Urban Climate News

Quarterly Newsletter of the IAUC

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From the IAUC President

Welcome to Edition 62 of the *Urban Climate News*. This issue we welcome new Urban Projects Editor **Helen Ward** (University of Reading, UK) and new Conferences Editor **Joe McFadden** (University of California Santa Barbara, USA) to the UCN team. Thank you Helen and Joe for volunteering!

This issue includes two feature articles, both of which include examination of carbon fluxes in cities, the first from a vegetated subtropical residential area in Auckland (Lena Weissert et al. University of Aukland, New Zealand) and the second as part of energy balance study from the tall megacity of Shanghai (Ao et al. Institute of Meteorological Science, Shanghai). Our series of urban project reports from ICUC-9 student award winners continues this issue with reports from Maxime Daniel (CNRM-GAME/Météo-France) on the use of watering practices for improving thermal comfort during heat waves, Bin Zhou (Potsdam Institute for Climate Impact Research) on a large satellite remote sensing study of heat island intensity and Veronica Bellucco (University of Sassari) on an approach to estimate the biogenic components of carbon fluxes over different ecosystems. We also feature two special reports. In the first, I report on the UN Habitat III meeting held in October in Quito, Ecuador, in which IAUC was a co-organizer of a special 'side event' on Climate change and urban disaster resilience and David Pearlmutter has provided an 18-month review of the *Urban Climate News*.

I am pleased to announce that **Walter Dabberdt**, Corporate Science Adviser to Vaisala, has been selected as the 2016 Luke Howard Award recipient. In a career extending over almost 50 years, Walt has made many significant leader leadership contributions to the international meteorological and urban climate community, and has helped to inspire generations of urban meteorologists through his research, particularly in the area of atmospheric dispersion in urban areas. The full award citation is available in this issue. Congratulations Walt and thank you to Nigel Tapper (Monash University) Chair, and the members of the IAUC Awards Committee (Yair Goldreich, Anthony Brazel, Andreas Christen, and Manabu Kanda) for their efforts.

Inside the Winter issue...

I am also happy to welcome to the IAUC Board our two new elected Board members. **R. Leena Jarvi** (University of Helsinki, Finland) is a researcher at the Division of Atmospheric Sciences at the University of Helsinki where she leads the urban meteorology group. Her work has focused on eddy covariance measurements of heat, water, greenhouse gases and aerosols over urban areas. **Ariane Middel** (Arizona State University, USA) studies urban climates through field work and modeling at the local and microscale with a particular emphasis on climate adaptation and heat mitigation strategies. Ariane and Leena will serve the Board from 2016-2020. As we look forward to 2017, we expect to replace one position on the Board.

Happy reading and best wishes to all IAUC members for a happy, healthful and successful 2017!

– James Voogt,
IAUC President

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Global cities make plea to US mayors to defy Trump on climate change

'Life gets better, cleaner, healthier, and more efficient as we embrace a clean energy future, work to eliminate dirty emissions, and put people – not fossil fuels – at the centre of our economies'

December 2016 — The mayors of five of the world's major cities have written a desperate plea to their counterparts in the United States, urging them to ignore Donald Trump's climate science denial and press ahead with steps to tackle global warming.

Urban areas are responsible for about 75 per cent of greenhouse gas emissions, so cities can make a significant contribution if they choose to do so.

The US President-elect has described climate change as a "hoax" and packed his Cabinet with people who have a track record of scepticism and denial about climate change.

The cities – Oslo, Rio de Janeiro, Stockholm, Sydney and Vancouver – are members of the Carbon Neutral Cities Alliance (CNCA), which wants to cut emissions by at least 80 per cent by 2050. Its membership already includes a number of US cities, such as New York, Washington DC and San Francisco, as well as the likes of London, Berlin and Yokohama in Japan.

Johanna Partin, director of the CNCA, said: "The US election makes clear that sub-national actors – especially cities – are America's only hope now in terms of climate action. President-elect Trump has picked a fellow climate science denier to lead the Environmental Protection Agency, an oil tycoon to head the State Department, an enthusiastic fossil fuel extractor as Energy Secretary, and gas pipeline supporter Ryan Zinke as Interior Secretary. These appointments are illustrative of how many steps back America is already starting to take. Climate policy cannot take a sabbatical and wait another four years or another election cycle for more aggressive action."

In the letter, the five mayors – Raymond Johansen of Oslo, Eduardo Paes of Rio de Janeiro, Karin Wanngård of Stockholm, Clover Moore of Sydney and Gregor Robertson of Vancouver – were unequivocal about the threat posed by the Trump presidency.

"America's President-elect has made it clear that he plans to eviscerate the country's environmental protections, including plans to cut emissions at coal-fired power plants, one of the most egregious carbon footprints in one of the world's largest greenhouse gas emitters," they wrote to the mayors of eight US cities, including Boston, Boulder in Colorado, Minneapolis and Seattle.

"President-elect Trump has stated that in his first 100 days he will do everything he can to dramatically expand the production of shale, oil, natural gas and coal; lift roadblocks to fossil fuel pipeline expansion projects like Keystone Pipeline; and cancel billions in payments for climate change programs. We see climate change as a core issue of national interest, and a key driver of the march toward a cleaner and more equitable future."

The President-elect has described climate change as a 'hoax'. *Source:* www.independent.co.uk

They pointed out that the number of jobs in renewable energy was growing rapidly with employment in the sector increasing 12 times faster than the general economy. "Business leaders understand this," the mayors said. "This is why you, the mayors of America's leading cities, must continue to be at the forefront of climate action in the US going forward.

"This is increasingly important as your new national leadership abdicates responsibility for protecting Americans and the world from fossil fuel impacts to our people's health, our economies, and our environment." And they pointed to other benefits from ditching oil, coal and gas beyond preventing dangerous climate change and creating new jobs.

"Life gets better, cleaner, healthier, and more efficient as we embrace a clean energy future, work to eliminate dirty emissions, and put people – not fossil fuels – at the centre of our economies," the mayors said.

They even pinched Mr Trump's favourite slogan.

"Making America great is about ensuring that its people are healthy and happy, its economies and environments are thriving, and its security is sound. We pledge to support you as you continue to do this. We hope the Trump administration will support you, America's leading cities, in your efforts. However if they do not, we, as fellow leading climate action cities, will stand by you to help in whatever ways we can."

Source: http://www.independent.co.uk/environment/global-cities-rio-vancouver-oslo-letter-us-new-york-city-mayors-defy-donald-trump-climate-change-a7479011.html#commentsDiv

Breathe less or ban cars: cities have radically different responses to pollution

When thick smog recently hit, Londoners were advised to avoid exercise, while Parisians got free public transport. Which is the best solution?

December 2016 — When a thick cloud of air pollution settled in over London last week, experts warned those with health problems to avoid strenuous exercise. The advice to Londoners essentially boiled down to this: breathe less.

Meanwhile, as Paris suffered a similar pollution episode – its worst in a decade – officials swung into action, waiving charges for public transport and restricting the number of cars allowed on roads, alternately barring those with odd and even license plates.

At the same time Paris mayor Anne Hidalgo joined officials from Madrid, Athens and Mexico City in announcing plans to get all diesel vehicles off the roads by 2025. Diesel is highly polluting, emitting far greater amounts of dangerous nitrogen dioxide and tiny pollution particles than petrol, and can cause cancer and heart attacks.

Despite the health damage it wreaks, governments across Europe, including Britain's, have offered motorists tax incentives that effectively encourage the use of diesel, on the assumption – now being questioned – that it produces less planet-warming carbon dioxide than petrol.

Doctors Against Diesel, a group formed last week to urge tougher action, says both the national government and London mayor Sadiq Khan must move quickly to protect Britons' health."If you're going to design something that would effectively deliver a toxic substance into the lungs, you couldn't do better than the diesel soot particle," says Jonathan Grigg, a consultant paediatrician at the Royal London Hospital and professor researching pollution's effects on children at Queen Mary University of London. "We need to get the current polluting, toxic diesel fleet off our roads as soon as possible."

Last week, Khan rolled out a new system of air quality alerts at bus stops, Tube stations and roadsides, warning those who experience symptoms from air pollution to reduce strenuous activity. The London Air Quality Network, based at King's College University, said vulnerable people, such as those with heart or lung problems, should consider limiting activity too.

The mayor also announced a doubling of funding for reducing pollution. He plans measures including charges for the dirtiest diesel cars entering central London from 2017, an acceleration and expansion of the Ultra Low Emission Zone, tighter standards for heavy vehicles and a cleanup of buses.

But he does not have the legal authority to institute a ban, and has demanded the government take urgent action, including a diesel scrappage scheme.

A view of foggy London, which has seen high levels of pollution this December. *Source:* www.theguardian.com

Cities around the world are confronting problems similar to London's. Some have been more aggressive than others, but overall, their experience shows that concerted steps to improve air quality do work, and they save lives.

Berlin is a notable exception to the story of the diesel disaster gripping much of western Europe. It has cleaned up its own fleet, installing pollution filters on buses and garbage trucks, and imposed tough rules on heavy goods vehicles. A strict emission zone bars older diesel vehicles, and rates of car use, which are already among the lowest in Germany, have dropped even further in recent years. Public transport is efficient and easy to use, with a two-hour pass costing just €2.70 (£2.25).

As a result, levels of the tiniest, most dangerous particles, known as ultrafines, fell 70% in just three years, says Axel Friedrich, former head of transport and noise at the federal environmental agency, and an adviser to government and advocacy groups. Next, environmentalists are pushing for a plan, now under court review, to require diesel cars to meet even stricter standards to enter Berlin and other German cities, he says.

Kraków has the worst air in Poland – one of Europe's most polluted countries. Every winter, heavy smoke wafts out of chimneys and blankets the city as residents burn coal in low-tech stoves to keep their homes warm.After a long legal fight, the city is now moving forward with a ban on burning coal for home heating, to take effect in September 2019.

New York has also targeted heating systems. After an analysis found that 1% of buildings burning the dirtiest kinds of fuel oil were producing more soot than all the city's traffic, officials made plans to gradually ban their use and to help landlords convert.

The changeover is already credited with saving hundreds of lives each year. It's just one piece of New York's air quality strategy, which also aims at slashing greenhouse gas emissions 80% from 2005 levels by 2050, says Mark

Chambers, director of the mayor's Office of Sustainability.

"Air quality is one of those things, you have to address it systemically," he says. "You have to really be thoughtful and intentional about looking at all sources for pollution and addressing them with whatever means you can."

Los Angeles, the city where American car culture reached its zenith, has also pushed hard to clean up its air. While it is still among the country's worst, the smogs that once tightened Angelenos' chests and made their eyes water are a thing of the past.

"We've made incredible progress, we can see the mountains in Los Angeles, when those of us who grew up here never could when we were young," says Joe Lyou, president of California's Coalition for Clean Air. Back then, in the 1960s and 70s, "you couldn't go outside, you couldn't breathe", on the worst days.

The dramatic improvement is the result of the most stringent air quality regulation in America. Inspectors even check the shelves of DIY stores for paints that are banned because the chemicals that drift off them contribute to smog. A statewide crackdown on dirty diesel lorries and a push to expand use of zero-emission vehicles are also a big part of the story.

In addition to the decades of regulation that have made American cars 99% cleaner than they were 40 years ago, cities like New York and LA have benefitted from American motorists' distaste for diesel, which accounts for only about 2% of cars in the US.

Even China, whose atrocious air the World Health Organisation says killed more than a million people in 2012, has begun to confront its crisis. Beijing has used license plate restrictions to limit the number of cars and set out plans to keep the oldest and most polluting vehicles off roads when air is especially bad. More importantly, the government has harnessed public anger over pollution to plough billions of dollars into wind and solar power, becoming the world's biggest investor in renewable energy. Officials have even begun cancelling plans for new coal-fired power stations – a move with repercussions for the health of those living in Chinese cities, and for the planet.

Los Angeles on one of its frequent smoggy days in 1958. *Source:* www.theguardian.com

Top: In November New Delhi experienced dangerously polluted air. Bottom: In 2008 German authorities established strict emission zones in Berlin, Hanover and Cologne. *Source:* www.theguardian.com

India, with air that is perhaps even worse, has been less aggressive. Prime minister Narendra Modi's government blames the Congress party that preceded him for letting pollution fester. But despite promises to clean up, the official response has been ineffectual.

Last month, Delhi's 20 million people suffered through the worst smog episode in 17 years, according to the Centre for Science and Environment. Officials temporarily shuttered a coal-fired power plant, halted all construction and demolition work and shut down many diesel power generators. In a sign that Delhi has begun to acknowledge the problem – if not to solve it – officials also closed 1,800 schools for three days, as particulate levels soared to 28 times the recommended maximums.

Tehran did the same when officials said a heavy blanket of smog had killed 412 people in 23 days. In fact, Iran is home to the city that currently tops the WHO's most polluted list for $PM_{2.5}$: Zabol, near the border with Afghanistan.

So what does it feel like to live in a city where the air doesn't make you sick? "It's nice," Berlin's Friedrich said with a laugh, adding that his neighbourhood in the south-western quarter is one of the cleanest. "My air quality is like the countryside." *Source:* https://www.theguardian.com/cities/2016/dec/15/breathe-less-ban-cars-cities-make-radically-different-responses-to-pollution

China's cities choke on heavy smog... with worse ahead

December 2016 — Hospital visits spiked, roads were closed and flights cancelled on Monday as cities across China choked under a vast cloud of toxic smog, with forecasters warning the worst was yet to come. At least 23 cities in the world's most populous country issued red alerts for air pollution from Friday to Monday (December 16-19), according to the official Xinhua news agency.

A host of emergency measures were implemented to protect the public's health from the smog, which is smothering almost a ninth of the entire country.

On Monday morning -- the fourth day of the alert which was scheduled to end on Wednesday -- Beijing's air quality was better than feared, with $PM_{2.5}$ levels hovering around 200, according to data maintained by the US Embassy.

However, the figure remained eight times the World Health Organization's daily recommended maximum exposure level to the microscopic particles that carry major health risks.

> *The issue (of air quality) is a source of enduring public anger in China, where fast economic growth in recent decades has come at the cost of widespread environmental degradation.*

And the relatively low number was just a temporary reprieve, Beijing's meteorological authority told AFP, adding that the worst haze would hit the city Monday night and linger until Tuesday.

In neighbouring Shijiazhuang, the capital of Hebei province, $PM_{2.5}$ levels stood as high as 701 at noon, with levels of larger PM_{10} particles even higher.

Heavy air pollution in China has caused a spike in hospital visits, closed roads and forced the cancellations of flights. ***Source:*** www.bangkokpost.com

In the port city of Tianjin, where readings for $PM_{2.5}$ climbed over 400 early in the morning, more than 180 flights had been cancelled and around 60 delayed since the alert began, according to national broadcaster CCTV.

Highways in the city were also closed, it said.

Several large hospitals in Tianjin saw a surge in the number of patients with respiratory diseases like asthma, according to the People's Daily.

A red alert, issued when severe smog is expected to last more than 72 hours, is the highest of Beijing's four-tiered, colour-coded warning system.

The capital issued its first ever red alert last year in December since the adoption of an emergency response programme for air pollution in 2013, despite frequent bouts of serious smog.

Most of China's smog is blamed on the burning of coal for electricity and heating, which spikes when demand peaks in winter.

The issue is a source of enduring public anger in China, where fast economic growth in recent decades has come at the cost of widespread environmental degradation. *Source:* http://www.bangkokpost.com/news/asia/1163397/chinas-cities-choke-on-heavy-smog-with-worse-ahead

Students wearing face masks walk across the street in a line in Jinan, in east China's Shandong province. ***Source:*** https://www.theguardian.com

C40 awards the 11 best cities of 2016 for addressing climate change

December 2016 — Eleven cities were honored recently at an awards ceremony in Mexico City. The C40 Cities Awards recognize the world's most inspiring and innovative cities tackling climate change. Sponsored by Bloomberg Philanthropies and BYD, the C40 Cities Awards ceremony was held during the C40 Mayors Summit, where more than 40 mayors from around the world gathered to create sustainable and liveable cities for citizens.

"On behalf of C40, I want to congratulate all the winning cities for their commitment to their citizens and their dedication to tackling climate change," said outgoing C40 Chair and Rio de Janeiro Mayor Eduardo Paes. "Throughout my tenure as C40 Chair, I have been increasingly impressed by the calibre of the C40 Cities Award winners, and I look forward to seeing other mayors around the world adapting and implementing these models in their own cities."

"The C40 Cities Awards recognize the best and boldest work being done by mayors to fight climate change and protect people from risks," said C40 President of the Board and U.N. Secretary General's Special Envoy for Cities and Climate Change Michael R. Bloomberg. "The winning projects show that great progress is being made on every continent, and they serve as an inspiration to other cities. They also show how cities can help the world meet the ambitious goals set a year ago in Paris."

An expert jury panel comprised of former mayors, climate experts and others, selected ten winning urban sustainability projects based on excellence in urban planning and dedication to reducing greenhouse gas emissions and improving resiliency. The selected cities exemplified the best policies, projects and programmes globally, and for the first time included a category recognizing social equity.

"Today, we celebrate some of the projects that are key to delivering on the world's climate ambition and will help put us on a path to a carbon-safe future," said Chuanfu Wang, Chairman and President of BYD Co. Ltd. "We recognise the incredible human power and thoughtful consideration that goes into making these projects reality. BYD is extremely proud to support the Awards and help to accelerate the implementation of these truly innovative programs."

Earlier in the day during the C40 Mayors Summit, C40 unveiled a report, Deadline 2020: How cities will get the job done, outlining a vision to reduce emissions by 2020 and help meet the Paris Agreement targets.

Stay tuned to upcoming editions of *Urban Climate News*, in which our News Editor Paul Alexander will provide an overview of each of the winning projects:

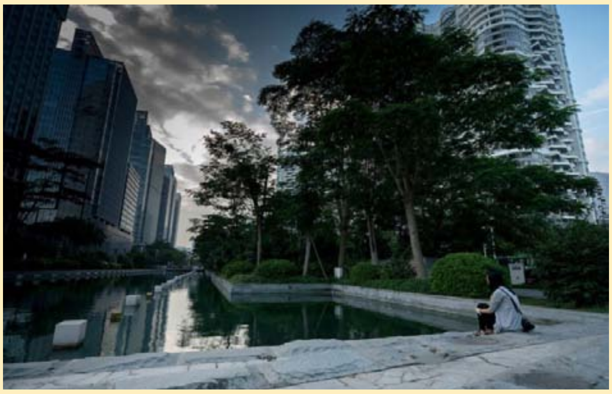
- **Climate Action Plans & Inventories: Portland**

- **Adaptation Plans & Assessments: Paris**

- **Building Energy Efficiency: Melbourne/Sydney**

- **Clean Energy: Yokohama**

- **Transportation: Addis Ababa**



- **Finance & Economic Development: Shenzhen**

- **Sustainable Communities: Curitiba**

- **Solid Waste: Kolkata**

- **Social Equity & Climate Change: Seoul**

- **Adaptation in Action: Copenhagen**

For more information on the Awards and the winning projects, visit: http://www.c40.org/awards.

For the most up-to-date details about the 2016 C40 Mayors Summit, please refer to the website http://www.mayorssummit2016.c40.org/.

Follow the C40 Cities Awards on social media with #C40Awards and the C40 Mayors Summit with the hashtag #Cities4Climate.

