# Urban Climate News

*Quarterly Newsletter of the IAUC*

ISSUE NO. 70 DECEMBER 2018 • www.urban-climate.org • INTERNATIONAL ASSOCIATION FOR URBAN CLIMATE


## From the IAUC President

As I begin to write this final column for 2018, the outside air temperature in suburban Melbourne is pushing 42°C as southeast Australia experiences one of its worst early summer heatwaves on record. Following the disturbing trends revealed in the recent IPCC Special Report on Global Warming of 1.5°C, the WMO Climate Statement, and (at least for us in Australia) the Australian State of the Climate 2018 report (https://www.csiro.au/en/Research/OandA/Areas/Assessing-our-climate/State-of-the-Climate-2018/Report-at-a-glance), it is natural for us to think about the significant impacts of climate change on urban environments where, by 2050, close to 70% of the global population will reside.

Interactions between climate change and urban warmth against background trends of more extreme heat events, hotter summer nights, reduced rainfall but greater intensity rainfall events for Australian and for many other cities around the world are of concern for the health of city dwellers, for urban infrastructure, and for the provision of urban services such as water supply and disposal. For this reason, the IPCC has a particular focus on human settlements in the current AR6 round. Our community of urban climate specialists is uniquely equipped to address critical areas of concern, especially in relation to heat mitigation and adaptation, and human thermal comfort. There is still time for our important work to be considered in AR6, with the current cut-off for 'submitted' papers being 1 July 2020 and for 'accepted' papers being 1 May 2021.

I am delighted to welcome **Helen Ward** (University of Innsbruck) and **Matthias Demuzere** (Founder and CEO of Kode) to the Board of the IAUC following our recent election. More details on the election follow below in the newsletter. Helen and Matthias take up their Board Membership in the New Year and replace retiring Members **Edward Ng** (The Chinese University of Hong Kong) and **Fei Chen** (NCAR, USA). I thank these two individuals for their important contributions to IAUC and to its Board in recent years. I also thank the unsuccessful candidates who stood for election. It is testament to the strength of the IAUC that we have quality individuals such as these, who are prepared to nominate. Finally, in relation to the election I would like to thank **Andreas Christen**, **Ariane Middel** and

*Inside the December issue...*



**David Sailor** for their efforts in running the election process.

As usual, we have a terrific edition of *Urban Climate News* put together by **David Pearlmutter** with assistance from **Paul Alexander**, **Helen Ward**, **Joe McFadden** and **Matthias Demuzere**. In particular we have four very nice project/experiment reports along with two special conference reports, one on the "Equity and Diversity in Urban Climate" event at our own ICUC-10, and the other on the recent World Forum on Urban Forests that was held in Italy. I'm sure that you will find plenty of interesting reading within.

Finally, I wish all members of IAUC the very best for the New Year and another successful year of urban climate research/activity.


– Nigel Tapper,
IAUC President
nigel.tapper@monash.edu


# We're almost out of time: The alarming IPCC climate report and what to do next

*October 2018* — The Intergovernmental Panel on Climate Change (IPCC) released a shocking report, "Global Warming of 1.5°C." An equally accurate but more evocative title could have been "We're almost out of time."

It is shocking, not because those working on the science are surprised by the messages (indeed they are all based on existing and published science), but because in aggregate the message is extraordinary and alarming. The diversity and severity of impacts from climate change read like a narrative we might see in a Hollywood movie, but are in fact, and disconcertingly, the clear-eyed projections of where we are heading in reality, barring massive economic mobilization and rapid transition to cleaner technologies.

To provide the first point of context, most people are familiar with the fact that the earth has gone through ice age cycles. During the depths of the last ice age, Chicago was under about half a mile of ice. The difference in global average surface temperature between the depths of the last ice age and today is around 4 to 7 degrees Celsius. While projecting "where we are heading" is complicated, it's fair to say that the momentum of our global economic system is hurtling us toward warming the planet by 3 to 4 degrees – in other words, a climate shift not that different between the last ice age and today.

The new report focuses on what impacts we might expect from even half of that warming, at 1.5 degrees and 2 degrees, and the remarkable story is even at these lowest levels of climate change that we believe are achievable – given that we've already warmed about 1 degree – the impacts are significant and quickly become severe as temperatures reach beyond 1.5 degrees. Other sources, including the interactive graphic in the report summary, detail some of the headline numbers and I will not catalog all of them here. Notable is the likelihood that going from 1.5 to 2 degrees would expose several hundred million people to dangerous climate-related risks by 2050, and would likely wipe out 99 percent of coral reefs. And the scale of the challenge to retool the economy on a short timeline is staggering: the study estimates that global emissions of greenhouse gases need to drop by 45 percent from 2010 levels by 2030 to stay on a 1.5 degrees path. Given dramatic recent increases in emissions, this is equivalent to a roughly 60 percent drop from today's levels, in 12 years.

**How risks increase with temperature, and why 1.5°C?**

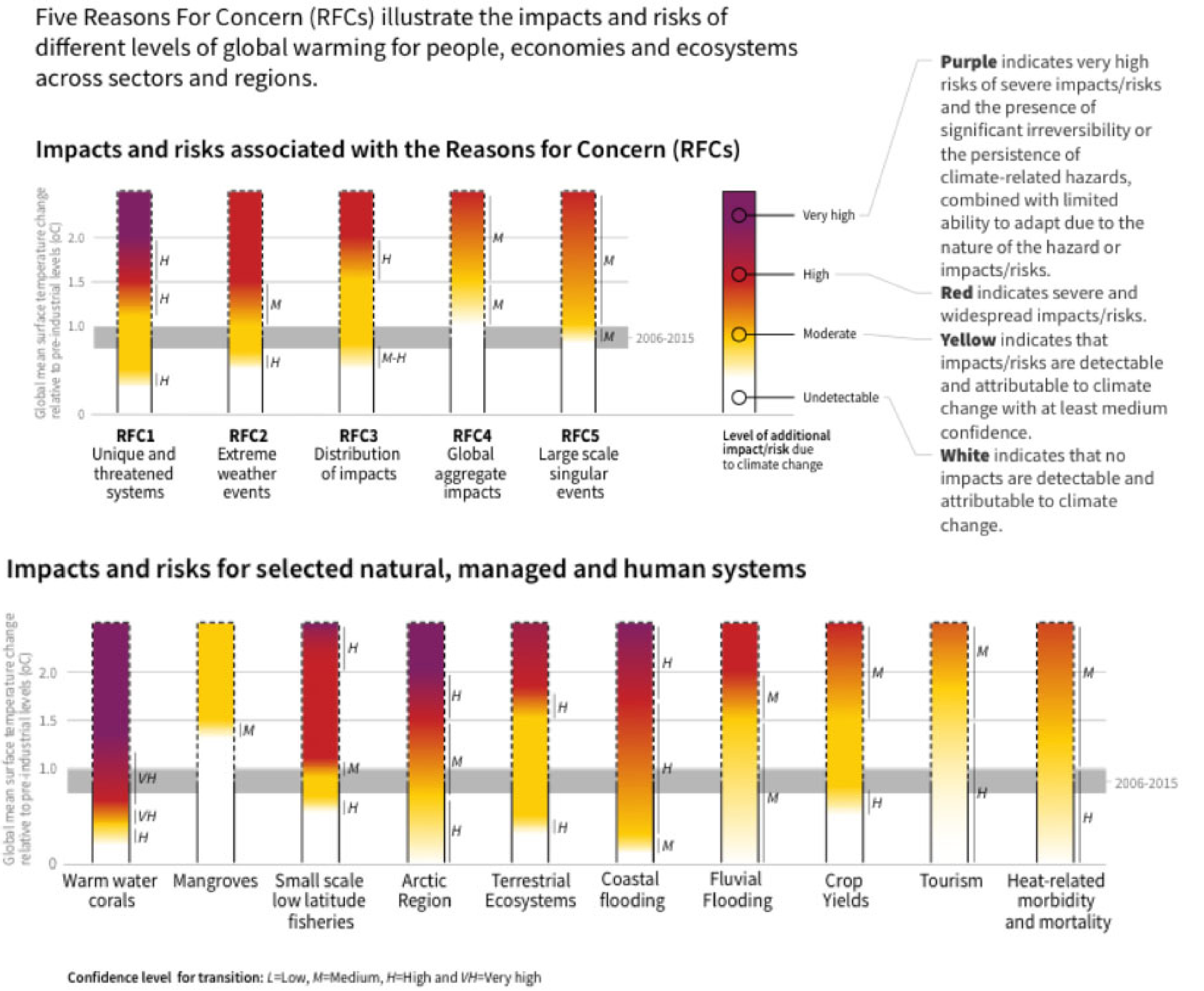
While the headline numbers matter profoundly, so does the fact that this report addresses a fundamental question: How much risk does climate change pose to us as we dial up global temperatures? In other words, as we continue to load nearly 50 billion tons of CO2 equivalent and other climate-changing substances into the atmosphere each year? Will we reach a tipping point?

The report dives into this question in a structured and specific way. First, it looks at impacts of some specific levels of climate change—assessing impacts specifically at 1.5 and 2.0 degrees warming above pre-industrial levels, but also looking at a broader spectrum of possible warming outcomes. It then aggregates and synthesizes what we know from previously published scientific, peer-reviewed, and otherwise vetted literature on how these warming outcomes would affect ecosystems, sea level rise, human health, livelihoods, communities, and more. An important and central aspect of this exercise was to better communicate how each of these risks changes with increasing temperature, asking questions like, "How much more would heavy rainfall events happen in a world of 1.5 degrees warming compared to today, and how much more severe would things get if warming increased to 2 degrees or beyond?"

> *"The only strategy that works is one that fully engages all levels of action … [for example] a coalition of over 3,500 cities, states, businesses, and more, have recommitted to doing their part to achieving the goals of the Paris Agreement."*

It's worth pausing to understand the seemingly odd concept of "1.5 degrees" which gives the report its title. Why 1.5? The origins are in the original international treaty on climate change, the 1992 Framework Convention on Climate Change. This treaty (which was negotiated under the George H.W. Bush administration), recognized the importance of climate change and set up a process for the international community to begin to address it. The core principle of the international approach to climate, formally embedded in that agreement, was "to avoid dangerous anthropogenic interference in the climate system."

It was left to future science and policy discussions to work out what exactly "dangerous" means. In any case, what eventually emerged is a consensus on the need to understand how risks of climate change increase as temperatures rise. As these discussions unfolded, it also became clear that different kinds of risks – such as sea level rise, risks to ecosystems, risks of tipping points, and risks to human systems – could have slightly different sensitivities to global warming, and thus such concepts were disaggregated and evaluated separately.




**The "Reasons for Concern" figure from the IPCC report "Global Warming of 1.5 Degrees C." Note that the planet in 2018 is already in the grey shaded area of about 1°C warming above pre-industrial levels. *Source:* www.ipcc.ch/report/sr15/**

The resulting concept was graphically depicted in a now well-known figure from the IPCC Third Assessment Report in 2001. While formally titled "Reasons for Concern," the vivid yellow, orange and red colors on the figure earned it the nickname of the "Burning Embers diagram." It went through several refinements as new science was developed, but was importantly the foundation for a discussion across government and civil society to narrow in on a more formal definition of dangerous. Based on the understanding at that time of risks, uncertainties, and potential impacts, this discussion increasingly cohered around the concept that there appeared to be more extreme and significantly worrying risks—across all of the categories—beyond about 2 degrees of warming. By the time of the Copenhagen U.N. Climate Change Conference in 2009, the international community formally adopted keeping warming to under 2 degrees.

Yet even as the consensus for 2 degrees was crystallizing, questions arose about whether the 2 degrees goal might be too high. On the one hand, additional published science bolstered confidence in impacts at lower warming levels, and indicated the possibility that impacts might be more broad and severe than originally thought. In addition, discussions in the broader international community grappled more directly (if not completely) with issues of equity and ethics and how those ought to relate to this core risk assessment. It's a fascinating and important story, but the upshot was an was an embedding of a 1.5 degree goal at the beginning of the landmark 2015 Paris Agreement: "Holding the increase in the global average temperature to well below 2 degrees above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 degrees above pre-industrial levels." As a direct result of the Paris Agreement, the international scientific body of the IPCC was asked to evaluate and report on our understanding of the difference between 1.5 degrees and 2 degrees, and what it would take to get onto a global path to keep warming under 1.5 degrees.

That is where the new IPCC report comes in. The report evaluates both quantitatively and qualitatively how much the risks rise as temperature increases. The short answer to these questions in the report is something like this: We're already at 1 degree warming and seeing some significant impacts; 1.5 degrees is going to have more severe impacts; 2 degrees has more; and we probably don't want to test what happens above 2 degrees – although our current momentum appears to have us on a trajectory for about a 3 degrees or more world.

In the new report, the updated Reasons for Concern figure shows a broad feature of increasing risks above 1.5 degrees across both the five reasons at the top and the new, even more disaggregated system assessments on the bottom row. Beyond the diagram, the report offers plenty of granular detail, for example, estimating how much additional habitat would be lost when moving from 1.5 to 2 degrees, or how many more ice-free summers the Arctic would have. Some of them are surprisingly sharp increases for half a degree—such as the estimate that the percent of global population exposed to extreme heat at least once every five years rises from 14 percent to 37 percent, or the estimate that coral reefs would degrade "only" an additional 70-90 percent under 1.5 degrees but 99 percent in a 2 degrees world. These are sobering because 2 degrees itself remains a hard-to-achieve goal and warming beyond 2 degrees would have even greater consequences. I won't exhaustively detail the other impacts as they have been centrally featured in much coverage of the report, so I refer you to those sources or to the report itself.

**Pathways to manage risks: Can we keep under 1.5°?**

While it is vital to understand the risks with different levels of warming, an equally urgent question is whether and how the planet can get onto an emissions trajectory that would keep on a 2 degrees or, if at all possible, a 1.5 degrees path. There are a few key aspects of this challenge: a dramatic retooling of the global production and consumption toward low or zero greenhouse gas approaches by roughly 2030; a likely build out of untested carbon removal technologies at large scales toward mid-century; and widespread measures to adapt to climate change.

The IPCC report illustrates several approaches that could achieve 1.5 degrees with limited "overshoot" (i.e., going above 1.5 and then back down). Coal power would have to drop by 60-80 percent from 2010 levels by 2030. Renewable energy sources would grow by roughly 100-500 percent, reaching about half of total global electricity generation by 2030 (again, 12 years from now), and 70-90 percent by 2050. These features and others are laid out in detail in an information-rich figure. The overall message is that the math can actually work, but the mechanism for realizing such rapid and dramatic transformations is, well, just not part of the report, and of course is the biggest question of all. In other words, the report tells us that these pathways are physically and technologically possible, but it is up to us to figure out what social and political approaches we have to take to implement those pathways.

So, the answer of "can we do it" is yes, technically. But if we are to do it, how can we do so? Clearly the problem is massive. Such large and complex problems certainly require transformational thinking, integration, and big movements. But tackling this problem will also require progress on myriad smaller and manageable elements.

> *"Many of our best and brightest are inspired to work on new energy and climate-friendly technologies and institutional approaches. Refocusing on building this technological innovation apparatus, educating students globally in relevant fields, providing the right structure for early stage financing, and bringing these technologies to market is a core part of the solution."*

The scale and speed of the technological transition is extraordinary but plausible. For example, individual technologies have undergone rapid transitions before. The first iPhone was revealed only 11 years ago—there was no such thing as an app in early 2007. Automobiles went from less than 1 percent of road vehicles in the United States in 1900 to nearly 100 percent thirty years later. While some technologies do not lend themselves to rapid replacement, the general principle is that relatively rapid transformational change is feasible in many applications. In addition, the IPCC report notes that, while the scale and duration of mobilization is unprecedented, the speed of mobilization is not, recalling the efforts in the United States to mobilize for World War II.

The social organizing (or political) challenge – how we collectively change behavior and make dramatically different choices – is the most daunting. There are certainly many reasons to be pessimistic about our collective ability to drive broad and significant change, for example, if we frame the problem around concepts like convincing voters (or politicians) to invest now for a future payoff. And national level leadership in some key countries – the U.S., Australia, and perhaps soon Brazil – is driving against climate action. Nevertheless, a few alternate framings can be helpful:

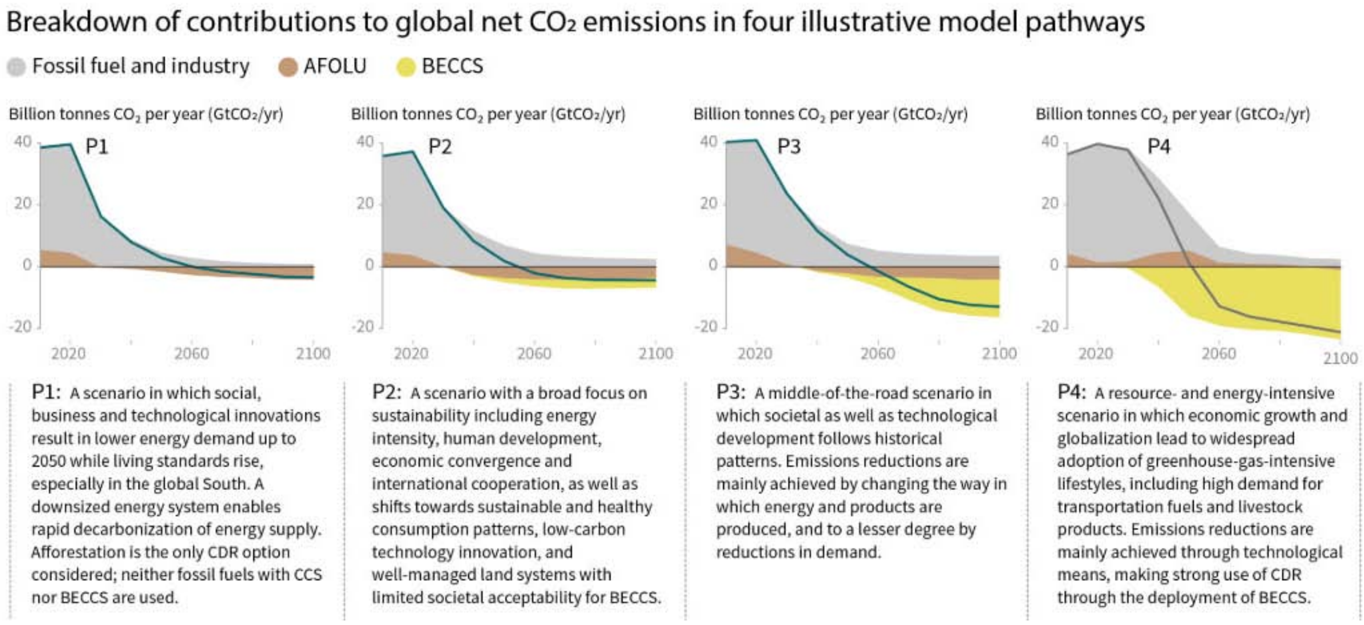



**Figure showing pathways to 1.5°C from the IPCC report "Global Warming of 1.5 Degrees C." There are four different illustrative scenarios, but with common features of rapid technological transition toward zero or low-emissions.** ***Source:*** **www.ipcc.ch/report/sr15/**

**Economic Growth.** Many studies have pointed out the economic growth benefits that accrue from such transitions. Clean energy provides jobs and in many cases more jobs than dirtier technologies. Clean air and a green environment are healthier for people. The recent New Climate Economy report estimated that a widespread, full investment in a clean economy transition would lead to a net $26 trillion in benefits by 2030.

**Innovation.** Technology is a real part of the solution to climate change, and we have developed a global innovation infrastructure that is by any standard impressive. Many of our best and brightest are inspired to work on new energy and climate-friendly technologies and institutional approaches. Refocusing on building this technological innovation apparatus, educating students globally in relevant fields, providing the right structure for early stage financing, and bringing these technologies to market is a core part of the solution.

**We are on a path.** This pathway is not new, and we have already begun the transition. Renewable energy deployment has shown remarkable progress, surpassing expectations and surprising analysts. Since 2012, more than half of new electricity power additions have been renewables. The cost of solar has fallen over 70 percent since 2010 and combined renewable costs are falling so rapidly that they are expected to be competitive or cheaper than fossil fuels by 2020. So, progress is already happening, in clean energy and many other areas relating to climate stabilization – it's just that we need to go faster and do more, which requires choices and policy.

**All Hands.** The only strategy that works is one that fully engages all levels of action, which includes personal actions but also includes policy and decisionmaking in all other communities and groups: cities, towns, counties, states, countries; places of work; businesses and investors; universities; communities of faith, and more. Each of these has ways they can address the issue. One recent example of this is here in the U.S., where a coalition of over 3,500 cities, states, businesses, and more, have recommitted to doing their part to achieving the goals of the Paris Agreement. A recent study that I helped lead indicated that this coalition, representing over 50 percent of the U.S. population, nearly 60 percent of U.S. GDP, and equivalent to the world's third largest economy – could drive U.S. emissions down by roughly 24 percent by 2025 relative to 2005 levels. Such engagement, while not yet enough, can help build the groundwork for the accelerated ambition that the report calls for. And it underscores that elections and political choices will matter greatly over coming years in the United States and globally.

The IPCC report crystallizes what we already knew about the risks of climate change and throws the challenge into stark relief. The scale and speed of transformation will require not just new technologies but innovation on new models to organize ourselves and our investment response. Nevertheless, a real and deep-rooted engagement with this issue could realize a genuinely improved quality of life in all parts of the world, with dramatically better outcomes on human well-being, economic growth, and health. That opportunity is there today, and the report calls us to grasp it.

— *Nathan Hultman. Source:* https://www.brookings.edu/opinions/were-almost-out-of-time-the-alarming-ipcc-climate-report-and-what-to-do-next/

# What was agreed at COP24 in Poland and why did it take so long?

*December 2018 — Fractious UN climate change talks ended with a deal on putting the Paris agreement into practice – but left much else unresolved*

**What was agreed at COP24?**

Countries settled on most of the tricky elements of the "rulebook" for putting the 2015 Paris agreement into practice. This includes how governments will measure, report on and verify their emissions-cutting efforts, a key element because it ensures all countries are held to proper standards and will find it harder to wriggle out of their commitments.

**Why did it take so long?**

There was a row over carbon credits, which are awarded to countries for their emissions-cutting efforts and their carbon sinks, such as forests, which absorb carbon. These credits count towards countries' emissions-cutting targets. Brazil, which hopes to benefit from its large rainforest cover, insisted on a new form of wording that critics said would allow double counting of credits, undermining the integrity of the system. This issue has been put off until next year.

**What wasn't agreed?**

Largely absent from these talks, which had a technical focus, was the key question of how countries will step up their targets on cutting emissions. On current targets, the world is set for 3C of warming from pre-industrial levels, which scientists say would be disastrous, resulting in droughts, floods, sea level rises and the decline of agricultural productivity.

**When will that be agreed?**

The key deadline is 2020, when countries must show they have met targets set a decade ago for cutting their emissions, and when they must affirm new, much tougher targets.

**What does the science say?**

The Intergovernmental Panel on Climate Change (IPCC), the global body of the world's leading climate scientists, warned two months ago that allowing warming to reach 1.5C above pre-industrial levels would have grave consequences, including the die-off of coral reefs and devastation of many species.

**How long have we got?**

If we extrapolate from the IPCC's findings, the world has little more than a decade to bring emissions under control and halve them, which would help to stabilise the climate.

**Are we getting there?**

After years in which the world's carbon emissions appeared to be stabilising, they are on the rise again. Coal use continues and oil is still the engine of much of the world's economy. Clean energy is coming on-stream at a faster rate than many predicted, and the costs of it have come down rapidly, but its adoption needs to be speeded up.

