Personal exposure to urban climate: Infilling the urban climate networks with IoT, ubiquitous, and crowdsourced sensing

Dr Negin Nazarian
University of New South Wales (UNSW), Sydney
Climate-Resilient Cities research lab

Who am I?

Dr. Negin Nazarian

Scientia Senior Lecturer | Assistant Professor, UNSW Built Environment

Fellow, City Futures Research Centre

Associate Investigator, ARC Centre of Excellence for Climate Extremes

n.nazarian@unsw.edu.au,

@neginNazarian

My research Lab:
https://www.climate-resilientcities.com/

Mechanical Engineer

Urban Climatologist

Conducting multi-disciplinary research on the interaction between built environments and climate challenges

Developing and promoting methodologies and data platforms for Climate-Resilient Cities

climate extremes
ARC centre of excellence

UNSW
City Futures
Research Centre

UNSW
SYDNEY

Climate-Resilient Cities Lab

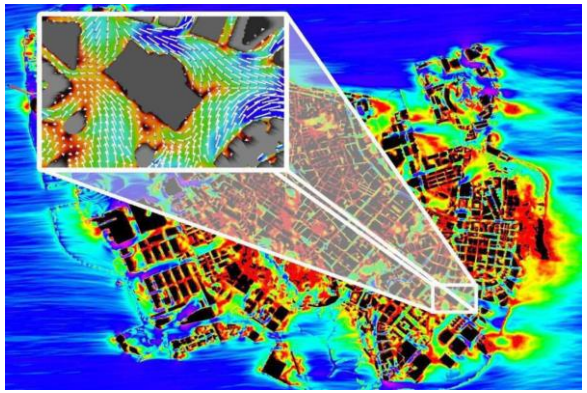
A **multidisciplinary** group dedicated to exploring the **climate impact in the built environment** and realizing **pathways to making our cities climate-resilient.**

Through our research, we aim to address the **pressing challenges of urban climate** (such as urban heat, ventilation, energy, and air quality) using a range of established and emerging methods such as climate modeling, environmental sensing, and IoT technologies.

Our team spans a broad range of expertise including **climate scientists**, **engineers**, **data experts**, and **architects**, and we aspire to enhance cutting-edge scientific, economic, and planning-related research that can aid decision-makers and stakeholders about the impacts of climate change on cities.

Climate-Resilient Cities Lab

Through our research, we aim to address the **pressing challenges of urban climate** (such as urban heat, ventilation, energy, and air quality) using a range of established and emerging methods such as climate modeling, environmental sensing, and IoT technologies.



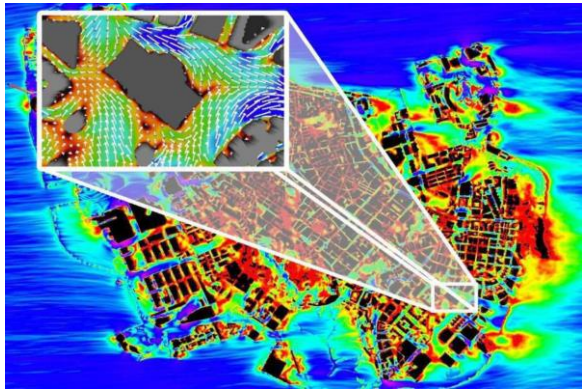
A. Multi-scale Urban Climate Modeling

B. Urban Climate Informatics: Infilling the urban climate networks with ubiquitous sensing, IoT, and crowdsourced monitoring

PhD positions available

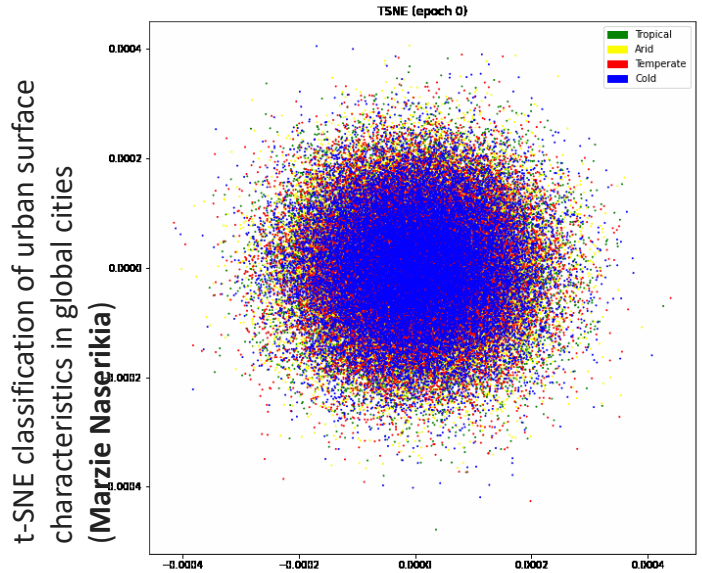
Climate-Resilient Cities Lab

Through our research, we aim to address the **pressing challenges of urban climate** (such as urban heat, ventilation, energy, and air quality) using a range of established and emerging methods such as climate modeling, environmental sensing, and IoT technologies.

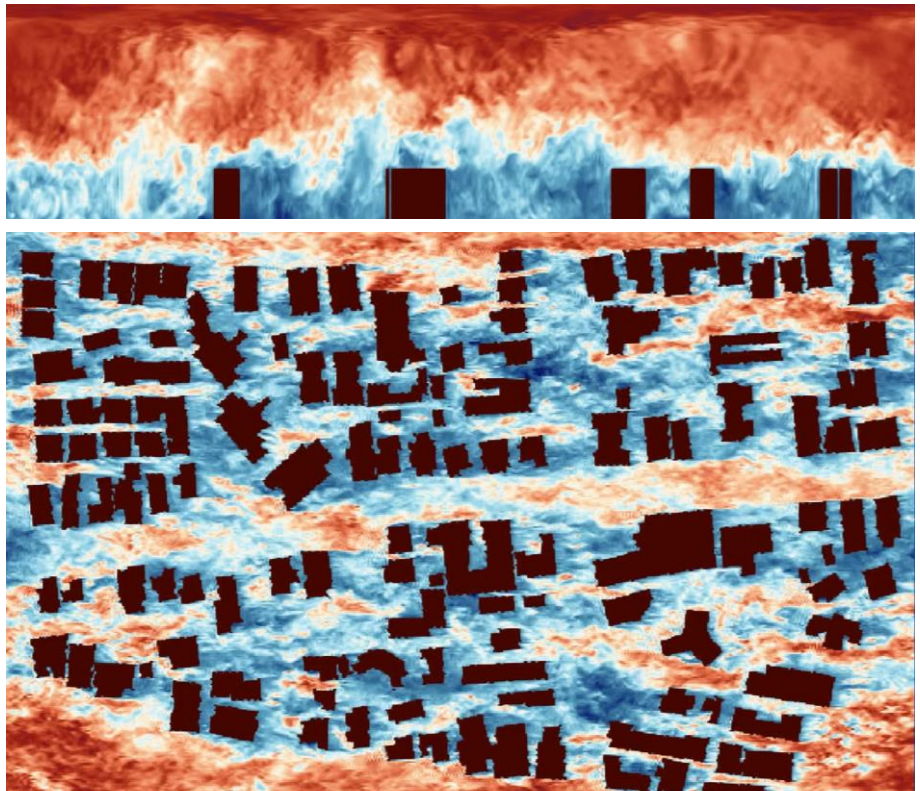


A. Multi-scale Urban Climate Modeling

B. Urban Climate Informatics: Infilling the urban climate networks with ubiquitous sensing, IoT, and crowdsourced monitoring



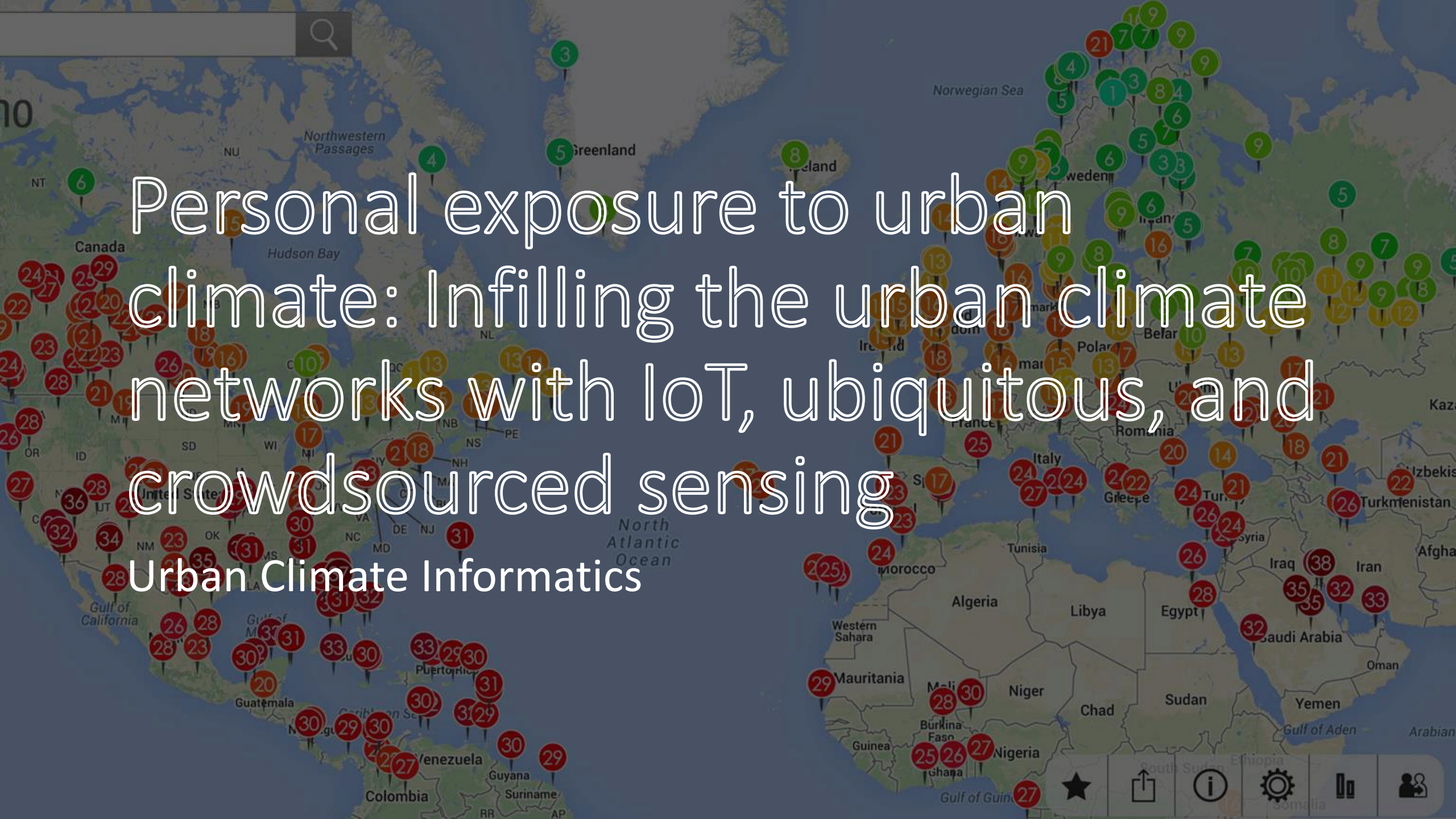
t-SNE classification of urban surface characteristics in global cities (**Marzie Naserikia**)



