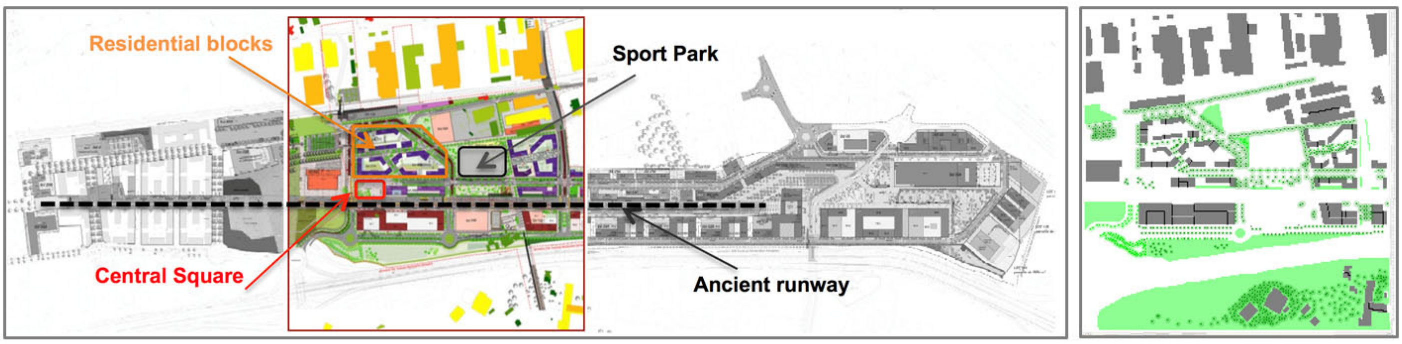

Figure 3: Delimited zone of interest to the study and its modelled representation in ENVI-met.

Since the existing streets, as well as the landmark runway, could not be widened or modified, the heights of the proposed buildings were altered to evaluate the effect of a different aspect ratio of the urban form. Vegetation strategies included creating recreational green zones, which could also be used as cycle routes. Water bodies included sustainable water systems to supply trees with enough water to maximize their cooling ability, and shallow canals to absorb and discharge heat. Based on these major UHI influencing factors, it was possible to build a set of reasonable, different scenarios representing the main climate strategies to mitigate UHI effects.

Microclimate simulations – Numerical simulation has increased in popularity in urban climate research over the years because of its ability to deal with the complexities and nonlinearities of urban climate systems, and also with parametric and comparative study methodologies (Arnfield 2003). The urban modelling tool ENVI-met (Bruse 2009) used here, reproduces the complexities of an urban climate system: simultaneous and interactive calculations of radiation, thermal and urban water budget together with the urban airflow at multiple scales. The model includes the calculation of the airflow between buildings, the impact of vegetation and water surfaces on the microclimate, exchanges between soil surfaces and building walls, bioclimatology and dispersion of pollutants (Bruse 2009). The calculation of the mean radiant temperature takes into account the direct and diffuse short-wave irradiances and also the long-wave radiation fluxes from the ground, building surfaces and the free atmosphere. All components are weighted by the sky view factor (Ali-Toudert & Mayer 2007). However, there are currently two important drawbacks: the software does not allow complex energy calculations for buildings, and the calculation time is prohibitive (typically more than 15 days of calculations on a powerful computer for a single simulated day of a relatively complex urban scene). Despite this drawback, ENVI-met remains one of the few software packages capable of performing realistic microclimatic simulations today. Furthermore, ENVI-met has been evaluated and extensively validated (Hedquist 2010, Ng et al. 2012).

Given the dimensions of the Montaudran development area, the simulation of its geometry involved a judicious choice of the spatial resolution of the analysis grid. ENVI-met is designed for the micro scale, with a typical horizontal resolution of 0.5 to 10 m and a typical time frame of 24 to 48 hours with a time step of 1 to 5 seconds. This resolution allows small-scale interactions to be analysed (Bruse 2009). The urban zone delimited in this study was modelled in the ENVI-met analysis domain comprising 230 x 230 x 26 grid cells plus 5 nested grids and a 3 m grid cell resolution. As described above, four variations of the delimited plan were modelled in order to compare and contrast the relative performance of the solutions considered (vegetation, water fountain, mean aspect ratio and low albedo building surfaces).

The Montaudran district presents similar morphology and climate conditions and is equidistant from the city centre and Toulouse Blagnac Airport. Therefore, it was considered acceptable to apply the meteorological data recorded at Blagnac airport as the climate data input to our simulation model in ENVI-met. For this study, hourly weather data typical of 21st June (summer solstice) was considered. For simple climate forcing, ENVI-met allows the forcing of air temperature and humidity. For the wind speed and direction, a mean value observed by the weather station at ground level was considered. Then, a simple, spatial and temporal, logarithmic interpolation was applied for the calculation of the vertical 1D wind profile (lateral and top boundary conditions imposed on the 3D model) on the day of simulation; the wind direction was kept constant at all levels; the humidity profile of the atmosphere is interpolated linearly, according to data observed at ground level and the specific humidity input at 2500 m above ground. Furthermore, the soil temperature and moisture at several depths were considered. All these data were obtained from the Toulouse weather station (MeteoFrance 2014).

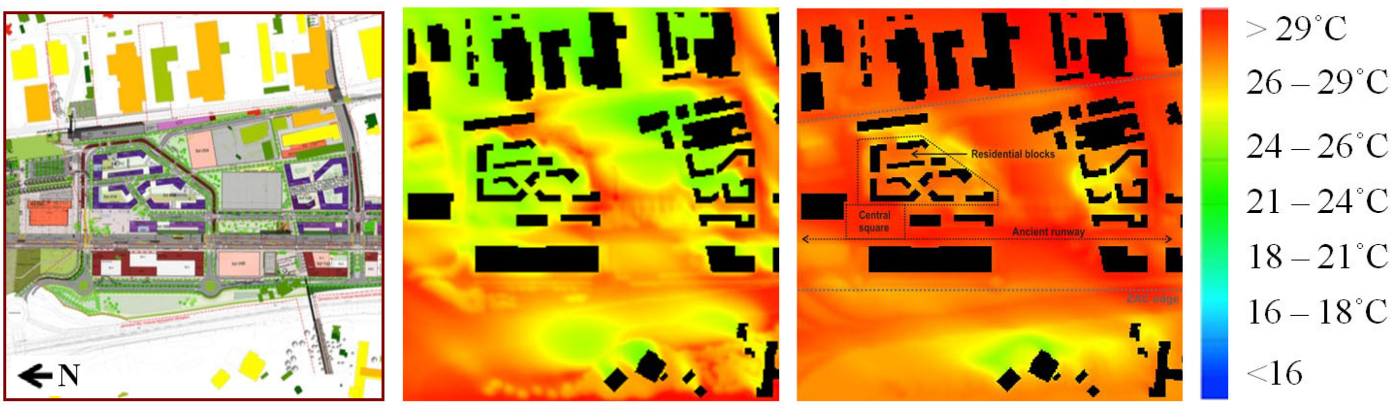

Figure 4. The original plan of Montaudran (left) followed by its spatially distributed air temperature during daytime at 12 noon (middle) and night-time at 12 midnight (right).