Find out more about the C40 Cities Climate Leadership Group, Bloomberg Philanthropies, BYD and the C40 Cities Awards Jury Panel at http://voices.nationalgeographic.com/2016/12/02/c40-awards-the-11-best-cities-of-2016-for-addressing-climate-change/

CO_2 fluxes and sources in a subtropical residential area dominated by evergreen vegetation – A case study from Auckland

By Lena F. Weissert[1] (lwei999@aucklanduni.ac.nz)
Jennifer A. Salmond[1], Jocelyn C. Turnbull[2,3] and
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CO_2 flux studies from cities with a temperate climate have shown that urban centres are a net source of CO_2 and that urban vegetation plays a minor role in mitigating local CO_2 emissions. However, few studies quantified CO_2 fluxes and sources in subtropical cities and residential areas where the vegetation cover is larger and dominated by evergreen tree species, which potentially sequester carbon throughout the whole year. This study presents eddy covariance and radiocarbon isotope measurements of CO_2 from a subtropical residential area in Auckland, New Zealand.

Introduction

In recent years, there has been a growing interest in understanding the role of cities in the carbon cycle. Urban anthropogenic CO_2 emissions have traditionally been quantified using bottom-up inventory approaches. The introduction of the eddy covariance (EC) technique to urban environments in the late nineties offered an opportunity to directly measure total net CO_2 fluxes, including both anthropogenic (fossil fuel combustion) and biogenic emissions (ecosystem respiration, combustion of biofuel/biomass) and uptake (photosynthetic CO_2 uptake). Since then several studies, particularly from mid-latitude cities with a focus on urban centres, have been published. These have shown considerable inter-urban temporal and spatial variability, with much larger positive (= net emissions) CO_2 fluxes in winter compared to summer (Velasco and Roth, 2010). Net CO_2 fluxes generally reached a minimum at midday and during the growing season, which was particularly visible in heavily vegetated areas, indicating the potential of urban vegetation to mitigate local CO_2 emissions. Yet, annual average CO_2 fluxes generally remained positive suggesting that vegetative CO_2 uptake was not sufficient to offset CO_2 emissions. However, the EC technique has rarely been applied in cities with a subtropical and tropical climate, where evergreen vegetation may act as a continuous CO_2 sink, and results are limited to Mexico (e.g., Velasco et al., 2014) and Singapore (Velasco et al., 2013). Similarly, few studies investigated CO_2 fluxes in residential areas, which often cover large proportions of a city. Alternatively, some studies used top-down measurement approaches to estimate CO_2 fluxes (= net exchanges between the surface and the atmosphere) from atmospheric observations combined with atmospheric transport models, using total CO_2 observations or isotopes to isolate the anthropogenic CO_2 component.

A major disadvantage of EC measurements is the inability to attribute CO_2 emissions to different CO_2 sources. In other words, the net CO_2 flux provides no information about the relative contributions of anthropogenic and biogenic CO_2 emissions. To partition CO_2 sources, we can use isotopic analysis, including stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotopes or radiocarbon (^{14}C) (e.g. Djuricin et al., 2010; Turnbull et al., 2006). Particularly ^{14}C proved to be useful to quantify anthropogenic CO_2 since fossil fuel derived CO_2 is free of ^{14}C. However, no studies have used radiocarbon isotope measurements in combination with EC measurements to disentangle CO_2 sources. To address these research gaps we measured CO_2 fluxes and mixing ratios for a period of 12 months as well as $^{14}CO_2$ for a week in summer and winter in Auckland, New Zealand. Our objectives were to 1) assess the temporal and spatial patterns of residential CO_2 fluxes in a subtropical city where evergreen vegetation is abundant, and 2) determine CO_2 sources that dominate the diurnal patterns of CO_2 fluxes.

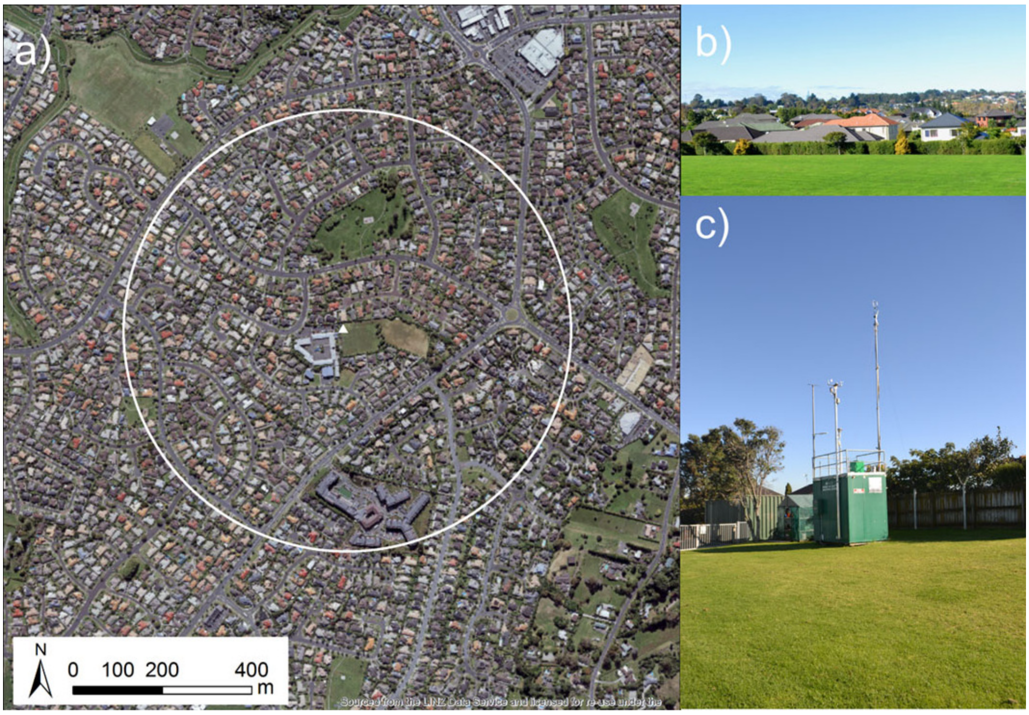

Fig. 1. a) Aerial photo of the study site (triangle) and the land cover within a 500 m radius, b) view towards south from the study site, c) EC mast.

Methods

The methods for this study are described in detail in Weissert et al. (2016a) and summarised below. Measurements were undertaken at a residential site approximately 15 km south-east of the Auckland city centre. The surroundings of the study site are characterised by one- to two-storey detached dwellings and a considerable amount of vegetation (approx. 47% surface cover fraction) with predominantly planted evergreen tree species (Fig. 1). On average, the 70% and 90% EC source footprint was within 500 m and 1300 m, respectively, although this varied across seasons and time of day. The residential area transitions into the rural area at around 700 m to the south-east of the EC site.

CO_2 fluxes were measured using the EC technique. A sonic anemometer (Gill WindMaster) and an enclosed infrared gas analyser (LI-7200) were mounted on a mast at 11 m. CO_2 fluxes were calculated as the mean covariance between the instantaneous deviations of the vertical wind velocity and mixing ratio and processed at 30 min intervals following standard procedures used in suburban EC studies. Positive CO_2 fluxes relate to fluxes towards the atmosphere (net emissions) while CO_2 fluxes towards the surface (net uptake) are negative.

To measure the radiocarbon content of CO_2 ($^{14}CO_2$) we used three samplers, which operated at three different times of the day. The samplers continuously drew air through an inlet line from an intake at 10 m, which was then passed through an initially carbon-free 1M sodium hydroxide (NaOH) solution to absorb CO_2 from the air. The samplers were running for three hours three times per day (06:00 – 09:00, 12:00 – 15:00, 01:00 – 04:00) for four consecutive weekdays (Tue – Fri) in summer (February 2015) and winter (June/July 2015). Fossil fuel (CO_2ff) and biogenic CO_2 (CO_2bio) was quantified using an isotopic mass balance approach as described in Weissert et al. (2016a).

Results

The diurnal variability of CO_2 fluxes and mixing ratios measured across different seasons is illustrated in Fig. 2a/b. Larger positive CO_2 fluxes were usually observed in the morning particularly during weekdays and when wind was from the east and southwest, likely due to morning traffic which peaks at 07:45. CO_2 mixing ratios also showed a peak in the morning, which can be explained by a combination of morning traffic and build-up in the nocturnal boundary layer before daytime boundary layer growth disperses the emissions.

CO_2 fluxes and mixing ratios varied little across seasons and reached a minimum at midday (Fig. 2a/b). Interestingly, the midday CO_2 fluxes remained negative all year-round, indicating larger CO_2 uptake than emissions. Although negative midday CO_2 fluxes were observed in previous studies (e.g. Bergeron and Strachan, 2011 (Montreal, Canada); Ward et al., 2013 (Swindon, UK)), these were limited to the growing season. This is the first study that showed mid-

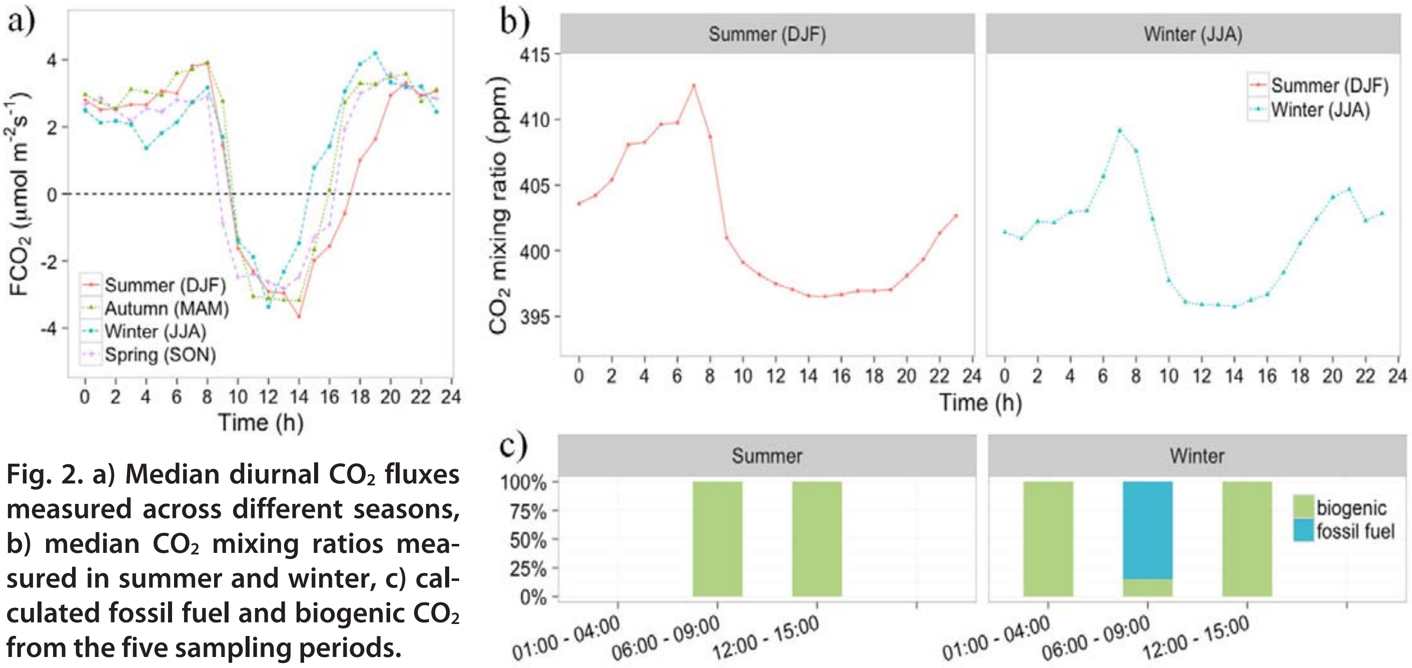

Fig. 2. a) Median diurnal CO_2 fluxes measured across different seasons, b) median CO_2 mixing ratios measured in summer and winter, c) calculated fossil fuel and biogenic CO_2 from the five sampling periods.

day CO_2 uptake across all seasons, demonstrating the ability of urban evergreen vegetation grown in a subtropical climate to maintain high photosynthetic rates throughout the whole year. This is supported by leaf-level gas exchange measurements of ten commonly planted tree species in Auckland, which showed almost 50% higher light saturated photosynthetic rates in winter compared to summer across all species (Weissert et al., in press). Opposite to findings from cities with cold winters where CO_2 emissions related to heating contribute to nighttime CO_2 fluxes, median nighttime CO_2 fluxes at the residential study site were lowest in winter, when soil CO_2 efflux reaches a minimum (Weissert et al., 2016b).

Despite the negative midday CO_2 fluxes, the residential study site remained a small CO_2 source across the whole year (mean CO_2 flux: 1.77 ± 3.94 μmol m^{-2} s^{-1}). Nevertheless, the annual CO_2 flux at the residential site in Auckland is below observations from other cities with a similar vegetation cover (Fig. 3) but colder winters (e.g. Helsinki, Montreal).

While CO_2 flux and mixing ratio measurements clearly show photosynthetic CO_2 uptake at midday, they are unable to evaluate the contributions of anthropogenic CO_2 emissions and respiration. Radiocarbon measurements show that in winter, when wind was from the SSW, fossil fuel CO_2 dominated the morning CO_2 peak, accounting for 85% of the CO_2 (Fig. 2c). However, when wind was from the SE/NE/E, in line with the more vegetated and rural area, no fossil fuel CO_2 was detected, even during the four-day morning rush hour sample in summer (Fig. 2c). During midday and nighttime, the fossil fuel CO_2 contribution was also negligible at this residential location. Most households in the study site region use electric heaters for home heating, which produces no local emissions and wood burning likely peaks in the evening, explaining the lack of anthropogenic CO_2 at nighttime in winter.

Conclusion

This study provided the first CO_2 flux measurements from a subtropical residential area where evergreen vegetation is a dominant land cover. The results showed previously unobserved CO_2 flux patterns, indicating year-round midday CO_2 uptake by evergreen vegetation grown in a subtropical climate. Thus, the potential of urban vegetation to mitigate local CO_2 emissions depends on climate, vegetation cover and type. Anthropogenic CO_2 emissions played a minor role at this residential site, which partly explains the negative midday CO_2 fluxes across all seasons. Nevertheless, this residential study site remained a small source of CO_2 across the whole year and photosynthetic CO_2 uptake was not sufficient to offset CO_2 emissions. The results of this study also demonstrate the potential of combining EC measurement with isotopic analysis to get a better insight into the underlying processes that drive urban CO_2 fluxes.

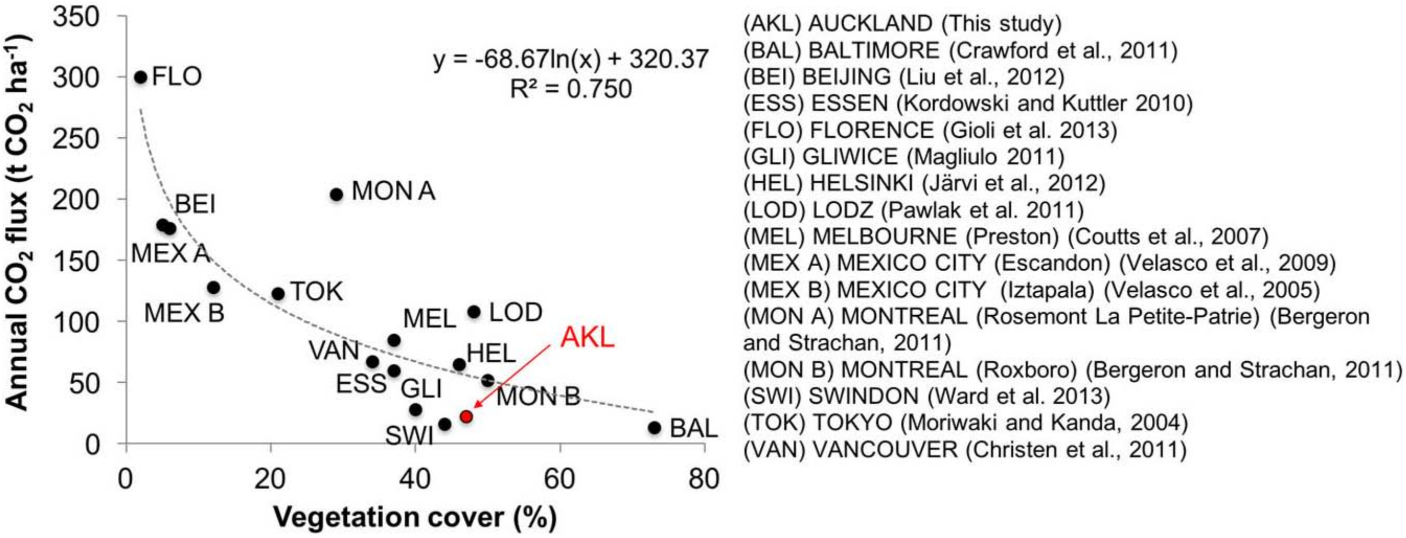

Fig. 3. Annual CO_2 fluxes measured in urban areas as a function of vegetation cover fraction (modified from Weissert et al. (2014)).

Adapted from the published paper:

Weissert, L.F., Salmond, J.A., Turnbull, J.C. and Schwendenmann, L. (2016) Temporal variability in the sources and fluxes of CO_2 in a residential area in an evergreen subtropical city. *Atmospheric Environment* 143:164-176. http://dx.doi.org/10.1016/j.atmosenv.2016.08.044

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Eddy covariance observations of surface energy balance and carbon fluxes in the tall megacity of Shanghai: Challenges and results

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Introduction

Urban growth has been particularly rapid in eastern China following the reform and opening-up policies in the late 1970s (Zhao et al. 2006). Many megacities have emerged, characterized by tall buildings and dense populations. Urbanization can result in modifications to energy, mass and momentum exchanges (Roth 2000, Collier 2006, Grimmond 2006, Loridan and Grimmond 2012) by altering surface properties and atmospheric conditions. Ultimately the modified urban energy balance creates distinct urban climate phenomena such as the urban heat island. The effect of urbanization on local or regional climate has been studied using climate models. However, large uncertainties still exist in these models due to insufficient knowledge of urban surface-atmosphere exchange processes. Thus, understanding surface-atmosphere interactions is essential to improve the forecasting ability of models and to mitigate urban climate effects.

The global FLUXNET programme (Baldocchi et al. 2001, Papale and Valentini 2003) has demonstrated the value of the eddy covariance (EC) technique (Aubinet et al. 2012) for direct measurement of fluxes of turbulent sensible heat (Q_H) and latent heat (Q_E), carbon dioxide (F_C) and momentum (τ) across a broad range of ecosystems (Baldocchi 2003). Although direct measurements of the energy balance in urban areas are needed for a wide range of applications, there are still remarkably few long-term measurements. Observations in cities are challenging because of the complex heterogeneity of urban surface structures (Ward et al. 2013, Kotthaus and Grimmond 2014a). EC measurements need to be made at least two times the height of the roughness elements to ensure that the equipment is within the inertial sublayer and thus the measurements represent local-scale fluxes.

Most of the previous urban EC measurements are from North American and European cities; long-term datasets for large, sub-tropical Asian cities are lacking. The objective of our study is to investigate temporal variability of radiation, momentum, heat and carbon dioxide exchange from a dense neighborhood with tall buildings in Shanghai (China) based on a full year of EC measurements. Particular attention is directed to the impact of complex urban surface heterogeneity and air quality on the fluxes, key surface parameters and the challenges of making EC measurements in this environment. The data presented also have important utility for an array of applications, especially evaluations of land surface models that can be used to contribute to the comfort, health and safety of city inhabitants and be instructive to urban planners and decision makers.