Infrastructure, such as energy generation plants, transport networks and buildings, is a central issue: infrastructure built now to rely on high-carbon energy effectively locks in high emissions for decades to come. Some people are also saying we need to invest in projects to remove carbon from the atmosphere, and a new focus of the talks is helping countries to adapt to the effects of climate change.


**Iran's Majid Shafiepour Motlagh, China's Xie Zhenhua and the COP24 president, Michal Kurtyka, smile after adopting the final agreement at the COP24 UN climate change conference 2018 in Katowice, Poland.** *Source:* theguardian.com**. Leaders were told by naturalist** David Attenborough: 'Continuation of civilisation is in your hands.'

**Were countries united at the talks?**

The US, Russia, Saudi Arabia and Kuwait joined forces to prevent the conference fully embracing the IPCC's findings, watering down a statement to a weak commendation of the timing of the scientists' report. Australia joined with the US in a celebration of coal, and Brazil signalled its climate scepticism under Jair Bolsonaro by withdrawing its offer to host next year's talks.

But the EU, a handful of other developed countries and scores of developing nations including the poorest and most vulnerable affirmed that they would strive to meet the IPCC's advice on limiting warming to no more than 1.5C.

**What happens next?**

The UN will meet again next year in Chile to thrash out the final elements of the Paris rulebook and begin work on future emissions targets. But the crunch conference will come in 2020, when countries must meet the deadline for their current emissions commitments and produce new targets for 2030 and beyond that go further towards meeting scientific advice.

That conference may be held in the UK or Italy, both of which have bid to be hosts. The UK's intention in offering to host is to signal it will retain its role on the world stage after Brexit. The event may also provide a welcome change from wranglings over Brexit and intractable trade deals. But whoever hosts will have a diplomatic mountain to climb, if the fractious nature of this year's talks is anything to go by. *Source:* https://www.theguardian.com/environment/2018/dec/16/what-was-agreed-at-cop24-in-poland-and-why-did-it-take-so-long

# As Storms Keep Coming, FEMA Spends Billions in 'Cycle' of Damage and Repair

*October 2018 —* In the exact spot where Hurricane Katrina demolished the Plaquemines Parish Detention Center, a new $105 million jail now hovers 19 feet above the marsh, perched atop towering concrete pillars. Described by a state official as the "Taj Mahal" of Louisiana corrections, it has so much space that one of every 27 parish residents could bunk there.

But on an average day in the first half of this year, more than 40 percent of its 872 beds went unoccupied, making it one of the emptiest jails in the state, records show. And because of its isolated, flood-prone location, the jail still must be evacuated before any major storm or risk becoming an accidental Alcatraz.

There is but one reason the Plaquemines jail was rebuilt on endangered land, with needless capacity, at immense cost: The sheriff wanted it that way. But unlike most new jail construction, his project did not have to be financed through bond sales or other local revenues, with voters able to hold him accountable. Rather, because the old jail was destroyed by a natural disaster, the cost was covered by federal taxpayers, through a Federal Emergency Management Agency program that is required by law to distribute billions in aid but exerts little control over how the money is spent.

FEMA's public assistance program has provided at least $81 billion in this manner to state, territorial and local governments in response to disasters declared since 1992, according to a New York Times analysis of federal data. But an examination of projects across the country's ever-expanding flood zones reveals that decisions to rebuild in place, often made seemingly in defiance of climate change, have at times left structures just as defenseless against the next storm.

Other efforts have required enormously expensive engineering to ensure protection. Yet in some instances, restrictions on construction in flood plains have effectively prohibited FEMA from safeguarding its multimillion-dollar investments in new and repaired public buildings.

One of every five public assistance dollars has streamed here to this quintessentially vulnerable place, Louisiana — by far the most per capita of any state. But billions more will soon flow from Washington to the states and territories devastated by the ferocity of the past two hurricane seasons. Last year, estimated to be the costliest ever with $306.2 billion in damage, saw back-to-back assaults by Harvey on Texas, Irma on Florida, Maria on Puerto Rico and Nate on Mississippi. Last month, Florence submerged the Carolinas, damaging public structures ranging from a high school in Jacksonville, N.C., to the town hall in North Topsail Beach.

Local officials desperate to restore normalcy to disoriented communities will get to decide how to spend those federal dollars — choices made more consequential, and costly, as sea levels rise and Atlantic storms generate greater surge and rainfall because of climate change. What once seemed random climatic misfortune now occurs more predictably. Coastal scientists and disaster recovery experts agree that if rebuilding in the same place once dared lightning to strike twice, it now tempts a more certain fate.

**The Plaquemines Parish Detention Center was rebuilt for $105 million in a Louisiana marsh that had been ravaged by Hurricane Katrina. *Source:* nytimes.com**

"Human settlements have been designed in a way that reflects a climate of the past, and this increases the likelihood that disaster-related losses will continue to rise," said Gavin Smith, a professor at the University of North Carolina at Chapel Hill who directs the Coastal Resilience Center of Excellence, a research consortium funded by the Department of Homeland Security. "This also means we need to rethink how and where we build before the storm, as well as how and where we reconstruct public buildings and infrastructure in the aftermath of extreme events."

For evidence, visit Princeville, N.C., a town of 2,000 on the Tar River. In 1999, a hurricane named Floyd engorged the river until it spilled over a levee, ruining the town hall, Princeville Elementary School, the police and fire station, the senior center and virtually every other structure. "I thought, 'Once in a lifetime,'" said Mayor Bobbie Darnell Jones, who was rescued from his house by helicopter.

Leaders of the town, which was settled by newly emancipated slaves, rejected suggestions from state officials to move the entire community to higher ground. Instead, FEMA spent more than $5 million in public assistance grants to clear debris, build a new town hall and school, repair other buildings and replace fire trucks, a garbage truck, even a riding lawn mower, the agency's records show.

Seventeen years later, Hurricane Matthew swamped Princeville once again. Repairs are now being made to the school, the fire house, the town hall, the recreation center, the senior center and a museum, at a cost of $2.5 million and counting (the town typically pays a 25% share). In mid-September, Princeville narrowly missed its third inundation in two decades, when Florence filled the Tar just shy of flood stage.

Since at least 1950, an empathetic nation has supported the impulse to rebuild in place by financing much of the cost of disaster recovery through the federal budget. But the process adheres to the American conviction that, regardless of who pays, decisions about land use and infrastructure should be made as locally as possible.

With local officials often incentivized to replicate the past, experts in disaster relief say changes in federal law and regulations may be needed to reorient the system to reflect climate realities.

Yet the Trump administration, if anything, is moving in the opposite direction. In August last year, President Trump rescinded an executive order signed by President Barack Obama that required consideration of climate science in the design of federally funded projects. In some cases, that had meant mandatory elevation of buildings in flood-prone areas. Then in March, FEMA released a four-year strategic plan that stripped away previous mentions of climate change and sea-level rise.

Despite repeated requests over five months, FEMA's public affairs office declined to make the agency's embattled administrator, Brock Long, or other top policymakers available for comment. Mr. Long has come under fire recently for using government vehicles for personal travel, and FEMA has been heavily criticized for its response to Hurricane Maria, which Puerto Rico estimates took nearly 3,000 lives.

The Trump administration's approach on climate change ignores loud warnings from government agencies about the budgetary threat it poses. The bipartisan Congressional Budget Office projected in 2016, for instance, that hurricane damage would "increase significantly in the coming decades because of the effects of climate change and coastal development." As a result, government spending for relief and recovery will outpace economic growth and devour an ever larger share of gross domestic product, the analysts concluded.

"You can't continue this with the pace and intensity of events we've seen today," said James Lee Witt, who led FEMA throughout the Clinton administration. "Somebody has got to break the cycle of damage, repair, damage, repair."

**Accepting the Inevitable**

FEMA's public assistance program is among the largest in a menu of post-disaster programs overseen by several federal agencies. It has grown substantially more costly over time. From 1992 through mid-September, it paid for 683,035 separate projects — removing debris after natural disasters (mostly hurricanes and floods) and repairing and reconstructing public buildings, roads, bridges and utilities — according to a computer analysis of agency data by The Times. More was spent on public assistance during that period than on reimbursements by FEMA's better-known National Flood Insurance Program, which covers losses by homeowners and businesses.

Grants have gone to every state and territory, with New York and Louisiana the biggest recipients because of Hurricane Sandy in 2012 and Hurricanes Katrina and Rita in 2005. About a fourth of the money has been used to repair and replace public buildings.

**Homes submerged after Hurricane Floyd struck Princeville, N.C., in 1999. *Source:* nytimes.com**

In most instances, grants cover at least 75 percent of the cost to return a damaged building to its prior state while also complying with current codes. If the cost of repair is more than half that of replacement, FEMA will pay to build anew. The program also provides grants for hazard mitigation to minimize future damage.

When structures in designated flood plains are rebuilt or repaired, FEMA requires that they be elevated to at least the 100-year flood level — high enough, that is, to withstand a storm with only a 1 percent chance of occurring in a year. Buildings that serve a critical function, like hospitals or power plants, must be raised to the 500-year level.

The agency can pay to relocate destroyed buildings if it is deemed cost-effective, but it often isn't. In New York City, FEMA spent more than $700 million — with the city pitching in $80 million more — to repair 72 schools damaged during Sandy. But the city's high cost of real estate and construction dictated that only one would be moved, to an adjacent site where it will be elevated, according to the Mayor's Office of Recovery and Resiliency. Instead, the money was spent on measures that accepted the inevitability of future flooding, like raising vents, relocating electrical systems to rooftops and replacing drywall with building materials that could be easily dried and disinfected.

Since Sandy, Congress has twice amended the law that authorizes federal disaster aid, the Stafford Act, to make it more financially attractive to use public assistance grants to relocate and to rebuild more responsibly. Mr. Trump signed a bill last week to provide more FEMA funding for projects designed to diminish future storm damage in vulnerable communities. None of those measures, however, fundamentally alters the balance of power between federal and local officials concerning those decisions.

Determining how much has been spent to rebuild the same structures more than once is impossible, because of a lack of transparency in publicly available data. FEMA's records provide a location for the grant recipient, a project number and an amount, but often only vague descriptions like "public buildings and facilities."

But the Natural Resources Defense Council, an environmental advocacy group, recently found that the separate flood insurance program had paid $5.5 billion from 1978 to 2015 to repair and rebuild more than 30,000 properties that had flooded more than once. Claims for those residences and businesses had been submitted an average of five times.

The group's report estimated that the number of "severe repetitive loss properties" could balloon to 820,000 if coastal sea levels rose three feet by the end of the century, which scientists consider possible. It recommended that the government restructure the program with incentives to encourage owners to take buyouts and move.

Critics see both FEMA programs as symptomatic of a disjointed and backward-looking approach to disaster planning that devotes inordinate resources to rebuilding at the expense of prevention.

"The fundamental problem is that the entire system is reactive," said Jeff Hebert, vice president for adaptation and resilience at the Water Institute of the Gulf, a Louisiana-based research group. "It would be transformational if we took the money that we spend on disasters and instead spent it on the front end on really good adaptation."

**A Tangle of Red Tape**

Among Hurricane Katrina's victims was Lakefront Airport in New Orleans, a general aviation airport built on a jut of land reclaimed from Lake Pontchartrain. Politics drove the selection of the site in the 1930s, but it seemed a good enough idea. The airport would be close to the city center and could accommodate seaplanes, a popular mode of passenger transportation at the time.

The classic Art Deco terminal, a working monument to the romance of flight, wowed travelers when it opened in 1934. Eight murals of exotic destinations ringed the second floor of a grand atrium, their locations corresponding to the directions on a compass rose inlaid into the terrazzo floor. Three years later, Amelia Earhart slept in the visiting pilots' quarters on her way to California for her final journey.

In 1964, the terminal acquired a Brutalist concrete cladding that made it usable as a Cold War fallout shelter, and its glamour faded. But after Katrina flushed four feet of water through the building, the authority that runs the airport decided to restore its prior glory.

It found a willing partner, up to a point, in FEMA, which provided $68.8 million in public assistance grants to repair the airport and its grounds, according to authority officials. That included $20 million for such a lush renovation of the terminal that it is booked regularly for charity galas and debutante balls.

And yet, despite FEMA's substantial investment, the agency has been stymied by its own rules from taking steps to prevent a recurrence in the next big storm.

The airport is not much more protected from Pontchartrain's storm surge than before. Parts are buffered only by a low bulkhead because of fears that a higher one might interfere with takeoffs and landings.

In 2015, the airport's operator, known as the Non-Flood Asset Protection Management Authority, asked FEMA to provide an additional $65 million to build a pump system and movable flood wall that could be put into place before storms. FEMA refused, arguing in part that it would qualify as new construction, which the agency said it could not pay for in certain designated flood zones.

**Homes and fields in Plaquemines Parish that were flooded during Hurricane Katrina. *Source:* nytimes.com**

The airport authority lost its appeal of that decision in July by the 2-to-1 vote of a federal arbitration board. In dissent, the chief judge, Jonathan Zischkau, wrote that the decision "leaves the entire airport facility — and a considerable number of people — at risk and unprotected from future hurricanes and flood disasters.

Wilma Heaton, the chairwoman of the authority, said she was determined to continue searching for funds, but considered FEMA's position nonsensical.

"Storm after storm, we know what happens without adequate flood protection," Ms. Heaton said. "Not addressing it is insanity."

**Vanishing Territory**

Few places have benefited from FEMA's largess like Plaquemines Parish, which protrudes southeast from the New Orleans suburbs into the Gulf of Mexico. And few places better embody the costly contradictions of rebuilding on endangered land."

Plaquemines was pummeled by Hurricanes Katrina and Rita in 2005 and again by Hurricane Isaac in 2012. Since 2000, FEMA has routed $902.1 million in public assistance grants to the parish for 1,000 separate projects, the Times analysis found, an average of $38,637 for each of the 23,348 current residents. That is barely less than the assessed value of all taxable property.

But the parish's susceptibility to rising sea levels and subsidence is high. The United States Geological Survey calculates that 462 square miles of Plaquemines disappeared into the Gulf between 1932 and 2008. The state's coastal planners project that 55% of what's left – another 300 square miles – will disappear within 50 years without significant action.

With the exception of the New Orleans bedroom community of Belle Chasse, the parish consists largely of two narrow strips, bordered by levees, on either bank of the Mississippi River. Floodwater breached and topped the 16-foot mounds during Katrina, but they have since been repaired and fortified. Nonetheless, state scientists project that in the case of a 100-year storm, most of the parish outside Belle Chase would be submerged at least 13 feet.

A fifth of the Plaquemines population left after Katrina, according to census estimates. But because FEMA will pay to rebuild to prior size and capacity, those changes have not always factored much into recovery planning.

FEMA allowed the Plaquemines school board to consolidate and restructure its system after Katrina, including eliminating one of eight schools. But it nonetheless spent nearly $100 million to rebuild three schools on the west bank, and another $36 million to rebuild Phoenix High, the only one on the east bank.

Like the jail, the new schools are engineering marvels, red brick fortresses raised more than 20 feet on a forest of columns. But some are clearly larger than needed. Phoenix was designed to accommodate 400 students from prekindergarten through 12th grade, but enrolled only 190 this fall, according to the school board. An average of 13 seniors have graduated each year since it reopened in 2012.

School board officials said they had not been willing to bus students long distances to Belle Chasse or across the river by ferry. "We're obligated to provide an education for the people who are here," said Ronald E. White Jr., the chief financial officer. "It's not our job to say you can't live here."

"Plus we wanted to rebuild our communities," said Denis Rousselle, the superintendent. "People would not come back if you didn't have schools."

FEMA provided enough money to replace damaged contents that the system was able to refurnish even the schools that were not destroyed, Mr. Rousselle said. "They've been so generous with us," the superintendent said. "I've been elated with it."

**A Lack of Leverage**

Even before Katrina made landfall nearby, the Plaquemines jail did not come close to filling its more than 800 beds. The average population was 395 in 2004 and 274 in 2003, according to reports obtained through an open records request. But that did not stop the sheriff at the time, Irvin F. Hingle Jr., known as Jiff, from insisting that the jail be rebuilt at the same capacity on the same site.

John Connolly, a senior public assistance adviser in FEMA's Louisiana Recovery Office, tried to persuade Mr. Hingle to make the jail smaller and move it to higher, more accessible ground. "They were not receptive to that and largely that was the end of it, sadly," Mr. Connolly recalled. "We really did not have the leverage to insist on it."

Because the jail site sits in a flood zone, FEMA could require that the 207,000-square-foot building be built atop columns, but not that it be moved, explained Thomas M. Womack, the director of the recovery office. "That's just what our regulation and policy call for," he said.

Mr. Hingle is not available to explain his thinking. He died this year at age 66 after serving a federal prison term for taking bribes from the jail's construction manager.

Those who knew and worked with him, including his successors and other parish officials, said Mr. Hingle had hoped to revive the devastated economy on the east bank, his political base. Additionally, they said, the sheriff viewed the jail as a profit center that supported his other operations and thus expanded patronage.

Essential to his success was his ability to win contracts with federal agencies that paid top rates to house their detainees. Mr. Hingle had a deal with the Department of Homeland Security to hold up to 220 immigration and customs detainees at a daily rate of $47.19 per inmate, records show. That is almost double the paltry $24.39 paid by the state and parish.

Things changed after Katrina forced the jail's evacuation. The federal agency now opts not to house inmates in Plaquemines, or anywhere else south of Lake Pontchartrain, said Bryan D. Cox, a spokesman for Immigration and Customs Enforcement.

Mr. Hingle, as it turns out, also made a shortsighted bet. As elsewhere, the prison population in Louisiana began to decline, enough that it recently ceded the top state incarceration rate to Oklahoma. Partly because of sentencing reforms, the number of offenders in state and local prisons dropped to 35,001 last year from a peak of 40,170 in 2012.

The state corrections system, which uses local jails to relieve crowding, nonetheless remains the Plaquemines jail's primary supplier. The current sheriff, Gerald A. Turlich Jr., also secured a contract with the United States Marshals Service. While the jail's average monthly census grew to 548 in the second quarter from fewer than 100 when it opened in 2015, only one in seven are there on local charges.

"Two hundred beds would have been fine, and you would have saved a lot of federal taxpayer dollars," said Lonnie Greco, who won the sheriff's job after Mr. Hingle's indictment (and then lost it to Sheriff Turlich). "At one time it was a thing to build big prisons to make money, but that time is gone."

The detention center is not so elevated that it would necessarily stay dry in another Katrina. But it was built of thick precast concrete to withstand a major storm, with backup generators and raised water tanks and circuitry, along with basketball courts, roomy living pods, more than 600 security cameras, biometric entrance scanners and video screens that inmates can use to talk to family members via Skype.

The cost of the project escalated from less than $20 million, when the plan was to replicate the old jail at ground level, to more than $100 million once FEMA ruled that the new one would have to be elevated if rebuilt in place. Jamie Saxon, the president of Morphy, Makofsky, the New Orleans engineering firm that helped design the jail and schools, estimated that the elevation and hardening of those buildings "added a 35 to 40 percent premium."

"It seemed an awfully expensive choice," he said.

Sheriff Turlich said that when he took over in 2016, the maintenance and operation of the all-but-empty jail was draining $2 million from the department's $25 million budget. To help bring it into balance, he raised property tax rates by 8 percent. *Source:* https://www.nytimes.com/2018/10/08/us/fema-disaster-recovery-climate-change.html

# Visual data: Every major city in Europe is getting warmer

*September 2018* — In December 2015, 195 members of the United Nations Framework Convention on Climate Change agreed to "limit the temperature increase to 1.5°C above preindustrial levels" in the Paris Agreement. For several cities in Europe - home to millions - the 1.5°C threshold has already been reached.

An exclusive investigation by the European Data Journalism Network (EDJNet) shows that in the Nordic and Baltic regions, in much of Andalusia and in south-eastern Romania, average temperatures in the 21st century were already much warmer, sometimes by more than 1.5 degrees, than in the 20th century, already affecting the life expectancy of Europeans, their health and well-being.

The 1.5°C temperature increase is a global threshold and areas that are warming faster are not off-track from this goal; scientists have expected for decades that polar regions would warm more than areas closer to the equator.

In Granada, Cordoba and Malaga, all Andalusian cities, the average yearly temperature in the 21st century was at least 1.5°C higher than in the 20th century. In Bucharest, capital of Romania, temperatures increased by 1.4°C. The increase relative to pre-industrial levels, a period often considered to be 1850–1900, is likely higher. By contrast, cities on the Atlantic shore saw the least amount of warming.

These findings are the result of an analysis of over 100 million data points made available by the European Centre for Medium-Range Weather Forecasts (ECMWF), an international organisation which computes so-called "re-analyses" of weather data, based on a variety of sources such as weather stations, weather balloons, buoys and satellite observations.

This is the first time reanalysis data is made easily accessible on this scale. Such data is well-suited to study weather patterns over periods spanning over a century, because it harmonises inputs from thousands of data sources and makes comparisons in time and space possible.

While absolute values might differ from data collected at weather stations directly, especially because cities suffer from the "heat island effect", meaning that temperatures within the cities can be up to 10°C higher than in their surrounding countryside, the overall trends are the same.

Looking at daily data, EDJNet was able to show how the number of hot and cold days varied over the last 117 years. In Split for instance, the second-largest city in Croatia, the number of days where the average temperature reached 27°C went from six per year in the 20th century to 14 per year in the 21st.

Conversely, the number of cold days decreased in most cities. In the Latvian capital Riga, the number of days where the average temperature was below -1°C went from 75 per year in the last century to 57 in the 21st. Such detailed information allows for a precise assessment of the local impact of temperature change.

**Longer droughts, more heatwaves**

Even limited to a couple of degrees or less, temperature increases can have severe consequences, said Mojca Dolinar, head of the department of climatology at the Slovenian Environment Agency, a government body.

**This summer, Europe experienced the effects of global warming at first hand. *Source:* euobserver.com**

A hotter atmosphere can absorb more water before releasing it in the form of rain, he explained. This implies that periods between rainy episodes become longer and droughts more severe.

On the other hand, rainfall, because of the higher concentration of water in the atmosphere, tends to be more concentrated, leading to more severe floods.

Higher temperatures, especially heatwaves, were responsible for several thousands deaths since 2000. The 2003 heatwave resulted in over 70,000 extra deaths in the western half of the European continent.

Despite the enactment of national heat plans in several countries, a review of the link between heat and mortality in nine European cities showed that, although excess mortality decreased in Paris, Rome and Athens since 2003, higher temperatures still cause excess deaths, not only in southern cities.

