

From the IAUC President

Colleagues, welcome to the June 2011 edition of *Urban Climate News*, which as usual meets the professional standards established by David Pearlmutter. The range of topics included in this edition again shows the international and wide-ranging scope of urban climate studies. There are just a few points that I would make.

Firstly, I would like to congratulate **John Arnfield**, who is the recipient of the 2010 Luke Howard Award in recognition of his contributions to our community over a thirty year period. Many of us would know John



well from conferences that sustained interest in the field of urban climatology during the 1980's and 1990's when such events were 'few and far between'. His primary research interest was in detailed radiation exchanges and his central work on urban climates

applied this study to urban canyons. This forensic approach to the study of the urban effect has proved prescient in the development of the field. John was a central figure in the establishment of the IAUC and created urbclim to allow communication among members. He is a consummate academic citizen and the field of Urban Climatology is great deal richer for his involvement.

Secondly, I want to draw attention to **Climate Change and Cities**, published by Cambridge University Press. This work represents a first assessment in the sense of the IPCC work, and was produced by the [Urban Climate Change Research Network](#) (UCCRN). According to the Executive Summary: *The book focuses on how to use climate science and socio-economic research to map a city's vulnerability to climate hazards, and how cities can enhance their adaptive and mitigative capacity to deal with climate change over different timescales.* In addition, UN-Habitat has recently published its Global Report on Human Settlements 2011, **Cities and Climate Change** (see [page 3](#)). These publications are further evidence of a direction that our field is taking and with which we have to engage seriously to ensure that the science of urban climates is integrated.

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Finally, over the last decade or so, biometeorologists have been working on developing a **Universal Thermal Climate Index** (www.ucti.org) that met the following requirements: *thermophysiologically significant in the whole range of heat exchange; valid in all climates, seasons and scales; useful for key applications in human biometeorology (e.g. daily forecasts, warnings, regional and global bioclimatic mapping, epidemiological studies, and climate impact research) and; independent of person's characteristics (age, gender, specific activities and clothing etc.).* Colleagues will have been aware of this project from ICUC meetings and will be anxious to see the results of this ambitious project. A great deal of the research that underpins this research is to be found in a special edition of the *International Journal of Biometeorology* published recently.



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Cities Join Forces to Fight Global Warming

June 2011 — Given that the world's 40 biggest cities account for eight percent of the global population and 12 percent of global greenhouse gas emissions, local governments play an increasingly important role in confronting climate change.

This was one of the conclusions reached at the fourth **C40 Cities Mayors Summit**, organised by the C40 Cities Climate Leadership Group (C40) in São Paulo, Brazil May 31 to June 3. The summit culminated in the signing of an agreement to establish a common standard for measuring greenhouse gas emissions and another with the World Bank to facilitate financing for environmental projects in urban areas.

The C40 member cities are Addis Ababa, Athens, Bangkok, Beijing, Berlin, Bogotá, Buenos Aires, Cairo, Caracas, Chicago, Dhaka, Hanoi, Houston, Hong Kong, Istanbul, Jakarta, Johannesburg, Karachi, Lagos, Lima, London, Los Angeles, Madrid, Melbourne, Mexico City, Moscow, Mumbai, New Delhi, New York, Paris, Philadelphia, Rio de Janeiro, Rome, São Paulo, Seoul, Shanghai, Sydney, Tokyo, Toronto and Warsaw.

"The leaders of C40 Cities - the world's megacities - hold the future in their hands," said New York City mayor and C40 chair Michael Bloomberg.

Every two years, the group's members meet to present and evaluate the results of their initiatives. The first summit was held in London in 2005, the second in New York in 2007, and the third in Seoul in 2009.

At this year's summit in São Paulo, the C40 and ICLEI - Local Governments for Sustainability, an association of over 1,200 local governments, signed an agreement to establish a global standard for accounting and reporting community-scale greenhouse gas emissions.

"Establishing a single global standard for reporting greenhouse gas emissions will empower local governments to accelerate their actions and access funding for mitigation and adaptation projects," said Bloomberg.

In addition, Bloomberg and World Bank Group president Robert Zoellick signed a "groundbreaking" agreement aimed at helping cities accelerate current actions to reduce greenhouse gas emissions and become more resilient to climate change. The World Bank Group [has allocated](#) 15 billion dollars to C40 cities, and another five billion has been granted in long-term loans at an interest of one percent annually for climate-related initiatives. Combined with other sources of financing, a total of 50 billion dollars would be made available, of which 30 percent is earmarked for private sector initiatives.

One of the featured speakers at the summit was Bill Clinton, former president of the United States (1993-2001) and founder of the Clinton Climate Initiative, which has worked in partnership with C40 since 2006. Clinton's address focused on ways to reduce greenhouse gas emissions, specifically highlighting the need to curb landfill emissions of methane gas.

When organic wastes in landfills decompose they pro-



São Paulo is one of the world's most populous cities.

duce methane, which is one of the greenhouse gases contributing to global warming, but can also be harnessed to generate energy. This represents another potential source of revenue, in addition to the recycling of plastic, glass and wood from landfills.

"The financing has not been available for these things because they have been looked at as eyesores, not goldmines," said Clinton. "World Bank financing may give us the chance to do something historic."

Curbing pollution and adapting to the effects of climate change require major investments, particularly considering the need for new technology in large construction projects.

But big cities have also found simple measures that offer significant results. In the Australian city of Melbourne, for example, the local government offers free transportation until seven in the morning, to reduce the use of private vehicles and take advantage of the public transport vehicles that usually sit idle during these hours.

Another initiative presented at the summit is a programme adopted in Seoul, the capital of South Korea, in which drivers leave their cars at home one day a week. Participants in the programme place a sticker on their vehicle indicating the day they have agreed not to drive, and sensors monitor whether or not they have complied with their commitment.

Initiatives highlighted by the summit's hosts included dedicated lanes for buses, taxis, and bicycles; the recovery of streams and rivers; the creation of strips of parkland between buildings and along highways and river banks; the expansion of green areas to increase rainwater absorption and reduce temperatures; and the use of renewable fuels.

Addis Ababa, the capital of Ethiopia, is currently investing in urban forests, the recovery of gallery forests and the renovation of housing, concentrating homes in complexes on smaller areas of land to free up space for parks and urban infrastructure. Seoul hopes to transform 10,000 buildings into green buildings by 2030, Austin has a zero waste plan for 2040, London aims to have 100,000 electric vehicles on the streets by 2020, and Tokyo is introducing higher energy efficiency standards for large urban developments.

Source: Neuza Árbocz, IPSNews
<http://ipsnews.net/news.asp?idnews=55960>

UN report: Cities ignore climate change at their peril

April 2011 — Urban areas are set to become the battleground in the global effort to curb climate change, the UN has warned.

The assessment by UN-Habitat said that the world's cities were responsible for about 70% of emissions, yet only occupied 2% of the planet's land cover. Yet while cities were energy intensive, the study also said that effective urban planning could deliver huge savings. The authors warned of a "deadly collision between climate change and urbanisation" if no action was taken.

The [Global Report on Human Settlements 2011, Cities and Climate Change: Policy Directions](#), said its goal was to improve knowledge of how cities contribute to climate change, and what adaptation measures are available.

Worrying trend

Joan Clos, executive director of UN-Habitat, said the global urbanisation trend was worrying as far as looking to curb emissions were concerned.

"We are seeing how urbanisation is growing - we have passed the threshold of 50% (of the world's population living in urban areas)," he said. "There are no signs that we are going to diminish this path of growth, and we know that with urbanisation, energy consumption is higher."

According to UN data, an estimated 59% of the world's population will be living in urban areas by 2030. Every year, the number of people who live in cities and towns grows by 67 million each year - 91% of this figure is being added to urban populations in developing countries.

The main reasons why urban areas were energy intensive, the UN report observed, were the result of increased transport use, heating and cooling homes and offices, as well as economic activity to generate income.

The report added that as well as cities' contribution to climate change, towns and cities around the globe were also vulnerable to the potential consequences, such as:

- Increase in the frequency of warm spells/heat waves over most land areas
- Greater number of heavy downpours
- Growing number of areas affected by drought
- Increase in the incidence of extremely high sea levels in some parts of the world

The authors also said that as well as the physical risks posed by future climate change, some urban areas would face difficulties providing basic services.

"These changes will affect water supply, physical infrastructure, transport, ecosystem goods and services, energy provision and industrial production," they wrote. "Local economies will be disrupted and populations will be stripped of their assets and livelihoods."

A recent assessment highlighted a number of regions where urban areas were at risk from climate-related hazards, such as droughts, landslides, cyclones and flooding. These included sub-Saharan Africa, South and South East Asia,



southern Europe, the east coast of South America and the west coast of the US.

Time to act

Dr. Clos said that while climate change was a problem that affected the entire world, individual towns and cities could play a vital role in the global effort to curb emissions.

"The atmosphere is a common good, which we all depend upon - every emission is an addition to the problem," he explained. But, he added: "Consumption is carried out at an individual level; energy consumption is also an individual choice. This is why local governments and communities can play a big role, even when their national governments do not accept or acknowledge the challenges."

The report called on local urban planners to develop a vision for future development that considered climate change's impact on the local area. It said that it was necessary to include mitigation measures (reducing energy demand and emissions) as well as adaptation plans, such as improving flood defences.

In order to achieve the most effective strategy, it was necessary for urban planners to seek the views of the local community, including businesses and residents. However, the UN-Habitat authors said international and national policies also had a role to play in supporting urban areas. These included financial support, reducing bureaucracy and improving awareness and knowledge of climate change and its possible impacts.

Source: <http://www.bbc.co.uk/news/science-environment-12881779>

NY Times: Across Europe, Irking Drivers Is Urban Policy

June 2011 — While American cities are synchronizing green lights to improve traffic flow and offering apps to help drivers find parking, many European cities are doing the opposite: creating environments openly hostile to cars. The methods vary, but the mission is clear – to make car use expensive and just plain miserable enough to tilt drivers toward more environmentally friendly modes of transportation.

Cities including Vienna to Munich and Copenhagen have closed vast swaths of streets to car traffic. Barcelona and Paris have had car lanes eroded by popular bike-sharing programs. Drivers in London and Stockholm pay hefty congestion charges just for entering the heart of the city. And over the past two years, dozens of German cities have joined a national network of “environmental zones” where only cars with low carbon dioxide emissions may enter.

Likeminded cities welcome new shopping malls and apartment buildings but severely restrict the allowable number of parking spaces. On-street parking is vanishing. In recent years, even former car capitals like Munich have evolved into “walkers’ paradises,” said Lee Schipper, a senior research engineer at Stanford University who specializes in sustainable transportation.

“In the United States, there has been much more of a tendency to adapt cities to accommodate driving,” said Peder Jensen, head of the Energy and Transport Group at the European Environment Agency. “Here there has been more movement to make cities more livable for people, to get cities relatively free of cars.”

To that end, the municipal Traffic Planning Department here in Zurich has been working overtime in recent years to torment drivers. Closely spaced red lights have been added on roads into town, causing delays and angst for commuters. Pedestrian underpasses that once allowed traffic to flow freely across major intersections have been removed. Operators in the city’s ever expanding tram system can turn traffic lights in their favor as they approach, forcing cars to halt.

Around Löwenplatz, one of Zurich’s busiest squares, cars are now banned on many blocks. Where permitted, their speed is limited to a snail’s pace so that crosswalks and crossing signs can be removed entirely, giving people on foot the right to cross anywhere they like at any time.

As he stood watching a few cars inch through a mass of bicycles and pedestrians, the city’s chief traffic planner, Andy Fellmann, smiled. “Driving is a stop-and-go experience,” he said. “That’s what we like! Our goal is to reconquer public space for pedestrians, not to make it easy for drivers.”

While some American cities – notably San Francisco, which has “pedestrianized” parts of Market Street – have made similar efforts, they are still the exception in the United States, where it has been difficult to get people to imagine a life where cars are not entrenched, Dr. Schipper said.

Europe’s cities generally have stronger incentives to act. Built for the most part before the advent of cars, their nar-



Pedestrians and trams are given priority treatment in Zurich. Tram operators can turn traffic lights in their favor as they approach, forcing cars to halt. Source: NYTimes.com

row roads are poor at handling heavy traffic. Public transportation is generally better in Europe than in the United States, and gas often costs over \$8 a gallon, contributing to driving costs that are two to three times greater per mile than in the United States, Dr. Schipper said.

What is more, European Union countries probably cannot meet a commitment under the Kyoto Protocol to reduce their carbon dioxide emissions unless they curb driving. The United States never ratified that pact.

Globally, emissions from transportation continue a relentless rise, with half of them coming from personal cars. Yet an important impulse behind Europe’s traffic reforms will be familiar to mayors in Los Angeles and Vienna alike: to make cities more inviting, with cleaner air and less traffic.

Michael Kodransky, global research manager at the Institute for Transportation and Development Policy in New York, which works with cities to reduce transport emissions, said that Europe was previously “on the same trajectory as the United States, with more people wanting to own more cars.” But in the past decade, there had been “a conscious shift in thinking, and firm policy,” he said. And it is having an effect.

After two decades of car ownership, Hans Von Matt, 52, who works in the insurance industry, sold his vehicle and now gets around Zurich by tram or bicycle, using a car-sharing service for trips out of the city. Carless households have increased from 40 to 45 percent in the last decade, and car owners use their vehicles less, city statistics show.

“There were big fights over whether to close this road or not — but now it is closed, and people got used to it,” he said, alighting from his bicycle on Limmatquai, a riverside pedestrian zone lined with cafes that used to be two lanes of gridlock. Each major road closing has to be approved in a referendum.

Today 91 percent of the delegates to the Swiss Parliament take the tram to work. Still, there is grumbling. “There are all these zones where you can only drive 20 or 30 kilometers per hour [about 12 to 18 miles an hour], which

(*NY Times*, cont.)

is rather stressful," Thomas Rickli, a consultant, said as he parked his Jaguar in a lot at the edge of town. "It's useless."

Urban planners generally agree that a rise in car commuting is not desirable for cities anywhere. Mr. Fellmann calculated that a person using a car took up 115 cubic meters (roughly 4,000 cubic feet) of urban space in Zurich while a pedestrian took three. "So it's not really fair to everyone else if you take the car," he said.

European cities also realized they could not meet increasingly strict World Health Organization guidelines for fine-particulate air pollution if cars continued to reign. Many American cities are likewise in "nonattainment" of their Clean Air Act requirements, but that fact "is just accepted here," said Mr. Kodransky of the New York-based transportation institute.

It often takes extreme measures to get people out of their cars, and providing good public transportation is a crucial first step. One novel strategy in Europe is intentionally making it harder and more costly to park. "Parking is everywhere in the United States, but it's disappearing from the urban space in Europe," said Mr. Kodransky, whose recent report "Europe's Parking U-Turn" surveys the shift.

Sihl City, a new Zurich mall, is three times the size of Brooklyn's Atlantic Mall but has only half the number of parking spaces, and as a result, 70 percent of visitors get there by public transport, Mr. Kodransky said.

In Copenhagen, Mr. Jensen, at the European Environment Agency, said that his office building had more than 150 spaces for bicycles and only one for a car, to accommodate a disabled person.

While many building codes in Europe cap the number of parking spaces in new buildings to discourage car ownership, American codes conversely tend to stipulate a minimum number. New apartment complexes built along the light rail line in Denver devote their bottom eight floors to parking, making it "too easy" to get in the car rather than take advantage of rail transit, Mr. Kodransky said.

While Mayor Michael R. Bloomberg has generated controversy in New York by "pedestrianizing" a few areas like Times Square, many European cities have already closed vast areas to car traffic. Store owners in Zurich had worried that the closings would mean a drop in business, but that fear has proved unfounded, Mr. Fellmann said, because pedestrian traffic increased 30 to 40 percent where cars were banned.

With politicians and most citizens still largely behind them, Zurich's planners continue their traffic-taming quest, shortening the green-light periods and lengthening the red with the goal that pedestrians wait no more than 20 seconds to cross.

"We would never synchronize green lights for cars with our philosophy," said Pio Marzolini, a city official. "When I'm in other cities, I feel like I'm always waiting to cross a street. I can't get used to the idea that I am worth less than a car."

Source: http://www.nytimes.com/2011/06/27/science/earth/27traffic.html?_r=2&pagewanted=2&sq=urban&st=cse&scp=1

Manhattanhenge approaching: July 11, 2011



Manhattanhenge – sometimes referred to as the Manhattan Solstice – is a semiannual occurrence in which the setting sun aligns with the east–west streets of the main street grid in the borough of Manhattan in New York City. The term is derived from Stonehenge, at which the sun aligns with the stones on the solstices.

<http://en.wikipedia.org/wiki/Manhattanhenge>

Stop the zealous air conditioning



Christopher DeWolf
Hong Kong Journalist

It's hot, we're bothered, but we need to fight our instinctual reach for the air conditioner remote, because it only makes things worse.

I love summer. I love the sunny days and the hot weather that makes it possible to swim at the beach without freezing off my appendages -- a novelty that still hasn't

worn off for someone born and raised in Canada.

But there's one thing I absolutely loathe about the warm season: air conditioning. Here's why.

1. Drip, drip, drip

Hong Kong's sidewalks are crowded enough, so the last thing I need to worry about is dodging drops of gross, slimy water that is dripping down from leaky air conditioners.

Every time a bit of air con water hits my neck, my heart jumps a beat and my brain goes through the same split-second thought process: Is it water? A cockroach crawling down my shirt? Or acid thrown by a [rooftop madman](#)?

Air con drip creates no-go zones that sometimes take up half the sidewalk. Usually, water drips right onto the spot where people wait for the bus, trapped inside those narrow metal holding pens that bus companies erect to force people to stand in a single-file line. The Marquis de Sade couldn't have dreamed up a more unholy form of torture.

None of this would be a problem if the government did its job and enforced the law. If water is dripping from your air conditioner and you do nothing to solve the problem, you could be fined HK\$10,000 and \$200 for every additional day of non-compliance.

But this rarely seems to happen, possibly because the worst offenders are usually the owners of decrepit old apartments who can't be bothered to keep their properties in decent shape, let alone fix a leaky air conditioner.

2. It's making everything hotter

Last year, I met with Dr. Lee Boon-ying, Hong Kong's top meteorologist and the affable director of the Hong Kong Observatory. As we sat inside the Observatory's beautiful Victorian-era headquarters, he explained to me that Hong Kong's climate is getting warmer and warmer, which has led to a surge in air conditioning use.

There are now more than 20 nights a year when the temperature does not drop below 28°C; in the 1950s, there were no such nights.

Part of the reason is climate change, but an even bigger one is the urban heat island effect. The urban areas of Hong Kong have very little greenery and way too much concrete, which absorbs heat during the day and releases it at night, keeping temperatures artificially high.

When you combine those high nighttime temperatures with Hong Kong's humidity, it makes it nearly impossible to sleep comfortably, even with an electric fan. So the air con is switched on.

Before air conditioning became pervasive in the 1970s, Hong Kong was built in a way that allowed people to stay cool even in the summer. Flats and houses had large balconies and verandas

that provided shade from the sun and a cool place to sit. High ceilings and large windows increased ventilation. And the relative lack of high-rises allowed the wind to travel uninterrupted down the slopes of Hong Kong's mountains.

These days, property developers build apartment towers that ignore Hong Kong's naturally warm climate. Instead of large balconies, apartments have bay windows that flood them with sunlight, which is not something you want when it's 32°C outside.

Massive wall-like housing estates block air flow and cause temperatures to soar in areas behind the wall. Trees that once lined the streets of neighborhoods like Tsim Sha Tsui were chopped down, raising temperatures even more.

Air conditioning provided an excuse to do away with the street trees, traditional architecture and urban form that kept Hong Kong from overheating; now we can't live without it.

3. The malling of Hong Kong

There's something sublime about being outdoors. It's the softness of a gentle breeze, the murmur of distant sounds, the blissfully unencumbered feeling that comes from escaping four walls and a ceiling.

It's why al fresco dining is so popular, why the bars and restaurants on Staunton Street have open fronts and why dai pai dong are still so popular, decades after they outgrew their original mission of providing cheap food to the masses.

Public outdoor space is also democratic. In the open air, you can loiter and protest and be as strange as you want. When you step indoors, the game is different, even in public buildings like libraries, where decorum is enforced with a far heavier hand.

Increasingly, Hong Kong is becoming an indoors city. Life that once took place on the street is now moving indoors, to shopping malls and covered market complexes, all of them air-conditioned and sealed off from the outside world.

For a glimpse of the future, just take a look at the huge Union Square development on top of Kowloon Station. Hotels, offices, community facilities and thousands of apartments are all linked by a single shopping mall podium, Elements. It's an entire neighborhood without public space.

This preponderance of enclosed, air-conditioned spaces is creating a culture oblivious to its climate.

In Singapore, it's acceptable to wear short sleeves to the office, but in Hong Kong, too many people are still expected to wear full suits even on the hottest summer days. Walking for the sheer pleasure of it is seen as eccentric behavior -- why go by foot when you can take an air-conditioned bus, taxi or train instead?

It's only getting worse. The Central street market will soon be replaced by a hotel and apartment towers, each of them connected by enclosed footbridges; most of the remaining street market stalls will be relocated inside a new, air conditioned market building.

In Kwun Tong, the entire commercial district around Yue Man Square is being torn down and rebuilt, no doubt with plenty of well-refrigerated indoor spaces.

This air con-addicted culture is not only killing Hong Kong's streetlife, it's damaging the environment, too. After all, most of our power comes from coal-fired power plants, and the more air conditioning we use, the more we pump pollution into our air.

Source: <http://www.cngo.com/hong-kong/life/christopher-dewolf-stop-zealous-air-conditioning-296541#ixzz1QkAlR6KA>

Call for Papers – Urban Monitoring

Earthzine.org is soliciting articles of 800-3,000 words for its 3rd Quarter Theme Issue on **Urban Monitoring**.

About half of the planet's 6.6 billion people now live in urban areas, which occupy less than 3% of the land area. By the year 2025, the global population is expected to reach 8 billion, of which 5 billion are expected to reside in urban areas. Now is an opportune time to examine trends and developments in urban monitoring.

Specific areas of focus include:

- How Earth observation technologies have contributed or can contribute to understanding the impacts of rapid urbanization;
- The implications of urbanization for climate change, and the implications of climate change for urbanization;
- The current capacity and projected need for urban monitoring;
- The state-of-the-art of in situ and remote sensing technologies;
- The extent to which urban monitoring informs urban planning and design practice;
- Data collection, access, sharing, and stewardship;
- Effective communication strategies for scholars, the general public, stakeholders, and policymakers;
- Use of Earth observation technologies to assess key environmental issues such as urban heat islands, and the public health implications of urbanization and climate change;
- Innovative people who are using Earth observation technologies for urban monitoring or who know how Earth observation technologies can be adapted to address urban issues.

Earthzine is an informative scientific online journal dedicated to promoting the societal benefits of Earth Observations and the use of Earth information in planning and policy. Sponsored by the IEEE (Institute of Electrical and Electronic Engineers), Earthzine supports the Group on Earth Observations in establishing the Global Earth Observation System of Systems. Earthzine seeks to explore the application of scientific and technological research as well as policy and its implementation for the benefit of society.

We invite you to submit an article and become part of a growing professionally diverse community and global readership network working to build the Global Earth Observation System of Systems (GEOSS).



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We seek to publish articles from all regions of the globe.

We welcome articles about programs, projects, organizations, examples of interdisciplinary and/or cross-regional research latest discoveries, and unusual findings. We also publish opinion essays, book and art reviews.

Submissions must be in English. They can be sent to Managing Editor Jeff Kart, jkart@earthzine.org.

Please consult our [Writers Guidelines](#) page for further information.

Important dates: Queries to our editors may be sent at any time. Submission of original articles for our Urban Monitoring Theme begins June 1, 2011, and ends Aug. 22, 2011.

Publication: All accepted contributions will be published online at earthzine.org in the fall of 2011 and will be freely accessible to the public.

Information:

Earthzine website: <http://www.earthzine.org>

Writer's Guidelines: earthzine.org/writers-guidelines/

GEO/GEOSS website: earthobservations.org

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UHI effects on temperature records near Brussels, Belgium: An observational and modeling study

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In the present study, we examine the local impact of change in impervious surfaces in the Brussels Capital Region (BCR, Belgium) on trends in maximum, minimum, and mean temperatures of Uccle (the national suburban recording station of the Royal Meteorological Institute of Belgium) between 1960 and 1999. Specifically, remote sensing imagery is combined with a land surface scheme that includes a state-of-the-art urban parameterization, the Town Energy Balance scheme. In order to: (i) isolate effects of urban growth on near-surface temperature independent of atmospheric circulations and (ii) be able to run the model over a very long period without any computational cost restrictions, we run the land surface model in a stand-alone mode coupled to downscaled ERA-40 reanalysis data. We also consider BCR as a lumped urban volume and the rate of urbanization was assessed by estimating percentage of impervious surfaces from Landsat images acquired for various years. Model simulations show that: (1) the 40-year annual mean urban bias on mean temperature is estimated to be 0.62°C, and (2) 45% of the overall warming trend is attributed to intensifying urban heat island effects rather than to changes in local/regional climate. During the summer, the UHI of Brussels was also estimated using ground-based weather stations. Analysis of model-based urban warming reveals that the urban bias on minimum air temperature is rising at a higher rate, 2.5 times (2.85 ground-based observed) more, than on maximum temperature, with a linear trend of 0.15°C (0.19°C ground-based observed) and 0.06°C (0.06°C ground-based observed) per decade respectively. The summer-mean urban bias on the mean air temperature is 0.8°C (0.9°C ground-based observed). The results based on remote sensing imagery are compatible with estimates of urban warming based on weather stations. Therefore, the technique presented in this work is a useful tool in estimating the urban heat island contamination in long time series, countering the drawbacks of a ground-based observational approach.