Methods

The site – Shanghai (Fig. 1), with a population of approximately 24 million (Shanghai Municipal Statistics Bureau 2011), is the economic, financial, shipping and trade centre of China. The measurement site, located in Xujiahui (XJH, 31.19 °N, 121.43 °E), at the headquarters of the Shanghai Meteorological Service, has a long history of meteorological observations (Tan et al. 2015). This densely built-up commercial and residential area is similar to large parts of central Shanghai.

The many tall buildings in the study area were mapped to develop a database of building heights within a 500 m radius of the tower using GIS data (Shanghai Surveying and Mapping Institute, http://www.shsmi.cn/) and a ground-based survey. The surface cover is dominated by impervious surfaces (85%). Vegetation cover (14%) includes deciduous and evergreen trees and shrubs (5% of the area). West to northwest of the measurement tower, is a small park with trees and grass.

Instrumentation and data processing – The instrumentation was mounted on the top of a 25 m triangular tower installed on the roof of the 55 m high building (Fig. 1a). Thus, the main sensors are 80 m above

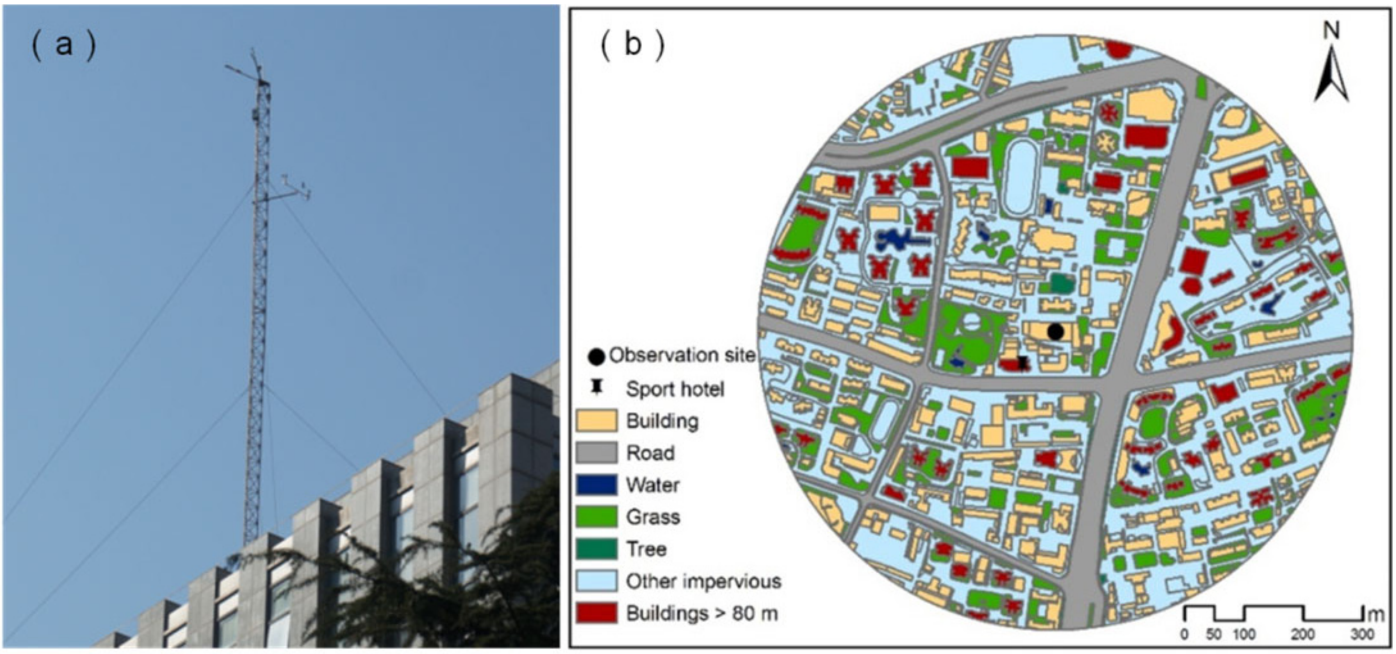

Figure 1. (a) flux tower at the XJH study site; (b) land cover map (500 m around XJH site). Adapted from Ao et al. 2016a.

ground level (agl). The turbulent fluxes are measured with an open-path infrared absorption gas analyzer integrated with a three-dimensional sonic anemometer (IRGASON, Campbell Scientific). When winds are from behind the tower (directions 320-337°), data are discarded.

The net radiometer (CNR4, Kipp & Zonen) measures the four components of net all-wave radiation. A Vaisala HMP155A probe measures air temperature and relative humidity. Precipitation is measured with a Vaisala MILOS500 automated meteorological station (AWS) at the Xujiahui Observatory (60 m from the tower). All data are collected and referenced to local time (UTC+8 h). Based on observed daytime cloud cover data (8:00, 14:00 LST) and hourly rainfall data, the daily sky conditions are classified into clear, cloudy, overcast and rainy. Particulate matter (PM) of 2.5 µm are measured at around 50 m agl (on top of a building, about 50 m to the south of the CNR4) using a Thermo Fisher Scientific 5030 SHARP Monitor. Following Xiao et al. (2011) and Zhang and Cao (2015), clear (cloudy) days are subdivided into haze or non-haze hours based on observed hourly visibility (Vaisala PWD22), relative humidity (RH) and $PM_{2.5}$ concentration.

Meteorological conditions – The study year was hotter than normal (1981-2010), notably in July and August, with 45 hot days (maximum > 35°C) compared to 8.7 days normally. The annual (2013) rainfall (1140 mm) was a little drier than normal (1259 mm). The prevailing wind direction in winter is from the northwest, in spring and summer the southeast, and in autumn the wind is more variable, from the north and the northeast.

Analysis methods – To determine the bulk atmospheric transmissivity (τ), the incoming solar radiation at the surface is compared to the solar radiation flux received at the top of the Earth's atmosphere ($K_{\downarrow,TOA}$):

$$\tau = K_{\downarrow} / K_{\downarrow,TOA} \qquad [1]$$

The larger τ, the more transparent the atmosphere. To calculate the incoming solar radiation at TOA, a solar "constant" (S_0) of 1361 W m^{-2} (Kopp and Lean 2011) was used with:

$$K_{\downarrow,TOA} = S_0 \left[\frac{r_0}{r}\right]^2 \sin h \qquad [2]$$

The Earth-Sun distance (r) changes over the course of the Earth's annual elliptical orbit around the Sun relative to mean Earth-Sun distance (r_0); h is the solar elevation angle.

Results and Discussion

Roughness characteristics around the site – The area weighted mean building height (z_H) within 500 m radius of the tower is 35.9 m. Mean values vary by direction from 7.8 to 149.2 m. One criterion for representative local-scale flux measurements is that instruments are within the inertial sublayer (or constant flux layer) and above the blending height (z_r). Here, for simplicity, the blending height is calculated based on the mean building height but for three flow regimes based on the plan area fraction (λ_P) which describes the packing density of roughness elements (Grimmond and Oke, 1999):

$z_r = f_r z_H$

1) *isolated* ($\lambda_P < 0.133$) f_r=2.5

2) *wake interference* ($0.133 \leq \lambda_P < 0.345$) f_r =2

3) *skimming* ($\lambda_P \geq 0.345$) f_r=1.5.

Those directions with a smoothed blending height lower than the measurement height (80 m) are assumed to be most likely to yield measurements that are representative of the local-scale.

The probable flux measurement source area extent for the site, determined with the Kljun et al. (2004) model, suggests the 80% source area extends to about 600 m from the tower, and the 90% source area to about 750 m.

The drag coefficient ($C_D^{0.5}$=u*/U; u*=friction velocity) provides a metric of the impact of the surface roughness elements on turbulence and wind fields. The high-rise area, primarily to the east (53-146°) and northwest (276-340°) of the tower, corresponds to the peak distribution of median $C_D^{0.5}$. Extremely large $C_D^{0.5}$ for wind directions 210-247° is caused by the influence of the nearest tall building (Sports Hotel, > 80 m). Data from this sector are relatively sparse as the air is diverted around the lateral edges of the building. This analysis of $C_D^{0.5}$ and other turbulence indices (not shown) by wind direction and stability provides one way to identify the wind sectors most likely to yield fluxes from the inertial sublayer, representative at the local-scale, and those from the roughness sublayer (RSL), representative of the micro scale. Five wind sectors (0-7°, 31-53°, 146-210°, 255-276° and 341-360°) are most likely to have measurements above the RSL (i.e. local-scale). In contrast, except the sectors influenced by the Sports Hotel (210-247°) and the tower (320-337°), the remaining five sectors (7-31°, 53-146°, 247-255°, 276-320° and 337-341°) are more likely to have measurements within the RSL (i.e. micro-scale). The subsequent analyses stratify the data into these two groups: local-scale and micro-scale.

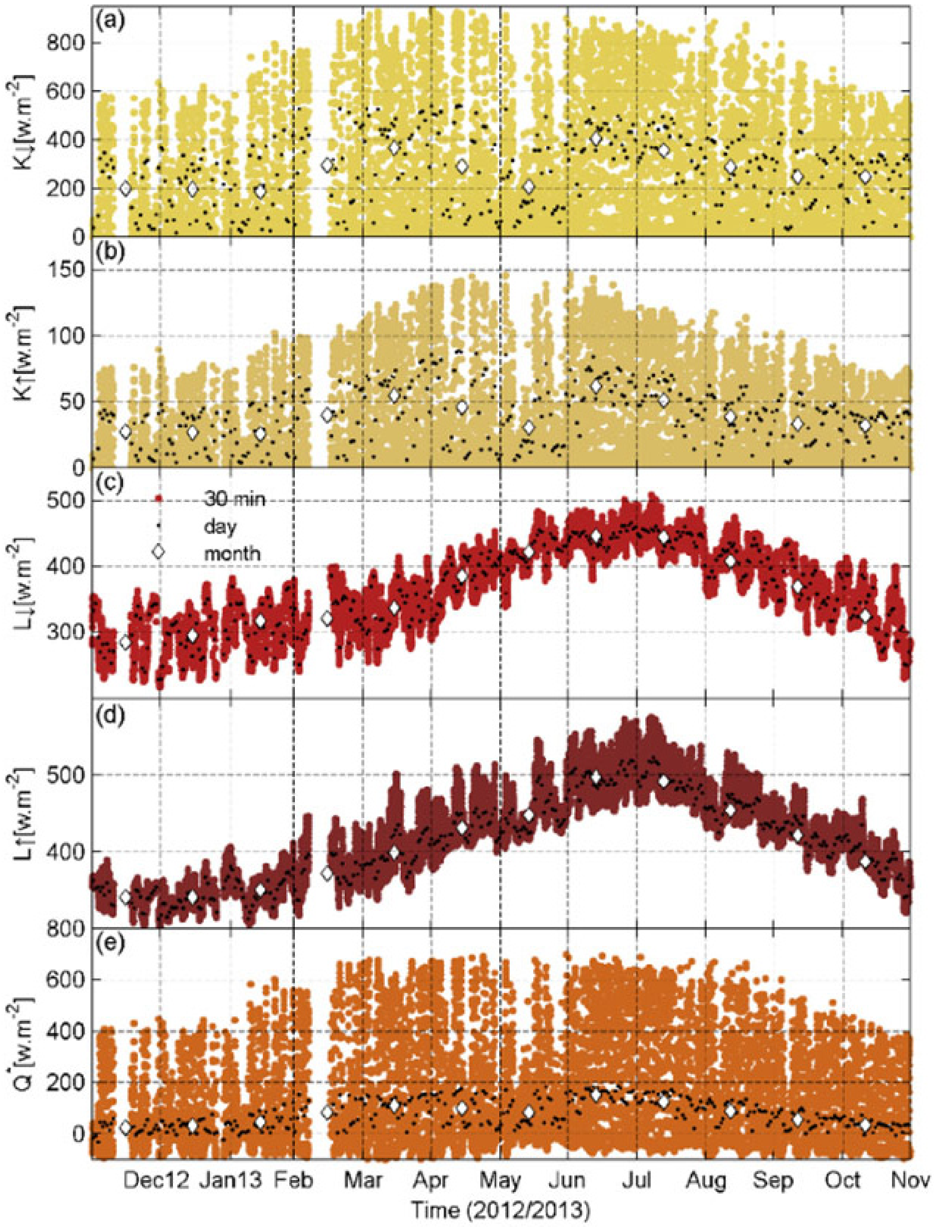

Figure 2. Observed 30 min fluxes (coloured dots) (a) incoming shortwave radiation (K↓), (b) outgoing shortwave radiation (K↑), (c) incoming longwave radiation (L↓) , (d) outgoing longwave radiation (L↑), (e) net all-wave radiation (Q*): hourly (dots), daily (solid line) in Shanghai (2012/2013) with monthly (white diamonds) and daily (black dots, shortwave radiation for sunlight hours) means. Reproduced from Ao et al. 2016b.

Characterization of the radiation fluxes – Radiative fluxes are key drivers of surface-atmosphere heat exchanges in cities. The median daytime maxima of incoming shortwave radiation K↓ for clear days ranged from 575 W m^{-2} in winter to 875 W m^{-2} in spring (Fig. 2). As expected,

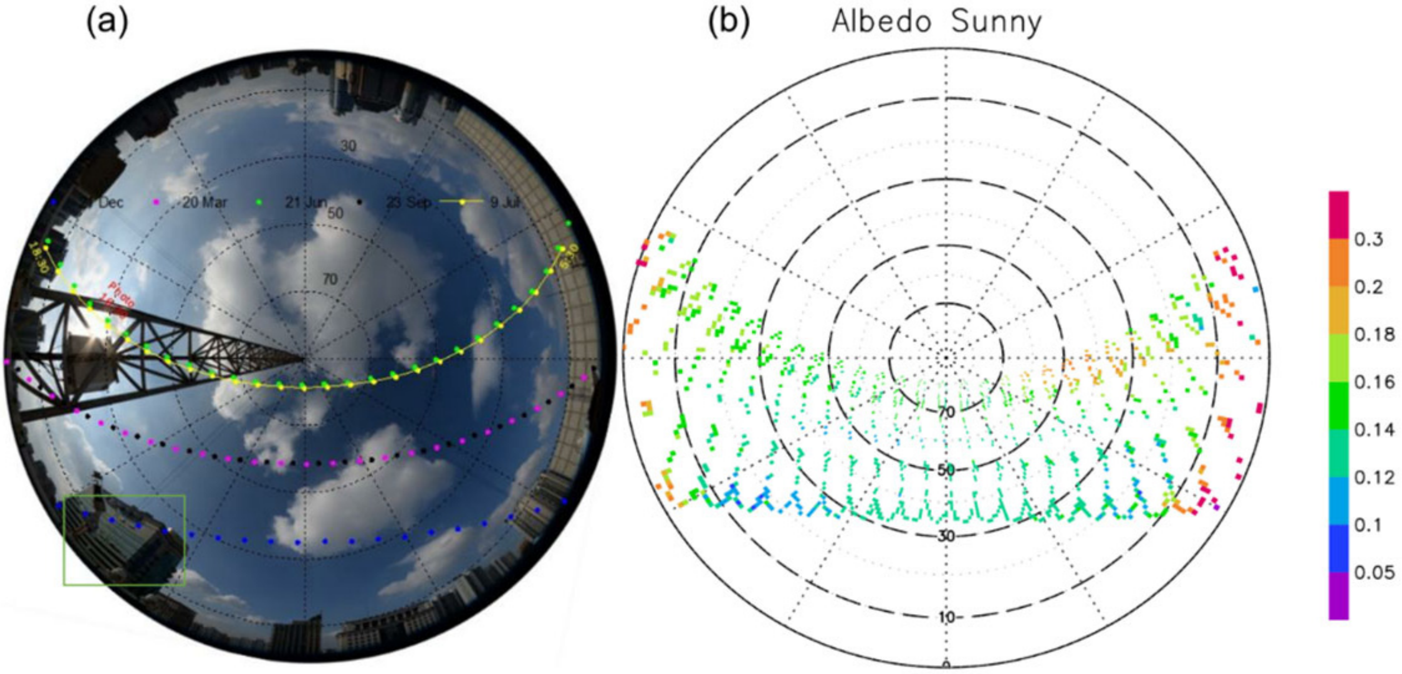

Figure 3 (a) Fish-eye photograph taken at the foot of the measurement tower. Dotted lines indicate sun position (every 30 min) on the summer solstice (green), winter solstice (blue), vernal equinox (pink), autumnal equinox (black) and "shooting" day (9 Jul 2014). The green rectangle shows the location of the Sports Hotel; (b) Mean surface albedo (bins 1° solar elevation (radial) x 1° solar azimuth (angular) angle) as a function of sun position. Adapted from Ao et al. 2016b.

this variation is much smaller than more northerly European cities, such as London (52° N) (Kotthaus and Grimmond, 2014a; b) and is similar to Tokyo, Japan (35.57 °N) (Moriwaki and Kanda 2004). Daily maxima of the reflected shortwave radiation ($K_{\uparrow}$) reported here for Shanghai, range between 80 W m^{-2} in winter and 150 W m^{-2} in summer.

The annual variation of the observed $L_{\downarrow}$ in Shanghai is very similar to that of the air temperature. The lowest monthly mean $L_{\downarrow}$ was observed in December 2012 and January 2013 (284, 294 W m^{-2}), the two coldest months in the observation period. The highest monthly mean $L_{\downarrow}$ was observed in July and August (446, 444 W m^{-2}, respectively). In general, cloud cover enhances $L_{\downarrow}$ (not shown).

Outgoing long-wave radiation ($L_{\uparrow}$) is directly influenced by the urban surface temperature. Thus it depends on the amount of the total incoming radiation energy, $Q_{\downarrow} = K_{\downarrow} + L_{\downarrow}$, the conduction and convection heat exchange processes at the surface, and the nature of the urban surface facets.

Median daily maximum values of the net all-wave radiation Q^* in Shanghai under clear conditions range from 400 W m^{-2} in winter to 640 W m^{-2} in spring. The monthly average Q^* remains positive throughout the year. However, during winter months radiative cooling exceeds the gain from solar input for individual days. Hence daily average Q^* can become negative.

The seasonal variation of the surface albedos is relatively small (not shown). The surface α varies with solar azimuth angle in correspondence with surface heterogeneity. Analysis of fish-eye photographs taken at the foot of the tower show a significant surface element is the Sports Hotel located to the southwest (Fig. 3a, indicated by the green rectangle). The mean albedo (binned 1° elevation x 1° azimuth) demonstrates that the significantly lower albedo (Fig. 3b) in the late afternoon in winter seems to be caused by shadows from the Sports Hotel. The median all-sky value (solar elevation $> 20°$) α is 0.14 (IQR= 0.02). This is similar to values for other central business districts (for example in London as reported in Kotthaus and Grimmond 2014a, b).

When clear days are stratified by the presence (or not) of haze, its effects on solar radiation can be assessed (Fig. 4). For the study period, the bulk transmissivity τ is decreased by about 0.07 (11.3% of the hourly average 0.65) between those hours with and without haze. The monthly median $PM_{2.5}$ concentrations were higher from November to April than May to October (not shown) which results in a larger reduction in transmissivity.