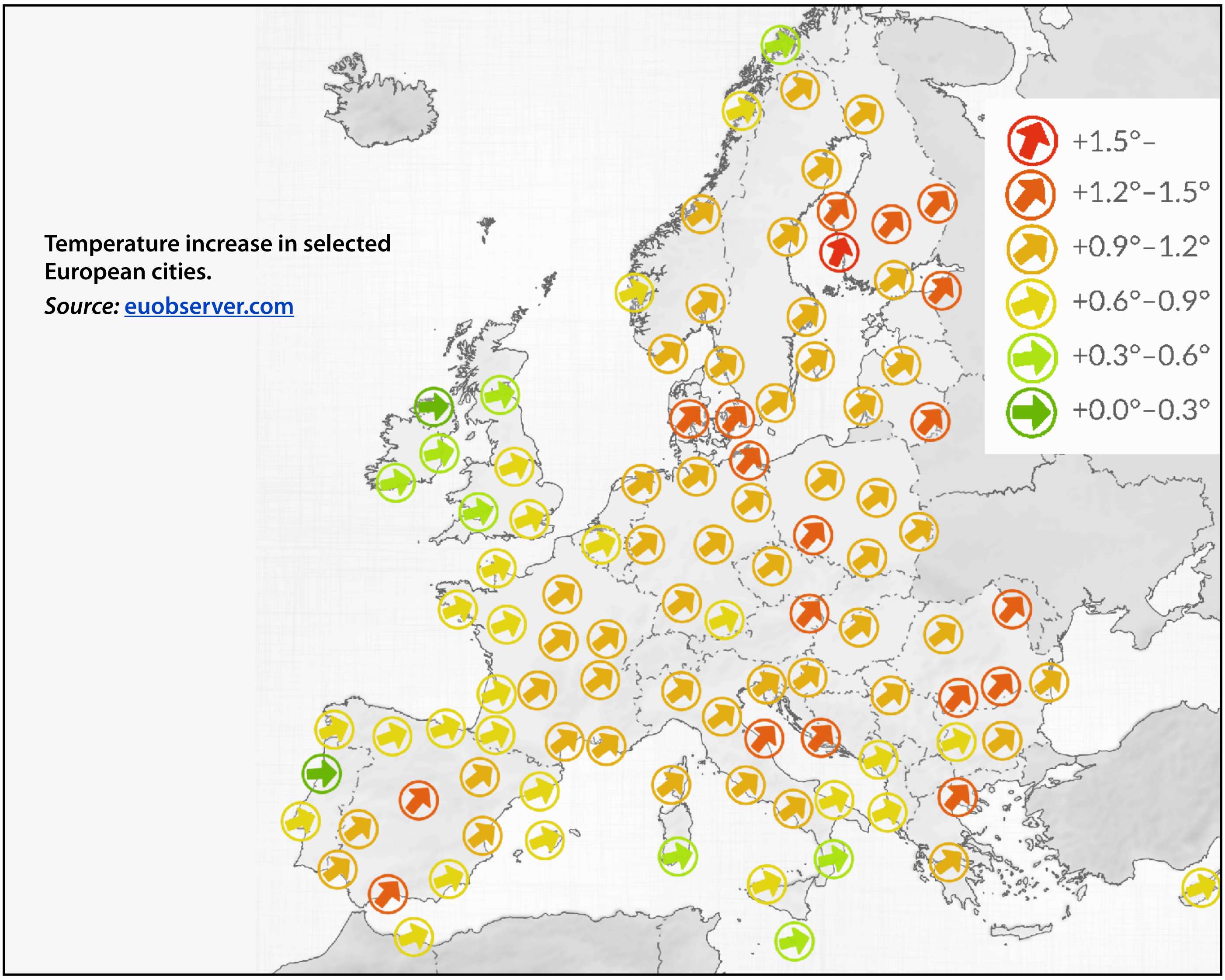
Nordic cities are more vulnerable to heat stress than those already facing heat regularly. In Madrid, for instance, mortality (relative to non-hot days) increases when the average daily temperature exceeds 21°C, against 19°C in Stockholm.

Excess mortality caused by the so-called "Lucifer" 2017 heatwave, during which temperatures rose above 40°C in the Balkans, Italy and Spain, and by the 2018 heatwave in Northern Europe, has yet to be analysed by national health authorities or by academics.

**Too hot for school**

Heatwaves are most deadly but higher temperatures affect Europeans in other ways. Researchers have shown that pupils perform less well, especially in mathematics, when the daily average temperature rises above 22°C.

In 415 of the 558 cities analysed by EDJNet, the number of school days per year with an average daily temperature over 22°C increased in the 21st century, relative to the 20th.




In Seville, for instance, pupils suffered from an average of 12 school days over 22C per year in the 20th century. This number doubled to 24 per year in the 21st century. The consequences of a hotter environment on the academic performance of European pupils have not yet been assessed.

**Crime**

Criminologists have known since the 1980s that, in the United States at least, violent crime increases with temperature. In Europe, despite rising temperatures, no national crime agency or academic tried to replicate the analysis.

Rail and road transport are also affected by rising temperatures, as tarmac softens the roads to the point that some of them need to be closed during especially hot days. Rail transit within cities (overground trains and trams) can suffer from rail buckling as the metal of the rail expands and becomes unstable. This can cause delays and, as happened in Washington D.C. underground in 2012, derailments.

Despite the wide array of effects higher temperatures have had on European cities, it is hard to see concerted, concrete adaptation efforts being carried out locally. Some national climate change plans conflate the fight against climate change with adaptation to higher temperatures.

Climate change can only be contained by keeping hydrocarbons in the ground and capturing carbon from the atmosphere (neither option has produced any net improvement so far), whereas adaptation to higher temperatures means ensuring that human settlements remain habitable under a changing climate.

National plans are often limited to regulatory instruments, such as incitative taxation for renewable energy.

When it comes to creating green spaces to limit the heat island effect and, therefore, mortality from heatwaves, to upgrading the local transport network to make it more resilient to heat or to installing cooling devices in classrooms, cities are on their own.

In the coming weeks EDJNet will publish a series of stories on the local impact of the rising in temperatures in specific European cities, and investigate if and what kind of measures local authorities and other stakeholders are preparing for mitigating the adverse effects of increasing temperatures.

For each city, a report on the temperature increase, and its consequences, is available in nine languages. You can browse all available city reports. *Source:* https://euobserver.com/environment/142894

# A dedicated experiment to infer energetic and hydrological behaviours of an asphalt concrete parking lot

By **Jean-Martial Cohard**[1] (jean-martial.cohard@univ-grenoble-alpes.fr)

**Jean-Michel Rosant**[2,3], **Fabrice Rodriguez**[2,4], **Hervé Andrieu**[2,4], **Patrice G. Mestayer**[2] and **Pierre Guillevic**[5]

[1] Institut des Géosciences de l'Environnement, Université Grenoble Alpes, Grenoble, France

[2] Institut de Recherche en Sciences et Techniques de la Ville (IRSTV), FR CNRS 2488, Nantes, France

[3] Laboratoire de recherche en Hydrodynamique, Énergétique et Environnement Atmosphérique (LHEEA), École Centrale de Nantes, France

[4] Laboratoire Eau & Environnement, Géotechnique, Environnement, Risques naturels et Sciences de la Terre, Institut Français des Sciences et Technologies des Transports, de l'Aménagement et des Réseaux (IFSTTAR), Bouguenais, France

[5] Department of Geographical Sciences, University of Maryland, College Park, USA

*This article summarizes the recently published paper: Cohard JM, JM Rosant, F Rodriguez, H Andrieu, PG Mestayer, P Guillevic, Energy and water budgets of asphalt concrete pavement under simulated rain events, Urban Climate 24:675-691. http://dx.doi.org/10.1016/j.uclim.2017.08.009*

## Introduction

Due to the complexity and variety of the urban fabric, assessment of environmental impacts, as well as evaluation of urban planning scenarios and sustainable development in response to climate change, increasingly rely on numerical simulations. However, the performance of numerical models depends on the model's ability to accurately characterize the urban landscape and represent the surface fluxes between landscape components. A large proportion of urban areas consists of streets, sidewalks, parking lots, and roads, usually covered with asphalt concrete pavement which plays a critical role in the urban water and energy exchange processes. Unfortunately, the various components of the water and energy budgets of urban surfaces are very difficult to measure due to complex experimental conditions, including the size, shape and 3-dimensional spatial variability of the surfaces, the heterogeneity and semi-closed environment of buildings, and city activities due to the presence of people and cars.

The interactions between urban canopies and the lower atmosphere impact both the dynamics of the atmospheric boundary layer, through the modification of the partition of latent and sensible heat fluxes, and the water cycle, enhancing clouds and modifying rain production (Changnon, 1981; Rozoff et al., 2003). In meteorological models, urban areas were traditionally represented as dry surfaces with high Bowen ratios (e.g. Thielen et al., 2000) where rain water is rapidly absorbed by the drainage system. In contrast, Oke (1979) already stressed the variability of the urban Bowen ratio, from 1.5 in dry periods to 0.3 after rain events and more recently Ramamurthy and Bou-Zeid (2014), and Santamouris (2014) reported Bowen ratios as low as 0.21 for wet urban surfaces and green roofs. In urban surface energy budget (SEB) models, rain water and latent heat were often not represented or were computed separately from the energy budget. Recent models include the influence of evaporation either by combining the water and energy budgets of pervious and impervious surfaces within a tiling approach or by juxtaposing models developed for urban (impervious) or natural (porous and vegetated) surfaces (see reviews by Grimmond et al., 2011; Grimmond et al., 2010). However, models initially developed for natural areas are usually based on parameterisations that cannot be easily calibrated for urban surfaces due to the lack of reliable observational networks. Furthermore, the representation of turbulence used by most of the SEB models is based on Monin-Obukhov similarity theory (MOST), a one-dimensional approach, and assumes horizontal homogeneity that is usually not valid for heterogeneous urban environments.

Surface runoff towards the drainage system represents the principal component of the water budget of urban surfaces. Runoff is usually represented using an empirical relationship based on a constant runoff coefficient. However, several studies showed that such parameterization cannot account for all involved processes (Berthier et al., 2004; Berthier et al., 1999). For example, water losses through evaporation during frequent rainfall events on urban surfaces cannot be neglected (Gash et al., 2008; Hollis and Ovenden, 1988; Ragab et al., 2003a; Ragab et al., 2003b). In addition, runoff water carries to the streams (1) chemical pollution from particles deposed on urban surfaces and washed out by rainwater, and (2) thermal pollution by transporting some of the heat released by the surfaces that had previously absorbed solar radiation. Vice versa this process may also be viewed as a technique to reduce the urban heat island (Kinouchi and Kanda, 1997) as recently experienced by Hendel et al. (2016) in Paris. For these issues the coupled simulation of urban water and energy budgets at various spatial and temporal scales would benefit from improved parameterisations of both evaporation and runoff losses on urban surfaces (Dupont et al., 2006; Lemonsu et al., 2007; Rodriguez et al., 2008).

In 2000, we launched the "Role of covered surfaces in urban hydro-system processes" (ROSURE) project to characterize the coupled water and energy transfer processes within urban canopies and conducted a series of in situ and numerical experiments at various spatial and temporal scales on semi-impervious surfaces covered with asphalt concrete pavement (Berthier et al., 2004; Dupont et al., 2006; Ramier et al., 2011; Rodriguez et al., 2008). A major field experiment was conducted in Nantes in June 2004 to evaluate the water and energy budgets of a parking lot during and after artificial rain events and the results of this experiment were recently published by Cohard et al. (2018). The present article summarizes our main experimental results. The latent heat flux data set (with derived evaporative fraction and Bowen ratio) is available upon request and has already been used by the scientific community (Azam et al., 2018).

### Methodological issues

The instantaneous water and energy budgets of a thin layer of water covering the experimental area are:

$$dh/dt = P(t) - R_R(t) - Ev(t) - I(t) \qquad [1]$$

$$\rho_w\, Cp_w\, dT_w/dt = R_n(t) - G(t) - H(t) - LE(t) - Q_R(t) \qquad [2]$$

where $h$ is the water storage above the parking lot surface and $T_w$ the temperature of the water layer, $P$, $R_R$, $Ev$ and $I$ are the precipitation, runoff, evaporation and infiltration rates, respectively, $\rho_w$ and $Cp_w$ are water density and heat capacity, respectively, $R_n$ the net radiation, $G$ the soil heat flux to the underlying ground layers by conduction, $H$ and $LE$ the sensible and latent heat fluxes to/from the atmosphere by turbulent convection, respectively, and $Q_R$ the heat flux carried away by runoff water. The water layer is assumed quasi-horizontal and homogeneous over the area.

These two budgets are coupled, since *Ev* and *LE* on the one hand, and $R_R$ and $Q_R$ on the other hand, are related by proportionality relationships. Our experiment consisted of simultaneously measuring all budget terms of both equations to reduce uncertainties. Furthermore, to control the precipitation we generated artificial showers with known rates. The experimental site was relatively isolated and far from areas with high rugosity such as buildings or trees to minimize as far as possible the environmental constraints.

The rain water returning to the atmosphere by surface evaporation (i.e. *Ev* in Eq. 1) is one of the most difficult fluxes to measure at the proper time and space scales, whatever the surface and vegetation properties. The most direct measurement technique for evaluating the turbulent fluxes to the atmosphere is eddy-covariance (EC).

This method was implemented with three-dimensional sonic anemo-thermometers (CSAT3, Campbell, Sci) and fast-response hygrometers (KH2O, Campbell Sci) at two different heights.

The Eddy-Covariance method is known to underestimate the sensible (*H*) and latent (*LE*) heat fluxes when estimated from the turbulent flux measurements at low level, which lead to recurrent energy budget imbalances. Several hypotheses may explain these budget imbalances, but there is no consensus about the final corrections that should be applied (Foken et al., 2011). In our experiment, we tested several alternative methods to measure *LE* and found that some of them were not adapted to the monitoring of a small urban area, such as methods based on gradients or profiles (Cohard et al., 2018). We also showed that an indirect method that estimates the surface evaporation as the resultant of the energy budget (Eq. 2) can give relevant *LE* observations when all other components of the budgets were measured in situ. Using scintillometry to estimate a spatial average sensible heat flux and latent heat flux, this method is considered as an indirect but aggregative method (further noted SEB method) in case of surface heterogeneity conditions (Guyot et al., 2009; Meijninger et al., 2002). Scintillometry is an optical method which consists of measuring a scintillation structure parameter ($Cn^2$) between a transmitter and a receiver installed at both edges of the studied area. In the optical domain, scintillation (refractive index fluctuation) is primarily caused by both spatial and temporal temperature variability between a light source and a receiver. It has been linked to temperature turbulent characteristics (Tatarskii, 1961) and then to sensible heat flux through Monin Obukov Similarity Theory (Hill et al., 1992). With the development of reliable microwave instrumentation the scintillometry method using microwave signal (Andreas,

**Figure 1. (a) View of the experimental site during a simulated rain event (the north is on the right); (b) zoom on some of the instruments. From left to right: small aperture scintillometers, radiation and wind sensors, 3D sonic anemometers and Krypton hygrometers at 2 m and 1 m.**

1989) recently found new perspectives to measure more directly aggregated latent heat fluxes at landscape scale, including urban canopy (Ward et al., 2015a; Ward et al., 2015b). However, there is nowadays no such microwave instrumentation available for hectare scales.

The field campaign was conducted from May 29 to June 19, 2004. The study site was a parking lot located within the IFSTTAR institute at Bouguenais (47°9.3′ N, 1°38.95′W) close to Nantes, France. About 40 km far from the Atlantic coast, this site is under the meteorological influence of the ocean but far enough to be never influenced by coastal breezes.

The instrumented area consisted of 50 m x 50 m flat bare asphalt (Fig. 1a), equipped with a sprinkler network supplied by a hydraulic pump simulating precipitation events with intensities up to 16 mm $h^{-1}$. The asphalt parcel represented a 2500 $m^2$ catchment whose outlet was equipped with a manhole (Fig 2). The structure of the ground was composed of a 5 cm thick layer of asphalt concrete pavement above an old filled ballast layer characterized by a very low porosity. The surrounding areas remained dry during the simulated showers, a condition that might generate a cool island and create divergent fluxes close to the ground during the spraying, but the diverging flow ended immediately after the end of the sprinkling. The surrounding environment consisted of a low-tree forest 100 m far to the west (Fig. 1a) and one tree row 100 m far to the north. The simulated rain flow rate ($P$ in Eq. 1) was measured by a flowmeter at the pump and two rain gauges were monitoring natural rains. Percolation and soil water storage were monitored at the point scale and evaluated at parcel scale by means

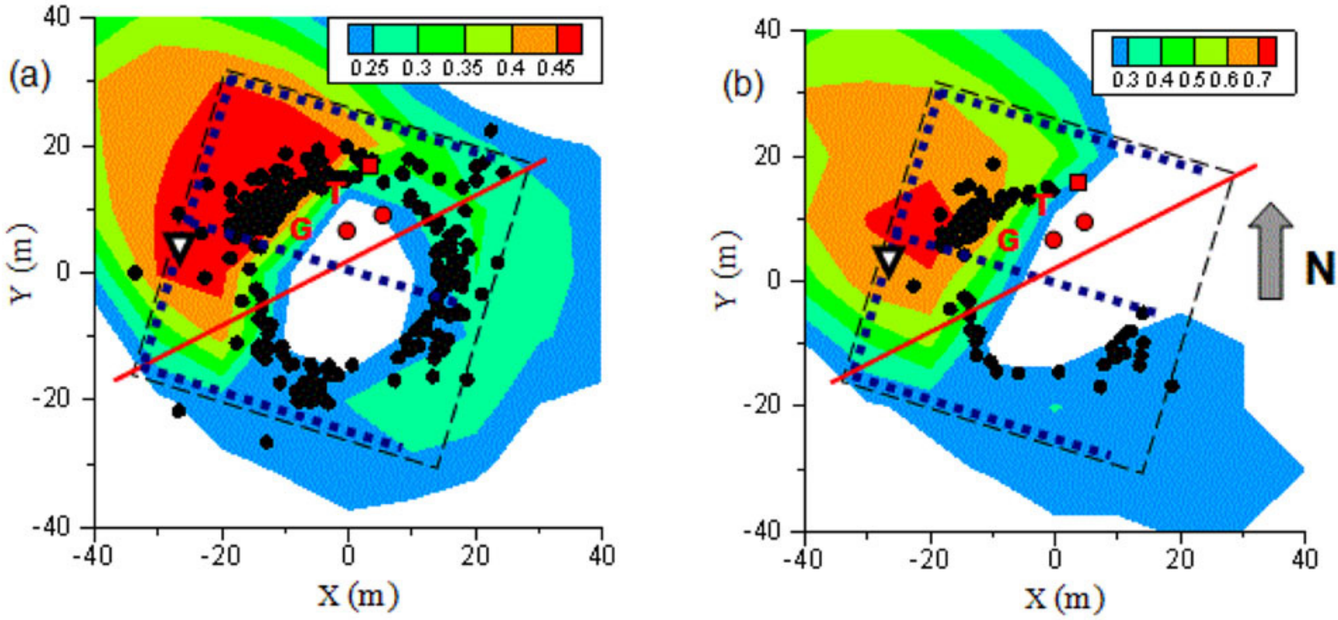



**Figure 2. Sketches of the measurement site showing the sprinkled experimental square (dashed line), sprinkler system (dotted blue lines), scintillometer beam (red line), two eddy-covariance sensor sets (red dots), meteorological station (red square), outlet manhole (white triangle), ground heat flux plate (G), and thermocouple sets (T). The coloured areas show the occurrence probabilities of the source function (80% contributions) of the eddy covariance measurements at 2 m, with the location of the individual 15 min maxima (black dots), for the entire data set (a) and for the ensemble of 3-hour drying periods after rain events (b).**

of borehole piezometers and humidity profiles. The total runoff $R_R$ was measured through a V-notch weir installed in the outlet manhole. The water temperature was measured by thermocouples at the pump and at the outlet. In addition, 4 thermocouples were set to average the surface temperature which allow to estimate the energy storage and export by the water layer. The ground heat flux and storage were derived from a heat plate and from profiles with eight thermocouples from the surface to a 50 cm depth, using a harmonic method (Heusinkveld et al., 2004; Van Wijk and De Vries, 1963; Verhoef, 2004), which was shown to be very relevant for our case study. The net radiation was derived from a four-component radiometer (Kipp & Zonen). Meteorological variables were measured between 1 and 2 m above the surface. Two different sensor systems were used for measuring the sensible and latent heat fluxes: (i) two identical packages composed of a sonic anemo-thermometer and a fast open-path krypton hygrometer (KH2O, Campbell Sci.) operated at 1 and 2 m above the ground using EC method, (ii) a small aperture scintillometer (SLS20, Scintec) set at a height of 1.2 m for measuring the average sensible heat flux over a 70 m long diagonal transect (Fig. 1b). A detailed description of the instrumentation has been provided by Cohard et al. (2018).

The EC sensor heights were derived from a sensitivity analysis of the footprint model developed by Schmid and Oke (1990) to verify the requirements for a suitable minimum and maximum installation height. The measurement quality also required that the EC sensor height was at least one order of magnitude larger than its spatial resolution (10 cm). Results for the 2 m high sensor (Fig. 2) show that (i) the maximum of the footprint function was always located within the asphalt area and (ii) the probability that 80% of the flux contributions were issued from the measurement square was of 45% for the whole data set and 70% for the data obtained during the showers and drying periods.

During the month of June 2004, the anticyclonic situation was favourable with sunny conditions, rare cumulus and low winds (< 3 m $s^{-1}$) from the northwest until the end of the campaign. Only one natural rain event was observed on June 10 at 12:30, and some drizzle occurred during the night of June 8–9, associated with some nebulosity in the morning. The surface temperature remained always higher than the air temperature, even at night by at least 3.75 K and up to 23.3 K at midday. The data were recorded continuously from June 6, a reference day without rain event, to June 11 with two simulated showers each day (three on June 9) at different times of the day; the second shower started after the asphalt had completely dried out. The showers lasted 20 to 40 minutes. The available data set includes the 6-day time series of 40 validated measured variables and 10-20 analysed variables.

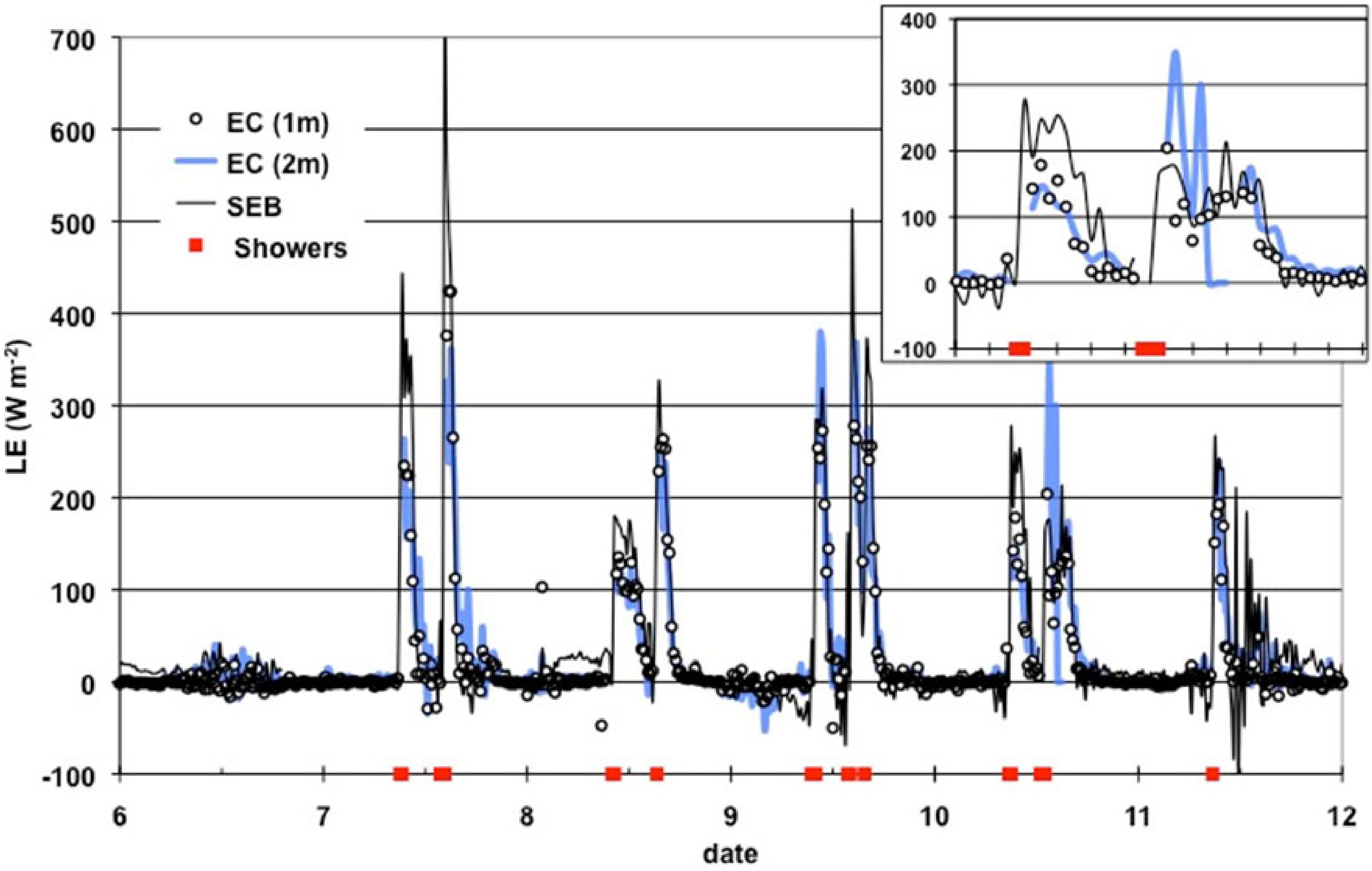



**Figure 3. Comparison of the latent heat flux estimated from the SEB residual using the scintillometer heat flux measurement and from the EC measurements at 1 m and at 2 m. Red rectangles along the time axis are the rain events. The inset is a zoom on June 10 events from 06:00 UTC till 19:00 UTC.**

**Results**

Time series of LE measured with the EC method and derived from the SEB method (Fig. 3) were used to evaluate the different methods and characterize the asphalt surface energetic response to rain events. The main results are summarized below:

• The rapid response of the surface to simulated showers was represented by large positive peaks in LE (the event of June 10 at 12:30 was a natural rain). The EC measurements at 2 m and even more so at 1 m were lower than the SEB estimations during most of the rain events. This is intrinsic to the EC method which is known to underestimate turbulent fluxes (*H* + *LE*) when compared to radiative and ground heat fluxes ($R_n - G - Q_R$). For the whole data series, we observed an average energy budget imbalance of around 30% of the available surface energy for measurements at 1 m (slope 0.70, $R^2 = 0.85$) and 24% for measurements at 2 m (slope 0.76, $R^2 = 0.79$). This is partly due to surface heterogeneity which are better aggregated with the SEB method. Thus, despite possible measurement error accumulation when using the SEB method, time series are temporally in very good agreement and slightly superior to EC measurements.

