Urban Climate News

Quarterly Newsletter of the IAUC

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From the IAUC President

Welcome to the third edition of the *Urban Climate News* in 2022. It is my first Presidential column since I took office in September, and I certainly have big shoes to fill. I feel honored and privileged to be taking over this role and thank the Board for their confidence and support.

On behalf of IAUC, I would like to thank **Nigel Tapper** for serving as President during what must have been the most challenging term for any IAUC President. Despite lockdowns, cancelled events, and little to no face-to-face interactions, Nigel kept the community engaged during the pandemic and provided strong leadership and vision. Thank you, Nigel, for your commitment and dedication to the success of the organization. I would also like to thank **Andreas Christen** for serving as Secretary and keeping all IAUC Board business on track.

Joining me on the Executive Board for the next four years are **Benjamin Bechtel** (Secretary) and **Dev Niyogi** (Treasurer). Thank you both for agreeing to serve, I look forward to working with you!

As the Executive transitions, we will also have changes to the Board. We owe a debt of gratitude to **Matthias Demuzere** (Ruhr-University Bochum, Germany) and **Helen Ward** (University of Innsbruck, Austria) who will complete their term at the end of this year. Please join me in thanking them for their hard work and contributions.

A call for Board member nominations will come out shortly. We strongly encourage nominations of young scholars and candidates who diversify the board in terms of study, geographical location, and gender. If you are interested in joining the Board or know someone who would be a great addition to the Board, please watch out for and respond to an email from Benjamin Bechtel asking for nominations.

I am delighted to announce that the IAUC Board has selected Professor **James Voogt** of the University of Western Ontario, Canada as the winner of the IAUC Luke Howard award. The award is given for outstanding research, teaching, and/or service contributions to the urban climatology field. Jamie is a leading expert on thermal anisotropy and remote sensing of urban surface temperatures and well known to members as a former IAUC president (2014-2018) and co-author of the *Urban Climates* textbook. He is one of the most enthusiastic, engaged, and highly regarded members of the IAUC and has made considerable fundamental and impactful scientific contributions of outstanding quality.

I am also pleased to announce that Associate Professor **Dan Li** at Boston University won the newly established Timothy Oke award, given annually to early- and mid-career researchers to recognize research excellence. Dan has made numerous outstanding intellectual contributions to the field of urban climate and boundary layer meteorology and will surely continue to have a major impact on our field.

Inside the September issue...

A detailed description of the recipients' accomplishments can be found in this newsletter. Please join me in congratulating the awardees for this highly deserved recognition! I would also like to acknowledge **Helen Ward** (Chair of the Awards Committee) and the Committee members for the hard work this year in support of the two awards.

This past quarter has been filled with IAUC activities, as you will see in this Newsletter. Most notably, our community came together at the *IAUC Virtual Poster Conference*, hosted by the University of New South Wales at the end of August. It was great to "see" everyone and to learn about all the exciting new research that has happened during the pandemic -- a taste of what's to come at ICUC-11 in Sydney in August 2023. Thank you so much, **Negin Nazarian** and **Melissa Hart**, for pulling double duty and for organizing a fantastic virtual event on top of organizing ICUC-11!

I hope you enjoy Issue no. 85 of the *Urban Climate News*. A big thank you to Editor **David Pearlmutter** and the production team for their outstanding work on bringing you "what's hot, what's new, and what's next" in urban climate.

– Ariane Middel, IAUC President

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Biden signs massive climate and health care legislation

President Joe Biden signs the Democrats' landmark climate change and health care bill in the State Dining Room of the White House in Washington, Tuesday, Aug. 16, 2022, as from left, Sen. Joe Manchin, D-W.Va., Senate Majority Leader Chuck Schumer of N.Y., House Majority Whip Rep. James Clyburn, D-S.C., Rep. Frank Pallone, D-N.J., and Rep. Kathy Castor, D-Fla., watch. (AP Photo/Susan Walsh)

https://apnews.com/article/biden-signs-climate-health-bill-9a7f349fa7b07387d20ad603f2ff4875/gallery/b4f310d99d974b5d88a5d15e37bdd9ad

August 2022 — WASHINGTON (AP) — President Joe Biden signed Democrats' landmark climate change and health care bill into law on Tuesday, delivering what he has called the "final piece" of his pared-down domestic agenda, as he aims to boost his party's standing with voters less than three months before the midterm elections.

The legislation includes the most substantial federal investment in history to fight climate change — some $375 billion over the decade. The measure is paid for by new taxes on large companies and stepped-up IRS enforcement of wealthy individuals and entities, with additional funds going to reduce the federal deficit.

In a triumphant signing event at the White House, Biden pointed to the law as proof that democracy — no matter how long or messy the process — can still deliver for voters in America as he road-tested a line he will likely repeat later this fall ahead of the midterms: "The American people won, and the special interests lost."

"In this historic moment, Democrats sided with the American people, and every single Republican in the Congress sided with the special interests in this vote," Biden said, repeatedly seizing on the contrast between his party and the GOP. "Every single one."

The House on Friday approved the measure on a party-line 220-207 vote. It passed the Senate days earlier with Vice President Kamala Harris breaking a 50-50 tie in that chamber.

"In normal times, getting these bills done would be a huge achievement," Senate Majority Leader Chuck Schumer, D-N.Y., said during the White House ceremony. "But to do it now, with only 50 Democratic votes in the Senate, over an intransigent Republican minority, is nothing short of amazing."

The signing caps a spurt of legislative productivity for Biden and Congress, who in three months have approved legislation on veterans' benefits, the semiconductor industry and gun checks for young buyers. The president and lawmakers have also responded to Russia's invasion of Ukraine and overwhelmingly supported NATO membership for Sweden and Finland.

With Biden's approval rating lagging, Democrats are hoping that the string of successes will jump-start their chances of maintaining control in Washington in the November midterms. The 79-year-old president aims to restore his own standing with voters as he contemplates a reelection bid.

The White House announced Monday that it was going to deploy Biden and members of his Cabinet on a

"Building a Better America Tour" to promote the recent victories. One of Biden's trips will be to Ohio, where he'll view the groundbreaking of a semiconductor plant that will benefit from the recent law to bolster production of such computer chips. He will also stop in Pennsylvania to promote his administration's plan for safer communities, a visit that had been planned the same day he tested positive for COVID-19 last month.

Biden also plans to hold a Cabinet meeting to discuss how to implement the new climate and health care law. Republicans say the legislation's new business taxes will increase prices, worsening the nation's bout with its highest inflation since 1981. Though Democrats have labeled the measure the Inflation Reduction Act, nonpartisan analysts say it will have a barely perceptible impact on prices. Senate Minority Whip John Thune, R-S.D., on Tuesday continued those same criticisms, although he acknowledged there would be "benefit" through extensions on tax credits for renewable energy projects like solar and wind.

"I think it's too much spending, too much taxing, and in my view wrong priorities, and a super-charged, super-sized IRS that is going to be going after a lot of not just high-income taxpayers but a lot of mid-income taxpayers," said Thune, speaking at a Chamber of Commerce event in Sioux Falls. The administration has disputed that anyone but high earners will face increased tax scrutiny, with Treasury Secretary Janet Yellen directing the tax agency to focus solely on businesses and people earning more than $400,000 per year for the new audits.

The measure is a slimmed-down version of the more ambitious plan to supercharge environment and social programs that Biden and his party unveiled early last year. Though the law is considerably smaller than their initial ambitions, Biden and Democrats are hailing the legislation as a once-in-a-generation investment in addressing the long-term effects of climate change, as well as drought in the nation's West.

The bill will direct spending, tax credits and loans to bolster technology like solar panels, consumer efforts to improve home energy efficiency, emission-reducing equipment for coal- and gas-powered power plants, and air pollution controls for farms, ports and low-income communities. Source: https://apnews.com/article/biden-signs-climate-health-bill-9a7f349fa7b07387d20ad603f2ff4875

The Inequitable Distribution of Urban Trees

September 2022 — Trees provide numerous environmental services: They draw carbon dioxide from the atmosphere and emit oxygen into it; they cool the air and the ground by providing shade; they absorb storm water and hold soil in place. Their mere presence raises property values. Research has also found that greener areas benefit human health and well-being.

But trees, and the benefits they provide, are not evenly distributed, especially in urban areas. And it is here, where buildings and streets create heat islands, that trees could help improve public health and reduce mortality, according to new research published in Frontiers in Public Health.

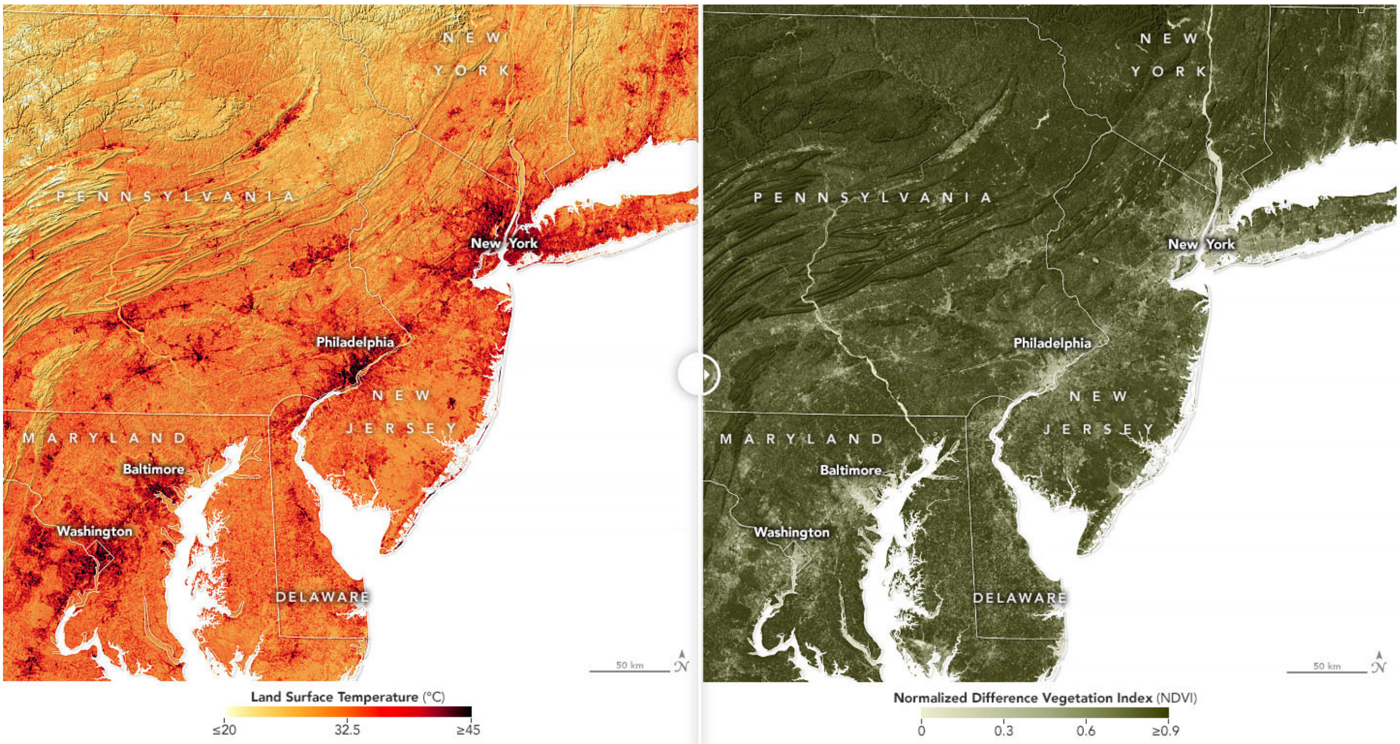
The researchers, led by Paige Brochu, a doctoral student in environmental health at Boston University, assessed the impact of greenness on human mortality across two decades in 35 of the most populated metropolitan areas in the United States. The team used a Normalized Difference Vegetation Index (NDVI) built from Landsat imagery to see how the quantity of green vegetation had changed around cities from 2000 to 2010 to 2019. NDVI is a calculation of the ratio of near-infrared to visible light, and it is used to measure the abundance and health of vegetation.

The maps above show the abundance of vegetation around several urban areas in the Northeast, as well as the average land surface temperatures. The maps were made using data acquired by the Operational Land Imager (OLI) on Landsat 8 from June 21 to September 22, 2019. (Calculations of NDVI for a given pixel result in a number that ranges from minus one (-1) to plus one (+1).)

Brochu's team found that overall greenness increased in the urban areas studied by an average of 2.86 percent between 2000 and 2010. It increased by an additional 11.11 percent from 2010 to 2019. The researchers then compared the changes in greenness to county-level mortality data for people aged 65 and older, as reported by the Centers for Disease Control and Prevention.

"The connection between exposure to greenness or green vegetation and mortality is not necessarily as direct as the connection between air pollution and respiratory diseases. There are multiple direct and indirect ways in which exposure to greenness—such as living near a green park or having trees along sidewalks on our daily walks—can impact our health and, in the long-term, impact all-cause mortality," Brochu said. "This can include reducing our exposure to heat islands in urban areas by having trees providing shade that can prevent heat-related deaths. There is also evidence that living near green spaces or parks can increase physical activity and recreation, in turn leading to lower risks of chronic diseases such as obesity."

The scientists assessed how an increase in greenness might affect mortality using previously identified expo-



Maps showing the the average land surface temperatures (left) and abundance of vegetation (right) around urban areas in the Northeast US. Source: earthobservatory.nasa.gov

sure-response functions, which quantify the relationship between greenness and health, Brochu said. Such metrics account for some societal factors, such as race and income, that can affect access and exposure to greenness.

The team's analysis found that even small improvements in greenness could have further reduced mortality. "We estimated that between 34,000 and 38,000 all-cause deaths could have been reduced in 2000, 2010, and 2019 with a local increase in green vegetation by 0.1 unit [of NDVI] across the most populated metropolitan areas," the team wrote."This study really helps quantify and give a tangible number to policymakers about the public health impact of greening initiatives and climate action plans," Brochu said.

Another study, led by Robert McDonald of the Nature Conservancy, investigated the disparities in tree cover and temperature in urban areas of the U.S. and found they correlated strongly with income.

Using high-resolution (2-meter) tree cover maps derived from aerial photographs and Landsat data on summer land-surface temperatures, McDonald's team examined how tree cover and urban heat related to income, race, and ethnicity. Working all the way down to the block level, the researchers examined 5,723 communities that are collectively home to 167 million people.

In 92 percent of the areas studied, low-income blocks were found to have an average of 15.2 percent less tree cover; they also endured summer temperatures that were 1.5°C (2.7°F) hotter than high-income blocks. Areas with less tree cover have less shade, and also lack the other cooling effects that vegetation provides.

"The greatest difference between low- and high-income blocks was found in the Northeast, where low-income blocks in some urbanized areas have 30 percent less tree cover and are 4°C hotter," the team wrote in PLOS ONE.

Even after controlling for other factors that could confound the associations, such as building and population densities, "the positive association between income and tree cover is significant, as is the positive association between [the] proportion [of] non-Hispanic white [residents] and tree cover," they wrote.

"It is true that high-density neighborhoods have more impervious surface cover, and we believe this is what leads on average to lower tree cover in these neighborhoods," McDonald said. Impervious surface cover, such as asphalt and concrete, also absorbs, holds, and re-radiates heat, creating the urban heat island effect. "There just isn't space for as much tree cover as [there is] in the suburbs."

The researchers found that low-income blocks collectively have 62 million fewer trees than high-income blocks. "An investment in tree planting and natural regeneration of $17.6 billion would be needed to close the tree-cover disparity," McDonald and colleagues wrote,"benefitting 42 million people in low-income blocks."

NASA Earth Observatory images by Lauren Dauphin, using Landsat data from the U.S. Geological Survey and topographic data from the Shuttle Radar Topography Mission (SRTM). Story by Sara E. Pratt. Source: https://earthobservatory.nasa.gov/images/150351/the-inequitable-distribution-of-urban-trees

First global survey of mayors shows urgent climate, infrastructure, equity challenges

September 2022 — A new global survey of city leaders underscores pressing challenges facing municipalities, including rising inequality, extreme heat and flood risks exacerbated by climate change, and a need to rebalance transportation systems that overly favor private automobiles.

The survey was conducted by researchers at Cornell University and is the first of its kind—capturing data from 241 cities worldwide. It reveals many cities in developing countries face enormous challenges in providing core urban services that support economic growth, as they have very limited fiscal resources. While in developed countries, large shares of urban leaders report land constraints, high housing costs, and a mismatch between available jobs and residents' skills.

"The future of the world is urban and many cities are unprepared for the urban population increase that will continue over the next three decades," said Victoria A. Beard, lead researcher and director of the Cornell Mui Ho Center for Cities housed in the College of Architecture, Art, and Planning. "This survey gives us a perspective we've never had before: a first-ever glimpse of what city leaders around the world see as their greatest challenges, where they will spend precious municipal resources, and underscores where cites have an opportunity to work together across diverse geographies on priority areas they have in common."