1. Introduction

It is important to know whether, and to what extent, estimates of global warming trends can be explained by the growth of the urban heat island (UHI) due to increased urbanization. In fact, if observations of near-surface air temperatures in growing cities are used in the assessment of global warming trends, these trends may be overestimated. However, the change in urbanization over time is smaller for a station that originally was established in a densely built-up area than for a station originally installed in a rural or little-urbanized environment that has experienced growth. Jones et al. (2008) have shown that near-surface air temperatures in central London and Vienna did not rise relative to rural locations nearby in recent decades. Nevertheless, suburban sites continue to warm relative to nearby rural areas until local urbanization is complete, as shown for London's Heathrow airport by Jones and Lister (2010).

The past observational approach compared urban near-surface air temperature records with records of a rural area. However, selective use of rural sites requires information (metadata) about the site and its surroundings. Some forms of metadata, such as city population statistics, must be used with care because they may not be representa-

tive of the immediate vicinity of the observing site. Also, in situ observations usually suffer from inhomogeneities caused by nonclimatic factors such as changes in observation time, instrumentation, location (altitude and latitude), and other local meteorological features.

With the advent of remote sensing, it has become possible to monitor local urban climate changes associated with land use changes over rapidly expanding urban areas. Specifically, the quantity of impervious surfaces is related to urban growth and urban density (Fricke and Wolff, 2002). The proportion of impervious surfaces has been reported to be a good indicator for the monitoring of the UHI. A positive correlation between the proportion of impervious surfaces and land surface temperatures was identified by Yuan and Bauer (2007) and many earlier studies; also the expansion of the built-up area was found to be the main factor in long-term changes in near-surface air temperatures (Huang et al., 2008; Shouraseni and Yuan, 2009).

The Brussels Capital Region (BCR) in Belgium has experienced a rapid overturning of agricultural land and native vegetation to buildings and impermeable pavements over the last century (Vanhuysse et al. 2006). In fact, while the population of the present BCR was only 140,000 in 1831,

the number of inhabitants had risen to about 1 million in 2004, which caused a massive expansion of the capital. In terms of ecological impact, urbanization is one of the most significant and long lasting forms of land use and cover change and its extent of increase is linked to population growth and economic development. At the same time, a gradual increase in temperatures has been observed at the national recording station of the Royal Meteorological Institute (RMI) of Belgium (1833-present), which is located some 6 km south of the center of the capital, in the Uccle suburban site. This time series has been used to monitor climate change in Belgium and is one used in the world database of land-surface air temperature and in the Global Climate Observing System (GCOS) surface network (Peterson et al. 1997). The temperature time series of Uccle has always been used as a rural station, whereas it is actually one of those series suspected of being influenced by the urban heat island (UHI) created by the surrounding growing urban areas.

The past observational approach (Vandiepenbeek 1998) has focused on empirical evidence for the UHI contamination in this temperature record. Vandiepenbeek (1998) compared air temperature records at Uccle with records of a rural area as a function of meteorological conditions. Recently, Van Weverberg et al. (2008) used a modeling approach to study the influence of the UHI development on temperature recordings at Uccle. The method consists of evaluating the simulated temperature difference of two model integrations initialized with different land cover patterns: first, the model was integrated using the contemporaneous land cover setting as input, and second, the model was integrated with a land cover setting similar to the one at the time the recording station was set up about 170 yrs ago – but with otherwise identical initial and boundary conditions as in the first run. The model was applied using one-way grid nesting with three levels, the later being a domain of 60 km x 60 km centered on Brussels with a horizontal resolution of 1 km. Investigations by Van Weverberg et al. (2008) revealed (their Fig. 5) that the temperature gradient from the rural environment toward the urban site is quite strong, while in the built area a temperature plateau is obvious with the Uccle station being within this area influenced by urban heating. However, the model runs were restricted to a few weather episodes given the large computational costs of simulations. Thus no representative urban bias corrections for the time series at Uccle can be derived from their simulations.

In this study we will update previous research by analyzing the local impact of change in impervious surfaces in the BCR on long-term trends in maximum, minimum, and mean temperatures between 1960 and 1999. Specifically, we combine data from remote sensing imagery and a land surface model including the urban parameterization of Masson (2000), the Town Energy Balance (TEB)



Figure 1. Study area of the Brussels Capital Region. The national recording station of the Royal Meteorological Institute of Belgium (Uccle, urban station) is marked with a red bulb, and rural stations (Asse and Brusse-gem) with a green bulb. The black arrow presents the direction of the prevailing wind in the region.

scheme. In the present study: (i) we use the land surface model in a stand-alone mode, coupled to downscaled ERA-40 reanalysis data, in order to isolate the local effects of urban growth on near-surface temperature independent of atmospheric circulations, and (ii) we consider BCR as a lumped urban volume with the underlying assumption that the entire BCR is composed of one homogeneous material comprised of uniform thermophysical properties, irrespective of spatial variability. These hypotheses enable us to simplify an extremely complex problem, the urban environment, but keep intact the surface energy balance. Urbanization was assessed by measuring changes of percent impervious surface areas in the BCR. Also, recently, a near-surface air temperature record (summer 1955-2006, minimum T_{MIN} and maximum T_{MAX} temperature) were found for a rural station about 20 km away from Brussels (Van de Vyver, 2010). This station allows the increase of the UHI around Brussels to be determined. Thus, the UHI effects on the near-surface air temperature time series of Brussels during summer months are estimated using both ground-based weather stations and remote sensing imagery combined with a land surface scheme and the results compared.

2. Data and model

Study area – The focus of our study is the Brussels Capital Region (see Fig. 1), centrally located in Belgium, with a size of 161.78 km² and a registered population of 1,031,215 on January 1, 2007, estimated by the National Institute of Statistics (INS, 2009). As in the majority of large European cities, it is only during the 19th century that the popula-

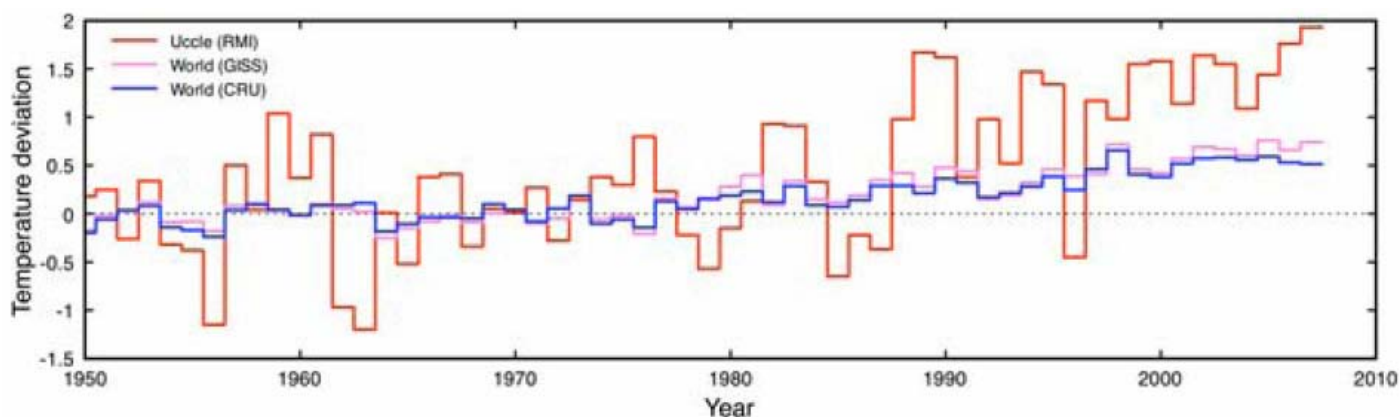


Figure 2. Mean annual time-series of the Uccle temperature (red) and the worldwide CRU/Hadley (blue) and the NASA/GISS (pink) temperature. All values are shown as deviations from their 1951-1980 means.

tion strongly increased, exceeding 1 million inhabitants in 2004. There has been a rapid expansion of the capital during the last 50 years. The area covered by the BCR is circular (Fig. 1) with a diameter of 12 km and the effects of urbanization variability dominate the topographic influence (orography is beneath 150 m).

Meteorological weather station – The national recording station of the Royal Meteorological Institute (RMI) of Belgium – World Meteorological Organization (WMO) code 06447 – is situated some 6 km south of the center of the capital (Fig. 1), in the Uccle suburb, at 50.80°N and 04.35°E, at 104 m above sea level. This time series has a long history, dating to 1833, and has been constructed within the EU IMPROVE project that focused upon the construction of time series of early daily European instrumental observations (Camuffo and Jones 2002). In this context, the homogenization of climatological time-series was a major issue. In particular, corrections due to changes in the thermometers and instrument corrections have been applied to the Royal Observatory of Brussels part of the series (since 1833). The daily mean temperature has been determined from the 1870s onwards by the arithmetic mean of the daily minimum and maximum temperature. Furthermore, the single relocation from the Gate of Schaerbeek in the city center of Brussels to the Plateau of Uccle in 1890 was duly taken

into account. More details about the homogenization of the time series of Uccle can be found in Demarée et al. (2002). However, impact of urbanization of the station environment has not been assessed in this time series. The signal of urban warming of the city of Brussels is embedded together with other aspects as global warming within the temperature time series of Uccle. The Uccle mean annual time series together with the mean annual worldwide time series as given by the CRU/Hadley Center and by the NASA/GISS are shown in Fig. 2. All values are calculated as deviations from the 1951-1980 period. An abrupt change in the Uccle time series is noted by the end of the 1980s. The aim of the present study is to quantify which part of this warm bias with respect to the global trend can be explained by urbanization of the city of Brussels. To this end, two ground-based meteorological stations, situated 20 km away from the center of Brussels and managed by the RMI, are used (see Fig. 1, Table 1). These rural stations are located outside the area influenced by the urban effect of Brussels (Van Weverberg et al. 2008, their Fig. 5) and are not influenced by the SW-prevailing wind direction. Therefore the impact of the city should be negligible. Though the UHI may not be zero in small villages (e.g. Fujibe, 2009), they did not experience a rapid growth during the last century and therefore the urban infrastructure should not have

Table 1. Individual near-surface air temperature series used to estimate the urban warming of the city of Brussels, their observation hours, location and approximate elevation. No missing daily data were found in the datasets of the four climatological series.

Time span	Observation time	Location (above mean sea level)
1 June 1955 – 31 August 2006	Daily max- and minimum	Uccle (104 m)
1 June 1991 – 31 August 2006	Daily max- and minimum	Brussegem (~53 m)
1 June 1980 – 31 August 1990	Daily max- and minimum	Asse (~53 m)
1 June 1955 – 31 August 1971	Daily max- and minimum	Asse (~53 m)

Table 2. Synthesis of satellite images used for the second period.

Year	Image	Spatial resolution
1986	Landsat TM	30 m (B, V, R, PIR, MIR), 120 m (TIR)
1987	Landsat TM	30 m (B, V, R, PIR, MIR), 120 m (TIR)
1993	Landsat TM	30 m (V, R, PIR, MIR), 120 m (TIR)
2003	Landsat ETM+	30 m (B, V, R, PIR, MIR), 60 m (TIR), 15 m (pan)
2005	Spot HRV	20 m (V, R, PIR)
2003	Spot HRG	2.5 m (pan – supermode)
2006	QuickBird	2.4 m (B, V, R, PIR), 0.6 m (pan)
2004	UrbOrtho	0.6 m (B, V, R)

changed its influence on outgoing longwave radiation.

Evolution of surface cover fraction – The evolution of surface cover fractions over the study region was derived from a study by Vanhuyse et al. (2006). This study aims to assess the evolution of the fraction of impervious surfaces in the BCR since the 1950s date of the acceleration of urban growth linked to widespread use of cars as a new mode of transport. Two periods were studied:

(i) From 1950s to 1980s: Vanhuyse et al. (2006) used the MURBANDY database (Fricke and Wolff, 2002) available for 1955, 1970, and 1985 and then estimated the fraction of impervious surfaces using topographic maps and aerial photos. Initially, an interpretation of land use in 1997 was carried out visually on the screen, based on satellite images IRS/1C (spatial resolution 5.8 m), and aerial orthophotos (5 m spatial resolution). The legend of reference is derived from CORINE Land Cover but has a higher degree of detail for artificial surfaces. The minimum mapped area is 1 ha for artificial surfaces and 3 ha for the other surfaces. Then, for 1955, 1970 and 1985, the database of 1997 was retrospectively updated using information from maps and aerial photos of the period. For each of the three dates, topographic maps at 1:5000 were scanned, georeferenced, and overlaid with the MURBANDY / MOLAND data. The interpretation was carried out visually using a geographic information system (ArcGIS v9.1). For 1985, the coverage map at 1:5000 was not comprehensive enough and had to be supplemented by aerial photographs. The final results indicate that the percentage of impervious surfaces has increased from 26% in 1955 to 39% in 1985 (see Fig 3).

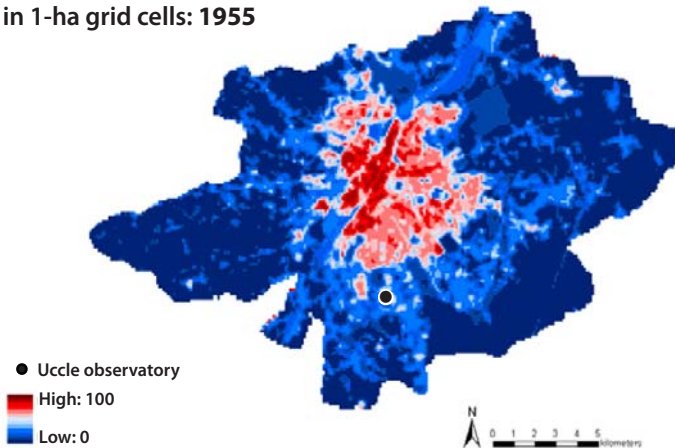
(ii) From 1980s to 2006: Vanhuyse et al. (2006) first conducted a binary classification of land use on the basis of a satellite image at very-high-resolution (UrbOrtho, QuickBird) dating from 2006 (see Table 2). They used the software eCognition Professional v4.0, which allows a

classification by region (object-oriented classification) based on fuzzy logic. The regions are assigned a class according to their degree of belonging to this class, as determined by the nearest neighbor algorithm and/or membership functions modeled by the user. The final result was made binary keeping only two classes: pervious and impervious surfaces. A grid mesh of 30 meters per side was generated by referring to the Landsat images, so that each mesh covers exactly one Landsat pixel. Thus, applying the binary classification on the grid, they were able to extract the percentage of impervious surfaces in each cell. Then they built a simple regression model between the percentage of impervious surfaces and different spectral variables derived from high-resolution Landsat images: NDVI (Normalized Difference Vegetation Index), PVI (Perpendicular Vegetation Index), SAVI (Soil Adjusted Vegetation Index), MSAVI2 (Second Modified Soil Adjusted Vegetation Index), and BI (Brightness Index). This model permitted estimation of the percentage of impervious surfaces for two previous dates (1993 and 1986) for which only high-resolution images (Landsat Thematic Mapper with 30 m resolution) are available. The final results indicate that the percentage of impervious surfaces has increased from 39% in 1985 to 47% in 2006 (see Fig 3).

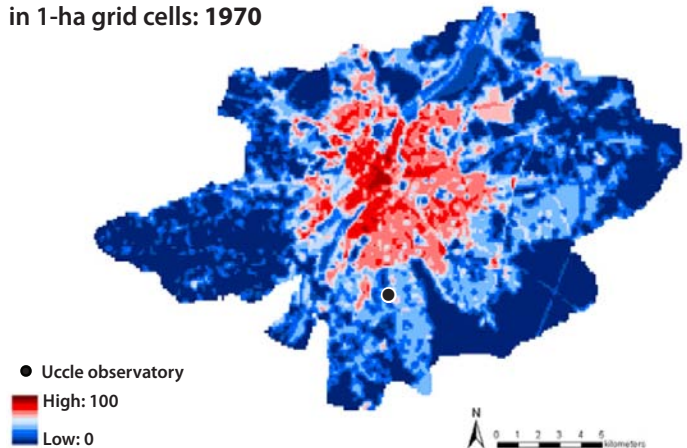
Atmospheric data – The ERA-40 re-analysis (Uppala et al., 2005), produced by the European Centre for Medium-Range Weather Forecasts (ECMWF), covers the period September 1957 to August 2002 with a temporal resolution of 6 h and a spatial resolution of about 120 km for Western Europe. In order to increase the spatial resolution over Belgium, a dynamical downscaling method was applied using the numerical weather prediction limited area model ALADIN developed by the ALADIN international team (1997).

A dynamical downscaling to 10 km resolution over

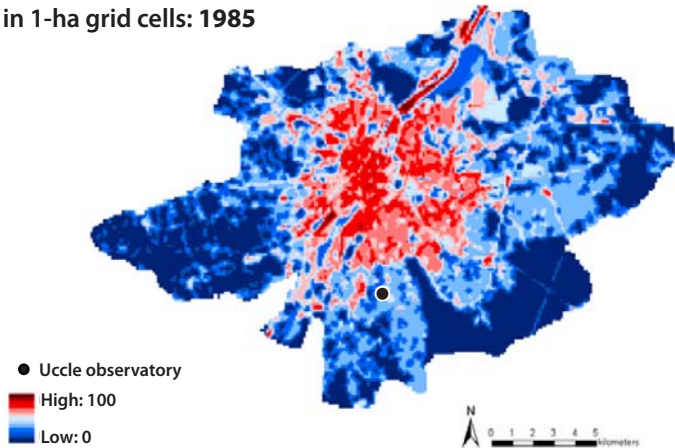
Percentage of impervious surfaces
in 1-ha grid cells: 1955



Percentage of impervious surfaces
in 1-ha grid cells: 1970



Percentage of impervious surfaces
in 1-ha grid cells: 1985



Percentage of impervious surfaces
in 1-ha grid cells: 2006

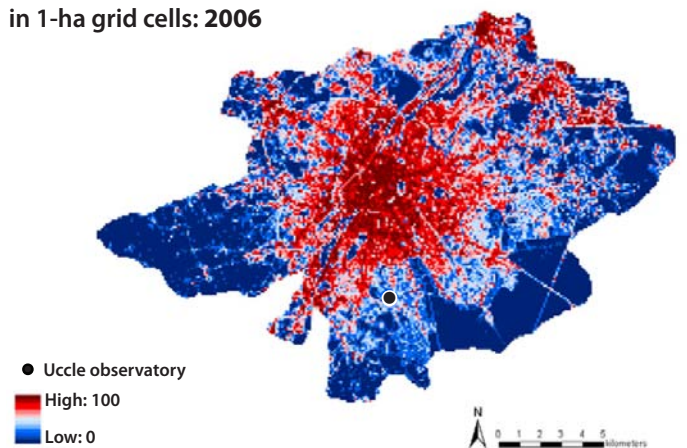


Figure 3. The percentage of impervious surfaces in the catchment basins including the Brussels Capital Region in 1955, 1970, 1985, and 2006. The black dot shows the Uccle observatory location.

Belgium is performed in 2 steps: (i) the ALADIN model is coupled to the ERA-40 data and run at a resolution of 40 km on a domain encompassing most of Western Europe, (ii) these results are then used as initial conditions and lateral boundary conditions for a second downscaling run at 10 km resolution on a smaller domain over Belgium (see Hamdi et al., 2009 for more details).

Land surface scheme – We use the offline surface scheme of Météo-France SURFEX (SURFace EXternalisée) (Le Moigne, 2009). In SURFEX, each grid box is made of four adjacent surfaces: nature, urban areas, sea or ocean, and lake. Horizontal interaction does not exist between the different surface area tiles. The coverage of each of these surfaces is known through the global ECOCLIMAP database (Masson et al., 2003). During a model time step (300 s), each surface grid box receives the upper air temperature, specific humidity, wind speed, pressure, total precipitation, long-wave radiation, and short-wave radiation.

For urban surfaces, SURFEX uses the Town Energy Balance (TEB) (Masson, 2000) single-layer urban canopy model which assumes an isotropic array of street can-

yons. The advantage is that relatively few individual surface energy balance evaluations need to be resolved, radiation interactions are simplified, and therefore computational time is kept low. TEB simulates heat and water exchanges and climate of three generic surfaces (roof, wall, and road), where heat transfers are computed through several layers of materials, generally four. Anthropogenic heat and vapor releases from buildings, vehicles and chimneys can also be added. For vegetated tiles, the Noilhan and Planton (1989) Interaction between Soil, Biosphere, and Atmosphere (ISBA) scheme is used. TEB is applied with literature-based surface thermal parameters and observed or simulated atmospheric and radiation data from above roof level. Despite the simplification, offline simulations of TEB have been shown to accurately reproduce surface energy balance, canyon air temperature, and surface temperatures observed in the dense urban areas of Vancouver and Mexico City (Masson et al., 2002), Marseille (Lemonsu et al., 2004) and Basel (Hamdi and Masson, 2008).

Model parameter – The domain is 10 km x 10 km over the BCR, centered on the city center of Brussels. This

Table 3. Performance statistics for daily maximum (T_{MAX}), minimum (T_{MIN}) and mean (T_{MEAN}) near-surface air temperature, obtained from the “urban” scenario, based on formulas by Willmott (1982). $RMSE_{SYS}$ and $RMSE_{UNSYS}$ are the systematic and unsystematic root mean square errors, respectively.

	Correlation	Index of agreement	Bias (°C)	$RMSE_{SYS}$ (°C)	$RMSE_{UNSYS}$ (°C)
T_{MAX}	0.96	0.97	1.12	1.38	2.33
T_{MIN}	0.96	0.97	-0.43	0.66	1.89
T_{MEAN}	0.98	0.98	0.34	0.81	1.69

small heterogeneous domain is overlaid on a 1 km resolution land cover classification provided by the ECOCLIMAP database. The land cover types contained in this domain are then aggregated into 4 tiles (Sea, Lake, Vegetation, and Urban) with the corresponding fractional coverage (0%, 0%, 53%, 47%) to be used as the contemporaneous land cover setting. SURFEX is run in one offline single column mode from June 1, 1960 to August 31, 1999 (40 years), and the forcing variables are derived from the downscaling of the ERA-40 for the grid point the closest to the BCR. For the vegetation tile, radiative, thermal, and soil properties (albedo, roughness length, emissivity, thermal inertia, leaf area index, etc.) are taken from the ECOCLIMAP database (Masson et al., 2003) and remain fixed through the simulation. For the urban tile, SURFEX uses only one urban land-use class as input. In this study, geometrical, thermal, and radiative properties of roofs, walls, and roads were set to values representing a typical midsize European city (see Table 1 in Hamdi et al., 2009). Another important urban-related aspect is the anthropogenic heat. This term includes all heat emitted by human activities: traffic, release from industry, and release from residential buildings. Over the area presented in this study, releases from buildings have been shown to be the dominant component of the anthropogenic heat (Van Weverberg et al., 2008). In SURFEX, to mimic space heating, a fixed minimum internal building temperature of 19°C is specified.

3. Results and Discussion

Urban warming from model simulations – To isolate effects of urbanization on local near-surface climate conditions, we calculate the difference between two model integrations: (i) the “rural” scenario representing a hypothetical situation with no urban areas inside the Brussels Capital Region domain and (ii) the “urban” scenario, which represented the climate in the presence of urban areas using the measured historical changes of surface cover fractions. For this run, the surface cover fractions are updated each year using a linear interpolation. The use of the land surface model in an offline mode does not account for atmospheric feedback and therefore allows isolation of the effects of landscape differences on local near-surface climate conditions. The UHI effect is estimated as the differ-

ence between the “rural” and “urban” model integrations.

To evaluate model performance, a comparison is made between the urban run and the routine observations of the Uccle ground station. Table 3 presents the statistics that quantify model performance for daily maximum (T_{MAX}) and minimum (T_{MIN}) air temperature using statistical measures (correlation coefficient, index of agreement, bias, and systematic and unsystematic root mean square error) based on formulas by Willmott (1982). The 2-m temperatures predicted by the urban run are consistent with meteorological observations, with a correlation coefficient of 0.96 and an index of agreement of 0.97 for T_{MAX} and T_{MIN} . The systematic root mean square error, ($RMSE_{SYS}$) which should account for physical processes that the model does not routinely simulate well, is small compared to the unsystematic root mean square error ($RMSE_{UNSYS}$). The proportions of systematic errors in the model are 26% and 11% for T_{MAX} and T_{MIN} respectively. The minimum temperature is better simulated by the model with a minor negative bias of -0.43°C and $RMSE_{SYS}$ of 0.66°C against 1.12°C and 1.38°C for maximum temperature. More details about the results of simulations in both scenarios can be found in Hamdi et al. (2009).