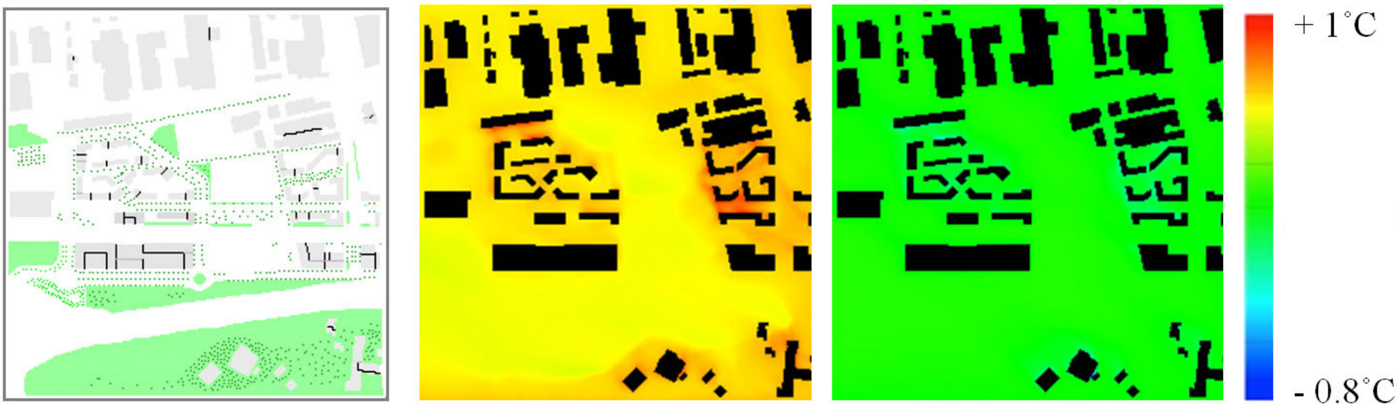

Figure 5. Air temperature difference in the "White case" relative to the Base case, during daytime (middle) and night-time (right).

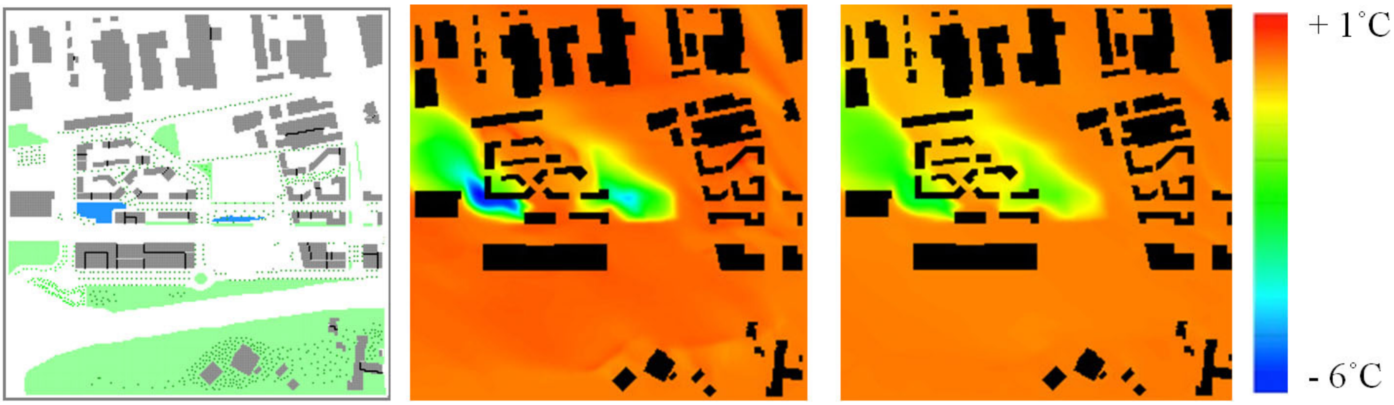

Figure 6. Air temperature difference in the "Blue case" relative to the Base case, as in Fig. 5.

Results

UHI effects can occur year-round, day or night, depending on the built and non-built area configurations. Urban-rural air-temperature differences are often largest on clear evenings, since rural areas can cool down faster at night than cities, which retain much of the heat stored in roads and buildings.

The base case plan of Montaudran shows a certain spatial heterogeneity of air temperature during the day and at night. The highest air temperature is found over the asphalt roads around the residential blocks and the sports park (Figure 4). It is possible to verify the combined effect of soil sealing and the local reduction of shading, especially around the sports park. Lower temperatures can be noted inside building blocks, due to the low sky-view-factor (SVF) and shading effects. As expected, the effect is reversed at night (Figure 4). The old runway, the residential blocks and the central square are important heat islands in this initial plan. From this observation, the research explored different strategies to see how these heat islands could be reversed.

The following maps and analysis bring out the air-temperature difference between a specific variant (scenario) of the plan and the base-case ($\Delta T = T_{variant} - T_{base\text{-}case}$).

As can be seen from the figures above for the "White" variant of the original plan, high albedo surfaces may generate slightly cooler nights than the base case but, on the other hand, they may produce slightly higher daytime temperatures (Figure 5), especially around buildings with a low SVF and surrounded by dark mineral soil surfaces (such as asphalt or dark concrete), due to the radiation trapping effect of this kind of urban features.

Contrary to expectations, applying cool façades and roofs may not always constitute an optimal strategy for creating urban cool islands, regarding air-temperature. Urban form and structure as well as paving materials must be considered simultaneously. In this particular case, light pavement was not initially a possibility for investors, but will necessarily be considered subsequently in the research project.

The implementation of two large lakes with high fountains ("Blue" variant) created two marked cool islands, during day-time and night-time, with a temperature reduction of 6˚C in the central square and around the residential blocks, compared to the base-case. It can be highlighted here the notable interaction effect of this kind of water strategy in association with the wind flow. A local air-temperature reduction of 2˚C was found on the wind outlet area (Figure 6).

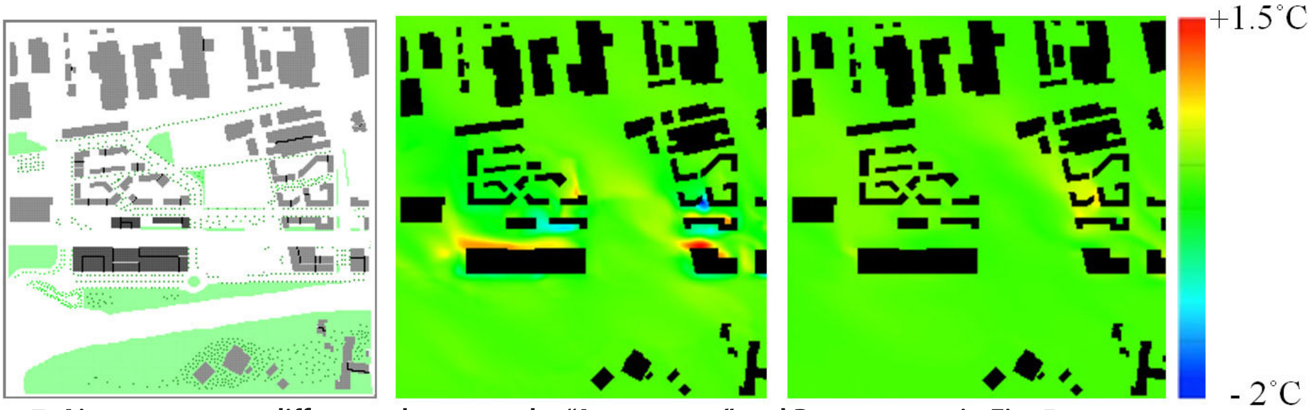

Figure 7. Air temperature difference between the "Aspect case" and Base case, as in Fig. 5.