City leaders universally agree climate change has intensified exposure to extreme heat, water scarcity and flooding, with 43% of leaders in developing cities agreeing climate change has intensified water scarcity. A little over half the cities in developing countries report having climate mitigation (57%) or adaptation plans (51%). Only 6% of developing-country city leaders (and just 2–3% in Sub-Saharan Africa and Latin America and the Caribbean) reported no climate change impacts, compared with 16% in developed countries.

A majority of all city leaders (66%) agree there is too much emphasis on private automobiles and that cities should support more active and sustainable urban mobility. Eighty-seven percent somewhat or strongly agree their city should be more receptive to biking and walking.

The challenges facing city leaders in developing regions are acute, especially on the economic front. While approximately 82% of leaders in developed cities consider their city's economic condition good or excellent, only 49% of leaders in cities in developing countries say the same.

The findings show that cities in developing countries will not realize the full benefits of urbanization because they lack core urban infrastructure, such as roads and public transportation systems as well as drinking water and wastewater infrastructure systems. City leaders in developing countries said their top three infrastructure priorities are wastewater infrastructure (50%), roads (44%), and public transportation (40%).

What happens when our urban transportation systems overly favor private cars? Source: phys.org

In developed-country cities, 87% of leaders thought their drinking water infrastructure was good or excellent, but only 46.5% in developing countries said the same. The top challenge identified in providing drinking water—cited by a quarter of city leaders in developing countries, and 54% in Sub-Saharan Africa—was the need to extend piped water to all households.

In terms of wastewater management, 91% of city leaders in developed countries rated their management of human waste as good or excellent, only 48% in developing-country cities did the same. Among the latter, almost 30% said they still needed to extend piped sewer service to all households, and 11% said their city had no wastewater treatment facility.

In terms of COVID recovery, city leaders report that their jurisdictions are returning to normal. The vast majority of cities are back to normal or almost back to normal. Only 17% of city leaders in developed cities say they are not back to normal (7% in developing cities).

Mental health is an overwhelming public health challenge for city leaders in the developed world. In cities in developed countries, 61% consider mental health a top public health challenge followed by substance abuse (47%), air pollution (39%) and obesity (38%). In developing countries, meanwhile, there were so many different public health concerns that only one, inaccessibility of quality health services (34%), was selected by more than a third of city leaders.

Budgetary concerns are weighing on city leaders in developing regions who believe they can only fund 59% of anticipated expenses in the coming year. Conversely, 85% of city leaders of developed cities feel confident they can meet their funding needs. Source: https://phys.org/news/2022-09-global-survey-mayors-urgent-climate.html

Integrated Assessment of Urban Overheating Impacts on Human Life

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The 21st century is acknowledged to be an urban century, with direct impacts on city-scale climate most notably manifested as the urban heat island (UHI). Urban form, fabric, and function of cities further lead to substantive intra-urban variations of air and surface temperatures, directly affecting urban residents' health and wellbeing (Martilli et al., 2020). The UHI is largely driven by separate mechanisms relative to the larger-scale temperature changes linked to regional and global climate change. Unequivocal increases in air temperatures have been observed since the 1950s across all climate zones and regions in which settlements are located (Stocker et al., 2013). Cities worldwide have also experienced significant increases in the number of heatwaves and hot days and nights (Mishra et al., 2015). In combination, both synoptically-driven extreme heat and the UHI contribute to negative health effects in cities, and there is clear evidence that these drivers interact, often synergistically (Ao et al., 2019; Li & Bou-Zeid, 2013).

The combined result of the local-scale UHI with increased mean and extreme temperatures from larger-scale climate change is projected to exacerbate overheating in cities globally (Argüeso et al., 2014; Chapman et al., 2017; Krayenhoff et al., 2018; Wouters et al., 2017). The initial use of the term "overheating" focused on building energy consumption, ambient indoor environmental conditions, and the health of urban residents from an architectural or building design perspective (Santamouris et al., 2015; Taylor et al., 2014). More comprehensively, "urban overheating" is defined as the exceedance of locally-defined thermal thresholds that correspond to negative impacts on people (e.g., health, comfort, productivity) and associated urban systems. These thermal thresholds depend not only on local urban climates and associated exposure to heat but also on the sensitivity and adaptive capacity of people and urban systems exposed to heat, which in turn depend on socio-political and economic factors. Furthermore, thermal thresholds are defined uniquely at different scales and considering different impact mechanisms. For example, thermal thresholds for human-scale heat stress refer to human heat indices that lead to heat strain in vulnerable individuals, while exceedance of air temperature and humidity thresholds at neighborhood- and city-scale is considered for negative impacts on urban energy grids.

In recent decades, extensive discipline-specific research has characterized urban heat and assessed its implications on human life, including ongoing efforts to bridge neighboring disciplines. The research horizon now encompass-

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es complex problems involving a wide range of disciplines, and therefore comprehensive and integrated assessments are needed that address such interdisciplinarity. Nazarian et al (2022) is a response to this emerging need in urban heat research. In this article, the objective is to go beyond a review of existing literature and instead, provide a broad overview and integrated assessments of urban overheating, defining holistic pathways for addressing the impacts on human life.

The first step is to define an integrated framework for determining the risks of urban overheating by synthesizing and describing the factors involved in realizing the negative impacts. Exposure to heat hazards in cities is the trigger, but in itself does not lead to risks. Urban heat vulnerability exists when sensitive individuals, populations, and infrastructures are exposed to heat. Should there be a lack of adaptive capacities to respond (both at the individual and city level), negative overheating impacts ensue. The multi-scale interactions that relate to urban overheating, from its causes to risks and impacts, represent a multi-faceted and multi-disciplinary challenge. Accordingly, the extent of urban overheating risk in an urban system is the integration of i) the compounding, multi-scale urban climate hazards of heat waves and heat islands, ii) individual and infrastructure exposure to heat hazards, iii) sensitivity and adaptive capacity of individuals, populations, and infrastructures that lead to vulnerability of urban environmental health and energy systems to urban overheating, and, iv) multi-disciplinary responses and solutions that effectively respond to urban overheating (Fig.1).

Nazarian et al. (2022) provides the first integrated outlook for characterizing, evaluating, and addressing overheating in existing and future cities. We discuss how overheating hazards and exposure are characterized using different observational and numerical methodologies across different scales (ranging from human to street and city scales). At the human scale, we then detail several physiological and psychological pathways that lead to individual sensitivities to overheating, as well as adaptive capacities that can be promoted to reduce sensitivity or exposure. At the population level, the key risk levels of overheating on health and urban energy are documented for vulnerable groups (Fig. 2). Lastly, we discuss state-of-the-art methodologies as well as future approaches and solutions in urban planning and governance that aim to address this multi-faceted challenge by mitigating exposure, reducing sensitivity, and increasing adaptive capacities at the individual and city levels.

Here, we summarize key priorities identified in Nazarian et al. (2022) to better assess and address overheating impacts, condensed into eight multidisciplinary research directions:

1. *Develop a new paradigm for heat exposure characterization:* More comprehensive characterization of heat hazards in cities is an ongoing focus in research. While both measurements and modeling practices need to quantify overheating at higher spatial and temporal resolutions, it is critical that exposure is better characterized where people are located, encompassing more diverse and targeted indoor and outdoor spaces. Additionally, metrics and indicators that fully characterize heat exposure (including relevant meteorological factors such as wind and radiation, as well as duration and intensity of exposure) should be integrated into sensing and modeling of thermal environments based on fit-for-purpose evaluations.

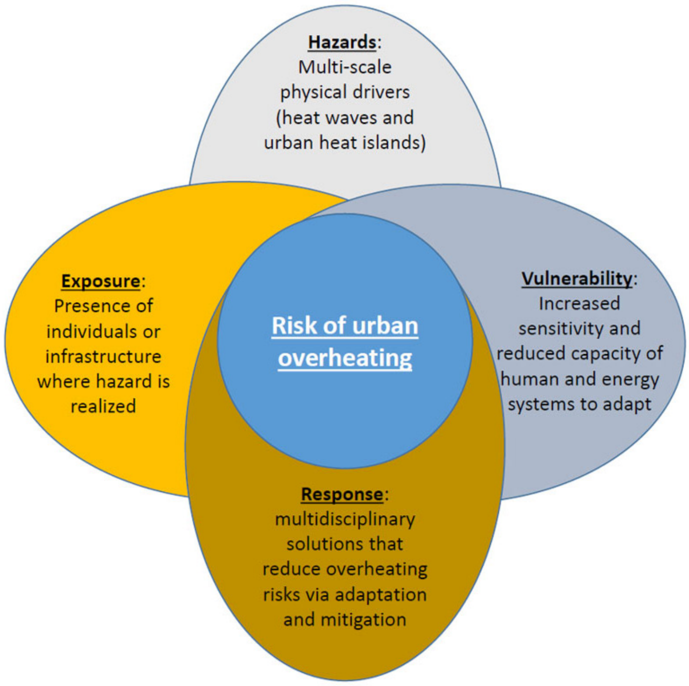

Figure 1. Integrated framework for determining risks of urban overheating. Each oval contributes to the overall urban overheating risk. The *hazard* oval includes the physical climate impact of heat in an urban system; the *exposure* oval indicates whether a component of the urban system (in this case, individuals or infrastructures exposed to heat) are affected by the hazard; the *vulnerability* oval reflects the sensitivity as well as the propensity of a system to be affected by exposure to the heat hazard, and its capacity to adapt to heat; and the *response* oval encompasses the various approaches or solutions employed by urban stakeholders in reducing risks from urban overheating by modifying the hazard, exposure, sensitivity or adaptive capacity (adopted from Simpson et al., 2021).

2. *Determine adaptive capacities at the individual level to reduce exposure and sensitivity:* Future research should provide a more expansive and inclusive knowledge of the physiological and psychological/behavioral pathways that lead to increased exposure and sensitivity of individuals and populations. This knowledge can then inform the evaluation of adaptive capacities that can be afforded at the individual level to reduce either sensitivity or exposure.

Inclusive evaluations include consideration of different clusters of personal or professional profiles (covering different professions, health conditions, and socioeconomic status) that may be more vulnerable to heat exposure.

3. *Prioritize personal heat exposure assessment over one-size-fits-all approaches:* More human-centric assessment of heat exposure, i.e. personal heat exposure, is a key priority in several subfields. A 'receptor-oriented' approach to heat is suggested, in contrast with existing 'source-oriented' assessments, to quantify the heat exposure in the immediate environment of humans as well as the impacts on human comfort, performance, well-being, and health. Future research in personal heat exposure requires not only targeted spatial coverage in data collection and modeling, but also better integration of knowledge and datasets that detail behavioral patterns and individual sensitivities in response to heat.

4. *Improved spatial assessment of intra-urban heat risk:* Prioritization of neighborhoods for heat adaptation requires finer-grained and more human-centric heat risk mapping with greater global coverage as well as improved metrics that more closely relate to actual exposure to the heat hazard with vulnerability. This focus will permit better assessments of inter- and intra-urban equity in terms of heat risk.

5. *Quantify the indirect health and wellbeing outcomes of overheating:* More human-centric assessment of heat exposure permits quantification of the links between heat exposure and indirect health and wellbeing outcomes. Empirical verification of causal links between urban heat and residents' behavior, their sedentariness, and heat-health impacts at the level of the individual and the urban population at large are essential directions for future research, such that evidence-based urban planning and policy can be more broadly effective at maintaining and enhancing well-being in a warming urban world.

6. *Develop equitable urban energy systems for human health and wellbeing:* For a more integrated assessment of overheating and urban energy, future research should consider the non-linear interactions between overheating and urban energy systems – involving electrical grids, buildings, equipment, energy production (e.g., photovoltaics), and air conditioning – that lead to reduced energy performance and energy poverty with adverse effects on heat exposure indoors. In other words, urban energy research should be framed to better support human health, particularly in vulnerable populations, moving beyond the focus on building-level energy computation or city-level CO_2 emissions.

7. *Develop guidelines for heat mitigation and adaptation strategies:* In addition to the continued development of novel materials and strategies with greater cooling potential, future research should focus on the development of regionally- and climatically-adaptive guidelines that optimally combine infrastructure-based heat mitigation strategies (e.g., green infrastructure, cool materials) and heat adaptation strategies (e.g., cooling centers), considering multi-faceted impacts of urban canopy air temperature, wind, humidity, and radiation on buildings, pedestrians and air quality. The efficacy of these guidelines should be evaluated in the context of contemporary and future extreme heat, and additionally with respect to their performance in cooler seasons. Further development of infrastructure-based approaches for evening and nighttime cooling are also important.

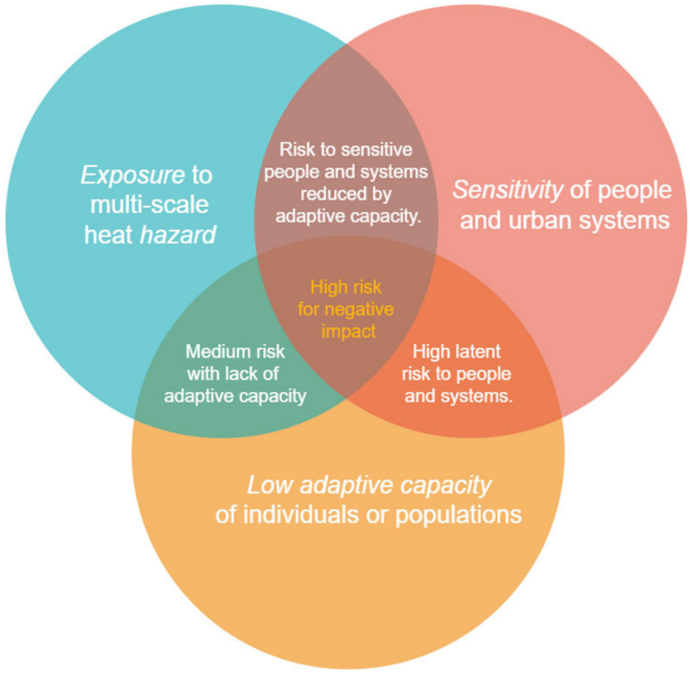

Figure 2. Risk framework for urban overheating impacts on people and urban systems.

8. *Expand time and space horizons in overheating analyses:* In many research directions noted above, there is a need to consider global assessments of municipal-level temperatures and extreme heat hazards (beyond air temperature) under different global climate change and urban development scenarios during the period 2030-2080. Furthermore, future research should focus on areas with high (current and projected) urbanization in developing countries as well as informal settlements that have traditionally been neglected in the urban climate literature. An estimated 25% of the world's urban population live in informal settlements and slums (UN-Habitat, 2013) with distinct urban climate characteristics, design, and sensitivity profiles to heat that have not been documented before. This calls for urgent attention in future research, further contributing to global environmental justice with regard to heat.

Additionally, further advancements in *research tools and methods* are needed to achieve the emerging research directions, including:

I. *Evaluate and advance smart technologies for heat exposure assessments:* The emerging IoT/ubiquitous sensing field can overcome the limitations of conventional methods to provide real-time and high-resolution/personalized heat exposure data, but still requires more focus on combining different sources of data (particularly on human behavior, activity, response) to holistically quantify exposure and health outcomes. To do this, we need technological, scientific, and societal advancements as well as open-access datasets, algorithms, and analytics that ensure not only data quality and completeness, but also digital inclusion and privacy.

II. *Develop high fidelity climate models suitable for integrated system analyses:* Overall, climate models should focus more on the multidisciplinarity of heat exposure, integrating existing knowledge from urban climatology, plant ecology, energy system analyses, and behavioral modeling to better uncover synergies, co-benefits, and tradeoffs in drivers of overheating and associated adaptive responses. Furthermore, better numerical representations of infrastructure-based heat mitigation strategies are needed to inform urban and building design in practice. Finally, simulation studies should make increased efforts to quantify uncertainties in projected overheating and heat mitigation effectiveness.