Figure 4 presents an isodiagram of daily and monthly

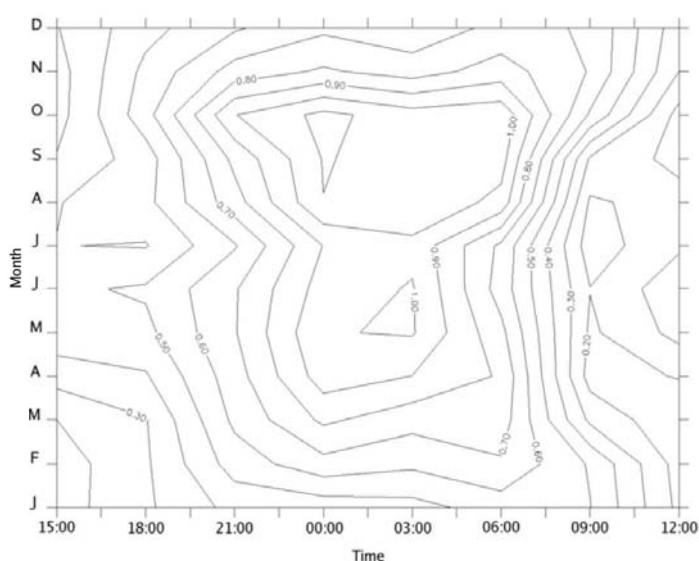


Figure 4. Isodiagram of daily (x-axis LT) and monthly (y-axis) variation of the 40-year average urban bias.

variation of the mean urban bias during the 40 years of the simulated period. A positive urban bias on the temperature record was found during the day and the night and for all seasons. During the day, temperature was hardly modified by the urban conditions with a maximum urban bias of about 0.3°C during summer (JJA). Not surprisingly, the most important influence of the urban effect on the temperature record at the Uccle site was found at night (between 21:00 and 06:00 LT) with an urban bias of about 1°C during the warm season (MJJAS). It should be noted also that the strongest gradients are found during the warm season at sunset/sunrise with a rapid increase/decrease of the urban bias.

The 40-year annual mean urban bias on mean temperature (T_{MEAN}) at Uccle is 0.62°C. Based on the classification and the relative frequencies of weather events, Van Weverberg et al. (2008) found a somewhat higher value. They estimated the weighted average UHI at the Uccle recording station to be 0.8°C. However, the authors used a very simple parameterization for representing urban land and the selected weather events in their study presented too small a sample to make a reliable weighted average for the annual urban effect. Vandiepenbeeck (1998) applied an observational approach to assess the average UHI contribution between 1966 and 1995. He studied the influence of urban heat advection on the temperature time series of Uccle empirically by comparing the meteorological observation with those of the rural station Saint-Hubert far away from Brussels (more than 100 km). He examined the dependence of the temperature differences on wind direction. He found the annual mean urban heat contamination to be 0.55°C, which is close to the value found in this study.

Model simulations (see Fig. 5) show that the UHI effect on near-surface minimum temperature is rising at a higher rate (2.5 times) than on maximum temperature, with a linear trend of 0.15°C ($\pm 0.01^\circ\text{C}$) and 0.06°C ($\pm 0.01^\circ\text{C}$) per decade, respectively. The summer-mean urban bias on the mean temperature ($T_{\text{MEAN}} = [T_{\text{MAX}} + T_{\text{MIN}}]/2$) at Uccle is 0.8°C. Based on a 3-D modeling approach using the ARPS model, Van Weverberg et al. (2008) found a somewhat higher value. They estimated the summer-mean urban bias at the Uccle station to be 1.13°C. Vandiepenbeeck (1998) applied another observational approach to assess the average UHI contribution between 1966 and 1995. He examined the dependence of

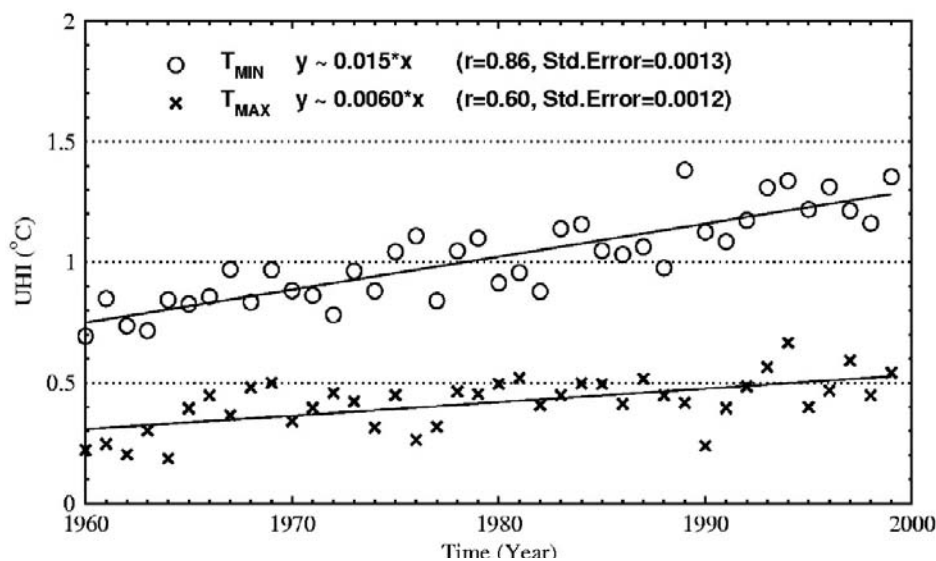


Figure 5. The summer-mean urban heat island (UHI) effect on minimum and maximum near-surface air temperature estimated as the difference between the “rural” and “urban” model integrations with the linear trend, 1960-1999. r is the correlation coefficient and Std.Error is the standard error of the regression coefficient.

the temperature differences on wind direction. He found the summer-mean urban heat contamination to be 0.8°C which is close to the value found in this study.

The annual mean (not shown) urban bias on minimum temperature is also rising at a higher rate (slightly 3 times) than on maximum temperature, with a linear trend of 0.14°C and 0.05°C per decade respectively. We now estimate that 45%¹ (the ratio between the linear trend of the annual mean urban bias and the urban scenario) of the overall warming trend is attributed to intensifying urban heat island effects rather than to changes in local/regional climate. This should correspond to $\sim 0.63^\circ\text{C}$ of the 20th century warming trend of 1.4°C in the Uccle series.

Urban warming from weather stations – Without assurance of homogeneity, trend estimates are unreliable and artifacts in long-term observations and rural/urban differences can be introduced and thus may bias the estimate of the UHI. For this reason, the assumption that the three rural subseries (Table 1) could be linked to constitute a reference rural series is tested with respect to homogeneity. Following the guidelines described in Wijngaard et al. (2003), the four methods selected to test the departure of homogeneity in the time series are: the standard normal homogeneity test for a single break, the Buishand range test, the Pettitt test, and the Von Neumann ratio test. Since three tests accept the null hypothesis at the 1% level, the constructed reference rural series is assigned to class 1 “useful” (details about the homogenization of the rural time series can be found in Hamdi and Van de Vyver, 2011).

¹ The linear trends of the urban and rural scenarios were found to be 0.20°C and 0.11°C per decade respectively.

The UHI intensity is defined as the difference in near-surface air temperature between urban and rural stations. Estimates of urban bias at the Uccle recording station, on maximum and minimum near-surface air temperature, calculated during the summer of each year between 1955 and 2006, are plotted with the linear trends in Fig. 6 (unfortunately, no data were found between 1972 and 1979).

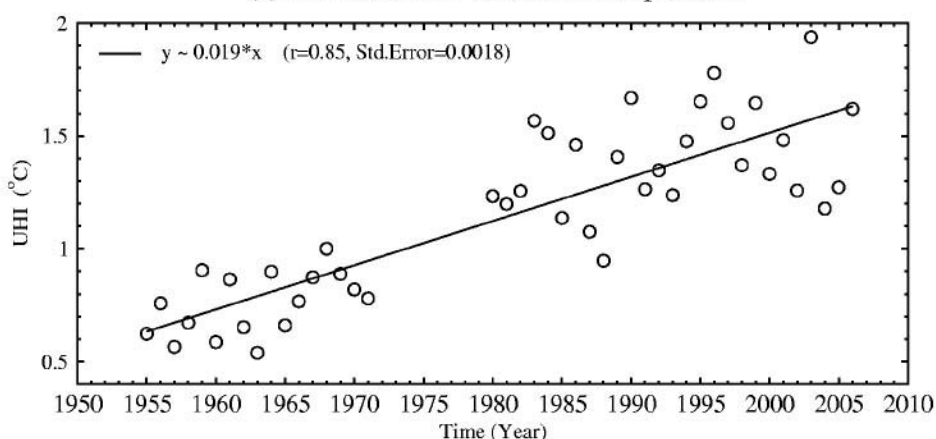
As indicated by Fig. 6, the UHI effect on minimum air temperature is shown to be rising at a higher rate (2.85 times more) than on maximum temperature, with a linear trend of 0.19°C ($\pm 0.02^{\circ}\text{C}$) and 0.06°C ($\pm 0.02^{\circ}\text{C}$) per decade, respectively. This result is consistent with previous work suggesting that the maximum air temperature is substantially less affected by urbanization than the minimum temperature (Landsberg, 1981; Karl et al., 1988; Kalnay and Cai, 2003; Hua et al., 2008).

4. Conclusions

In this study, the urban heat island (UHI) effects on the near-surface air temperature time series of Uccle during summer months was estimated using both ground-based weather stations and remote sensing imagery combined with a land surface scheme. The modeled estimate of urban warming was based on calculating the difference between two model integrations: (i) "the rural" scenario representing a hypothetical situation with no urban areas inside the Brussels Capital Region domain and the "urban" scenario, which represented the climate in the presence of urban areas using the measured changes of surface cover fractions. Results of our simulations are compatible with estimates of urban warming based on weather stations. However, exact compatibility is not to be expected because with the 10 km horizontal resolution of the climate drivers used to run the land surface scheme, we are not able to replicate the micrometeorology in the required detail.

This new technique combining data from remote sensing imagery and a land surface scheme presented in this study is a useful tool to estimate the urban heat island contamination in long time series, countering the drawbacks of an observational approach. It would be

(a) Minimum near-surface air temperature



(b) Maximum near-surface air temperature

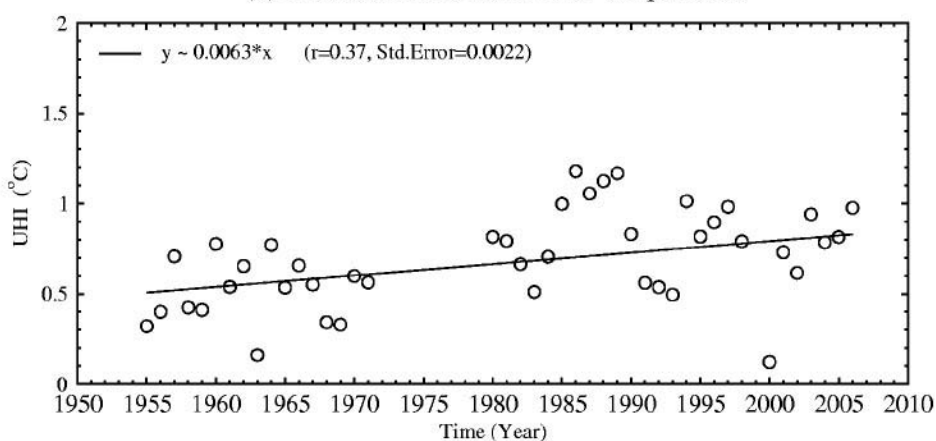


Figure 6. The summer-mean urban heat island (UHI) effect on (a) minimum and (b) maximum near-surface air temperature estimated as the difference between urban and rural ground-based weather stations, with the linear trend, 1955-2006. r is the correlation coefficient and Std.Error is the standard error of the regression coefficient (no data were found between 1972 and 1979).

very simple and useful to apply this research method to other cities where credible rural ground weather stations do not exist. Furthermore, because of its local character, the results of this study will be particularly helpful for planners in developing scenarios for future land cover changes.

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Thermal adaptation and attendance in outdoor public spaces

1. Thermal environment and usage of space in hot-humid regions

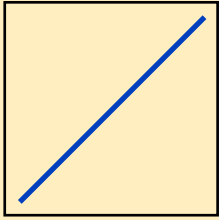
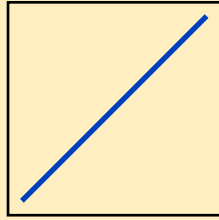
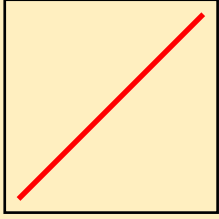
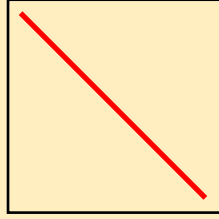
Weather can significantly impact the thermal perception of human body, which may affect people's usage and attendance in outdoor spaces. Previous studies focusing on unshaded public spaces in temperate regions revealed that the number of people using the spaces increased as thermal indices (e.g. air temperature (T_a), globe temperature (T_g), mean radiant temperature (T_{mrt}), and physiologically equivalent temperature (PET)) increased during both summer and winter (Eliasson et al., 2007; 2001; Thorsson et al., 2007; Thorsson et al., 2004).

In hot-humid regions, Lin (2009) conducted similar studies in Taiwan, indicating that the number of people visiting an unshaded square increased as the T_a or PET, calculated by the RayMan model (Matzarakis et al., 2010), increased during the cool season. However, the number of people frequenting the square decreased as the PET and T_a value increased during the hot season. These experimental results were compared with those for temperate regions (Table 1), indicating that the human energy balance model cannot fully explain the influence of climate on use of public spaces; that is, psychological and behavioral factors, i.e. thermal adaptation, also play important roles in outdoor thermal comfort. In order to realize the thermal comfort and adaptation characteristics of people in hot and humid regions, the FIOT project (Field Investigation of Outdoor Thermal Comfort) was conducted in Taiwan from 2004 to 2005 (Hwang and Lin, 2007).

2. Analysis of the FIOT project data

The data analyzed in this study were taken from the FIOT project in which both physical microclimatic measurements were made concurrently with questionnaire surveys in a variety of indoor, semi-outdoor,

Table 1. Comparison of studies of the number of people visiting unshaded outdoor public spaces versus thermal environment indices PET in different regions of study.

	Temperate Region	Sub(tropical) Region
Summer		
Winter		

and outdoor spaces in central Taiwan, including Taichung, Yunlin and Chiayi (Fig. 1). A total of 8,077 sets of data were collected from the winter of 2004 to the summer of 2005. Figure 1 presents photographs of the locations of the field experiments in Taichung and Yunlin. A total of 1644 interviews from the FIOT database, drawn from the outdoor surveys, are analyzed in this study.

The physical microclimatic parameters considered in the analysis are T_a , relative humidity (RH), air speed (v) and T_{mrt} . A questionnaire survey was administered during the measurements of physical microclimate, including the thermal sensation vote (TSV: -3 =cold;



Figure 1. Photos of locations of field experiment in Taichung (a) and Yunlin (b). The T_{mrt} is evaluated both by the globe thermometer and the six-direction short- and long-wave radiation measurement station (c).

-2=cool; -1=slightly cool; 0=neutral; 1=slightly warm; 2=warm; and 3=hot), and thermal preference vote (TPV, right now I prefer "cooler," "no change" or warmer"). Subjects were also asked to rate their instantaneous sensation of, and preference for, wind, sunshine, and humidity in a similar way as TPV. As a thermal index, the Standard Effective Temperature (SET*) (Gagge et al., 1986), which is based on the energy balance of human body, is applied in this study.

3. Neutral temperatures

The temperature coinciding with the central thermal sensation (TSV=0) in the ASHRAE 7-point scale is referred to as the neutral temperature; the temperature at which people feel neither cool nor warm (Fanger, 1972). The general approach to obtaining neutral temperature is to calculate the mean TSV (MTSV) within each temperature interval, and then fit a linear regression function between MTSV and SET* (de Dear and Fountain, 1994). The width of temperature bins used in this analysis was 1°C SET*. Figure 2 plots the MTSV observed in each SET* bin, for both hot and cool seasons. Substituting MTSV=0 into both equations yields the neutral temperatures for subjects; 29.3°C and 28°C SET* in hot and cool seasons, respectively. A difference of 1.3°C SET* exists between the neutral temperatures in the hot and cool seasons, revealing a moderate effect of seasonal adaptation on thermal comfort. This seasonal offset in neutralities is evidence of psychological adaptation such as different expectations of seasonal comfort.

4. Sunshine and wind preferences in cool and hot seasons

As stated in the Introduction, the number of people frequenting the square decreased as the PET value increased during the hot season, which is contrary

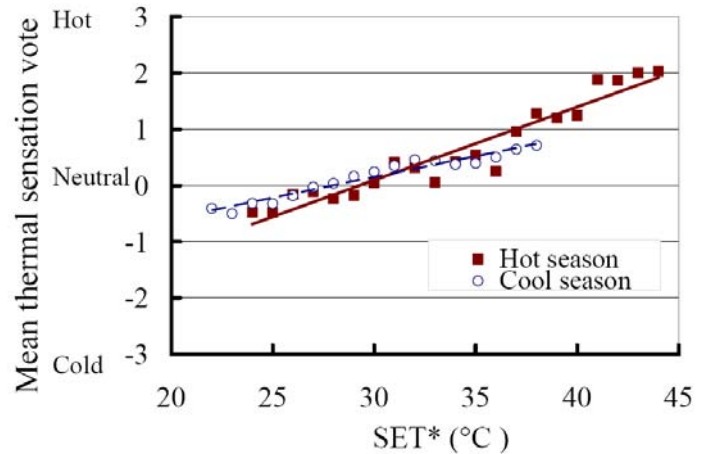


Figure 2. Correlation between mean thermal sensation votes (MTSV) and SET* in central Taiwan's hot and cool seasons.

to previous results in temperate regions. This study seeks to clarify whether people's thermal preferences can be completely interpreted in terms of thermal indices, or whether their preferences are determined by the combination of physical microclimatic parameters and psychological factors. To explore this issue within the FIOT database, all datasets were sorted into bins, each corresponding to a 1°C SET* interval; Figs. 3–4 plot the subjects' thermal preferences within each bin, together with the corresponding mean values of the relevant physical microclimatic parameters for the bins.

Figures 3 (a) and (b) plot the subjects' preference for sunshine intensity versus actual measurements of the mean T_{mrt} for each SET* bin in the hot and cool seasons. As SET* and T_{mrt} increase, the percentage who "prefer stronger sunshine" declines, and therefore the percentage who "prefer weaker sunshine" increases. It should be noted that the cool season sample of subjects preferred more sunshine than their hot season counterparts experiencing the same levels of SET*.

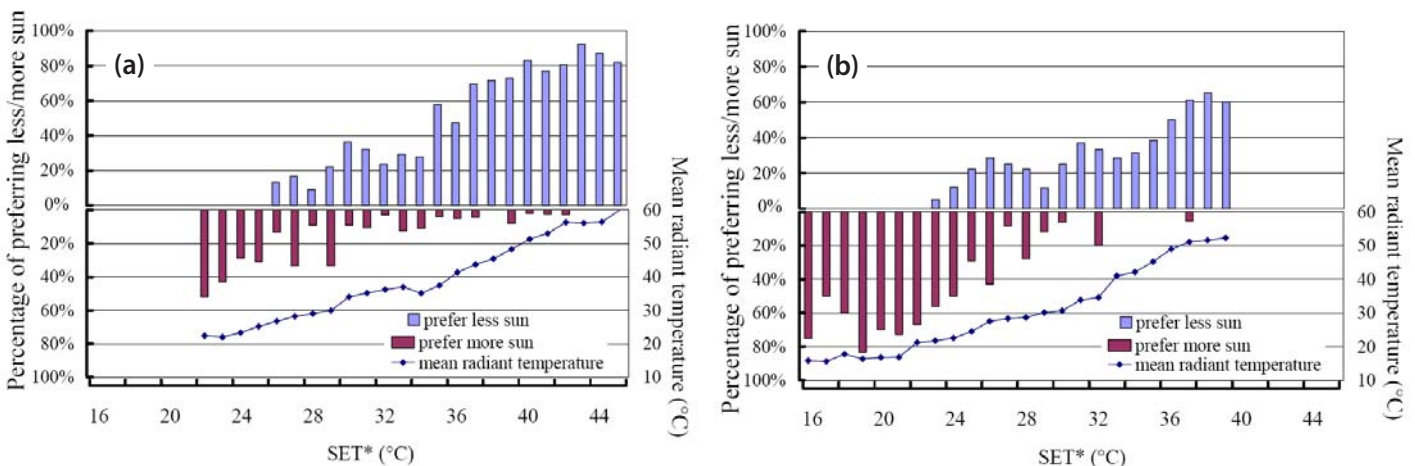


Figure 3. Subjects' preference for sunshine versus mean T_{mrt} for each SET* bin in the hot (a) and the cool seasons (b).

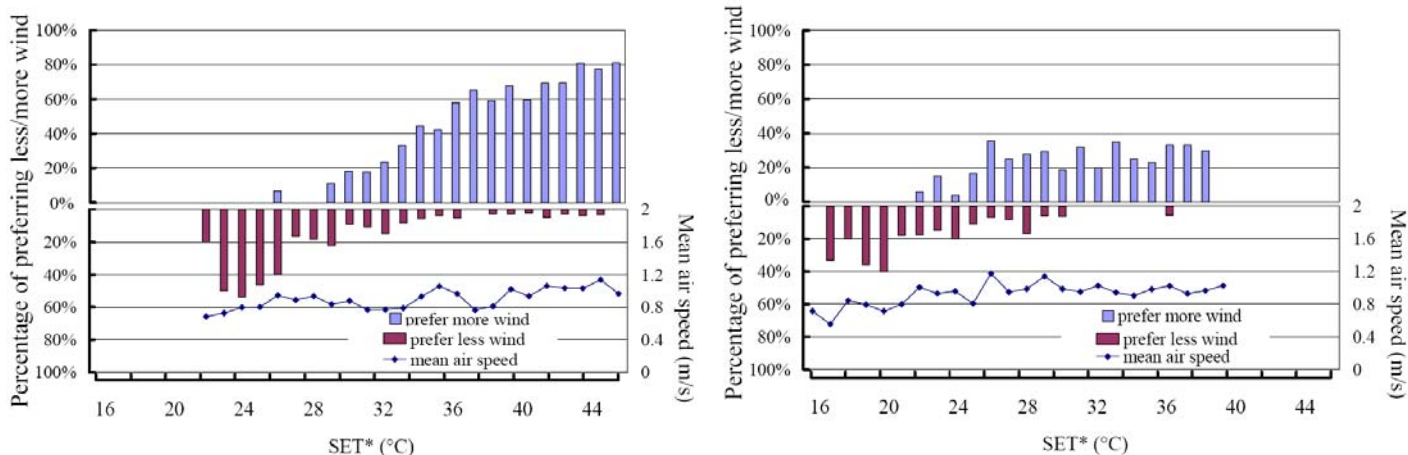


Figure 4. Subjects' preference for wind versus mean air speed for each SET* bin in the hot (a) and the cool seasons (b).

Figures 4 (a) and (b) show the subjects' preference for wind versus mean air speed (v) for each SET* bin in both the hot and cool season surveys. In the hot season, as overall heat loads (SET*) on the subjects increased, the percentage of subjects preferring stronger wind also increased, reaching 80% at $>43^{\circ}\text{C}$ SET*. Despite this trend it is worth noting that the actual wind speed was almost constant (0.8–1.2 m/s) across all SET* bins. A possible explanation is that subjects preferred more wind because they felt that it would help to eliminate their overall discomfort, based on their previous experience. In the cool season, the wind preference results were similar to those in the hot season. However, the percentage of subjects who "prefer stronger wind" at high SET* (34–38°C SET*) in the cool season was only 35%, which is significantly lower than in the hot season. This finding suggests that wind preferences are contextualized to season, and this context may override the body's instantaneous heat-balance status as the driver for wind preference.

In summary, the results in Figs. 3–4 reveal that people have different thermal preferences in different contexts, despite their having identical values of SET*. The results also suggest that the thermal preferences for outdoor people cannot be completely explained by thermal indices based on the energy balance of the human body. Moreover, the conditions of sunshine and wind that are preferred by people outdoors are affected not only by the prevailing values of related physical microclimatic parameters but also their experience and expectation in different seasons, which fact provides the evidence of thermal adaptation in the outdoor environment.

5. Conclusions

This investigation not only confirms the effect of thermal adaptation on seasonal outdoor thermal comfort, but also demonstrates the limitation of ther-

mal indices based exclusively on a heat-balance analysis of the human subjects in predicting their thermal preferences. The physical microclimatic parameters that dominate subjects' thermal perceptions are also explained in terms of the local weather and people's experiences. By elucidating outdoor occupants' thermal comfort, the results of this study may contribute to the planning and design of outdoor environments in hot-humid regions, supporting the use of outdoor spaces and increasing their occupants' satisfaction.