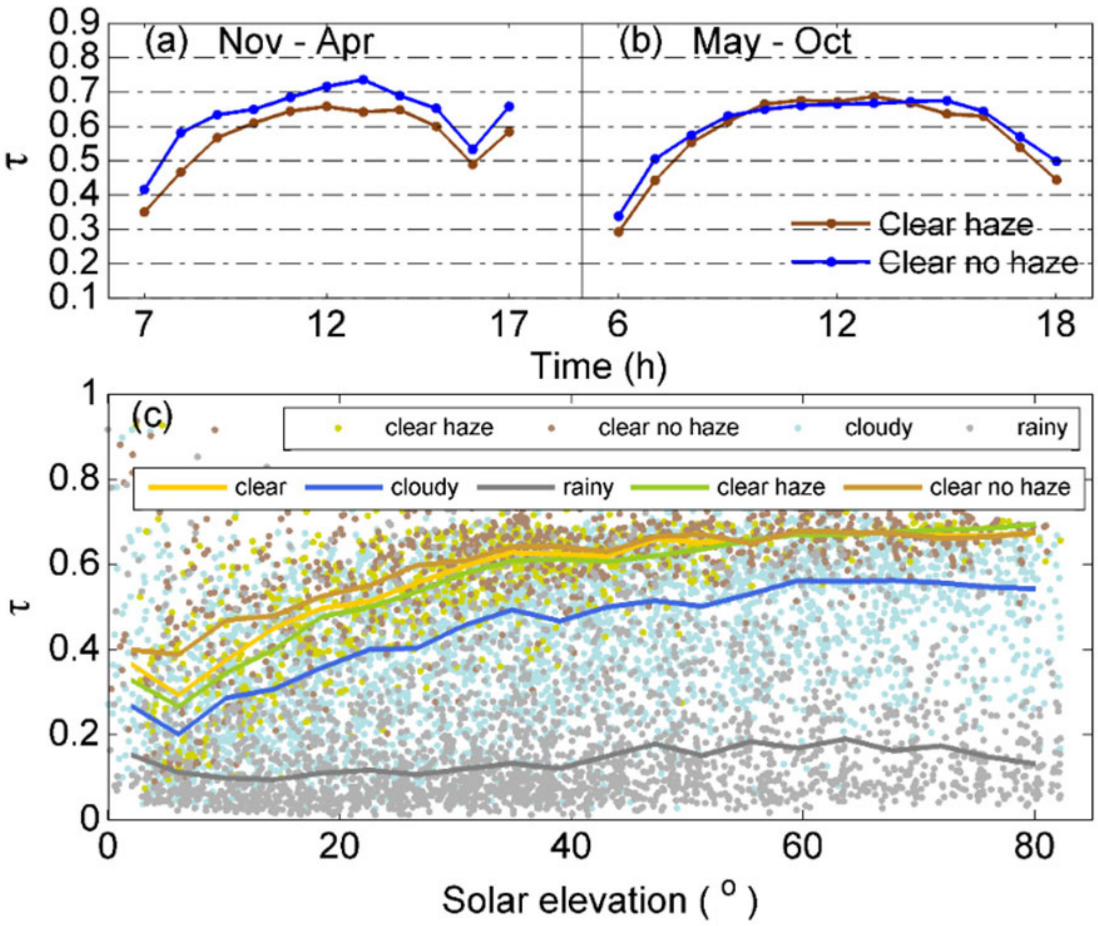

Figure 4. Median diurnal transmissivity (τ) under (a, b) clear 'haze' and 'no haze' conditions: (a) November to April and (b) May to October; (c) 30 min (dots) and median (lines, 4° bin midpoint plotted (i.e. 2 is for 0 - 4°)) τ as a function of solar elevation angle under clear skies (haze, no haze), cloudy and rainy conditions. Adapted from Ao et al. 2016b.

Characterization of the local-scale and micro-scale fluxes – The EC sensors are most likely to be within the inertial sublayer for 48% of the available data. Seasonal median diurnal variation of these local-scale (subscript L) sensible heat (Q_{HL}), latent heat (Q_{EL}) and carbon dioxide (F_{CL}) fluxes are shown in Fig 5. Median hourly Q_{HL} peaked in the early afternoon (winter: 86.8, spring: 204.7, summer: 291.7, autumn: 134.7 W m^{-2}), remaining positive throughout the year, with the exception of a few early morning autumn values. The seasonal pattern of Q_{Hm} (subscript m denotes micro-scale) is similar to that of the local-scale fluxes but the median values are larger by about 15-30 W m^{-2}. While the median Q_{Hm} in summer around noon is more variable than Q_{HL}, the median diurnal peak for Q_{Hm} is 7.1 W m^{-2} larger than Q_{HL}.

The seasonal median hourly Q_{EL} also remained positive throughout the year. Winter values were smallest, with daily peak values (20.7 W m^{-2}) less than half those in spring (48.8 W m^{-2}). The median diurnal peak in summer and autumn were 65.1 and 49.1 W m^{-2}, respectively. The seasonal diurnal pattern of micro-scale Q_{Em} are similar to the local-scale fluxes. The biggest difference relates to the larger magnitude of the micro-scale fluxes, attributed to less mixing of the air and the effects of intense micro-scale conditions.

The carbon dioxide fluxes (F_{CL}) have two diurnal peaks that are more distinct in summer and autumn (Fig. 5c). The morning F_{CL} emission peak is weaker than the evening one. Similar to the local-scale measurements, transportation emissions dominate the micro-scale CO_2 fluxes, evidenced by the two prominent rush hour peaks (08:00 to 10:00 LST and 17:00 to 19:00 LST). Relatively, the micro-scale daytime emission in July and the local-scale daytime emission in June are lower than the other months. This may be because of

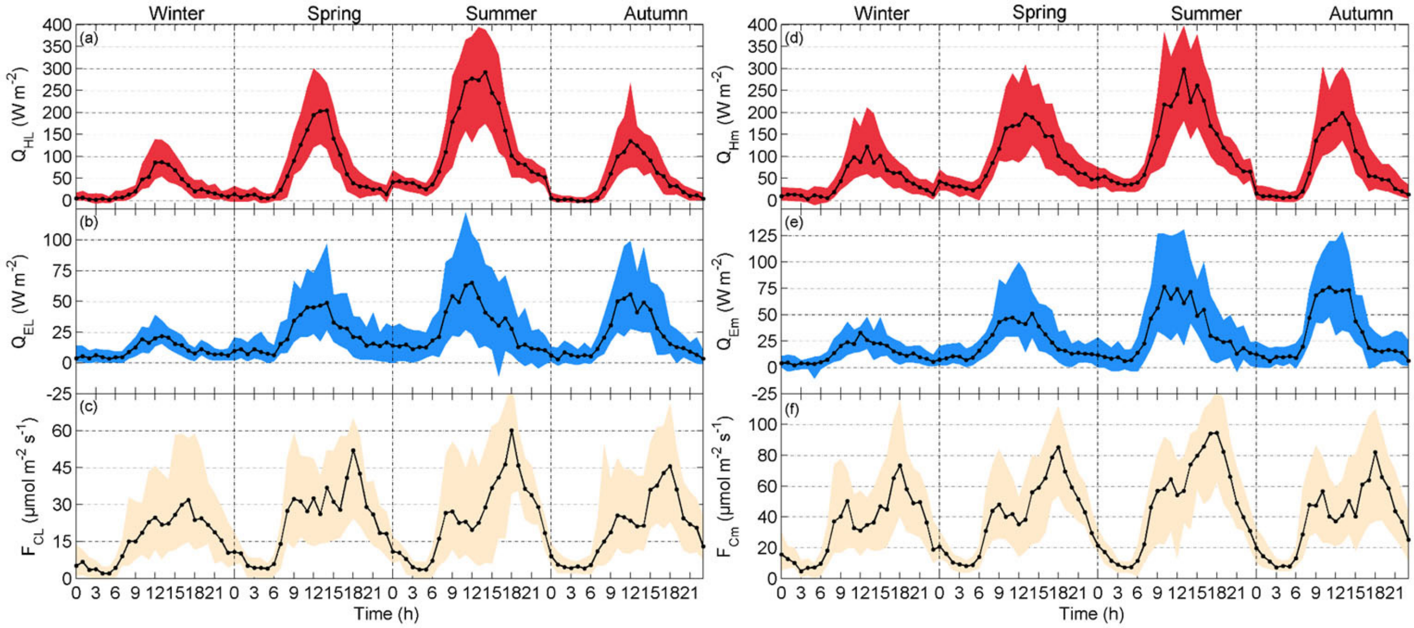

Figure 5. Seasonal median (line) and inter-quartile range (shaded) diurnal variation of (a-c) local and (d-f) micro scale turbulent (a, d) sensible heat (b, e) latent heat and (c, f) carbon dioxide fluxes. Note that the y-axes limits are different between local and micro-scale fluxes. Reproduced from Ao et al. 2016a.

stronger photosynthetic activity in these months that in part offset carbon emissions.

Conclusions

This paper reports results from an analysis of radiation, turbulent heat, water and carbon dioxide fluxes for a year (1 December 2012 to 30 November 2013) over a central business district of Shanghai, China. This area, with numerous tall buildings of varying heights, is particularly challenging for micrometeorological measurements, but is important given it is representative of an increasing number of urbanized sites being constructed globally.

Given the latitude of this site, the annual range of median daytime maxima of incoming solar radiation is much smaller than for higher latitude cities. Cloud cover has a significant impact on the radiation fluxes. Incoming long-wave radiation is larger under cloudy conditions, as expected, thereby reducing radiative cooling at night. Median daily maximum values of Q* under clear conditions range from about 400 (winter) to 640 W m^{-2} (spring).

Midday bulk transmissivity (τ) ranged between 0.6 and 0.7 under clear conditions. Increased atmospheric aerosol loading under haze conditions results in a decrease of τ by about 0.07 (11.3%). A bulk surface albedo of 0.14 was calculated to represent the overall characteristics of this site across radiative conditions. Individual tall buildings casting shadows have a dominant impact, reducing the albedo.

Analysis of the drag coefficient ($C_D^{0.5}$=u*/U) by wind direction revealed correlations with building height, standard deviation of wind direction and blending height. Based on these findings, fluxes measured at the site are stratified by wind direction and interpreted in terms of those representing local-scale and those representing micro-scale. Local-scale median daily peaks of sensible heat flux Q_{HL} occurred in the early afternoon. Latent heat fluxes (Q_{EL}) are smaller but not negligible. The daily median Q_{EL} remained positive throughout the year, with variations driven by rainfall and available energy. Patterns of micro-scale fluxes are similar, but the magnitude of Q_{Hm} is larger. This is attributed both to the influence of large vertical wall surfaces and the relative roughness of the surface.

This dense urban site is a net source of CO_2 for the whole year, dominated by traffic emissions with two rush hour peaks in the morning and evening (larger). The vegetation uptake effect is relatively small given the limited vegetation around the site.

The surface-atmosphere exchange data presented here provide much needed insights into the magnitudes of fluxes and controls on partitioning in areas with tall-buildings, increasingly common in cities of Asia and South America. They also provide site-specific data for land-surface models, critical both for model performance and evaluation. It is these models that can effectively underpin evaluations of the effects of different urban planning strategies in the context of rapid global urbanization and climate change.

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Role of watering practices in large-scale urban planning strategies to face the heat-wave risk in future climate

Introduction

Increasing heat-wave risk due to regional climate evolutions, exacerbated by Urban Heat Island (UHI) effects, is a major threat for the inhabitants of many cities. To face this issue, it is essential to devise, evaluate, and implement efficient climate change adaptation and UHI mitigation strategies. Urban greening is a solution more and more studied and promoted at different spatial scales (Gaffin et al. 2012; Rosenzweig et al. 2011; Bowler et al. 2010). In another way, pavement watering to refresh locally is a more recent approach that has been so far investigated essentially through experimental works (Takahashi et al. 2010; Hendel et al. 2015). Nonetheless, these various methods used to magnify evaporation are highly dependent on water availability and thus raise the issues of water supply for irrigation and vegetation efficiency.

Within the framework of the VURCA French research project, a complete modeling chain has been developed in order to study the evolution of urban climate for the Paris region at the end of the 21st century and under heat wave conditions. A socio-economical model has been applied to simulate the urban sprawl of the Paris area in 2100, and the urban climate of Paris has been simulated for various heat waves varying in duration and intensity. The present study is focused on an episode that is comparable to the 2003 heat wave (seven consecutive days with a maximum daily temperature of 38°C in the countryside). For such an event, and by accounting for the future urbanization of Paris, different scenarios of watering for vegetation and pavement have been simulated and compared.

Modeling set-up

Urban climate modeling – The modeling methodology developed for the VURCA project is described in detail in Lemonsu et al. (2015). The urban climate of Paris is simulated using the TEB physically-based urban canopy model (Masson 2000). This model is sophisticated enough to simulate, at the city scale, the air temperature at pedestrian level for various urban typologies, as well as the evapotranspiration of plants in an urban environment (Lemonsu et al. 2012). On the basis of 1-km spatial resolution atmospheric simulations of the 2003 heat wave performed by de Munck et al. (2013) and Kounkou-Arnaud et al. (2014) for Paris region, we have built a set of meteorological forcing that has been used to run TEB in a stand-alone mode. This configuration has enabled to assess the sensitivity of the urban climate to different irrigation practices under heat-wave conditions.

Irrigation scenarios – A first reference simulation has been performed without water supply for vegetation during the whole heatwave (simulation referred to as REF). It is assumed that no water is available for other actions than daily life usages, so that private gardens and urban parks are not watered.

A second simulation for which the vegetation irrigation is activated has been simulated. It is based on the most common watering practices in Paris according to de Munck (2013). An irrigation by sprinkling is activated at night from 11 pm to 7 am with a water supply of 1.2 10^{-7} m^3 s^{-1} (i.e. about 3.46 L per day and per m^2 of garden). Note that it is generally recommended to water plants at night because, during the day, water loss by evaporation significantly reduces the water supply for the soil, and the water droplets on the leaves magnify the sunlight and threaten to burn the foliage (see de Munck, 2013). From a technical point of view, this irrigation process is modeled in the model as an input water flux that is received by soil and vegetation (as it is already done for rainfall, for instance). By modeling water supply this way, a part of the water (depending on leaf area index of vegetation) is intercepted by the foliage, and consequently can be directly evaporated.

In addition, a scenario of pavement wateringhas been simulated. In this case, watering is set-up for sidewalks alone, assuming they cover 50% of the pavement. The watering protocol is based on a sensitivity study conducted within the framework of the EPICEA project (Kounkou et al., 2014). We suppose that the pavement is watered at a rate of 1.1 10^{-6} m^3 s^{-1} during three minutes at the beginning of every hour between 8 am and 8 pm (i.e. about 2.77 L day^{-1} and per m^2 of roads). For higher sprinkling rates, the water quantity is greater than the maximum storage capacity of the road reservoir simulated in the model (Masson 2000, Lemonsu et al. 2007), so the water excess would be lost by surface runoff to the sewer. Note that in this scenario, gardens and parks are not irrigated at all in order to be able to assess separately the different practices.

Results

Impacts of watering on latent heat fluxes – We have first analysed the effects of watering practices on the evaporation. Figure 1 compares the daily cycles of latent heat flux (Q_E) in W m^{-2} simulated after seven days of heat wave in two types of urban typologies (historical city center and residential areas) for the reference scenario and the two watering scenarios. For the reference case, Q_E reaches a maximum of 73 W m^{-2} at middayin residen-

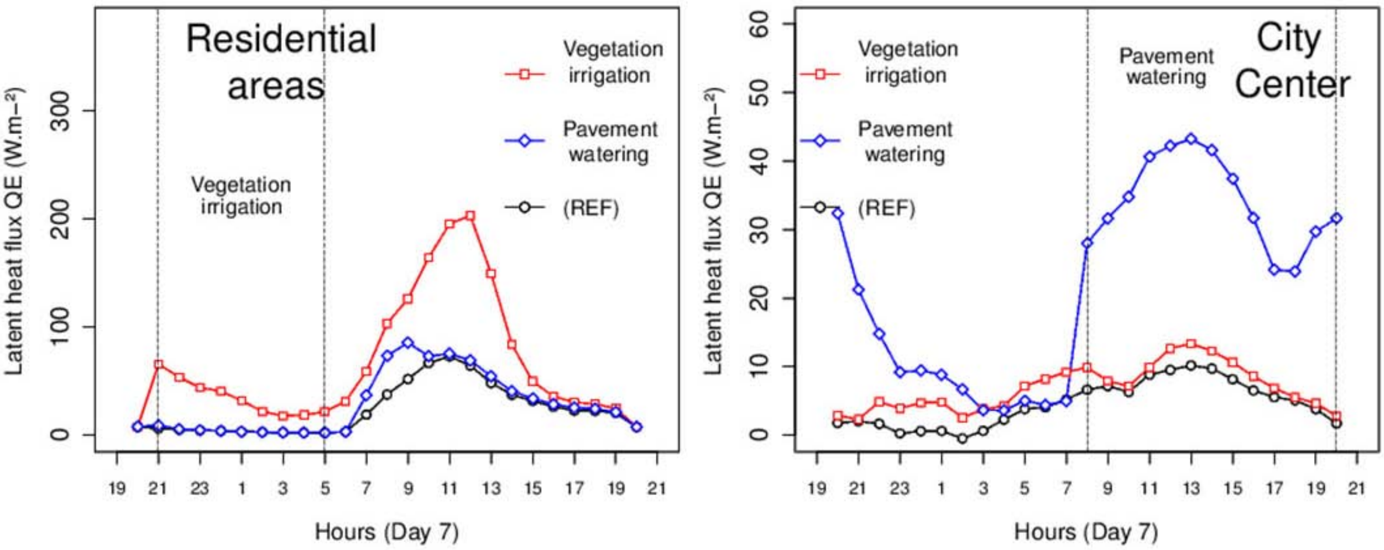

Figure 1. Daily cycle of latent heat flux for the three different scenarios.

tial areas, and is almost zero at night when vegetation is photosynthetically inactive. The absence of irrigation for vegetation results in an important water stress for plants which significantly limits the relevance of greening strategies. By activating the vegetation watering, the transpiration of plants is boosted, so that Q_E increases by +138 W m^{-2}. The pavement watering enhances less significantly evaporation in residential areas; it leads to a 50 W m^{-2} increase of Q_E in the morning in the first hours following the pavement watering start.

In the city center for the reference case, Q_E does not exceed 11 W m^{-2} in the middle of the day due to the predominance of impervious covers in this area. The increase in evapotranspiration is limited in the scenario based on vegetation irrigation since the vegetation cover fraction is low. The pavement watering is here more efficient. It leads to an additional Q_E up to +33 W m^{-2}. In this part of the city, the roads provide an important surface area for sprinkling, and consequently offer a higher evaporation potential than vegetation.

Impacts of watering on urban heat island – If urban vegetation is not watered (REF), air temperature is significantly increased in urban areas compared to the surrounding countryside. Maps of UHI are calculated as the difference between the local air temperature (temperature simulated by the model 2 meters above the ground) and a reference temperature corresponding to the temperature of rural areas, i.e. the mean temperature of peripheral and uninhabited grid cells. More details on the method can be found in Lemonsu et al. (2015).

During the day (Figure 2, top-left), the UHI is very extended: about 98% of the city area is impacted by an UHI greater than 1.5°C. The maximum values of UHI (up to 2.5°C) are located in the suburbs rather than in the city center where shading effect of buildings reduces the intake of solar radiation. At night (Figure 2, bottom-left) the UHI has a different pattern: it is less extended than during the day since 26% of the urban area is impacted in this case. But it reaches higher values in the most urbanized areas with a maximum intensity of 3.2°C in the city center.

The benefits of watering strategies on urban climate are evaluated by computing the difference in UHI intensity between the reference scenario (REF) and the other scenarios. The maps of UHI mitigation are presented in Figure 2 (center and right) for daytime (top) and nighttime (bottom) hours.

During the day, the pavement watering induces a cooling that goes up to 1.0°C in the city center. The impacts are negligible in residential areas where the fraction of the ground-based impervious surfaces are limited (only 22% of ground surfaces are watered). With vegetation irrigation a maximum UHI mitigation of 0.8°C is noted in residential areas. In the city center, the proportion of green spaces is too low to generate a significant cooling related to evapotranspiration of plants.