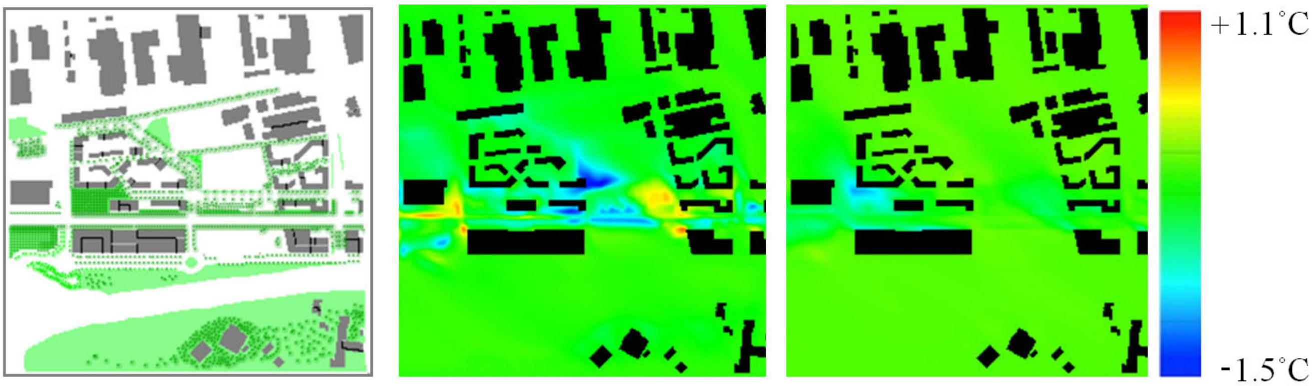

Figure 8. Air temperature difference between the "Green case" and Base case, as in Fig. 5.

For the mean aspect scenario ("Aspect" case), slight increases/reductions of air temperature with respect to the base case could be seen around buildings. Great spatial temperature homogeneity was found since the original unchangeable urban form (notably regarding building implementation) did not actually represent a real canyon street, which could have played a decisive role in producing cooler daytime temperatures (by shading effect) (Figure 7).

Similar to the "White" case, doubling the height of buildings that border the runway (as permitted by local planners) disregarding the kind of implementation and the contiguity of form, may not always represent an ideal solution to provide daytime cooling effects. As it can be seen from the figures above, the non-contiguity of the buildings at the border of the old runway makes east-side oriented surfaces heat up early in the morning, generating a local heat island. Since this runway is particularly large and buildings are not contiguously uniform, one cannot observe the negative urban heat island effect during the night. Due to these morphology characteristics, the absorbed heat can be more easily dispersed during nighttime. Doubling building height (in this case) does not seem to produce any significant heat island effect during the night, when compared to the original plan.

Applying vegetation ("Green" case) that was twice as dense as in the base-case allowed cool islands to be created along the old runway and in the central square (Figure 8). However, no marked changes in air-temperature were found at night compared to the base-case.

Discussion and Conclusions

In a context of climate change, the effects of urban heat islands can be broadly intensified and heat stress is expected to progressively increase in mid-latitude cities. The current urbanization process of new suburban districts in European cities, such as Toulouse, should consider the challenge of planning more climate-adapted and resilient urban spaces. Thus, systematic analysis of the microclimatic impact of different climate-adapted strategies can be valuable for new urban planning. This can only be achieved by simulating the microclimate of prospective scenarios. This kind of analysis allows feedback to support the design decision process and provides opportunities to choose appropriate measures to improve the local climate conditions.

Vegetation, materials and water strategies can be relatively easily considered as adaptation measures for new on-going suburban planning, as for Montaudran. Another important finding may contradict most generalisations regarding the aspect ratio impact on urban heat island. Raising the aspect ratio of a particular street with buildings not contiguously uniform may not significantly raise air temperature during the night. Due to the important space between adjacent buildings of different shapes, thermal radiation, which has accumulated during the day, can be easily dissipated during the night. It is therefore very important to take into account other important morphology factors, such as: contiguity, porosity, sinuosity, building setbacks, etc., which may significantly affect the street climate performance.

The results presented enable us to discuss some claims related to well-known urban design study variables when they are applied to real, constrained urban planning. They allow some actions to be prioritized and more specific strategies to be suggested to urban planners. Working with a real urban design in progress means coping with its schedule, constraints and opportunities. Thus, instead of studying multiple isolated actions at a time, this research sought to apply a referential contrasted scenarios approach, which aims to distinguish appropriate solutions from a set of major potential strategies.

Factors such as urban vegetation coverage and water spaces are important strategies that could directly affect on-going design decisions but they should be carefully studied for each case. This is where policies and programmes to reduce the impacts of heat islands – and meet related environmental and energy-saving goals – can be most effective.

The present study is complementary to the traditional assistance provided to urban planners. It highlights a mix of specific strategies that should be integrated in the final plan. It gives significant added value for decision-making by suggesting relatively simple solutions. Adapting or mitigating the UHI does not mean fundamentally altering existing or on-going urban plans, but can be pursued through small, inexpensive strategies such as the urban solutions evaluated in this study. In the urban development of the emblematic Montaudran district of Toulouse, they could drastically alter the perceived quality of public space.

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Urban Areas and Global Change Sessions featured at Fall Meeting of American Geophysical Union in San Francisco

By Erin Wetherley
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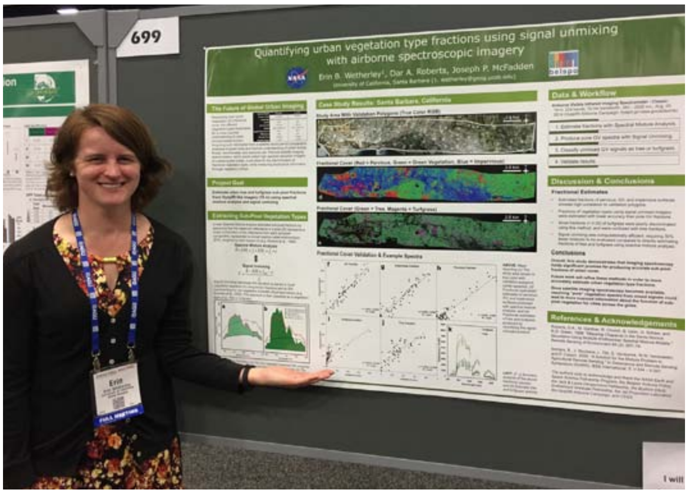
The 49th American Geophysical Union (AGU) Fall Meeting was held December 12-16, 2016 in San Francisco, California. This year, AGU featured the Urban Areas and Global Change session, convened by Dr. **Galina Churkina** (Institute for Advanced Sustainability Studies, Potsdam, Germany), Prof. **Joe McFadden** (University of California, Santa Barbara, USA), Dr. **Patricia Romero-Lankao** (National Center for Atmospheric Research, USA), and Dr. **Tim Butler** (Institute for Advanced Sustainability Studies, Potsdam, Germany). As a part of this large Earth and space science gathering, with approximately 24,000 attendees, the Urban Areas and Global Change program included a total of 51 presentations in three sessions of talks and a large poster session, making it an exciting showcase for urban climate studies and related research.

The session featured a range of observational, experimental, and modeling research that examines the human-land-atmosphere interactions of cities and urban carbon emissions. It also highlighted a variety of new techniques, including measurements, scaling methods, and urban modeling, with applications for social science, engineering, and urban climate studies. Specific topics of interest included urban energy budgets, greenhouse gases, impacts of urbanization, the role of social factors (including demographics, affluence, and socio-political conditions), and broader implications of urban research for public policy and urban planning.