This report is the combination of three published papers in Building and Environment (Lin, 2009), Architectural Science Review (Hwang and Lin, 2007), and International Journal of Climatology (Lin et al., 2011). More information on the method and results related to this report are included in these papers.

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CO₂ flux measurements in Łódź, Poland

Introduction

Łódź (51°46'N, 19°27'E) is the third largest city in Poland, with a population of approximately 750,000. In the old centre of the city, buildings constructed in this period are mainly 15-20 m high and make up an extensive, fairly homogenous and compact settlement of great density. The old centre is surrounded by new districts of blocks of flats, industrial and residential areas. Łódź is situated in central Poland, on relatively flat terrain (altitudes range from 180 m to 235 m a.s.l.).

Measurements of turbulent mass and energy exchange have been carried out in Łódź since November, 2000. The first part of this research, during the years 2000-2004, started under cooperation between the Department of Meteorology and Climatology, the University of Łódź and the the Department of Geography of the University of Indiana (Fortuniak, 2003, 2010; Offerle, 2003; Offerle et al., 2003, Offerle et al., 2005, Offerle et al., 2006a, 2006b; Pawlak et al., 2004). Originally a measurement point was located at the Lipowa Street site in the city centre (Figs. 1-2), but because of insufficient instrumentation, FCO₂ flux measurements were not registered. Another eddy covariance mea-



Figure 1. Locations of CO₂ flux measurement in Łódź (left: L - Lipowa Street, R - residential area, I - post-industrial area, A - airport, suburban area) and the surroundings of the Lipowa measurement point (right). Solid white lines indicate source areas at P = 50%, 75% and 90% calculated for unstable stratification (all available data in the period July 2006-April 2011). Map and aerial photo source: Municipal Center of Geodesics and Cartographic Documentation of Łódź.

surement set, equipped with an Li7500 CO₂/H₂O IRGA analyzer, enabled implementation of a few short-term experiments (of a few days to a few weeks) in other parts of Łódź, outside the city centre (Fig. 1), including residential, post-industrial, and suburban areas (Offerle, 2003; Pawlak et al., 2007). Regular investigations of CO₂ exchange and other fluxes started in July 2006 when the measurement point at Lipowa Street was equipped with a new system including a CO₂ gas analyser (Fortuniak et al., 2006; 2008; 2010). Results registered until today cover almost 5 years and are the first and only long-term FCO₂ measurements from an urban area in Poland and one of a very few Polish FCO₂ data sets obtained with the eddy-covariance technique (Pawlak, 2010; Pawlak et al., 2009; 2010; 2011).



Figure 2. Urban canopy around the Lipowa measurement site (top), and measurement tower at Lipowa Street (bottom, with sensor maintenance shown at middle and right). Photo: K. Fortuniak.

Site descriptions

The Lipowa Street eddy covariance measurement point for FCO_2 (Fig. 1) is located in the western part of the densely built-up city centre ($51^\circ 45' 45''\text{N}$, $19^\circ 26' 43''\text{E}$, 204 m a.s.l.). The nearest surroundings of the measurement point are characterised by compact building development. Artificial surfaces (buildings, roads, pavements, etc.) cover $\sim 50\text{--}70\%$ of the surface in this part of the city (Kłysik, 1998). Vegetation is interspersed with buildings; it consists mainly of many small lawns and covers 38% of all surfaces. The measurement height is 37 m above ground level, which is more than twice the canopy height, so it is possible to make the assumption that measurements are carried out above the roughness layer. The high elevation of the sensors results in a

large source area for turbulent fluxes, which for unstable conditions has been evaluated as a circular shape up to 1 km in diameter (Fig. 1, right).

The other sites, where short-term experiments were carried out in the years 2002–2003, are located outside the city centre, on terrain characterised by less dense building development and a bigger portion of areas covered by vegetation (Fig. 1). In the post-industrial district, $\sim 40\%$ of the measurement site's surroundings are covered by artificial surfaces, while for the residential area with small houses the artificial cover is $\sim 30\%$ and for the suburban site (grass surface on the Łódź Wladyslaw Reymont Airport) it is $\sim 5\%$. Thus the green area coverage in these parts of Łódź is $\sim 60\%$, $\sim 70\%$ and $\sim 95\%$ respectively.

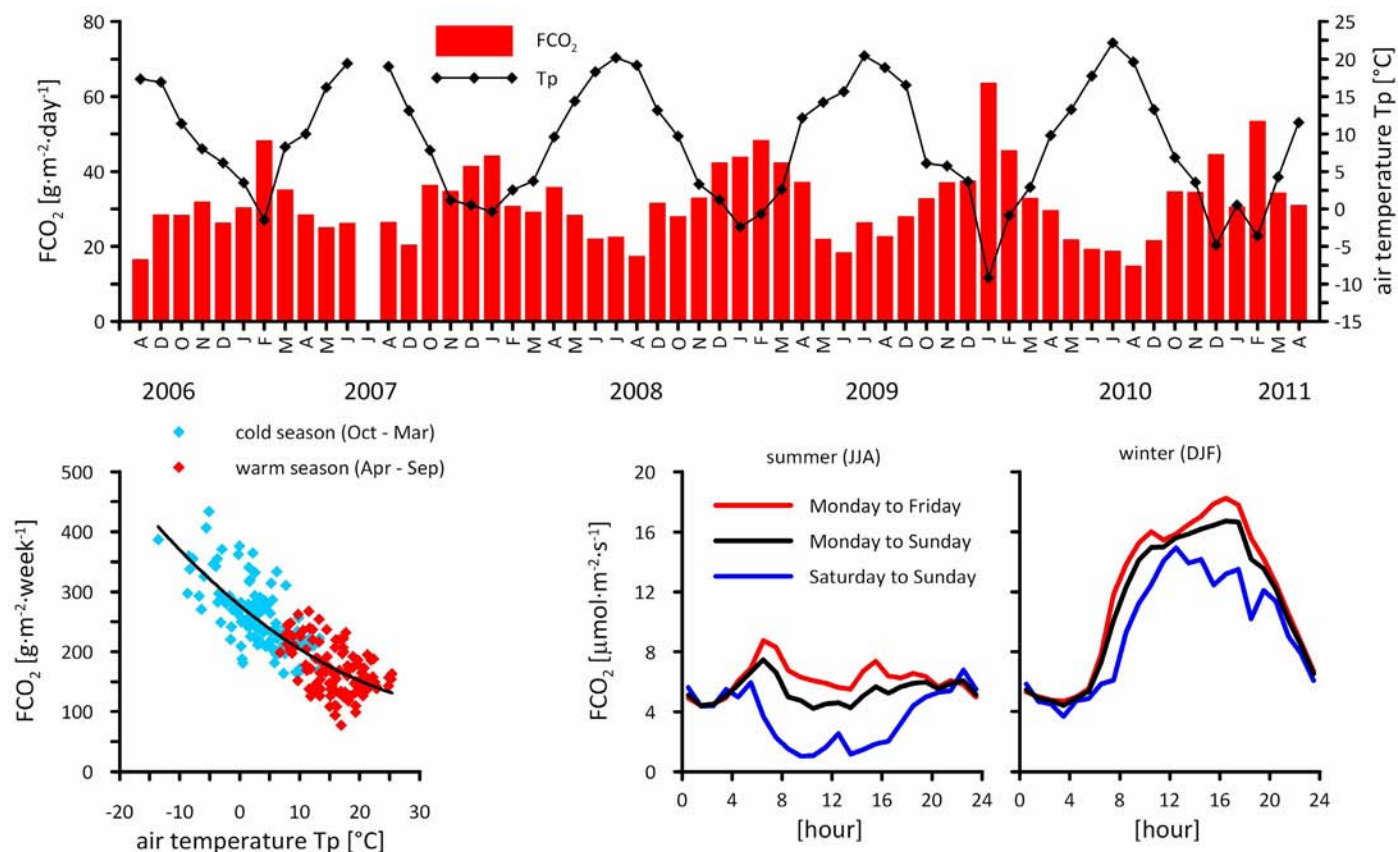


Figure 3. Mean daily net CO₂ exchange in the period July 2006–April 2011 (top), weekly CO₂ exchange in relation to mean air temperature (bottom left), and mean diurnal course of FCO₂ in summer and winter calculated separately for weekdays, full weeks and weekends (bottom middle and right).

Results

Long term FCO₂ measurements registered at the Lipowa site (Fig. 3, top) show that regardless of the season, the centre of Łódź is a significant source of carbon dioxide. FCO₂ during the analysed period is characterised by an annual course that is the reverse of the air temperature course (Fig. 3, top and bottom left). Mean daily fluxes observed during the winter season often exceed 40 g m⁻² day⁻¹. Such high FCO₂ in wintertime is caused by increased emissions of anthropogenic CO₂ in the cold season from domestic heating sources (Kłysiak, 1996; Offerle et al., 2005) and increased traffic densities observed in urban areas especially during the day. Summertime FCO₂ does not exceed values on the order of 30 g m⁻² day⁻¹. This can be explained by a decrease in anthropogenic CO₂ emissions (lack of domestic heating and reduced private car traffic) and CO₂ absorption by vegetation.

An extremely high FCO₂, when mean daily fluxes exceed 50–60 g m⁻² day⁻¹, can be observed during the cold season but only when air temperature is adequately low, as was observed in January 2010 (mean daily air temperature ~ -10°C). In comparison, a relatively warm January the next year (with mean air temperature of about 0°C) caused much less intensive carbon dioxide

exchange, on the order of only 30 g m⁻² day⁻¹. Mean annual FCO₂ exchange in the centre of Łódź in the analysed period has been estimated as ~11 kg m⁻².

FCO₂ variability is also characterized by a clear diurnal rhythm (Fig. 3 bottom middle and right). As the factors determining this rhythm change seasonally (anthropogenic emission, vegetation age, length of the day etc.), variability changes by season. Maximal mean winter values of FCO₂, observed between 9 am and 6 pm, are significantly higher than in summer, primarily because of the high emission of anthropogenic CO₂ all day long. In summer, anthropogenic CO₂ fluxes are much lower and exchange is related to the increase in biological processes. As a consequence, instead of the FCO₂ maximum occurring at noon and in the afternoon, minimum FCO₂ occurs at those times. As CO₂ emitted by car traffic is suspected to be a significant anthropogenic source, diurnal courses were recalculated separately for working days and for weekends (Fig. 3, bottom middle and right). Diurnal courses show lower FCO₂ values on weekends. Summer weekends are the only occasion when, on average, minimal FCO₂ is close to 0 which indicates that CO₂ uptake during photosynthesis almost compensates for its anthropogenic emission. In the winter, the mean diurnal weekend course

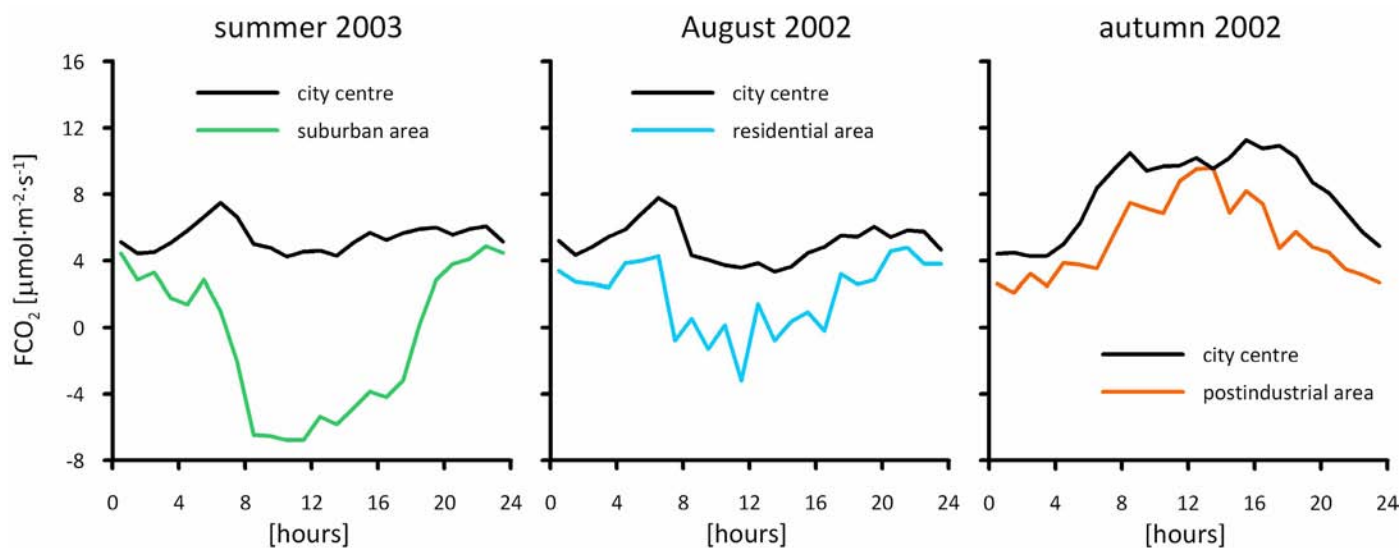


Figure 4. Mean diurnal course of FCO₂ measured during short-term experiments in suburban, residential and industrial areas in the period of August 2002-July 2003.

also reaches lower values as a result of less intensive car traffic.

As mentioned, a few short-term experiments were also carried out in the years 2002-2003 (Fig. 4). Because FCO₂ wasn't measured in the centre of Łódź during these years, results have been compared with averaged data obtained at Lipowa Street after July 2006. Only FCO₂ measured above the post-industrial area seems to reach similarly high values, as in the city centre mean daily exchange measured in autumn 2002 is about 10 g m⁻² day⁻¹ lower than that registered in the centre in the period 2006-2011 (31 g m⁻² day⁻¹). CO₂ exchange measured above residential and suburban areas was clearly different in comparison with the city center. In both cases the daytime minimum was negative, which indicates a prevalence of CO₂ biological uptake over the anthropogenic emission. Especially fluxes observed above the grassy suburban area were high and negative. Mean daily FCO₂ measured in the residential area in summer 2002 was 12 g m⁻² day⁻¹ lower than at Lipowa Street (19.3 g m⁻² day⁻¹). As expected, mean FCO₂ registered in summer 2003 above the suburban area was negative and reached -2.9 g m⁻² day⁻¹ (mean summer FCO₂ at Lipowa Street was 20.5 g m⁻² day⁻¹).

Measurements obtained from Łódź are similar to those obtained for sites established in city centres like Tokyo, Edinburgh and Helsinki. Results confirm that one of the factors determining CO₂ exchange intensity is land use. As a next step, we plan more detailed measurement outside the Łódź centre.

Acknowledgements

Many thanks to Sue Grimmond and Brian Offerle who initiated eddy covariance measurements in Łódź at the

Lipowa station. Funding for this research was provided by the Polish Ministry of Science and Higher Education (State Committee for Scientific Research) under grants 2P04E 041 28 (2005-2007), N N306 276935 (2008-2010) and N N306 519638 (2010-2011).

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The experimental campaign FluxSAP 2010: Climatological measurements over a heterogeneous urban area

In the framework of a research program on the role of vegetation in sustainable urban development, the FluxSAP campaign was conducted with the objective of quantifying the importance of vegetation in the sensible heat and water vapour fluxes from a mixed district. The 2010 campaign, which took place around the permanent hydro/meteorological survey site of IRSTV, was principally devoted to the feasibility of measurement over a very heterogeneous area, by using in parallel five sets of sensors which all allow measurement of fluxes. This creates the possibility, by evaluating their origin, of separating the contributions of the various land cover modes.

This report is a translation of an article published in "La Météorologie", the bulletin of the Société Météorologique de France (Mestayer et al., 2011).

Context and Objectives

The study of the urban atmosphere is a relatively recent topic. While wind measurements around isolated buildings and wind tunnel simulations for comfort and material sizing purposes were the object of numerous works during the 20th century, it was only by the end of the 90's that the first models were launched allowing a predictive simulation of the urban energy budget (Masson 2000, Grimmond and Oke 2002) and the first experimental campaigns allowing researchers to validate them. Logically, following the seminal series of works performed by Tim Oke and his group in Vancouver during the 80's and 90's (see, e.g., Grimmond and Oke, 1999), the large cooperative experimental campaigns were focused on large city centers where we could find both the conditions most remote to natural soils – i.e., the dense city with largely paved surfaces and elevated buildings – and a relative horizontal homogeneity allowing the use of Monin–Obukhov (1954) similarity theory (MOST) to analyze the lower atmosphere measurements.

In Europe, the campaigns BUBBLE¹ in Basel (Rotach et al. 2005), CLU-ESCOMPTE² in Marseille (Mestayer et al. 2005) and CAPITOU³ in Toulouse (Masson et al. 2008) covered large urban areas to explore the spatial structure of the urban boundary layer, but mainly the city center data have been analyzed to assess the aerodynamic and thermo-radiative influence of buildings, to quantify the anthropic heat fluxes and to precisely describe the structure of the urban heat island. Yet, the largest part of the cities is constituted of mixed residential districts which superimpose impervious surfaces and buildings on the one hand with gardens, parks and non-impervious developments on the other hand, in a patchwork whose spatial scales are usually much less than 1 km. On these heterogeneous urban zones the measurement analysis encounters additional problems linked to this spatial heterogeneity: sparse or discontinued vegetation presence, "footprint" evaluation, neighboring surface influence, flux divergence, reshaped grounds of ill-known nature, surface water flows, etc.

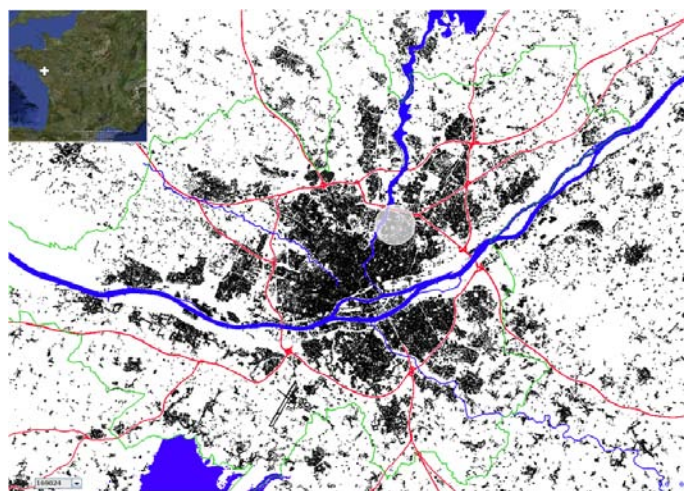


Figure 1. Location of the experimental domain (white disc) within the Nantes urban area. The buildings are represented in black, the water surfaces in blue, the main roads in red and the administrative limits of Nantes Metropole in green.

The key factors of micrometeorology and quantitative hydrology are especially interdependent in these urban areas. Evapotranspiration is a factor appearing in both the water budget and the energy budget, while heat transfer by conduction in the soil strongly depends on the water content. In urban zones the twinned processes are modified by the presence of either semi-impervious surfaces (roads) or totally impervious surfaces (roofs), which are totally or partially connected to the hydrographic network (sewer pipes, gutters, channeled brooks) but are also generators of horizontal transfers by surface runoff and by modern storm water management (infiltration ditches or basins, urban streams).

This strong interdependence brought several groups of IRSTV (www.irstv.fr) since 2004 to perform limited urban hydrometeorology measurement campaigns within the INSU⁴ hydrology programs, and further set up long-term observatory instrumentation over a district of Nantes (previously called SAP, now ONEVU – Nantes Observatory of Urban Environment). More recently IRSTV launched a cooperative program with some 15 partners⁵ aimed at understanding and quantitatively assessing the vegetation impact in present and future urban development projects (VegDUD, The role of vegetation in sustainable urban development; an approach linked to climatology, hydrology, energy control, and environment), funded by the French National Research Agency (ANR) over 4 years (2010–2013). Within this framework two campaigns of at-ground and airborne measurements are organized, the first one in 2010 and the second one in 2012, in the vicinity of the permanent observation sites (Figure 1).

1) Basel urban boundary layer experiment. 2) Couche limite urbaine - expérience sur site pour contraindre les modèles de Pollution atmosphérique de transport des émissions. 3) Canopy and aerosol particles interactions in Toulouse urban layer. 4) Institut national des sciences de l'univers du CNRS. 5) LMF - École Centrale de Nantes, GER - IFSTTAR, CAPE - CSTB, LPGN - Univ. Nantes, CESBIO - Toulouse, EPHYSE - INRA Bordeaux, LRC - IRSN, LSIIT - Strasbourg, LTHE - Grenoble, OU - Norman, Oklahoma, USA, SAFIRE - CNRS-CNES-Météo France.

FluxSAP is altogether one of the experimental components of the program VegDUD, in connection with the modeling component, and a project of methodology and measurement development in urban hydrometeorology and remote sensing, both in the continuation of the previous hydrometeorology studies of the IRSTV groups and as a follow-up of CLU-ESCOMPTE and CAPITOUL meteo-climatology programs combining experimental campaigns and numerical modeling. As such, FluxSAP is funded by the INSU.

The experimental set-up includes sensing systems for temperature and water content in the soils, temperature and humidity of air at 2-3 m above ground, turbulent fluxes on meteorological masts, scintillometers on elevated building roofs, surface temperatures by airborne infrared remote sensing, soil and surface identification by airborne hyperspectral remote sensing, and passive tracer dispersion exercises.

Objectives

The program objectives are twofold, methodological and quantitative. The methodological objective concerns the feasibility of measuring the heat fluxes in a heterogeneous urban area: How can we measure them? How can we analyze them? The quantitative objective is to obtain over one heterogeneous urban site some heat and water vapor transfer reference data allowing us to assess models which take into account the heterogeneity of urban grounds and the presence of networks; for this purpose it is necessary to perform reliable and precise measurements but also to identify the footprints of these measurements.

The heat and water budgets at the surface of an urban fragment are usually described by the following twinned equations:

$$R_n + F = H_s + LE + G$$

$$P = RET + R_s + I$$

where R_n is net radiation (energy gain during daytime and loss at night) and F anthropic heat contribution (produced by human activity, heating, vehicles, industry), H_s and LE the aerodynamic fluxes of sensible and latent heat, and G the conduction heat flux into the ground and materials (buildings, vegetation). P is the water contribution of precipitation (rain and condensation), RET the real evapotranspiration, R_s the surface runoff flux and I the ground infiltration flux. The evapotranspiration RET is called real by reference to the potential evapotranspiration PET furnished by the meteorological office, Météo France, based on Penmann-Monteith formulas (Climathèque, 2010). This term represents the strongest coupling between the two budgets, since $LE = L_v RET$, where L_v is the specific heat of vaporization. Very low in the "mineral city" of the city centers and predominant over the vegetated surfaces, its relative importance is a direct function of the distribution of land uses and urban management, and it is one of the keys of the urban climate since the available energy which is restituted to the lower atmosphere is the sum $H_s + LE$ – the stronger the evapotranspiration, the lower the air-warming sensible heat.

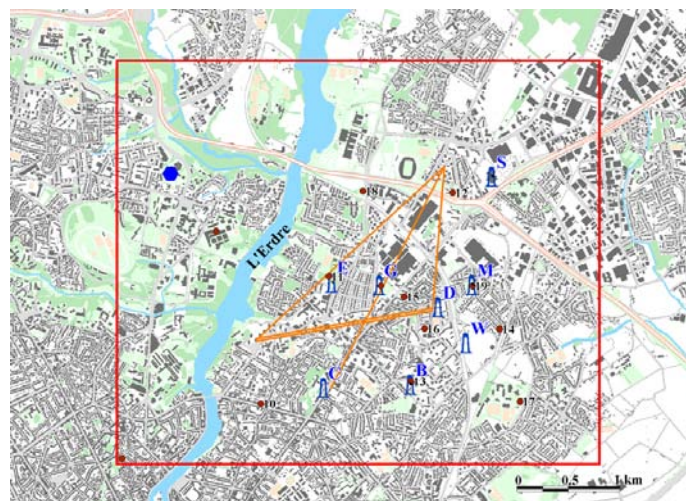


Figure 2. Measurement setup during the FluxSAP 2010 campaign: the red frame indicates the limits of the geographical data base, the red dots the locations of T-RH sensors, the blue symbols the turbulent flux sensors on masts or available supports, the orange lines scintillometer paths, and the blue hexagon the Sodar. The sensors in the ground appear in Figure 3.

The measurement of surface fluxes – Several methods can be used to measure surface fluxes with presently available instrumentation. They evaluate the fluxes between the surface and the atmosphere over very variable scales, from a few cm^2 (gradients within the ground) to a few hectares (covariance of turbulent variables at the top of a meteorological mast), or even several km^2 (satellite remote sensing or "bulk" methods). Many works have demonstrated that they are more or less equivalent to evaluate the heat flux of a homogeneous surface like large crops and ocean surfaces since the flux is the same here and there, and constant over the whole height of the atmospheric surface layer or constant flux layer described by MOST. But can we use these methods in an agreeable way in urban sites? What is their representativeness? What is the influence of ground heterogeneity upon elevated measurements? Our objective is to implement 5 flux measurement methods over one domain and to compare their results.