Furthermore, we summarize existing *priorities for policymakers, planners, and government managers*, such that we address, mitigate, or adapt to overheating challenges in current and future cities:

a. *Implement strategies for climate change mitigation:* It is critical that we continue to reduce greenhouse gas emissions (from transportation, building, and other sectors), plant trees, and undertake related climate mitigation strategies locally and abroad, to help reduce long-term global climate warming and the intensity, frequency, and duration of future extreme heat events. However, climate mitigation must be approached to avoid unintended consequences to climate or water-energy-food systems at the local scale due to shifting energy sources or energy efficiency (Davies & Oreszczyn, 2012; Giuliani et al., 2022). For example, a lower surface temperature may decrease the height of the local planetary boundary layer and decrease horizontal and vertical transfer, leading to an increase in the concentration of pollutants (Mohammed et al., 2021).

b. *Implement strategies to cool the built environment:* In addition to large-scale climate change mitigation strategies, implementing street- to city-scale cooling strategies (including green and blue infrastructure and advanced materials) in harmony with local climate and resources are critical for mitigating the intensity of urban overheating, particularly in ways that target heat where vulnerable populations reside and work and that are developed collaboratively with local residents.

c. *Provide behavioral options for reducing exposure:* Adaptive opportunities should be considered in urban design such that individuals can reduce their heat exposure as they go about their lives in the city. In this context, strategies should focus on changing the environment to provide behavioral options for reducing heat exposure in addition to cooling the built environment. These options range from local design elements such as cool furniture or green and blue infrastructures to building cool refuges for reducing the duration of heat exposure. These strategies should be implemented in collaboration with local residents and initially focus on neighborhoods with the highest densities of heat-vulnerable individuals.

d. *Provide evidence-based personalized heat-health advisories:* Building on personal heat exposure assessments, evidence-based heat-health advisories can be developed that are suitable for identifying optimal personalized heat risk mitigation strategies for sensitive individuals, as opposed to taking a one-size-fits-all approach. This can further lead to city-specific early-warning and response systems for heat extremes that are supported by heat vulnerability maps and more tailored to specific individuals.

e. *Provide personal recommendation systems to reduce heat exposure:* Human-centric data collection in the built environment can further promote personalized recommendation systems to enable more adaptive capacities for individuals, i.e. avoiding the heat by different routes or adjusting activity level to overheating intensity.

f. *Promote and incentivize the use of sustainable heat adaptation solutions:* While promoting cooling strategies in cities, it is also critical to overcoming the barriers related to the use of more energy-efficient and sustainable adaptation solutions, such as fans for indoor cooling or shading for outdoor cooling. These barriers may relate to various aspects ranging from perceived effectiveness to aesthetic concerns that can be overcome through more public engagement and education.

g. *Future directions for policy and governance:* Developing urban overheating governance, in combination with climate change governance and policy across different scales, is one of the most critical pathways for reducing the negative impacts of overheating on human life. These governance frameworks should embrace principles of iteration, flexibility, and learning, i.e., adaptive governance, and integrate engagement strategies in the pursuit of participatory justice, allowing residents to bring critical domain expertise from their lived experience. Moreover, legacy effects of practices that placed certain populations at greater risk of harm from heat and other environmental hazards must be identified and rectified.

The primary focus of this contribution has been on understanding and responding to overheating challenges, depicting cities as the epicenter of the developing situation. While this view accurately reflects contemporary and projected urban climates in the context of ongoing climate change and urbanization, alternative perspectives should not be overlooked. Responding to increasing temperatures, cities can potentially be envisioned as places of refuge from overheating and extreme events, where more thermally acceptable conditions can be achieved through climate-sensitive design and planning. Cities have the opportunity to cool built environments more than surrounding rural areas especially during afternoon periods when potential heat exposure is maximum (for instance, taking advantage of urban shading and ventilation that have long been embedded in traditional architecture), and in doing so, can influence a larger number of inhabitants due to higher population densities. Urban areas may also provide opportunities to host outdoor workers (for instance, in urban agriculture) that can benefit from cooling mitigation and adaptation strategies otherwise not afforded in non-urban areas. Accordingly, further research and implementation measures are needed to assess the opportunities embedded in cities to expose fewer people to projected overheating and climate extremes.

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Temperature heterogeneity across the subsurface of the Chicago Loop: Measurements from a district-wide sensing network

This report is based on: Rotta Loria, A. F., Thota, A., Thomas, A. M., Friedle, N., Lautenberg, J. M. and Song, E. C. (2022) Subsurface heat island across the Chicago Loop District: Analysis of localized drivers. *Urban Climate*. 44: 101211. https://doi.org/10.1016/j.uclim.2022.101211

Introduction

Temperatures are significantly rising in the subsurface of many urban areas, causing an underground climate change, also known as subsurface urban heat islands (SUHIs). SUHIs result from two types of heat sources in the subsurface: large-scale drivers at the surface and localized drivers in the subsurface (Ferguson and Woodbury, 2007; Visser et al., 2020). Large-scale drivers mainly consist of buildings and infrastructure located above the ground surface that trap heat within themselves, subsequently reject it into the atmosphere, and eventually lead to an indirect heat transfer to the subsurface. Localized drivers consist of infrastructure located below the ground surface, such as heated basements, parking garages, subway and train tunnels, subterranean metro and train stations, sewers, district heating networks, and other facilities that directly reject heat in the subsurface (Visser et al., 2020; Menberg et al., 2013a). SUHIs tend to be more intense than their surface counterpart, generally called urban heat islands (UHIs), and are an emerging issue for urban areas globally (Huang et al., 2009; Menberg et al., 2013b).

The changes in the underground thermal environment due to SUHIs can have detrimental effects on the biodiversity and health of subsurface ecosystems (Robinson et al., 2018). Excessive heat in the subsurface also poses a real risk to public health, as people resorting to mass transit can suffer from heat stroke and related health issues (Jacob et al., 2008). Waste heat in the subsurface further affects transportation infrastructure, as rising temperatures can cause over-heated switch gears, along with expansion and buckling of steel rails (Brodwin, 2014). Considering these influences, SUHIs significantly affect the underground in urban areas worldwide. For this reason, it is crucial to understand the key variables and fundamental mechanisms that govern this silent hazard.

Numerous studies have shown that subsurface temperatures are highly heterogeneous (Bidarmaghz et al., 2019a; Ferguson and Woodbury, 2004; Krcmar et al., 2020b; Kreitmair et al., 2020; Menberg et al., 2013b). This heterogeneity of the temperature field in the subsurface is certainly linked to the non-uniformity of the heat diffusion, but arguably also to the variable intensity of the heat sources themselves. Currently, limited information is available about the spatial variability that characterizes the intensity of localized drivers of SUHIs. This study presents the features and measurements of a unique subsurface sensing network deployed in the Chicago Loop district to monitor the temperature across a myriad of underground built environments and the ground. This facility provides the opportunity to understand the inherent characteristics of the sources of SUHIs and underpin future studies devoted to the spatial and temporal evolution of SUHIs.

Method

For this study, a state-of-the-art sensing network comprising >150 HOBO temperature sensors was deployed across the Chicago Loop district to assess the presence and intensity of a SUHI. Sensors were deployed in underground structures such as building basements, underground parking garages, train lines, pedways, tunnels, underground streets, and the ground. Fig.1 highlights the Loop with an exploded view of the underground environments, the locations of the sensors, and the soil stratigraphy. Sensors were also deployed in surface green spaces and surface streets to compare subsurface temperatures with surface temperatures. The deployed sensors record the ambient air temperatures in the subsurface and surface locations or the ground temperature where applicable. They are wireless, weatherproof, and compact, making them convenient to install and access to retrieve data from the targeted locations. These sensors record one temperature measurement per hour, resulting in their AC batteries' approximate lifetime of 10 years. The sensors are installed as uniformly as possible across the Loop, from the ground surface down to a maximum depth of z=17 m, within environments that are typically embedded by or consist of a shallower layer of dry backfill/sand (0 ≤z≤ 4 m) and a layer of clay fully saturated with water (4 ≤z≤ 16 m: soft clay; 16 ≤z≤ 19 m:

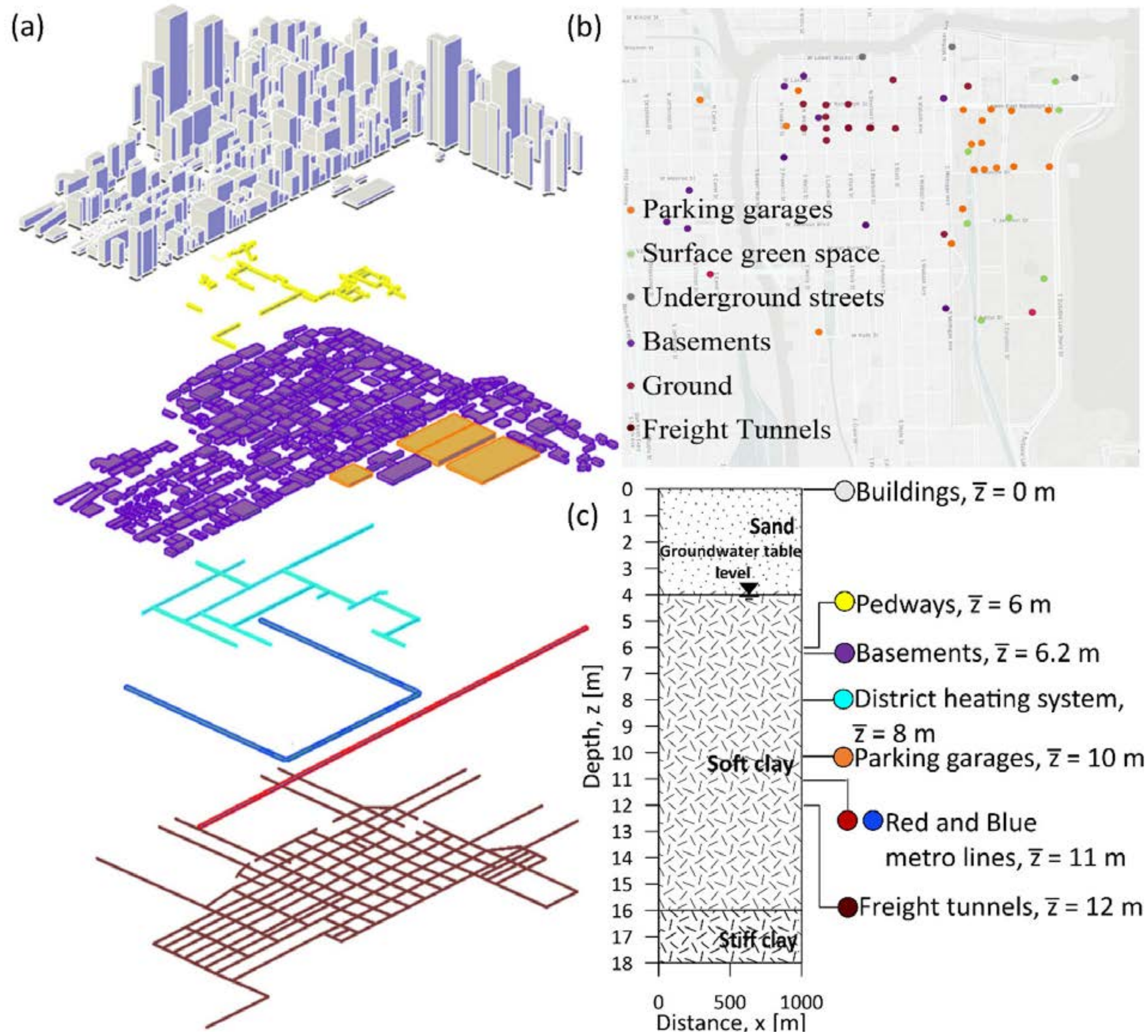

Figure 1. (a). 3D model of the subsurface, showing the different layers of the subsurface infrastructure; (b) Location of sensors installed in subsurface and surface environments across the Chicago Loop district; (c) Soil stratigraphy at the considered area, showing the average location of subsurface infrastructure across the Loop.

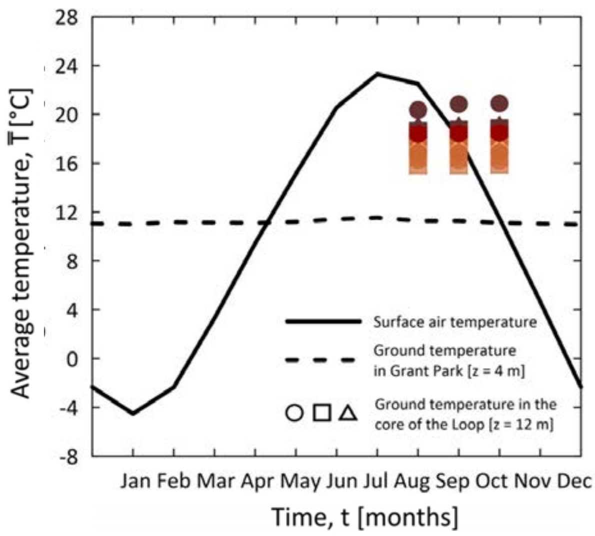

Figure 2. Comparison of monthly average temperatures for sensors installed in the ground with surface air temperature.

hard clay).

Results and Discussion

Fig. 2 shows the monthly average ground temperatures for sensors located in the heart of the Loop and Grant Park and compares them to the monthly average surface air temperatures. Temperatures in the ground are measured by sensors deployed at a depth of 4 m in Grant Park with no known presence of thermal drivers and by sensors deployed at a depth of 12 m in the heart of the Loop. Recorded data indicate that the annual mean ground temperature in Grant Park is 11.2 °C, while the annual mean surface air temperature reads 8.4 °C. Temperatures in the ground at the considered depth remain stable throughout the year, as the seasonal temperature variations at the surface have minimal influence on the recorded data. Temperatures in the heart of the Loop are significantly higher than those measured in Grant Park,

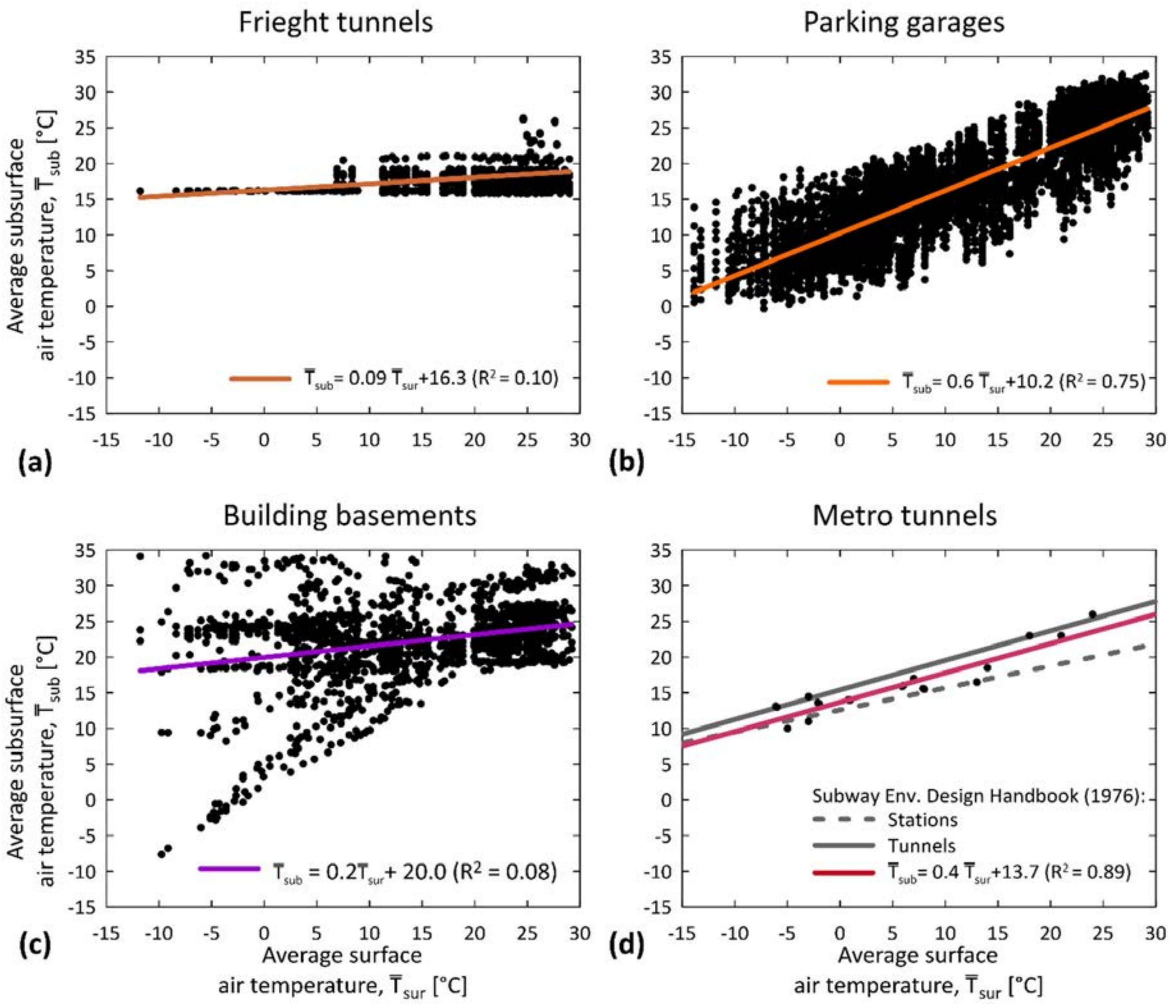

Figure 3. Comparison between average subsurface temperature values measured in freight tunnels, parking garages building basements, and metro tunnels relative to the undisturbed ground temperature.

with temperature differentials ranging from 5.7 °C to 9.5 °C between the two locations. While no localized drivers of waste heat appear to be present in the vicinity of the sensor deployed in Grant Park, multiple buildings and the blue line of the metro system run by the CTA are present in the vicinity of the sensors located in the Loop. This result provides evidence of the influence of localized sources of waste heat on the ground temperature of an urban environment and quantifies the local intensity of the subsurface heat island for the Chicago Loop district.