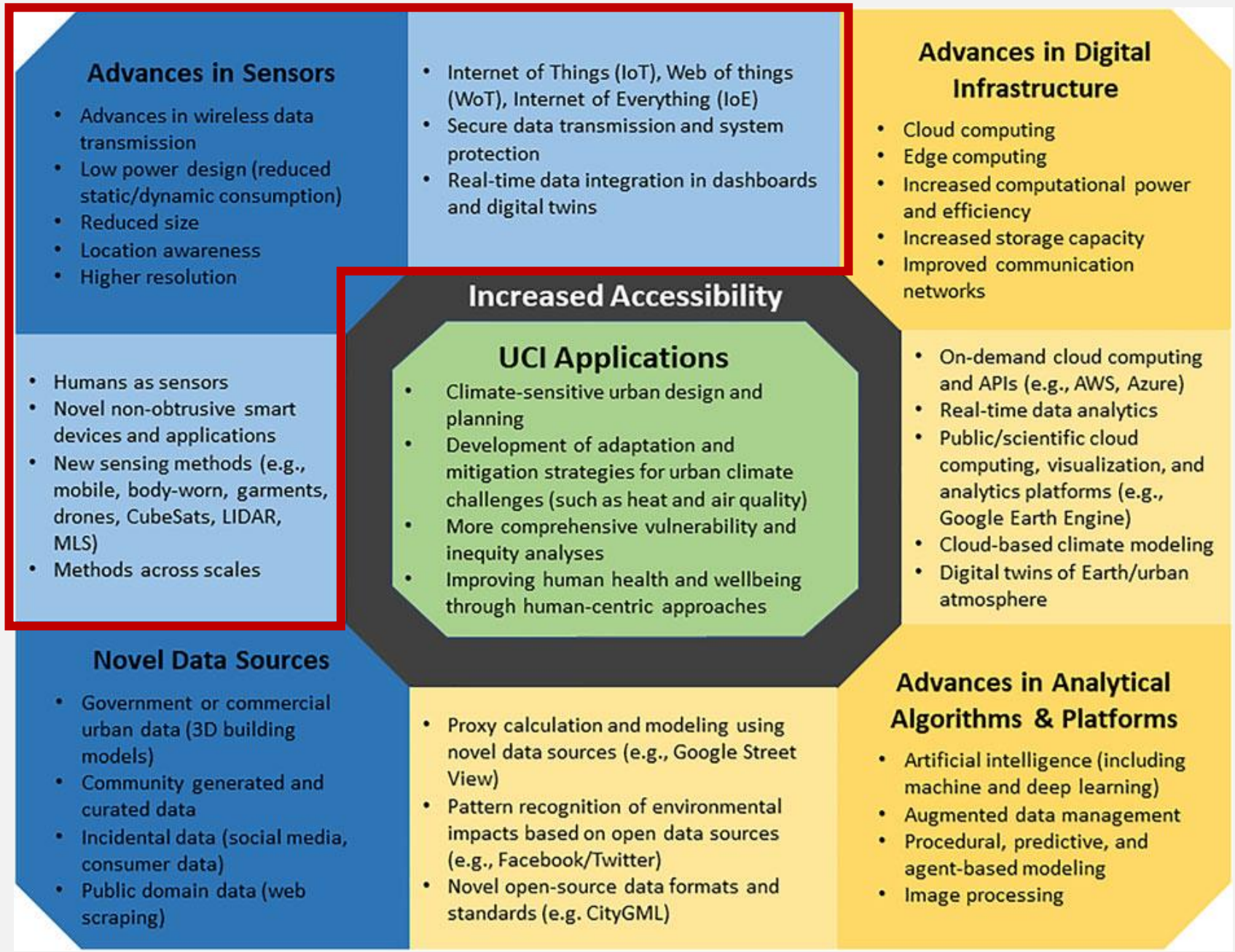
Microscale simulation of Sydney neighborhoods (**Jiachen Lu**)

Personal exposure to urban climate: Infilling the urban climate networks with IoT, ubiquitous, and crowdsourced sensing

Urban Climate Informatics



Urban Climate Informatics: an emerging research field



Middel et al 2022
https://doi.org/10.3389/fenvs.2022.867434

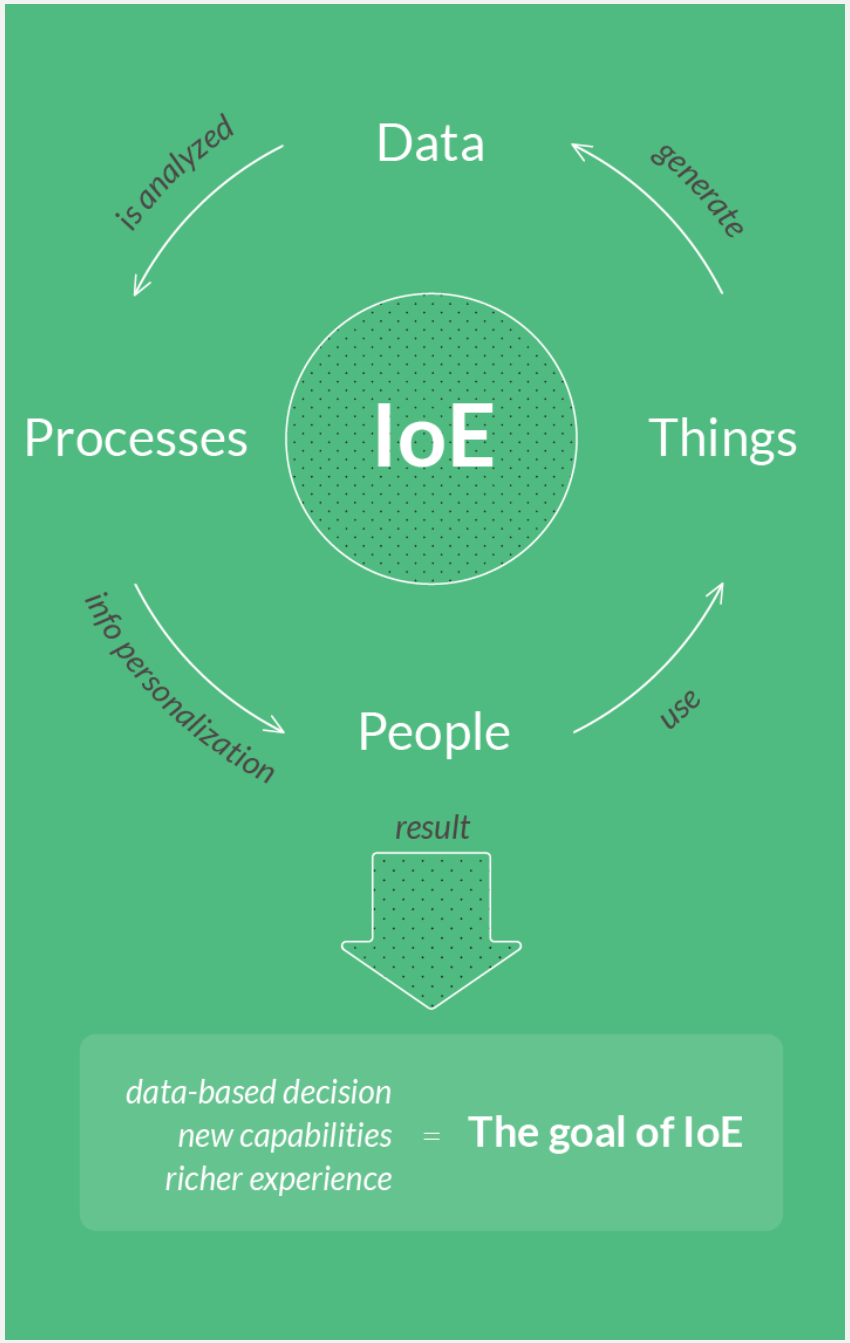
The Internet of things **(IoT)** is the network of devices that contain electronics, software, sensors, actuators, and connector which allows these things to **connect, interact** and **exchange data** in **real-time**.

Ubiquitous, or 'geo Ubiquitous' sensing emphasizes on the **spatial dimension** & refers to the wide variety of omnipresent technical and human sensors and networks with ability to probe geographic phenomena even in real time.