- The water table level, water content and temperature measurements in the ground allow us to monitor water and heat transfers through the soil layers. The temperature profiles allow us to evaluate the conduction heat flux with the gradient harmonic method based on a Fourier analysis of temperature time series at several depths. These are point measurements and their locations have been chosen to assess the behavior variability of the district open green spaces.

- The temperature and humidity measurements at the surface (T_s, q_s) and at a height z of a few meters above the surface (T_z, q_z) are analyzed by the method of the mean gradients:

$$H_s = \rho C_p C_H U_z (T_z - T_s); LE = L_v C_v U_z (q_s - q_z)$$

where U_z is the wind speed at height z , C_H and C_v transfer coefficients whose values are a function of surface char-

acteristics. These “bulk” formulas are commonly used for homogeneous sea surfaces or over large crops but not for heterogeneous areas with measurements at a low level (2–3 m), therefore representative of small and near footprints. The analysis of these measurements at the district scale requires the computation of geomatic interpolations based on ground cover modes and sensor environment classification. Remote sensing measurements with airborne thermal infrared (TIR) cameras allow us to complete ground measurements to determine the spatial distribution of the surface temperatures.

- Sensible heat and water vapor turbulent flux measurements with fast sensors (at least 10 Hz) of turbulent fluctuations of wind speed, temperature, water vapor concentration (and CO₂ concentration as well), at the top of meteorological masts, are analyzed with the aerodynamic “eddy correlation” method, with footprints on the order of 10 ha depending on wind direction and meteorological data.

- The measurements with elevated scintillometers, above the urban canopy, allow us to evaluate the sensible heat fluxes, integrated over their path lengths of 1–2 km by using several semi-empirical, supposedly universal surface layer formulas based on the MOST assumptions and on Kolmogorov-Obukhov (1946–1971) turbulence universality theory.

- Temperature, humidity and wind speed measurements at several levels of the instrumented mast of the permanent observation site allow us, in principle, to evaluate the fluxes with the mean vertical profile or gradient method.

Quantitative assessment & identification of footprints – The quantitative objective of the campaign is related to the general objective of the VegDUD program, to assess the vegetation contribution to the urban climatology. The first purpose of these experimental data are the validation of urban meteorological and hydrological models, especially ARPS-Canopy⁶ for the atmospheric boundary layer, with the drag-force model for the canopy “porous” layer (Maché et al., 2009, 2010) and SM2U for the heat and water surface transfers (Dupont and Mestayer, 2006; Dupont et al., 2006) and the model URBS⁷ for the water budgets and the urban catchment hydrology (Berthier et al., 2006; Rodriguez et al., 2007, 2008). For this purpose, the measurements are repeated at several points of a domain about 6 km² wide and it will be necessary to establish if they show a sufficient coherency to ensure a high level of confidence – because the meteorology is the same over the whole domain – and sufficient differences to demonstrate the influence of the different land use distributions of their footprints – since the differences are the signature vegetation contributions.

Used over an urban district, all these measurement methods require an analysis bearing on urban geographical databases (digital elevation model, land uses and land covers) to determine either measurement spatial representativeness, transfer coefficient values, surface TIR emissivities, ground slopes, building heights and volumes, or roughness parameters used in footprint models. Due to the extreme heterogeneity of the materials covering the urban surfaces, the commonly available geographical databases do not contain

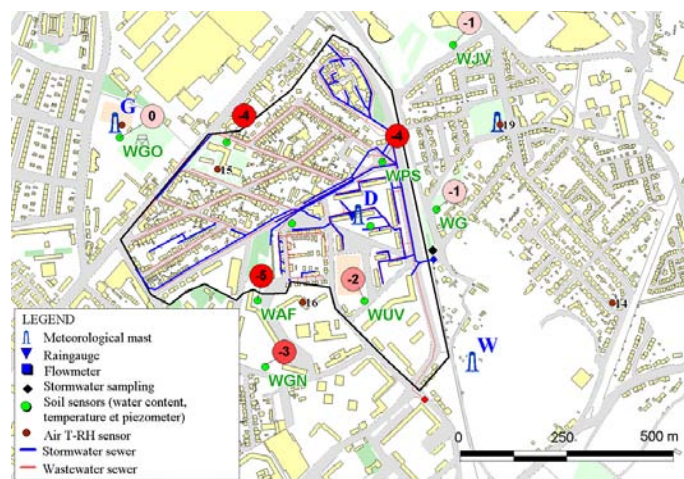


Figure 3. Hydrologic instrumentation of the Pin Sec catchment. The temperature profiles in the ground were set at the same places than the piezometers. G and D indicate the permanent meteorological masts at the Goss site (30 m) and on the Dunant building roof. The black line indicates the Pin Sec watershed. The pink/red dots give the measured soil drying at 35 cm during the month of May 2010 (in moisture %).

enough information to document their radiative, thermodynamic and hydrologic characteristics. Hyperspectral remote sensing, at high spatial and spectral resolutions, allows us to complement them, based on comparisons of their spectral signatures to spectral reflectivity banks generated from measurements at ground and at the laboratory. The analysis of high spatial resolution satellite data (SPOT, Quickbird) with spatial segmentation methods also allow us to monitor the land cover changes.

Due to the strong heterogeneity of urban grounds the determination of measurement footprints is crucial and complex. If, for a radiation sensor at the top of a mast the footprint is easily determined by a geometry calculation, and it does not change, this is not the case for a sensor system measuring the turbulent flux of a scalar (heat, water vapor, gas or aerosol concentration): its footprint depends not only on the sensor height but also on the wind speed and direction, the ground roughness, and the thermal stratification; in low winds it is located nearly at the mast foot but much farther in strong wind conditions, and also farther when the atmosphere is stratified. The experimental determination bears on footprint models based on backward trajectory or inverse plume computations (Leclerc and Thurtell, 1990; Schmid, 1997, 2002) which in turn bear on the MOST classical assumptions, especially horizontal homogeneity. But these assumptions are generally not verified in urban areas. Passive tracer dispersion exercises allow us to test the validity of these models. These measurements will be analyzed with a Lagrangian backward trajectory model implemented within the ARPS atmospheric model including the drag-force model for the porous canopy.

The feasibility questions – Among the practical questions raised by the experimental assessment of urban meteo/cli-

6) ARPS: Advanced regional prediction system, University of Oklahoma.
7) Urban runoff branching structure.



Figure 4. View of meteorological masts and turbulence sensor supports.

matology we expect to answer with the FluxSAP campaigns the following queries:

- Are the flux measurements operated on several masts spread over a district sufficiently precise to altogether show a sufficient coherency to ensure a high level of confidence and include significant differences that can be attributed to their footprint differences?
- Due to the technical and administrative problems raised by the setting of sensors within an urban fabric we may be led to install provisional meteorological masts on platforms which are not optimal as regards the theoretical recommendations (Oke, 2004) but which are well secured as, e.g., building roofs: How can we determine the quality of the resulting measurements? How can we take advantage of these “sub-optimal” measurements?
- Is it possible to continuously monitor the fluxes in an urban environment without meteorological masts? Is it possible to interpolate point measurements at ground to produce maps of the fluxes?
- What is the measurement reliability of scintillometers set over building roofs? Can they be used to monitor a district? Can they be integrated in a long-term observation system?
- Do the measurements with slanted infrared cameras allow us to separate the sensible heat flux contributions of building facades and roofs (Hénon, 2008)?

The May 2010 set-up

The measurements have been performed around the small urban watershed of Pin Sec, a district located in the “second ring” between the XIXth century boulevards and the rim speedway, with heterogeneous land uses including small areas of collective and individual housing, athletic facilities, schools, supermarkets and small industrial plants. The Pin Sec catchment has been equipped with hydrology and meteorology sensors for several years in the framework of the permanent observatory SAP/ONEVU of the IRSTV. Launching cooperative experimental campaigns on a permanent observation site creates an especially interesting synergy, allowing us on the one hand to extend to other seasons the results obtained during the limited period of time of the



Figure 5. Setup of scintillometers on high building roofs.

campaign, and on the other hand to multiply the points of measurement (and the points of view) which are limited by necessity in the permanent setup.

The campaign spread over the 4 weeks of May 2010, with a few technical operations by the end of April and beginning of June.⁸ In spite of a generally favorable reception by the inhabitants and local authorities the selection of relevant and secured measurement sites has been rather difficult, most often due to the administrative circuits delivering the authorizations. Six scintillometers have been set on 5 high building roofs, with accesses sometimes difficult but rather well secured. But, in addition to the SAP permanent instrumentation we have been able to equip only 6 additional sites for the turbulent flux measurements. We did not observe any malevolence or deterioration; only one turbulent flux measurement system did not work well due to deficient cable connectors and one ground temperature sensor was deteriorated during a rain storm. The campaign therefore attained a success which passes beyond its primary objective of a feasibility study. The meteorology was rather favorable since over the measurement period we observed a range of situations from overcast with showers to very strong insolation. Thanks to the good provisions of the met office station of Nantes airport the airborne measurement flights have been successfully planned for the 3 most sunny days.

The setup is shown in Figure 2 with a zoom on the Pin Sec central area in Figure 3, while Figures 4 and 5 illustrate the sensor positioning. Eight masts or available supports (one crane and one wind mill) have been equipped with sonic anemo-thermometers at heights of 10 to 26 m above ground level (agl), among which are two at 2 levels (G and E) and six with H₂O/CO₂ sensors (LiCor 7500 or 7000). Five large aperture scintillometers have been set to form a triangle and a cross, among which 2 were twinned in parallel to test a method to obtain the friction velocity (Figure 5). A small aperture scintillometer was set between two neighbor buildings at the central site (D), with a 75 m long path. The network of ground sensors included 10 piezometers composed of a pressure sensor at the bottom of a hole, 8 water

8) http://ftpa.ec-nantes.fr/FluxSAP/Rapport_de_campagne

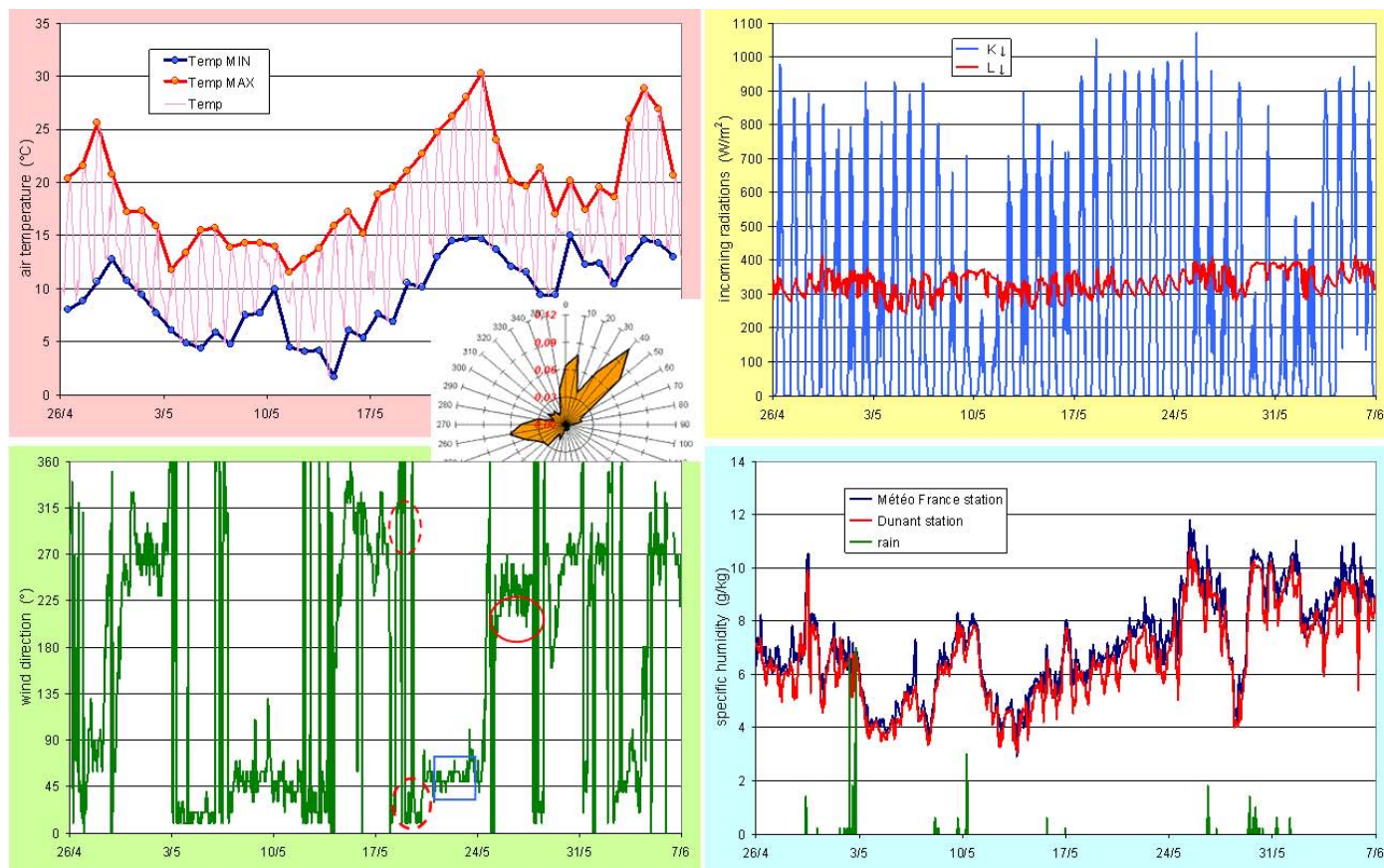


Figure 6. Meteorology during the campaign: temperatures, solar and infrared incoming radiations, wind direction, water vapor density and rain.

content sensors TDR CS625 connected to Campbell CR200 recorders to which 8 temperature profile systems have been joined: 4 Taupe recorders with 3 sensors at the depths of 0, -5 cm, -35 cm and 4 Taupe recorders with 4 sensors at the depths of 0, -5 cm, -35 cm, -50 cm or -1m (Figure 3). The network of air temperature and humidity (T-RH) sensors at 2-3 m agl included 10 systems composed of a sheltered sensor and an autonomous Hydrolog-D recorder in addition to the permanent SAP network which includes 4 similar sensors over the campaign domain.

From May 21 to 23, 13 infrared remote sensing flights (150 legs) have been performed with two IRT cameras on board the Piper Aztec 21 of the research and environment French instrumented airplane service (SAFIRE) flying at 600 m agl; one camera aimed at Nadir and the second one was slanted 50° backward, which allows us both to map the surface temperatures and to evaluate the directional brightness temperature anisotropy (Lagouarde et al., 2000). These measurements were coordinated with measurements with a third IRT camera from the top of Brittany Tower overlooking the city center (70 images) and with 140 reference measurements at the ground with 2 radio-thermometers (grounds, facades, Erdre and Loire river surfaces). The flights were alternated to document each hour of the day and the flight lines crossed each other over Pin Sec on the one hand, and the city center area observed from the Brittany Tower on the other hand. The hyperspectral flight (20 parallel flight lines at a height of 1600 m agl) took place on May 21 between 10 and 12 UTM

with Hypsics cameras VNIR (400–1000 nm, 160 bands of 4 nm, 17° fov, 0.6 m spatial resolution at ground) and SWIR (1000–2500 nm, 256 bands of 6 nm, 12° fov, 1.2 m resolution). Simultaneously 95 reference measurements were performed at the ground with a portable spectrometer.

The local meteorology was documented by the permanent observation site data (Figure 6) and by those from Météo France station at the Nantes Atlantique airport. A Sodar was run on the CSTB site on the other side of the Erdre river (Figure 2) but it was operated during only 2 days due to the noise nuisance. The wind rose is rather representative of the dominant wind regimes over the year in Nantes. Note that the dispersion exercises (weeks 20 and 21) were performed with different stable wind regimes, respectively from N, N NE and SW. For the remote sensing flights during the Whitsun week-end the wind remained stable from the NE sector with a strong insolation. May 10 and 29 stand out with a strong cloud coverage. The temperatures varied largely, sometimes rapidly (by 2 to 30°C). The rain showers were numerous and regularly spread, but the precipitation quantity was about the half of those of the same period in the preceding years (on average 41 mm over Pin Sec).

Preliminary Results

The air temperature time series of 3 m agl T-RH network sensors during the campaign appear in Figure 7. We have selected a two week period when the temperature rose progressively. We also indicate the measurements obtained at

the permanent station on the roof of building D (15 m agl) and at the foot of the permanent mast (G). The ensemble of sensors correctly represent the general evolution of temperature, but one can note differences in the diurnal cycles which, although not systematic, reflect some tendencies. During the nights the differences are smaller, within the measurement uncertainty range, except for one site with a very vegetated nearby environment (T-RH 11) which causes a 2°C cooler temperature at sunset. During daytime the dispersion is larger, with extreme differences between sites of up to 5°C during the most sunny days. A finer documentation of the near environment of each sites is being performed to better characterize them and to relate the differences to the footprint characteristics.

As for the sensible heat and vapor fluxes, the partial results which are presented here have been obtained from 15-minute samples obtained at 3 sites among the 8: G at 26 and 21 m, D at 3 m above roof level (18 m agl), and M at 10 m. Figure 8 shows:

- a good coherency between the fluxes at 26 m and 21 m on mast G ;
- a good coherency also between the heat fluxes at masts G and M ;
- sensible heat and latent heat fluxes of the same order of magnitude during this month of May for this mixed zone;
- neatly lower flux measurements at the building D roof, especially for the water vapor flux. Is this a systematic bias due to the low position above a big building ? The analyses will need to answer this question which is important for the urban site instrumentation.

The ground temperatures have been measured at 3 or 4 depths. To illustrate the spatial variability of temperatures and storage fluxes in the upper layers, Figure 9 displays the profiles obtained during two typical days (see Figure 6): May 9 after a relatively cool and humid period and May 23 at the end of the hot period. The site 7 (close to sensors WAF) is most of the time in shadow (in May it "sees" the sun from 9h30 to 11h only), while the site 4 (WPS) is open and the temperature variation amplitude is larger. The phase shift between the surface and the depth 5 cm is about 1 hour for the two sites. At the surface the temperature is directly dependent on the local insolation condition; thus the storage flux, associated to the surface gradient, is negative during the night and may stay so during a large part of the day at a masked site (site 7) while it is largely positive all day long at an open, sunlit site (site 4 on May 23). Besides, Figure 9 shows that the temperature variations at 1 m in the ground are small at the day and week scales, which validates the choice of this maximal depth for future studies.

The ground hydrological sensor network worked well from

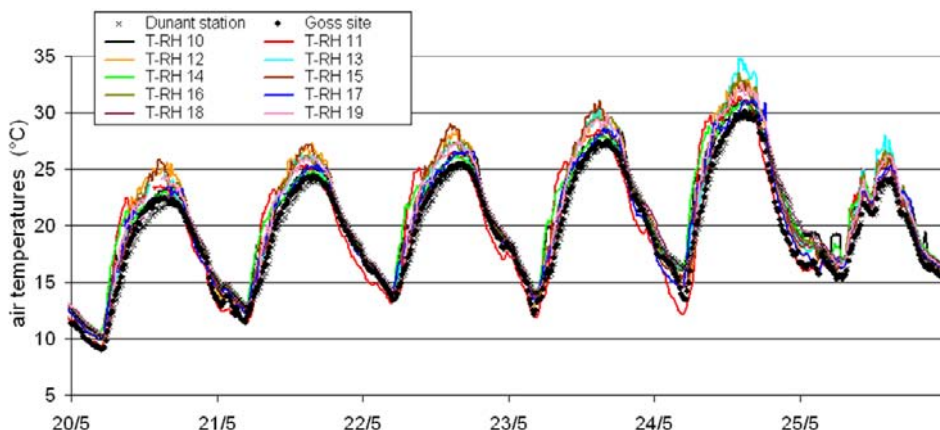


Figure 7. Air temperatures from the T-RH network sensors.

May 7. The precipitations have been relatively low and the observation period belongs to the decline phase of ground saturation levels, after a high water-table period which ended by the end of March in this area. The measurements in the ground indicate that the saturation level decreased by 22 cm on average during the period and the ground water content decreased by 2.4 % on average. A noticeable spatial variability has been observed between the various measurement points, located on public and semi-public green spaces as shown by Figure 3, which indicates that the ground drying during the month of May is not homogeneous on these sites and varies from 0 to 5% of the volumetric soil moisture. Over this period two significant rain events have been observed: 8.5 mm in 4 hours on May 10, and 26.5 mm in 4 hours on June 6. The smaller rain event did not induce noticeable variations of the soil moisture at this depth: on May 10 only one sensor records a weak variation (Figure 10). On the other hand, the event of June 6 generated a ground moistening visible on half of the sensors, with very different amplitudes: some sensors indicate moisture jumps of 10 to 20 % over a few hours while some others hardly vary. This observation confirms the high variability of the sites with respect to water infiltration. The sub-surface flows are indeed influenced by the presence of buried networks and that of roots, and the morphology of the instrumented green spaces is variable, at the surface as well as in the subsoil. Last, the most intense drying period has been observed during the sunny period from May 20 to 27; it is also over this period that soil moisture daily oscillations are observed; they are related to the time variation of ground drying by evapotranspiration during the diurnal cycle, and therefore to the daily profile of latent heat flux. The data from these TDR sensors, which are sensitive to temperature, have been corrected thanks to the temperature measurements at the same depth.

First lessons and outlook for 2012

Several lessons can already been drawn about the feasibility:

- It is rather difficult to find sufficiently open spaces to set a meteorological mast satisfying the criteria proposed by Oke (2004), and available securely and without nuisance for

the users;

- For installing “heavy” set-ups (masts, scintillometers...) the authorizations are easier to obtain from private landlords or lessors than from public services, except those with whom a cooperation has been previously established;

- Inversely, the provisional installation of autonomous, “light” sensors (T-RH, ground) are easily obtained;

- We observed no deterioration, although some sensors were hardly protected and/or at publicly open places;

- The building roofs provide well secured platforms but they are rarely of easy access;

- Ground measurements at apparently similar green spaces may be influenced by the local configuration (presence of trees, drainage by buried networks...) which may generate a variability of hydrologic and thermal functioning.

The first results are encouraging and especially show a rather strong coherency between the various measurement sites. For the 2012 campaign, we plan to invest efforts on the following points:

- to better document the experimental domain ;
- to better quantify the role and the functioning of vegetation, in the traditional arrangements as well as in the ecologically innovative management zones.

With parallel developments of models, we think that this requires us to refine the understanding of the evapotranspiration flux, notably:

- to better document the connections of impervious surfaces to the rainwater network to know better the contribution of the runoff from these surfaces to the water flow at the network outlet;

- to evaluate the water storage in the ground by the measurement of at least one vertical profile of soil moisture and suction;

- to differentiate more clearly the neighboring sites, with strongly mineral footprints on the one hand, strongly vegetal ones on the other hand;

- to follow the fluxes in the ground, not only of non-covered spaces but also under the pavement of roads and parking lots;

- to use the scintillometers on two long paths to estimate the heat flux of the bulk of the district, as well as on shorter, eventually very short, paths to evaluate the fluxes of homogeneous and well-defined sub-districts ;

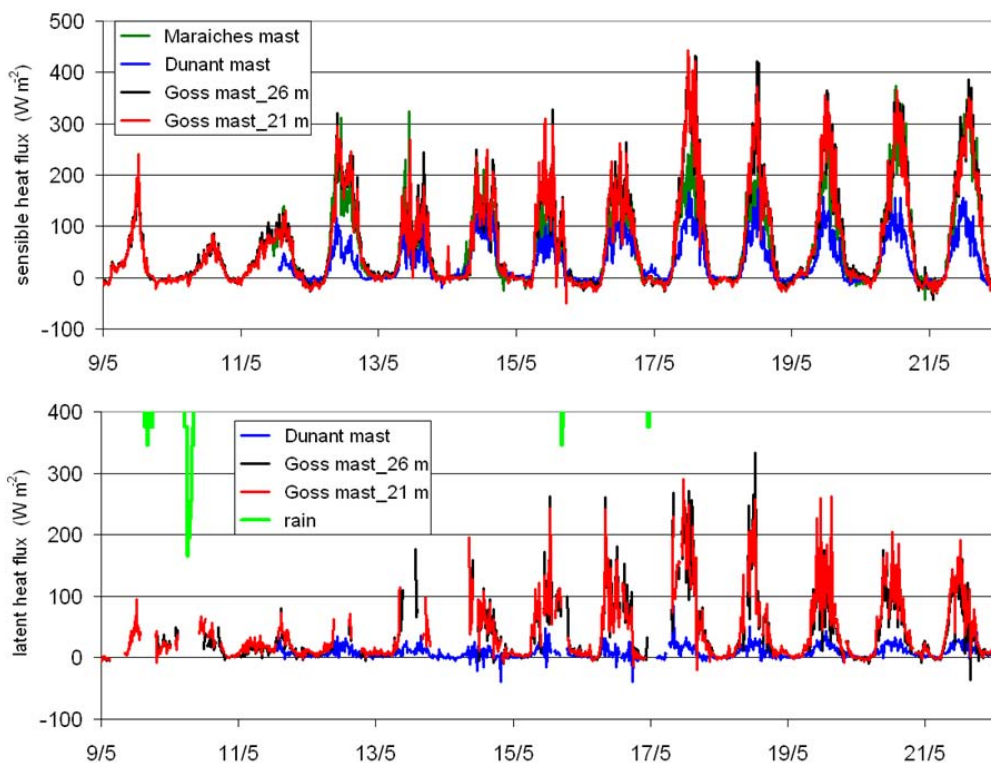


Figure 8. Sensible and latent heat fluxes measured by the eddy covariance method at three sites.