Fig. 3 shows the relationship between the daily average subsurface and surface air temperature for freight tunnels, parking garages, building basements, and metro tunnels. The relationship between subsurface and surface air temperatures is approximately linear for all the considered subsurface environments. However, the slope of the regression line significantly varies for the different environments.

Fig. 3(a) shows the following relationship between the recorded subsurface and surface air temperature measurements in freight tunnels: $\overline{T}_{sub} = 0.09\ \overline{T}_{sur} + 16.3$. This result indicates that the temperature in the freight tunnels remains approximately stable throughout the year, with limited influences from seasonal surface temperature variations. Meanwhile, subsurface temperatures as high as 27 °C are measured in the freight tunnels, which result in a 15.8 °C temperature differential compared to the average undisturbed ground temperature of 11.2 °C measured in Grant Park.

Fig. 3(b) shows the following relationship between the recorded subsurface and surface air temperature measurements in parking garages: $\overline{T}_{sub} = 0.6\ \overline{T}_{sur} + 10.2$. Subsurface air temperatures as high as 36.3 °C are measured in parking garages throughout the day, which results in a significant temperature differential compared to the average undisturbed ground temperature of 11.2 °C. An analysis of the measured data shows temperature variations within the same level of a chosen parking garage, across different levels of the same garage, as well as across different parking garages. Temperature differences within a given level of the same garage can be as high as 15.2 °C, whereas they can amount to 10.8 °C across different levels of the same garage. Further investigation of the measured data highlights the variability in the recorded temperatures throughout the day, with observed air temperature rises during the day and drops at night.

Fig. 3(c) shows the following relationship between the recorded subsurface and surface air temperature measurements in building basements: $T_{sub} = 0.2\ T_{sur} + 20$. Air temperatures as high as 35.7 °C are measured in basements, which result in a 24 °C temperature differential compared to the average undisturbed ground temperature of 11.2 °C. An analysis of the recorded temperatures in building basements shows that average air temperatures are relatively stable throughout the year in some basements, whereas they fluctuate in the other basements. The differences in the measured temperatures are attributed and verified to depend on architectural features of the considered environments, human activity, and the use of machinery rejecting heat in such environments. The observed differences in temperature for building basements are much more pronounced than those measured in parking garages.

Fig. 3(d) shows the following relationship between the subsurface and surface air temperatures in metro tunnels: $T_{sub} = 0.4\ T_{sur} + 13.7$. This trend agrees well with the average range of temperatures specified for stations and tunnels in Chicago by the Subway Environmental Design Handbook (Kennedy, 1976). The air temperatures in metro tunnels are found to be consistently higher than the surface air temperatures, with a maximum recorded temperature difference of 19.2 °C and an average temperature difference of 10.2 °C. In comparison to the average undisturbed ground temperature of 11.2 °C in Grant Park, the average temperature in metro tunnels is 16 °C higher, resulting in a 4.8 °C temperature differential.

Fig. 4 shows the annual average subsurface air temperatures for the monitored underground environments across the Chicago Loop. The results show that the subsurface air temperature in the monitored environments can be up to 10 °C warmer for parking garages, up to 19 °C warmer for building basements, and 5 °C warmer for metro tunnels than the average annual undisturbed ground temperature of about 11 °C for Chicago. These significant temperature differences yield a marked SUHI intensity for the Chicago Loop district.

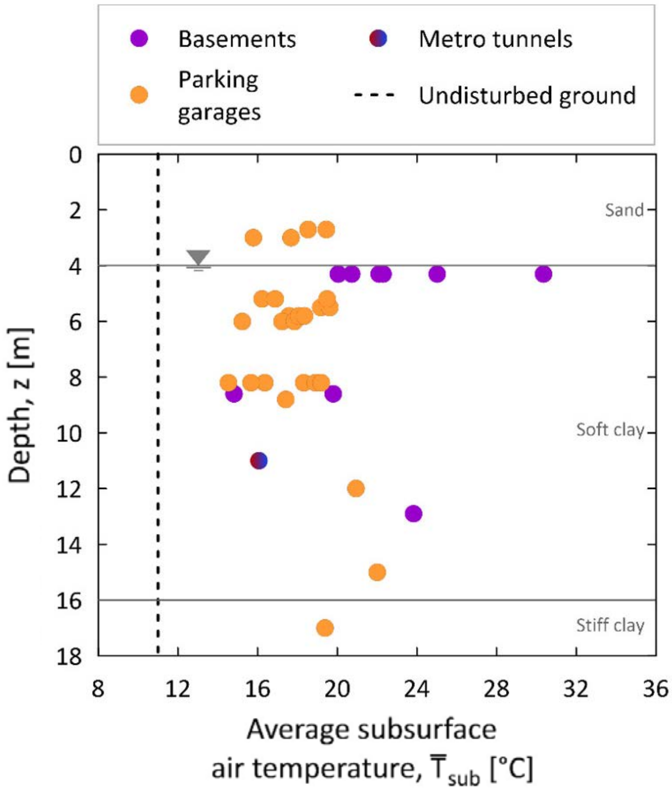

Figure 4. Comparison between average annual temperature values measured in parking garages, building basements, and metro tunnels relative to the undisturbed ground temperature.

Conclusions

The sensing network presented in the study elucidates key features characterizing the sources of subsurface urban heat islands affecting urban areas worldwide. The deployment of a district-scale temperature sensing network across the Chicago Loop has unraveled that temperature in underground built environments can rise to 36 °C, which is 25 °C higher than the ground temperature in a park located in the studied area where no localized sources of waste heat are present. Because of these very sources of waste heat, the ground temperature in the heart of the Loop reads 18 °C, highlighting a significant subsurface urban heat island intensity in the considered area.

An analysis of the monitored data shows that temperature in underground built environments is markedly heterogeneous. Such heterogeneity can result in temperatures that vary up to 15 °C within the same level of a considered environment and up to 10.8 °C across different levels of the same environment. The differences in air temperatures among the monitored subsurface built environments can be attributed to the influence of different architectural and operational features of such environments, including the materials constituting the envelope, the number of distribution channels and apertures, and the presence of ventilation systems and sources of waste heat. Air temperatures in underground environments follow an approximately linear trend with surface air temperatures, depending on the features of the underground built environment considered. The identified features of the localized drivers of subsurface urban heat islands observed in this study arguably characterize not only the Chicago Loop but many other cities across the globe.

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SEBU: the novel fully automated Google Earth Engine Surface Energy Balance Model for Urban areas

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https://doi.org/10.1016/j.uclim.2022.101187

Introduction

Surface energy balance models are essential to understand the energy partitioning and associated atmospheric processes over different land features (Chrysoulakis et al., 2018). These models play a pivotal role in retrofitting and addressing growth of existing cities, designing future cities to reduce urban heating and improve outdoor human comfort as well as conserving natural resources under the pressing climate change phenomenon.

In this context, and depending on the scale of application, several models, used as tools in urban design and planning as well as in climatic and environmental performance evaluation, have been developed. Some examples include Surface Urban Energy and Water Balance Scheme (SUEWS) (Järvi et al., 2011; Ward et al., 2016), the integrated Weather Research and Forecasting (WRF)/urban modelling system (Chen et al., 2011), Town Energy Balance (TEB) (Masson, 2000), and Environmental Meteorology Model (ENVImet) (Bruse and Fleer, 1998). Still, these models require resources that are often hard to acquire. They also generate results that may be difficult to extrapolate. These two constraints have slowed the development of many of these models and reduced their performances. In addition, the complexity of atmospheric processes and lack of sufficient field data and observations further complicate this issue.

As a response to this situation, we propose the Surface Energy Balance for Urban areas (SEBU), a fully automated and open-source model. It directly addresses the two main limitations mentioned in previous models (i.e., resources intensive and extrapolation) by benefiting from the widely available massive directory of satellite images and other databases hosted at the Google Earth Engine platform, as well as its outstanding computational power. SEBU main outputs include 100-m monthly turbulent latent and sensible heat fluxes. We evaluate SEBU over seven cities (i.e., Denver, New Hampshire, Basel, Heraklion, Singapore, Phoenix and Vancouver) with different urban characteristics in cold, arid, warm and equatorial climatic regions. A spatio-temporal assessment is also made, as a proof of concept, over Denver, Phoenix, Heraklion and Singapore. Main findings are discussed, as well as the strengths, limitations and potential future developments of SEBU.

Materials and Methods

We collect data from seven flux towers over Denver, New Hampshire, Basel, Heraklion, Singapore, Phoenix and Vancouver, spanning between 2011 and 2021. These data include monthly-median sensible heat flux (Qh) and the latent heat flux (Qe). Urban configurations over these sites can be seen in Figure 1.

We use nine different data sources from five satellite sensors in this study, four being produced by the Landsat satellites (i.e., Landsat-4, Landsat-5, Landsat-7, and Landsat-8), two by the Terra Moderate Resolution Imaging Spectroradiometer (MODIS) satellite (i.e., MOD10 and MCD12), one from the Sentinel-1 satellite, one from ERA5 climate reanalysis, and one from NASA Shuttle Radar Topographic Mission (SRTM). These data are accessed and further processed over-the-cloud on the Google earth engine (GEE) online platform.

SEBU can be divided into four main components. The first calculates the Penman-Monteith Reference Evapotranspiration λET based on climatic and remote sensing databases. The second component retrieves inputs (e.g., Normalized Difference Vegetation Index, Land Surface Temperature, roughness length) for the Qh and Qe assessments from the available satellite images. The third component tries to automatically identify hot/cold pixels (Mhawej et al., 2020) for a better internal calibration and more accurate Qh and Qe outputs. The last component adds another water-based internal calibration, producing improved Qh and Qe outputs. Following calibrations and validations in different cities with diverse climates, 100-m Qh and Qe monthly images are generated. Further information on each subsection can be found in the original article.

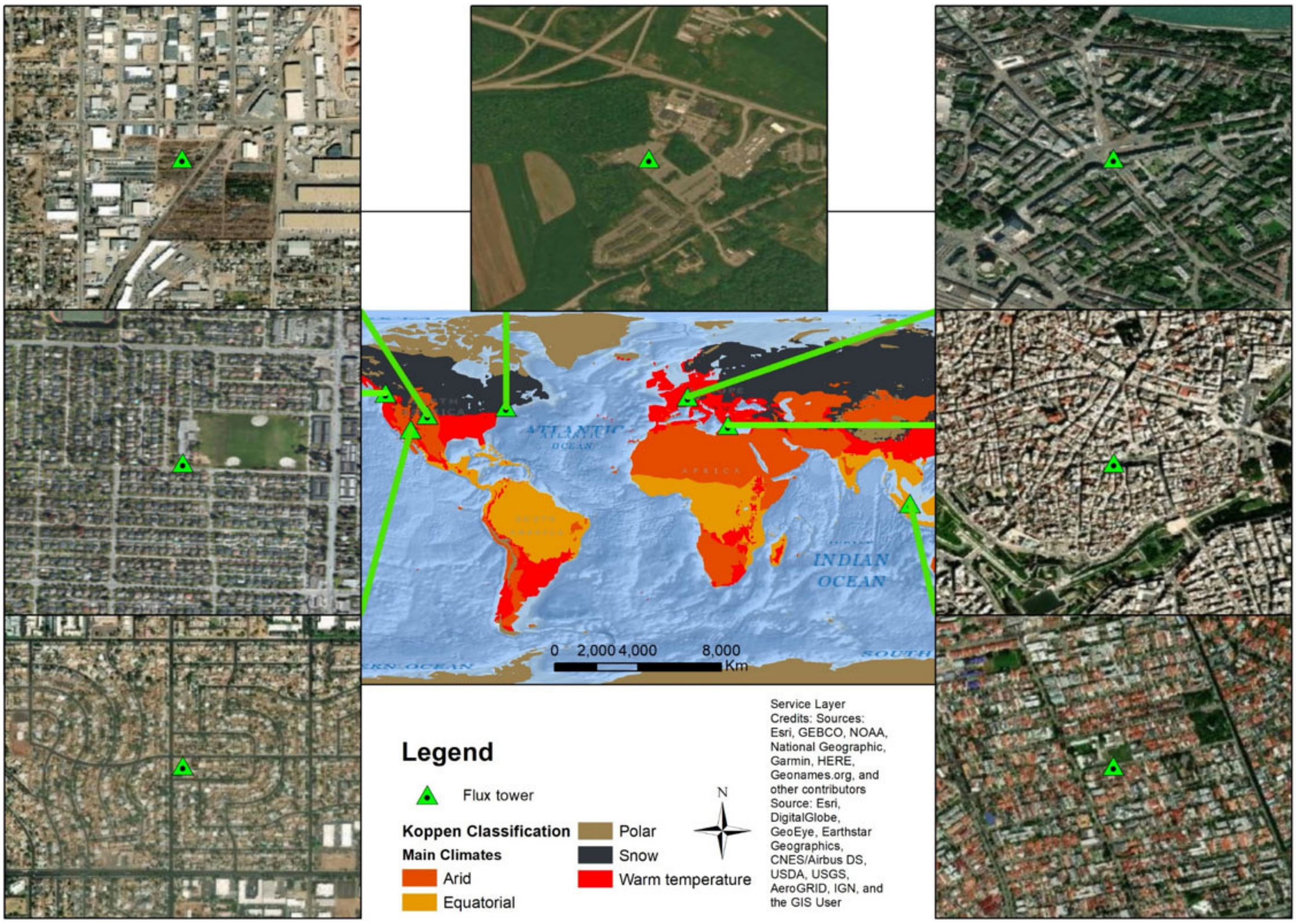

Figure 1: Location of the flux towers in seven locations (clockwise from the top left: Denver, New Hampshire, Basel, Heraklion, Singapore, Phoenix and Vancouver) as well as a Google Earth satellite (Eagle-eye) view above each tower (scale: 1:15000). The world map at the middle corresponds to Köppen climate classification.

Results

SEBU Outputs' Validations

A validation against in-situ flux tower datasets is made in each city following the application of the calibration equations. Only Qh values found from the initial SEBU (before calibration) in Singapore remained the same after the calibration. Qe RMSE (Root Mean Square Error) and AME (Absolute Mean Error) values were 7.62 and 6.13 W m^{-2} $month^{-1}$, respectively. For Qh, AME values were 14.46 W m^{-2} $month^{-1}$ above the considered cities.

Spatial Assessment

Annual Qe and Qh, based on the 2019 monthly Qe and Qh outputs provided by SEBU, over Denver, Phoenix, Singapore and Heraklion are shown in Figure 2. The highest Qe values are found in Singapore, followed by Heraklion, with Qe as high as 44 and 38 W m^{-2} $year^{-1}$, respectively. These values are mostly seen nearby or over vegetation cover, from trees to shrubs. In Phoenix, for instance, road verges appearing on main roads showed high Qe values as well, around 30 W m^{-2} $year^{-1}$. The lowest Qe values amongst these cities are shown at the city center in Heraklion and over many regions in Denver.

As expected, Qh showed low values over green areas. Very high Qh values amongst the considered cities appear to be in Singapore and Heraklion with values of ~110 W m^{-2} $year^{-1}$, but only in some limited areas. Widespread high Qh values are found in the arid city of Phoenix. On the other hand, very low Qh values are illustrated over white-colored infrastructures.