At night, the pavement watering has a limited impact since it is activated only between 8 am and 8 pm and water evaporates rapidly on impervious surfaces. A slight but not significant cooling (less than 0.5°C) is however noted in the city center compared to (REF) because during the day the roads consume a large part of the energy they received by evaporation and they consequently store less heat. For the vegetation irrigation, a UHI mitigation between 0.5 and 1.5°C is displayed in residential areas. At that time of the day, the vegetation is watered by sprinkling, so that a part of the water is intercepted by the foliage and can be directly evaporated, thereby inducing a nocturnal cooling. Therefore the cooling (up to 2.6°C) is explained by the lower daily heat storage but also by the significant evaporation at night.

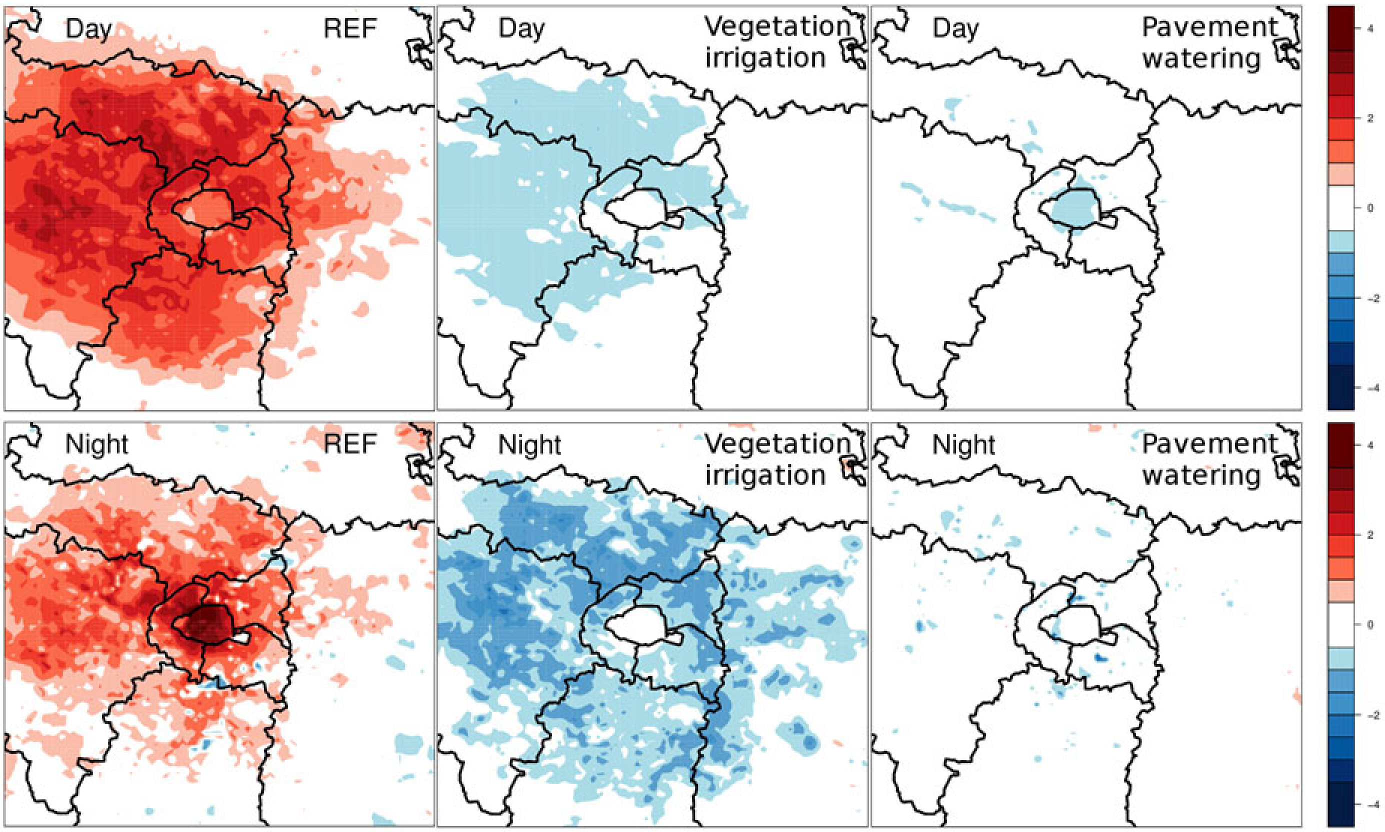

Figure 2. Spatial representation of UHI after seven days of heat wave for the reference case (left) and maps of 2-m air temperature difference between each watering scenario and the reference (center, right) for daytime (top) and nighttime (bottom) hours.

Water consumption and efficiency of watering strategies – In order to compare scenarios in a more objective and integrative way, a cooling efficiency coefficient (Eff) has been proposed. It links the cooling effect (expressed in K day^{-1}) to the daily water consumption (in mm^3 day^{-1}):

$$Eff_{(R)} = \frac{\sum_t \left(T_{2m(R)}(t) - T_{2m(N)}(t)\right)}{V_{wat(R)}} \qquad [1]$$

The cooling effect is estimated by calculating first the spatial field of temperature difference between a given scenario and the reference case (cumulated over all hours of the day). A spatial average of this field is then computed by weighting each grid point of the modeling domain according to the urbanization rate (method 1) or to the population density (method 2). The daily water consumption that is computed over the whole urban area (V_{wat}) is equal to 4.9 mm^3 of water per day for the vegetation irrigation scenario and 1.5 mm^3 of water per day for the pavement watering scenario.

The most efficient scenario is the pavement watering, whatever the method of calculation for cooling efficiency coefficient: $Eff_{(P)}$ reaches 5.5 and 7.5 K per mm^3 of water based on urbanization and population distribution, respectively, whereas for vegetation irrigation $Eff_{(R)}$ ranges from 4.0 to 4.6. However, even though it is more efficient because it consumes little water, the pavement watering does not allow high cooling values: ΔT_{2m} is limited to -8.5 K day^{-1} in this case while it goes up to −22.8 K day^{-1} for vegetation irrigation. It is interesting to emphasize that $Eff_{(P)}$ is even better when it is calculated on the basis of population distribution (7.5 instead 5.5) because the pavement watering is especially efficient in the most populated areas in the city center and inner suburbs. Inversely, $Eff_{(R)}$ is weaker when calculated this way (4.0 instead of 4.6).

Table 1. Water demand and Cooling efficiency coefficients (spatially averaged temperature decrease, in °C, per total mm^3 of water) of watering scenarios evaluated after seven days of heat wave. The coefficients are calculated based on map of urbanization rate or of population density, and starting from the 2-m air temperature (Eff).

	Pavement watering	Vegetation irrigation
Water demand (10^6 m^3 day^{-1})	1.5	4.9
Eff (urbanization rate)	5.5	4.6
Eff (population density)	7.5	4.0

Conclusion

Greening the city can be a relevant a tool to mitigate UHI in case of heat wave. However, this study highlights that in order to preserve the cooling potential of vegetation, it is critical to insure it a sufficient water supply. The scenario for which vegetation is watered according to an *a priori* realistic protocol results in a significant cooling of air temperature near the ground between 0.5 and 1.5°C, both during daytime and nighttime. Despite reasonable watering rates, the implementation of such greening policies at the city scale leads to a very large water consumption.

Considering the simulation results, the benefits of vegetation for regulating the urban microclimate are undeniable over a large part of the city. Only the most urbanized areas are not impacted due to the too low coverage of vegetation. The pavement watering can be an interesting solution in such an environment. It enables a very local but significant cooling effect during the day for the city center and inner suburbs. As a conclusion, the two strategies of watering that have been tested have complementary roles. They do not involve the same physical processes, and are consequently efficient in different urban configurations, so that they can be combined for an optimized effect.

Acknowledgements

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Cities as urban clusters: An empirical study of surface urban heat island intensity and its implication for benchmarking UHI adaptation

Introduction

There is obviously no need to review and motivate here why understanding the urban heat island (UHI) from multiple levels is of great importance in the current discussion on sustainable urban planning in a world with more persistent and more frequent heat waves (Coumou & Rahmstorf 2012). In particular, heat waves are shown to pose an added stress on cities (Li & Bou-Zeid 2013), raising serious concerns of general well-being and potential threats to human health, which in turn demands effective adaptation measures to alleviate the UHI.

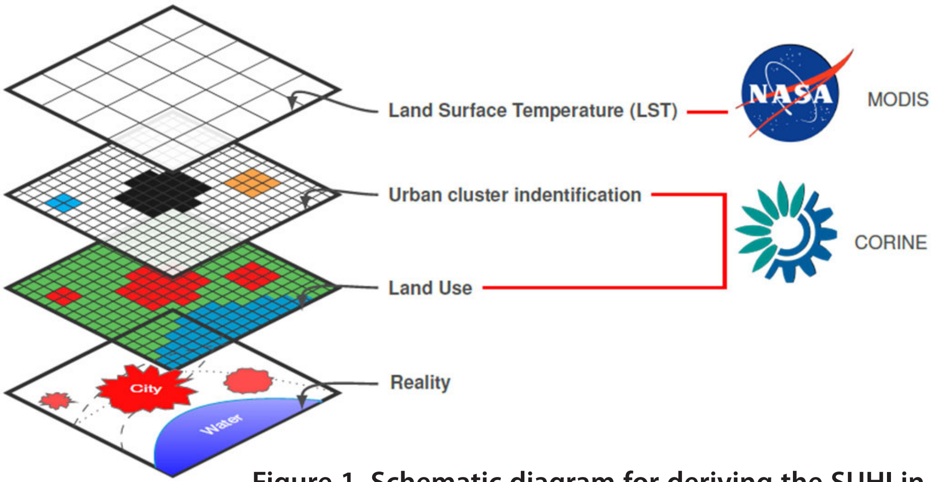

Figure 1. Schematic diagram for deriving the SUHI intensity of city clusters by combining land cover data and surface skin temperature data.

Conventionally, the UHI intensity is assessed by using 2 m air temperature data obtained from observations or numerical simulations for one or several case study cities. In contrast to this long-established approach, the study of UHI from the perspective of surface skin temperature could not have been possible without a constant development of remote sensing technologies (Voogt & Oke 2003).

In the last decade, the availability of remotely sensed surface skin temperature with global coverage (e.g. Landsat sensors) has given rise to a number of empirical surface UHI (SUHI) studies focusing on a large quantity of cities (Zhou et al. 2015; Zhou et al. 2013; Zhao et al. 2014; Clinton & Gong 2013; Peng et al. 2012). These ensemble or cross-sectional studies combine land cover data and remotely sensed surface skin temperature, i.e. urban land cover is used to define the physical extent of urban areas enabling to systematically extract the temperatures inside the cities and in their rural surroundings, as shown in Figure 1.

These studies, based on a large number of cities, aim at a comprehensive understanding of common characteristics or fundamental differences among the investigated cities. These merits can scarcely be promised by the conventional case study work.

This article elaborates an established standard protocol for robustly benchmarking the SUHI across cities, and for deciphering statistical features of the SUHI associated with biophysical and socio-economical indicators. Since one-size-fits-all type of solutions are generally not available while configuring adaptive and mitigating strategies (Georgescu et al. 2015), it is of course good to know whether or to which extent measures alleviating the UHI suggested by the computation-intensive urbanized meso-scale modelling in a case study city can be further implemented, with the same effectiveness, in other cities. Therefore, a better understanding on the typology of UHI is needed. To this end, we take Europe as an example to classify the typology of cities based on their SUHI seasonal variation and discuss its potential practical implications. For details, we refer to our published papers (Zhou et al. 2013; Zhou et al. 2016).

Data

Land cover data – CORINE urban morphological zones (UMZ) 2006 data at 250 m spatial resolution are used for delineating urban areas in Europe (Simon et al. 2010). The binary urban/non-urban information for 38 European countries are projected to the sinusoidal coordinate system which is consistent with that used in the LST data.

Surface skin temperature data – We used the Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua 8-day composite (MYD11A2, Version 5) Land Surface Temperature (LST) products from 2006 to 2013, in total 368 observations across 8 years. The data are at 926.6m ≈ 1 km spatial resolution and are measured at 13:30 (daytime) and 01:30 (night time) local solar time. For simplification we focus only on the daytime LST throughout the study. We disregarded pixels with LST error > 2 K by referring to the inherent pixel-wise LST error flag. Hu et al. (2014) suggested a view angle threshold of 35° to minimize the thermal angular anisotropy bias, while guaranteeing a sufficient data quantity for further analyses. Therefore, we abandoned pixels with view zenith angle above that threshold.

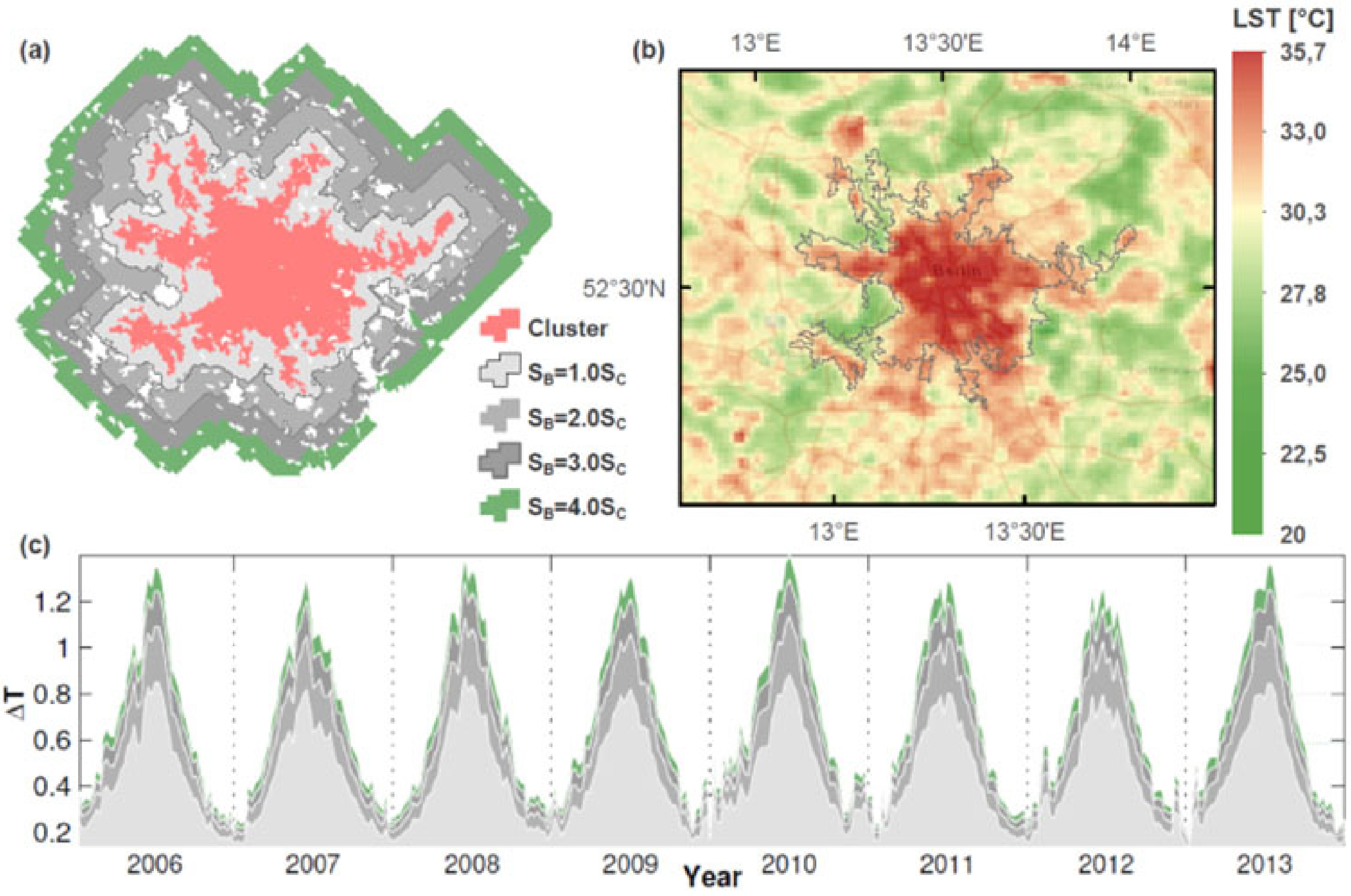

Figure 2. Example of a city cluster, superimposed with LST data and time series of calculated SUHI intensities. (a) The city cluster (Berlin-Potsdam) surrounded by non-urban belts of various sizes, devoid of other urban clusters and water courses. (b) Multi-year (2006-2013) summer mean LST for the same area. (c) Time series of the SUHI intensities based on varying S_B / S_C ratios.

Methods

City Clustering Algorithm – We applied the City Clustering Algorithm (CCA) to the UMZ data to define city clusters. The CCA was proposed by Rozenfeld et al. (2008), with its principles dating back to Stauffer & Aharony (1994) who used this technique to model the forest fire dynamics. According to CCA, any pair of urban cells with a distance no larger than L are assigned to the same urban cluster. The CCA resembles another well-known clustering algorithm in machine learning and data mining – Density-based spatial clustering of applications with noise – DBSCAN (Ester et al. 1996).

Here, we specified L = 500 m. We denote the cluster size as S_C. Subsequently, we defined an equal-area belt region around an identified city cluster as its rural or suburban reference, devoid of water courses and urban pixels of other clusters. Analogously, the size of the surrounding belt is defined as S_B.

SUHI intensity – The SUHI intensity of an urban cluster is defined as the difference between average urban and background (rural) temperature, i.e. $\Delta T = T_C - T_B$. We introduced a data coverage threshold of 50% to minimize the bias of individual pixels, thereby ensuring the validity. Figure 2a shows the identified cluster for Berlin, including Potsdam (situated adjacent to its southwest), where everyday a non-negligible share of its residents commute to Berlin. Superimposed with multiyear averaged summertime LST field, the temperature elevation exhibits a good agreement with the city cluster (Figure 2b).

The ratio of S_B to S_C is adjustable. In general, the larger the ratio is, the more pronounced is the calculated SUHI intensity, as shown in Figure 2c. D. Zhou et al. (2015) assessed the decay of temperature away from the city center in 32 Chinese cities. Though varying from city to city, the extent of UHI can be up to 5 times of the urban area.

Decomposing seasonality of SUHI – A second order Fourier approximation is applied on the time series of the background temperature T_B and the SUHI intensity ΔT, in order to decompose the seasonal variation of SUHI. The order of approximation is determined by the Akaike Information Criterion (AIC). Fourier coefficients are used as proxies to quantify the seasonal variation of SUHI. For more details, we refer to Zhou et al. (2013).