- to measure the turbulent fluxes from footprints corresponding to these sub-districts, which implies adapting the measurement point height to that of vegetation and buildings and to have at our disposal more secured supports and more water vapor sensors.

It also seems interesting:

- to extend the instrumented zone to the neighboring district of Bottière-Chenaie, recently developed as an eco-district by the city of Nantes;
- to instrument a neighborhood building with temperature sensors to monitor its energy budget;
- to better document the wind, temperature and humidity profiles in the lowest atmosphere, e.g. with a 0-200 m profiler based on a small tethered balloon;
- to document the differences between concentration and flux footprints (Schmid, 1997) by developing a passive tracer flux measurement system.

Last, we hope to implement one or two water vapor prototype scintillometers.

Acknowledgements

We wish to thank all our correspondents in the services and institutions who helped us to set up the FluxSAP 2010 campaign: Direction of sewerage and Aubinière pole of Nantes Metropole, Service of green spaces of the city of Nantes (SEVE), Nantes Habitat, La Nantaise d’Habitation, the Cabinet Coudray Lorraine, the companies Goss, Defontaine and Societe Generale Securities Services.

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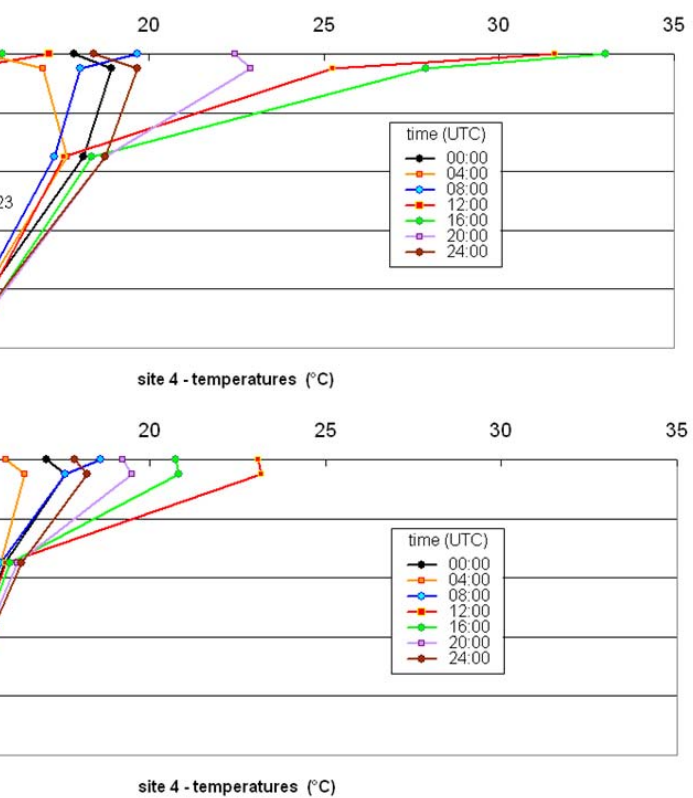


Figure 9. Temperature profiles in the ground at two sites.

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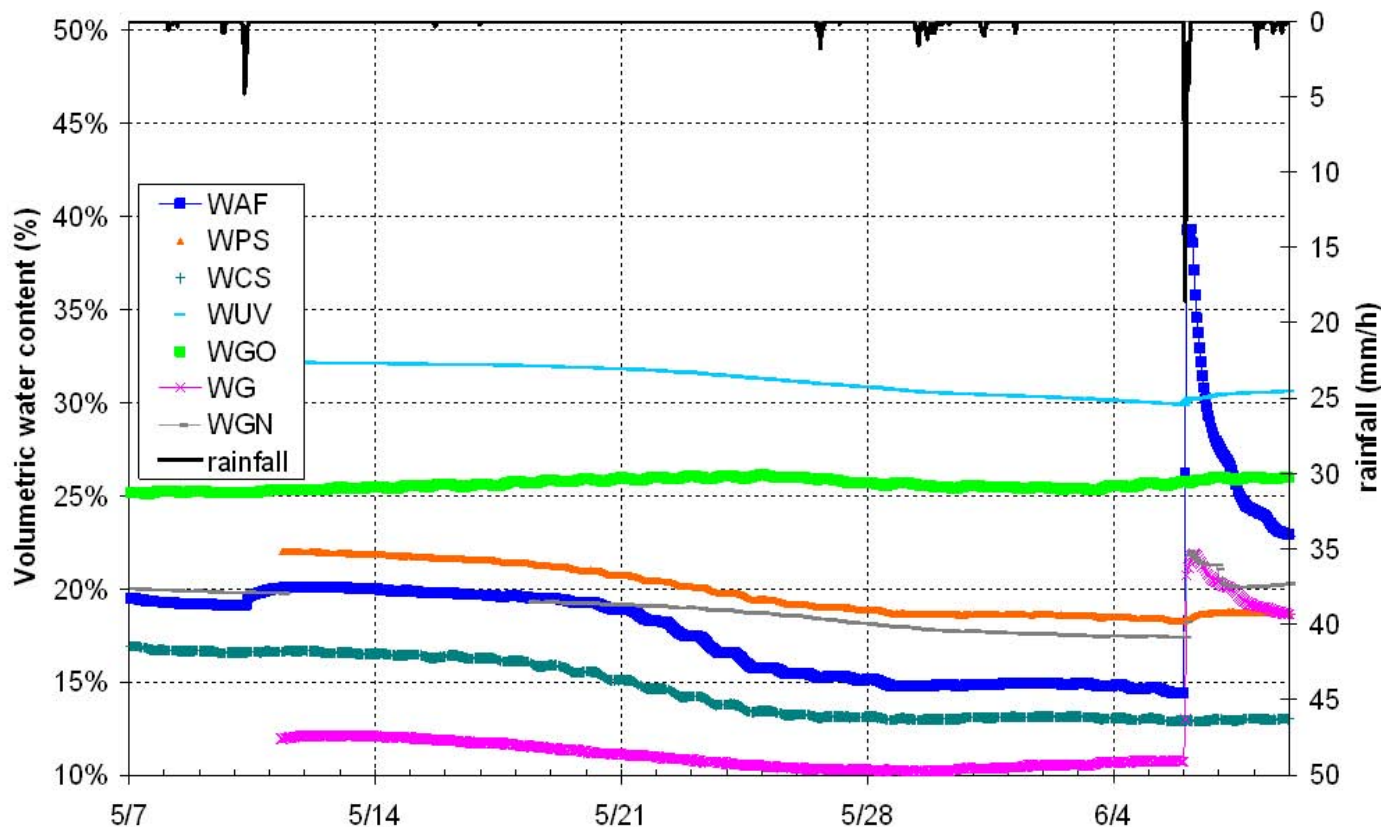


Figure 10. Variations of ground water content at 35 cm during the month of May 2010.

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Country Report: Urban Climate Research in Spain



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Introduction

Of the 46 million people that live in Spain, 76% are in cities of more than 10,000 inhabitants and 50% are in cities with more than 50,000. This urbanization process received a strong boost between 1987 and 2000, when the artificial land cover in the country increased by 29.5%. Such an increase was localised mainly along the Mediterranean coast (within the first kilometre inland, more than the 20% of the land is urbanized), and around the biggest city of the country, Madrid, in the interior (Fig 1). Other large cities are Barcelona (1.5 million), Valencia, Sevilla, Malaga and Zaragoza (all with more than 500,000 inhabitants).

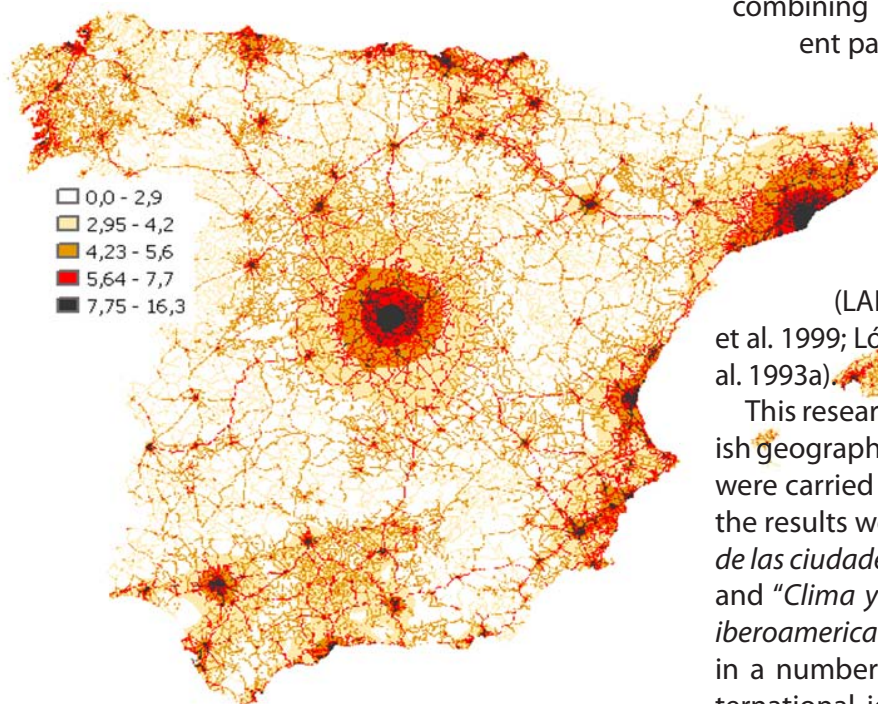


Figure 1. Percentage of artificial land cover (Source: Ministry of Environment of Spain)

In Spain there is a wide variety of climates, but the predominant is the Mediterranean, with cold winters and hot and dry summers. The highly frequent stable situations, with strong solar radiation and high temperatures, are the characteristics that best define the climate of the peninsula, and those that most affect

the urban climate. Summer temperatures easily reach 30°C in the majority of the country, and days with more than 36°C or even 40°C in the interior are common. These very hot situations are becoming more frequent in the last decade and this tendency is forecasted to continue in the rest of the XXI century.

The first study about the urban climate of Madrid was published in 1984 by a group of researchers from the Department of Geography of the Universidad Autonoma of Madrid and the CSIC (Consejo Superior de Investigaciones Científicas) (López Gómez and Fernández García, 1984). The aim of the study was to characterize the Madrid urban heat island (UHI) by combining point measurements, located in different parts of the city and the surroundings, with mobile measurements obtained with instruments placed over cars moving in three principle directions (NS, NE-SW, and NW-SE) (Fernández García, et al., 2003). Later, this information was integrated with images taken from satellites (LANDSAT) and airplanes (Fernández García, et al. 1999; López Gómez, et al., 1990; López Gómez, et al. 1993a).

This research line was soon followed by other Spanish geographers. During the 90s urban climate studies were carried out in several Spanish cities (Fig. 2), and the results were published in two key books: "*El clima de las ciudades españolas*" (López Gómez, et al. 1993b) and "*Clima y ambiente urbano en ciudades ibéricas e iberoamericanas*" (Fernández García, et al. 1998) and in a number of research articles in national and international journals. For example, a combination of point measurements and transects obtained with instruments mounted on cars was used to investigate the urban climate of Granada (Montavez et al., 2000a), Zaragoza (Cuadrat et al., 2005; Vicente Serrano et al., 2005), and Barcelona (Moreno, 1994; Matín Vide et al., 2003), among others.

Today several groups, together with the Geography Department of the Universidad Autonoma (Madrid),

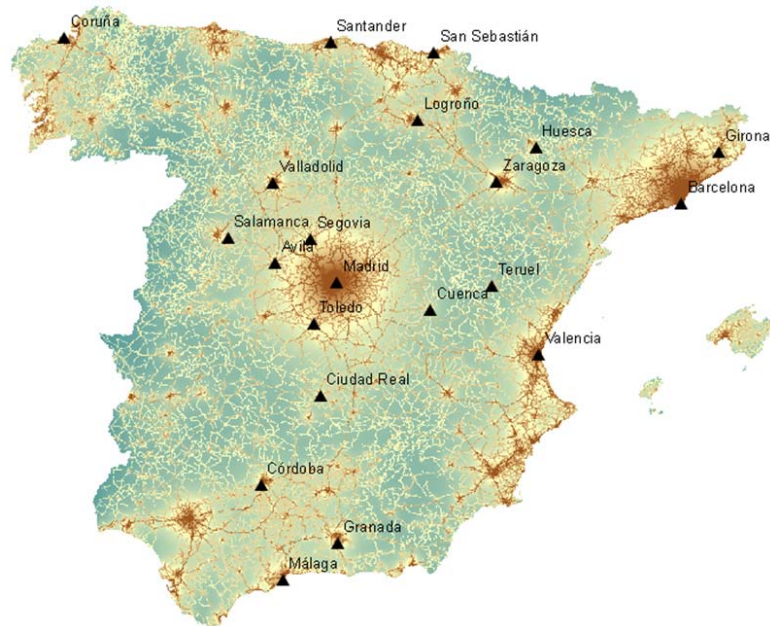


Figure 2. Spanish cities where urban climate studies have been carried out.

are active on urban climate – including TECNALIA-LABEIN in Bilbao (Juan Angel Acero), the University of Murcia (Juan Pedro Montavez), and CIEMAT in Madrid (Alberto Martilli). The focus of these researches is not only the urban heat island, but also thermal comfort, energy consumption and their links with air quality and health.

In this contribution we will focus mainly on studies in the region of Madrid carried out by the geographers of the Universidad Autonoma, and we will only briefly describe the main achievements of the other groups.

Relating urban morphology, UHI and thermal comfort during Heat Waves in Madrid

The metropolitan region of Madrid is an area with a high population density (more than 5 million within a radius of 50 km) that has been strongly modified by human activity (30% of the surface is artificial; see Fig. 3). It is located on a Plateau (600-700 m a.s.l.) in the middle of the Iberian Peninsula, with a mountain ridge about 40 km to the NW. Being characterized by a high percentage of anticyclonic situations, it is an ideal location to study urban climate. As mentioned previously, the first studies date back to 1984, but since then, other works on the UHI, thermal comfort, and the influence of Heat Waves on UHI have been published (Fernández García et al., 2010; Fernández García, 2001-2002; Fernández García, and Rasilla Álvarez, 2009). In 2008 the DESIREX field campaign (funded by the ESA, Sobrino et al. 2009) took place in Madrid with the aim of investigating the UHI and Urban Thermography (UT). In 2009, the GEOCLIMA group of the

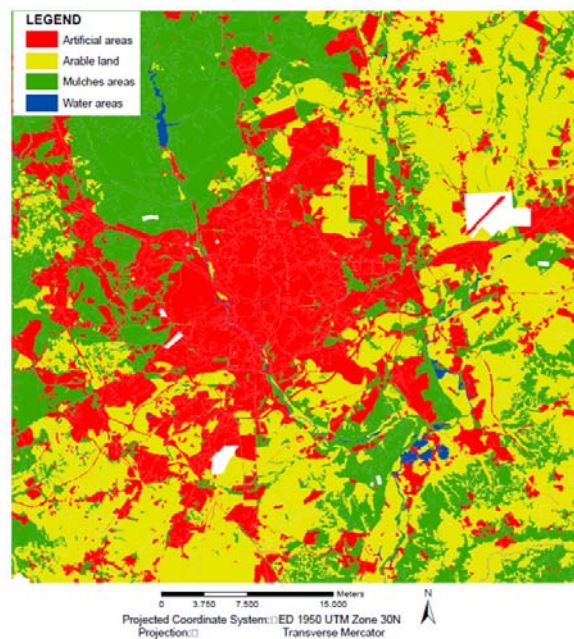


Figure 3. Land-use in the metropolitan area of Madrid. (source CORINE, 2006)

Universidad Autonoma started a project on *Urban climate and thermal comfort during heat wave episodes in the Madrid region*. The aim of the work is twofold: 1) to quantify the impact of urbanization on heat stress during heat waves, by means of an Accumulated Heat Index (time integral of the UHI), and 2) to establish the influence of different urban attributes like building density or green spaces on thermal stress by means of complex bioclimatic indices like PET (Physiological Equivalent Temperature). The main results can be summarized as follows:

a) UHI analysis: Madrid's UHI has been obtained by combining climatic data from different sources like point measurements, car transects, flight data from DESIREX, etc. with land-use and urban morphology data. By using the principal component analysis, a series of indices has been created starting from information on building density and green areas. The high correlation obtained between the Empirical Orthogonal Functions and these indices means that it is possible to build the spatial structure of the UHI starting from urban morphological data (Fernández-García et al, 2003). Figure 4 shows the results obtained with this methodology for 0400 LST on the 26th of June 2008 for surface temperatures (computed from the airborne data of the DESIREX campaign), and urban canopy temperatures. At this time, the surface UHI is 19.3°C, while the canopy UHI is 13.6°C. In both cases the hottest areas are those more heavily urbanized, and the coldest those with more vegetation.

b) UHI during Heat Waves. To understand if UHI exacerbates the heat waves, the intensity of the UHI for

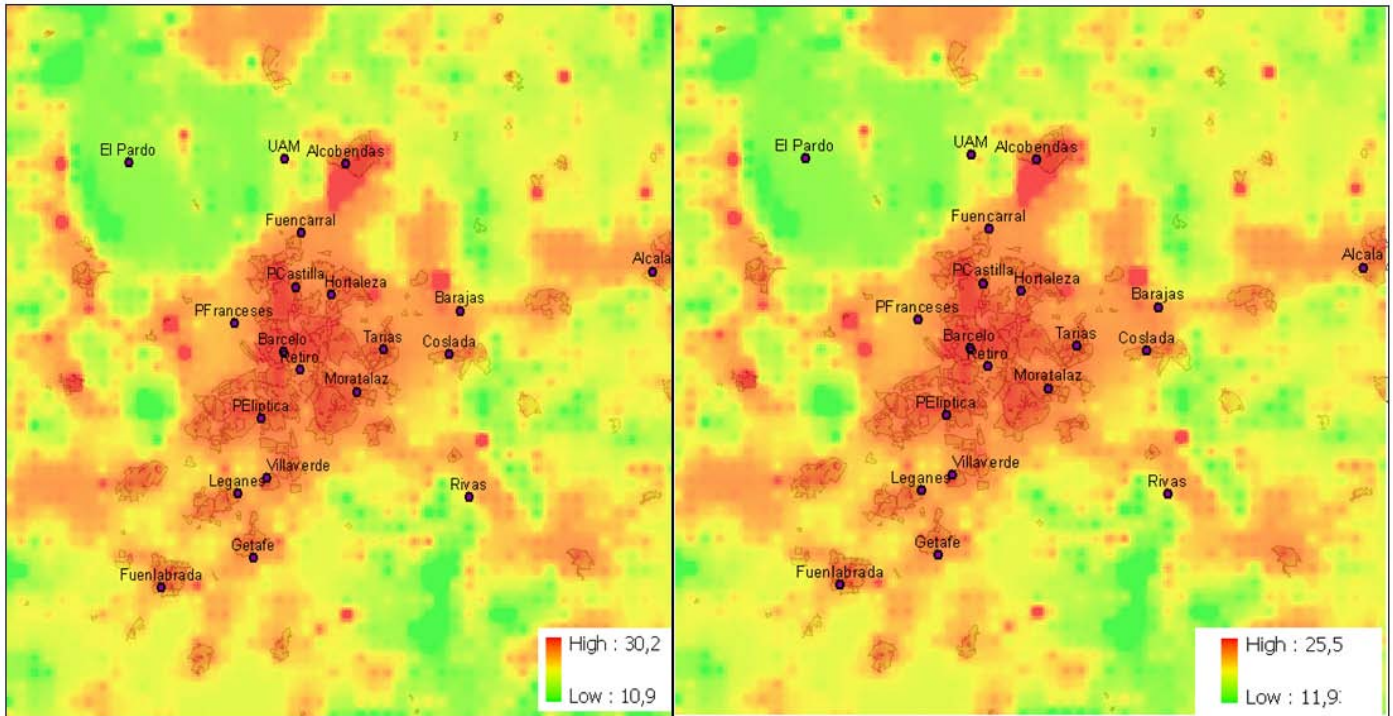


Figure 4. Soil Surface Temperature (left) and air temperature (right) in the metropolitan area of Madrid at 0400 LST for the 26-06-2008 (Fernández García, 2010).

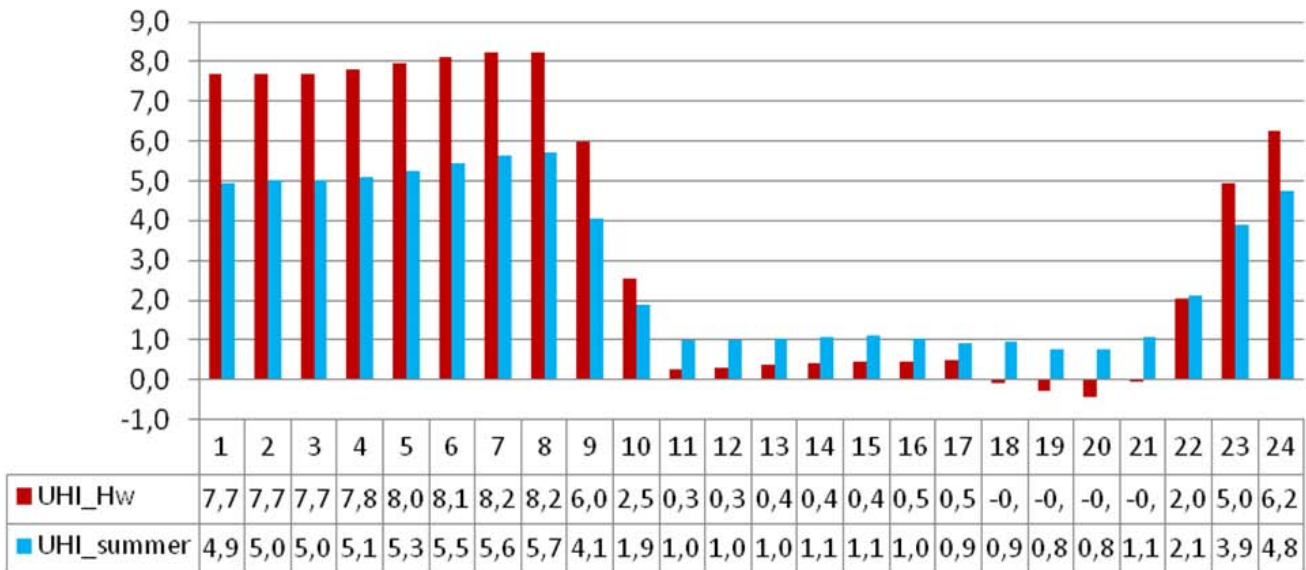


Figure 5. Average UHI intensity time evolution during all the summer days (blue) and the heat wave days (red) (2004-2007).

days with maximum temperature of more than 36.5°C was analyzed and compared against the rest of the summer days. Results show that during heat wave periods, the strength of the daytime UHI is slightly reduced compared to normal summer days, but the nighttime UHI is significantly stronger (Fig. 5, Table 1).

c) Characterization of the thermal comfort regimes in Madrid. The PET has been computed with RAYMAN (Matzarakis et al. 2000; Matzarakis et al. 2007) for the metropolitan area of Madrid, based on meteorological data (maximum and minimum temperature, wind

UHI intensity	% of days		% of nights	
	all	heat waves	all	heat waves
<2°C	99.0	100.0	34.7	11.0
2-4°C	0.0	0.0	44.9	47.0
4-6°C	1.0	0.0	19.7	40.2
>6°C	0.0	0.0	0.7	1.8