• The uncertainty associated with the available energy ($R_n - G$) estimates mainly associated with the ground heat flux *G*, was assessed using night-time data when no turbulent fluxes (*H*, *LE*) were measured by the EC systems (nights of June 6, 10 and 11 in Figure 3), and when the residual of the energy budget was lower than 20 W m$^{-2}$.

• During the June 7–8 night, the effect of a drizzle event was visible in the EC measurements at 1 m but not at 2 m, showing that the near-neutral nocturnal condition hindered the vertical transfer between 1 and 2 m while the surface was still drying during several hours, as shown by the SEB estimation.

• Negative values were observed in the SEB residual time series at night-time and early morning of June 9. During that night, surface condensation might occur and negative fluxes were also measured by the EC systems. During this morning the continuous decrease of the SEB residual cannot be explained based on our data set.

• In June 9 and 11, the residual from the SEB method showed strong alternations of positive and negative latent heat fluxes due to very unsteady conditions during and just after the rain events. It should be noted that the different fluxes contributing to the SEB energy budget have different time constants, e.g. ~0.1 s for scintillometry heat flux and several minutes for ground heat flux. Therefore, the derived latent heat may strongly fluctuate if the input fluxes, namely net radiation and ground heat flux, are not exactly in phase.

• Integrating these latent heat flux time series at event scale (see Cohard et al. 2018), the closure of the water budget ($P - R_R - (\rho_a L_w)^{-1} LE$ ) / $P$ was reached within 9 –10% on average using the EC-based evaporation measurements and within 5% using the SEB method. These results could have probably been improved (by 8% and 4% respectively) by accounting for infiltration, which was estimated at 0.1–0.2 mm for a similar surface (Ramier et al., 2011).

• Evaporative fraction ($EF = LE/(H+LE)$) and Bowen ratio ($H/LE$) time series estimated from minute data ($H$ from scintillometry and $LE$ from SEB method) showed constant values ($EF$ ~0.8 and Bowen ~0.25) as long as the surface was wet (30 – 45 min in our case for hot sunny conditions). EF (Bowen ratio) values decreased (increased) and returned to zero (infinity) when dry patches appeared on the parking lot.

## Conclusion

For the first time, we led an experiment to document simultaneously all the water and energy budget terms of an asphalt concrete parking lot surface. This provided a complete data set, available upon request, which led to a reduction in the uncertainties in urban surface behaviours after a rain event. All results, both on the energy and water terms, may be found in Cohard et al. (2018), some of which have been reported above.

This experimental study demonstrated the interest of implementing micrometeorological and hydrological instrumentations and methods jointly for assessing the earth system behaviour and more specifically the urban climatology. This research is also the result of a shared vision between IFSTTAR the French institute of science and technology for transport, development and networks and the INSU CNRS department (National Institute for Universe Sciences). This shared vision allows a more rapid connection of scientific results to adaptation strategy. Since then, we further developed our cooperation between urban micro-meteorologists and hydrologists in the framework of IRSTV/IFSTTAR collaboration for modelling studies as well as experimental surveys, especially around our communal observatory ONEVU in Nantes. This aimed at improving the scientific knowledge on urban area behaviour through continuous monitoring and field campaigns.

## Acknowledgements

The authors thank Richard De Jeu and Roland Vogt for the scintillometer, and Bernard Flahaut, Yves Lorin, David Ramier, Jean-Marc Rouaud and Michel Violleau for their help in the measurements. The ROSURE (2001-2002) and HydroVille (2003-2004) projects were funded by the National Institute for Earth Sciences and Astronomy (INSU) of the Centre National de la Recherche Scientifique (CNRS).

## References

Andreas, E.L., 1989. Two-Wavelength Method of Measuring Path-Averaged Turbulent Surface Heat Fluxes. *Journal of Atmospheric and Oceanic Technology*, 6(2): 280-292.

Azam, M.-H., Bernard, J., Morille, B., Musy, M. and Andrieu, H., 2018. A pavement-watering thermal model for SOLENE-microclimat: Development and evaluation. *Urban Climate*, 25: 22-36.

Berthier, E., Andrieu, H. and Creutin, J.D., 2004. The role of soil in the generation of urban runoff: development and evaluation of a 2D model. *Journal of Hydrology*, 299(3-4): 252-266.

Berthier, E., Andrieu, H. and Rodriguez, F., 1999. The Rezé Urban Catchments Database. *Water Resources Research*, 35(6): 1915-1919.

Changnon, S.A., 1981. Metromex, a Review and Summary. *Meteorological Monographs*, 18. AMS, Boston, MA, 181 pp.

Cohard, J.-M. et al., 2018. Energy and water budgets of asphalt concrete pavement under simulated rain events. *Urban Climate*, 24: 675-691.

Dupont, S., Mestayer, P.G., Guilloteau, E., Berthier, E. and Andrieu, H., 2006. Parameterization of the Urban Water Budget with the Submesoscale Soil Model. *Journal of Applied Meteorology and Climatology*, 45(4): 624-648.

Foken, T. et al., 2011. Results Of A Panel Discussion About The Energy Balance Closure Correction For Trace Gases. *Bulletin of the American Meteorological Society*, 92(4): ES13-ES18.

Gash, J.H.C., Rosier, P.T.W. and Ragab, R., 2008. A note on estimating urban roof runoff with a forest evaporation model. *Hydrological Processes*, 22(8): 1230-1233.

Grimmond, C.S.B. et al., 2011. Initial results from Phase 2 of the international urban energy balance model comparison. *International Journal of Climatology*, 31(2): 244-272.

Grimmond, C.S.B. et al., 2010. The International Urban Energy Balance Models Comparison Project: First Results from Phase 1. *Journal of Applied Meteorology and Climatology*, 49(6): 1268-1292.

Guyot, A., Cohard, J.-M., Anquetin, S., Galle, S. and Lloyd, C.R., 2009. Combined analysis of energy and water balances to estimate latent heat flux of a sudanian small catchment. *Journal of Hydrology*, 375(1-2): 227-240.

Hendel, M., Gutierrez, P., Colombert, M., Diab, Y. and Royon, L., 2016. Measuring the effects of urban heat island mitigation techniques in the field: Application to the case of pavement-watering in Paris. *Urban Climate*, 16: 43-58.

Heusinkveld, B.G., Jacobs, A.F.G., Holtslag, A.A.M. and Berkowicz, S.M., 2004. Surface energy balance closure in an arid region: role of soil heat flux. *Agricultural and Forest Meteorology*, 122(1-2): 21-37.

Hill, R.J., Ochs, G.R. and Wilson, J.J., 1992. Measuring surface layer fluxes of heat and momentum using optical scintillation. *Boundary-Layer Meteorology*, 58: 391-408.

Hollis, G.E. and Ovenden, J.C., 1988. One year irrigation experiment to assess losses and runoff volume relationships for a residential road in hertfordshire, England. *Hydrological Processes*, 2(1): 61-74.

Kinouchi, T. and Kanda, M., 1997. An observation on the climatic effect of watering on paved roads. *J. Hydrosci. Hydraul. Eng.*, 15(1): 55-64.

Lemonsu, A., Masson, V. and Berthier, E., 2007. Improvement of the hydrological component of an urban soil–vegetation–atmosphere–transfer model. *Hydrological Processes*, 21(16): 2100-2111.

Meijninger, W.M.L. et al., 2002. Determination of Area-Averaged Water Vapour Fluxes with Large Aperture and Radio Wave Scintillometers over a Heterogeneous Surface – Flevoland Field Experiment. *Boundary-Layer Meteorology*, 105(1): 63-83.

Oke, R.T., 1979. Review of urban climatology 1973-1976., World Meteo Organ.

Ragab, R., Bromley, J., Rosier, P., Cooper, J.D. and Gash, J.H.C., 2003a. Experimental study of water fluxes in a residential area: 1. Rainfall, roof runoff and evaporation: the effect of slope and aspect. *Hydrological Processes*, 17(12): 2409-2422.

Ragab, R., Rosier, P., Dixon, A., Bromley, J. and Cooper, J.D., 2003b. Experimental study of water fluxes in a residential area: 2. Road infiltration, runoff and evaporation. *Hydrological Processes*, 17(12): 2423-2437.

Ramamurthy, P. and Bou-Zeid, E., 2014. Contribution of impervious surfaces to urban evaporation. *Water Resources Research*, 50(4): 2889-2902.

Ramier, D., Berthier, E. and Andrieu, H., 2011. The hydrological behaviour of urban streets: long-term observations and modelling of runoff losses and rainfall–runoff transformation. *Hydrological Processes*, 25(14): 2161-2178.

Rodriguez, F., Andrieu, H. and Morena, F., 2008. A distributed hydrological model for urbanized areas - Model development and application to case studies. *Journal of Hydrology*, 351(3-4): 268-287.

Rozoff, C.M., Cotton, W.R. and Adegoke, J.O., 2003. Simulation of St. Louis, Missouri, Land Use Impacts on Thunderstorms. *Journal of Applied Meteorology*, 42(6): 716-738.

Santamouris, M., 2014. Cooling the cities – A review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. *Solar Energy*, 103: 682-703.

Schmid, H.P. and Oke, T.R., 1990. A model to estimate the source area contributing to turbulent exchange in the surface layer over patchy terrain. *Quarterly Journal of the Royal Meteorological Society*, 116(494): 965-988.

Tatarskii, V.I., 1961. Wave Propagation in a Turbulent Medium, New York, 285 pp.

Thielen, J., Wobrock, W., Gadian, A., Mestayer, P.G. and Creutin, J.D., 2000. The possible influence of urban surfaces on rainfall development: a sensitivity study in 2D in the meso-γ-scale. *Atmospheric Research*, 54(1): 15-39.

Van Wijk, W. and De Vries, D., 1963. Periodic temperature variations in a homogeneous soil. *Physics of Plant Environment*: 103-143.

Verhoef, A., 2004. Remote estimation of thermal inertia and soil heat flux for bare soil. *Agricultural and Forest Meteorology*, 123(3-4): 221-236.

Ward, H.C., Evans, J.G. and Grimmond, C.S.B., 2015a. Infrared and millimetre-wave scintillometry in the suburban environment - Part 2: Large-area sensible and latent heat fluxes. *Atmospheric Measurement Tech*niques, 8(3): 1407-1424.

Ward, H.C., Evans, J.G., Grimmond, C.S.B. and Bradford, J., 2015b. Infrared and millimetre-wave scintillometry in the suburban environment - Part 1: Structure parameters. *Atmospheric Measurement Tech*niques, 8(3): 1385-1405.

# Integrating Planning and Climate: A Collaborative Framework to Address Heat Vulnerability

*This article reflects ongoing dissertation research, presented during ICUC10 in August 2018.*

## Introduction

Prolonged exposure to heat and extreme heat events is associated with high morbidity and mortality rates in the United States (US). In 2017, hurricanes Irma and Maria caused massive power outages and pointed to the harmful and potentially deadly effects of heat exposure as the aftermath of natural disasters. Coastal communities in the Southeastern US are used to high temperatures; however, they are not prepared for prolonged exposure to heat. To address this issue, cities must develop heat response plans (HRP) that reduce health risks related to prolonged exposure (Luber and McGeehin, 2008). To do so public health, emergency management, planning agencies and climatologists must work collaboratively to develop plans that (a) identify at-risk populations through heat vulnerability maps, (b) create public communication strategies, and (c) incorporate environmental design strategies that mitigate the effects of heat in urban areas.

This short paper introduces the collaborative framework applied to work with local, state and federal agencies to address heat vulnerability in Chatham County, GA. It uses a combination of geodesign (Batty, 2013; Dangermond, 2010; Ervin, 2011; Flaxman, 2010a; Steinitz, 2012) and co-production (Dilling and Lemos, 2011; Eriksen et al. 2015; Jasanoff 2004; Meadow et al. 2015) frameworks to engage with practitioners from governmental institutions to co-produce a replicable methodological framework to address heat health impacts. The use of this methodology also seeks to aid land-use planners to visualize and understand localized and dynamic climate processes that affect human health.

## Case Study – Chatham County, GA

Chatham County is on the coast of the US state of Georgia. Its county seat and largest city is Savannah, a historic port city and tourist attraction. The choice of site and focus occurs for three reasons: (1) Like many coastal counties, planning departments both at the county and city level in Chatham County have begun to discuss climate through stormwater management and sea level rise, while addressing the vulnerability of such cities to flooding. Such actions and interests stem from the creation of the Biggert-Waters Act (2012), that presents changes to the US Federal Flood Insurance, and has generated an opportunity to discuss the impacts of climate on communities. (2) Chatham County is situated in a hot-humid climatic region of the state of Georgia, thus exposed to heat, particularly in the summer. Recent reports (ASTHOCCC, 2014; USGCRP, 2016) have pointed to an increase in health risks due to extreme heat exposure in the city of Savannah. These reports also call upon institutions, such as the Georgia Coastal Health District, to engage with planners to address growing risks of extreme heat events. Additionally, the county was impacted by power outages caused by hurricane Irma. And (3) Savannah's downtown neighborhood, a representation of colonial planning (de Vorsey, 2012), has proven to be resilient to natural hazards over time. From a thermal standpoint its design, composed of plazas, allows contiguous tree cover to permeate the urban fabric, which promotes wind flow and reduces impacts of urban heat islands, as discussed by Debbage and Shepherd (2015).

## Methodology

Collectively, very few planners and climatologists have attempted to address the limitations and barriers that exist in developing plans and policies that address urban climate interactions at the city scale (Snyder et al. 2012). While examining the literature on climate in both planning and urban climatology, this project started off by analyzing how methodological approaches in planning and urban climatology differ from each other, to better understand potential barriers to knowledge transference. More specifically, the research looked at the process of understanding information through space and time by both disciplines. It also considered observations and the professional experiences of the researchers in one or both fields of study.

As depicted in Figure 1, participant observation showed that urban climatologists look at climate processes throughout time, understanding the localized and dynamic characteristics of the phenomenon. On the other hand, for planners, climate is but one issue that informs decision-making. In the plan development phase information is synthesized and overlaid to compose land-use suitability maps and analysis (McHarg, 1971). Therefore, the analysis of the environment tends to be static and, in some ways, generalized. Based on the premise that methodological divergences are a key factor in knowledge transference, this research used a combination of geodesign and co-production frameworks to develop a collaborative decision-making process.

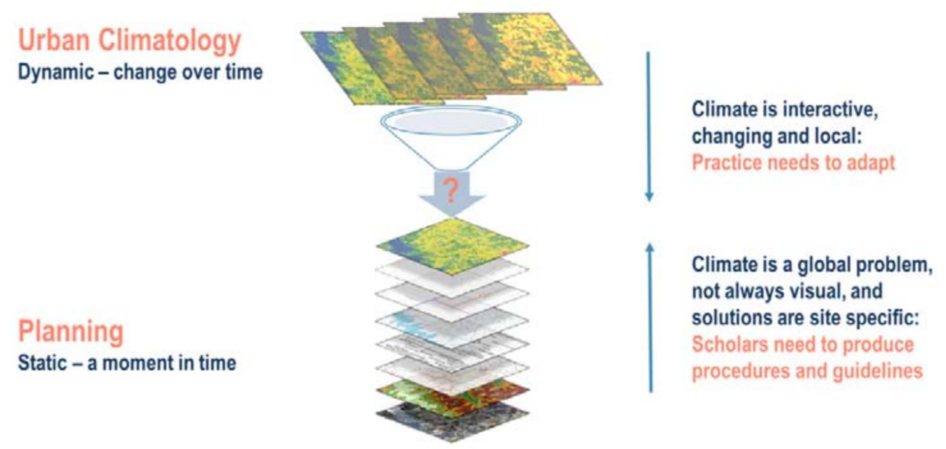



**Figure 1. Methodological divergences between urban climatology and physical planning.**

*Geodesign* – Geodesign is a conceptual framework that seeks to promote a collaborative pathway for plan conception and evaluation. As Flaxman (2010b) describes, "its axioms are that design and plan quality is increased by informed professional and public deliberation, that all projects have multiple impacts (good and bad), and that proposed changes should be judged within an explicit spatial context." It attempts to overcome a tendency from design fields, such as landscape architecture and planning, to work in isolation, recognizing that urban spaces are complex and require a team effort (Steinitz, 2012). Furthermore, geodesign attempts to break from the traditional model of design, which tends to be static, to embrace dynamic forms of design that look at diverse temporal and spatial aspects of the urban landscape (Batty 2013).

In this context, the use of the geodesign framework was made possible by using Geodesign Hub© (www.geodesignhub.com), a planning support system (PSS) developed to connect geography and design in a participatory process (Campagna et al., 2016), and applied to multidisciplinary and multiscale planning processes (Rivero et al., 2015). In simple terms, it is a geovisualization tool that incorporates aspects of Geographical Information Systems (GIS) as a common language between multiple fields of study.

*Co-production* – Similar to geodesign, co-production seeks to work in collaboration, however, it focuses on the production of actionable knowledge. It proposes an iterative process between science and decision-making fields to develop research questions and methods (Lemos and Morehouse, 2005). It aims to address complex socio-environmental issues, understanding that they are intertwined and affected by scientific knowledge and decisions made with them (Jasanoff 2004). However, as discussed by Meadows et al. (2015) it is still an ongoing process, with promising potentials if explored through different avenues and integrated to multiple disciplines. The combination of the geodesign and co-production frameworks attempts to simultaneously incorporate methods familiar to design fields, while recognizing the transdisciplinary nature of an HRP and its socio-environmental ramifications.

*Defining research and application needs* – Following the co-production framework, the project began through conversations with collaborators from planning, public engagement, natural resources and public health fields to decide which climatic issues needed to be addressed from a planning perspective. The discussions focused on potential climate hazards and knowledge that could be produced to reduce risks. A total of 9 meetings took place between July and November of 2017. These initial conversations pointed to a need for addressing heat vulnerability, particularly in the aftermath of a major hurricane and power outages. The difficulties of incorporating new models and software to existing decision-making practices were also discussed. Some of the participants had ongoing experiences with flood resiliency planning and discussed the challenges of using tools and datasets that were not compatible with current practices. All collaborators recognized the need to visualize how climate is impacted by urban morphology and how people will feel under certain thermal conditions. The feedback received during this phase led the project to focus on heat, and led to the proposal for developing an HRP for Chatham County.

The preliminary meetings led the research to two key questions: (1) what methodology would be best suited to spatially and temporally depict heat vulnerability, while using readily available data? and (2) who should be involved in the collaborative process? The project partnered with the Coastal Regional Commission (CRC) of Georgia to engage with land-use planners and attempt to understand potential avenues for the development of an HRP. It also requested collaboration from the National Weather Service (NWS) and Chatham County Emergency Management (CEMA). The format chosen for the workshop was a 1-and-a-half-day workshop, using Geodesign Hub©, followed by a 45-minute focus group to discuss the process, knowledge exchange, sustainability and implementation of an HRP. The workshop took place between July 17 and 18, 2018, in Richmond Hill,

**Figure 2. Photograph taken during the negotiation phase of the workshop.**

Georgia. There were nine participants in attendance, six members from the CRC, a private planning consultant, a member from the NWS and another from CEMA. Also, two members from the University of Georgia worked on mediation and note taking, with remote support from one member from the University of Georgia and another from Geodesign Hub.

The workshop began with two hours of presentations and discussions. Representatives from the NWS, CEMA, and the University of Georgia talked about the forecasting and messaging process, statistics on current and predicted vulnerabilities, the existing CEMA Comfort Station plan, and the linkages between land-use, heat and health. Participants were encouraged to ask questions, make comments and express their experiences with the use of climate data. The intent of this part of the workshop was to start a conversation and stimulate knowledge exchange between professionals from climate and planning fields.

After presentations participants were introduced to the Geodesign Hub platform and were asked to use it as a tool to develop an HRP. Participants began the process with a set of eight evaluation maps, developed by the research team with the use of readily available datasets. Categories ranged from green infrastructure (divided into two maps: Savannah and Chatham County), environmental vulnerability, social vulnerability, housing demand, housing vulnerability, transportation and heat.

The heat dataset was developed in collaboration with the University of Georgia's Center for Geospatial Research to produce an evaluation map that considered spatial and temporal aspects of heat. The heat evaluation map produced is the result of the compilation of 44 Landsat satellites 5 and 7 images, surface reflected corrected (Tier 1). The images were analyzed for brightness temperature (Band 6), during summer months (June through August) between the years of 1994 and 2012. The evaluation map was generated through the development of an adapted model of the applied extreme heat vulnerability index (Johnson et al., 2012).*

Participants initially worked individually, each focused on a single evaluation category. They proposed policies and projects that would seek to mitigate or address heat vulnerability. For instance, a participant working on green infrastructure focused on policies that promoted urban greening and proposed projects for the creation of greenways and parks that served more vulnerable areas of the county. On the second day of the workshop participants were split up into two groups, one tasked to focus on the physical planning (e.g. sustainable development), while the other was tasked with heat health and communication (e.g. siting of cooling stations and health promotion policies). Each group set priorities and goals, and produced a plan using the policies and projects proposed during the evaluation phase. Once the teams produced their plans, they were then asked to present them and discuss the points of divergence. This then led them to a negotiation phase so that the teams could combine their visions into a single HRP.

## Results

The workshop served as a test to see how collaboration focused on methodology can promote a better understanding of issues at the intersection of planning

* The development of this methodology is part of an ongoing dissertation project and will be described in detail in future publications by the authors.