Crowdsensing or **crowdsourcing** focus on **leveraging the power of the crowd** in science to collectively share data and extract information to measure, map, analyze, estimate or predict any process.

Internet of Everything

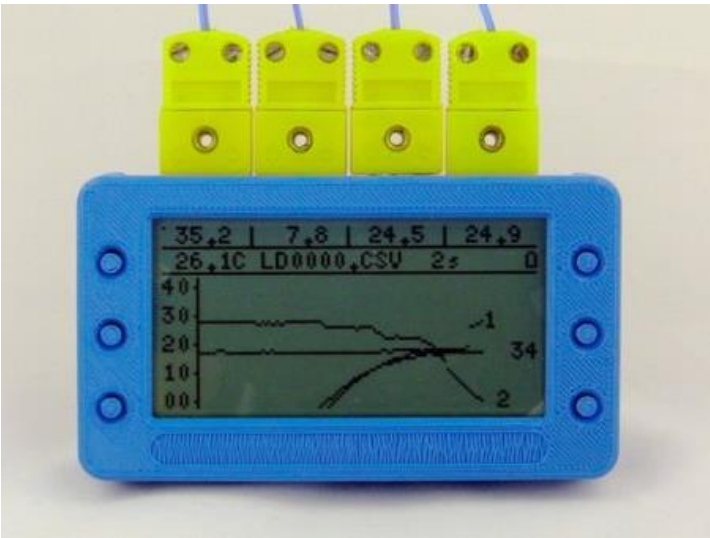
Internet of Everything (IoE) as **the networked connection of people, process, data, and things**. The benefit of IoE is derived from the compound impact of connecting people, process, data, and things, and the value this increased connectedness creates as “everything” comes online.

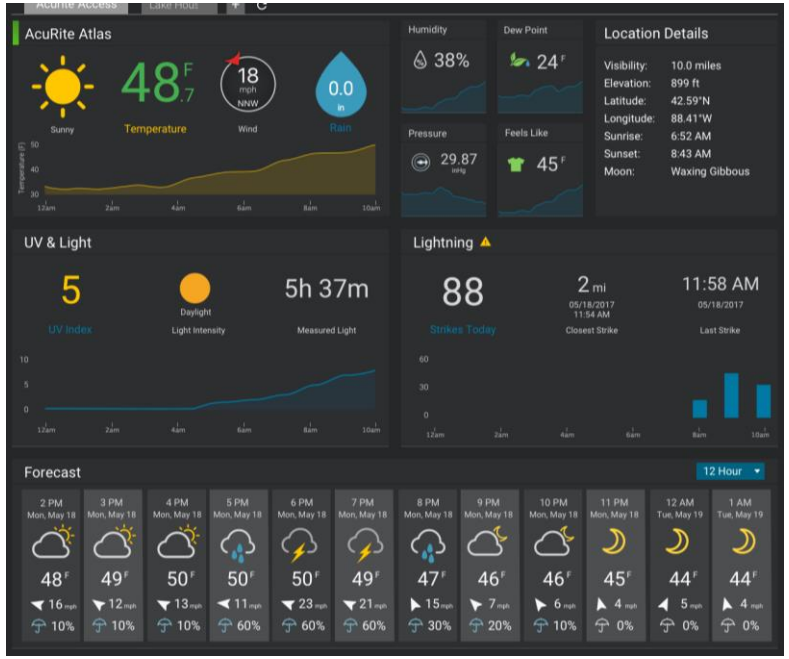


The paradigm shift

I. Technology

- Advancement in smart sensor solutions
  - Internet connectivity, Size, Power, Durability, Price
- Advancement in computation (edge computing, …)





The paradigm shift

II. Processes

- Ability to manage and maintain data infrastructure:
  - Data storage, exchange and platforms
  - Digital communication and visualization platform
- Creating data culture and data governance rules (re data quality, safety and security)

The paradigm shift

III. People

- Widespread use of personal sensors: citizen weather stations, smart home sensors, wearables
- Citizen awareness and Citizen Science initiative
- More capacity in workforce in analyzing data

Heat exposure in urban environments

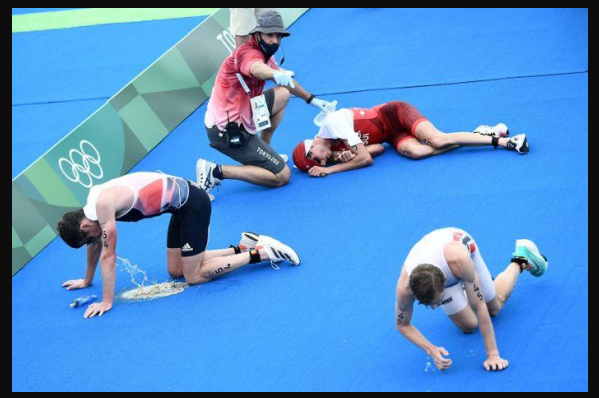
Crowdsourced, ubiquitous, and personalized sensing

How are individuals and communities exposed to heat in cities?

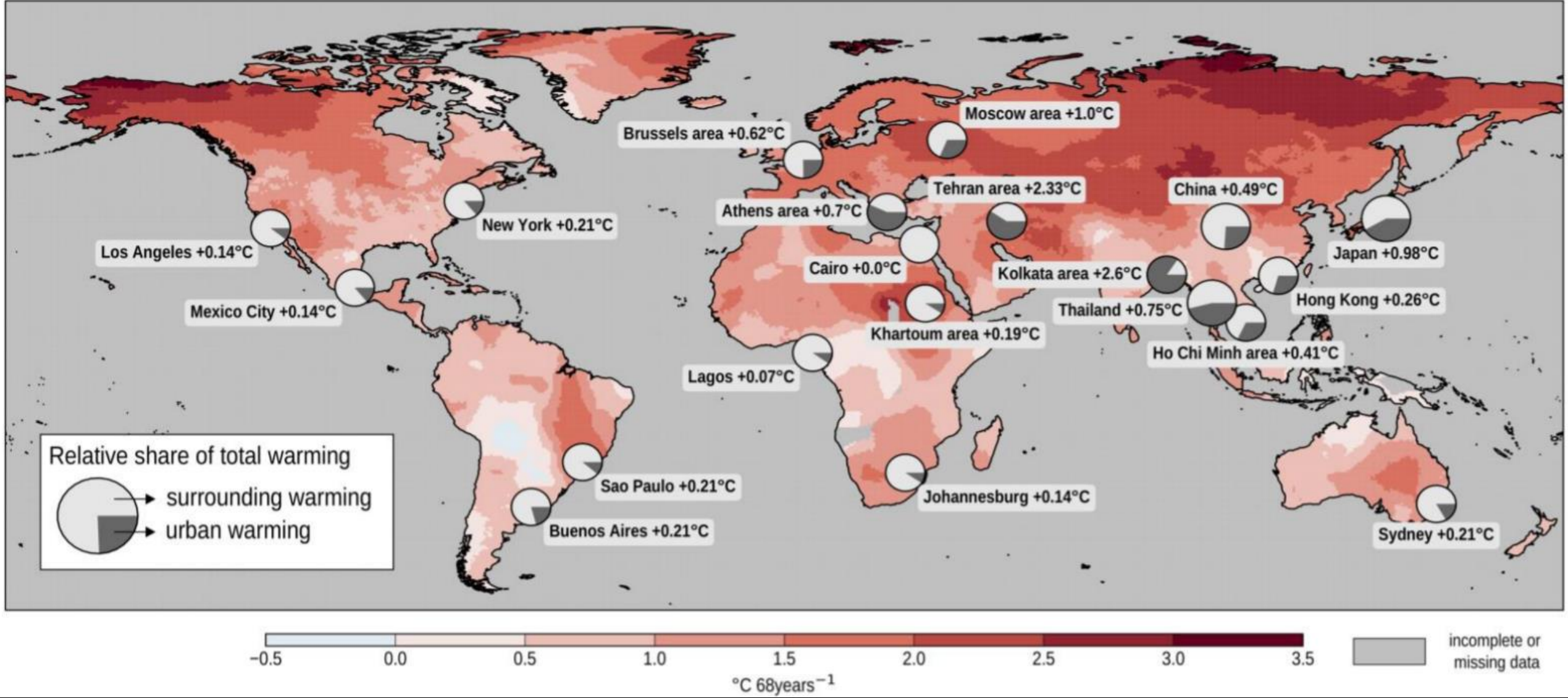
What constitute heat exposure?

Heat exposure is defined as the *immediate thermal environment (affected by air temperature, humidity, wind speed and mean radiant temperature)* that results in any of the following:

- change in thermal sensation and pleasure (**thermal discomfort**), or
- increase in core temperature, heart rate, or sweating (**physiological strain**),
- change in various aspects of life quality and lifestyle (including change in physical activity, food intake, sleep quality and mental health).