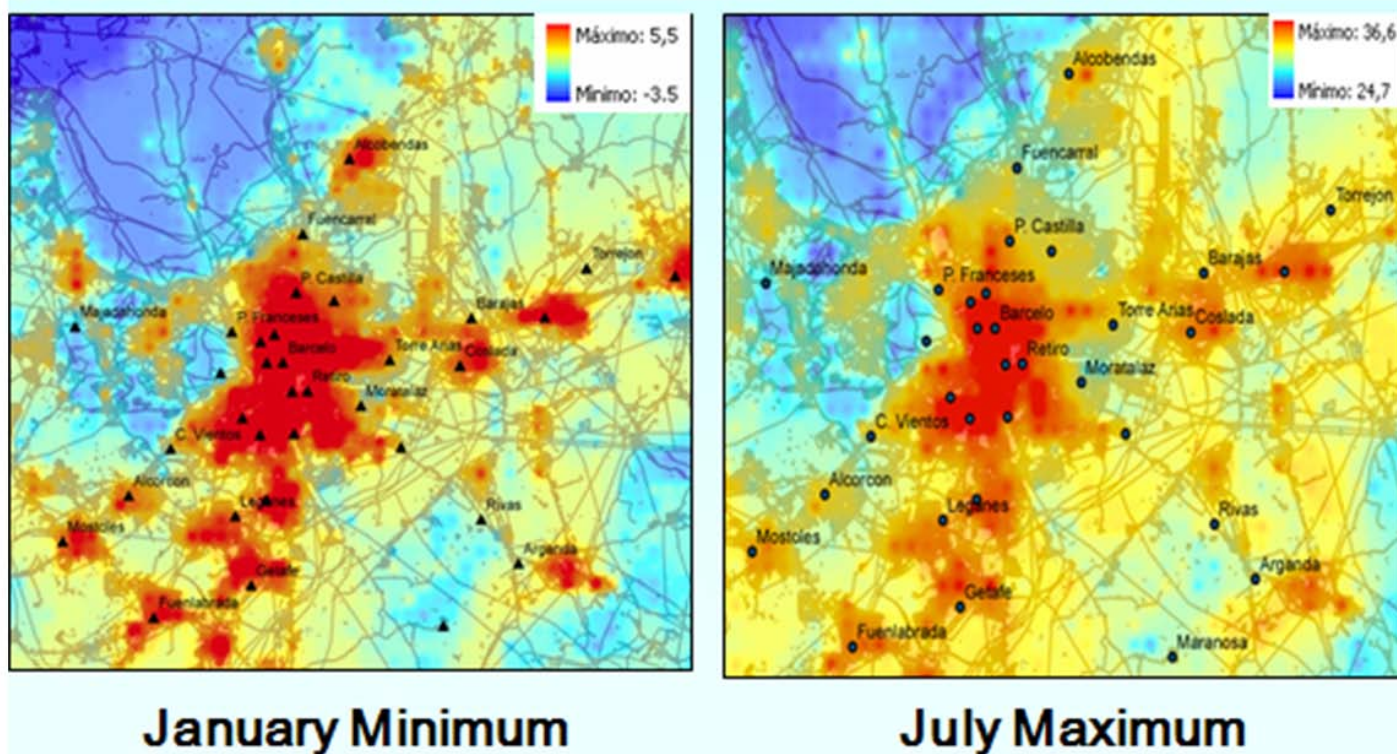


Figure 6. Minimum PET in the metropolitan area of Madrid during January (left) and Maximum PET during July (right), for the period 2002-2004 (Fernández-García, F. 2009)

speed, maximum and minimum relative humidity, radiation, cloud cover), and type of clothing. The PET map (Figure 6) shows an archipelago of hot spots associated with the urban areas. In winter, values oscillate between -3.5°C and 5°C , while in summer the lowest maximum PET is 24.7°C and the highest 36.6°C . One of the most remarkable features that can be seen in the map is the difference between the very hot SW part of the city, very dense and with little vegetation, and the relatively cooler N and NE parts, which are residential and with a larger percentage of green areas. The importance of vegetation can be seen even more clearly in the spatial distribution of the extremely hot days (Figure 7), where the cool footprint of the *Parque del Retiro* (a large urban park with an extension of 118 acres) is prominent. Based on this study three urban bioclimatic zones can be established based on the urban morphology: 1) very hot for the very dense urban areas with scarce vegetation, 2) hot for the low density residential areas with some vegetation, and 3) relatively cool for the urban parks. The differences between these three zones are exacerbated during the heat waves. For example, during the heat wave of 2003 (Figure 8) the maximum PET computed for the dense urban area was above the extreme heat threshold (*umbral extremo*) nearly for the whole period studied (July and August). On the contrary, in the residen-

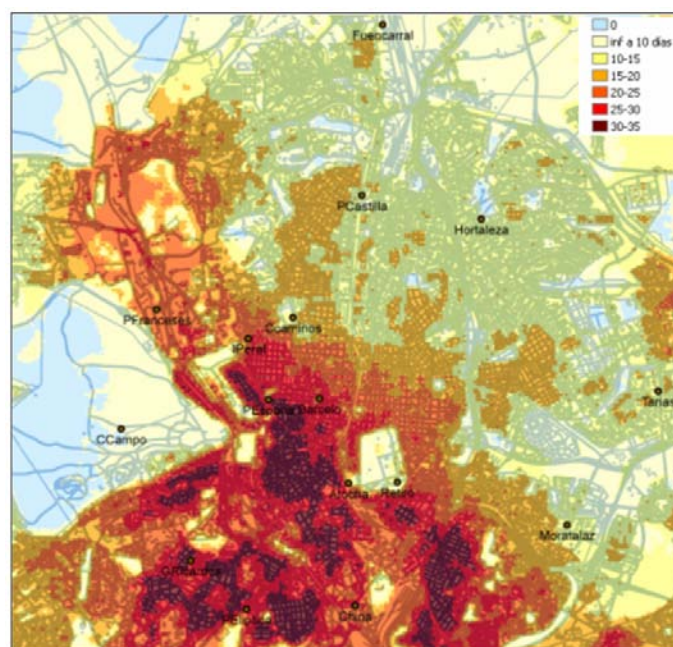


Figure 7. Spatial distribution of the extremely hot days in Madrid (2002-2004) (Fernández-García, 2009).

tial neighborhood of Barajas only occasionally the PET exceeded the extreme threshold, and finally in the urban park of Retiro, the maximum PET never exceeded the extreme value, and only on a few occasions the very hot value (*umbral muy cálido*). Based on this, we can conclude that the urban impact on climate in Madrid increases during the heat waves.

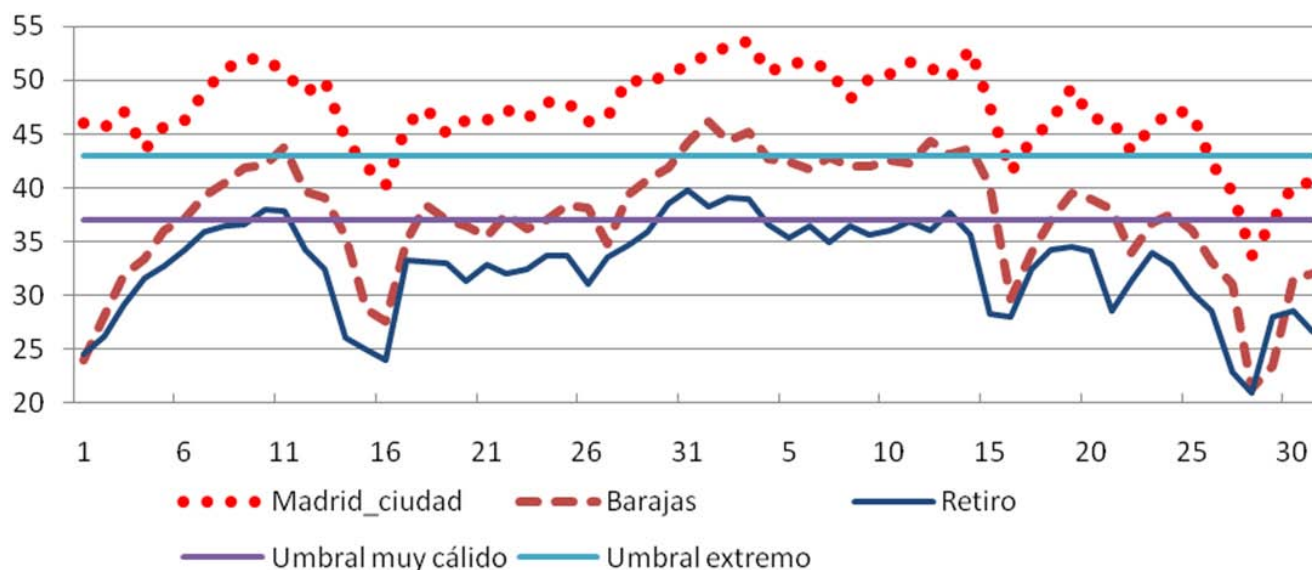


Figure 8. Maximum daily PET for an urban station (red dots), a residential station (brown dashed), and an urban park (solid blue) for the heat wave of July and August 2003. (Fernández-García, 2009).

Urban climate map reconstruction

The studies carried out by Tecnalia (in Bilbao, in particular by Juan Angel Acero) in collaboration with Kassel University (Germany) focus on a new method to develop Urban Climate Maps (UC-Map). These maps aim to translate urban climate information into urban planning recommendations. The method is easy to apply and is based on GIS calculations. It requires urban climate expert knowledge to evaluate ventilation issues, and also measurement campaigns inside the Urban Canopy Layer to validate/calibrate the GIS calculations. Finally, the UC-Map shows different climatopes (i.e. areas with relatively homogeneous climatic variables) and presents urban planning recommendations in order to improve actual thermal comfort and prevent future problems. The concept of UC-Map was firstly developed in Germany and is now applied also in other countries (Ren et al., 2010). In Spain this mapping has firstly been carried out in Bilbao where the influence of sea breezes and complex terrain, together with cold air drainage flows, have shown an interesting case study. In this case three measurement campaigns were carried out along the urban area combining stationary with mobile devices. Considering spatial scale limitations of the UC-Map, additional microscale studies have been done to evaluate the influence of vegetation, shadowing, building orientation etc. This is an important aspect, since the inclusion of urban climate in urban planning requires a multi-scale spatial approach.

Urban climate modelling studies

The impact of cities on local climate has been also

studied in several Spanish institutions by using meso-scale atmospheric models. For example, researchers from the Universities of Murcia, Granada and Madrid have used MM5 (Montavez et al., 2003) to simulate the Madrid region, and found that the Katabatic winds induced by the mountain ridge NW of the city extend the urban temperature perturbation several kilometers downwind of the city itself.

In CIEMAT (Madrid), urban climate research is carried out by using the Weather and Research Forecast model (WRF) adapted for urban areas (Chen et al. 2010). The main contribution of CIEMAT to this model is the implementation of a multilayer urban canopy parameterization (Martilli et al., 2002) linked to a simple Building Energy Model (Salamanca et al., 2010). Thanks to this module, key features that characterize urban climate can be simulated: shadowing and radiation trapping in the street canyon, heat storage in the buildings, and exchanges of heat between the interior and exterior of buildings, including heat flux due to air conditioning. Moreover, the BEM module can provide the electric consumption due to space cooling. The WRF-urban model has been applied to study the Madrid metropolitan area during a few days of the DESIREX campaign in summer 2008 (Salamanca, et al. 2011). Results show that the model is able to capture the UHI correctly as compared with available measurements, and that the impact of the heat ejected by the air conditioning systems on the atmosphere can reach up to 1.5-2°C in some parts of the city in late afternoon (Fig. 9). These results open the door to future studies of the interactions between urban climate, energy consumption and air quality.

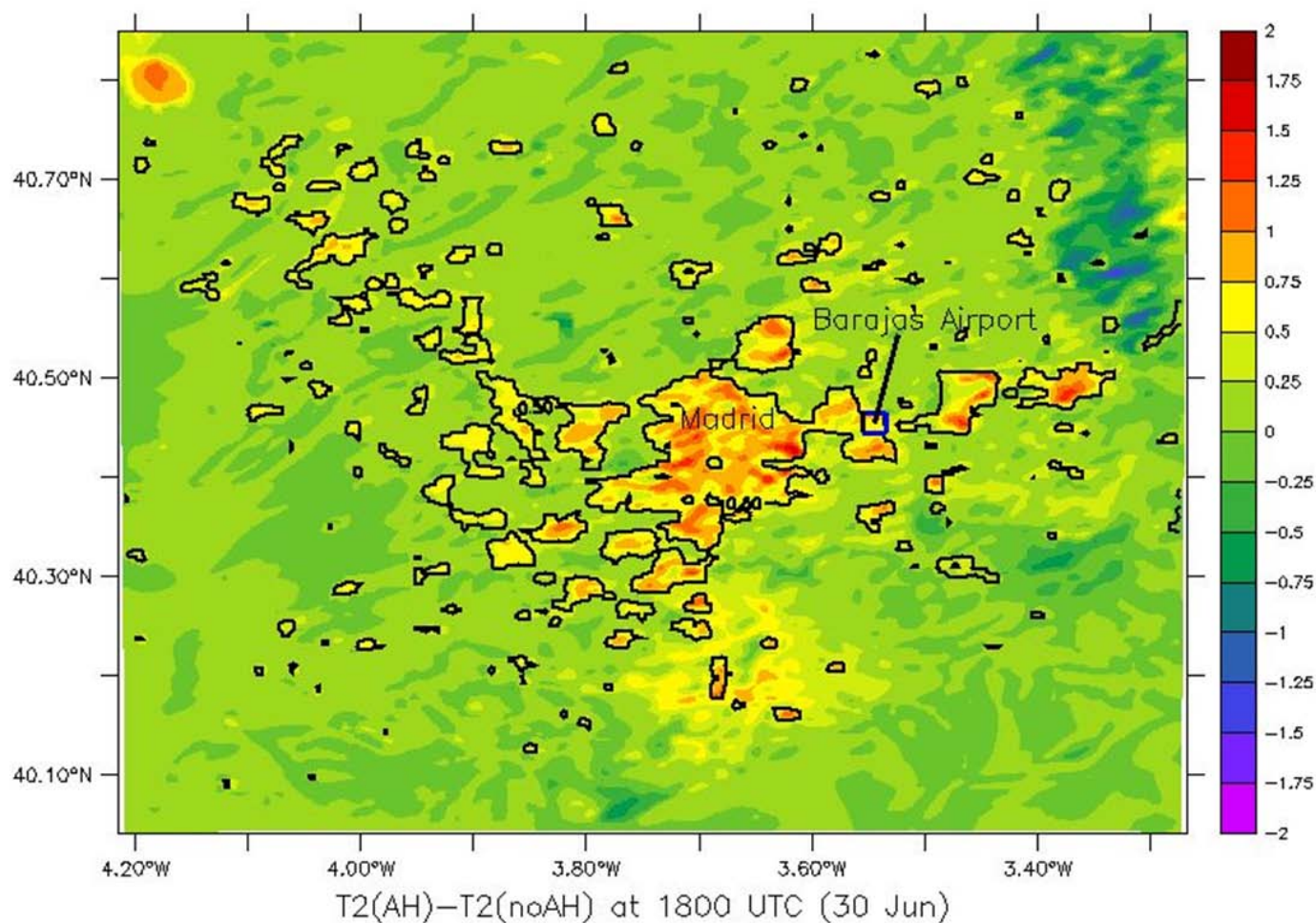


Figure 9. Differences in 2 m temperature at 1800 UTC (2000 LST) on the 30th of June, between a simulation with air conditioning systems ejecting heat to the atmosphere and not ejecting. Results obtained with WRF-urban (Salamanca et al., 2011).

Tecnalia (Bilbao in particular, Iratxe Gonzalez) in collaboration with the Danish Meteorological institute (Denmark) is using Enviro-HIRLAM (Environment – High Resolution Limited Area Model), which is an online coupled numerical weather prediction and atmospheric chemical transport modelling system. The Interaction Soil-Biosphere-Atmosphere (ISBA) land surface scheme is modified to include urban effects using the Building Effect Parameterization (Martilli et al., 2002) module and Anthropogenic Heat Fluxes (AHF) extracted from the Large-scale Urban Consumption of energy (LUCY) model of Sue Grimmond, including energy fluxes from traffic, metabolism and energy consumption. The research is focused on the impact of urban sulphate aerosols on specific climatic variables such as air temperature, wind, cloudiness, cloud liquid water content and precipitation, and the assessment of urban influence on the aerosol dispersion, transport and deposition. Air quality and meteorological scenarios at regional and urban scale are devoted to ana-

lysing the changes expected over the Basque Country (Spain) and aim to support strategies for impact assessment and adaptation to climate change.

Urban canyon modelling

A model for the urban canyon was built by Montavez et al. (2000b) at the University of Granada. Thermal radiation, conductivity and convection are simulated by means of the Monte Carlo method. The model was satisfactorily tested under ideal conditions and observational data. A strong surface temperature gradient across streets, with the canyon corners up to 4°C warmer than the canyon centre, was found for the deepest canyons.

From the results of this model (Montavez et al., 2008), a simple model for estimating the maximum intensity of the nocturnal urban heat island as a function of the thermal properties of rural and urban areas as well as urban geometry was created. This model permits an easy evaluation of the maximum UHI.

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European Geosciences Union (EGU) General Assembly in Vienna

The EGU General Assembly was held in Vienna, Austria from 3rd to 8th August, 2011 and attracted 4,333 papers and 8,439 posters in 707 sessions. The conference itself is vast and the programme covers the spectrum of Geosciences. For the first time four of these (two oral and two poster sessions) were focused on urban climatology and biometeorology. The sessions were entitled **Urban climate, urban heat island and urban biometeorology** and organized by Konstantinos Kourtidis and Koen de Ridder. The urban sessions took place on the first full day of the conference and drew on a wide range of topics, much of it associated with the urban heat island and its linkages to heatwaves (see table).

The full list of papers and posters is available online at: <http://meetingorganizer.copernicus.org/EGU2011/session/6426/urban>.

From my vantage point, I was surprised by the scope and sophistication of many papers. It is clear that the field

has moved considerably from descriptive assessments of urban climate effects to detailed assessments of processes using a variety of tools. There were a number of developments that were apparent in presentations that have implications for the field in general. On the methodological side, it is clear that remote sensing is beginning to play a significant role in the assessment of urban climates and that the results of modelling experiments can now be presented to the community with a limited introduction. On the observational side, the measurement of energy and CO₂ fluxes is increasingly commonplace and the analysis is becoming very sophisticated. In terms of topics, the importance of climate change and of events (such as the 2003 heatwave) as drivers of much of the recent urban climate research in Europe is evident. All of this bodes well for the future of the subject.

– Gerald Mills, UCD Dublin

Presentations in Urban Climate sessions at the EGU General Assembly in Vienna, August 2011

Speaker	Topic
Gerald Mills	Urban climatology: The state of the field
Maja Zuvella-Aloise, Barbara Früh, Christoph Matulla, and Reinhard Böhm	Urban climate of Vienna - modelling study of urban heat stress under climate change conditions
Benedicte Dousset, Françoise Gourmelon, Karine Laaidi, Abdelkrim Zeghnoun, Emmanuel Giraudet, Philippe Bretin, and Stéphanie Vandentorren	Summer warming trends, heat waves and health impact in the Paris metropolitan area
Iphigenia Keramitsoglou, Chris Kiranoudis, Bino Maiheu, Koen De Ridder, Giulio Ceriola, Ioannis Daglis, Paolo Manunta, and Marc Paganini	Spatial and temporal distribution of heat wave hazard and risk in Athens, Greece, using artificial intelligence fuzzy logic
Tsing-Chang Chen and Ming-Cheng Yen	Enhancement of Afternoon Thunderstorm Activity by Urbanization in a Valley for the Past Four Decades: Taipei
Björn Lietzke and Roland Vogt	Variability of CO ₂ in an urban environment: from street canyon to neighbourhood scale
Bino Maiheu, Koen De Ridder, Benedicte Doucet, Paolo Manunta, Giulio Ceriola, and Iphigenia Keramitsoglou	Modelling air temperature via assimilation of satellite derived LST within the Urban Heat Island project
Julia Hidalgo, Bruno Bueno, and Valéry Masson	How to obtain atmospheric forcing fields for Surface Energy Balance models in climatic studies
Bruno Bueno and Grégoire Pigeon	Development and evaluation of a comprehensive building energy model in the Town Energy Balance scheme

Urban climate methods at AAG annual meeting: Progress and gaps

The study of urban climates has always had a strong presence in North American geography and this year there was one session on urban climatology at the annual meeting of the Association of American Geographers (AAG) in Seattle, which focussed on methodological issues. Each paper challenged and critically assessed existing knowledge on aspects of the urban effect and its study. I was fortunate enough to attend the event while on a Fulbright Scholarship to Arizona State University.

The session was introduced by **Gerald Mills**, who provided an overview of the field and its strengths and gaps. Four presentations followed, by **David Sailor** (Portland State University), **Chandana Mitra** (University of Georgia), **Paul Alexander** (Arizona State University), **Iain Stewart** and **Tim Oke** (both of University of British Columbia). Tony Brazel (Arizona State University) unfortunately could not attend.

David Sailor highlighted the sometimes tunnel vision of UHI mitigation efforts (carried out by government bodies, urban planners etc.) that are undertaken without due consideration of the potential feedbacks. For instance, he pointed to the use of higher albedo surfaces in the reduction of surface and air temperatures as an example, a strategy that on first glance would appear to serve the purpose of reducing heat stress on buildings and populations that may have unintended consequences. One consequence could be the lowering of UCL mixing heights and an overall reduction of urban ventilation.

Chandana Mitra focussed on the impact of cities on precipitation, which after decades of research, cannot clearly state whether cities increase, decrease, or have no effect on rainfall. However, the methodological considerations (particularly those proposed by Lowry, 1998) highlighted by

Chandana do seem to have brought greater coherency to the debate.

Paul Alexander highlighted a recent study carried out in Dublin, Ireland surrounding the canopy layer UHI. The study employed a new methodology which employs Iain Stewart's Local Climate Zone (LCZ) classification (see IAUC Newsletter Feature, [Dec. 2009](#)) for UHI investigation. This method allows the UHI to be expressed more meaningfully as the differences among LCZs, replacing the familiar urban-rural air temperature difference. The results from Dublin make a strong case for the universality and potential of the LCZ system. Iain Stewart, who developed the LCZ system, highlighted the methodological considerations that were incorporated into the development of the scheme. The paper stood alone in terms of Iain's talent for synthesising international research utilising the scheme. One particularly nice feature of Iain's paper was to highlight a recent study carried out using the LCZs system as a proxy for urban affluence.

The session ended on a high note. Tim Oke discussed the placement of instruments in the urban landscape and the conclusions drawn from the observations that are acquired. In particular, he pointed out that the source areas for in situ instruments within the urban canopy is unknown for many circumstances and that this has implications when results are interpreted. Tim's presentation emphasized the need for care in the placement of instruments and the interpretation of their results, particularly in urban areas that are heterogeneous and characterised by micro-advection. In the absence of such care, we are in danger of making little progress.

– Paul Alexander, UCD Dublin



City Weathers: Meteorology and Urban Design 1950-2010

Climate Science and Urban Design is the title of a historical and comparative study of applied urban climatology, focusing on the period after 1950. The comparative framework includes the seminal work of German and Japanese urban climatologists, as well as the more recent climate policy initiatives of New York City and the City of Manchester. Its emphasis is on the small-scale climatic impacts of a city's physical form and functions. The design of buildings and spaces directly affects urban temperature, wind, rain and air quality – which in turn influence human comfort and health. These relations are systematically studied by urban climatologists, whose discipline has immediate relevance for urban design. Out of this project a short workshop meeting was held in Manchester (June 23-24) that drew together climatologists and designers with interests in urban climates. Details of the programme (including short papers) are available on the University of Manchester website: www.sed.manchester.ac.uk/architecture/research/csud/.

From the perspective of an urban climatologist, this meeting provided a rare opportunity for discussion among

groups of individuals representing scientists and practitioners and to get a historical perspective on the divide between planning and climate, which appears to have widened since 1950. In particular, the lack of consideration for the outdoor urban environment in planning was noted. The current concern for global climate change provides a fresh impetus to include climate issues in urban planning. However, urban climate science has not to this point been incorporated into the IPCC assessment reports. One hopes that the 5th assessment report, which is being compiled, is more inclusive in this regard. The role of Stuttgart as an exemplar was emphasised in a number of talks both directly and indirectly as its approach to climate-based planning has spread to other places. Despite this success, there has been little research on the efficacy of design interventions. The film, *Urban Development and Urban Climate-Stuttgart*, which was made in 1976, was shown at the event and a copy has been placed in the [Teaching Resources section](#) of the IAUC website.

– Gerald Mills

Recent publications in Urban Climatology

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In this edition you will find the compilation of papers published until May 2011. Thanks to everyone for their contribution. All readers are invited to send any peer-reviewed references published since August 1st 2011 for inclusion in the next newsletter and the online database. Please send your references to julia.hidalgo@gmail.com with a header "IAUC publications" and the following format: Author, Title, Journal, Volume, Pages, Dates, Keywords, Language, URL, and Abstract.

Happy reading,

Julia Hidalgo



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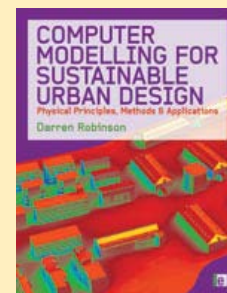
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Computer Modelling for Sustainable Urban Design, Edited by Darren Robinson, [Earthscan](#), 320 pages.

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Upcoming Conferences...