Poster session

The session kicked off with a well-attended poster session highlighting 29 projects from around the world, including Brazil, Canada, China, Columbia, France, Germany, India, Japan, Korea, Mexico, Turkey, and the United States, and at scales ranging from local to global. Posters featured urban modeling, simulations, experiments, and data analysis. Physical science research included analysis of the role of cities in broader biogeochemical cycles, including carbon, water, and energy cycles. Other work examined anthropogenic influences, including pollution from heavy metal, black carbon, and urban gas emissions, and anthropogenic heat. Social science research identified vulnerable urban populations, particularly in regards to extreme heat events and access to urban sanitation, and examined scenarios for reducing traffic emissions.



Erin Wetherley displaying her poster at AGU.

Urbanization, social science, and policy

The first oral session focused on a range of social science and policy challenges and tools. Urbanization was a dominant theme, with talks on developing a global historic time series of urban expansion, monitoring urbanization trends using satellites, and using urban growth models to make future climate predictions. The importance of spatially and temporally rich data was emphasized in the first two invited talks of the program. Prof. **Peter Marcotullio** of Hunter College, City University of New York, USA, in his talk titled "Developing a historical energy and GHG emission inventory for the New York City Metro area," noted the need for long-term longitudinal studies of the relationship between urbanization, energy use, and GHG emissions. His work in New York provides a preliminary framework for a long-term, spatially disaggregated inventory of energy use and GHG emissions, which could provide important data for policymaking in the context of the 2015 Paris Agreement. Prof. **Johannes Feddema** of the University of Victoria, Canada, presented the second invited talk of the session, titled "The WUDAPT Project: Engaging a Global Community to Map and Characterize Cities Worldwide." The World Urban Database and Portal Tools (WUDAPT) is an ambitious endeavor to merge local knowledge with open source remote sensing and GIS tools to classify cities into Local Climate Zones, based on local urban morphology, at a global scale. To date, a combined force of scientists and citizens has classified 200 cities under this framework.

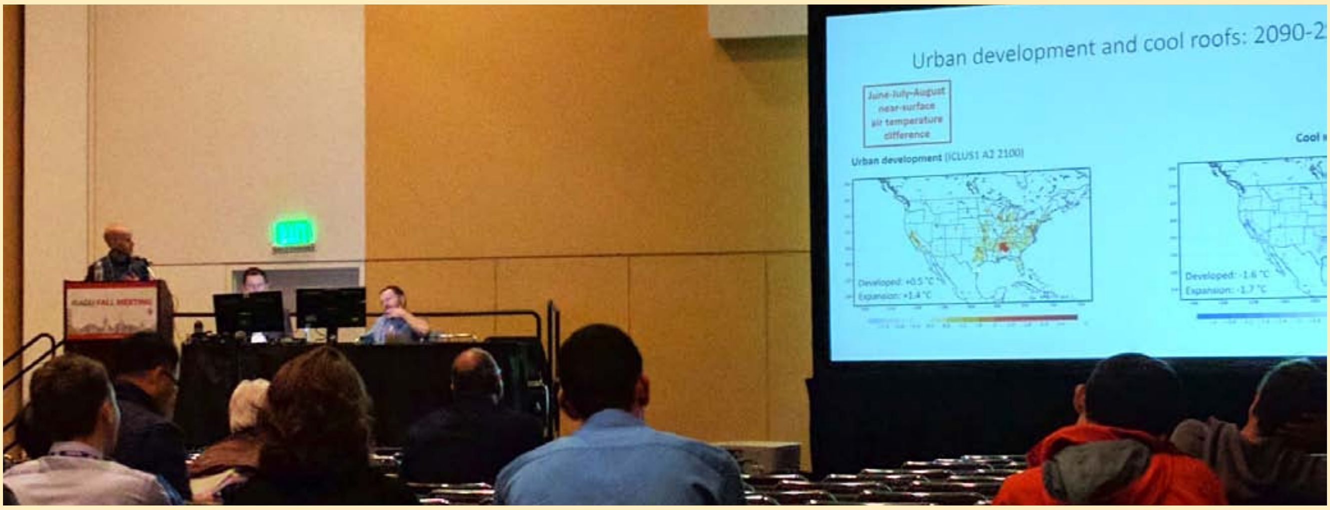
Urban flux studies

The second session of oral presentations drilled down into the specifics of urban surface-atmospheric interactions with several urban flux projects. Some of this work focused on spatial gradients, examining temporal and seasonal carbon fluxes, atmospheric temperature, and humidity along gradients of development. Others sought to define the controls on measured fluxes, including evaluating the controls on the energy and water balance in cold climate cities or estimating anthropogenic heat flux sources. Observational studies of carbon dioxide and black carbon were featured as well. Dr. **Eli Melaas** of Boston University, USA, presented a case study in the third invited talk of the program, "Interactions between Urban Vegetation and Surface Urban Heat Islands: A Case Study in the Boston Metropolitan Region." His work showed that several factors, including vegetation species composition, land cover configuration, and vegetation fraction, influence the coupling of vegetation phenology to the surface urban heat island and the effect of vegetation on local heat island intensity.

Urban heat island research

Dr. Melaas' talk provided an excellent transition to the final session, which featured research on the urban heat island effect (UHI). Studies highlighted the complicated task of studying the relationship between the UHI and a warming global climate, finding that under warmer climate scenarios the intensity of UHI may decrease, while it may also increase regional rainfall. Other work focused on strategies for combating the UHI, recommending a combined approach implementing cool roofs, street vegetation, and highly reflective pavement to cool urban centers, and finding that the use of cool roofs also could reduce consumption of water for urban vegetation irrigation. Additional studies examined anthropogenic heat, presenting estimates of anthropogenic heat contributions and examining its impacts on rainfall.

Overall, the contributions of the organizers, presenters, and attendees made the Urban Areas and Global Change session at the 2016 AGU Annual Meeting an exciting forum for exchanging urban research and highlighting the current state-of-the-art.



13th Symposium of the Urban Environment highlighted at American Meteorological Society annual meeting in Seattle

By Rainer Hilland
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In late January of this year the 97th annual meeting of the American Meteorological Society took place in Seattle, WA. The annual meeting is the "world's largest yearly gathering for the weather, water, and climate community," with over 4,400 attendees across 2,325 oral presentations and 1,436 poster presentations, according to the AMS website. Among the symposia this year was the 13th Symposium of the Urban Environment.

I was in the fifth month of my graduate program and had never before attended any kind of academic conference. The annual meeting that included the urban environment symposium seemed like the perfect introduction to the broader academic community, and the opportunity to leave behind the freezing temperatures of southwest Ontario was too good to pass up.

I was unsure of what to expect of the conference, but the journey to the US certainly set an interesting stage – I was travelling to a meteorological conference in a country that had just elected a president who doesn't believe in climate change. While I waited for a connecting flight from Chicago, thousands of protesters were taking part in the Women's marches in cities across the country. Walking through downtown Seattle to my 'airbnb' later that evening, the streets were littered with protest signs. I was intensely curious how these events would impact the conference.

The conference was immediately exciting despite my nervousness at being in such uncharted territory – I felt like a small fish in a big pond, but the convention center was full of people excitedly discussing their work. AMS emphasizes the size of the conference, and I would certainly agree that that was a very apparent feature. Set in the giant convention center in downtown Seattle, the size of the gathering was indeed impressive. I think it is all too easy as a grad student to become so intensely focused on one small area of a field that you lose, or never gain for that matter, an understanding of the breadth of that field. Meteorology is of course a vast umbrella under which many related, but different sub-disciplines fall, and I spent a lot of time wandering through the poster exhibits getting a feel for the breadth of different work being done.