Temporal Assessment

The urban agglomerations over Denver, Phoenix, Singapore and Heraklion are produced based on the MODIS land cover product for the year 2019. Monthly Qe and Qh assessments are made based on these boundaries. Denver and Phoenix provided comparable Qe monthly trends, with Phoenix illustrating higher values between October and February. For the other months, Denver Qe values are higher. Anyhow, the monthly Qe in both cities varied between 15 and 32 W m^{-2} $month^{-1}$. Heraklion

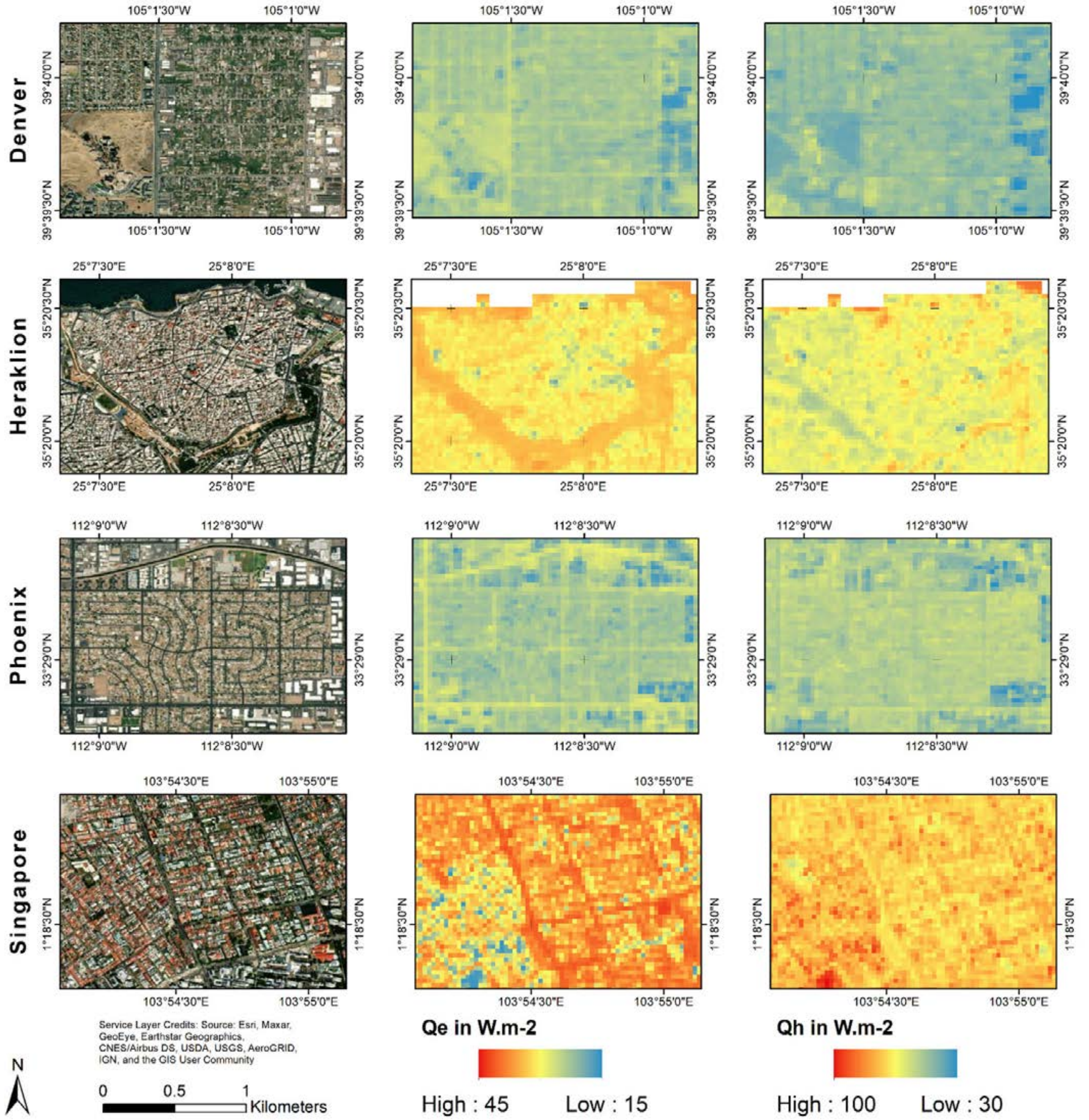

Figure 2. Annual Qe and Qh over Denver, Phoenix, Singapore and Heraklion, 2019

showed a similar trend, but values ranged between 15 W m^{-2} month^{-1} in the winter months to 41 W m^{-2} month^{-1} in the summer months. Singapore, on the other hand, showed nearly constant Qe throughout the year with values between 36 and 39 W m^{-2} month^{-1} (Figure 3).

Again, Denver and Phoenix showed similar values of monthly Qh. Heraklion had usually higher Qh values for most of the year in comparison to these cities, especially in August 2019 when Qh peaked at 102 W m^{-2} month^{-1}. In these three cities, the highest Qh values were found in the middle of the year. Singapore remained unique, with Qh monthly values between 62 and 76 W m^{-2} month^{-1} throughout the year.

Discussion

SEBU Outputs' Assessments

As previous urban SEB models do not have similar spatial or temporal resolutions, it would be difficult to compare between them. This is due to the fact that efforts to produce satellite-based urban SEB has re-started

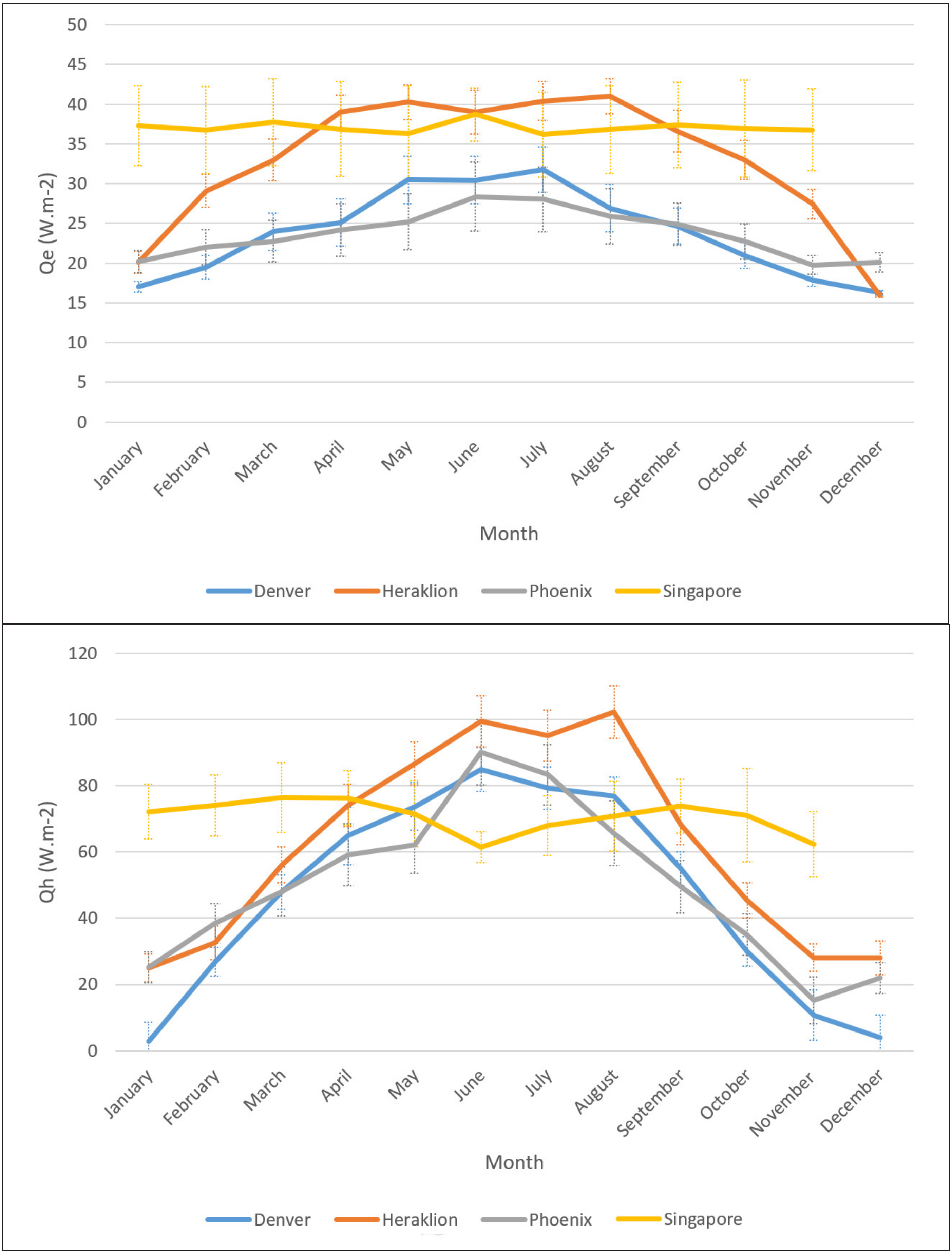

Figure 3. Monthly Qe and Qh over the whole urban agglomeration in Denver, Phoenix, Singapore and Heraklion.

only in the last five years with the project URBANFLUXES (i.e., http://urbanfluxes.eu/). Their products, highlighted in Chrysoulakis et al. (2018), obtained a Qe AME of 13.9 W m^{-2} and a Qh AME of 41.2 W m^{-2} when applied over London, Basel and Heraklion. SEBU Qe and Qh AME values were 6.13 and 14.46 W m^{-2}, respectively. With these promising outputs, SEBU can be applied in different climates across the globe. This can be done easily with its migration towards the large directory and massive computation power of the GEE platform.

Furthermore, we implement SEBU as a proof of concept in four different cities, each having its characteristic climate (i.e., cold climate in Denver, arid climate in Phoenix, warm climate in Heraklion and equatorial climate in Singapore). The comparison between these cities showed that the cold-climate Denver city has the lowest annual Qe values, followed by the arid Phoenix city. Understandably, the highest Qe values are located over green infrastructures, and more precisely over trees, which exhibit the highest transpiration rates. Over these same regions, Qh values are lowest due to the cooling effect of transpiration. More in-depth analysis can be made to investigate the diverse Qh and Qe values over different land cover and use types.

Still, over the whole urban agglomeration, Denver, Phoenix and Heraklion showed similar and expected concave-shape monthly trends, where values are large between April and September. The monthly change of values is characteristic for each city. Singapore behaves similarly to other tropical cities (Velasco et al., 2013), with steady Qe and Qh values across the year. These outputs are in fact in close relation with the Penman-Monteith Reference Evapotranspiration λET monthly values in each city, which SEBU is based on.

SEBU Strengths, Limitations and Future Potential

SEBU produces 100-m monthly Qe and Qh information. To our knowledge limited previous studies were able to arrive at this spatial scale. This is achieved by the usage of the remote sensing-based Landsat satellite datasets, providing an image of the earth each 16-days since the 1980s. More importantly, it is based on the widely validated SEBALI model (Mhawej et al., 2020), requiring a reduced number of inputs. Furthermore, with its migration to the on-the-cloud GEE platform, the required inputs by users are reduced further to only the selection of month, year and the study area in any region across the globe. Thus, any interested party, from principal investigators to researchers shall have access to monthly 100-m Qe and Qh data within a few seconds and over any device with internet browsing capacity (e.g., mobile, laptop, desktop). The transitioning towards the GEE platform is pivotal for three main aspects; the first is the easiness of accessibility to the SEB required datasets; the second is related to the future calibration and validation, as well as adaptation of SEBU to any specific region and sub-region; and the third is based on its open-source nature, where further developments can be made and customized for any interested party. To conclude, the main advantages of SEBU over other SEB models are related to its user-friendly and open-access nature along with improvements in the spatial and temporal accuracy and its scalability.

Here, the limitations of using satellite images over urban areas should be noted. More particularly, retrieving steady images above these areas is not always granted. This is related to the capability of the sensors used as well as atmospheric interactions at the satellite overpass time (Voogt and Oke, 2003). Another limitation of using satellite images over urban regions concerns the difficulty of viewing a significant portion of urban surfaces due to the three-dimensional structure of urban space (Mirzaei and Haghighat, 2010). This urban anisotropy means that walls, streets and roofs cannot be registered due to the viewing angles and canyon structures of a city (Soux et al., 2004). To overcome these limitations, many models were and are being developed (Marconcini et al., 2017).

In this context, many limitations still exist in SEBU and should be addressed, particularly because of the complexity of using satellite-based earth observations over urban fabrics. For instance, better climate datasets are required to reflect the spatial heterogeneity of urban micro meteorological elements. The usage of ground-based meteorological stations is always an option but would require further calibrations and validations. Of course, having better spatial resolution modelled climatic data, such as found in Nikoloudakis et al. (2020), would improve the accuracies of SEBU even further.

Even though MODIS daily product was used to compute the cloud coverage, MODIS overpass time does not exceed twice daily. SEBU can be improved by including other cloud datasets such as ground-based measurements from local weather stations or to directly derive net radiation from reanalysis products such as the hourly ERA5-Land.

Also, z0m is calculated based on the Sentinel-1 satellite. Thus, SEBU would not be able to calculate z0m for dates prior to April 2014. This can be fixed by including an already-produced z0m layer for the required city before 2014 or conduct a study, even regional one, to retrieve z0m in urban areas based on the Landsat, MODIS or AVHRR optical sensors. Globally available radar satellites such as SMAP and SMOS usually have very coarse spatial resolution, but other geostationary radar datasets can be used when available.

More sophisticated data imputation processes, particularly over cloudy pixels, can be addressed as well and included within SEBU. This can be resolved, for instance, by merging information collected from different satellites or

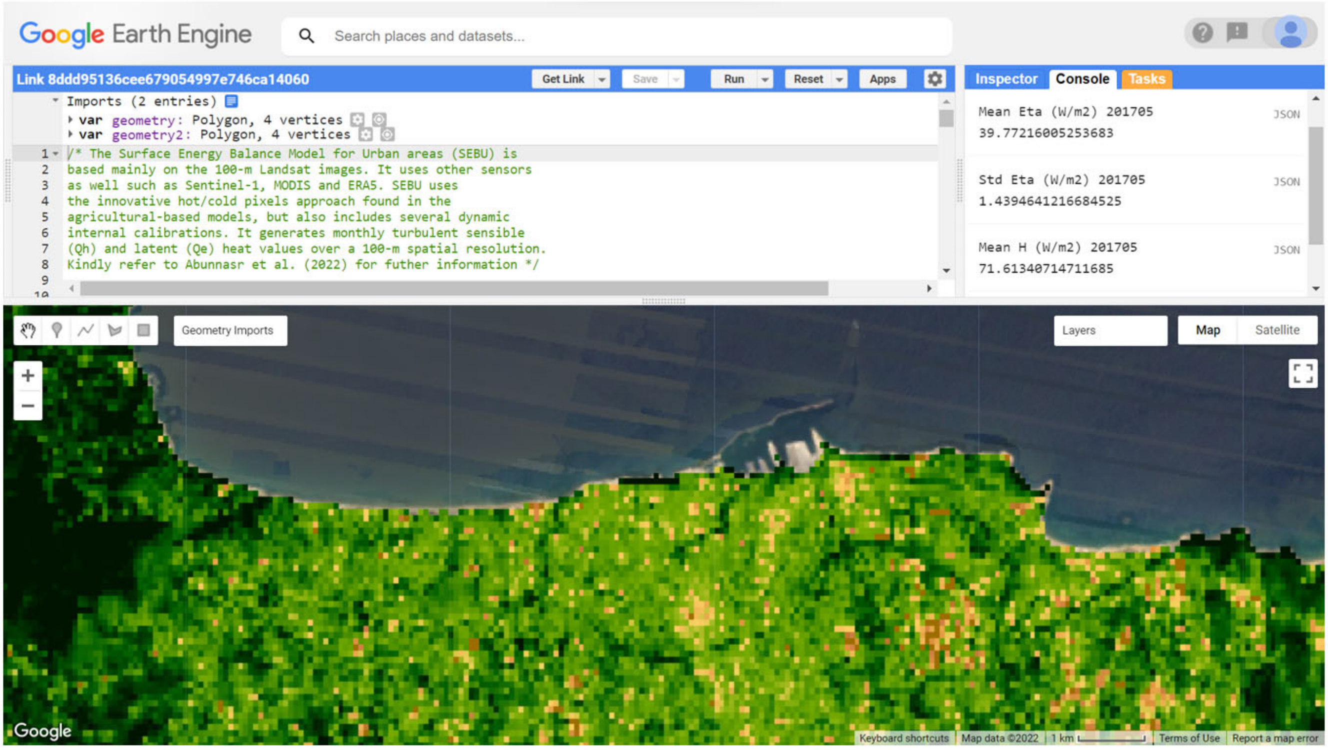

Figure 4. Snapshot of the SEBU system over GEE, with the Qh layer seen over Heraklion, Greece in May 2017; Mean Qe and mean Qh values are shown in the console tab.

from the same satellite but at a different date. More importantly, anthropogenic heat needs to be calculated as it is directly related to the urban heat island mitigation initiatives, affecting human health and well-being.

Lastly, as none of the previous SEB models was built for water bodies (e.g., lakes and ponds), due to the water-atmosphere interaction complexity, particular attention should be made in that direction to have a more comprehensive overview on the urban heat exchange and how to reduce its impact vis-à-vis climate change.

Conclusion

Using remote sensing images are pivotal for future smart cities, as they save on time, personnel and resources, with only limited traditional field campaigns required (Ghoussein et al., 2018). The ability to access any region across the globe is clearly advancing our understanding of our surroundings. The remote sensing technique coupled with the GEE platform has enabled boundaries to be pushed further, with prompt fetching of information and computation of the outputs within a few seconds only.

SEBU is proposed, benefitting from both the remote sensing satellite images and the GEE platform. It provides 100-m monthly Qe and Qh images in different climates across the globe. It is validated in seven locations with different climates according to Köppen classification. Qe and Qh accuracies are promising. This is related to the inclusion of the hot/cold pixel approach as well as the existence of several internal and dynamic calibrations. Thus, SEBU can be implemented and used by any interested users, for example to inform current and future policies and adjust our goals for smart and sustainable future cities. Users require only to define the month and year values as well as pinpointing their study area. SEBU will run instantly, providing monthly Qe and Qh information within few seconds and over any region (Figure 4).