2021 Olympics, Loic Venance, AFP

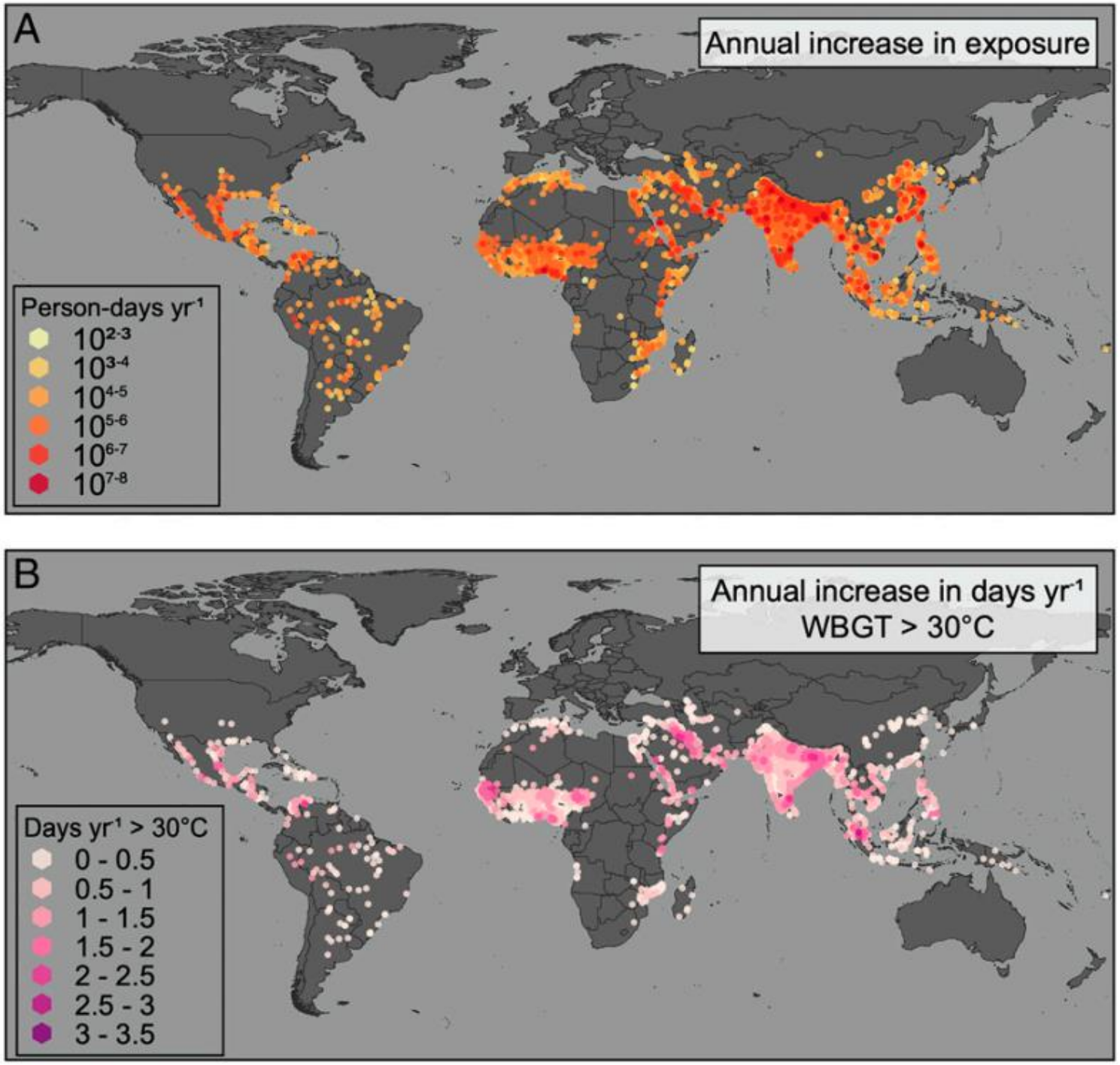


(IPCC AR6, 2021)

Heat exposure in cities is driven by urbanization and exacerbated by global warming

Analyzing where urban population growth and extreme heat intersect

Global heat exposure increased nearly 200% from 1983 to 2016.



(A) Municipality-level increase in the rate of urban population exposure to extreme heat from 1983 to 2016 and (B) the rate of increase in the total number of days per year when WBGTmax > 30 °C (*Tuholske et al. 2021. Proceedings of the National Academy of Sciences*).

Sensing, monitoring, and quantifying *exposure* to urban heat is key direction in urban climate research

Shortcomings in Urban Climate Sensor Networks

Reference meteorological station data (that are at times far from where people reside and occupy) are often used to estimate heat exposure in cities.

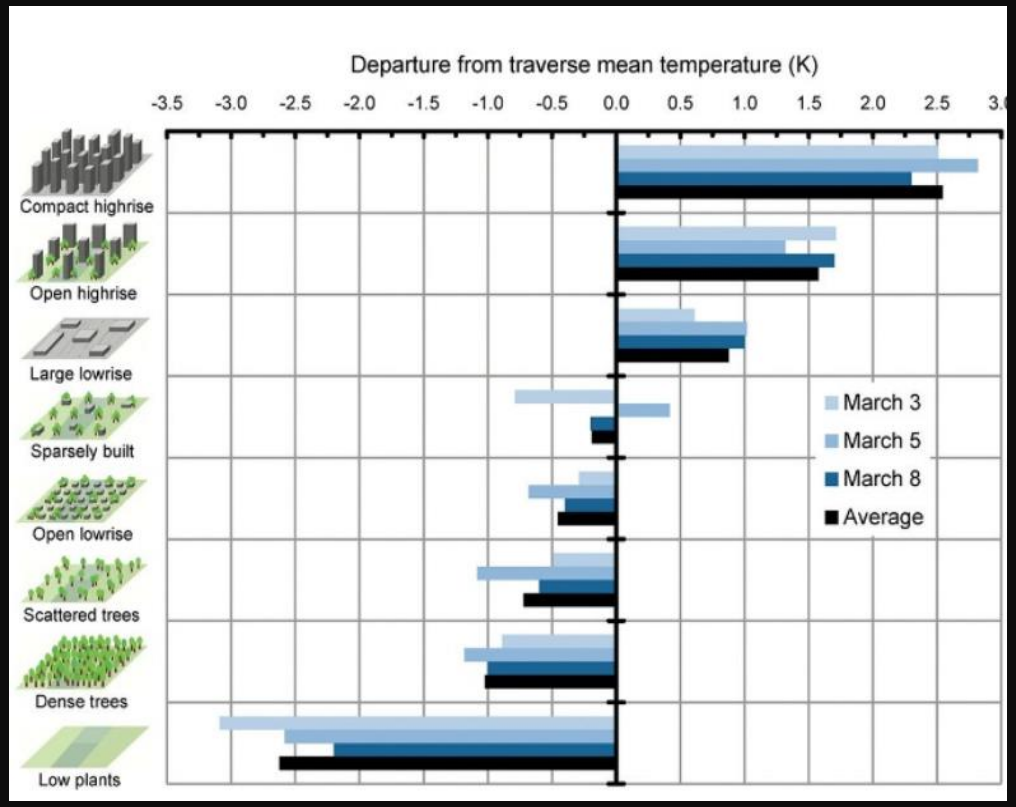
The spatial and temporal variabilities are not fully incorporated in urban heat and air quality research.

Shortcomings in Urban Climate Sensor Networks

Reference meteorological station data (that are at times far from where people reside and occupy) are often used to estimate heat exposure in cities.

The spatial and temporal variabilities are not fully incorporated in urban heat and air quality research.

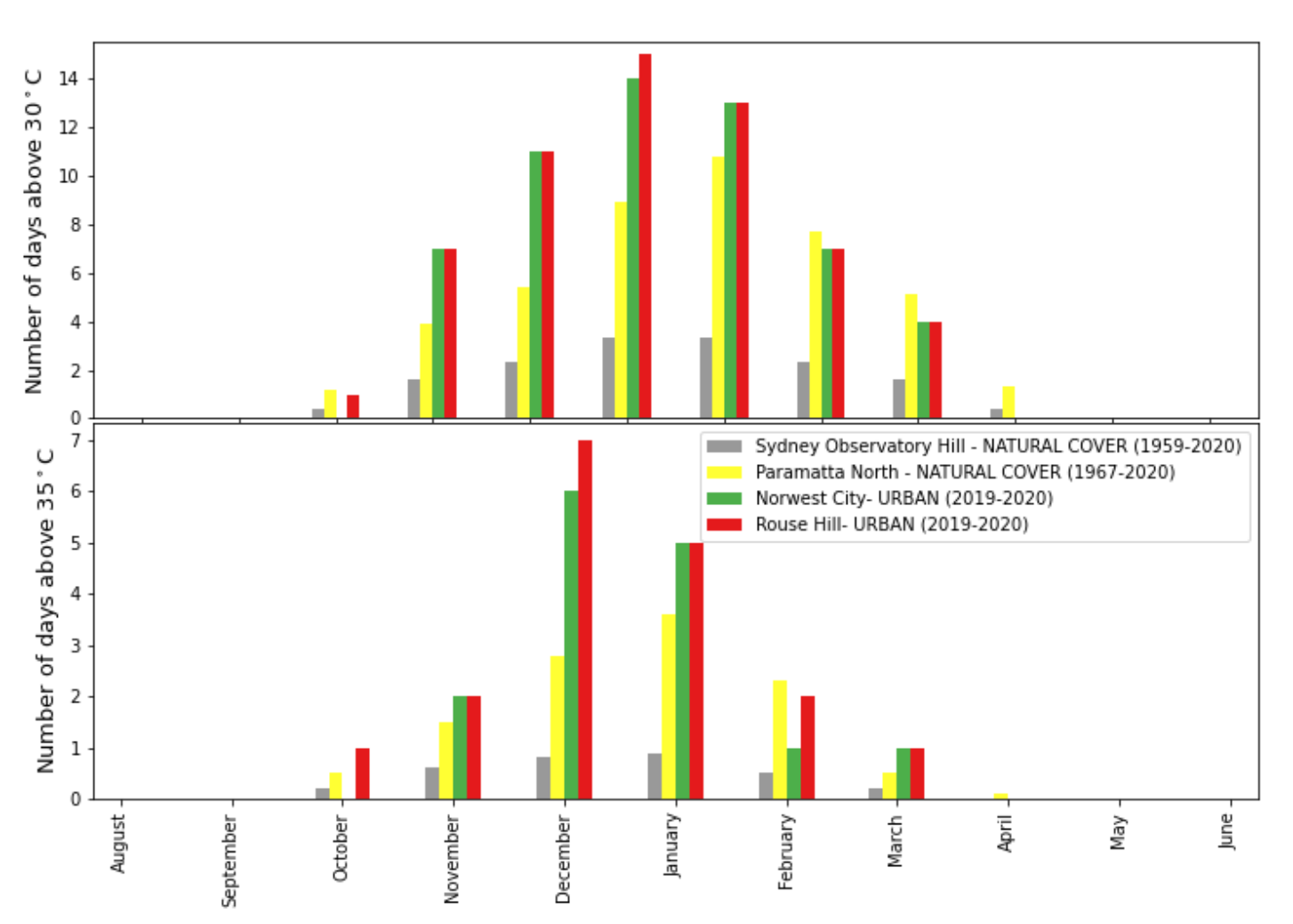
Traditional approaches to heat and air quality exposure often neglect the vast microclimate variability people experience and more importantly, indoor environmental conditions that greatly differ from outdoor environments.