There were too many sessions and speakers to detail each one, however there are a few that stand out in my memory, the first being the Prof. **Robert Bornstein** named session. This session detailed the career and some of the achievements of Dr. Bornstein through colleagues, students, and students who became colleagues. As a first year grad student I found throughout the conference that it was often difficult to place research within the broader framework of the urban climate literature. In contrast, the quasi-chronological tracing of Dr. Bornstein's contributions up until the present day in this session gave me a helpful orientation for many of the other talks during the conference. His myriad contributions to climate modeling and urban effects on precipitation were discussed in addition to his mentoring of young scientists in various countries. This type of reflective analysis struck me as quite valuable, not only for recognizing his personal contributions, but for rooting present research in the work that has come before it, and providing suggestions on where future work might go.

At the AMS meeting in Seattle, 2016 Luke Howard Award Winner Walter Dabberdt shows off his Luke Howard volumes following the award presentation. Walter was joined in the photo by previous winners Sue Grimmond (2009, left), and on the right Bob Bornstein (2008) and Tim Oke (2004). Photo: Matthias Roth

The theme of this annual meeting was *observations lead the way*. For AMS this means conveying, "that our first priority should be to obtain the necessary observations and information." My own Master's project is observational and this focus appealed to me. My impression, however, is that observations tended to take a back seat role in terms of focus to modeling, model parameterization, model results, etc. There seemed to be an implicit emphasis on models and simulations in the urban environment symposium. This is not to say that observations were absent: the sessions explicitly focusing on observations and field studies in urban climate were very interesting, and observation-based papers were included in many sessions.

AMS student awards by the AMS Board on the Urban Environment
Oral Presentations
Lento Manickathan, ETZH: "Conjugate Vegetation Model for Evaluating" Evapotranspirative Cooling in Urban Environment"
Luis Ortiz, City College of New York: "Urban Impacts on New York City Weather During a Heat Wave"
Michael A. Allen, U of Western Ontario: "A Climatology of Urban Surface Heat Islands Derived from Hemispherical Radiometric Surface Temperatures"
Poster Presentations
Erin B. Wetherley, U. California Santa Barbara: "Urban Composition and Surface Temperature at Multiple Scales Using Airborne Spectroscopic and Thermal Imaging"
Alexandria J. Herdt, Texas Tech University: "Urban Microclimate Monitoring in Seoul, Korea: Fine Scale Summer Heating along the Cheonggye Stream Renewal Project"
Guangdong Duan, City University of Hong Kong: "Mixing of a Passive Scalar in an Urban-Street Canyon"
Jiajun Gu, Cornell University: "Intercomparison of Three Source Estimation Methods in a Building Down-wash Environment: Applicability, Limitations and Research Needs"
Toshiya Yoshida, Kyoto University: "Influences of Complex Roughness over an Actual Urban Area on Turbulent Flows as Revealed by Large-Eddy Simulations"
Anamika Shreevastava, Purdue University: "Incorporation of Urban Form and Function for Improved Correlation Between Land Use Types and Land Surface Temperatures"

In the middle of a session on Thursday, one of the speakers didn't show up. The chair of this session took that block of time to open up a discussion that I found extremely interesting. Without any structure or specific topic to discuss, it felt like the conversation turned quickly to the topic of what was and wasn't being addressed in the discipline, and as a new entrant to the field this was very exciting. A few important ideas were brought up: One speaker suggested that too much focus was being placed on the Urban Heat Island and its magnitude (i.e. the ΔT), while ignoring the question of the actual temperatures. Another argued that more consideration should be given to how cities are used and experienced when discussing the impacts of climate change on cities – the same temperature increase has a different impact on an industrial district than on a residential neighbourhood by virtue of how these spaces are used. I think a big question that was raised during this informal discussion was how people interact with and experience urban environments, and *how* that might guide research. Dr. **Alberto Martilli**'s presentation that harvested temperature data from cell phones might not be able to tell us what the outside air temperature is, but it may tell us the temperatures that individual persons actually experience in their day to day lives. Further to the question of how people experience the city, Prof. **Matthias Roth** raised an interesting point that most energy flux studies are conducted in mid-latitude cities, which leaves out a massive portion of the global urban population.

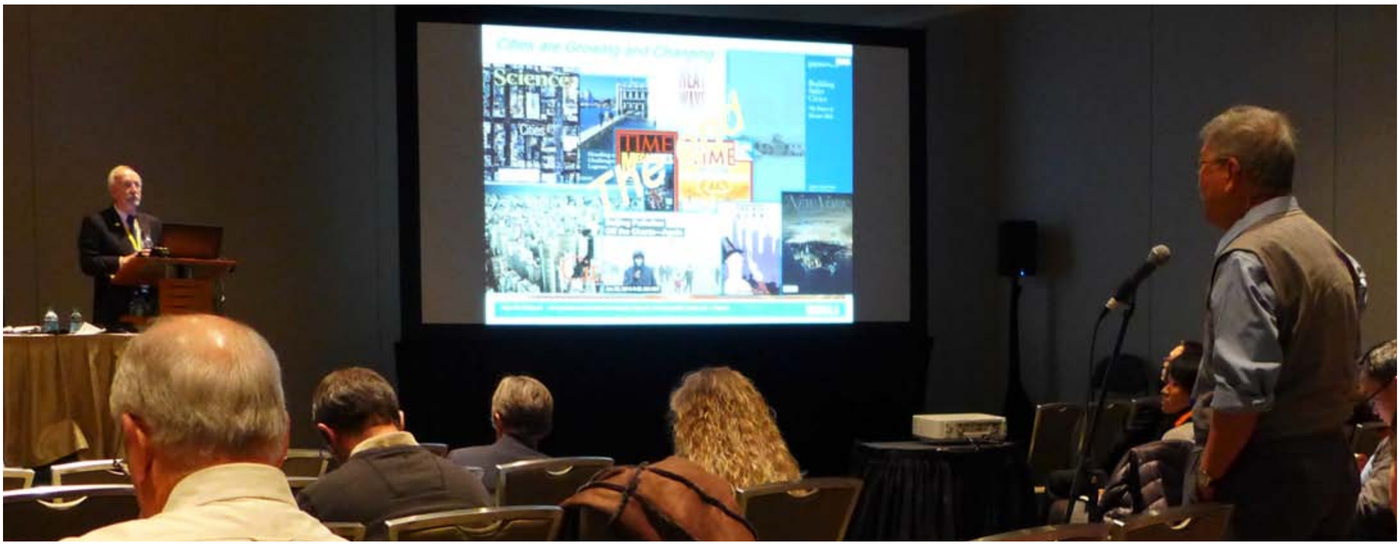
The sessions covered a wide range of topics related to urban environments, with topics devoted to the urban boundary layer, extreme heat, open challenges in observation or modeling, and many more. The oral sessions were complimented by thirteen poster sessions on an equally wide range of topics, from energy and water balance studies to extreme weather and urban resiliency. The buzz of conversation in the poster hall and the opportunity to discuss research in a less formal setting was always welcome.

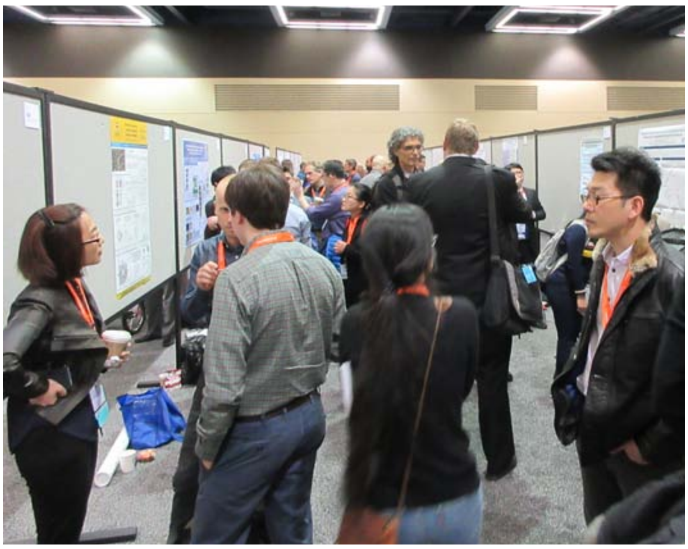
Throughout the course of the week I found the entire conference to be almost conspicuously apolitical. Even at the recruiting and networking events I found that representatives of organisations and universities were quick to dismiss any questions that I brought up about the current political climate, assuring me that funding was secure and the research was not under any threat. I often get the impression that the US is a country of vast internal contradictions and that was upheld in my conversations at AMS.