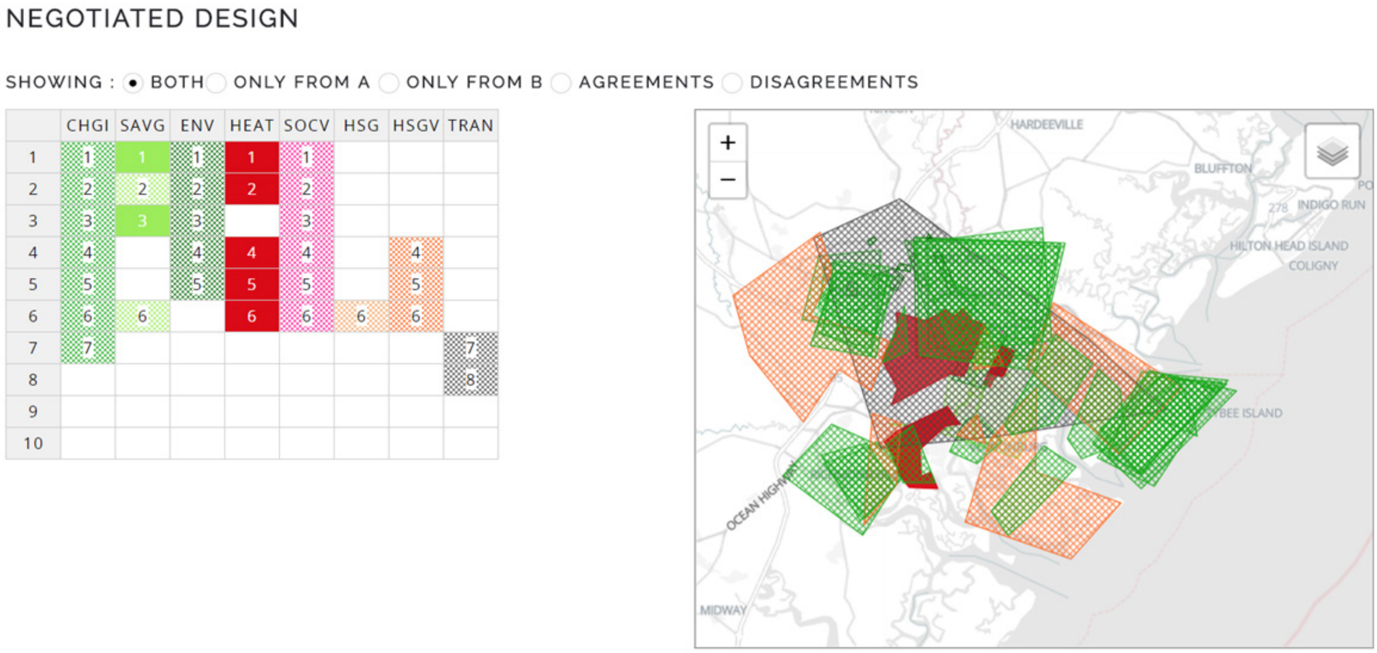



**Figure 3. Negotiated HRP plan developed during the July 17 -18, 2018 workshop in Richmond Hills, GA.**

and urban climatology. The negotiation phase showed how the initial presentations and discussions created a base of knowledge for the group. Discussions during the negotiation phase at times resulted in research for supporting evidence of the decisions made. Participants from different fields expressed their disciplinary understandings of how a policy or project could be effective in responding to heat, and the group compromised on actions based on knowledge exchange. The resulting plan can be seen in Figure 3. Moreover, the participants all struggled in some way to interpret or visually represent their ideas. For the non-planners, the scale and unfamiliarity with the use of tools such as GIS and outlining ideas, seemed intimidating. While for the planners the topic seemed foreign and though relatable, some struggled to propose actions without the establishment of guidelines.

During the 45-minute focus group the participants discussed the need for further dissemination of information concerning heat and its relations to the built environment. The group recognized that Chatham County has a growing elderly population, projected to grow by 70.8% by 2030, and identified the need for the incorporation of heat as a component of the existing Regional Assessment and Regional Comprehensive Plan. This would not only raise awareness on heat vulnerability for Chatham County, but for surrounding coastal counties in the state. Furthermore, the group discussed the need for the creation of what was described as a Heat Coalition. It would be composed of regional, county and city planning departments, the Georgia Department of Natural Resources, local non-profit organizations, Chatham County Health Department, the NWS, CEMA, among others. The intention, according to the participants, would be to create a concerted effort to keep the collaborative framework going, recognizing the complexity of heat response planning, as well as the need for continuous knowledge transference and decision-making support.

## Discussion

This project takes a transdisciplinary approach to integrate urban climatology and land-use planning to understand practical barriers to the creation of an HRP. It innovates by collaboratively working with decision-makers focused on planning and weather-climate to identify struggles in the incorporation of urban climatology, as a component of plans at a county scale. The use of geodesign and co-production seem to reinforce the initial observations that led to the premise that knowledge transference struggles are related to methodology and practice. The workshop tested the use of temporal evaluations of heat vulnerability to better express the dynamic and localized effects of climate. At the same time, by using Geodesign Hub, the research sought to find a platform for decision-making that displayed information and promoted collaborative decision-making. While previous studies have focused on knowledge gaps and the creation of new methods, this approach seeks to understand practice and its compatibility to dynamic and localized effects of climate. Moreover, this approach seeks to find replicable forms of addressing climate decision-making without attempting to create a generalizable methodology. There is no 'one size fits all' approach to climate planning.

**Acknowledgements**

This study was made possible thanks to funding received from the University of Georgia's Innovative and Interdisciplinary Research Grant (Summer 2017) and Summer Research Travel Grant (Summer 2018), as well as to the support and collaboration from the Coastal Regional Commission of Georgia, Geodesign Hub, the University of Georgia's Center for Geospatial Research, Center for Integrative Conservation and Integrative Conservation PhD Program, National Weather Service, and Chatham County Emergency Management.

**References**

Act, B.-W. F. I. R., 2012: of 2012. *Public Law*, 112-141.

ASTHOCCC, 2014: Extreme Weather and Climate Readiness: Toolkit for State and Territorial Health Departments.

Batty, M., 2013: Defining geodesign (= GIS+ design?). SAGE Publications Sage UK: London, England.

Campagna, M., A. Moura, J. Borges, and C. Cocco, 2016: Future scenarios for the Pampulha region: A Geodesign workshop. *Journal of Digital Landscape Architecture*, 1, 292-301.

Dangermond, J., 2010: Geodesign and GIS–designing our futures. Peer Reviewed Proceedings of Digital Landscape Architecture, Anhalt University of Applied Science, Germany.

de Vorsey, L., 2012: The Origin and Appreciation of Savannah, Georgia's Historic City Squares. *Southeastern Geographer*, 52, 90-99.

Debbage, N., and J. M. Shepherd, 2015: The urban heat island effect and city contiguity. Computers, *Environment and Urban Systems*, 54, 181-194.

Dilling, L., and M. C. Lemos, 2011: Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. *Global Environmental Change*, 21, 680-689.

Eriksen, S. H., A. J. Nightingale, and H. J. G. E. C. Eakin, 2015: Reframing adaptation: The political nature of climate change adaptation, 35, 523-533.

Ervin, S., 2011: A system for GeoDesign. Proceedings of Digital Landscape Architecture, Anhalt University of Applied Science, 145-154.

Flaxman, M., 2010a: Geodesign: Fundamentals and routes forward. Presentation to the Geodesign Summit, January, 6, 2010.

——, 2010b: Fundamentals of geodesign. Proceedings of Digital Landscape Architecture, Anhalt University of Applied Science, 2, 28-41.

Jasanoff, S., 2004: States of knowledge: the co-production of science and the social order. Routledge.

Johnson, D. P., A. Stanforth, V. Lulla, and G. Luber, 2012: Developing an applied extreme heat vulnerability index utilizing socioeconomic and environmental data. *Applied Geography*, 35, 23-31.

Lemos, M. C., and B. J. J. G. e. c. Morehouse, 2005: The co-production of science and policy in integrated climate assessments, 15, 57-68.

Luber, G., and M. McGeehin, 2008: Climate Change and Extreme Heat Events. *American Journal of Preventive Medicine*, 35, 429-435.

Meadow, A. M., D. B. Ferguson, Z. Guido, A. Horangic, G. Owen, T. J. W. Wall, Climate,, and Society, 2015: Moving toward the deliberate coproduction of climate science knowledge, 7, 179-191.

Rivero, R., A. Smith, H. Ballal, and C. Steinitz, 2015: Promoting Collaborative Geodesign in a Multidisciplinary and Multiscale Environment: Coastal Georgia 2050, USA.

Snyder, P., P. Hamilton, B. Stone, T. Twine , and J. M. Shepherd, 2012: RCN-SEES: Urban Heat Island Network. University of Minnesota-Twin Cities.

Steinitz, C., 2012: A framework for geodesign : changing geography by design. Redlands, Calf. : Esri, 2012.

USGCRP, 2016: The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. U.S. Global Change Research Program, 312 pp.



Mariana B. Alfonso Fragomeni[1], J. Marshall Shepherd[2] and Rosanna G. Rivero[3]

[1] Department of Geography and Integrative Conservation, University of Georgia (maribaf@uga.edu)

[2] Department of Geography, University of Georgia

[3] College of Environment and Design, University of Georgia

# Stable stratification effects in a spatially-developing urban boundary layer


## Abstract

Large-Eddy Simulations (LES) with inflow boundary conditions were used to investigate stable stratification effects on turbulence and dispersion over a rural-to-urban transition region. Firstly, LES results for weakly stable stratification conditions ($R_i$=0.2) were validated with data from wind tunnel experiments for a stable boundary layer over a regular array of cuboid buildings. Mean velocity, normal stresses and mean concentration from a ground-level point source were in good agreement. Subsequently, LES of greater stratification ($0.2<R_i\leq1$) were performed with a line source downstream of the step change in surface roughness. It was found that the mean concentration of the line source at $R_i$=1 was two times greater than that at $R_i$=0.2 below the canopy. More interestingly, the mean concentration of the point source below the canopy at $R_i$=1 was found to be four times greater than that at $R_i$=0.2 due to the decrease of both lateral and vertical scalar spreading above the canopy at high Richardson number. The analysis of vertical turbulent fluxes of the line source in several streamwise locations confirmed that the vertical scalar mixing decreased with increasing stratification. Moreover, the height where the vertical flux became negligible decreased as the stratification increased, maybe due to the trapping effects of the internal boundary layer (IBL) which is shallower for stronger stratification.


## Introduction

Until recently, only a few wind tunnel (e.g. Marucci et al, 2018) and numerical studies (e.g. Korycki et al, 2016; Xie et al, 2013) have examined the effects of thermal stratification on turbulent structures and the dispersion over urban canopy of varying morphologies. These works have shown that stratification effects on turbulence and dispersion are not negligible even under weakly unstable or stable thermal conditions (e.g. Boppana et al, 2014, Tomas et al, 2016; Xie et al, 2013). Tomas et al (2016) investigated the effect of stable stratification on flow and line source dispersion by simulating a smooth-wall boundary layer entering a generic urban environment. They found that under weakly stable thermal conditions ($R_i$=0.147) the depth of the internal boundary layer (IBL) was 14% shallower after 24 rows of obstacles compared to neutral conditions and the turbulent kinetic energy (TKE) was reduced by 21%. As a consequence, the area-averaged street concentration from a line source in stable conditions was found to be 17% higher than that in neutral conditions due to the decreased streamwise advection and pollutant trapping in the IBL. Nevertheless, they simulated an approaching-flow with smooth-wall properties, therefore turbulence intensity and integral length-scales achieved upstream of the step change did not represent a genuine rural boundary layer. Therefore, the simulation does not model a rural-to-urban transition. Moreover, stable stratification effects on dispersion from a line source are much weaker than those for a point source dispersion at the same Richardson number, because for the former the dispersion only appears to occur in the streamwise and vertical directions while for the latter it occurs in three directions. In this paper we systematically examined the effects of various stratification conditions ($R_i\leq1$) over a rural-to-urban transition region. We were particularly interested in understanding to what extent the dispersion of gas from point source and line sources were affected by stable stratification.

## Numerical settings

The LES model was implemented within the CFD package OpenFOAM. The following set of filtered equations were solved: the momentum equation in buoyancy-driven flow [Eq. 1], the filtered transport equation of a passive scalar [Eq. 2] and the filtered temperature transport equation [Eq. 3].

$$\frac{\partial u_i}{\partial t}=-\frac{\partial}{\partial x_j}(u_i u_j)-\frac{1}{\rho}\frac{\partial p}{\partial x_i}+\frac{g}{T_0}T\delta_{i2}+\frac{\partial}{\partial x_j}(v_r+v)\frac{\partial u_i}{\partial x_j} \quad [1]$$

$$\frac{\partial C}{\partial t}+\frac{\partial}{\partial x_j}(C u_j)=\frac{\partial}{\partial x_j}[(K+K_r)\frac{\partial C}{\partial x_j}]+S \quad [2]$$

$$\frac{\partial T}{\partial t}+\frac{\partial}{\partial x_j}(T u_j)=\frac{\partial}{\partial x_j}[(D+D_r)\frac{\partial T}{\partial x_j}] \quad [3]$$

where $g$ is the acceleration due to gravity, and $C$ and $T$ are respectively the concentration of the scalar and temperature. The subgrid-scale (SGS) viscosity $v_r$ was calculated by applying the mixed-time scale model. $S$ is the source term, $K$ and $K_r$ are the molecular and sub-grid turbulent diffusivities and $D$ and $D_r$ are the molecular and subgrid thermal diffusivities. The array of regular buildings modelled in this paper represents part of a larger array used in a wind tunnel experiment designed to simulate a neighbourhood-scale region. An efficient inflow turbulence generation method (Xie and Castro, 2018) was used at inlet with prescribed mean velocity, Reynolds stresses and integral length scales, which were obtained from a turbulent boundary layer developed over a surface roughness of thin plates in the wind tunnel (WT). For non-neutral condition cases, the turbulence data at the inlet were all the same as those WT data at $R_i$=0.2

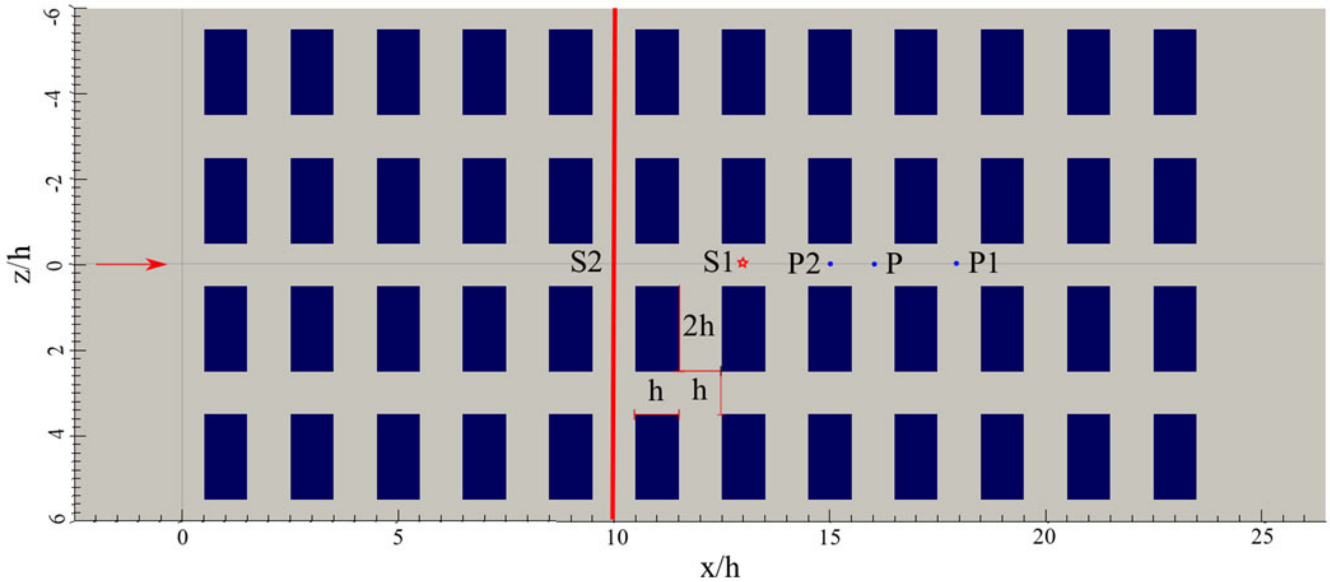



**Figure 1. A sketch of the array configuration: dimensions of buildings and streets, the coordinate system, the source positions S1 and S2 and measurement locations P, P1 and P2.**

(Marucci et al, 2018). The same method was used to prescribe the WT mean temperature profile and temperature variance at the LES inlet. Periodic conditions were used at the lateral boundaries, stress-free conditions were used at the top and zero-gradient velocity was used at the outlet. The Reynolds number based on building height h was approximately 10,000 and the flow was averaged over 180 flow-passes. The section of the array modelled is shown in Fig.1 where the street units parallel to the x axis are *h* long and referred to as 'short street' hereinafter. Street unit parallel to the *z* axis are 2h long and referred to as 'long street'.

The rectangular array comprised 48 uniform buildings with resolution *h*/16, spacing *h* and plan area density $\lambda_p$=0.33. The ground-level point source S1 was positioned at *x*/*h*=13 and the ground-level line source S2 was placed at *x*/*h*=10.

**Results**

*Validation* – LES results for mean streamwise velocity, mean concentration from the point source S1 (Fig. 1), streamwise and lateral Reynolds stresses for neutral ($R_i$=0) and weakly stable conditions ($R_i$=0.2) were validated against WT measurements (Marucci et al, 2018) in three different locations. Fig. 2 shows the comparison below and immediately above the canopy, over a vertical line at the street intersection at *x*=16*h* (position P, Fig. 1). The mean concentration was normalized as follows:

$$\overline{C}* = \overline{C} u_0 h^2 / Q \quad [4]$$

where $u_0$ is the reference velocity at the top of the domain and *Q* is the emission rate. The comparison shows that LES predictions of mean velocity (Fig. 2a), streamwise stress (Fig. 2b), lateral stress (Fig. 2c) and mean concentration (Fig. 2d) at $R_i$=0.2 were in very good agreement with WT measurements below and immediately above the canopy. The streamwise stress at $R_i$=0.2 was found to be three times smaller than that at $R_i$=0. Similarly the lateral stress at $R_i$=0.2 and close to the ground was found to be four times smaller than that at $R_i$=0. This confirmed that even under weakly stable conditions, the turbulent kinetic energy is significantly damped by the buoyancy gradient. Fig. 2d shows that LES mean concentration from a point source at $R_i$=0.2 was four times greater than that at $R_i$=0 close to the ground.

*Dispersion in increasing stratification* – LES mean concentration from the point source S1 was analysed at position P1 at $R_i$=0.2, 0.5, 0.7 and 1 over a vertical line (Fig. 3a). The mean concentration at *x*=5*h* from the source increased significantly close to the ground with stronger stratification. In particular, at $R_i$=1 it was found to be four times greater than that at $R_i$=0.2. Conversely, above *y*=0.5*h* the mean concentration decreased with increasing stratification due to the reduced vertical mixing. Similarly, vertical mean concentration from the line source S2 was analysed at a distance of *x*=5*h* in position P2 for various stratification conditions (Fig. 3b). The mean concentration from the line source increased close to the ground with stronger stratification. However, the mean non-dimensional concentration close to the ground at $R_i$=1 was found to be less than twice the mean concentration at $R_i$=0.2 and about *10%* different from that at $R_i$=0.7. This is partly because the same turbulence statistics were used at the inlet for all non-neutral cases. It is to be noted that dispersion from the line source is a *2D* problem where the plume is laterally homogeneous. This means that the increased concentration close to the ground for greater stratification demonstrates the impact of reduced vertical mixing above the canopy.

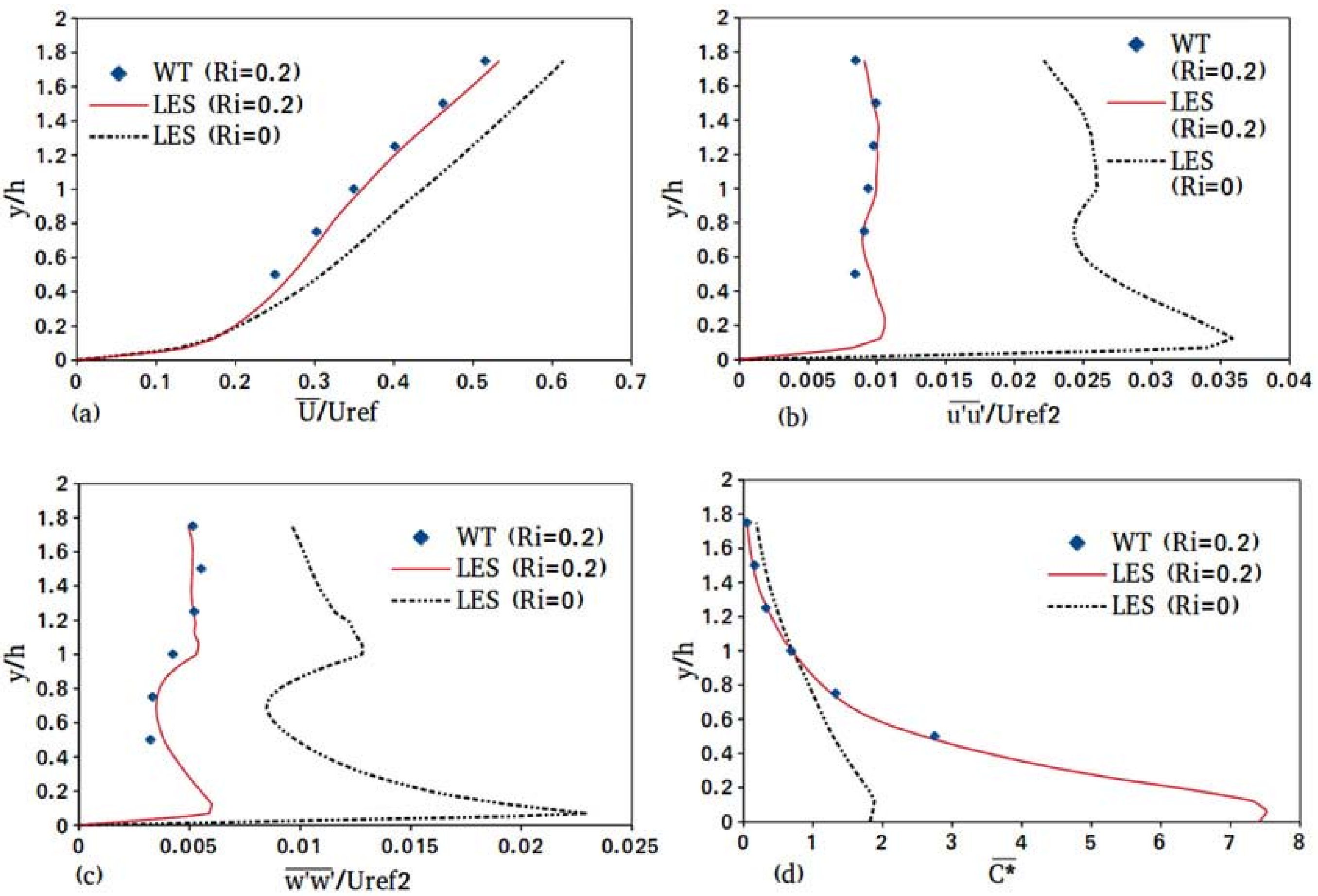



**Figure 2. LES ($R_i$=0.2 and $R_i$=0) and WT ($R_i$=0.2) comparison at position P (Fig.1). Mean streamwise velocity (a), streamwise Reynolds stress (b), lateral Reynolds stress (c) and normalized mean concentration (d).**

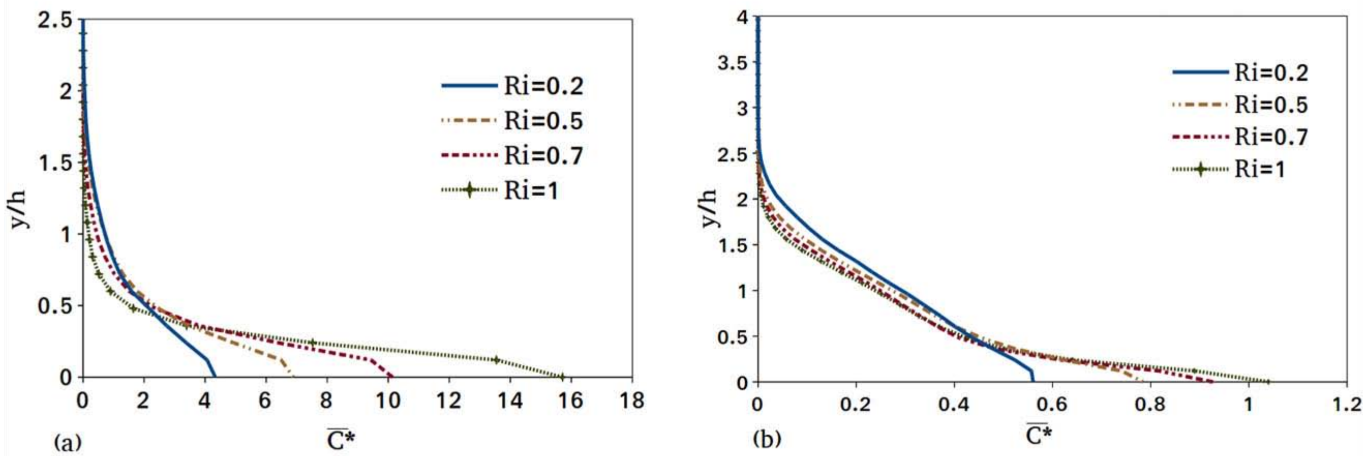



**Figure 3. (a) LES normalized mean concentration of point source S1 (Fig.1) over a vertical line (P1, Fig.1) and (b) LES normalized mean concentration of line source S2 over a vertical line (P2, Fig.1) for various stratification conditions ($R_i$≤1).**

*Vertical fluxes in increasing stratification* – The vertical turbulent flux of scalar dispersion was normalized as follows:

$$\overline{v'c'}* = (\overline{vC} - \bar{v}\bar{C})\,h^2/Q \quad [5]$$

where $v$ is the vertical velocity and $v'$ the vertical velocity fluctuation, $C$ and $c'$ are filtered concentration and concentration fluctuation respectively. The first term on the right-hand side is the total vertical flux while the second term on the right-hand side is the vertical advective flux. Fig. 4 shows the vertical turbulent flux of the line source S2 in several streamwise locations for various stratification conditions ($R_i \leq 1$). The figure also shows the depth of the IBL at $R_i$=0 as calculated by Sessa et al (2018). It was found that the vertical flux decreased as the stratification increased and thus, the vertical mixing was reduced.