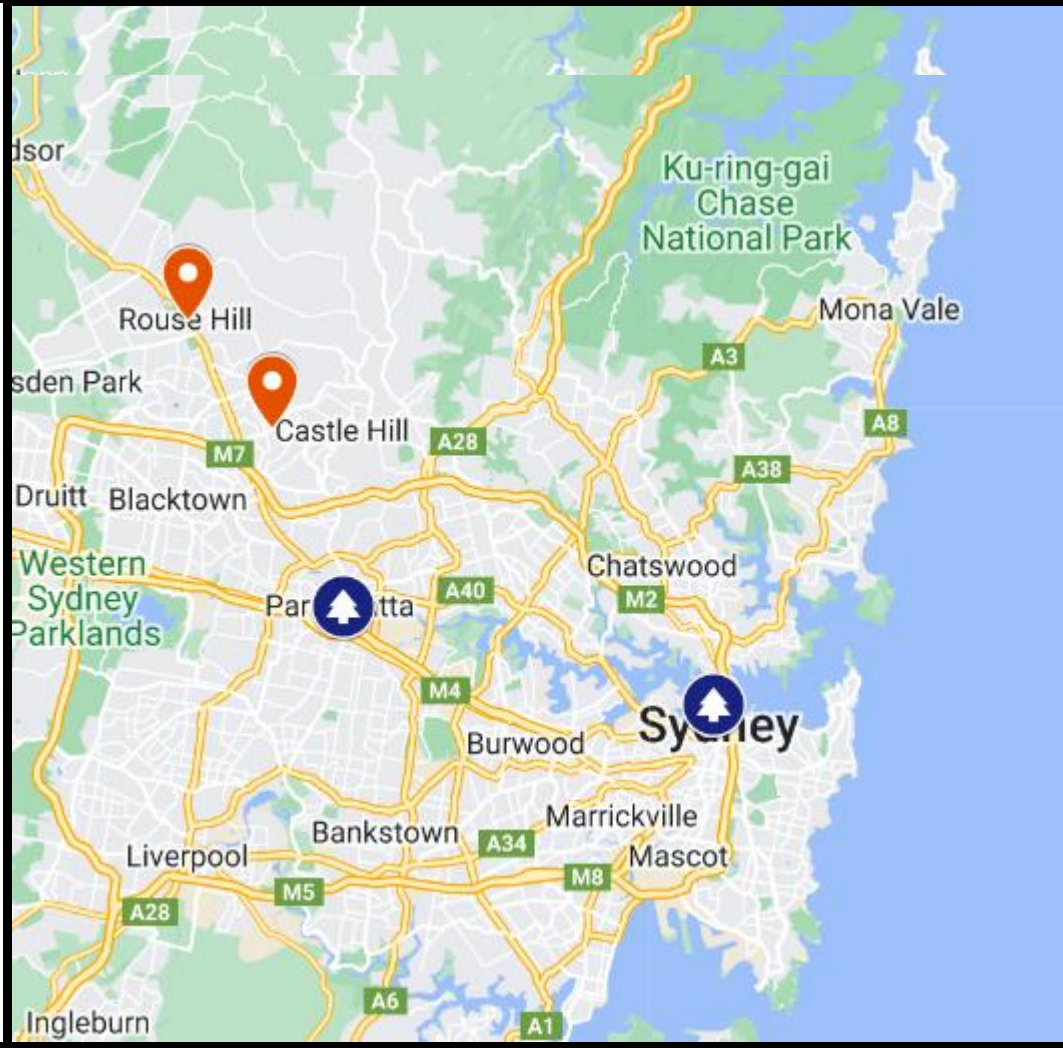


Taken from Stewart & Oke. 2012. Thermal differentiation of local climate zones using temperatures from automobile traverses in Vancouver during calm, clear evenings, Mar 2010. Raw temperature data provided by Andreas Christen (University of British Columbia).

Reference meteorological station data (that are often far from where people reside and occupy) cannot capture spatial and temporal variabilities in urban heat exposure

Urban heat is modified by form, fabric, and function as well as local geography



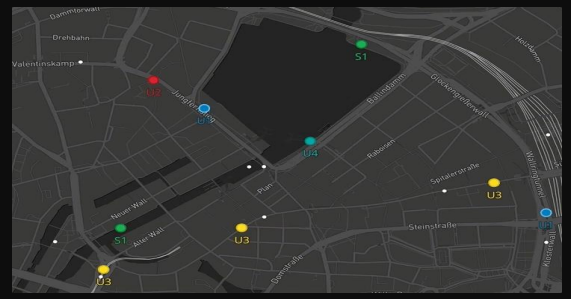


Shortcomings in Urban Climate Sensor Networks

“Human factors” are traditionally either neglected or studied in controlled conditions that do not cover realistic urban conditions.

These factors include

- physiological responses (such as variability in metabolic rate and physiological strain),
- behavioral patterns (including mobility and travel patterns),
- psychological determinants (including motivation, autonomy, or competence), and
- climatic and cultural background (including acclimatization, previous exposure, and habits)



How hot is too hot?

A comparison between the modified PET "Neutral" and UTCI "no thermal stress" ranges.

Town, Country	Climatic Zone	Neutral/No thermal stress range (°C)	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Athens, Greece	Csa	17.4-24.5																									
Crete, Greece	Csa	20.0-25.0																									
Wuhan, China	Cfa	15.2-28.8																									
Shanghai, China	Cfa	15.0-29.0																									
Tianjin, China	Dwa	12.0- 25.0																									
Tianjin, China	Dwa/BSk	11.0- 24.0																									
Germany	Cfb	9.0 - 26.0																									
Middle/western Europe	Cfb	18.0-23.0																									
Umea, Sweden (summer)	Dfc	12.0 - 17.0																									
Umea, Sweden (summer)	Dfc	10.0-17.0																									

Modified PET "Neutral" sensation

Modified PET "Neutral" sensation for Germany

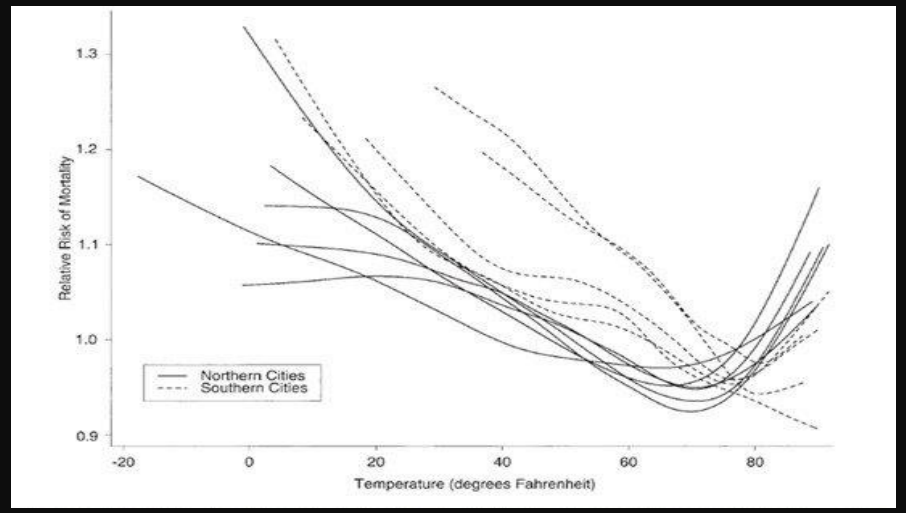
Modified UTCI "no thermal stress" sensation

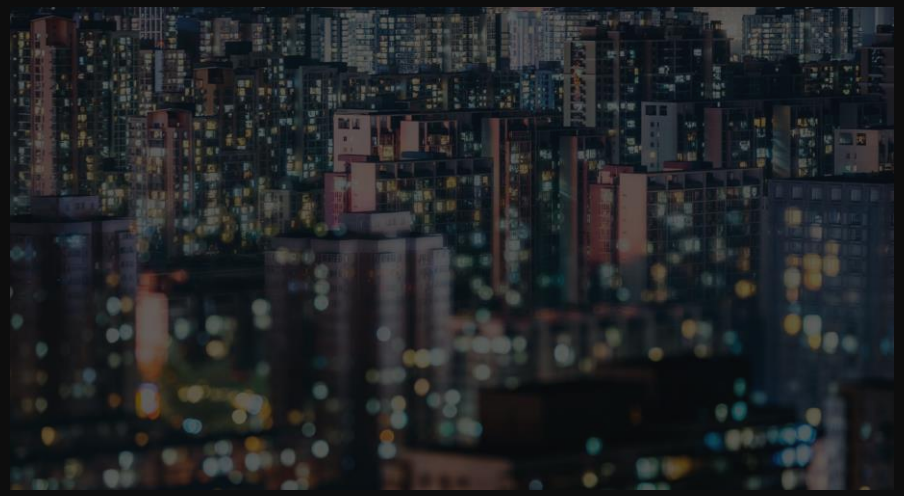
Modified PET "no thermal stress" sensation for Germany

Shortcomings in Urban Climate Sensor Networks

Extensive focus on “after-the-fact” phenomena such as mortality and morbidity.