Computer code availability

Name: Surface Energy Balance Model for Urban areas (SEBU)
Developers: Mario Mhawej, Yaser Abunnasr, Nek Chrysoulakis
E-mail: mm278@aub.edu.lb
Year first available: 2022
Hardware required: any device with browsing capability
Software required: none
Program language: JavaScript
Source code: https://bit.ly/3HxYbD7; https://code.earthengine.google.com/8ddd95136cee679054997e746ca14060

Acknowledgments

The flux datasets were provided generously by different researchers and institutions*, including Dean Anderson (USGS) for Denver, Andrew Ouimette (University of New Hampshire) for New Hampshire, Winston Chow (Singapore Management University) for Phoenix, Andreas Christen (University of Freiburg) for Vancouver, Erik Velasco (independent) and Matthias Roth (National University of Singapore) for Singapore, Nektarios Chrysoulakis (Foundation for Research and Technology – Hellas) for Heraklion, and Roland Vogt (University of Basel) for Basel data.

* *The conclusions set forth in this article are those of the authors and do not necessarily represent the position of the data providers.*

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Urban Climatology Course (UCC) returns to Manizales, Colombia

After a two-year hiatus, the Urban Climatology Course (UCC) returned to Colombia last July for its third edition since 2019. This year's edition, UCC 2022, was held July 5-15 at the Universidad Nacional de Colombia (UNAL) in Manizales city, and was hosted by the Faculty of Engineering and Architecture. Manizales is located in spectacular terrain in the Central Andean Mountain Range, which gives an ideal setting for an intensive, two-week program in urban climatology.

UCC Program

Designed for both academic and non-academic audiences, the UCC program takes a broad-based approach to urban climate instruction. The program consists of twelve classroom lectures, four lab exercises, and one field trip. Interconnecting each activity is an underlying emphasis on methodological standards in urban climatology (mainly for proper siting of meteorological sensors in urban and rural areas), and appropriate use of urban design strategies for climate mitigation and adaptation. Throughout the program, participants are introduced to the history, purpose, and international profile of the IAUC (International Association for Urban Climate). At the conclusion of the program, participants are invited to present their work in a short, conference-style format. This is a voluntary exercise for those wanting to share their ideas with the group, and to relate their work with the topics covered in the UCC program.

Instructional materials for UCC are sourced from four principal texts: "Urban Climates" by T.R. Oke et al. (2017); "The Urban Heat Island—A Guidebook" by I.D. Stewart and G. Mills (2021); "Atmospheric Ecology for Designers and Planners" by W.P. Lowry (1991); and "Weather in the City" by S. Lenzholzer (2015). The materials are adapted to the regional setting of the host city, and targeted to local issues relating to air quality, human health, urban expansion, environmental justice, sustainable development, and global change.

Prior to admission into the UCC program, applicants are screened for their interests and career pursuits related to urban climate. Typically, participants in UCC have little or no training in physical climatology, but their work relates directly to the design, construction, and/or management of urban spaces. Participants can earn "UCC certification" for attending more than 80 percent of the program activities during the two-week schedule. The UCC certificate confirms that 30 hours of training in urban climatology was completed by the participant.

UCC 2022 in Manizales

UCC 2022 was attended mainly by graduate and senior undergraduate students from the engineering and architecture programs at UNAL Manizales. Students and professors from other local and regional universities and institutions across Colombia (and beyond) were also invited to attend this year's event. Several of the invitees accepted the invitation and travelled from Medellin and Pereira, Colombia, and Santiago, Chile. A total of 25 participants were admitted into UCC 2022, of which 15 graduated with a UCC certificate.

The tropical mountain setting of Manizales, Colombia.

Lectures for UCC 2022 covered a breadth of topics, including the core methods, concepts, and classifications of urban climatology; the temperature, moisture, and wind fields of urban environments; the effects of cities on global climate change; the rise of megacities and the urban metabolism; the role of urban climatic maps in settlement planning; and the design of climate-sensitive cities and communities. Labs were focused on the practical application of these topics and required UCC participants to employ Google Earth tools to parameterize the urban surface; use Local Climate Zone (LCZ) guidelines to classify urban and rural areas; analyze weather datasets to detect urban heat islands; and follow WMO and LCZ conventions to design urban meteorological networks.

The field trip in Manizales involved a half-day visit to a rooftop weather- and air-monitoring station in the historic center of the city. The site is part of a statewide network of monitoring stations whose data are managed by the Instituto de Estudios Ambientales (IDEA) at UNAL Manizales. The trip was led by a team of engineering professors and technical experts from UNAL. Prior to the visit, the team gave a series of informative talks to the class about the air-quality and hydro-climatological networks in Manizales, and their role in providing early warnings about landslides and flash floods. Upon arrival at the station, participants were briefed on the siting, operation, and technical specifications of the equipment, while taking time to observe the built form and atmospheric effects of the city from a rooftop perspective.

By the end of UCC 2022 in Manizales, all participants had reached their learning goals and were well qualified to assess the value and purpose of climate data in their own projects. They were also positioned to think critically (and creatively) about the established methods and results in the urban climate literature. The knowledge gained by the participants of UCC 2022 is fundamentally important to this new generation of urban climate researchers, especially those faced with the difficult task of transferring large bodies of urban climate theory to the tropical mountain cities of Latin America.

Classroom lecture on the urban heat island effect.

UCC Sponsorship

All participants of UCC 2022 expressed deep appreciation for the two program sponsors—UNAL and IAUC—whose generous support ensured that the course could be offered at no cost to local participants, and with travel subsidies for those coming from outside the region. Free access to urban climate instruction is a founding principle (and the highest priority) of the UCC program, and the sponsorship provided by UNAL and IAUC ensured that this standard could be upheld. The sponsorship also meant that, for the first time in the program's history, UCC staff and participants could enjoy a farewell lunch together on the final day of the program—Graduation Day! On July 15, following a short ceremony to close the proceedings of UCC 2022, the group gathered at a nearby restaurant and drank a deserving toast to a fruitful and fascinating immersion into the field of urban climatology.

For more details on the UCC program, including testimonials from this year's participants, visit the course website at https://cursoclimatologiau.wixsite.com/course.

Field trip to a rooftop air-monitoring station in the centre of Manizales: (left) UCC participants study the built form of Manizales from an elevated perspective; (right) a local expert explains the operation of meteorological sensors at the monitoring station.

The graduating class of UCC 2022.

Farewell lunch with UCC staff and participants.

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Bochum Urban Climate Summer School (BUCSS22) returns with in-person program in Germany

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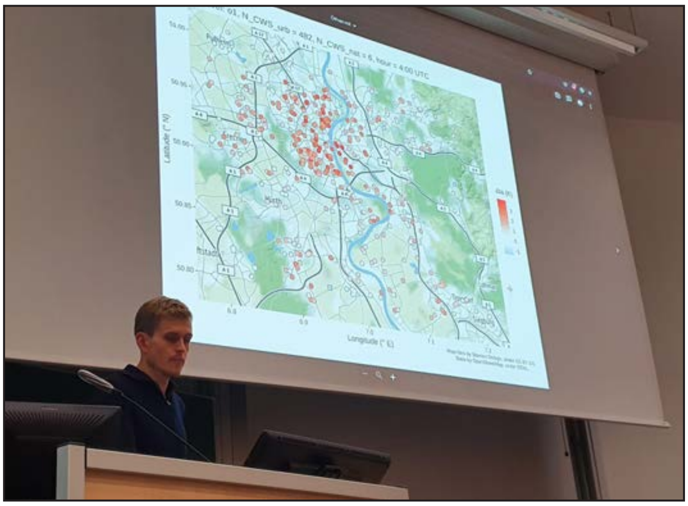
At the end of the 3rd BUCSS in Bucharest (Romania) it was decided to have the 4th edition in Bochum (Germany), in 2020. Unfortunately, COVID19 threw a spanner in the works, resulting in an online (light) version in 2020, and no school in 2021. But third time's the charm, and we successfully offered BUCSS22 as an in-person event in Germany, and finally had the opportunity to say hello from the Bochum Urban Climate Lab that was founded in 2019.

The school was free of charge, and was attended by 42 students and 13 lecturers, covering 22 countries and all continents except Antarctica. Attendance of students coming from low- and middle-income countries was financially supported by the IAUC and the Mercator Foundation. Two EU students were supported by the Young Scientist Travel Award provided by the European Meteorological Society. All other activities would have been impossible without the financial support from the Mercator foundation, Ruhr-University Bochum's research school and the German science foundation that funded the co-hosted workshop of the ENLIGHT project (https://www.climate.ruhr-uni-bochum.de/research/projects/enlight/).

The summer school provided a general introduction to different facets of urban climatology with a special focus on urban climate informatics. After the welcome



Daniel Fenner quality-controlling crowdsourced information.

(Benjamin Bechtel and Sorin Cheval) and the students' own introductions, Gerald Mills and Andreas Christen introduced the field of urban climatology, dynamics and metabolism, all in the context of climate change. Their broad introduction set the stage for more focused presentations on satellite (Benjamin Bechtel) and ground-based remote sensing (Simone Kotthaus), urban climate informatics (Ariane Middel), personal exposure to urban climate via IoT, ubiquitous, and crowdsourced sensing (Negin Nazarian), crowdsourcing station data (Daniel Fenner), a general introduction to urban climate modelling (Leena Järvi), urban climate modelling with PALM (Robert Rauterkus) and WRF (Andrea Zonato), and an in-depth overview on how to evaluate models at various temporal and spatial scales (Helen Ward).

A team presenting their WRF analysis.

These state-of-the-art lectures were complemented with various hands-on sessions in Google Collaboratory, in order to explore the ESA CCI SUHI database developed in the ENLIGHT project (Panagiotis Sismanidis), to learn about the capacities of Google Earth Engine (Matthias Demuzere), to extract and quality-control crowdsourced stations (Daniel Fenner and Jonas Kittner), and to evaluate and interpret WRF simulations over the larger Ruhr area (Germany) for a heat wave in 2019 (Matthias Demuzere and Andrea Zonato). For the latter, a range of WRF simulations were provided, differing in their (urban) land cover characteristics and rooftop mitigation strategies (RMS). As a last activity of BUCSS22, all students presented the WRF hands-on results in smaller teams, providing

Participants and lecturers in front of the Gasometer in Oberhausen.

all attendees with an impressive in-depth assessment of the modelled thermal behaviour, strengths and weaknesses of the RMSs, and a critical reflection on the model setup and available evaluation strategies.

Of course, a summer school is much more than scientific training. It also enables students and lecturers to connect, get to know each other, and discuss potential future collaborations or activities. This informal interaction is at the core of a school, and was further enabled by various non-scientific events, such as the daily joint lunch, the ice-breaker dinner on campus, a guided city tour in Bochum, a visit to the Fragile Paradise exposition at the gasometer in Oberhausen, and the official summer school dinner at the Blankenstein castle.

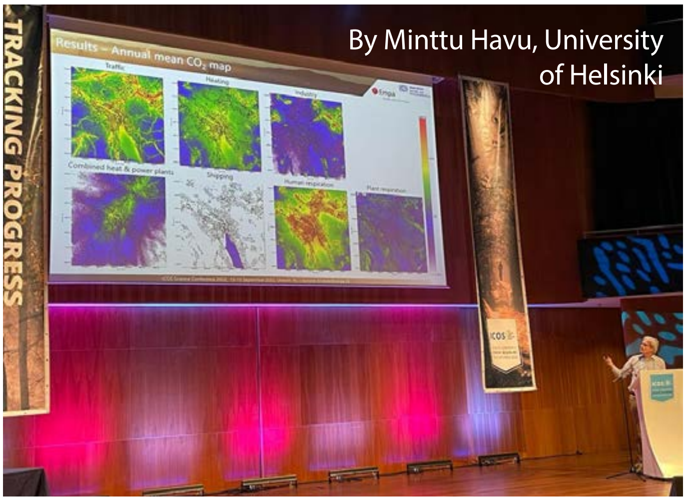
More details about BUCSS22, including the daily program, invited lecturers and their biographies are available at https://www.climate.ruhr-uni-bochum.de/bucss/. All lecture presentations, hands-on notebooks and used datasets are available at: https://github.com/RUBclim/BUCSS22. Finally, a questionnaire will be sent to all participants to solicit feedback on the program. That feedback can be integrated in the next edition of the summer school, which we hope to organise in 2023. If you are interested to join, please keep an eye on the IAUC communication channels. We hope to see you all there.

Students discussing the WRF outputs in small teams.

Official dinner at Blankenstein castle.

Top: Students with smiles.
Bottom: Same, but lecturers.

"Tracking progress to carbon neutrality" from an urban climate perspective at ICOS Science Conference 2022



By Minttu Havu, University of Helsinki

The urban climate community played a key role in the 5th ICOS Science Conference in September 2022, which was held as a hybrid event with on-site participation in Utrecht, the Netherlands, and virtual participation online. The overarching theme of the conference was "Tracking progress to carbon neutrality" and how standardized and open data from measurement stations across Europe provided by the Integrated Carbon Observation System (ICOS) could be used to achieve this goal. ICOS has connections to urban climate research because it now provides urban observational data via recently funded EU Horizon 2020 project ICOS Cities (PAUL – *Pilot Application in Urban Landscapes* – towards integrated city observatories for greenhouse gases). ICOS Cities develops systematic observations to monitor greenhouse gas (GHG) emissions in urban areas. It supports the European Green Deal and develops useful tools and services for cities in support of their local climate action plans. In addition to urban climate community participants from European countries, the conference had representation also from the urban climate community from other parts of the world, such as North America, Japan, Australia, and New Zealand.

The conference was a 3-day event with one full day of urban-themed sessions, mainly focusing on emission modelling and atmospheric monitoring of anthropogenic carbon emissions. Three plenary presentations focused on urban areas. Urban areas are of special importance, as Jocelyn Turnbull (GNS Science, New Zealand; the University of Colorado, USA) emphasized in her presentation, because mitigation policies are often driven by city and local governments. To support such policy actions, detailed information about sources, temporal changes, and whole-city emissions are needed. She also presented a document on the Urban Greenhouse Gas Emission Observation and Monitoring Best Research Practices that was recently published by the WMO-sponsored Integrated Global Greenhouse Gas Information System (IG3IS).

Temporal changes of CO_2 fluxes monitored by the eddy covariance technique from European cities during the COVID-19 lockdowns were presented by Giacomo Nicolini (Euro-Mediterranean Centre on Climate Change, Italy). CO_2 emissions decreased due to reduced mobility but, as restrictions were lifted, emissions quickly rebounded to pre-COVID levels. In addition to monitoring GHG emissions, understanding the carbon mitigation potential of urban vegetation is extremely important. Gabriele Guidolotti (Research Institute on Terrestrial Ecosystems, Porano, Italy) measured both carbon and water fluxes with eddy covariance and showed that both were affected by drought in an urban park in Naples, Italy. Overall, the impact of drought on different ecosystems was visible in many presentations during the conference.

The parallel sessions consisted of 15-minute oral presentations and poster sessions with 2-minute PICO-style presentations. Following the tone set by the plenary sessions, there was a lot of interest in partitioning anthropogenic carbon sources at the whole-city level, and in understanding how emissions vary spatially, including human metabolism and biogenic fluxes. Both anthropogenic sources and biogenic fluxes were estimated using a variety of approaches, including eddy covariance measurements, remote sensing, models, and emission inventories. In addition, the ICOS Cities project was introduced with both oral and poster presentations, mainly focusing on the first steps in the project to set up urban CO_2 sensor networks in Zürich and Munich.

Overall, the ICOS Science Conference 2022 provided a comprehensive overview of how tracking progress to carbon neutrality in cities could be supported through different methods. The organizers and participants look forward to the next meeting in two years to see what progress has been made during this time.

Notes on the first Brazilian Symposium on Human Biometeorology

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Introduction

As in many other countries worldwide, human health in Brazil has been and will be affected by climate change in multiple ways. Souza Hacon et al. (2019) identified heat waves, droughts, and alterations in rainfall regimes as extreme weather events with direct impacts on the country's public health. Indirectly, climate change is expected to aggravate vector-borne and water-borne diseases, as well as increase air pollutant emissions with severe burdens to human health, particularly for the most vulnerable populations. In Brazil, such impacts will likely be exacerbated due to deficiencies in the national health care system.

Regarding water scarcity and extreme weather events, half of all natural disaster events in Brazil are drought-related (Vanham et al., 2021). In particular, the northeastern semi-arid region of Brazil is a long-time risk area with a history of droughts (Vanham et al., 2021). This is particularly relevant considering that the region is characterized by the highest poverty and illiteracy levels and the lowest Human Development Index (HDI) in the country (Sena et al., 2014), which generates a perverse weather/climate-socio-economic conundrum. As for floods, these are becoming more and more frequent in Brazil, where the mortality rate from river floods is the highest worldwide between December and April (Alfieri et al., 2020). The floods and landslides that caused widespread displacements and injuries, as well as over 200 documented deaths in the city of Petrópolis in the Brazilian State of Rio de Janeiro in the summer of 2022, demonstrate the extra burden floods can put on health care (The Rio Times, 2022).