For example, the vertical flux at $R_i$=0.2 decreased by almost half in most locations as the stratification was increased up to $R_i$=1. Sessa et al (2018) found that the vertical turbulent flux decayed quickly when approaching the interface of the IBL. Here, the height where the vertical flux becomes negligible decreased as the stratification increased. In particular, the vertical flux at $x$=22$h$ and at $R_i$=1 was found to be negligible above the height $y$=2$h$, which was 30% lower than the height at $R_i$=0.2. According to Tomas et al (2016), this might be due to the trapping effects of the IBL which is shallower for stronger stratification.

**Conclusions**

In this paper we examined LES predictions for various stratification ($0 \leq R_i \leq 1$) on turbulence, line and point source dispersion over a rural-to-urban transition region. Comparisons of mean velocity, Reynolds stresses and mean concentration at $R_i$=0.2 were found to be in good agreement with WT data. We confirmed that turbulent kinetic energy is significantly damped even under weakly stratified conditions. Mean concentration from the point source at $R_i$=1 was found to be significantly greater than that at $R_i$=0.2 close to the ground. Mean concentration from the line source at $R_i$=1 was also found to be greater than that at $R_i$=0.2 but the increase was less significant than that of the point source. Because dispersion of the line source is somewhat similar to a *2D* problem, the increased concentration close to the ground demonstrates the impact of reduced vertical mixing above the canopy. The analysis of vertical turbulent flux for the line source dispersion revealed that the increased stratification damped vertical scalar mixing. In addition, the height where the vertical flux became negligible decreased as the stratification increased. We conclude that the impact of even a weakly thermal stratification on ground-level dispersion within an array is definitely not negligible.

**Acknowledgements**

VS is grateful to Dstl and the University of Southampton for the funding of PhD studentship. We thank the Enflo team for providing wind tunnel data.

**References**

Boppana V.B.L., Xie Z.-T., Castro I.P. (2014). Thermal stratification effects on flow over a generic urban canopy, *Bound.-Layer Meteorol.*, 153.1:141-162.

Korycki M., Lobocki L., Wyszogrodzki A. (2016) Numerical simulation of stratified flow around a tall building of a complex shape, *Env. Fluid Mech.*, 16.6:1143-1171.

Marucci D., Carpentieri M., Hayden P. (2018). On the simulation of thick non-neutral boundary layers for urban studies in a wind tunnel, *Int. J Heat & Fluid Flow,* 72:37-51.

Sessa V., Xie Z.-T., Herring S. (2018) Turbulence and dispersion below and above the interface of the internal and the external boundary layers, *JWEIA*, Submitted.

Tomas J. M., Pourquie B.M., Jonker H.J.J. (2016). Stable stratification effects on flow and pollutant dispersion in boundary layers entering a generic urban environment, *Bound.-Layer Meteorol.* 159.2:221-239.

Xie Z.-T. , Hayden P., Wood C.R. (2013). Large-eddy simulation of approaching-flow stratification on dispersion over arrays of buildings, *Atmos Environ*. 71:64-74.

Xie, Z.-T., & Castro, I. P. (2008). Efficient generation of inflow conditions for large eddy simulation of street-scale flows, *Flow, Turbul. Combust*. 81:449-470.

Vincenzo Sessa (V.Sessa@soton.ac.uk)[a], Zheng-Tong Xiea[a] and Steven Herring[b]

[a] Faculty of Engineering and Environment, University of Southampton, UK

[b] Dstl, Porton Down, Salisbury, UK

# Refinement of the roughness length for the Weather Research and Forecasting Model based on an understanding of Local Climate Zones

## Background and current limitations

Roughness length is one of the key parameters required to forecast wind using a regional climate model. The roughness length may vary greatly depending on the land cover types and morphological characteristics. For example, urban areas generally have a higher roughness length value; while grassland and water bodies have lower values. Given the variation of roughness in different areas, obtaining a representative roughness length value is crucial to improve wind speed predictions and eventually to enable more accurate pollutant dispersion forecasts by associated chemical models.

Currently, in the Weather Research and Forecasting (WRF) model, roughness length is determined by a look-up table based on the land use category. In the look-up table, several discrete values are assigned to 'urban', which is still not representative of the heterogeneous morphological properties. Such unrepresentative roughness length values would lead to an underestimation or overestimation of wind speed in the urban areas, as the urban canopy is not accurately reflected in WRF.

To better represent the roughness elements in urban areas and hence improve wind speed prediction, urban canopy models in WRF are implemented, known as urban WRF (uWRF) (Chen et al., 2011). These urban canopy models are the Single Layer Urban Canopy Model (SLUCM), the Building Effect Parameterization (BEP) and the BEP coupled with Building Energy Model (BEP-BEM) respectively. These models are able to take anthropogenic heat and the impacts of the urban canopy into account. However, each of the models has its own limitations. The SLUCM assumes all buildings are below the first model layer (i.e. the first vertical layer near the ground) of the WRF simulation. Despite no such restriction in BEP and BEP-BEM, both require a higher vertical resolution near the ground. Such a setting will inevitably lead to a high computational cost.

Given these limitations, it is difficult to perform an operational forecast using uWRF for regions where there are exceptional amounts of skyscrapers, such as the Pearl River Delta (PRD) region in southern China. As such, this study attempts to refine the roughness length values in WRF based on the metadata and morphological characteristics of Local Climate Zones (LCZ) from the World Urban Database and Access Portal Tools (WUDAPT) products. By having a more representative roughness length value, wind speed prediction from WRF could be improved, and it would also help the associated operational pollutant dispersion models.

## The WUDAPT data and its use in roughness length calculation

WUDAPT is a collaborative project which aims to collect land use and morphology data in different cities (Ching et al., 2014). Data collected from the project can be categorized into different levels of detail, from land use classification ("Level 0") to sufficient and accurate parameters for boundary-layer models ("Level 2").

In this study, we applied the "Level 0" data from the WUDAPT project covering the Guangdong province. As the LCZs classification and several statistical morphological parameters concerning each LCZ are readily available, it is possible for us to calculate roughness length.

Besides, there are two advantages to using WUDAPT. First, a high resolution (100 m) of LCZ classification is available. Second, the LCZs classification, as defined by Stewart and Oke (2012), is capable of classifying the heterogeneous nature of urban areas. In the LCZs classification, there are ten categories to distinguish different urban types based on the compactness and height of buildings. These two advantages allowed us to have a more accurate roughness length value.

Based on the approximated road width, roof width and building height in each LCZ, the averaged morphological parameters in each 1-km grid cell are obtained. Then, these morphological parameters are normalized by the corresponding urban fraction in the grid cell, and will be used to calculate the roughness length representing urban areas ($z_{0,urb}$) using the formula from Macdonald, Griffiths and Hall (1988):

$$z_{0,\mathrm{urb}} = H\left(1-\frac{d}{H}\right)\exp\left(-\left(0.5\beta\frac{C_d}{\kappa^2}(1-d/H)\lambda_f\right)^{-0.5}\right)$$

where $H$ is the building height, d is the displacement height, $\beta$ is a constant with value 1.0 (calibrated from experimental data), $C_d$ is the drag coefficient, $\kappa$ is von Kármán's constant and $\lambda_f$ is the frontal area index. The calculation of the frontal area index and displacement height will adopt the approach used in SLUCM.

Since urban planning policies differ from place to place, Hong Kong and regions outside Hong Kong have their own set of morphological parameters.

Regarding the roughness length representing rural areas, we retain the traditional look-up approach from the Noah Land Surface Scheme (Noah-LSM) (Tewari et al., 2004) in WRF, where the roughness length value is determined based on the land use category. For each rural type of LCZ, we look up its roughness length value, which should be consistent with the value specified in WRF, and multiply by its corresponding LCZ fraction in the 1-km grid cell. By summing the resultant values of the rural LCZs, roughness length values representing rural areas are obtained ($z_{0,rur}$). Consequently, the final estimated roughness length ($z_0$) will be calculated by the following formula, in which $\lambda_u$ is the urban fraction:

$$z_0 = \lambda_u z_{0,\mathrm{urb}} + z_{0,\mathrm{rur}}$$

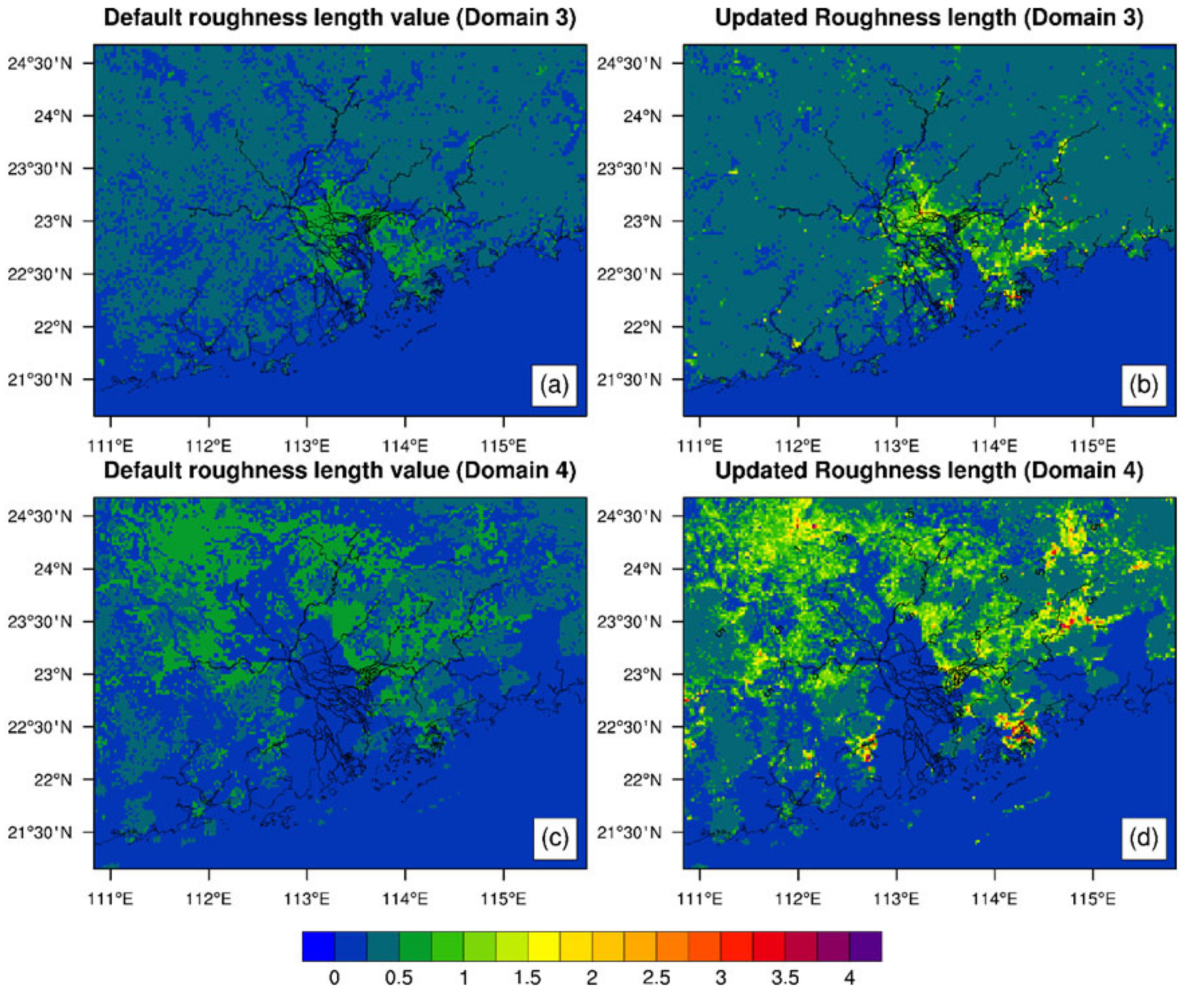



**Figure 1. Spatial distribution of roughness length before and after updating the roughness length estimation (unit in m) in (a-b) domain 3 covering major cities in Guangdong province and (c-d) the PRD region.**

The spatial distribution of roughness length before and after the update is depicted in Figure 1. The distribution of roughness length after the update is consistent with the actual situation. Areas with a certain proportion of skyscrapers generally attain a higher roughness length value, including Hong Kong Island, Macau and Guangzhou city (2.5-3 m). Moreover, the roughness length becomes more discrete when compared with the original look-up table approach.

**Experiment setup**

To test the impact of refining roughness length on the wind speed prediction, WRF simulations were performed. The simulation periods cover January and July in 2010, which correspondingly represent winter and summer scenarios. In the simulations, a total of 4 domains with horizontal resolution 27 km (domain 1), 9 km (domain 2), 3 km (domain 3) and 1 km (domain 4) are configured. Domain 4 covering the PRD region is the area of interest in this study.

To apply the new roughness length dataset in WRF, the Noah-LSM is modified accordingly. The model will use the newly calculated roughness length value whenever available. Otherwise the default look-up method is applied.

**Simulations results**

Various statistical metrics and spatial plots are performed to evaluate the changes.

Table 1 summarizes the change of root mean square error (RMSE), mean bias (MB), and index of acceptance (IOA) in 10-m wind speed and 2-m temperature. These metrics are calculated using observational values from more than 100 automatic weather stations in the PRD region within domain 4.

From the table, it can be seen that there are general improvements in wind speed regarding RMSE, MB and IOA respectively. In particular, the overestimation of wind speed is alleviated, with RMSE and MB reduced by 15% and 30% correspondingly. Regarding 2-m temperature, there is almost no change, as the physical thermal properties of the surface are not modified.

Figure 2 shows the difference in 10-m wind speed before and after updating roughness length. Note that daytime and night-time (spanning 0800 – 1600 LST and 2000 – 0400 LST, respectively) are averaged for the spatial plots. The figure suggests that the weakening of wind speed is widespread, especially in the urban areas where skyscrapers exist. For in-

| Table 1: Statistics metrics on 10-m wind speed and 2-m air temperature before and after updating the roughness length value. | | | | | | | |
|---|---|---|---|---|---|---|---|
| Simulation cases | | 10-m wind speed [m $s^{-1}$] | | | 2-m temperature [K] | | |
| | | RMSE | MB | IOA | RMSE | MB | IOA |
| January | Before | 2.41 | 1.61 | 0.44 | 2.78 | 1.43 | 0.88 |
| | After | 2.06 | 1.15 | 0.55 | 2.77 | 1.41 | 0.88 |
| July | Before | 2.73 | 2.01 | 0.32 | 2.01 | -0.0002 | 0.85 |
| | After | 2.40 | 1.60 | 0.45 | 2.04 | -0.01 | 0.85 |

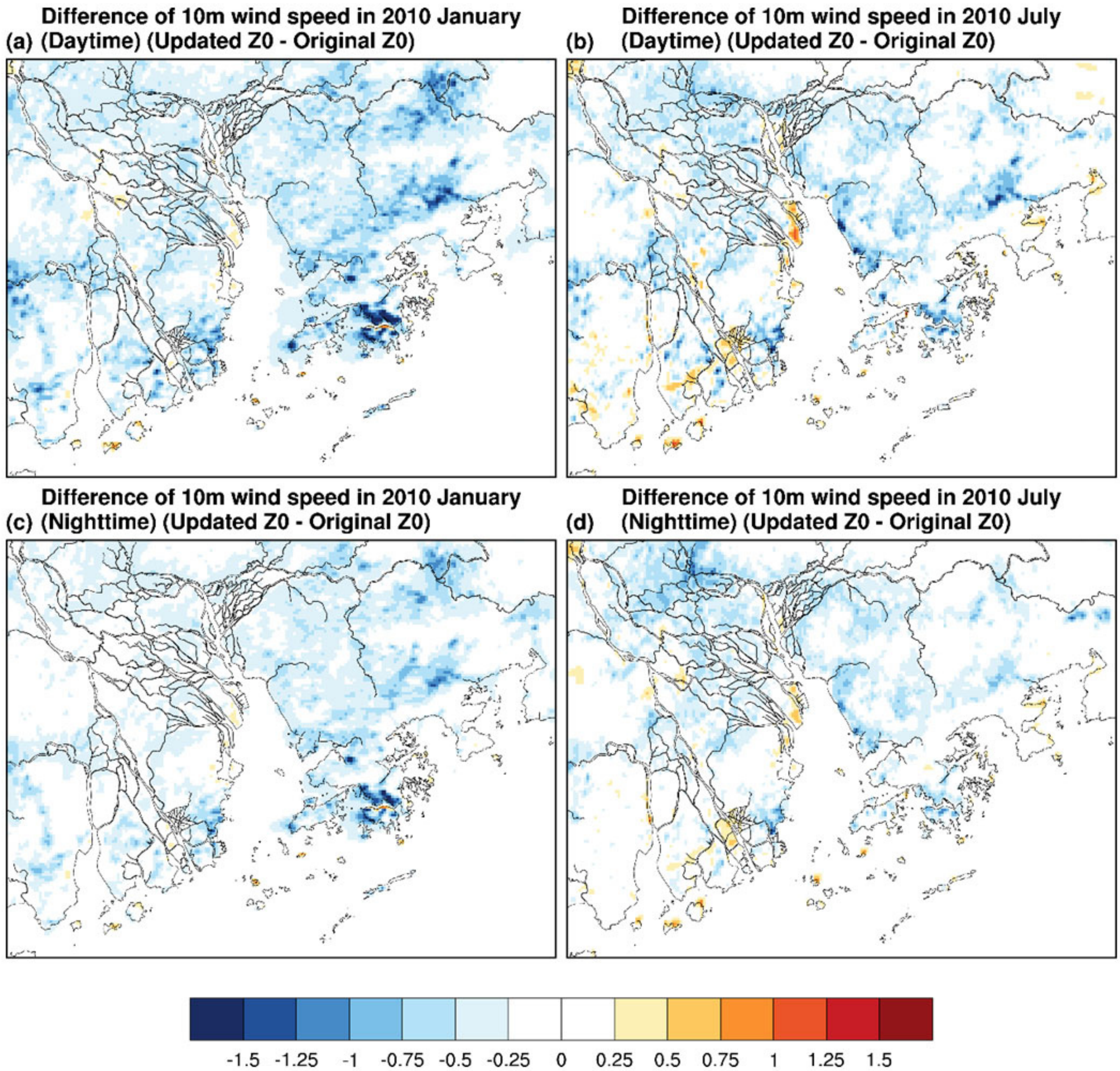



**Figure 2. Spatial plot of 10-m wind speed (in m $s^{-1}$) before and after updating roughness length in (a-b) January and (c-d) July.**

stance, there is a significant decrease in wind speed in the urban core of Hong Kong, where the decrease can be up to 1.5 $ms^{-1}$. Regions with less change in roughness length value have correspondingly less change in the wind speed.

**Conclusions**

In this study, we demonstrated through applying the metadata and morphological parameters of LCZs that a 1-$km^2$ resolution roughness length dataset has been created. By modifying the Noah-LSM in WRF, the roughness length data is integrated into the model. Afterwards, two months' simulation are performed to evaluate the impact of updating roughness length.

Based on the comparison of the two-month simulation with original and updated roughness length, it is found that the overestimation of wind speed is successfully alleviated while maintaining almost the same amount of computational cost. There is no significant change in temperature as the thermal properties of the land surface is not modified.

It is believed that with the morphological parameters and refined roughness length values, wind speed prediction in WRF and hence results of pollutant dispersion simulation can be improved.

**Further work**

There are attempts that could be made to refine the roughness length value further.

Firstly, the creation of 100-m resolution LCZ data is based on a machine learning method, through which incorrect classification may occur. Therefore, further improving the accuracy of LCZ classification would theoretically lead to a more accurate roughness length value.

Secondly, it is possible to couple the roughness length value with the vegetation parameters provided in the initial condition data during the model pre-processing stage. This could then capture the dynamics of vegetation, e.g.the loss of vegetated areas due to deforestation. Eventually, the change of roughness elements in rural areas could be reflected.

Last, but not least, an attempt could be made to refine the roughness length value by using the formula from Kanda et al. (2013) instead of the original approach. Apart from considering the conventional parameters like average building height and frontal area index, Kanda's approach also takes the standard deviation of building height into account. As such, it is also worthwhile to apply such an approach and evaluate its effectiveness.

**Acknowledgement**

The study is supported by the RGC Grants 16300715 and 14611015 respectively. It is also partially supported by The Vice-Chancellor's Discretionary Fund of The Chinese University of Hong Kong.

The authors would like to thank to Miss Meng Cai, Miss Ran Wang and Miss Xinwei Li for their help on training sample collection and the LCZ map development. We also appreciate the assistance of the Hong Kong Observatory (HKO), which provided the meteorological data.

**References**

Chen, F., Kusaka, H., Bornstein, R., Ching, J., Grimmond, C. S. B., Grossman-Clarke, S., Loridan, T., Manning, K. W., Martilli, A., Miao, S., Sailor, D., Salamanca, F. P., Taha, H., Tewari, M., Wang, X., Wyszogrodzki, A. A., & Zhang, C. (2011). The integrated WRF/urban modelling system: development, evaluation, and applications to urban environmental problems. *International Journal of Climatology*, 31(2), 273-288.