Little is known about the real-time thermal conditions people experience as they go about their daily lives.





Curriero et al. 2002. Temperature-mortality relative risk functions for 11 US cities, 1973–1994.

Each case of heat impact, illness, or death is highly individualized and context-specific, based on a person's activities and “pathway” to heat exposure

Nazarian et al 2022. Earth’s Future

From Urban Heat Island Intensity to Urban overheating

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

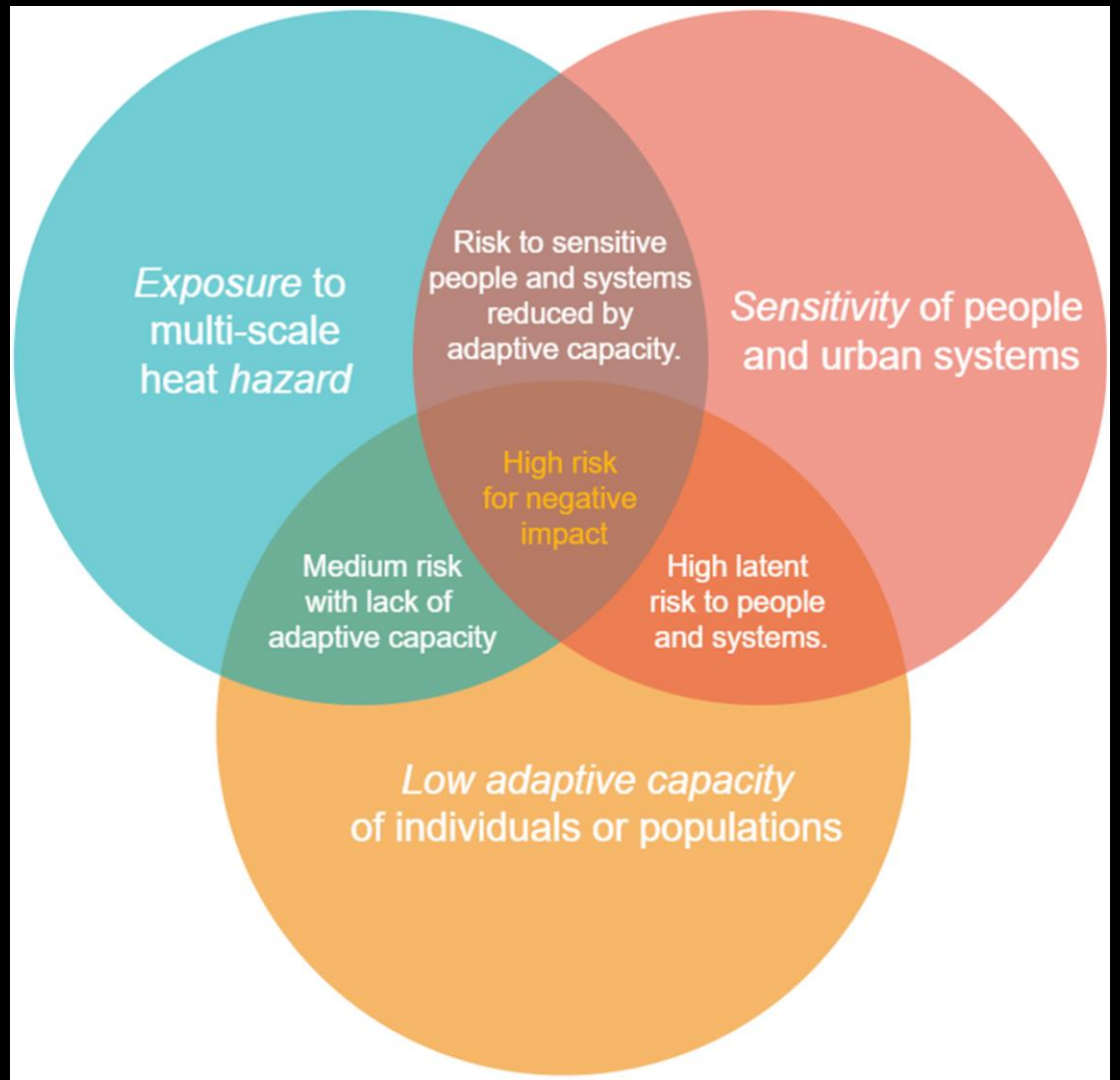
These factors in turn depend on socio-political and economic indicators.

Thermal thresholds are defined uniquely at different scales and considering different impact mechanisms.

Nazarian et al 2022. Earth's Future

What determines the risks of heat exposure?

What determines the risks of heat exposure?



Nazarian et al 2022. Integrated Assessment of Urban Overheating Impacts on Human Life

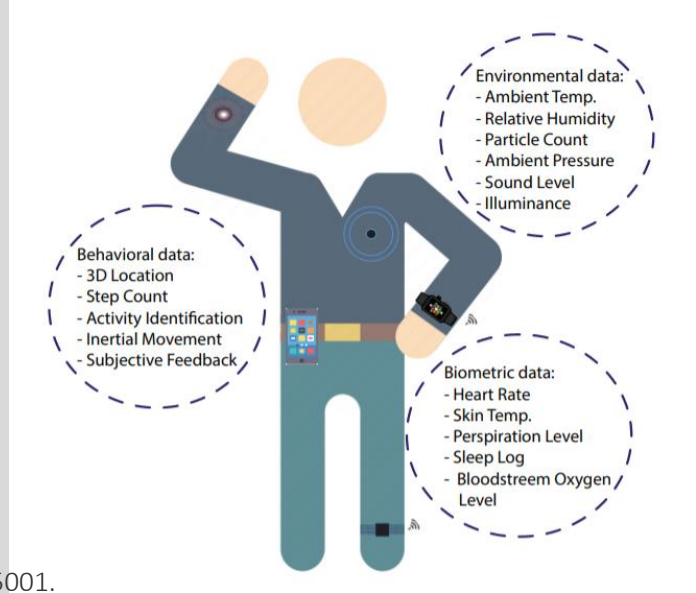
©Estimote

How can personalized monitoring or crowdsourcing assist in addressing heat exposure in the built environment?

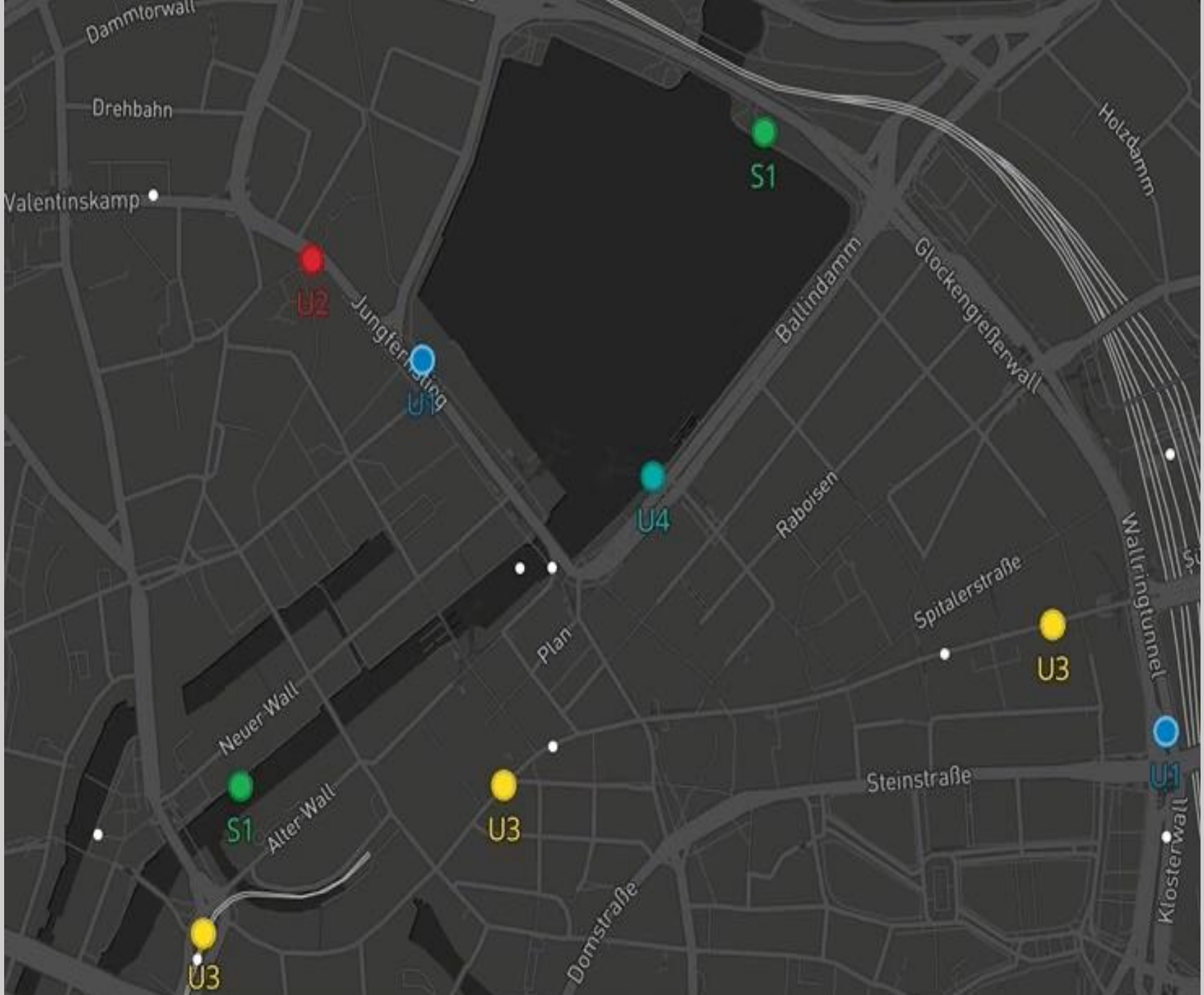
Personalized Assessment of Urban Heat Exposure