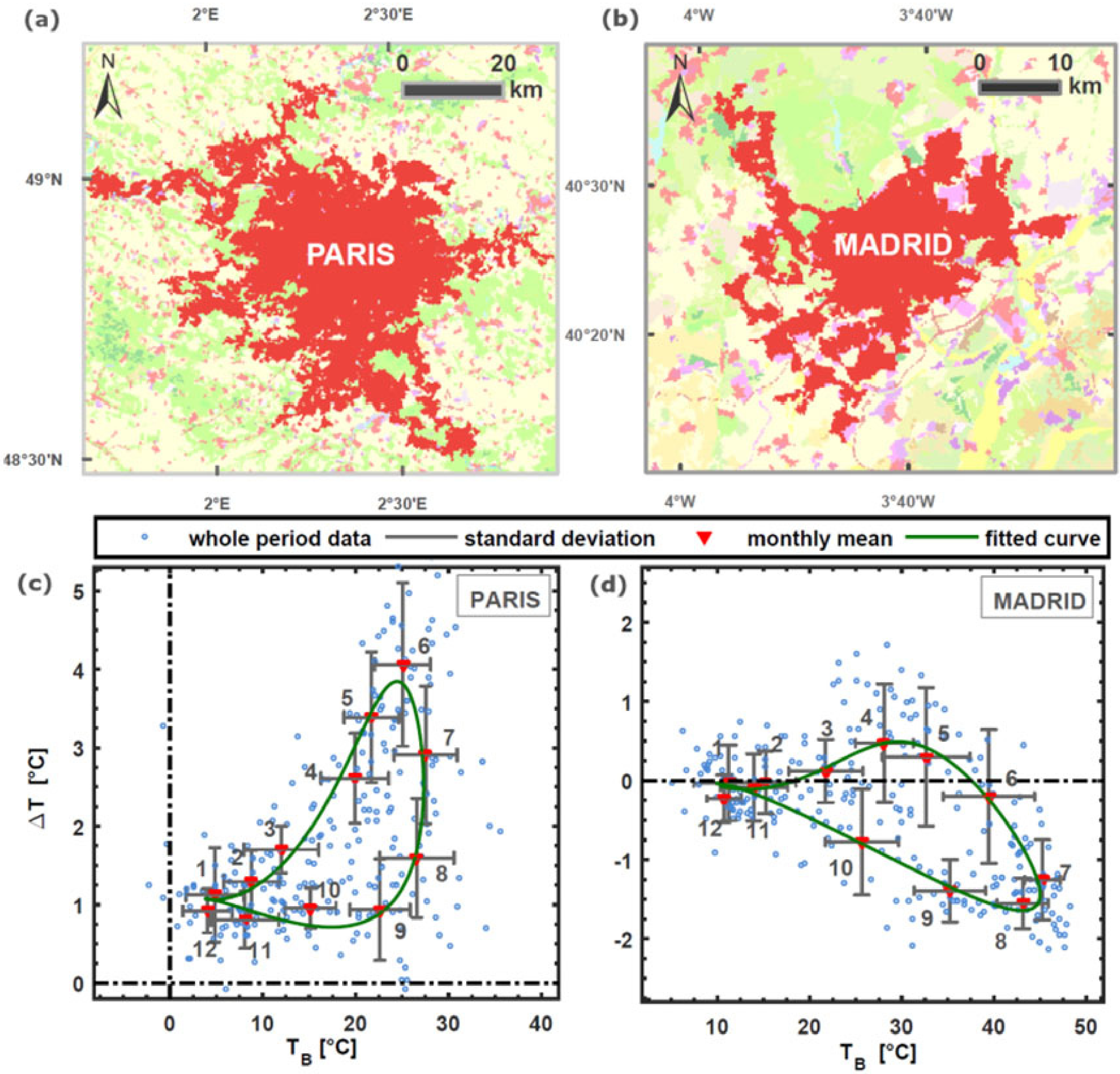

Figure 3. City clusters for (a) Paris and (b) Madrid and the seasonality of SUHI intensities. (c - d) The SUHI intensity ΔT is plotted versus the background temperature T_B. The fitted green solid curves are given by applying Fourier approximation on ΔT and T_B. It is not rare to observe an Urban Cool Island in Madrid during the second half of the year, whereas Paris exhibits a pronounced SUHI throughout the year.

Results and Discussion

Seasonality of SUHI – In many cities, city and background temperatures are poorly correlated because of the large variation of ΔT throughout the year. Instead, we calculated monthly means of both variables to track their seasonal interactions, together with the fitted Fourier curves. The fitted curves resemble hysteresis curves, representing a phase shift between the two variables. Figure 3 shows two examples, Paris and Madrid, exhibiting remarkably different seasonal variations. At least two points are quite crucial to distinguish a city from others.

Correlation between ΔT and T_B. In Paris and a majority of cities, high SUHI intensity coincides with high background temperature, while in Madrid, the opposite is found. During the summer, the SUHI intensity is even negative in Madrid (Urban Cool Island, or Oasis effect) (Georgescu et al. 2011).

Convergence of upper and lower curves reflecting the amount of phase shift between time series of ΔT and T_B. In Paris, although the background temperature in May is almost the same as in September, the SUHI intensity in May (> 3°C) is more pronounced than in September (about 1°C). The disparity can be weak in some cities (not shown here).

Typology of SUHI – Based on the Fourier coefficients obtained from the Fourier approximation, we performed

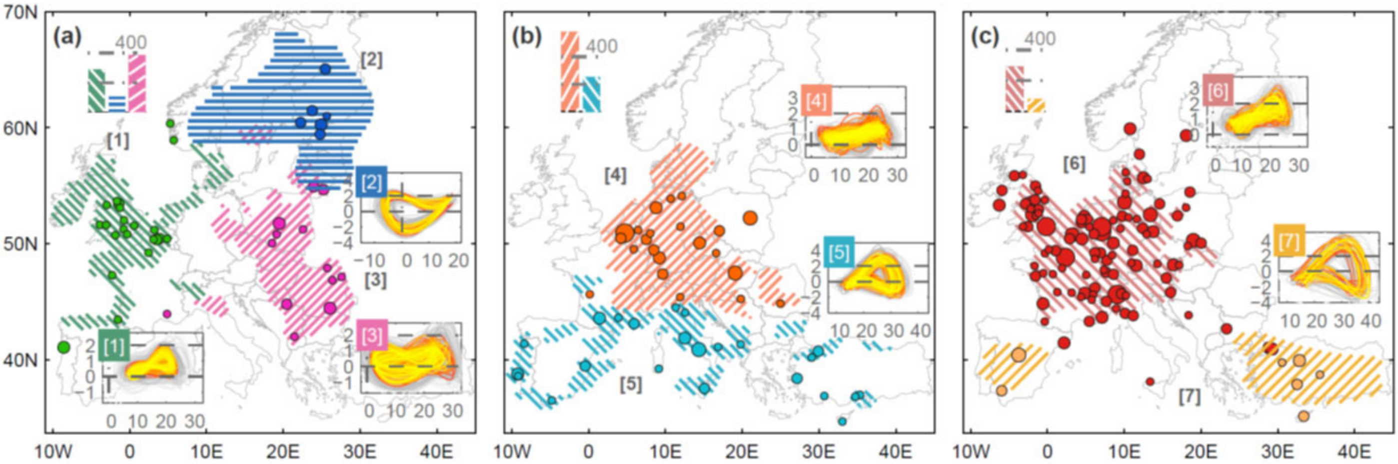

Figure 4. The geographical distribution of the classified groups based on the seasonal hysteresis of SUHI. The largest 200 cities are marked with dots. The inlets on the upper left corner show the amount of cities in each group. This figure is reproduced based on Zhou et al. (2013).

k-means clustering algorithm on the largest 2000 cities (for details see Zhou et al. 2013). Figure 4 shows the spatial distribution of identified groups with their characteristic hysteresis-like SUHI seasonal variations.

In contrast to most cities located in the temperate climate zones, urban cool islands are widely observed in arid and semi-arid Mediterranean cities, distinguishing into two groups – coastal [5] and inland [7] ones. These results could imply some basic notes or caveats while implementing the doctrinal adaptive solutions. The local climatic condition does matter in the planning phase. However, strategies that have been proven successful in a city might work equally well in another cities, if they share similar UHI characteristics.

Discussion – The presented method is performed merely based on the surface skin temperature. Zhou et al. (2016) extended the investigation of seasonality based on 2 m air temperatures, taking the Greater London Area as a case study. The air temperature data are obtained from weather station observations, and simulated by an urban boundary layer climate model – UrbClim (De Ridder et al. 2015). It is aimed to check if similar seasonality exists in the context of 2 m air temperature. However, the seasonal variation of air temperature-based UHI is much weaker or absent, suggesting that the hysteresis-like seasonality could be due to peculiarities of surface skin temperature data. This finding might restrict the extension of this classification scheme to studies based on air temperature data.

Perspectives

Today we have huge problems in the course of urbanization, but we also have solutions. Some seem too incredible to believe. Some sound extremely easy but work amazingly. When I hung out this summer with friends in a bar in Stockholm, I was immediately attracted by the scenes in front of me, a bar on a blossomy rooftop. It was

Figure 5. A city terrace bar on green roofs in Stockholm, a best practice to integrate the three pillars of sustainability – Environment, Society and Economy – by (1) alleviating urban thermal stress and air pollution, (2) stimulating social cohesion, and (3) creating job opportunities.

a wonderful serendipity to closely explore a textbook solution against the UHI and its dubious fellows, air pollution, urban flooding, etc. My *déformation professionnelle* as an urban researcher drove me to snap the pictures in Figure 5. This innovative creation, as many other well-conceived adaptive or mitigating solutions, perfectly illuminates the concept of sustainability by simultaneously integrating economic, social and environmental objectives.

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An empirical approach to estimate the biogenic components of urban CO_2 flux

Introduction

Vertical CO_2 fluxes are the result of the net exchange between an ecosystem and the overlying atmosphere (NEE). In natural or cultivated sites the total flux accounts for soil respiration and vegetation uptake whereas in urban environments biogenic and anthropogenic components are mixed in a complex balance. NEE varies from site to site, and in cities it depends on land cover fractions, population densities, anthropogenic activities and surface characteristics. In suburban areas, where vegetation cover fraction (λ_V) is usually greater than in city centers, patterns and magnitudes of CO_2 fluxes are similar to natural ecosystems (Crawford et al., 2011; Ward et al., 2015) and therefore the CO_2 uptake is helpful in reducing emissions from other local sources such as traffic, household activities, soil management, and human or animal respiration (Bergeron and Strachan, 2011; Crawford et al., 2011).

The CO_2 flux can be measured by the micrometeorological eddy covariance (EC) technique, and partitioned into its main components using indirect methods. As an example, the non-rectangular hyperbola (Rabinowitch, 1951) is used in natural sites to estimate ecosystem respiration (vegetation and soil) and CO_2 uptake (Gilmanov et al., 2003; Stoy et al., 2006).

Studies on eddy covariance measurements in urban environments have shown that the higher the vegetation cover fraction is, the more carbon emissions are reduced (Bergeron and Strachan, 2011; Velasco and Roth, 2010; Ward et al., 2015). In addition, Nordbo et al. (2012) have shown that in urban areas land cover fractions can correspond with estimations of annual carbon exchange. This suggests that vegetation cover fraction can be used to estimate the biogenic components of the carbon balance. But is it possible to figure out relations among different ecosystems and simulate the net CO_2 exchange due to vegetation from λ_V, both in urban and non-urban ecosystems?

The aim of this work was (1) to investigate how the net CO_2 exchange varies from vegetated to urban ecosystems and relate the biogenic components of CO_2 exchange to the main controlling factors, and (2) to look for general and empirical relations that allow an estimation of CO_2 flux components from environmental variables (i.e. global radiation, R_g) and λ_V. A general model which can run over natural, agricultural, urban, and suburban ecosystems, was therefore developed and tested in a natural Mediterranean site (during non-water stress conditions) and a suburban neighborhood (during the growing season).

A brief description of the model development is reported below along with results from the model testing.[1]

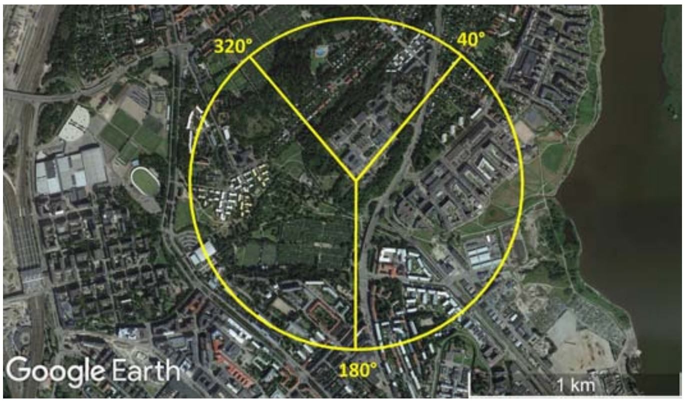

Figure 1. Helsinki SMEAR III station: around the EC tower (800 m circle) 40°–180° road sector, 180°–320° vegetated sector, 320°–40° buildings sector.

Materials and Methods

Sites description – EC measurements from six sites are analyzed to develop the model (Table 1; see Bellucco et al., 2015 for more details). The sites are characterized by different vegetation types and cover fractions: a natural Mediterranean Maquis site (Capo Caccia, Italy, Marras et al., 2011), two managed vineyards (Serdiana and Montalcino, Italy, Marras et al., 2015 and Marras, 2008, respectively), two suburban areas (Swindon, UK and Baltimore, MD, USA, Ward et al., 2013 and Crawford et al., 2011, respectively) and a forest site (Morgan Monroe State Forest, IN, USA, Schmid et al., 2000). Where available, original datasets (non-gapfilled) are used (i.e. Mediterranean sites), otherwise data are obtained from the literature (i.e. forest and suburban sites).

For model testing, two independent sites are chosen: a residential area of Helsinki, Finland (SMEAR III, 60.203° N, 24.961° E) and a natural Mediterranean maquis site located within a natural reserve called Le Prigionette, on the Capo Caccia peninsula (40.61° N, 8.15° E) in the municipal district of Alghero (SS), Italy.

In Helsinki, around the EC tower, the vegetation cover is 48% (within a radius of 800 m) but it varies according to wind sectors (Figure 1): the most vegetated area corresponds to 180°–320° (Vesala et al., 2008; Järvi et al., 2012, 2014) with λ_V equal to 60% (800 m radius). As most of the buildings in the area use district heating, which is generated outside the footprint area by power plants, emissions from buildings can be neglected.

The Mediterranean ecosystem has typical vegetation (Mediterranean maquis) which appears as a shrubland of species (mainly juniper and lentisk) randomly distributed in the measurement area (Marras et al., 2011). The discontinuous vegetation covers 70% of the surface on average.

Model development – Light-response curves of each site

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[1] For more details on this work please refer to: Bellucco V., Marras S., Grimmond C.S.B., Järvi L, Sirca C., Spano D. 2017. Modelling the biogenic CO2 exchange in urban and non-urban ecosystems through the assessment of light-response curve parameters. *Agricultural and Forest Meteorology*. http://dx.doi.org/10.1016/j.agrformet.2016.12.011. (in press)

Table 1. Eddy covariance measurement sites used to develop (d) and test (t) the biogenic general model. Each site has a different vegetation type and cover fraction (λ_V - see text for description of wind sectors in Helsinki).

Site	Area	Latitude	Period	λ_V
Morgan Monroe State Forest^{L} (MMSF), IN, USA (Schmid et al., 2000)	Deciduous forest	39.32° N 86.42° W	May–September (1998)	1.00
Baltimore, MD, USA^{L} (Crawford et al., 2011)	Suburban	39.41° N 76.52° W	June–August (2002–2006)	0.67
Swindon, UK^{L} (Ward et al., 2013)	Suburban	51.58° N 1.80° W	June–August (2011)	0.44
Serdiana, Italy^{or} (Marras et al., 2015)	Vineyard	39.36° N 9.12° E	June–August (2009–2011)	~0.50
Montalcino, Italy^{or} (Marras, 2008)	Vineyard	43.08° N 11.80° E	June–August (2005–2006)	~0.50
Capo Caccia, Italy^{or} (Marras et al., 2011)	Mediterranean Maquis	40.61° N 8.15° E	(d) Jan–Dec (2005-2010) (t) January-March 2011	~0.70
Helsinki, Finland^{or} (Järvi et al., 2012)	Suburban	60.20° N 24.97° E	weekends June–August (2010)	0.60 (veg.) 0.48 (all)

(i.e. CO_2 fluxes as a function of photosynthetically active radiation, PAR) are analyzed selecting daytime data (R_g > 5 W m^{-2}) and by calculating median values of CO_2 fluxes (in bins of 50 µmol m^{-2} s^{-1} of PAR) (Figure 2). The growing season is selected for all the sites, except for the evergreen Mediterranean maquis site of Capo Caccia, for which the whole year is analyzed. The light-response curves were fitted by the non-rectangular hyperbola (NRH) equation:

$$NEE = R_{eco} + GPP = \gamma - \frac{1}{2\theta}\{\alpha PAR + \beta - [(\alpha PAR + \beta)^2 - 4\alpha\beta\theta PAR]^{0.5}\} \quad [1]$$

where α represents the mean apparent ecosystem quantum yield (initial slope of the light-response curve), β is the light saturated gross photosynthesis of the canopy (plateau parameter), γ is the ecosystem respiration (intercept value), and θ is an a-dimensional bending parameter. Site-specific α, β, γ, and θ coefficients were estimated through non-linear least square regression.

For two of the Italian sites (the Serdiana vineyard and the Capo Caccia Mediterranean maquis site), measurements of soil water content (SWC) were also available, and the variability of the NRH coefficients as a function of SWC is investigated (Figure 3a). All the estimated NRH coefficients (not shown here) are in accordance with literature reported values (Boote and Loomis, 1991; Gilmanov et al., 2003). The site-specific coefficients are then analyzed as a function of λ_V through linear regression analysis to infer general NRH coefficients to drive the model in different ecosystems (Figures 2 and 3b). If no clear relation results from this analysis, the gen eral coefficients are set to the median value across the sites (see Bellucco et al., 2015 for more details).

Biogenic empirical model – Across a range of vegetation cover fractions, the biogenic model estimates the surface-atmosphere carbon net exchange due to soil efflux and canopy respiration, and vegetation uptake. R_g and λ_V are needed as input variables (Figure 4): with the first PAR is inferred; with the latter the model estimates the NRH generalized coefficients as a function of vegetation cover fraction.

Model testing and statistical analysis – Independent EC measurements of two distinct sites with different morphological characteristics, vegetation cover fractions, and climatic conditions are chosen to test the biogenic empirical model: the suburban area of Helsinki and the unmanaged evergreen Mediterranean maquis ecosystem of Capo Caccia. For both sites, periods corresponding to maximum ecophysiological activity (June–August 2010 for Helsinki, and January–March 2011 for Capo Caccia) are chosen. For Helsinki the summer season also corresponds to reduced

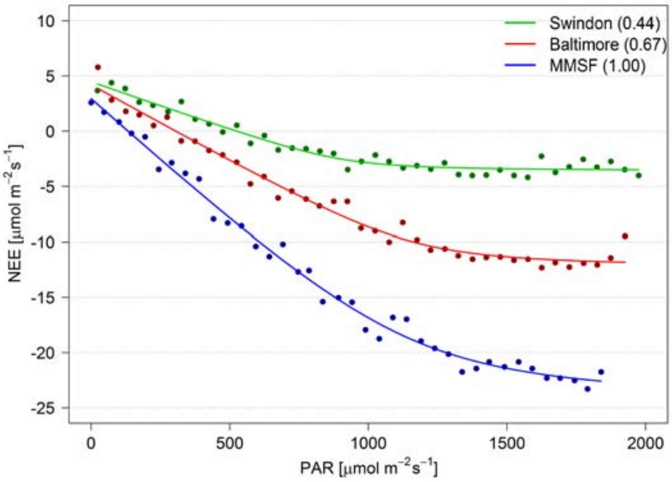

Figure 2. Literature-based light-response curves and result of the fitting procedure. The legend reports in brackets the vegetation cover fraction.