Risk assessment of heat is also highly relevant for Brazil. In a study on heat stress vulnerability in six Brazilian metropolitan areas, Lapola et al. (2019) showed that heat stress risk is higher where socio-economic conditions are the worst and, in those locations, especially in less developed city areas. Confalonieri et al. (2009) showed that the richest states of Brazil present the lowest 'general vulnerability' to heat. One particularly vulnerable group of outdoor workers is agricultural and construction workers

Figure 1. Group picture at the closing session (from left to right: Fabio Luiz Teixeira Gonçalves, Loyde Abreu-Harbich, Anderson Spohr Nedel, Eduardo L Krüger, Paulo Sérgio Lucio, José Aguiar, Ana Carla dos Santos Gomes, Claudia Di Napoli

who are exposed to extreme weather conditions, including intense heat (Pires Bitencourt et al., 2020). The 2020 report of the Lancet Countdown on health and climate change estimated that in 2019 Brazil lost 4.0 billion work hours due to excess heat versus 2.8 billion in 2000 (Watts et al., 2021). Urgent measures are therefore required towards improving working conditions, diminishing risk exposure and improving technological development related to outdoor labor activities as well as changes in employment legislation to mitigate heat-related impacts (Pires Bitencourt et al., 2020).

This background highlights Brazil as a 'climate-health hotspot', i.e. a country where climate affects local populations negatively through multiple pathways (Di Napoli et al., 2022). However, deficiencies and knowledge gaps still need to be filled concerning the climate dimensions of tourism, vector-borne diseases, mortality and morbidity in urban centers in Brazil (Krüger et al., 2022). Motivated by this, the first Brazilian Symposium on Human Biometeorology (Simpósio Brasileiro de Biometeorologia Humana 2022) was organized and held at the Federal University of Rio Grande do Norte (UFRN) in Natal, northeastern Brazil, between July 4 and 8, 2022 (Figure 1).

The symposium was organized as a hybrid event from a research collaboration started in 2021 that culminated with a systematic review on human biometeorology research in Brazil (Krüger et al. 2022). Aim of the symposium was to promote human biometeorology in Brazil in response to the deficiencies and knowledge gaps to be filled with regard to human biometeorology in the country. To achieve this, we focused on five main topics: a) climate-driven diseases; b) thermal comfort, urban and architectural biometeorology; c) atmospheric pollution and health; d) climate change; e) climate, health and climate change. This summary highlights some of the presentations shown during the 5-day meeting.

Highlights of the first Brazilian Symposium on Human Biometeorology

Climate-driven diseases

Pablo Fernández de Arroyabe (Universidad de Cantabria; former president of the International Society of Biometeorology - ISB) set the stage for the subsequent talks focusing on the influence of atmospheric processes on human health in the framework of climate-dependent diseases. Customized warning systems that integrate monitoring systems, global data sources, innovative models and approaches, GIS data, biometeorological profiles and inform local populations through apps were addressed (Fdez-Arroyabe et al., 2018). Challenges for pursuing such topics further include the development and implementation of wearable and implantable medical devices (Fdez-Arroyabe et al., 2020). Land-use consequences on environmental degradation and the proliferation of vector-borne diseases were shown for Latin America. To each of these topics, Fdez-Arroyabe identified gaps for future research endeavours, including indoor thermal comfort and climate-related occupational health (Vega-Calderón et al., 2021), atmospheric electric fields (Fdez-Arroyabe et al., 2021), atmospheric nanoparticles in relation to human health (Fdez-Arroyabe et al., 2022).

Thermal comfort, urban and architectural biometeorology

Cho Kwong Charlie Lam (Sun Yat-sen University, Zhuhai, China) addressed in his talk climate change adaptation and the design of healthy cities, and focused on outdoor environments and the multisensory interaction of diverse factors regarding environmental quality and perception (Lam et al., 2020). Of particular interest to the climate-responsive design, urban greenery has been proposed as a feasible solution to improve thermal and visual comfort, and reduce noise levels and air pollution in urban areas. Lam's talk tackled this urban design strategy, showing the complexity behind its implementation in terms of heat stress attenuation (Chen et al., 2021). Other relevant issues related to outdoor thermal comfort have also been addressed, such as acclimatization and psycho-

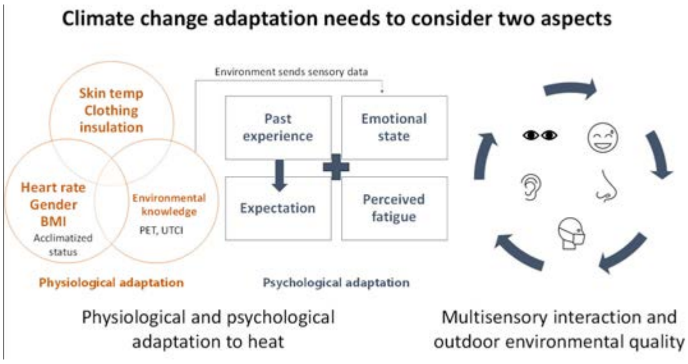

Figure 2. Climate change adaptation framework that incorporates thermal adaptation (adapted from Lam et al., 2021c) and multisensory interaction.

logical thermal adaptation (Lam et al., 2021a; Lam et al., 2021b; Lam et al., 2021c), which need to be included in climate change adaptation assessment (Figure 2).

Atmospheric pollution and health

Luis Fernando Amato-Lourenço (Institute of Advanced Studies, University of São Paulo, USP) adressed the deleterious impacts of microplastics in humans. In one of the studies presented (Amato-Lourenço et al., 2021), the autopsy of non-smoking deceased patients that had spent at least 10 years of their lives in the megacity of São Paulo showed that particles and fibers were present in their lungs whereas the autopsy of stillborns showed no signs of such elements in their lung samples. In another study (Amato-Lourenço et al., 2022a) on atmospheric fallout in outdoor and indoor environments, the sampling of airborne particulates revealed that microplastics were present in both outdoor and indoor environments, with a higher proportion in the latter. A further study on the combination of airborne microplastics and SARS-COV-2 in total suspended particles in the surrounds of the largest medical center in Latin America (in São Paulo) (Amato-Lourenço et al., 2022b) showed that SARS-COV-2 genes were present in airborne microplastics (mostly polyester), which acted as relevant disease-vectors. Negative correlations between microplastics with SARS-COV-2 were found for temperature and humidity, reinforcing the climate-dependent pattern of the virus transmission. In occupational health, evidence has been shown of the damaging effect of pristine particulates on human health. Further studies discussed in the presentation pointed to the presence of microplastics even in human placenta and in human blood.

Climate change

Claudia Di Napoli (University of Reading, UK) focued on the monitoring of human health indicators in view of a climate change. The "Lancet Countdown: Tracking progress on health and climate change" initiative was presented as a worldwide monitoring system able to track the multiple pathways in which climate change and weather extremes have been affecting human health since the 1980s. The initiative makes use of climate-health indicators via a hazard-exposure-vulnerability overlaying framework, and it has worldwide coverage (Di Napoli et al., 2022). Examples of indicators were given from the 2021 annual report, with a focus on indicators tracking the linkages between heat, heat extremes and human health. According to one of these indicators, Brazil had the biggest absolute increase in heat-related mortality between 2018 and 2019 (Romanello et al., 2021). Annual indicators can be retrieved for Brazil and any other country of the world from the Lancet Countdown data platform and are available for free (wwww.lancecountdown.org/data-platform/, Figure 3).

Also related to online platforms that should foster public awareness regarding climate and health, Lincoln Muniz Alves (National Institute for Space Research / Instituto Nacional de Pesquisas Espaciais - INPE) presented the complexity of coping with climate change impacts on human health, of quantifying associated risks, and of establishing action plans. The AdaptaBrasil (https://adaptabrasil.mcti.gov.br) online platform was introduced. which consolidates, integrates, and disseminates robust information in a centralized and easily-accessible manner (Figure 4). This platform analyzes observed and projected impacts over the 5,570 Brazilian municipalities (and other territorial aggregations) on strategic sectors such as food, energy, health, and water security.

In the same token, Laurence Kalkstein (Arsht-Rockefeller Foundation Resilience Center, Arsht-Rock, U.S.A.) presented his most recent project involving the categorization of heat waves based on human health outcomes (Axios, June 2022). The categorization is based on a synoptic classification of air masses and uses mortality data for establishing different levels of impact of excessive heat (Nairn & Fawcett, 2015). Within this framework a ranking system is proposed as part of a heat warning system so that stakeholders, policymakers and authorities can take actions or interventions against upcoming heat waves. The system is currently being tested in cities in U.S.A. and Europe, and can be applied elsewhere in the world, Brazil included (Figure 5).

Way forward

This summary attempted to present some of the main topics discussed during the 5-day meeting as a memento of the first Brazilian Symposium on Human Biometeorology. The need for more studies aimed at improving human biometeorological conditions in urban areas and 'climate-health hotspots' (Di Napoli et al., 2022) was frequently stressed by presenters and moderators during the meeting in Natal. Possibilities and intentions of starting research collaboration were discussed such as the implementation of novel heat-wave warning systems in Brazil. The symposium was a further step beyond the systematic

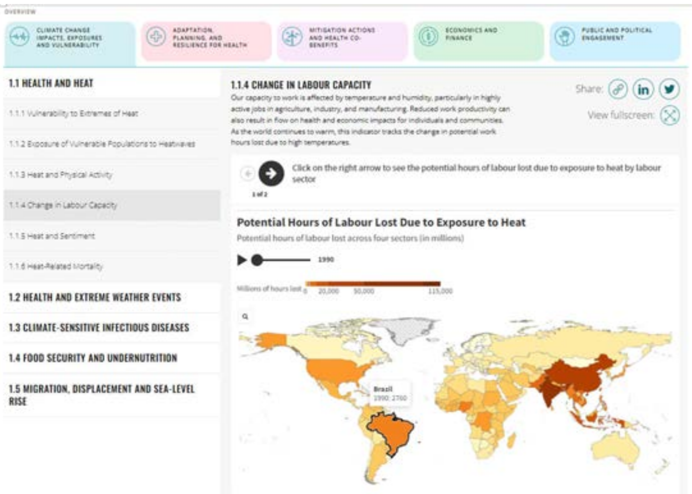

Figure 3. Lancet Countdown's data platform.

Figure 4. INPE's AdaptaBrasil online platform.

Figure 5. Heat warning system for Seville – test phase.

literature review conducted for Brazil by the event organizers, toward a more consistent development and promotion of the broad area of human biometeorology in the country. It is intended that a second symposium shall be organized in the near future, on a biannual basis.

Acknowledgments

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Recent Urban Climate Publications

In this edition is a list of publications that have generally come out between **May and August 2022**. Publications in **boldface** are highlighted papers recommended by the members of the Bibliography Committee. If you believe your articles are missing, 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, Abstract. Important: do so in a .bib format.

As of this month, Dr. Rohinton Emmanuel decided to leave the committee after serving as a committee member for more than 14 years. Thank you, Rohinton, for your enthusiasm and contribution to the community! We are always looking for researchers at any career stage (especially early career) to join the committee and contribute to the IAUC community. If you are interested in joining or would like to learn more information, please feel free to let me know via the email address below.

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Upcoming Conferences...

36TH PLEA CONFERENCE ON SUSTAINABLE ARCHITECTURE AND URBAN DESIGN
Santiago, Chile • November 23-25, 2022
https://plea2022.org/

AMERICAN GEOPHYSICAL UNION FALL MEETING
Chicago, USA and Online • December 12-16, 2022
https://www.agu.org/Fall-Meeting/
Abstract deadline: Aug. 3, 2022

AMERICAN METEOROLOGICAL SOCIETY (AMS) SPECIAL SYMPOSIUM ON URBAN ENVIRONMENT
Denver, Colorado, USA • January 8-12, 2023 (hybrid)
https://annual.ametsoc.org/index.cfm/2023/program-events/conferences-and-symposia/special-symposium-on-urban-environment/

JOINT URBAN REMOTE SENSING EVENT (JURSE)
Heraklion, Crete, Greece • May 17-19, 2023
http://jurse2023.org

Calls for Papers...

Special issue on "Remote Sensing of the Urban Environment: Beyond the Single City" in *Remote Sensing of Environment*

Submission Deadline: January 31, 2023 (Note to authors: Please email an abstract in advance of a full manuscript to the guest editors and EiC for preliminary evaluation)

https://www.journals.elsevier.com/remote-sensing-of-environment/forthcoming-special-issues/remote-sensing-of-the-urban-environment-beyond-the-single-city

Special issue on "Recent progress in atmospheric boundary layer turbulence and implications to surface-atmosphere exchange" in *JGR Atmospheres*

Open for Submissions: September 1, 2022
Submission Deadline: August 31, 2023

https://agupubs.onlinelibrary.wiley.com/hub/jgr/journal/21698996/features/call-for-papers

ELEVENTH INTERNATIONAL CONFERENCE ON URBAN CLIMATE (ICUC-11)

University of New South Wales (UNSW)
Sydney, Australia • August 28 - September 1, 2023

Conference website: https://icuc11.com/
Abstract submission page: https://icuc11.com/abstracts/

Design the ICUC11 logo to get free registration for the conference!

Are you a student or ECR with a knack for graphic design & keen to attend the ICUC11 event in Sydney?

Submit your logo (to n.nazarian@unsw.edu.au and melissa.hart@unsw.edu.au) by Nov 7, 2022, for a chance to win.

Logo requirements: 1) promote ICUC11 mission 2) compatible with the branding used in ICUC11.com: https://twitter.com/NeginNazarian/status/1581833725343854592

IAUC Virtual Poster Conference held in advance of ICUC11

The 11th International Conference for Urban Climate (ICUC11) will now run Aug 28 – Sept 1, 2023 in Sydney Australia. We are delighted to say that we are now open for abstracts!

The link for the conference website is https://icuc11.com/

And the abstract submission page is https://icuc11.com/abstracts/

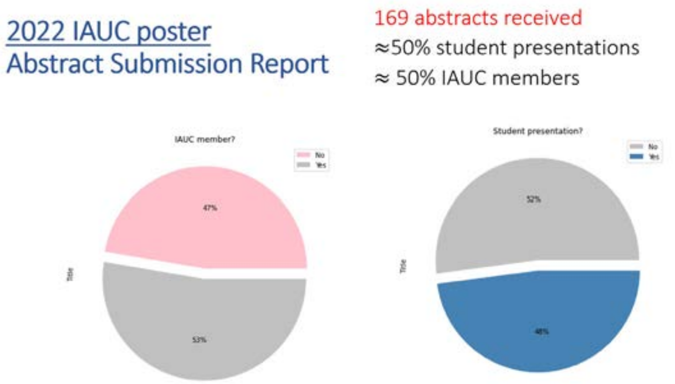
With ICUC11 two years later than expected due to COVID related delays, we were proud to present a virtual poster conference which provided an opportunity for the community to come together in an interactive and engaging virtual space to share our research.

Members of the community had the opportunity to present posters in a virtual poster room, with poster sessions held throughout different time zones so that all were able to be involved. We received over 170 abstracts submitted, from 31 countries, and 210 registrations were received. The online platform used, Remo, allowed participants to gather around a virtual table for discussions over a poster. Many mentioned that it felt very close to being at an in-person poster event.

We were also excited to present a series of keynote speakers, and professional development events.

Our keynote speakers were all early- to mid-career researchers who spoke to emerging topics in the urban climate field. The speakers came from across the globe, representing the diversity of IAUC researchers.