In retrospect I found many of the most interesting moments to be the informal discussions and conversations in which ideas were exchanged very freely. The presentations, both oral and poster, struck me as very high calibre. As an introduction to the urban climate academic community it was an amazing experience and has certainly encouraged me to invest in my work and the field.

A full list of authors and presentations along with their recordings may be found at: https://ams.confex.com/ams/97Annual/webprogram/13URBAN.html


The Life and Scientific Times of
Bob Bornstein
Tim Oke
University of British Columbia, Canada





Tony Brazel honored with lifetime achievement award at 5th Jeffrey Cook Workshop in Israel

Invited speakers from Arizona State University (ASU) joined local academics and planners to address "The challenge of climate responsive architecture in hotter and drier cities"

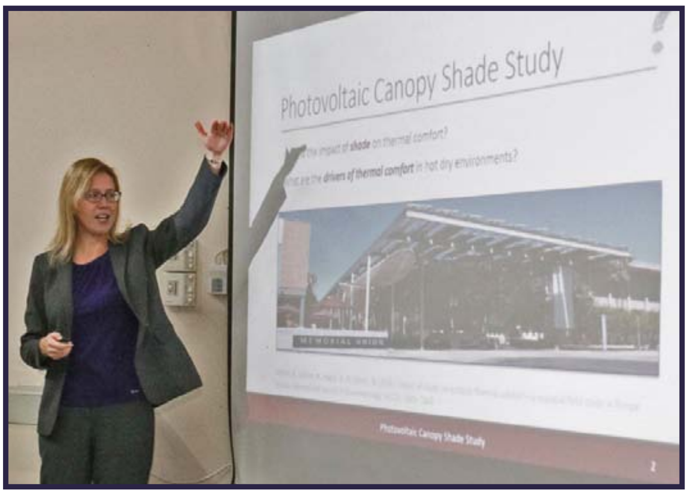
Left to right: Ariane Middel, Shai Kaplan, Tony Brazel, David Pearlmutter and Isaac Meir. Photos: Wolfgang Motzafi-Haller

As the warming of cities due to local heat island effects is compounded by global climate change, some urban areas may also experience drier conditions – meaning less water to keep cool, but also a range of opportunities for thermal adaptation which are unique to arid regions. On March 8th, researchers who have been tackling such issues for decades were brought together from desert regions on opposite sides of the world to discuss these challenges at the 5th Jeffrey Cook Workshop on Desert Architecture in Sede-Boqer, Israel.

The meeting was held at the Institutes for Desert Research of Ben-Gurion University of the Negev (BGU), and organized by Dr. Shai Kaplan, project manager of the ASU-BGU Partnership, and Prof. Isaac Meir, coordinator of the Jeffrey Cook Workshop. This biennial gathering is convened in memory of Prof. Jeffrey Cook from ASU, who was a pioneer in research, teaching and practice devoted to bioclimatic design in the built environment.

As part of the workshop, a prize for lifetime achievement is awarded to an internationally renowned figure who has made extraordinary contributions to the field, starting with Prof. Baruch Givoni in 2008. This year's award represented the closing of a circle, as it is the first time the prize has been bestowed upon an honoree from Arizona: Professor **Anthony Brazel**, who not only is a pioneer in the study of urban climates in arid regions (and a recent recipient of the Luke Howard Award), but in fact was a colleague of Jeff Cook at ASU.

The citation recognized Tony Brazel as "one of the world's preeminent authorities on the climate of desert cities," and emphasized the versatility and depth of his scientific work on the energy balance and development of heat islands in arid urban areas. It also paid tribute to his contributions to larger society as the Arizona State Climatologist, and his generosity of spirit in the many partnerships he formed over half a century with students and colleagues.



In his presentation, Tony described at length his collaborations with Jeff Cook over the years, painting a portrait not only of the way our understanding of the climate of Phoenix and other desert cities has evolved, but also of the way that innovators from fields like architecture and physical geography can pool their efforts to produce truly synergistic and groundbreaking insights on how to produce better urban design for such climates.

Additional invited guests speaking at the workshop included **Ariane Middel** from ASU, whose presentation summarized a series of innovative studies on shade and thermal comfort in hot dry climates, and **James Wang** from Singapore, who presented his in-depth research on outdoor thermal comfort in urban parks. Local researchers also presented their recent work, and, along with the organizers, included Guedi Capeluto, Hofit Itzhak Ben-Shalom, Yodan Rofe, Adi Vulkan & Evyatar Erell, Aviva Peeters & Limor Shashua Bar, and yours truly. Further information and material presented at the workshop can be requested from Isaac Meir (sakis@bgu.ac.il).

— David Pearlmutter, *UCN Editor*

Recent Urban Climate Publications

In this edition a list is presented of publications that have generally come out between **December 2016 and February 2017**. As usual, papers published since this date are welcome for inclusion in the next newsletter and IAUC online database. Please send your references to the email address below with a header "IAUC publications" and the following format: Author, Title, Journal, Year, Volume, Issue, Pages, Dates, Keywords, URL, and Abstract. In order to make the lives of the Bibliography Committee members easier, please send the references **in a .bib format**.

I would like to take this opportunity to thank **Bharathi Boppana** (Singapore A*Star Institute of HPC). She contributed to the Bibliography Committee over the last several years, and now decided to resign. Thank you Bharathi for your continued effort in providing recent urban climate literature references to the whole IAUC community.

Note that we are always looking for (young) researchers to join and contribute to the Committee. If you are interested to join or would like to receive more information, please let me know via the email address below.

Regards,

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Ai ZT, Mak CM (2017) CFD simulation of flow in a long street canyon under a perpendicular wind direction: Evaluation of three computational settings. *Building and Environment* 114:293-306.

Akbari H, Kolokotsa D (2016) Three decades of urban heat islands and mitigation technologies research. *Energy and Buildings* 133:834-842.

Allegrini J, Kubilay A (2017) Wind sheltering effect of a small railway station shelter and its impact on wind comfort for passengers. *Journal of Wind Engineering and Industrial Aerodynamics* 164:82-95.

Allen MJ, Sheridan SC (2016) Spatio-temporal changes in heat waves and cold spells: an analysis of 55 U.S. cities. *Physical Geography* 37:189–209.

Ando T, Ueyama M (2017) Surface energy exchange in a dense urban built-up area based on two-year eddy covariance measurements in Sakai, Japan. *Urban Climate* 19:155-169.

Antonyova A, Antony P, Korjenic A (2017) Evaluation the hygrothermal effects of integration the vegetation into the building envelope. *Energy and Buildings* 136:121-138.

Ao X, Grimmond CSB, Chang Y, Liu D, Tang Y, Hu P, Wang Y, Zou J, Tan J (2016) Heat, water and carbon exchanges in the tall megacity of Shanghai: challenges and results. *International Journal of Climatology* 36:4608–4624.

Badas MG, Ferrari S, Garau M, Querzoli G (2017) On the effect of gable roof on natural ventilation in two-dimensional urban canyons . *Journal of Wind Engineering and Industrial Aerodynamics* 162:24-34.