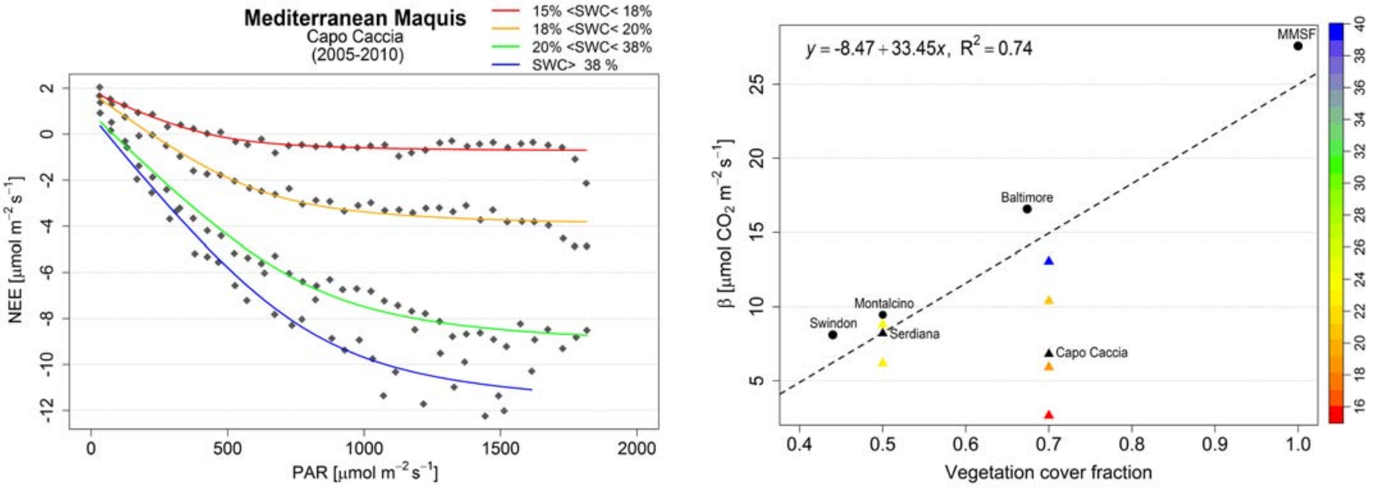

Figure 3. (a) In Capo Caccia the light-response curves are fitted to NEE stratified into soil water content classes; (b) the site-specific NRH coefficients β is plotted as a function of vegetation cover fraction: the linear regression is across the six sites (black markers). In Mediterranean ecosystem data during non water-stress conditions (i.e. higher soil moisture and higher uptake) should be considered to avoid underestimation.

vehicular traffic rates (Järvi et al., 2012), whereas data of the winter season and early spring in Capo Caccia match up with well-watered conditions (during summer rainless periods affect ecophysiological processes in Mediterranean ecosystems).

The EC measurements of CO_2 fluxes from both sites are sorted and averaged by time, and then compared with CO_2 fluxes simulated by the biogenic empirical model.

For the suburban area, the biogenic module is first run for all wind sectors (λ_V=0.48), and then considering the vegetated wind sector only (180°–320°, λ_V=0.60). In both cases, data are stratified into workdays and weekends. For the natural Mediterranean site, the model is run considering λ_V=0.70 and all wind sectors.

As a first assessment, linear regressions between simulated and measured CO_2 fluxes are calculated. Then, six statistical indices are calculated (see Table 2): the coefficient of determination (R^2, adimensional), the root mean square error (RMSE, µmol m^{-2} s^{-1}), the normalized root mean square error (nRMSE, adimensional) the mean absolute error (MAE, µmol m^{-2} s^{-1}), the mean bias error (MBE, µmol m^{-2} s^{-1}), and the index of agreement (IOA, adimensional).

Results and discussion

EC observations are modelled and compared with simulations to evaluate the general model performances. The best results of model runs are shown in Figure 5 for both Helsinki and Capo Caccia.

As expected the model reproduces better the mean daily trend of CO_2 fluxes at the unmanaged natural Mediterranean ecosystem than at the suburban site. The model run in Capo Caccia shows good evaluation metrics (RMSE=0.72 µmol m^{-2} s^{-1}, nRMSE=0.06, MAE=0.58 µmol m^{-2} s^{-1}), with the simulation catching the diurnal trend of CO_2 fluxes (IOA=0.99) both during nighttime and during daytime (Figure 5a). The regression between modelled and observed data explains from 93% to 96% of half hourly variance for single months, and up to 98% when considering the summed period January-March. The model simulation almost always fall within the interquartile range of measured data (Figure 5a) with MBE indicating a little overestimation (MBE=0.23 µmol m^{-2} s^{-1}).

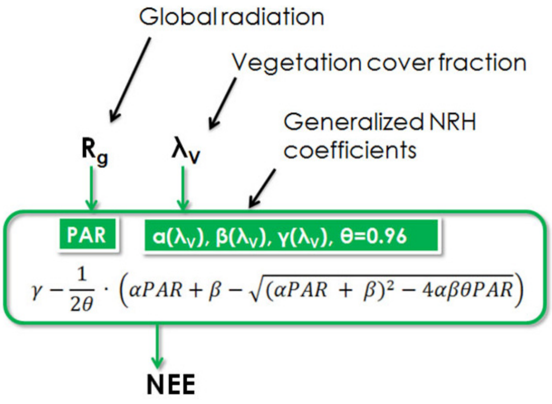

Figure 4. Scheme of the biogenic empirical model.

However, good performances also result from the model run in Helsinki during the weekends (RMSE=1.78 µmol m^{-2} s^{-1}, nRMSE=0.16, R^2=0.94) and especially within the vegetated sector (RMSE=1.65 µmol m^{-2} s^{-1}, nRMSE=0.12, R^2=0.96). In general, the MBE index indicates a slight tendency of the model to underestimate real measurements at the suburban site (MBE=-1.10 µmol m^{-2} s^{-1}) probably due to the residual traffic emissions.

More detailed comparisons between weekdays and weekends show how in Helsinki the net CO_2 flux is affected by higher traffic emissions during workdays, mostly due to the morning and afternoon rush hours. Conversely, during weekends the traffic rates are smaller and model performance improves. However, workdays and weekends exhibit a more similar behavior when considering the more vegetated sector, with measurements showing

Table 2. Evaluation metrics for the model applied in Helsinki (during weekends), and in Capo Caccia. Statistical indices are: root mean square error (RMSE, μmol m^{-2} s^{-1}), relative root mean square error (nRMSE, adimensional), mean absolute error (MAE, μmol m^{-2} s^{-1}), mean bias error (MBE, μmol m^{-2} s^{-1}), index of agreement (IOA, adimensional), and coefficient of determination (R^2). All values are significant with $P<0.001$.

Site	Days	Period	Sector	RMSE	nRMSE	MAE	MBE	IOA	R^2
Helsinki	weekend	Jun-Aug	0°-360° (λ_V=48%)	1.78	0.16	1.58	-1.09	0.93	0.94
			180°-320° (λ_V=60%)	1.65	0.12	1.46	-1.10	0.97	0.96
Capo Caccia	all days	Jan-Mar	0°-360° (λ_V=70%)	0.72	0.06	0.58	0.72	0.99	0.98

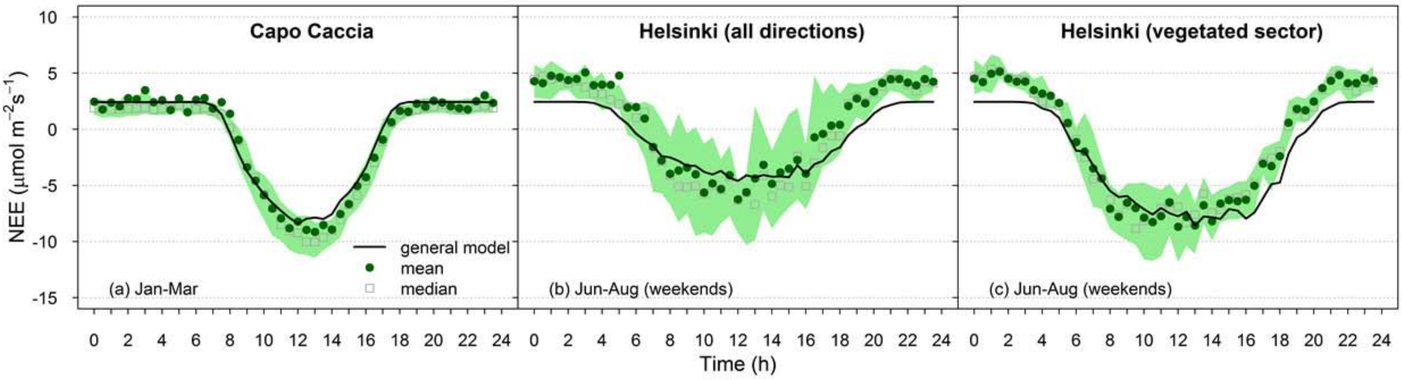

Figure 5. Simulated (solid line) and observed (dots) 30-min CO_2 flux data for (a) Capo Caccia and (b-c) Helsinki sites. The green shadow represents the interquartile range. For Capo Caccia (a) all days and all wind directions are considered; for Helsinki only weekends: (b) all wind direction (λ_V=48%); (c) vegetated sector (λ_V=60%).

a narrower interquartile range (IQR) and similar mean and median vales. These findings are valid both for simulations for single months (not shown), and the cumulative period (June-August).

These assessments highlight the capability of the model to reproduce the diurnal mean trend of biogenic CO_2 fluxes and capture vegetation uptake, especially during midday hours where the biogenic processes are more important. At night, as well as in the early morning and late evening, differences between modelled and observed data are observed. These deviations are most likely due to the magnitude of other sources, such as traffic emissions and human respiration, but also to the approximations due to the obtained generalized NRH coefficients. However, in general, daytime and nightime trends are reproduced (IOA>0.90) both when simulating within the vegetated sector, and during weekends for all wind directions.

Conclusions

The dependence of urban CO_2 fluxes on vegetation cover is well documented (Velasco and Roth, 2010; Nordbo et al., 2012). This study presents the development of a general empirical model based on land cover fraction and environmental variables. This general model reproduces ecosystem respiration and vegetation uptake both in urban and non–urban ecosystems during periods when maximum ecophysiological processes occur. Results show good performance between modelled and observed data explaining up to 96% and 98% of total variance over the suburban site of Helsinki (for weekend measurements in the vegetated sector) and over the natural Mediterranean Maquis ecosystem, respectively.

The good agreement of the biogenic module, both with human-modified and unmanaged ecosystems, confirms the evidence that CO_2 fluxes depend on vegetation cover fraction, and that λ_V can be used to infer information on biogenic CO_2 exchange. It opens a new outlook in the study of relations among different ecosystems and the role of vegetation in urban areas.

Further improvements on this topic are addressed to widen the initial analysis of light-response curves accounting for more sites, and vary the NRH coefficients according to vegetation cover fraction, type and soil water content.

An interesting comparison between this general approach and a site-specific light-response model is elaborated for the Helsinki suburban site and is presented in Bellucco et al. (2017, in press).

Acknowledgment

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UN Habitat III Conference in Quito

From Oct 17-20, 2016 I attended the UN Habitat III conference in Quito, Ecuador on behalf of the IAUC. In the sections below I outline the scope of the conference, the IAUC involvement and some personal observations.

By James Voogt

What is Habitat III?

"Habitat" is the name given to the United Nations Conference on Housing and Sustainable Urban Development. The Habitat series of conferences are intentionally held with a long repeat cycle in order to implement and assess the conference outcomes. Habitat III follows on from the first (Vancouver 1976) and the second (Istanbul 1996) Habitat conferences.

The mission of the Habitat III conference was for UN member countries to adopt a New Urban Agenda. The New Urban Agenda is described as "an action-oriented document which will set global standards of achievement in sustainable urban development, rethinking the way we build, manage and live in cities through drawing together cooperation with committed partners, relevant stakeholders, and urban actors at all levels of government as well as the private sector." Given that sustainable urban development has social, economic and environmental dimensions, its scope is broad. It commits to sustainable urban development as a critical step for realizing sustainable development at all scales and is linked to the 2030 Agenda for Sustainable Development.

The shared vision described by New Urban Agenda is broad. Among the eight identified elements are two of particular relevance to IAUC. The New Urban Agenda envisages cities that:

- adopt and implement disaster risk reduction and management, reduce vulnerability, build resilience and responsiveness to natural and human-made hazards and foster mitigation of and adaptation to climate change;
- protect, conserve, restore and promote their ecosystems, water, natural habitats and biodiversity, minimize their environmental impact, and change to sustainable consumption and production patterns.

In achieving the broad vision, the New Urban Agenda is guided by three broad principles – one of which is to ensure environmental sustainability. To do this the New Urban Agenda will promote clean energy and sustainable use of land and resources in urban development; protect ecosystems and biodiversity, including adopting healthy lifestyles in harmony with nature; promote sustainable consumption and production patterns; build urban resilience; reduce disaster risks; and mitigate and adapt to climate change.

Left: The line up for security on Monday, the first main day of sessions. Umbrellas serve a useful dual purpose in Quito – shade in the morning and at midday and shelter from afternoon and evening rainshowers that are typical of the local climate. Right: Photo exhibit in the Parque El Ejido adjoining the conference centre. The work is by UK Photographer Simon Roberts from a series on urban parks (http://www.simoncroberts.com/work/urban-parks/#PHOTO_0) and is entitled *English Garden, Munich Germany 2015*. The photo caption reads in part: "Over the past few decades the urban park, in all its varied forms, has emerged as a critical tool in revitalising cities and a way to solve a variety of urban issues: regenerating economically deprived areas, bringing nature to the city, providing recreation, rejuvenating neighborhoods, creating a place for physical interaction in our digital world and a key ingredient for city sustainability."

Left: High-level roundtable on Ecological, Climate change-resilient, Disaster-responsive Cities. Right: A scene from inside the Exhibition Hall.

IAUC Related Sessions

IAUC was a partner in an official event classified as a "side event" along with several smaller and shorter "Talk with the UN" sessions. The official side event arose from a merger of three proposed events from different groups with overlapping themes by the Habitat III organizers. The combined event was entitled "Climate change and urban disaster resilience" and was subdivided into two parts: Part 1 – Climate Change and Urban Disaster Resilience: Current and Future Challenges and Part 2 – Urban Disaster and Climate Risk: Solutions and Ways Forward. The lead organizers were UNESCO, UN University and WMO, with 7 additional partners (including IAUC). The aim of the event was to provide a state-of-the-art overview and reflection on knowledge-based solutions for improving urban resilience and reducing urban risks from natural and climatic hazards from a range of science, practice and policy makers. The sessions were held sequentially on Thursday morning in the One UN Pavilion, a separate purpose-built bamboo structure on the conference grounds.

In the first part four different speakers made short presentations. These included M. Garschagen (UNU) who spoke on "Urbanization and climate change: Evolving risks from two colliding mega-trends", S. Yasukawa (UNESCO) on "Disaster Resilient Architecture", D. Satterthwaite who contributed "Synthesis of the IPCC 5th Assessment WGII Chapter on Urban Adaptation", and G. Carmichael who provided an overview of the "WMO Integrated approach for urban weather, climate, environment and water systems: from research to urban information service". A panel discussion followed that asked the

Left: Presenters from Part 1 – Climate Change and Urban Disaster Resilience. From the left, David Satterthwaite (IIED), Soichiro Yasukawa (UNESCO), Matthias Garschagen (UNU), Gregory Carmichael (Univ. Iowa / WMO) and moderator Filiep Decorte (UN-Habitat). Right: Edward Ng, CUHK and IAUC Board member during his presentation.

A wide angle view of the official 'side event'. Photo: N/A

presenters and panelists (K. Warner, UNFCCC; P Romero-Lankao, NCAR; E. Figueroa U. de El Salvador, and myself) for their response to three guiding questions: Which future trends in urban risk are to be expected, particularly in countries with rapid urbanization and high exposure to natural and climatic hazards? Which opportunities do exist to harness the social and economic development potential of urbanization for the long-term mitigation of risk and the facilitation of sustainable adaptation? How can – and should – long-term and proactive risk reduction in the city be guided by different adaptation paradigms of resistance, resilience and/or transformation? Koko Warner (UNFCC) pointed out that a big gap exists between national and international aspirations and the actual actions at a city level but that the UNFCC recognizes the opportunity that cities present for helping with climate resilience and mitigation.

In the second part, the benefits of climate-smart cities were outlined in three presentations: "Urban Integrated Services and Multi-Hazard Early Warning Systems; WMO practices and the experience from Shanghai" (A. Baklanov, WMO), "Lessons learned from air quality management in Mexico City" (L. Molina, Molina Center), and "Climate resilient urban planning for high density Asian cities – an experience from Hong Kong" (E. Ng CUHK). These were followed by short talks on urban risk reduction solutions from selected projects and programs, including Future Earth Coasts, UCCRN and then a panel discussion.

The sessions were well attended, estimated at about 60-80 in each session, which was near room capacity, but suffered somewhat from noise from an adjacent busy roadway that was easily heard because the building was designed to be open between the top of the walls and the roof structure. The interest of the audience was reflected in a large number of photographs and recordings of presentations that appeared to take place. It is planned for the presentations to be made available on a public website once permissions are gained.

Overall the sessions identified the challenge for vulnerability reduction amongst the urban poor, a need for stronger political engagement with urban vulnerability reduction, that basic development underlies much urban resilience building, and that the success of example projects in engaging decision makers to use science-based results in policy could be replicated and adapted elsewhere. The implementation of integrated urban weather, water, environment and climate services is suggested as a mechanism to help realize increases in urban resilience, sustainability and to achieve disaster risk reduction. The collaborating groups have suggested building a coordinated urban climate and disaster risk reduction plan and to coordinate the choice of demonstration cities.

Left: View of Quito from Basilica del Voto Nacional to the southwest. Right: A view of urban development in Quito extending up the slopes at the base of Pichincha volcano, taken from outside the main conference venue with temporary tent structures housing some conference services in the foreground.

The Habitat III experience

Quito is the capital of Ecuador and a UN World Heritage City. The city is located just south of the equator (a large complex celebrating the equator is located on the northern outskirts of the city) at an altitude of 2850 m in a valley bordered by the slopes of the Pichincha Volcano. I stayed in an apartment a few blocks north of the conference site in a mixed residential/commercial area of the city (probably LCZ 2).

Habitat III was held at the Casa de la Cultura Ecuatoriana and adjoining grounds next to El Arbolito Park. There were approximately 30,000 accredited participants from 167 countries, including 10,000 international participants. Nearly 1000 events took place during the 4 main days of the conference (a number of sessions were also held in the week prior to the main event days).

The Casa de la Cultura Ecuatoriana hosted most sessions and provided auditoriums of a suitable size and setup for the main sessions; this was accessed through a gate that only participants could enter. Also on the site was the One UN Pavilion; this was accessible to all who passed through security (which was opened to the general public later in the day). There were also separate pavilions that celebrated Ecuador (run by Tourism Ecuador) that included some museum exhibits and various booths that advertised Ecuadorian products (did you know that Ecuador is a top producer of shrimp?) and destinations. A separate Quito pavilion was also on the site. The conference grounds were located adjacent to a large urban park, Parque El Ejido. Many participants passed through the park on their way to and from the conference due to a security fence perimeter that was established around the conference grounds. The park hosted a number of food and artisan stands and groups of performers. The Habitat III Exhibition Hall was located just outside the main conference perimeter in a temporary tent structure and had approximately 100 separate exhibitor stands. These were open to the public, again with access similar to airport security screening.

The airport-style security screening required to enter the conference grounds or Exhibition Hall resulted in long lineups. On Monday, arriving shortly after 09:00, I, and many other regular participants, waited over 4 hours to access the main site. Higher priority categories of participants – e.g. official delegations, UN personnel etc. had special access. The umbrella I had packed in anticipation of afternoon and evening rain showers came in handy in providing shade from the morning and midday sun, with its small noon zenith angle. For the remainder of the week I adjusted to a much earlier arrival time that meant the wait for screening could be reduced (I waited 40 min on Tuesday and managed to mark some student assignments while in the line). An increase in the number of screening stations also helped reduce wait times.