Personal heat exposure assessments are defined as evaluation of heat exposure either

- *in the **immediate environment of individuals** and where people mostly reside in cities (extrinsic) or*
- *with the **inclusion of physiological and/or behavioral and subjective factors** (intrinsic) together with the environmental parameters.*



Kuras, Evan R., et al. "*Opportunities and challenges for personal heat exposure research*." Environmental health perspectives. 125.8 (2017): 085001.
Nazarian N, Lee JK. "*Personal assessment of urban heat exposure: a systematic review*". Environmental Research Letters. (2021): 16 033005



OBJECTIVES

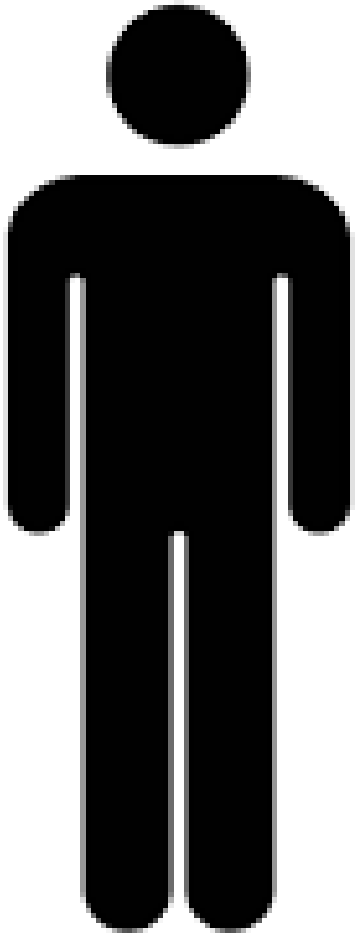
1

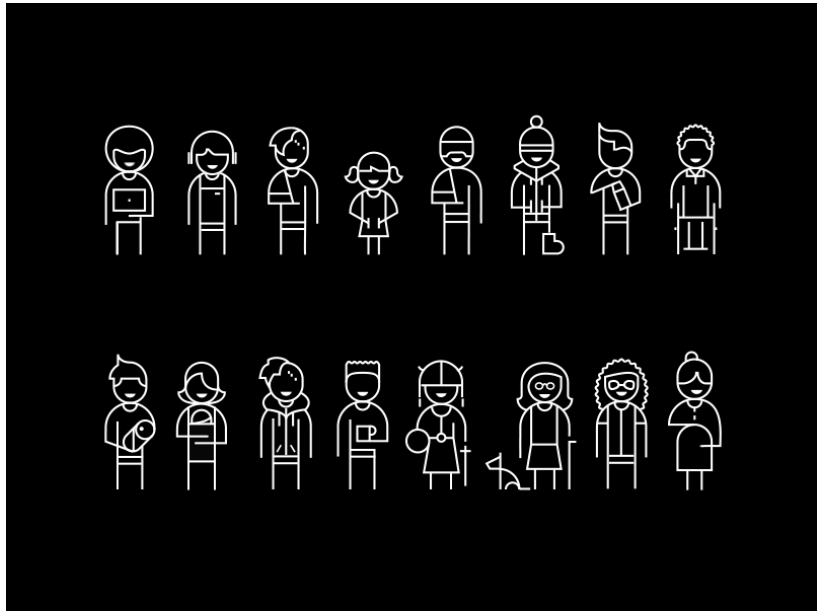
Span a larger range of **temporal and spatial distribution** of heat exposure in cities

2

Obtain **real-time, unsupervised, or non-intrusive** data on thermal environment and heat stress in cities

OBJECTIVES

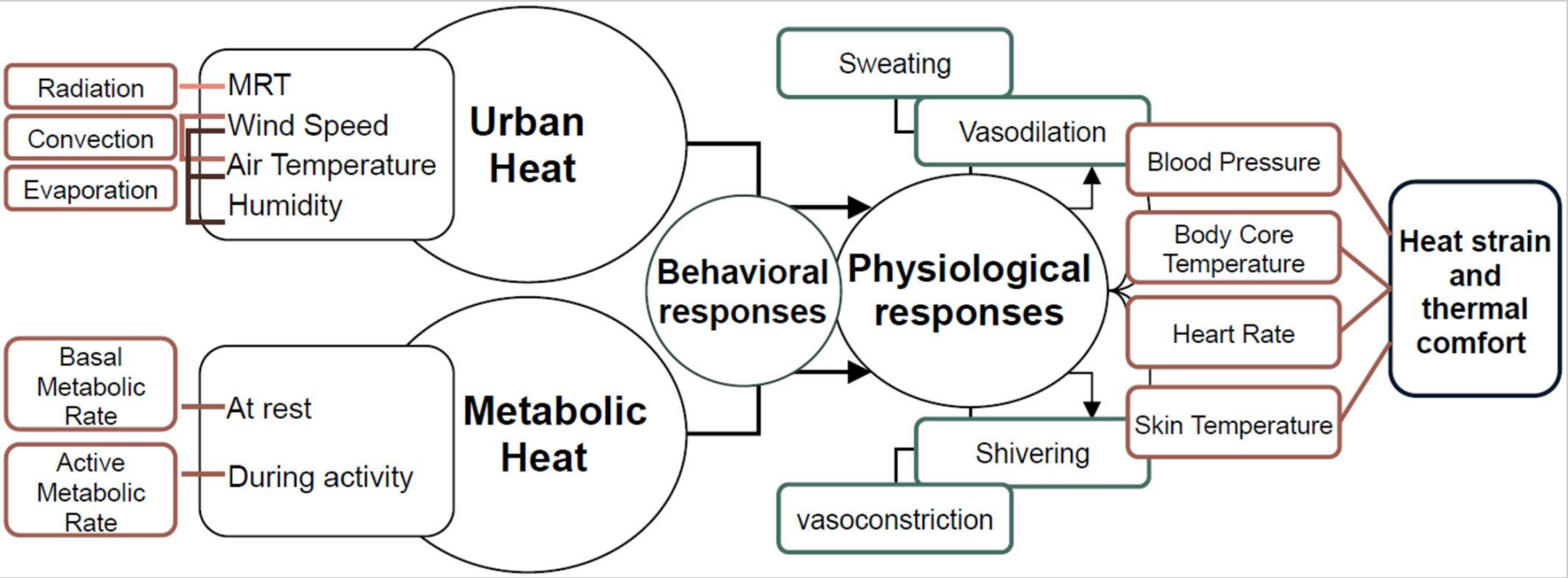




3 **Personalized** versus One-size-fits-all

- Assess the **individual impact** of urban heat, including physiological and behavioral responses
- Achieve **Human-centric** approach