Bailey BN (2017) Numerical Considerations for Lagrangian Stochastic Dispersion Models: Eliminating Rogue Trajectories, and the Importance of Numerical Accuracy. *Boundary-Layer Meteorology* 162:43–70.

Bao J, Sherwood SC, Alexander LV, Evans JP (2017) Future increases in extreme precipitation exceed observed scaling rates. *Nature Climate Change* 7:128+.

Battista G, Carnielo E, Vollaro RD-L (2016) Thermal impact of a redeveloped area on localized urban microclimate: A case study in Rome. *Energy and Buildings* 133:446-454.

Benmarhnia T, Kaufman JS (2017) When evidence of heat-related vulnerability depends on the contrast measure. *International Journal of Biometeorology* 61:391–393.

Cao B, Luo M, Li M, Zhu Y (2016) Too cold or too warm? A winter thermal comfort study in different climate zones in China. *Energy and Buildings* 133:469-477.

Carvalho D, Martins H, Marta-Almeida M, Rocha A, Borrego C (2017) Urban resilience to future urban heat waves under a climate change scenario: A case study for Porto urban area (Portugal). *Urban Climate* 19:1-27.

Castro IP, Xie Z-T, Fuka V, Robins AG, Carpentieri M, Hayden P, Hertwig D, Coceal O (2017) Measurements and Computations of Flow in an Urban Street System. *Boundary-Layer Meteorology* 162:207–230.

Chen B, Dong L, Liu X, Shi GY, Chen L, Nakajima T, Habib A (2016) Exploring the possible effect of anthropogenic heat release due to global energy consumption upon global climate: a climate model study. *International Journal of Climatology* 36:4790–4796.

Chen Y, Yu S (2017) Impacts of urban landscape patterns on urban thermal variations in Guangzhou, China. *International Journal Of Applied Earth Observation And Geoinformation* 54:65-71.

Coccolo S, Kampf J, Scartezzini J-L, Pearlmutter D (2016) Outdoor human comfort and thermal stress: A comprehensive review on models and standards. *Urban Climate* 18:33-57.

Creutzig F, Agoston P, Minx JC, Canadell JG, Andrew RM, Le Quere C, Peters GP, Sharifi A, Yamagata Y, Dhakal S (2016) Urban infrastructure choices structure climate solutions. *Nature Climate Change* 6:1054-1056.

Dhar TK, Khirfan L (2017) A multi-scale and multi-dimensional framework for enhancing the resilience of urban form to climate change. *Urban Climate* 19:72-91.

El-Bachawati M, Manneh R, Belarbi R, El-Zakhem H (2016) Real-time temperature monitoring for Traditional gravel ballasted and Extensive green roofs: A Lebanese case study. *Energy and Buildings* 133:197-205.

Falabino S, Trini Castelli S (2017) Estimating wind velocity standard deviation values in the inertial sublayer from observations in the roughness sublayer. *Meteorology and Atmospheric Physics* 129:83–98.

de Freitas CR, Grigorieva EA (2017) A comparison and appraisal of a comprehensive range of human thermal climate indices. *International Journal of Biometeorology* 61:487–512.

Ge H, Deb Nath U, Chiu V (2017) Field measurements of wind-driven rain on mid-and high-rise buildings in three Canadian regions. *Building and Environment* 116:228–245.

Gondhalekar D, Ramsauer T (2017) Nexus City: Operationalizing the urban Water-Energy-Food Nexus for climate change adaptation in Munich, Germany. *Urban Climate* 19:28-40.

Grossman-Clarke S, Schubert S, Fenner D (2017) Urban effects on summertime air temperature in Germany under climate change. *International Journal of Climatology* 37:905–917.

Han M, Chen H (2017) Effect of external air-conditioner units' heat release modes and positions on energy consumption in large public buildings. *Building and Environment* 111:47-60.

Harter H, Weiler V, Eicker U (2017) Developing a roadmap for the modernisation of city quarters: Comparing the primary energy demand and greenhouse gas emissions. *Building and Environment* 112:166-176.

Henits L, Mucsi L, Liska CM (2017) Monitoring the changes in impervious surface ratio and urban heat island intensity between 1987 and 2011 in Szeged, Hungary. *Environmental Monitoring and Assessment* 189:

Hoffmann P, Schoetter R, Schlünzen K (2016) Statistical-dynamical downscaling of the urban heat island in Hamburg, Germany. *Meteorologische Zeitschrift* -.

Huang M, Gao Z, Miao S, Chen F, LeMone MA, Li J, Hu F, Wang L (2017) Estimate of Boundary-Layer Depth Over Beijing, China, Using Doppler Lidar Data During SURF-2015. *Boundary-Layer Meteorology* 162:503–522.

Hui Y, Tamura Y, Yang Q (2017) Analysis of interference effects on torsional moment between two high-rise buildings based on pressure and flow field measurement. *Journal of Wind Engineering and Industrial Aerodynamics* 164:54-68.

Ichinose T, Lei L, Lin Y (2017) Impacts of shading effect from nearby buildings on heating and cooling energy consumption in hot summer and cold winter zone of China. *Energy and Buildings* 136:199-210.

Jaffe DA, Zhang L (2017) Meteorological anomalies lead to elevated O-3 in the western U. S. in June 2015. *Geophysical Research Letters* 44:1990-1997.

Jamei E, Rajagopalan P (2017) Urban development and pedestrian thermal comfort in Melbourne. *Solar Energy* 144:681–698.

Jänicke B, Meier F, Fenner D, Fehrenbach U, Holtmann A, Scherer D (2017) Urban–rural differences in near-surface air temperature as resolved by the Central Europe Refined analysis (CER): sensitivity to planetary boundary layer schemes and urban canopy models. *International Journal of Climatology* 37:2063–2079.

Kikumoto H, Ooka R, Sugawara H, Lim J (2017) Observational study of power-law approximation of wind profiles within an urban boundary layer for various wind conditions . *Journal of Wind Engineering and Industrial Aerodynamics* 164:13-21.

Kohler M, Tannier C, Blond N, Aguejdad R, Clappier A (2017) Impacts of several urban-sprawl countermeasures on building (space heating) energy demands and urban heat island intensities. A case study. *Urban Climate* 19:92-121.

Kristof G, Peter DF (2017) Optimization of urban building patterns for pollution removal efficiency by assuming periodic dispersion . *Journal of Wind Engineering and Industrial Aerodynamics* 162:85-95.

Kruger EL, Tamura CA, Brode P, Schweiker M, Wagner A (2017) Short- and long-term acclimatization in outdoor spaces: Exposure time, seasonal and heatwave adaptation effects. *Building and Environment* 116:17–29.

Kuik F, Lauer A, Churkina G, Van der Gon HACD, Fenner D, Mar KA, Butler TM (2016) Air quality modelling in the Berlin-Brandenburg region using WRF-Chem v3.7.1: sensitivity to resolution of model grid and input data. *Geoscientific Model Development* 9:4339-4363.

Ladas DI, Stathopoulos T, Rounis ED (2017) Wind effects on the performance of solar collectors on rectangular flat roofs: A wind tunnel study . *Journal of Wind Engineering and Industrial Aerodynamics* 161:27-41.

Lai A, Maing M, Ng E (2017) Observational studies of mean radiant temperature across different outdoor spaces under shaded conditions in densely built environment. *Building and Environment* 114:397-409.

Li K, Zhang Y, Zhao L (2016) Outdoor thermal comfort and activities in the urban residential community in a humid subtropical area of China. *Energy and Buildings* 133:498-511.