Ching, J., See, L., Mills, G., Alexander, P., Bechtel, B., Feddema, J., Oleson, K. L., Stewart, I., Neophytou, M., Chen, F., Wang, X., & Hanna., A. (2014). WUDAPT: Facilitating advanced urban canopy modeling for weather, climate and air quality applications. 94th AMS Annual Meeting, 2-6 February, 2014.

Kanda, M., Inagaki, A., Miyamoto, T., Gryschka, M., & Raasch, S. (2013). A new aerodynamic parametrization for real urban surfaces. *Boundary-layer Meteorology*, 148(2), 357-377.

Macdonald, R. W., Griffiths, R. F., & Hall, D. J. (1998). An improved method for the estimation of surface roughness of obstacle arrays. *Atmospheric Environment*, 32(11), 1857-1864.

Stewart, I. D., & Oke, T. R. (2012). Local climate zones for urban temperature studies. *Bulletin of the American Meteorological Society*, 93(12), 1879-1900.

Tewari, M., Chen, F., Wang, W., Dudhia, J., LeMone, M. A., Mitchell, K., Ek, M., Gayno, G., Wegiel, J., & Cuenca, R. H. (2004, January). Implementation and verification of the unified NOAH land surface model in the WRF model. 20th Conference on Weather Analysis and Forecasting/16th Conference on Numerical Weather Prediction (Vol. 1115).




Pak Shing Yeung[a], Jimmy Chi-Hung Fung[a,b], Michael Mau-Fung Wong[c] and Chao Ren[d,e]

[a] Division of Environment and Sustainability, The Hong Kong University of Science and Technology, Hong Kong (ypspak@gmail.com); [b] Department of Mathematics (HKUST); [c] Environmental Science Program (HKUST); [d] Faculty of Architecture, The University of Hong Kong; [e]Institute of Future Cities, The Chinese University of Hong Kong

# ICUC-10 event on Equality and Diversity in Urban Climate



*By Leena Järvi, Ariane Middel and Helen Ward*

To raise awareness and work towards improving equality and diversity within IAUC and find solutions for increasing participation of underrepresented groups, we organized the event "Equality in Urban Climate" at ICUC-10 in New York. Around 25 conference attendees participated in fruitful discussions on how to promote both gender and geographic equality and diversity in the urban climate community. Current IAUC membership statistics show that members are equally divided between men and women. The same should, in principle, be reflected in positions of trust in the community. However, out of all 46 board members since 2000, only 22% (10 people) were female. Current board member statistics are more balanced with four women out of ten (40%). The Luke Howard Award has been presented to 12 awardees since 2004, but only to one woman, showing that certainly there is room for improvement. Looking at the ICUC plenary presentations, men have generally dominated the statistics, and some years none of the speakers were women. At ICUC-10, two out of five plenary speakers were female, which is much more balanced.

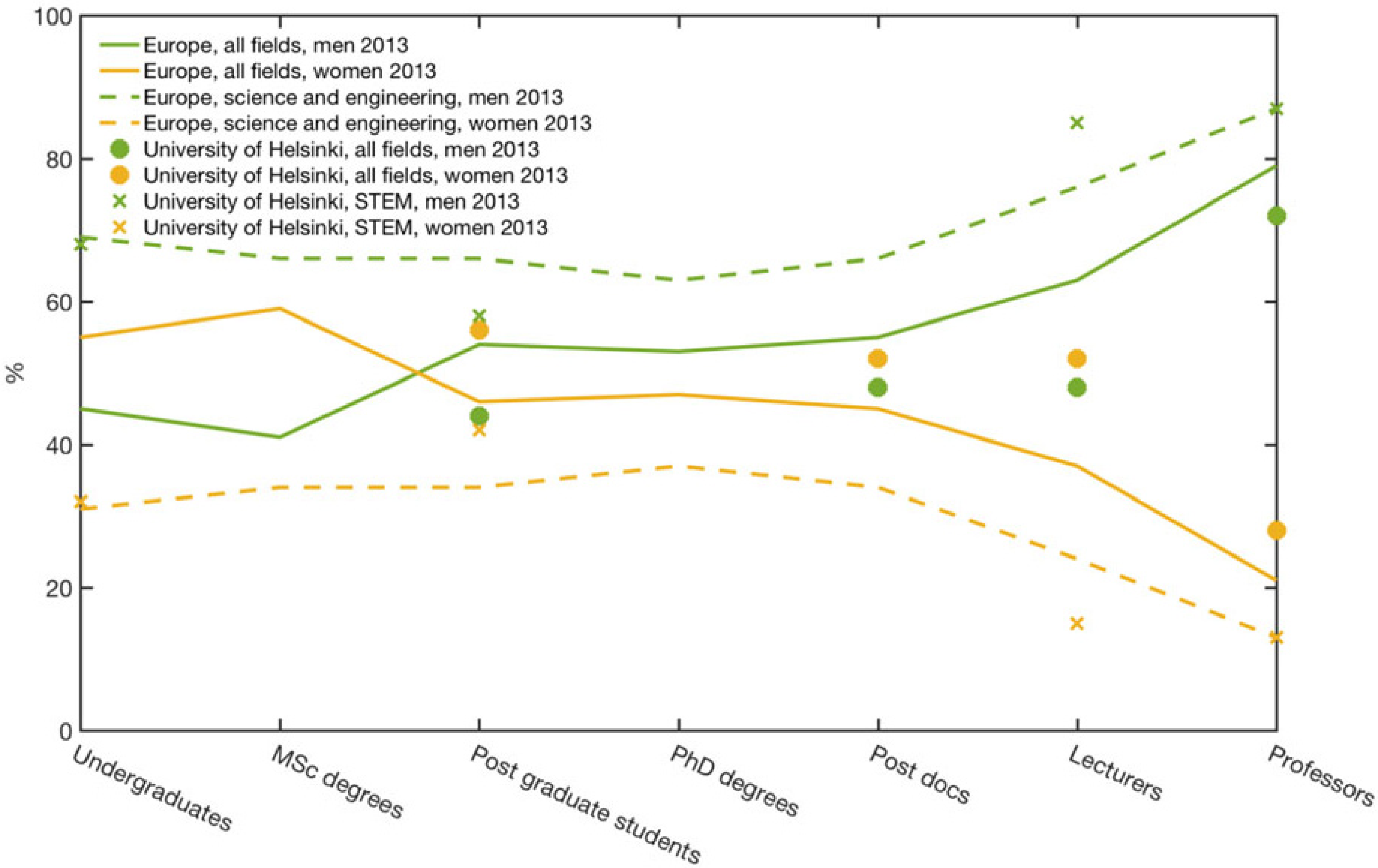
So, what could be done to improve these statistics? The event participants were divided into small groups to (a) discuss reasons for gender imbalance in general, (b) assess imbalances within IAUC, and (c) brainstorm about what steps could be taken to achieve more gender and ethnic equality and diversity in the urban climate community. Everyone seemed to agree that the focus should first be on the IAUC Board and ICUC conference activities, because those are the most important and most visible bodies for the community. In recent years, the IAUC board composition has become more balanced, and the number of female plenary speakers has grown, which resulted from a stronger focus on equality aspects. Female nominees for board elections were encouraged, and the conference organizers paid more attention to imbalances. One question that arose was if geographically underrepresented regions should be encouraged in a similar way or if elections should be conducted following the fraction of members from different continents. More solutions offered included (a) appointing an IAUC Board member who is responsible for equality and diversity, (b) offering IAUC fellowships to promote equality within IAUC, and (c) collecting data on the members' gender, race, ethnicity, country of origin, and career stage to be analyzed and presented regularly in the newsletter and at ICUC. These are small actions that can potentially have great impacts on the urban climate community.

Regarding ICUC conference locations, the board could request a plan from host applicants on how they will promote equality and diversity before and during the conference. Plenary speakers and session chairs should exhibit a healthy mix of gender and geographic diversity. Post-doc level researchers could be engaged in chairing and thus act as role models. Furthermore, there could be guidance for chairs on how to be more inclusive in questions and discussions (i.e. ask a female, early-career scientist, or non-white first). The same diversity should be ensured for presenters. Attention should also be paid to possible cost and visa barriers and to countries that encourage more diverse attendees than others.

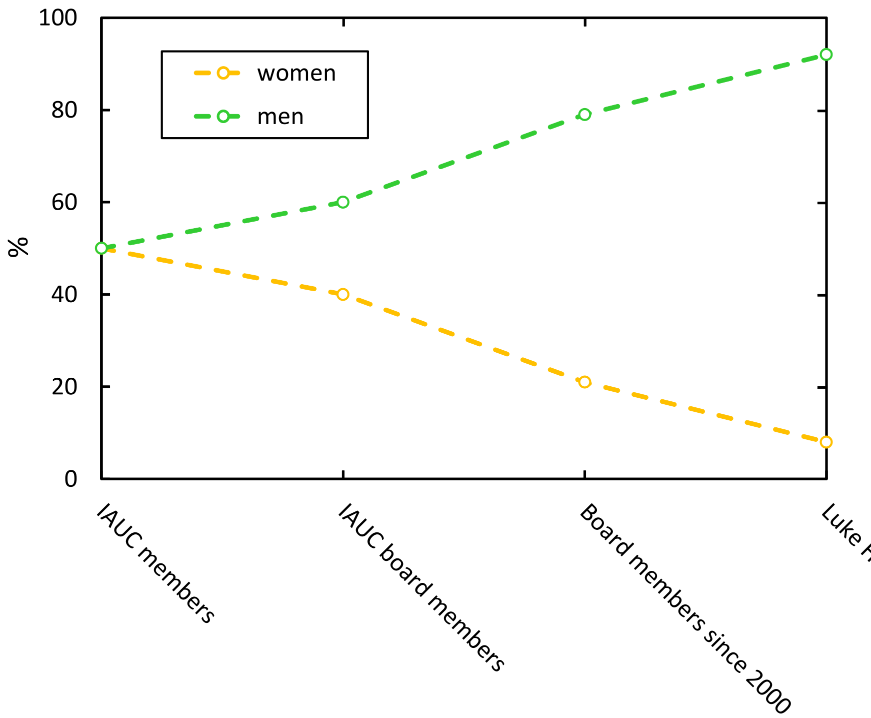
One of the key points raised was to increase opportunities for networking and peer support. Several solutions exist, varying from speed-dating style events (where students would have the chance to talk for a few minutes with established researchers about science, equality, background etc.) to women-only dinners.

Naturally, the discussion at the event was broader than what is summarized above, but the suggestions outlined here may be the first steps towards improving awareness, equality and diversity within IAUC. The organized event was the first of its kind, but hopefully the discussions will continue in forthcoming conferences.

If you have more ideas about how to increase diversity and equality, please do not hesitate to contact Leena Järvi (leena.jarvi@helsinki.fi).




**Fractions of men and women in different academic career stages. Courtesy of Prof. Hanna Vehkamäki.**




**Fractions of men and women within the IAUC.**


# World Forum on Urban Forests convened in Mantova, Italy

Northern Italy was the setting for the first ever World Forum on Urban Forests (WFUF), with some 700 attendees converging on the picturesque town of Mantova between 27 November and 1 December 2018. Following on a series of annual European (EFUF) gatherings, this worldwide forum attracted researchers, practitioners and policy makers from across the globe to discuss their common interest: trees in cities.

This concern for urban trees and the potential benefits they offer was captured in the inaugural WFUF theme, "Changing the nature of cities: the role of urban forestry for a green, healthier and happier future." The growing public confidence in this potential was also evident in the collaboration of international and local bodies who co-organized the event, including the Food and Agriculture Organization (FAO), the Municipality of Mantova, the Italian Society of Silviculture and Forest Ecology (SISEF) and the Politecnico di Milano.

The scientific co-chairs of the conference, Prof. Stefano Boeri (Politenico di Milano and an Tongii University) and Prof. Cecil Konijnendijk (University of British Columbia), emphasized both the interdisciplinary nature of Urban Forestry and its prime focus on climate. Considering that cities of the world represent the main source of anthropogenic carbon emissions to the atmosphere, and forests represent the main sink, bringing forests into cities means "fighting the eneny on his own battle field."

Opening the forum was a series of fascinating plenary keynote addresses by Fabio Salbitano (University of Florence), C.Y. Jim (University of Hong Kong) and Joe McBride, who offered a historical perspective on the role of trees and forests in the urban planning and landscape architecture of various cultures. This whirlwind tour of urban greening through time led into the conference sessions, which were organized in three stages examining green cities in the Past, Present and Future. Each stage was further divided into sessions on the different aspects of change related to dynamic urban forests: Changing People (focusing on socio-cultural issues), Changing Spaces and Places (focusing on design and governance issues) and finally, Changing Environments (focusing on biophysical, and to a large extent climatic, issues).

Further information on WFUF 2018 can be found on the Forum website (https://www.wfuf2018.com/). The Book of Abstracts will be published online in mid-January, and two documents have been produced as outcomes from the conference: A "Call for Action" and a description of the "Mantova Challenge/Tree Cities of the World programme," which may be obtained on reques at Info-WFUF-2018@fao.org. — *David Pearlmutter, Editor*


David Nowak (US Forest Service) presented a recent study on the global extent and benefits of urban tree cover.



Presentations by Rocio Alonso (left) on the contribution of urban and peri-urban vegetation to improving air quality in Mediterranean areas, and Artur Goncalves (right) on the role of green spaces in the urban climate of Bragança, Portugal, were among many that explored the connection between urban forests and climatology.

## Recent Urban Climate Publications


Aarich N, Raoufi M, Bennouna A, Erraissi N (2018) Outdoor comparison of rooftop grid-connected photovoltaic technologies in Marrakech (Morocco). *Energy and Buildings* 173 138-149.

Acero JA, González-Asensio B (2018) Influence of vegetation on the morning land surface temperature in a tropical humid urban area. *Urban Climate* 26 231-243.

Ahmed K, Shahid S, Ismail T, Nawaz N, Wang X (2018) Absolute homogeneity assessment of precipitation time series in an arid region of Pakistan. *Atmósfera* 31 301-316.

Aliyu YA, Botai JO (2018) Reviewing the local and global implications of air pollution trends in Zaria, northern Nigeria. *Urban Climate* 26 51-59.

Ambade B (2018) The air pollution during Diwali festival by the burning of fireworks in Jamshedpur city, India. *Urban Climate* 26 149-160.

Anderson CI, Gough WA, Mohsin T (2018) Characterization of the urban heat island at Toronto: Revisiting the choice of rural sites using a measure of day-to-day variation. *Urban Climate* 25 187-195.

Baniassadi A, Sailor DJ, Crank PJ, Ban-Weiss GA (2018) Direct and indirect effects of high-albedo roofs on energy consumption and thermal comfort of residential buildings. *Energy and Buildings* 178 71-83.

Beck C, Straub A, Breitner S, Cyrys J, Philipp A, Rathmann J, Schneider A, Wolf K, Jacobeit J (2018) Air temperature characteristics of local climate zones in the Augsburg urban area (Bavaria, southern Germany) under varying synoptic conditions. *Urban Climate* 25 152-166.

Bhardwaj P, Singh O (2018) Spatial and temporal analysis of thunderstorm and rainfall activity over India. *Atmósfera* 31 255-284.

Cai D, Fraedrich K, Guan Y, Guo S, Zhang C, Zhu X (2019) Urbanization and climate change: Insights from eco-hydrological diagnostics. *Science of The Total Environment* 647 29-36.

Chatzipoulka C, Nikolopoulou M (2018) Urban geometry, SVF and insolation of open spaces: London and Paris. *Building Research and Information* 46 881-898.

Cheung PK, Jim CY (2018) Subjective outdoor thermal comfort and urban green space usage in humid-subtropical Hong Kong. *Energy and Buildings* 173 150-162.

Cheung PK, Jim CY (2018) Global pattern of human thermal adaptation and limit of thermal neutrality: Systematic analysis of outdoor neutral temperature. *International Journal of Climatology* 38 5037-5049.

Chew LW, Norford LK (2018) Pedestrian-level wind speed enhancement in urban street canyons with void decks. *Building and Environment* 146 64-76.


In this edition is a list of publications that have come out between **September and November 2018**. As usual, papers published since this date are welcome for inclusion in the next newsletter and IAUC online database. Please send your references to the email address below with a header "IAUC publications" and the following format: Author, Title, Journal, Year, Volume, Issue, Pages, Dates, Keywords, URL, and Abstract. Please send the references in a .bib format.

As of this month, **Anurag Bagade** (Department of Architecture and Planning V.N.I.T Nagpur, India) joined the BibCom team. He is taking over from **Marie-Leen Verdonck** (Ghent University, Belgium), who contributed to this community for more than 2 years. On behalf of the community I would like to thank Marie-Leen for her enthusiasm and contribution to the community, and wish her the best of luck in her new professional endavours. Note that we are always looking for (young) researchers to join and contribute to the Committee. If you are interested to join or would like to receive more information, please let me know via the email address below.

Regards,


**Matthias Demuzere**

Chair IAUC Bibliography Committee

CEO & Founder Kode, Affiliated researcher at Ghent University and Leuven University

mdemuzere@gmail.com


### The Bibliography Committee


Lilly Rose Amirtham


Anurag Bagade


Pravin Bhiwapurkar


Ashley Broadbent


Peter Crank


Rohinton Emmanuel


Kathrin Feige


Lech Gawuc


Rafiq Hamdi


Julia Hidalgo


Martina Petralli


Iara Santos


Abel Tablada


Hendrik Wouters


Qunshan Zhao

Ching J, Mills G, Bechtel B, See L, Feddema J, Wang X, Ren C, Brousse O, Martilli A, Neophytou M, Mouzourides P, Stewart I, Hanna A, Ng E, Foley M, Alexander P, Aliaga D, Niyogi D, Shreevastava A, Bhalachandran P, Masson V, Hidalgo J, Fung J, Andrade M, Baklanov A, Dai W, Milcinski G, Demuzere M, Brunsell N, Pesaresi M, Miao S, Mu Q, Chen F, Theeuwes N (2018) WUDAPT: An Urban Weather, Climate, and Environmental Modeling Infrastructure for the Anthropocene. *Bulletin of the American Meteorological Society* 99 1907-1924.

Crank PJ, Sailor DJ, Ban-Weiss G, Taleghani M (2018) Evaluating the ENVI-met microscale model for suitability in analysis of targeted urban heat mitigation strategies. *Urban Climate* 26 188-197.

Dalziel BD, Kissler S, Gog JR, Viboud C, BjON, Metcalf CJE, Grenfell BT (2018) Urbanization and humidity shape the intensity of influenza epidemics in U.S. cities. *Science* 362 75–79.

Deng Y, Wu C, Zhang X, Jia X (2018) Examining the effectiveness of weighted spectral mixture analysis (WSMA) in urban environments. *International Journal of Remote Sensing* 0 1-21.

Dienst M, Linden J, Esper J (2018) Determination of the urban heat island intensity in villages and its connection to land cover in three European climate zones. *Climate Research* 76 1-15.

Doan VQ, Kusaka H (2018) Projections of urban climate in the 2050s in a fast-growing city in Southeast Asia: The greater Ho Chi Minh City metropolitan area, Vietnam. *International Journal of Climatology* 38 4155-4171.

Droste AM, Steeneveld GJ, Holtslag AAM (2018) Introducing the urban wind island effect. *Environmental Research Letters* 13 094007.

Eisma HE, Tomas JM, Pourquie MJBM, Elsinga GE, Jonker HJJ, Westerweel J (2018) Effects of a Fence on Pollutant Dispersion in a Boundary Layer Exposed to a Rural-to-Urban Transition. *Boundary-Layer Meteorology* 169 185–208.

Emmanuel R, Steemers K (2018) Connecting the realms of urban form, density and microclimate. *Building Research and Information* 46 804-808.

Flaga A, Kocon A, Klaput R, Bosak G (2018) The environmental effects of aerodynamic interference between two closely positioned irregular high buildings. *Journal of Wind Engineering and Industrial Aerodynamics* 180 276–287.

Florio P, Probst MCM, SchÃ¼ler A, Roecker C, Scartezzini J-L (2018) Assessing visibility in multi-scale urban planning: A contribution to a method enhancing social acceptability of solar energy in cities. *Solar Energy* 173 97 - 109.

Futcher J, Mills G, Emmanuel R (2018) Interdependent energy relationships between buildings at the street scale. *Building Research and Information* 46 829-844.

Gaur A, Lacasse M (2018) Multisite multivariate disaggregation of climate parameters using multiplicative random cascades. *Urban Climate* 26 121-132.

Gocer O, Gocer K, Basol AM, Kirac MF, Ozbil A, Bakovic M, Siddiqui FP, Ozcan B (2018) Introduction of a spatio-temporal mapping based POE method for outdoor spaces: Suburban university campus as a case study. *Building and Environment* 145 125 - 139.

Godoy-Shimizu D, Steadman P, Hamilton I, Donn M, Evans S, Moreno G, Shayesteh H (2018) Energy use and height in office buildings. *Building Research and Information* 46 845-863.

Gross G (2018) A windthrow model for urban trees with application to storm Xavier. *Meteorologische Zeitschrift* 27 299-308.

Guo F, Zhang H, Fan Y, Zhu P, Wang S, Lu X, Jin Y (2018) Detection and evaluation of a ventilation path in a mountainous city for a sea breeze: The case of Dalian. *Building and Environment* 145 177 - 195.

Guo P, Zhang Q, Chen Y, Xiao J, He J, Zhang Y, Wang L, Liu T, Ma W (2019) An ensemble forecast model of dengue in Guangzhou, China using climate and social media surveillance data. *Science of The Total Environment* 647 752-762.

Hang J, Chen L, Lin Y, Buccolieri R, Lin B (2018) The impact of semi-open settings on ventilation in idealized building arrays. *Urban Climate* 25 196-217.

Hoehne CG, Hondula DM, Chester MV, Eisenman DP, Middel A, Fraser AM, Watkins L, Gerster K (2018) Heat exposure during outdoor activities in the US varies significantly by city, demography, and activity. *Health & Place* 54 1–10.

Hou Y, Wang L, Zhou Y, Wang S, Du C, Wang F (2018) Spatiotemporal variations of tropospheric column nitrogen dioxide over Jing-Jin-Ji during the past decade. *International Journal of Remote Sensing* 0 1-16.

Ignatieva M, Hedblom M (2018) An alternative urban green carpet. *Science* 362 148–149.

Iizuka S (2018) Future environmental assessment and urban planning by downscaling simulations. *Journal of Wind Engineering and Industrial Aerodynamics* 181 69-78.

Jain R, Luo X, Sever G, Hong T, Catlett C (2018) Representation and evolution of urban weather boundary conditions in downtown Chicago. *Journal of Building Performance Simulation* 0 1-14.

Kaboré M, Bozonnet E, Salagnac P, Abadie M (2018) Indexes for passive building design in urban context – indoor and outdoor cooling potentials. *Energy and Buildings* 173 315-325.

Karimi M, Nazari R, Dutova D, Khanbilvardi R, Ghandehari M (2018) A conceptual framework for environmental risk and social vulnerability assessment in complex urban settings. *Urban Climate* 26 161-173.

Kolokotroni M, Shittu E, Santos T, Ramowski L, Mollard A, Rowe K, Wilson E, Filho JPB, Novieto D (2018) Cool roofs: High tech low cost solution for energy efficiency and thermal comfort in low rise low income houses in high solar radiation countries. *Energy and Buildings* 176 58-70.

Koopmans S, Ronda R, Steeneveld G-J, Holtslag AA, Klein Tank AM (2018) Quantifying the Effect of Different Urban Planning Strategies on Heat Stress for Current and Future Climates in the Agglomeration of The Hague (The Netherlands). *Atmosphere* 9 353.