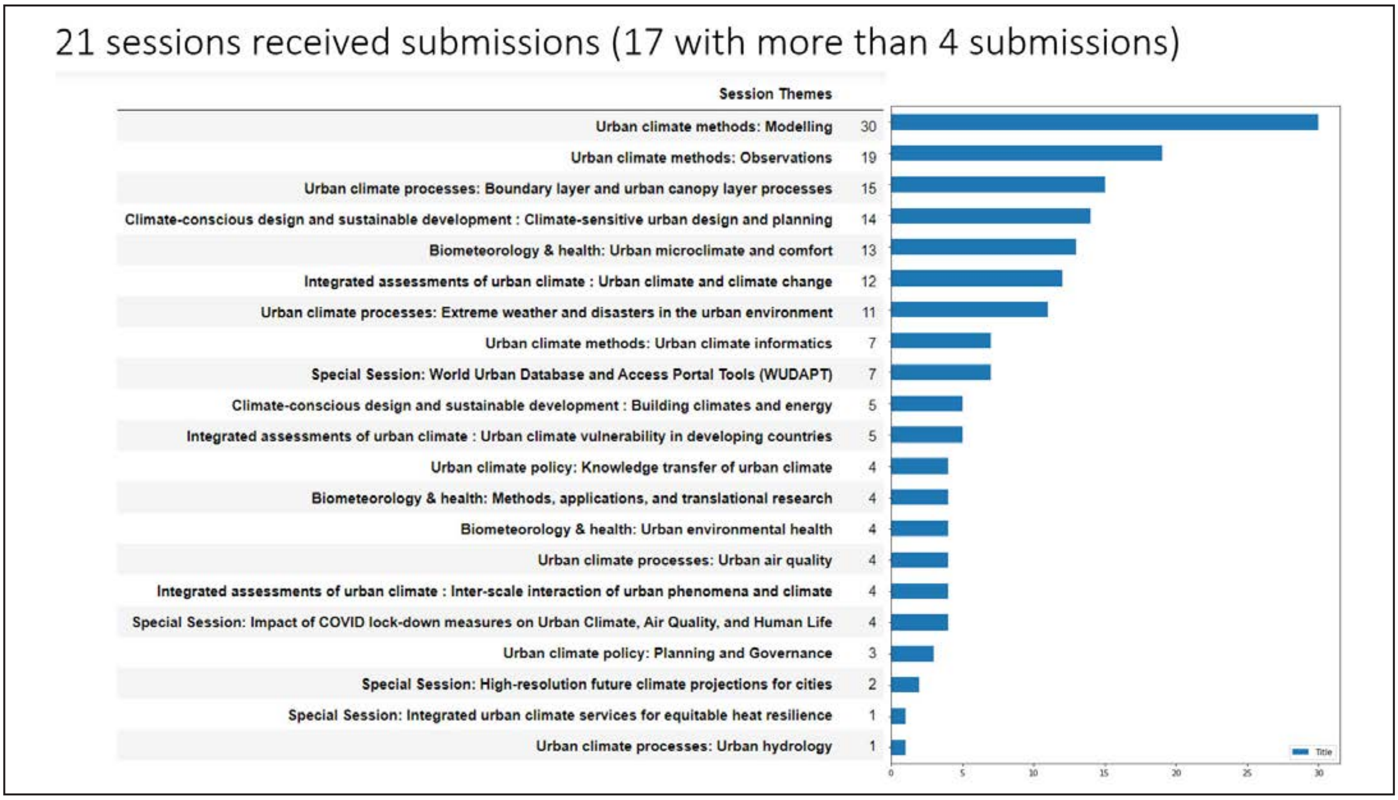
Professional development events were organised by members of the IAUC early career researcher community

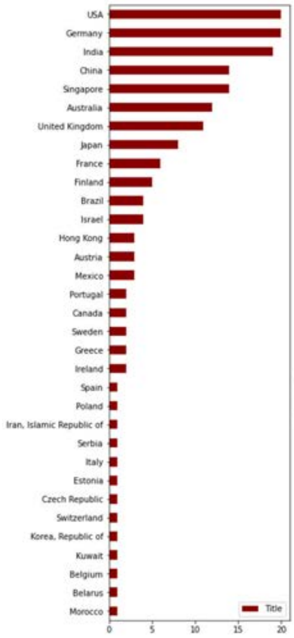


and covered topics that are of great relevance to all researchers. Recordings of the keynotes and professional development events can be found on the IAUC YouTube Channel.

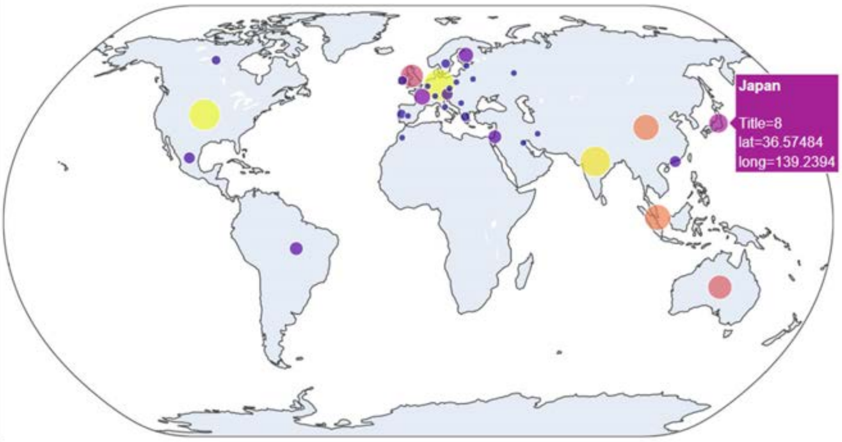
Finally, the virtual poster sessions provided an opportunity to thank and farewell the outgoing IAUC executive, and welcome the incoming IAUC executive. We thank all those involved in this virtual event and look forward to welcoming everyone in-person to Sydney in 2023.

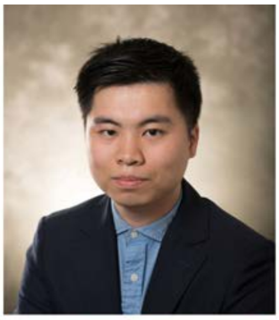
—Negin Nazarian and Melissa Hart





Submission were received from 31 countries. North America, Europe, and APAC show strong representation of urban climate research while Africa and South America are under-represented





Keynote sessions:

Three keynotes were organized with 6 early- to mid-career experts from 5 countries (USA, UK, Singapore, India, South Africa, and India).

Three emerging topics in urban climate field was covered: Urban Climate Informatics, Heat Health in the Built Environment, and Urban Climate Justice.

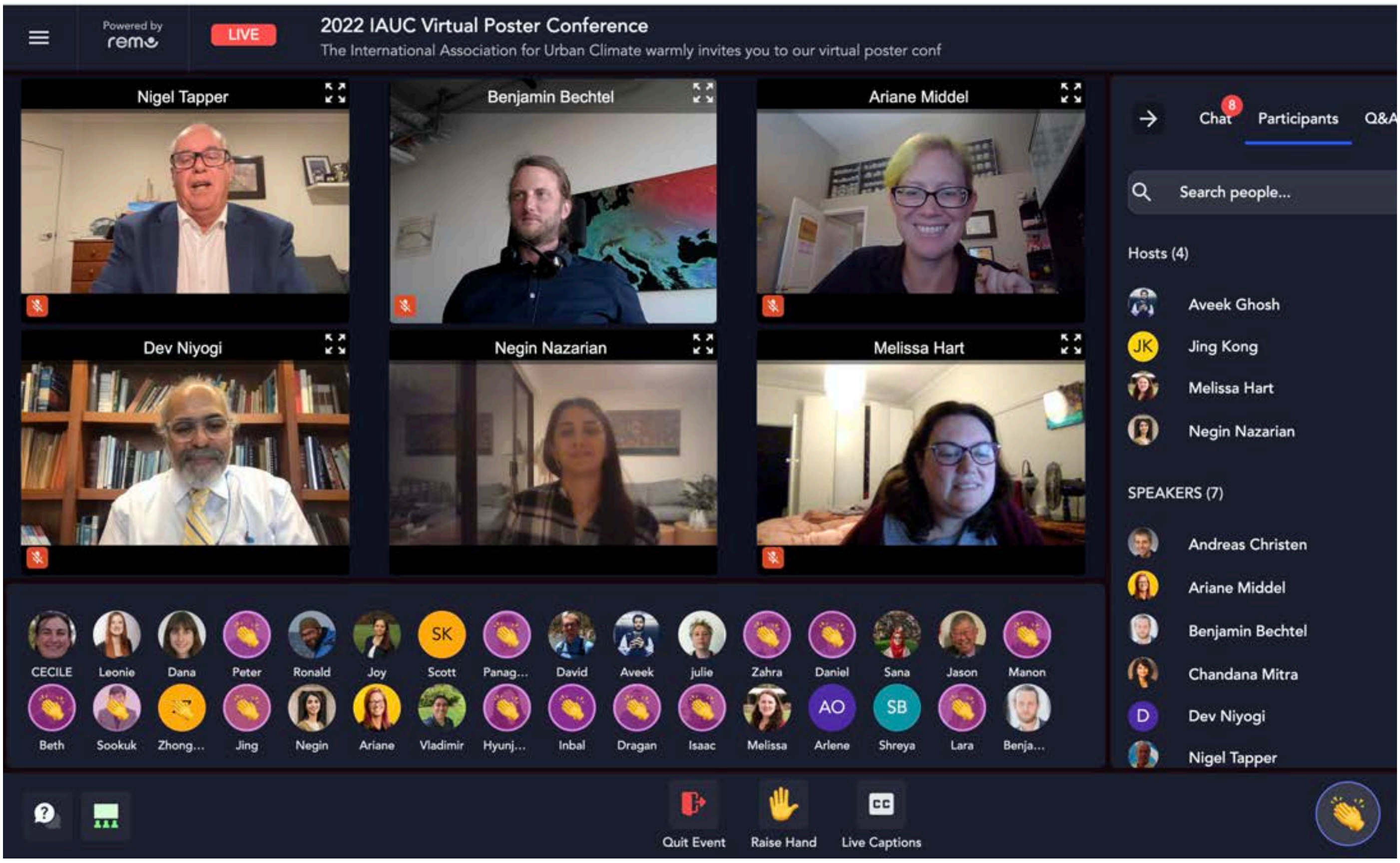
Each keynote attracted 50-80 participants online.

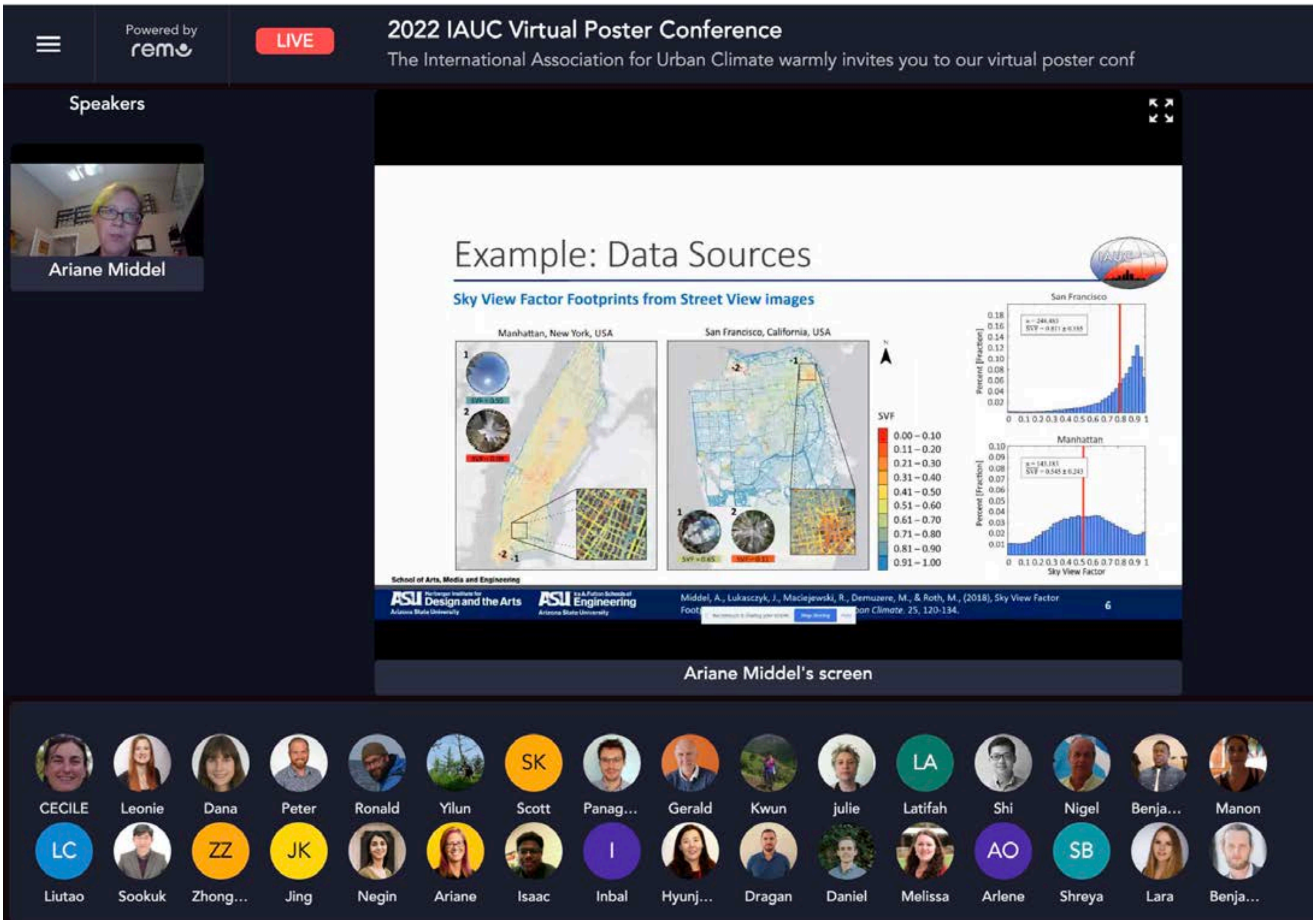
Three ECR sessions with eight global experts were organized focused on preparing CVs, applying for proposals, and implementing JEDI principles in the IAUC community. Each event attracted 20-30 participants.









Screenshots from the IAUC Virtual Poster Conference, from August 30th to September 1st 2022.

IAUC honors Jamie Voogt with 2022 Luke Howard Award

We are delighted to announce Professor **James Voogt** of the University of Western Ontario, Canada, as the winner of the 2022 Luke Howard Award for Outstanding Contributions to the Field of Urban Climatology.

Jamie is an excellent scientist and very well respected pillar of the urban climate community on multiple fronts. His research contributions are of the highest quality, resulting from his careful attention to detail and exemplary unhurried approach to solving complex issues. He is a world-renowned expert on urban climatology, and the leading expert on thermal anisotropy and remote sensing of urban surface temperatures. His early publications are considered classics and remain highly relevant (and extensively cited) since they underpin much of our current understanding concerning both observational and modelling topics. Given the already widespread use of remote sensing in urban areas, and the ongoing development in this field, these publications remain key for the numerous applications and services making use of remotely sensed data, as well as for our fundamental understanding of urban climate processes.

Professor Jamie Voogt, a former President of the IAUC, has been recognized with the 2022 Luke Howard Award for his outstanding contributions to the field of urban climatology.

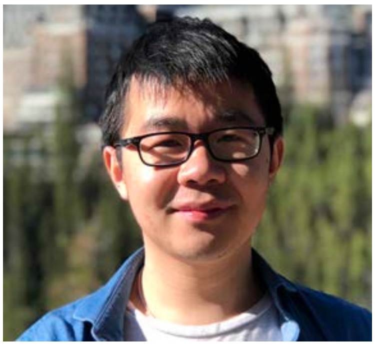
In addition to these considerable scientific contributions, Jamie has achieved an immense amount for the urban climate community. He played a crucial role in helping to establish the IAUC and has shown continued selfless dedication to IAUC activities, in part through numerous board positions (including president from 2014-2018). He also served on the AMS Board of the Urban Environment (including as chair from 2002-2005). He has been instrumental in raising the profile of urban climatology in national and international meteorological organisations, which led to the development of joint urban climate sessions between multiple organisations and has helped to foster inter-disciplinary collaborations and the exchange of knowledge and skills that are important for safeguarding the well-being of urban populations.

Jamie obtained his PhD from the University of British Columbia in 1995 before joining the University of Western Ontario where he is currently Professor of Geography. He is not only an excellent communicator in front of a considerable international audience but also one-to-one. Jamie's dedication to his students and research assistants, his friendly and approachable manner, and his exceptional skills as a mentor have inspired and continue to inspire numerous young scientists. He co-authored the Urban Climates textbook, which has been translated into multiple languages and has become one of the key texts for current and future generations of urban climatologists all over the world.

Jamie is one of the most enthusiastic, engaged and highly regarded members of the international academic community. His service to the field of urban climatology is hard to match and he is a creative, thoughtful and talented scholar who has provided considerable fundamental and impactful scientific contributions of outstanding quality. He is thus highly deserving of the 2022 Luke Howard Award.

— Helen Ward
Chair of the IAUC Awards Committee

Dan Li recognized with 2022 Timothy Oke Award



We are delighted to announce that this year's IAUC Timothy Oke Award for Original Research in the Field of Urban Climatology will be given to a truly exceptional scientist: Associate Professor Dan Li, at Boston University.

Dan has made numerous outstanding intellectual contributions to the field of urban climate and boundary layer meteorology. In the nine years since obtaining his PhD from Princeton University, Dan has produced a remarkable amount of highly cited and significant research which spans a phenomenal range of topics including turbulence, fluid mechanics, thermodynamics, hydrology and global climate.

His work combines extensive observations, numerical modelling, analytical methods and fundamental theory to make substantial advances in our understanding of meteorological concepts and associated real-world applications. This impressive skillset in combination with creativity, curiosity and diligence mean Dan's work has already had, and will surely continue to have, a major impact on urban climate.

— Helen Ward, IAUC Awards Committee Chair

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

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The next edition of *Urban Climate News* will appear in late December. Contributions for the upcoming issue are welcome, and should be submitted by November 30, 2022 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: Chenghao Wang and BibCom members
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