Li Q, Li X, He Y, Yi J (2017) Observation of wind fields over different terrains and wind effects on a super-tall building during a severe typhoon and verification of wind tunnel predictions . *Journal of Wind Engineering and Industrial Aerodynamics* 162:73-84.

Liang P, Ding Y (2017) The long-term variation of extreme heavy precipitation and its link to urbanization effects in Shanghai during 1916–2014. *Advances in Atmospheric Sciences* 34:321–334.

Lipson MJ, Hart MA, Thatcher M (2017) Efficiently modelling urban heat storage: an interface conduction scheme in an urban land surface model (aTEB v2.0). *Geoscientific Model Development* 10:991-1007.

Liu L, Lin Y, Wang L, Cao J, Wang D, Xue P, Liu J (2017) An integrated local climatic evaluation system for green sustainable eco-city construction: A case study in Shenzhen, China. *Building and Environment* 114:82-95.

Meier F, Fenner D, Grassmann T, Otto M, Scherer D (2017) Crowdsourcing air temperature from citizen weather stations for urban climate research. *Urban Climate* 19:170-191.

Middel A, Selover N, Hagen B, Chhetri N (2016) Impact of shade on outdoor thermal comfort—a seasonal field study in Tempe, Arizona. *International Journal of Biometeorology* 60:1849–1861.

Mikhailuta SV, Lezhenin AA, Pitt A, Taseiko OV (2017) Urban wind fields: Phenomena in transformation. *Urban Climate* 19:122-140.

Montazeri H, Toparlar Y, Blocken B, Hensen J (2017) Simulating the cooling effects of water spray systems in urban landscapes: A computational fluid dynamics study in Rotterdam, The Netherlands. *Landscape and Urban Planning* 159:85-100.

Morakinyo TE, Kong L, Lau KK-L, Yuan C, Ng E (2017) A study on the impact of shadow-cast and tree species on in-canyon and neighborhood's thermal comfort. *Building and Environment* 115:1–17.

Morris KI, Chan A, Morris KJK, Ooi MCG, Oozeer MY, Abakr YA, Nadzir MSM, Mohammed IY (2017) Urbanisation and urban climate of a tropical conurbation, Klang Valley, Malaysia. *Urban Climate* 19:54-71.

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Upcoming Conferences...

EUROPEAN GEOSCIENCES UNION GENERAL ASSEMBLY
Vienna, Austria • April 23–28, 2017
http://www.egu2017.eu/

RESILIENT CITIES 2017: THE 8TH GLOBAL FORUM ON URBAN RESILIENCE AND ADAPTATION
Bonn, Germany • May 4-6, 2017
http://resilientcities2017.iclei.org

REMOTE SENSING OF URBAN CLIMATE AND URBAN HEAT FLUXES AT ISRSE37
Tshwane (Pretoria), South Africa • May 8-12, 2017
https://events.sansa.org.za/isrse-37

14TH ATMOSPHERIC SCIENCES AND APPLICATION TO AIR QUALITY (ASAAQ) CONFERENCE
Strasbourg, France • May 29-31, 2017
https://cloud.agoraevent.fr/Site/197201/2512/Event

URBAN SESSIONS AT 3RD EUROPEAN CLIMATE CHANGE ADAPTATION CONFERENCE (ECCA)
Glasgow, Scotland • June 5-9, 2017
http://ecca2017.eu/conference/

INTERNATIONAL WATER ASSOCIATION, EMBRACE THE WATER: A CITIES OF THE FUTURE CONFERENCE
Gothenburg, Sweden • June 12-14, 2017
http://www.embracethewater2017.com

PASSIVE & LOW ENERGY ARCHITECTURE (PLEA 2017)
Edinburgh, Scotland • July 3-5, 2017
https://plea2017.net/

AMERICAN GEOPHYSICAL UNION (AGU) FALL MEETING
New Orleans, USA • December 11-15, 2017
https://fallmeeting.agu.org/2017/

IAUC Board Statement on the US Executive Order

March 24, 2017

The International Association for Urban Climate (IAUC) is a non-governmental organization representing the international urban climatological and meteorological community. The IAUC fosters a view of a diverse and inclusive community of researchers, scholars, academics, students and others with interests related to the study of urban climate and meteorology.

The recently revised Executive Order, and its predecessor, issued by the President of the United States run counter to the ideals of the IAUC. The IAUC identifies itself as a free and open society with three primary goals: to foster education and scholarship related to urban climate and meteorology, to facilitate communication with policy makers and end-users of urban meteorological and climatological data, and to encourage the use of urban climate and meteorological information in the design, planning and operation of urban areas so that they may become safer, healthier and more sustainable.

We denounce this Executive Order and assert our support for all IAUC members. The success of scientific and academic organizations depends on a willingness for open collaboration and exchange of information, people and ideas. This order is detrimental to the scientific, educational and operational goals of the IAUC and to the aspirations of our members. We urge the US Executive to reconsider the order.

We are committed to supporting all IAUC members who may be impacted by the Executive Order requiring travel to the United States to attend meetings sponsored by the IAUC including the upcoming ICUC-10, to take up visiting scientist appointments, for graduate studies, or for temporary or permanent employment in research centers and universities. We will work with US organizations to develop processes by which we can minimize the impacts of any such order to our membership and their IAUC-related activities.

On behalf of the IAUC Board,

James Voogt, PhD
President

IAUC Board Members & Terms

- Gerald Mills (UCD, Dublin, Ireland): 2007-2011; President, 2009-2013; Past President, 2014-2018 (nv)
- James Voogt (University of Western Ontario, Canada), 2000-2006; Webmaster 2007-2013; President, 2014-2018
- Rohinton Emmanuel (Glasgow Caledonian University, UK): 2006-2010; Secretary, 2009-2013; Past Secretary 2014-2018 (nv)
- David Pearlmutter (Ben-Gurion University of the Negev, Israel): Newsletter Editor, 2009-*
- Aude Lemonsu (CNRS, France): 2010-2014; ICUC-9 Local Organizer, 2013-2018 (nv)
- David Sailor (Arizona State University, USA): 2011-2015; Secretary, 2014-2018
- Alexander Baklanov (University of Copenhagen): 2013-2017
- Valéry Masson (Météo France, France): ICUC-9 Local Organizer, 2013-2018 (nv)
- Fei Chen (NCAR, USA): 2014-2018
- Edward Ng (Chinese University of Hong Kong, Hong Kong): 2014-2018
- Nigel Tapper (Monash University, Australia): 2014-2018
- Aya Hagishima (Kyushu University, Japan): 2015-2019
- Jorge Gonzales (CUNY, USA): ICUC-10 Local Organizer, 2016-2021
- Dev Niyogi (Purdue University, USA): ICUC-10 Local Organizer, 2016-2021
- R. Leena Jarvi (University of Helsinki, Finland): 2016-2020
- Ariane Middel (Arizona State University, USA): 2016-2020

** appointed members*
nv = non-voting

IAUC Committee Chairs

Editor, IAUC Newsletter: David Pearlmutter
Bibliography Committee: Matthias Demuzere
Chair Teaching Resources: Gerald Mills
Chair Awards Committee: Nigel Tapper
Webmaster: James Voogt

Newsletter Contributions

The next edition of ***Urban Climate News*** will appear in late June. Contributions for the upcoming issue are welcome, and should be submitted by May 31, 2017.

Editor: David Pearlmutter (davidp@bgu.ac.il)
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Conferences: Joe McFadden (mcfadden@ucsb.edu)
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Submissions should be concise and accessible to a wide audience. The articles in this Newsletter are unrefereed, and their appearance does not constitute formal publication; they should not be used or cited otherwise.