INTERNATIONAL WORKSHOP ON URBAN WEATHER AND CLIMATE: OBSERVATION AND MODELING

Beijing China • July 12-15, 2011

wksp@ium.cn

COHERENT FLOW STRUCTURES IN GEOPHYSICAL FLOWS AT EARTH'S SURFACE

Burnaby, British Columbia • August 3-5, 2011

<http://www.sfu.ca/CoherentFlowStructures/>

KLIMACAMPUS-WMO WORKSHOP ON URBAN AIR QUALITY AND CLIMATE CHANGE (UAQCC)

University of Hamburg, Germany • Aug. 16-18, 2011

<http://www.klimacampus.de/>

"URBANIZATION AND ITS IMPACTS ON TERRESTRIAL ECOSYSTEM" and "URBAN GREEN SPACES, HUMAN HEALTH AND ECO-ENVIRONMENT QUALITY," Association of Landscape Ecology (IALE) World Congress

Beijing China • August 18-23, 2011

<http://www.iale2011.org>

URBAN MORPHOLOGY AND THE POST-CARBON CITY: 18th International Seminar on Urban Form

Montréal, Canada • August 26- 29, 2011

<http://www.isuf2011.com/>

URBAN CLIMATE SESSION, Annual Meeting of European Meteorological Society (EMS) and European Conference on Applications of Meteorology (ECAM)

Berlin, Germany • September 12-16, 2011

<http://meetingorganizer.copernicus.org/EMS2011/session/8118/urban>

14TH INTERNATIONAL CONFERENCE ON HARMONISATION WITHIN ATMOSPHERIC DISPERSION MODELLING FOR REGULATORY PURPOSES

Kos Island, Greece • October 2-6, 2011

<http://www.harmo.org/>

"CLIMATE AND CONSTRUCTIONS" CONFERENCE AND WORKSHOPS

Karlsruhe, Germany • October 24-25, 2011

<http://www.kit.edu>

WORLD RENEWABLE ENERGY ASIA REGIONAL CONGRESS AND EXHIBITION

Chongqing, China • October 28-31, 2011

<http://www.wrenuk.co.uk/index.html>

TRAINING WORKSHOP: URBAN RESPONSE TO CLIMATE CHANGE IN ASIA – UNDERSTANDING MITIGATION AND ADAPTATION STRATEGIES

National Taipei University, Taiwan • November 10-15, 2011

http://www.sarcs.org/new/capacity/2011_%20Urban_%20Response/Urban.htm

19TH INTERNATIONAL CONGRESS OF BIOMETEOROLOGY (ICB2011)

Auckland, New Zealand • December 5-9, 2011,

<http://www.icb2011.com>

URBAN METABOLISM and DYNAMICS OF URBANIZATION, Special Sessions at AGU Fall Meeting

San Francisco CA, USA • December 5-9, 2011

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A. John Arnfield honored as 2010 Luke Howard Award recipient

The IAUC Board is delighted to announce that A. John Arnfield is the recipient of the 2010 IAUC Luke Howard Award. His career as an urban climatologist has been marked by a focus on fundamental processes, and an attention to detail that is rare. He has been one of the guiding figures in the field since the mid-1970s. In addition, John has been central to the development of a community of urban climate scholars.

John's urban research focus grew out of his interest in radiation exchanges, acquired while a student at McMaster University. With the benefit of hindsight, it is easy to see that a detailed approach to the radiation exchange at urban surfaces must be the starting point for the evaluation of climates within the urban canopy layer. He employed the urban canyon as the fundamental unit of canopy-layer research and thoroughly examined multiple radiation exchanges within this scheme. As it transpired, this approach to the study of



street climates was sufficiently 'fundamental' that it could be developed to consider streets of finite length and to incorporate models concerned with flow within city streets. His work as a result, has grown in significance with time and has provided the starting point for many urban climate models that were to follow. His research approach was theoretical in

scope, but was informed by carefully constructed measurement experiments. John's grasp of the breadth of urban climate research is evident in his widely cited work: "Two decades of urban climate research: a review of turbulence, exchanges of energy and water, and the urban heat island" (*Int. J. of Climatology*, 2003).

John's lasting legacy will be the establishment and maintenance of a "community" of climatologists – and in particular of urban climatologists. He organized many special sessions for urban climate at meetings of the American Association of Geographers during a period with few other relevant meetings. These sessions helped provide the impetus for a resurgence of the AMS's Urban Environment Symposium and the ICUC series of urban conferences. Indeed, he helped found both the AMS Board of the Urban Environment and the IAUC. He created CLIMLIST, a moderated electronic bulletin board, which has become indispensable as a means of communicating with fellow climatologists. In short, it is impossible to conceive of a climatology community without this simple mechanism for interac-



Professor John Arnfield, a physical geographer from Ohio State University, is recognized for his lifelong contribution to urban climatology.

tion. The substantial growth in collaboration among research workers in the field can be attributed in no small part to the establishment of CLIMLIST. The creation of URBCLIM, a moderated discussion board for urban climatologists has been substantially modeled on this success. He has been awarded the AAG Climate Specialty Group Lifetime Achievement Award for substantial contributions to climatology and geography.

Tim Oke has characterized the recent history of urban climatology as an 'ending of the solitudes' – a phrase that captures the transformation of a field from one dominated by researchers pursuing individual agendas in isolation, to one that substantially agrees on a framework for research and explores outstanding issues through co-operative, team-based, research projects.

John Arnfield was one of those that can claim credit to 'ending the solitudes'. He has been part of modern urban climate research from its inception and has worked selflessly to help produce an international community of scholars. John is a complete academic citizen and a model for developing academic researchers. His motivations for research are naive – they are based on a desire for learning and for sharing insights. The urban climate community is thus fortunate that such an individual chose to dedicate his efforts to the development of the field of urban climate.

- The IAUC Awards Committee



The [IAUC website](#) has been modified considerably in the last few months to change its appearance and some of its content. We hope that the current look meets with the approval of the members.

A new look for [urban-climate.org](#)

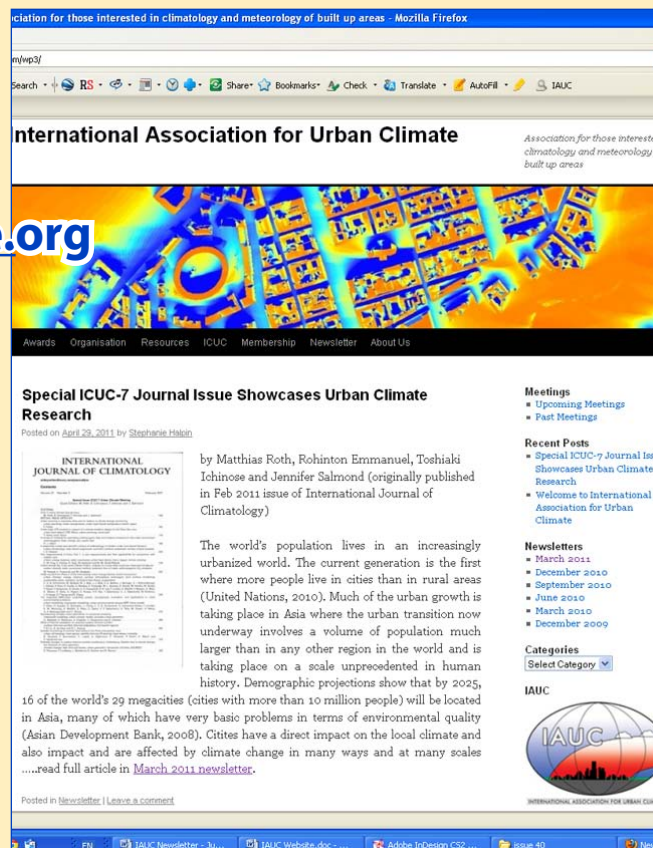
The intent of the design is to manage our content through a hierarchy of pages associated with major themes, such as ICUC events. As much as it possible, the content on any given page should fill your screen and not require lengthy scrolling. The overall appearance of the site will be much more visual in the future and it is hoped to feature a story from Urban News on the front page on each occasion that it is published. This will ensure that the webpage is modified on a regular basis.

The content of the webpage is much as it has been with some notable exceptions:

ICUC events: The proceedings of ICUC5 (Łódz, Poland) and of ICUC6 (Göteborg, Sweden) are now part of the IAUC website. Those of ICUC7 (Yokohama, Japan) will be added in the near future. Over time, it is hoped to add the proceedings of previous ICUC meetings and to allow members to search this content. But, that is a project for another day.

Classics in urban climatology: The teaching resource section of the website is poorly developed but it is hoped to radically improve this over the coming year. However, the IAUC has managed to publish electronically three classic texts in the field of urban climatology. Although they are well known and continue to be referenced, they are difficult to obtain for many. The IAUC has undertaken to republish such texts where permission is provided (or copyright has expired). The texts included thus far are:

Luke Howard (1833) The Climate of London. This is the first volume of the first study of the urban effect on air temperature. It is out of copyright and the version on the site was republished by the IAUC.



Albert Kratzer (1956) The Climate of Cities (*Stadtklima*). This text has two German editions. This is the translation of the second edition. It is republished with the permission of the American Meteorological Society. In its current form, it is a scanned version of the AMS publication, which unfortunately has faded somewhat. This will be cleaned and a reformatted version will be placed on the website. The IAUC is still trying to obtain permission to publish *Stadtklima* in the original form.

Tony Chandler (1965) The Climate of London. This is a remarkable and comprehensive study of the urban climate in London, based on an intensive measurement campaign. The work represents a high point of descriptive urban climatology by one of its leading researchers. This copy was scanned from a printed volume and has been republished with the permission of Random House.

- Gerald Mills, IAUC President

IAUC web site statistical update: A global traffic report

Origin of connections to
www.urban-climate.org
(January – April, 2011)

Most of you connect regularly to the IAUC web site at www.urban-climate.org. Time for us to tell you about all this incoming traffic. We have screened the logs for the period January 1st – April 30th 2011.

The site is hosted by the French hosting company www.ovh.com. It is using a shared infrastructure, allowing to us keep minimal hosting and maintenance costs, while being able to handle temporary high loads (for example the days on which the newsletter is issued).

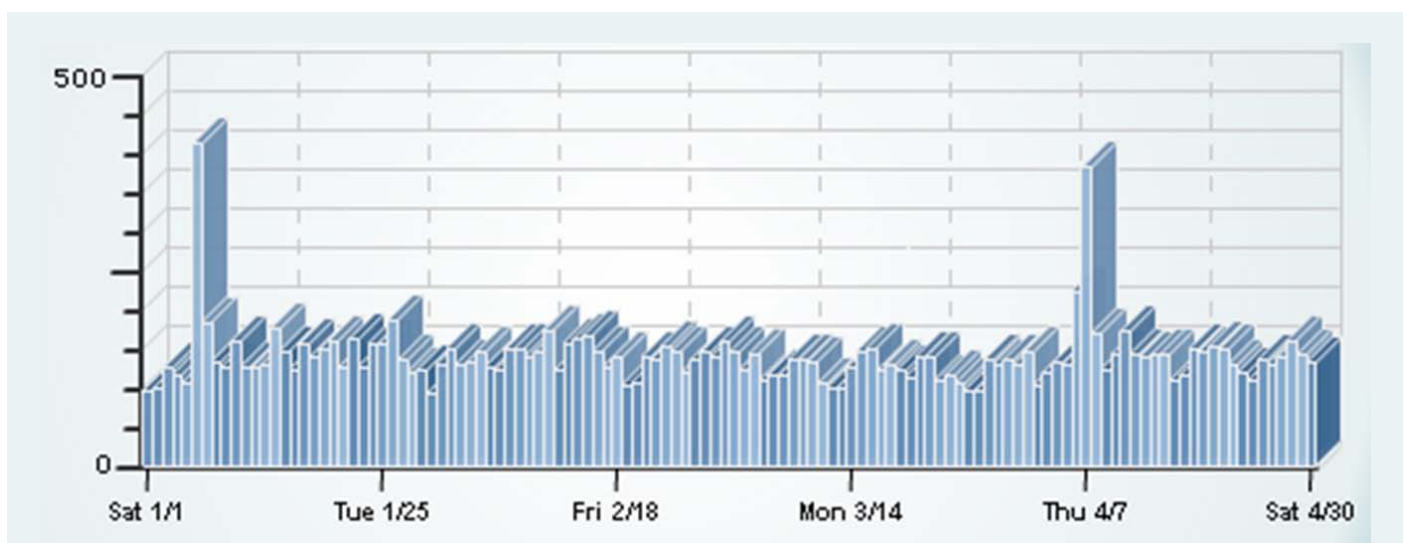
Users connect from all over the world. Lots of requests come from the USA, Europe, India and Japan, but there

are connections from nearly all inhabited parts of the planet, as seen above.

The site usually serves close to 140 unique visitors every day, with daily connection peaks reaching around 400 visitors, as seen below.

Each visit consists of browsing an average of 5 pages inside the site. In terms of bandwidth this gives an average of 155 megabytes per day (17 gigabytes for the period).

Of all users, a total of 72% come directly, either by typing www.urban-climate.org in the address bar of their browser or using a link in their email, while 12% come



Number of www.urban-climate.org visitors per day (01 Jan-30 Apr 2011). Peak visitation values in the first week of January and the first week of April correspond with the quarterly online publication of *Urban Climate News*.

from a Google search. Other connections come from a variety of links all over the Internet.

In terms of browsers, most of you use Firefox (72%), then Internet Explorer (12%). Other browsers are also found from time to time in the logs: Chrome (4%), Safari (2%) and Opera (1%).

Regarding content, the most viewed pages are:

- The newsletters, at http://www.urban-climate.org/newsletter_fr.htm (more than 1000 visits),
- The resources pages at http://www.urban-climate.org/UHI_Canopy.pdf and http://www.urban-climate.org/resources_fr.htm (1000 and 500 visits)
- The bibliography at http://www.urban-climate.org/bibliography_fr.htm (500 visits)
- The meetings list at http://www.urban-climate.org/meetings_fr.htm (500 visits)
- The board photo at http://www.urban-climate.org/Board_photo_02_fr.htm (500 visits)

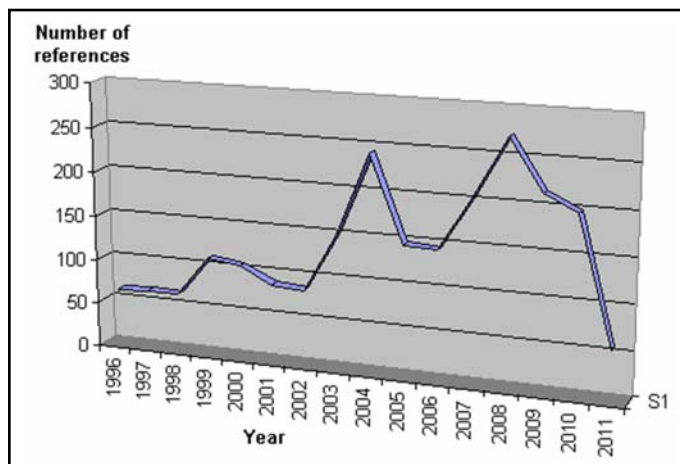
Zooming to the **IAUC Bibliographic and Flux Network databases** statistics, we have found the following:

The IAUC online Bibliographic database, launched in June 2008 and updated regularly after each Newsletter edition, was recently enriched with the references compiled by Jennifer Salmond from 1996. At present, around 2000 publications and 4000 authors are accessible through the following link: http://www.urban-climate.org/bibliography_fr.htm. To log in you should write "user" both for login and password. Some users reported issues when using Internet Explorer. Until we manage to fix this issue, please use Firefox to explore the site.

The number of references identified increased significantly after 2002. At present, 64 journals are regularly meticulously consulted by 11 collaborators. The list of journals is systematically surveyed and the number of urban climate-related articles per time period is shown in Table 1 (following page). This Table and the list of journals presented below shed light on the fact that we can optimise our efforts by reviewing the list and including additional journals in which relevant articles can be found but which we do not presently check.

All researchers are invited to send any peer-reviewed references for inclusion in the newsletter and the on-line database, sending an email directly to julia.hidalgo@ymail.com.

The IAUC Urban Flux Network intends to prove a simple, web-based database with the objective of collecting and sharing information about ongoing and discontinued micrometeorological tower sites located in urban environments. The IAUC Urban Flux Network collects and records meta-data (site location, publications, operation periods, urban surface characteristics, photos, contacts, etc.), but is not a data-sharing platform for measurements.



Number of references from Jan 1996 - Feb 2011.

Any site that fulfils certain criteria and is of interest to the IAUC research community can join the IAUC Urban Flux Network. To be listed in the IAUC Urban Flux Network, a site must be located in an urbanized area and have a proven record of successful flux data acquisition and publications in any of the following categories: Energy balance, carbon dioxide, aerosol, or trace-gas flux site. Flux measurements must be representative of the neighbourhood scale over a homogeneous area of any city. Both ongoing and historical sites can be added.

At present the urban flux network lists location and information about 40 sites on 6 continents that measure fluxes of radiation, energy and/or greenhouse gases above urban surfaces. Pls are encouraged to submit new measurement efforts using the simple <http://www.geog.ubc.ca/urbanflux/add.php> online form.

A new mailing list urbanflux has been set up along with the web-database to connect researchers and students working on urban-atmosphere exchange. The specific objectives of the urbanflux mailing list are:

- Discuss urban-specific problems such as sensor exposure, urban surface description, data-processing and analysis of urban flux measurements.
- Develop standardized protocols to describe instrument siting and placement, urban surface parameters, and data processing specifically for urban flux measurements.
- Maintain and improve the IAUC Urban Flux Network database.
- Disseminate information on planned or recent urban field projects and model developments related to urban-atmosphere exchange.

To join the urbanflux mailing list, please follow the instructions given at: <https://mailman.kcl.ac.uk/mailman/listinfo/urbanflux>

By Julia Hidalgo¹, David Podeur² and Andreas Christen³
 (1) CNRM-GAME (Météo-France & CNRS) Toulouse, France
 (2) ITG, Paris, France
 (3) University of British Columbia, Vancouver BC, Canada

Table 1. List of Journals systematically surveyed and their rates per time period. "Others" section includes: Environmental Science and Technology, Journal of Urban Technology, Urban Ecosystems, Atmospheric Chemistry and Physics, Aerosol Science and Technology, and Journal of the Air and Waste Management Association

	1996-1999	2000-2004	2005-2009	2010-2011
Acta Climatologica et Chorologica			5	
Advances in Atmospheric Sciences		8	16	1
Advances in Building Energy Research			5	
Agricultural and Forest Meteorology	1	3		1
Annals of the Association of American Geographers		1	1	
Applied Energy		1	2	
Atmosfera	1	2	7	4
Atmospheric Environment	116	147	144	15
Atmospheric Research	3	5	37	7
Australian Meteorological and Oceanographic Journal		1		
Boundary Layer Meteorology	6	32	66	22
Building and Environment		6	49	39
Building Research and Information			1	
Built Environment on Climate Change and Cities			11	
Bulletin of the American Meteorological Society		1	7	
Chinese Journal of Atmospheric Science		2	3	
Climate Research	2	9	11	3
Climatic Change	1	1	3	2
Computers and Geosciences			3	1
Energy and Buildings	3	12	25	14
Environmental Monitoring and Assessment	3	19	2	4
Environmental Research			3	1
Environmental Science and Pollution Research	6	5	6	11
Geophysical Research Letters	3	4	21	3
Habitat International				
Hydrological Processes			6	
Idojaras - Quarterly Journal of Hungarian Meteorological Service		2		2
International Journal of Environmental Studies			5	
Int. Journal of Applied Earth Observation & Geoinformation			4	4
International Journal of Biometeorology	7	8	13	6
International Journal of Climatology	7	11	31	16
International Journal of Environment and Pollution	10	37	25	14
Int. Journal of Environmental Technology & Management		1	3	2
International Journal of Remote Sensing	3	3	13	
International Journal of Sustainable Energy			13	
International Journal of Ventilation			1	
Italian Journal of Agrometeorology			5	
Journal of Applied Meteorology and Climatology	7	34	63	12
Journal of Arid Environments			2	
Journal of Atmospheric and Oceanic Technology		6	4	
Journal of Geophysical Research	7	27	51	27
Journal of Natural Hazards			4	
Journal of the Atmospheric Sciences		2	3	
Landscape and Urban Planning	1	6	5	3
Meteorological Applications		1	5	2
Meteorologische Zeitschrift	2	10	11	
Meteorology and Atmospheric Physics		12	19	2
Monthly Weather Review			1	
Physical Geography		4	2	1
Physics and Chemistry of the Earth		3	7	4
Progress in Physical Geography	1	4	2	
Quarterly Journal of the Royal Meteorological Society	2	5	4	1
Remote Sensing of the Environment		2	4	2
Renewable Energy	1	3	2	3
Russian Meteorology and Hydrology			4	1
Science Magazine			2	
Science of the Total Environment	10	14	22	3
Solar Energy		2	8	4
Tellus Series A: Dynamic Meteorology & Oceanography			3	
The European Physical Journal Plus (ex "il Nuovo Cimento C")		2	1	
Theoretical and Applied Climatology	11	8	46	6
Transport Research D: Transport & Environment			2	
Urban Forestry and Urban Greening			2	1
Others	88	175	38	10

ICUC-8 in Dublin 6-10 August 2012



The 8th International Conference on Urban Climate will take place in Dublin (Ireland) in 13 months' time. An initial schedule is presented below and it is expected that the first call for papers will be issued at the end of July. The event is planned to accommodate 350-400 participants, of which perhaps a third will be graduate students. Based on previous ICUC events, we hope that the participants will be drawn from diverse academic and professional backgrounds and represent the international nature of urban climate research. The main sponsoring body is of course the IAUC but, on this occasion, the event is co-sponsored by the Board of the Urban Environment, a specialty group within the American Meteorological Society (AMS).

At this stage the basic framework for the event is in place. The meeting will take place on a university campus, which is three miles south of the city centre and is well served by public transport (including regular buses to Dublin Airport). Some accommodation on campus has been set aside and a special rate secured at nearby hotels. The facilities on campus that we will use are modern and consist of both large lecture theatres and small meeting rooms. In addition to the meeting itself, there will be a full programme of events for the evenings and a schedule of daytime events for partners.

At this stage the local organisers are beginning the process of obtaining sponsorship. In the coming months, more details will be presented through the pages of *Urban Climate News* and via the IAUC website. The conference website is www.icuc8.org and this will be regularly updated in the coming months. – *Gerald Mills*

Dublin, August 2012	
First call for papers	July 31
Second call for papers	October 31
Closing date for submission of abstracts	January 31
Abstract review by Scientific Committee	February 31
Extended abstract deadline	May 31
Early online registration	March 31 - May 1
Late registration	June 1 - July 15
Conference Website: www.icuc8.org	

Board Members & Terms

- Toshiaki Ichinose (National Institute for Environmental Studies, Japan): 2007-2011
- Rohinton Emmanuel (Glasgow Caledonian University, UK): 2006-2010; Secretary, 2009-2011
- Petra Klein (University of Oklahoma, USA): 2007-2011
- Sue Grimmond (King's College London, UK): 2000-2003; President, 2003-2007; Past President, 2007-2009*
- Manabu Kanda (Tokyo Institute of Technology, Japan): 2005-2009, ICUC-7 Local Organizer, 2007-2009.*
- Sofia Thorsson (University of Gothenburg, Sweden): 2008-2012
- Gerald Mills (UCD, Dublin, Ireland): 2007-2011; President, 2009-2011
- Tim Oke (University of British Columbia, Canada): President, 2000-2003; Past President, 2003-2006; Emeritus President 2007-2009*
- Matthias Roth (National University of Singapore, Singapore): 2000-2003; Secretary, 2003-2007; Acting-Treasurer 2006; President, 2007-2009; Past-President 2009-2011*
- Jennifer Salmond (University of Birmingham, UK): 2005-2009; Secretary, 2007-2009
- James Voogt (University of Western Ontario, Canada), 2000-2006; Webmaster 2007-*, 2009-2013
- Jason Ching (EPA Atmospheric Modelling & Analysis Division, USA): 2009-2013
- Alberto Martilli (CIEMAT, Spain), 2010-2014
- Aude Lemonsu (CNRS/Meteo France), 2010-2014
- Silvana di Sabatino (Univ. of Salento, Italy), 2010-2014
- David Pearlmutter (Ben-Gurion University of the Negev, Israel): Newsletter Editor, 2009-*

* appointed members

IAUC Committee Chairs

Editor IAUC Newsletter: David Pearlmutter
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 Membership Committee: TBA
 Nominating Committee: Tim Oke
 Int. Representative Committee: TBA
 Chair Teaching Resources: Gerald Mills
 Interim-Chair Awards Committee: Jennifer Salmond
 WebMaster: James Voogt

Newsletter Contributions

The next edition of *Urban Climate News* will appear in late September. Items to be considered for the upcoming issue should be received by **August 31, 2011** and may be sent to editor David Pearlmutter (davidp@bgu.ac.il) or to the relevant section editor:

News: Winston Chow (wchow@asu.edu)

Conferences: Jamie Voogt (javoogt@uwo.ca)

Bibliography: Julia Hidalgo (julia.hidalgo@gmail.com)

Projects: Sue Grimmond (Sue.Grimmond@kcl.ac.uk)

General submissions should be short (1-2 A4 pages of text), written in a manner that is accessible to a wide audience, and incorporate figures and photographs. Images you think would be of interest to the IAUC community are welcome.