My general sense from the first day of the conference was that the demographic of Habitat III attendees was young and that there was an air of expectancy; it was not just an event where old familiar friends from past conferences were getting together – logical given the long repeat cycle of the Habitat events, although clearly there was a contingent of attendees who knew each other from other UN-sponsored meetings. The attendees represented a broad spectrum of students, non-governmental organization representatives, UN and member country representatives, city and regional representatives and a few academics from various fields.

On the second day I attended a "High level round table" on "Ecological, Climate Change Resilient, Disaster-responsive Cities". This type of session (there were 13 different types of sessions including Plenary sessions, High-level Roundtable sessions, Assemblies, Stakeholders Roundtables, Policy Dialogues, Special Sessions, Urban Talks, UN events, Village projects and side, networking, training and parallel events organized by various stakeholders) involved a small panel, each of whom provided a short presentation, and then time for delegates of member states to make short statements. Seating for regular participants was limited as the main section of the room was reserved for representatives of all the member states as well as UN agency representatives. Conference participants were keen at the outset of the session (scheduled for three hours) and seating became limited, but following the panel presentations, interest began to wane. I heard some interesting statements by member countries – the US Habitat delegation speaker was notable – but in general attendance by member nations was somewhat spotty and it became apparent that some members simply repeated talking points at various venues during the week.

I attended some other interesting sessions through the week. "Planning for Clean, Green and Healthy Cities" emphasized health as a focus for planning and gave a sense that health, used as an integrative goal for planning, may be able to accomplish many of the New Agenda objectives. A mayor from a city in the Philippines noted that their city had become so dense it was creating health and other problems. "Health as the Pulse of the New Urban Agenda" continued this theme. It identified improvements in urban air quality as a critical element sustainable development. The session included a nice pre-recorded presentation by Andy Haines (Tropical Medicine, London UK) that covered a broad range of topics related to planetary health combined with human health and natural systems. Robert Glasser (UNISDR) in the session "Cities, Climate Change and Urban Disaster Risk Reduction" gave a good presentation that highlighted the significant impacts of hydrometeorological events that have been related to 90% of major disasters in the last 20 years. He stressed that "Mayors need to hear the scientific community" in order to take action. In the following panel session, one of the panelists (mayors themselves) confirmed the need for education and the moderator of the session pointed out the challenge of "packaging" scientific information. These are issues that urban climatology has grappled with and are also elements that IAUC can help resolve by providing educational materials and training.

IAUC members at Habitat III. From left: Edward Ng (CUHK), James Voogt (Western University), Alexander Baklanov (WMO). Photo: L. Molina

View of the Casa de la Cultura Ecuatoriana (right) and the slopes of the Pichincha volcano. All photos (unless otherwise noted): J. Voogt

Finally, on the same day that the New Urban Agenda was formally adopted in Quito, the Intergovernmental Panel on Climate Change, meeting in Bangkok, announced a forthcoming 2018 Cities and Climate Change Science Conference co-sponsored by a number of other organizations. Its aim is to stimulate scientific research around cities and climate change and to inform upcoming IPCC reports, including AR6, and a Special Report on cities and climate change to be undertaken during the seventh assessment cycle. It seeks to build on the momentum of the Paris Agreement, the New Urban Agenda, and the Sustainable Development Goals.

What was my take-away from the conference? I felt that the importance of cities to environmental sustainability was well recognized by participants, the UN and member nations. I saw a young cohort who embrace, and are keen to implement, the New Urban Agenda and speakers who could provide a broader perspective on the New Urban Agenda. I saw opportunities for IAUC members to contribute to the science and education that are needed to help implement the New Urban Agenda. And I felt that significant barriers to implementation on an urban scale remain with challenges of funding and competing interests. In short, a sense of optimism tempered by the realization that we have a long way to go.

World Urban Parks side event at Habitat III a success

The World Urban Parks (WUP) Large Urban Parks Committee (and Network) held a successful side event at the UN Habitat III Conference in Quito on 17 October 2016, titled "Large Green Spaces and Urban Forests, Key Public Infrastructure for Equitable, Healthy and Sustainable Cities". This event was presented in collaboration with the Italian Society of Silviculture and Forest Ecology (SISEF).

Large Urban Parks Committee Co-Chair Dr. Richard Murray congratulated Patricia O'Donnell for leading the event, and the panellists for their contributions, noting the side event was the best-attended side event of that day of the programme.

Together with a successful Habitat III side event held in Barcelona earlier this year, this event highlighted the value of large urban parks and raised the profile or World Urban Parks, as well as developing relationships with allied organisations.

As summarized by Simone Borelli of the UN Food and Agriculture Organisation (FAO):

"This side event focused on Green Infrastructure including a wide set of components, from city parks to large urban parks, urban forests and peri-urban parks plus the greenery of cemeteries, gardens, street trees etc. Special emphasis was given to large urban parks and urban forests and their strategic role in green infrastructure planning and in city governance.

Left to right: Jeet Mistry, Patricia O'Donnell, Andrew Potts, Fabio Salbitano and Simone Borelli.

Speakers included: Patricia O'Donnell of WUP ('Large green spaces, key public infrastructure for equitable, health and sustainable cities'), Fabio Salbitano and Giovanni Sanesi of SISEF ('The strategic role of Public Green Spaces and Urban Forests in Latin America and the Caribbean for a new inclusive urban agenda'), Andrew Potts of ICOMOS ('Connecting natural and cultural heritage, the role of large urban parks in achieving SDG target 11.4'), Jeet Mistry of WWF ('Large Green Parks as Urban Solutions'), Simone Borelli of FAO ('Urban parks – balancing city and nature'), and Raquel Penalosa of IFLA ('The role of a large park in a large city – the case of Montreal').

Concluding the event, a set of recommendations for city planners was presented and discussed. Overall, I think UF and green spaces got quite a bit of attention and I hope that the New Urban Agenda will serve as a useful reference for the years to come."

The presentation of Patricia O'Donnell is available here, the presentation of Fabio Salbitano co-authored with Prof. Giovanni Sanesi is available here, and the presentation of Simone Borelli is available here. *Source:* http://www.worldurbanparks.org/en/news-events/news/449-world-urban-parks-habitat-iii-event-a-success

Urban Climate News: A brief review of the last 18 months

A year and a half have passed since ICUC9 in Toulouse, and my last 18-month review of contributions to the *Urban Climate News* (previous 18-month reviews can be seen in the June 2009, December 2010, June 2012, and December 2013 issues).

I would firstly like to recognize **Paul Alexander**, who during this period has taken over the role of News Editor after years of dedicated service by **Winston Chow**. A huge thanks to Winston for continually bringing us timely tidbits from the media and showing how urban climate issues permeate our public life, and thanks to Paul for filling these large shoes superbly.

Events over the recent past have accentuated the vital links between cities and humanity's ongoing struggle with a changing climate. The encyclical by Pope Francis highlighted the special vulnerability of urban populations to both economic and environmental threats, and led many to consider the moral ramifications of ignoring climate science. And after years of failure at the international level to reach a climate accord between the countries of the world, the Paris agreement one year ago has offered hope that meaningful action to curb emissions and warming will accelerate. Well before COP21 it had become clear that cities – as the prime source of CO_2 emissions – must take on an active role in developing and implementing climate mitigation strategies, rather than leaving this responsibility to national governments. As each country formulates its plans to meet the non-binding Paris goals, this "urban mandate" is no less crucial. In fact as reported on page 2 of this issue, we face the possibility that government inaction is being replaced by open hostility toward climate science – making the role of cities more consequential than ever. And as illustrated by the initiative of the C40 consortium of mayors (see page 6), this role is indeed being taken seriously.

Leading the way in addressing these challenges through scientific research are the members of IAUC and others whose work has been presented in recent **Feature articles** (see Table below), and **Urban Project** reports (see Table on the following page). In this regard I would like to welcome **Helen Ward** from the University of Reading, who has recently taken on the editorial role of collecting these important contributions – and I encourage you to contact Helen at h.c.ward@reading.ac.uk if you have have work that would interest the urban climate community.

This interest in the link between urban development and climate change has also been evident in the **Special Reports** published in recent issues, which summarize recently-held international conferences and relevant meetings. Foremost among these in the last eighteen months was ICUC9 in Toulouse, which was graciously hosted by **Valéry Masson** and **Aude Lemonsu** of Météo-France and whose excellent presentations provided much of the material for the Feature articles and Project reports mentioned above. The final addition (for now) to the *Urban Climate News* staff is **Joe McFadden** from UC

Feature Articles	Author(s)	Issue
Green infrastructure for cities: It's all about trees!	Andrew Coutts	September 2015
Urban Meteorological Networks: An Urban Climatologist's Panacea?	Lee Chapman	December 2015
Adapting Asian Cities to Climate and Urban Climatic Changes: A Chinese Tale	Edward NG	March 2016
An Anthropogenic Heating Database for US Cities	David J. Sailor et al.	June 2016
Research Through Designing: Bridging the gap between urban climate science and design practice	Sanda Lenzholzer & Robert Brown	September 2016
CO_2 fluxes and sources in a subtropical residential area dominated by evergreen vegetation – A case study from Auckland	Lena F. Weissert et al.	December 2016
Eddy covariance observations of surface energy balance and carbon fluxes in the tall megacity of Shanghai: Challenges and results	Xiangyu Ao et al.	December 2016

Urban Project Reports	Author(s)	Issue
Analyzing the Influence of Urban Forms on Surface Urban Heat Islands in Europe	Nina Schwarz	September 2015
Calculation of the CO_2 storage term in an urban environment: Results and guidance from Central London	Alex Bjorkegren & Sue Grimmond	December 2015
Large-eddy simulations to characterize the role of turbulent and dispersive production, transport and dissipation of TKE over and within a realistic urban canopy	Marco Giometto et al.	December 2015
Transpiration of urban trees and its impact on daytime and nocturnal cooling in Gothenburg, Sweden	Janina Konarska et al.	December 2015
The urban cool island and atmospheric boundary layer dynamics	Natalie Theeuwes et al.	December 2015
Local soil moisture product improves Australian heatwave simulation	Stephanie Jacobs et al.	March 2016
Incorporating resolved vegetation in city-scale simulations of urban micrometeorology & its effect on the energy balance	Brian N. Bailey	March 2016
Effects of Urban Form and Atmospheric Stability on Local Microclimate	Patricia Drach	June 2016
Monitoring the urban climate of the city of Ghent, Belgium	Steven Caluwaerts & Piet Termonia	September 2016
Assessment of cultural differences of thermal perception by UTCI during a heatwave	Cho Kwong Charlie Lam	September 2016
A comprehensive evaluation of breathability and thermal comfort in the urban canopy	Negin Nazarian et al.	September 2016
Role of watering practices in large-scale urban planning strategies to face the heat-wave risk in future climate	Maxime Daniel et al.	December 2016
Cities as urban clusters: An empirical study of surface urban heat island intensity and its implication for benchmarking UHI adaptation	Bin Zhou	December 2016
An empirical approach to estimate the biogenic components of urban CO2 flux	Veronica Bellucco et al.	December 2016

Santa Barbara, who will be soliciting intersting reports on recent conferences as well as details on upcoming events. I urge you to share any information on urban climate-related conferences with Joe at mcfadden@ucsb.edu.

I would also like to thank **Matthias Demuzere** and the Bibliography Committee for compiling the extensive lists of urban climate publications, and I invite you to send details of your recently published articles to Matthias at his new address: matthias.demuzere@ugent.be.

Finally a big thanks to the entire IAUC Board and to President **Jamie Voogt**, with whom it has been my pleasure to work and who I'm sure will continue to capably lead the way... and thanks most of all to you, the readers and contributors, who make this all happen. All the best for 2017!

— *David Pearlmutter, Editor*

Recent Urban Climate Publications

In this edition a list is presented of publications that have generally come out between **September and November 2016**. 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**.

Please note that we are still supporting (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,

Matthias Demuzere

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Upcoming Conferences...

13TH SYMPOSIUM ON THE URBAN ENVIRONMENT AT THE AMS 97TH ANNUAL MEETING
Seattle, WA USA • January 22–26, 2017
https://annual.ametsoc.org/2017/index.cfm/programs/conferences-and-symposia/13th-symposium-on-the-urban-environment/

INTERNATIONAL CONFERENCE ON URBAN GEO-INFORMATICS (ICUG) AT TERI UNIVERSITY
New Delhi, India • February 22-23, 2017
http://icug.teriuniversity.ac.in/

JOINT URBAN REMOTE SENSING EVENT (JURSE 2017)
Dubai, UAE • March 5-7, 2017
http://jurse2017.com/

GREEN INFRASTRUCTURE: NATURE BASED SOLUTIONS FOR SUSTAINABLE & RESILIENT CITIES
Orvieto, Italy • April 4-7, 2017
http://www.greeninurbs.com/finalconference/

AMERICAN ASSOCIATION OF GEOGRAPHERS (AAG) ANNUAL MEETING
Boston, MA USA • April 5-9, 2017
http://www.aag.org/cs/annualmeeting

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

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

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

AMERICAN ASSOCIATION OF GEOGRAPHERS (AAG) SPECIAL SESSIONS:

- Sustainable approaches to urban weather and climate
- Urban climatology in Asia

Boston, MA USA • April 5-9, 2017
http://www.aag.org/cs/annualmeeting

EUROPEAN GEOSCIENCES UNION (EGU) SPECIAL SESSIONS:

- Urban air quality
- Urban climate and urban biometeorology

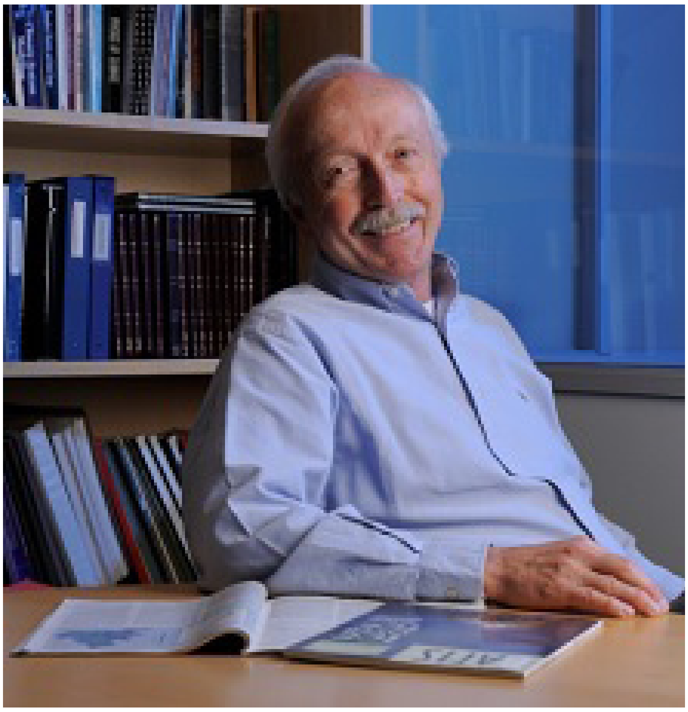
Vienna, Austria • April 23–28, 2017
http://www.egu2017.eu/

Walter F. Dabberdt selected for the 2016 Luke Howard Award

Dr. Walter F. Dabberdt has been recognised by the International Association for Urban Climate as recipient of the **2016 Luke Howard Award**. In a career extending over almost 50 years, Walt has made outstanding research and service contributions to the international urban climatological community, particularly in the area of atmospheric dispersion in urban areas. In addition to his fundamental work on urban meteorology and dispersion, he has undertaken truly ground breaking work on boundary layer and mesoscale meteorology, fluid modelling, and in the development of innovative terrestrial observing systems. While he has also served the broader international scientific community, his major contributions have been in the fields of urban climate, meteorology and air quality.

Following his BS degree (1964) in meteorology from the New York State Maritime College and his MS (1966) and PhD (1969) degrees in meteorology from the University of Wisconsin at Madison, Walt undertook postdoctoral fellowships in turbulence and dispersion with the National Research Council and the Alexander von Humboldt Foundation. From 1970-1985 he undertook research at the Stanford Research Institute (now SRI International), where he became Associate Director of their Atmospheric Science Center. He spent the next 15 years at the National Center for Atmospheric Research (NCAR), becoming Surface & Soundings Systems Facility Manager and then NCAR Associate Director (de facto Chief Operating Officer). Walt joined the Vaisala Group at their Boulder, Colorado facility in 2000, where he was/is Director of Strategic Research, Chief Science Officer, and (currently) Corporate Science Adviser. In this role he has been instrumental in helping to shape a range of new-generation meteorological observing systems and approaches, many of which are particularly appropriate for the complex-geometry conditions found in urban street canyons and urban planetary boundary layers. Although mostly employed in research and industry, Walt's work through his many research papers has been an inspiration to many university educators and graduate research students over the last half century.

Walt Dabberdt's wide-ranging research interests have resulted in over 250 papers, reports, and journal publications. His urban research activities began at SRI, which was at that time the premier urban research laboratory in the United States. There he focused on observation and modelling of urban climate impacts on air quality, resulting in one of the first numerical urban-canyon layer dispersion models, described in publications during the 1970s in many top meteorology and air quality journals. During this period, he also published on urban surface characteristics and urban boundary layer stability. During the 1980s and 1990s, he teamed with Dr. W. Hoydysh on research and publications on highly innovative wind-tunnel simulations of urban street canyon meteorology and dispersion that led to new ways of thinking about air motions in urban areas.


Dr. Walter F. Dabberdt has been recognised by the International Association for Urban Climate as recipient of the 2016 Luke Howard Award.

Walt has served with distinction on numerous regional, national, and international panels and committees. In the US he was a member of the National Academy of Sciences Board on Atmospheric Sciences and Climate (BASC) and served on several study committees under the National Research Council (NRC) Board on Environmental Studies and Toxicology. He was Chair of the Environmental Prediction in Canadian Cities (EPiCC) research program, member of the International Science Steering Committee for the GURME Shanghai Air Quality Forecasting Program, and Chair of its International Science Advisory Committee for the Workshop on Urban Meteorological Observation Design. He was twice in US Delegations to World Meteorological Organisation Congresses and Executive Council meetings, and served as Chair of the American Meteorological Society (AMS) Board on the Urban Environment. Walt is a Fellow of both the AMS and Royal Meteorological Society, and a lifetime National Associate of the NRC of the National Academies. As AMS President (2008), he both designated urban climate as the theme of its annual meeting and he initiated and led the International Forum of Meteorological Societies, currently with about 30 member-societies from six continents, which meets biennially to promote outreach, exchange, and collaboration. Walt is also the 2017 recipient of the AMS' Helmut E. Landsberg Award for urban meteorology. In 2016, the President of Finland bestowed on Walt recognition as Knight First Class in the Order of the Lion of Finland for building scientific relationships between Finland and the United States and China.

In summary, the International Association for Urban Climate resolves that the many significant leadership contributions of Walter Dabberdt to the international meteorological and urban climate community as listed above, along with his role in inspiring multiple generations of urban meteorologists through his significant research, befit him as a very worthy recipient of the Association's highest honour, the Luke Howard Award.

Respectfully,
Nigel Tapper
Chair, IAUC Awards Committee

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Newsletter Contributions

The next edition of ***Urban Climate News*** will appear in late March. Contributions for the upcoming issue are welcome, and should be submitted by February 28, 2017.

Editor: David Pearlmutter (davidp@bgu.ac.il)
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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.