Kosaka E, Iida A, Vanos J, Middel A, Yokohari M, Brown R (2018) Microclimate variation and estimated heat stress of runners in the 2020 Tokyo Olympic Marathon. *Atmosphere* 9

Kotthaus S, Grimmond CSB (2018) Atmospheric boundary-layer characteristics from ceilometer measurements. Part 2: Application to London's urban boundary layer. *Quarterly Journal of the Royal Meteorological Society* 144 1511-1524.

Kristensen MH, Hedegaard RE, Petersen S (2018) Hierarchical calibration of archetypes for urban building energy modeling. *Energy and Buildings* 175 219-234.

Lai D, Chen C, Liu W, Shi Y, Chen C (2018) An ordered probability model for predicting outdoor thermal comfort. *Energy and Buildings* 168 261-271.

László E, Salavec P (2018) Relationship between weather conditions advantageous for the development of urban heat island and atmospheric macrocirculation changes. *International Journal of Climatology* 38 3224-3232.

Lau KK-L, Ng E, Ren C, Ho JC-K, Wan L, Shi Y, Zheng Y, Gong F, Cheng V, Yuan C, Tan Z, Wong KS (2018) Defining the environmental performance of neighbourhoods in high-density cities. *Building Research and Information* 46 540-551.

Leo LS, Buccolieri R, Di Sabatino S (2018) Scale-adaptive morphometric analysis for urban air quality and ventilation applications. *Building Research and Information* 46 931-951.

Li C, Wang Z, Li B, Peng Z-R, Fu Q (2019) Investigating the relationship between air pollution variation and urban form. *Building and Environment* 147 559 - 568.

Li J, Niu J, Mak CM, Huang T, Xie Y (2018) Assessment of outdoor thermal comfort in Hong Kong based on the individual desirability and acceptability of sun and wind conditions. *Building and Environment* 145 50 - 61.

Li X, Yao R, Liu M, Costanzo V, Yu W, Wang W, Short A, Li B (2018) Developing urban residential reference buildings using clustering analysis of satellite images. *Energy and Buildings* 169 417-429.

Liang X, Miao S, Li J, Bornstein R, Zhang X, Gao Y, Chen F, Cao X, Cheng Z, Clements C, Dabberdt W, Ding A, Ding D, Dou JJ, Dou JX, Dou Y, Grimmond CSB, González-Cruz JE, He J, Huang M, Huang X, Ju S, Li Q, Niyogi D, Quan J, Sun J, Sun JZ, Yu M, Zhang J, Zhang Y, Zhao X, Zheng Z, Zhou M (2018) SURF: Understanding and Predicting Urban Convection and Haze. *Bulletin of the American Meteorological Society* 99 1391-1413.

Lin Y, Jim C, Deng J, Wang Z (2018) Urbanization effect on spatiotemporal thermal patterns and changes in Hangzhou (China). *Building and Environment* 145 166 - 176.

Lipson MJ, Thatcher M, Hart MA, Pitman A (2018) A building energy demand and urban land surface model. *Quarterly Journal of the Royal Meteorological Society* 144 1572-1590.

Llaguno-Munitxa M, Bou-Zeid E (2018) Shaping buildings to promote street ventilation: A large-eddy simulation study. *Urban Climate* 26 76-94.

López-Lambraño AA, Fuentes C, López-Ramos AA, Ramírez JM, López-Lambraño M (2018) Spatial and temporal Hurst exponent variability of rainfall series based on the climatological distribution in a semiarid region in Mexico. *Atmósfera* 31 199-219.

Lu Y, Zang X, Yao H, Zhang S, Sun S, Liu F (2018) Assessment of trace metal contamination in groundwater in a highly urbanizing area of Shenfu New District, Northeast China. *Frontiers of Earth Science* 12 569-582.

Machete R, Falcão AP, Gomes MG, Rodrigues AM (2018) The use of 3D GIS to analyse the influence of urban context on buildings' solar energy potential. *Energy and Buildings* 177 290-302.

Martín-Consuegra F, Frutos F, Oteiza I, Agustín HA (2018) Use of cadastral data to assess urban scale building energy loss. Application to a deprived quarter in Madrid. *Energy and Buildings* 171 50-63.

Mauree D, Blond N, Clappier A (2018) Multi-scale modeling of the urban meteorology: Integration of a new canopy model in the WRF model. Urban Climate 26 60-75.

Melecio-Vazquez D, Ramamurthy P, Arend M, Gonzalez-Cruz JE (2018) Thermal Structure of a Coastal-Urban Boundary Layer. *Boundary-Layer Meteorology* 169 151-161.

Middel A, Lukasczyk J, Maciejewski R (2017) Sky view factors from synthetic fisheye photos for thermal comfort routing – A case study in Phoenix, Arizona. *Urban Planning* 2.

Middel A, Lukasczyk J, Maciejewski R, Demuzere M, Roth M (2018) Sky View Factor footprints for urban climate modeling. *Urban Climate* 25 120-134.

Mirzaee S, Özgun O, Ruth M, Binita KC (2018) Neighborhood-scale sky view factor variations with building density and height: A simulation approach and case study of Boston. *Urban Climate* 26 95-108.

Mohammad AF, Zaki SA, Ikegaya N, Hagishima A, Ali MSM (2018) A new semi-empirical model for estimating the drag coefficient of the vertical random staggered arrays using LES. *Journal of Wind Engineering and Industrial Aerodynamics* 180 191–200.

Nageler P, Koch A, Mauthner F, Leusbrock I, Mach T, Hochenauer C, Heimrath R (2018) Comparison of dynamic urban building energy models (UBEM): Sigmoid energy signature and physical modelling approach. *Energy and Buildings* 179 333-343.

Nandkeolyar N, Kiran S (2018) A climatological study of the spatio-temporal variability of land surface temperature and vegetation cover of Vadodara district of Gujarat using satellite data. *International Journal of Remote Sensing* 0 1-19.

Nazarian N, Sin T, Norford L (2018) Numerical modeling of outdoor thermal comfort in 3D. *Urban Climate* 26 212-230.

Orozco-Aguilar L, Nitschke CR, Livesley SJ, Brack C, Johnstone D (2018) Testing the accuracy of resistance drilling to assess tree growth rate and the relationship to past climatic conditions. *Urban Forestry & Urban Greening* 36 1-12.

Ouyang Z, Lin M, Chen J, Fan P, Qian SS, Park H (2019) Improving estimates of built-up area from night time light across globally distributed cities through hierarchical modeling. *Science of The Total Environment* 647 1266-1280.

Palme M, Inostroza L, Salvati A (2018) Technomass and cooling demand in South America: a superlinear relationship? *Building Research and Information* 46 864-880.

Pauleit S, Ambrose-Oji B, Andersson E, Anton B, Buijs A, Haase D, Elands B, Hansen R, Kowarik I, Kronenberg J, Mattijssen T, Olafsson AS, Rall E, van der Jagt AP, van den Bosch CK (2018) Advancing urban green infrastructure in Europe: Outcomes and reflections from the GREEN SURGE project. *Urban Forestry & Urban Greening* (in press).

Pérez A, Ortiz JC, Bejarano LF, Luis OD, Juan CRL, Andrés FH (2018) Land use/land cover change and extreme climatic events in the arid and semi-arid ecoregions of Mexico. *Atmósfera* 31 389-406.

Peronato G, Rastogi P, Rey E, Andersen M (2018) A toolkit for multi-scale mapping of the solar energy-generation potential of buildings in urban environments under uncertainty. *Solar Energy* 173 861-874.

Peronato G, Rey E, Andersen M (2018) 3D model discretization in assessing urban solar potential: the effect of grid spacing on predicted solar irradiation. *Solar Energy* 176 334 - 349.

Pontifes PA, García-Meneses PM, Gómez-Aíza L, Monterroso-Rivas AI, Chávez MC (2018) Sea breeze in the Colombian Caribbean coast. *Atmósfera* 31 355-372.

Revesz M, Oswald SM, Trimmel H, Weihs P, Zamini S (2018) Potential increase of solar irradiation and its influence on PV facades inside an urban canyon by increasing the ground-albedo. *Solar Energy* 174 7 - 15.

Richard Y, Emery J, Dudek J, Pergaud J, Chateau-Smith C, Zito S, Rega M, Vairet T, Castel T, Thévenin T, Pohl B (2018) How relevant are local climate zones and urban climate zones for urban climate research? Dijon (France) as a case study. *Urban Climate* 26 258-274.

Romero-Lankao P, Bulkeley H, Pelling M, Burch S, Gordon DJ, Gupta J, Johnson C, Kurian P, Lecavalier E, Simon D, Tozer L, Ziervogel G, Munshi D (2018) Urban transformative potential in a changing climate. *Nature Climate Change* 8 754-756.

Rosenzweig C, Solecki W (2018) Action pathways for transforming cities. *Nature Climate Change* 8 756-759.

Roupioz L, Kastendeuch P, Nerry F, Colin J, Najjar G, Luhahe R (2018) Description and assessment of the building surface temperature modeling in LASER/F. *Energy and Buildings* 173 91-102.

Salata F, Golasi I, Ciancio V, Rosso F (2018) Dressed for the season: Clothing and outdoor thermal comfort in the Mediterranean population. *Building and Environment* 146 50-63.

Shaeri J, Aflaki A, Yaghoubi M, Janalizadeh H (2018) Investigation of passive design strategies in a traditional urban neighborhood: A case study. *Urban Climate* 26 31-50.

Sharifi A (2019) Resilient urban forms: A review of literature on streets and street networks. *Building and Environment* 147 171 - 187.

Shen L, Sun J, Yuan R (2018) Idealized large-eddy simulation study of interaction between urban heat island and sea breeze circulations. *Atmospheric Research* 214 338 - 347.

Shi Y, Lau KK, Ren C, Ng E (2018) Evaluating the local climate zone classification in high-density heterogeneous urban environment using mobile measurement. *Urban Climate* 25 167-186.

Shooshtarian S, Rajagopalan P, Wakefield R (2018) Effect of seasonal changes on usage patterns and behaviours in educational precinct in Melbourne. *Urban Climate* 26 133-148.

Sikder SK, Nagarajan M, Kar S, Koetter T (2018) A geospatial approach of downscaling urban energy consumption density in mega-city Dhaka, Bangladesh. *Urban Climate* 26 10-30.

Singh V, Sahu SK, Kesarkar AP, Biswal A (2018) Estimation of high resolution emissions from road transport sector in a megacity Delhi. *Urban Climate* 26 109-120.

Song J, Fan S, Lin W, Mottet L, Woodward H, Wykes MD, Arcucci R, Xiao D, Debay JE, ApSimon H, Aristodemou E, Birch D, Carpentieri M, Fang F, Herzog M, Hunt GR, Jones RL, Pain C, Pavlidis D, Robins AG, Short CA, Linden PF

(2018) Natural ventilation in cities: the implications of fluid mechanics. *Building Research and Information* 46 809-828.

Song X-P, Hansen MC, Stehman SV, Potapov PV, Tyukavina A, Vermote EF, Townshend JR (2018) Global land change from 1982 to 2016. *Nature* 560 639+.

Sosa MB, Correa EN, Cantón MA (2018) Neighborhood designs for low-density social housing energy efficiency: Case study of an arid city in Argentina. *Energy and Buildings* 168 137-146.

Sreekanth V, Mahesh B, Niranjan K (2018) Gradients in PM2.5 over India: Five city study. *Urban Climate* 25 99-108.

Stavropulos-Laffaille X, Chancibault K, Brun J-M, Lemonsu A, Masson V, Boone A, Andrieu H (2018) Improvements to the hydrological processes of the Town Energy Balance model (TEB-Veg, SURFEX v7.3) for urban modelling and impact assessment. *Geoscientific Model Development* 11 4175-4194.

Suhaila J, Yusop Z (2018) Trend analysis and change point detection of annual and seasonal temperature series in Peninsular Malaysia. *Meteorology and Atmospheric Physics* 130 565–581.

Sun S, Tian L, Cao W, Lai P-C, Wong PPY, Lee RS-y, Mason TG, Krämer A, Wong C-M (2019) Urban climate modified short-term association of air pollution with pneumonia mortality in Hong Kong. *Science of The Total Environment* 646 618-624.

Toja-Silva F, Kono T, Peralta C, Lopez-Garcia O, Chen J (2018) A review of computational fluid dynamics (CFD) simulations of the wind flow around buildings for urban wind energy exploitation. *Journal of Wind Engineering and Industrial Aerodynamics* 180 66–87.

Tse JWP, Yeung PS, Fung JC, Ren C, Wang R, Wong MM, Cai M (2018) Investigation of the meteorological effects of urbanization in recent decades: A case study of major cities in Pearl River Delta. *Urban Climate* 26 174-187.

Vallati A, Mauri L, Colucci C (2018) Impact of shortwave multiple reflections in an urban street canyon on building thermal energy demands. *Energy and Buildings* 174 77-84.

Vousdoukas I M, Mentaschi L, Voukouvalas E, Bianchi A, Dottori F, Feyen L (2018) Climatic and socioeconomic controls of future coastal flood risk in Europe. *Nature Climate Change* 8 776+.

Wang K, Li Y, Li Y, Lin B (2018) Stone forest as a small-scale field model for the study of urban climate. *International Journal of Climatology* 38 3723-3731.

Wei Z, Xu W, Wang D, Li L, Niu L, Wang W, Wang B, Song Y (2018) A study of city-level building energy efficiency benchmarking system for China. *Energy and Buildings* 179 1-14.

Xu D, Zhou D, Wang Y, Xu W, Yang Y (2019) Field measurement study on the impacts of urban spatial indicators on urban climate in a Chinese basin and static-wind city. *Building and Environment* 147 482 - 494.

Xu Y, Knudby A, CÃ´tÃ©-Lussier C (2018) Mapping ambient light at night using field observations and high-resolution remote sensing imagery for studies of urban environments. *Building and Environment* 145 104 - 114.

Yuan C, Shan R, Zhang Y, Li X-X, Yin T, Hang J, Norford L (2019) Multilayer urban canopy modelling and mapping for traffic pollutant dispersion at high density urban areas. *Science of The Total Environment* 647 255-267.

Yuan W, Xu H, Yu R, Li J, Zhang Y, He N (2018) Regimes of rainfall preceding regional rainfall events over the plain of Beijing City. *International Journal of Climatology* 38 4979-4989.

Zare S, Hasheminezhad N, Sarebanzadeh K, Zolala F, Hematjo R, Hassanvand D (2018) Assessing thermal comfort in tourist attractions through objective and subjective procedures based on ISO 7730 standard: A field study. *Urban Climate* 26 1-9.

Zekar A, El-Khatib S (2018) Development and assessment of simplified building representations under the context of an urban energy model: Application to arid climate environment. *Energy and Buildings* 173 461-469.

Zeng ZC, Natraj V, Xu F, Pongetti TJ, Shia RL, Kort EA, Toon GC, Sander SP, Yung YL (2018) Constraining Aerosol Vertical Profile in the Boundary Layer Using Hyperspectral Measurements of Oxygen Absorption. *Geogphysical Research Letters* 45 10772–10780.

Zhang K, Chui TFM (2019) Linking hydrological and bioecological benefits of green infrastructures across spatial scales – A literature review. *Science of The Total Environment* 646 1219-1231.

Zhang L, Pan Z, Zhang Y, Meng Q (2018) Impact of climatic factors on evaporative cooling of porous building materials. *Energy and Buildings* 173 601-612.

Zhang R, Mirzaei PA, Jones B (2018) Development of a dynamic external CFD and BES coupling framework for application of urban neighbourhoods energy modelling. *Building and Environment* 146 37 - 49.

Zheng ZF, Ren GY, Wang H, Dou JX, Gao ZQ, Duan CF, Li YB, Ngarukiyimana JP, Zhao C, Cao C, Jiang M, Yang YJ (2018) Relationship Between Fine-Particle Pollution and the Urban Heat Island in Beijing, China: Observational Evidence. *Boundary-Layer Meteorology* 169 93–113.

Zhou LW, Wang Q, Li Y, Liu M, Wang RZ (2018) Green roof simulation with a seasonally variable leaf area index. *Energy and Buildings* 174 156-167.

Zhu X, Wang X, Yan D, Liu Z, Zhou Y (2018) Analysis of remotely-sensed ecological indexes' influence on urban thermal environment dynamic using an integrated ecological index: a case study of Xi'an, China. *International Journal of Remote Sensing* 0 1-27.

## Workshop on Open-grown and Urban Trees

### Albert-Ludwigs-Universität Freiburg, Freiburg, Germany • 7-10 April 2019

**Aim**

Bringing together experts and other interested persons on wind-tree interactions and stability of individual, open-grown und urban trees against high-impact wind loading. The workshop provides information on the latest scientific findings in these fields. Approaches used to excite tree response to external loads are demonstrated and discussed.

The workshop is hosted by PD Dr. Dirk Schindler of Chair of Environmental Meteorology, Albert-Ludwigs-Universität Freiburg.

Dates are 7-10 April 2019, Registration until 28 Feb 2019. The maximum number of participants is 30 persons. More information:

https://www.meteo.uni-freiburg.de/en/events/workshop-on-open-grown-and-urban-trees-2019

**Detailed description**

The response of open-grown trees to wind loading is complex and complicated. In contrast to plantation forest-grown trees, which usually have small crowns and only one main axis, the crowns of open-grown trees are often either much larger and/or have more than one dominating axis. The resulting complexity of the wind-induced crown motion, complicates the in situ assessment of destructive wind loads and thus the assessment of tree stability. Since open-grown trees are an integral part of urban spaces, the assessment of their stability against destructive wind loading is of great importance. The importance becomes particularly evident when the urban tree population gets damaged. At irregular intervals, storms throw and break trees and endanger the urban population and property. It is therefore in society's interest to minimise the hazard to urban trees from storms through appropriate management. The basis for successfully increasing the resistance of the urban tree population against high-impact storms is science-based knowledge about destructive wind-tree-soil-interactions. You can register here:

https://www.meteo.uni-freiburg.de/en/events/workshop-on-open-grown-and-urban-trees-2019/registration-1

*Upcoming Conferences...*

**EUROPEAN GEOSCIENCES UNION (EGU) GENERAL ASSEMBLY SESSION: "URBAN CLIMATE, URBAN BIOMETEOROLOGY, AND SCIENCE TOOLS FOR CITIES"**
Vienna, Austria • April 7–12 2019
https://www.egu2019.eu

**WORKSHOP ON OPEN-GROWN AND URBAN TREES 2019**
Freiburg, Germany • April 7-10, 2019
https://www.meteo.uni-freiburg.de/en/events/workshop-on-open-grown-and-urban-trees-2019

**COMFORT AT THE EXTREMES: ENERGY, ECONOMY AND CLIMATE (CATE)**
Dubai • April 10-11, 2019
https://comfortattheextremes.com

**JOINT URBAN REMOTE SENSING EVENT (JURSE)**
Vannes, France • May 22-24, 2019
http://www.jurse2019.org

**ENERGY AND SOCIETY IN TRANSITION: 2ND INTERNATIONAL CONFERENCE ON ENERGY RESEARCH AND SOCIAL SCIENCE**
Tempe, Arizona USA • May 28-31, 2019
https://www.elsevier.com/events/conferences/international-conference-on-energy-research-and-social-science

**INTERNATIONAL CONFERENCE ON SUSTAINABILITY IN ENERGY AND BUILDINGS (SEB-19)**
Budapest, Hungary • July 4-5, 2019
http://seb-19.kesinternational.org/

## Helen Ward and Matthias Demuzere elected to the IAUC Board

Congratulations to Helen Ward and Matthias Demuzere, who have been elected to the Board of the IAUC for the period 2019-2022. Helen and Matthias will replace Edward Ng (The Chinese University of Hong Kong) and Fei Chen (NCAR, USA) whose terms on the Board expire.

**Helen Ward** is post-doctoral researcher at the University of Innsbruck in Austria. Her current research is focused on the analysis of turbulence observations in and around Innsbruck and the evaluation of the Weather Research and Forecasting (WRF) model for cities located in mountainous terrain. Helen obtained her PhD in urban micrometeorology at King's College London (2009-2013). Subsequently she worked as a post-doctoral researcher at Reading University. In the past two years Helen has served as editor for the 'Projects' section of Urban Climate News, and over the last year she has been involved in the promotion of diversity and equality within IAUC.

**Matthias Demuzere** is founder and CEO of Kode, and affiliated researcher at Ghent University and Leuven University, Belgium. Matthias obtained his PhD (IWT) in Science at KU Leuven, where he also completed a six-year post-doctoral position. During both the PhD and post-doc position Matthias has been working abroad, including long-term research stays at the National University of Singapore, Monash University (Australia) and at MPI for Biogeochemistry (Germany). He was consequently post-doctoral researcher at the Laboratory of Hydrology and Water Management at Ghent University. Matthias has been coordinating the IAUC Bibliography Committee for the past four years.

The IAUC executive thanks Edward and Fei for their commitment and contributions to IAUC and to its Board and also thank the four unsuccessful candidates for standing for election. A total of 228 members participated in the vote, although some members voted for one candidate only, which yielded a total of 416 votes. Mathias with 101 votes (24%) and Helen with 88 votes (21%) received the highest share.

— *Andreas Christen and Nigel Tapper*

### IAUC Board Members & Terms

- **President**: Nigel Tapper (Monash University, Australia), 2018-2022.
- **Secretary**: Andreas Christen (Albert-Ludwigs Universität Freiburg, Germany), 2018-2022.
- Alexander Baklanov (WMO, Switzerland), *WMO Representative*, 2018-2022.**
- Benjamin Bechtel (Universität Hamburg, Germany), 2017-2021.
- Matthias Demuzere (Kode, Belgium), 2019-2022.
- Jorge Gonzalez (CUNY, USA): *ICUC10 Local Organizer*, 2016-2021.
- Aya Hagishima (Kyushu University, Japan), 2015-2019.
- Leena Järvi (University of Helsinki, Finland), 2016-2020.
- Ariane Middel (Temple University, USA), 2016-2020.
- Dev Niyogi (Purdue University, USA): *ICUC10 Local Organizer*, 2016-2021.
- David Pearlmutter (Ben-Gurion University, Israel), *Newsletter Editor*, 2008-*
- Chao Ren (University of Hong Kong, Hong Kong), 2017-2021.
- David Sailor (Arizona State University, USA), *Past Secretary* 2014-2018.*
- James Voogt (University of Western Ontario, Canada), *Past President*: 2014-2018.*
- Helen Ward (University of Innsbruck, Austria), 2019-2022.

* non-voting, ** non-voting appointed member

### IAUC Committee Chairs

- **Editor, IAUC Newsletter**: David Pearlmutter
  - News Editor: Paul Alexander
  - Urban Projects Editor: Helen Ward
  - Conferences Editor: Joe McFadden
- **Bibliography Committee**: Matthias Demuzere
- **Chair Teaching Resources**: Gerald Mills
- **Chair Awards Committee**: Nigel Tapper

### *Urban Climate News – The Quarterly Newsletter of the International Association for Urban Climate*

**Editor**: David Pearlmutter
davidp@bgu.ac.il

**Urban Projects:** Helen Ward
Helen.Ward@uibk.ac.at

**News:** Paul Alexander
paul.alexander@cso.ie

**Conferences:** Joe McFadden
mcfadden@ucsb.edu

The next edition of ***Urban Climate News*** will appear in late March. Contributions for the upcoming issue are welcome, and should be submitted by February 28, 2019 to the relevant editor.

Submissions should be concise and accessible to a wide audience. The articles in this Newsletter are unrefereed, and their appearance does not constitute formal publication; they should not be used or cited otherwise.

**Bibliography:** Matthias Demuzere and BibCom members
mdemuzere@gmail.com