OBJECTIVES



3

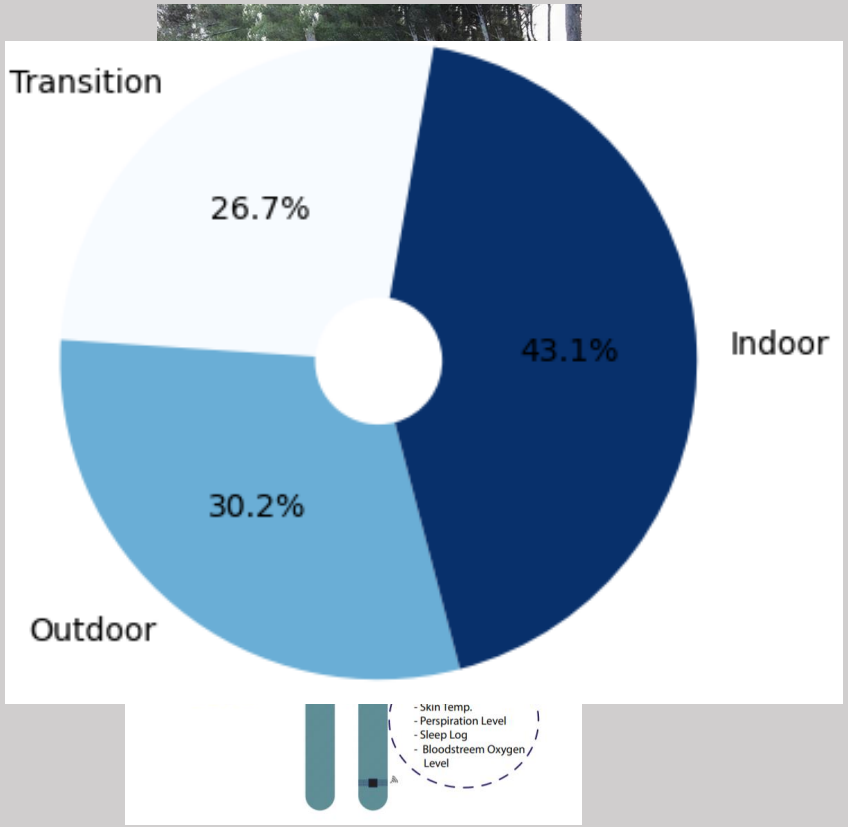
Personalized versus One-size-fits-all

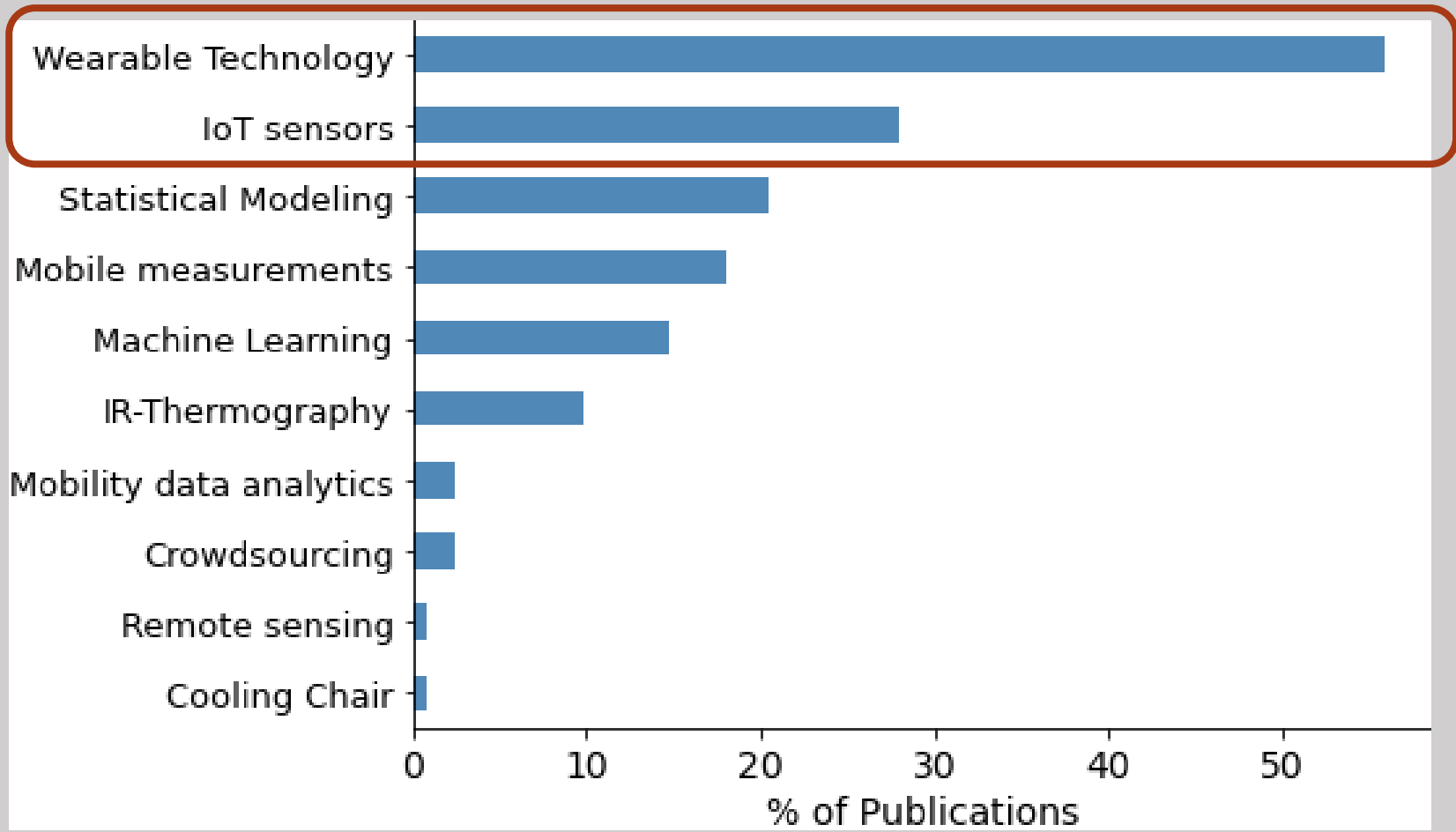
- Assess the **individual impact** of urban heat, including physiological and behavioral responses
- Achieve **Human-centric** approach

Nazarian et al, 2022. “Integrated assessment of urban overheating impacts on human life”, Earth’s Future. https://doi.org/10.1029/2022EF002682

Personalized Assessment of Urban Heat Exposure

METHODS



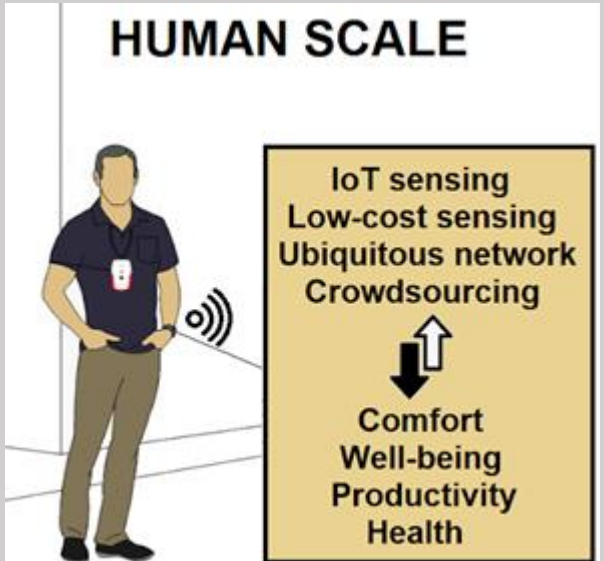


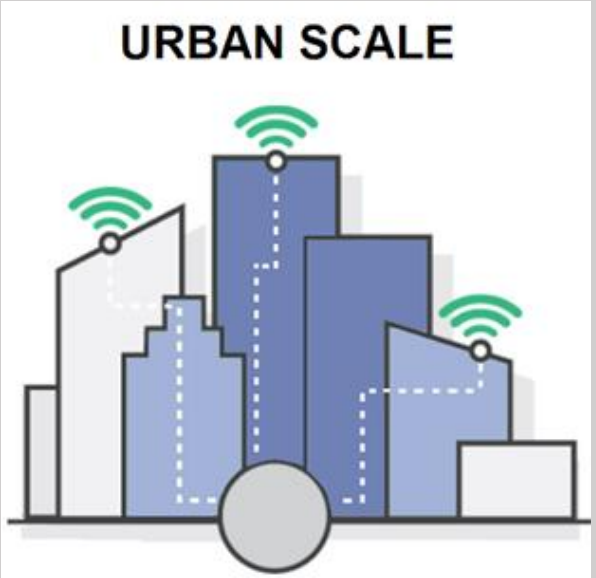
Nazarian N, Lee JK. “Personal assessment of urban heat exposure: a systematic review”. Environmental Research Letters. (2021): 16 033005

Urban heat monitoring across scales and applications

SCALES

- Better characterization of urban areas and human exposure
- Informing observation and modelling
- Citizen Engagement





On the use of wearables for assessing urban heat exposure

EXAMPLES
WEARABLES

PLOS | MEDICINE

ESSAY

The Rise of Consumer Health Wearables: Promises and Barriers

Lukasz Piwek[1]*, David A. Ellis[2], Sally Andrews[3], Adam Joinson[1]

1 School of Management, University of Bath, Bath, United Kingdom, **2** Department of Psychology, Lancas University, Lancaster, United Kingdom, **3** Division of Psychology, Nottingham Trent University, Nottinghar United Kingdom

* lpiwek@gmail.com

Summary Points

- Consumer wearables can provide patients with personalized health data, which could assist with self-diagnosis and behaviour change interventions.
- There are a number of concerns about the safety, reliability, and security of using consumer wearables in health care.
- Practitioners and researchers should consider how these technological advances may impact health care in the 21st century.

CrossMark
click for updates

OPEN ACCESS

Citation: Piwek L, Ellis DA, Andrews S, Joinson A

NRC Research Press

REVIEW

On the use of wearable physiological monitors to assess heat strain during occupational heat stress

Sean R. Notley, Andreas D. Flouris, and Glen P. Kenny

Abstract: Workers in many industries are required to perform arduous work in high heat-stress conditions, which can lead to rapid increases in body temperature that elevate the risk of heat-related illness and even death. Traditionally, effort to mitigate work-related heat injury has been directed toward the assessment of environmental heat stress (e.g., wet-bulb globe tempera ture), rather than toward the associated physiological strain responses (e.g., heart rate and skin and core temperatures) However, because a worker's physiological response to a given heat stress is modified independently by inter-individual factors (e.g., age, sex, chronic disease, others) and intra-individual factors both within (e.g., medication use, fitness, acclimation and hydration state, others) and beyond (e.g., shift duration, illness, others) the worker's control, it becomes challenging to protect workers on an individual basis from heat-related injury without assessing those physiological responses. Recent advancements in wearable technology have made it possible to monitor one or more physiological indices of heat strain. Nonetheless information on the utility of the wearable systems available for assessing occupational heat strain is unavailable. This commu nication is therefore directed toward identifying the physiological indices of heat strain that may be quantified in the workplace and evaluating the wearable monitoring systems available for assessing those responses. Finally, emphasis is placed on the barriers associated with implementing these devices to assist in mitigating work-related heat injury. This information is fundamental for protecting worker health and could also be utilized to prevent heat illnesses in vulnerable people during leisure or athletic activities.

Key words: wearable technology, heat strain, work performance, monitoring, body core temperature.

[1] Notley SR, Flouris AD and Kenny GP (2018) On the use of wearable physiological monitors to assess heat strain during occupational heat stress. *Applied physiology, nutrition, and metabolism = Physiologie appliquee, nutrition et metabolisme* 43(9). NRC Research Press: 869–881.
[2] Piwek L, Ellis DA, Andrews S, et al. (2016) The Rise of Consumer Health Wearables: Promises and Barriers. *PLoS medicine* 13(2). journals.plos.org: e1001953.
[3] Li Q, Zhang L-N, Tao X-M, et al. (2017) Review of Flexible Temperature Sensing Networks for Wearable Physiological Monitoring. *Advanced healthcare materials* 6(12). DOI: 10.1002/adhm.201601371.

On the use of wearables for assessing urban heat exposure

EXAMPLES
WEARABLES

Int J Biometeorol (2015) 59:503–515
DOI 10.1007/s00484-014-0864-y

ORIGINAL PAPER

Outdoor thermal physiology along human pathways: a study using a wearable measurement system

Makoto Nakayoshi · Manabu Kanda · Rui Shi · Richard de Dear

Received: 6 January 2014 / Revised: 26 May 2014 / Accepted: 4 June 2014 / Published online: 11 July 2014
© ISB 2014

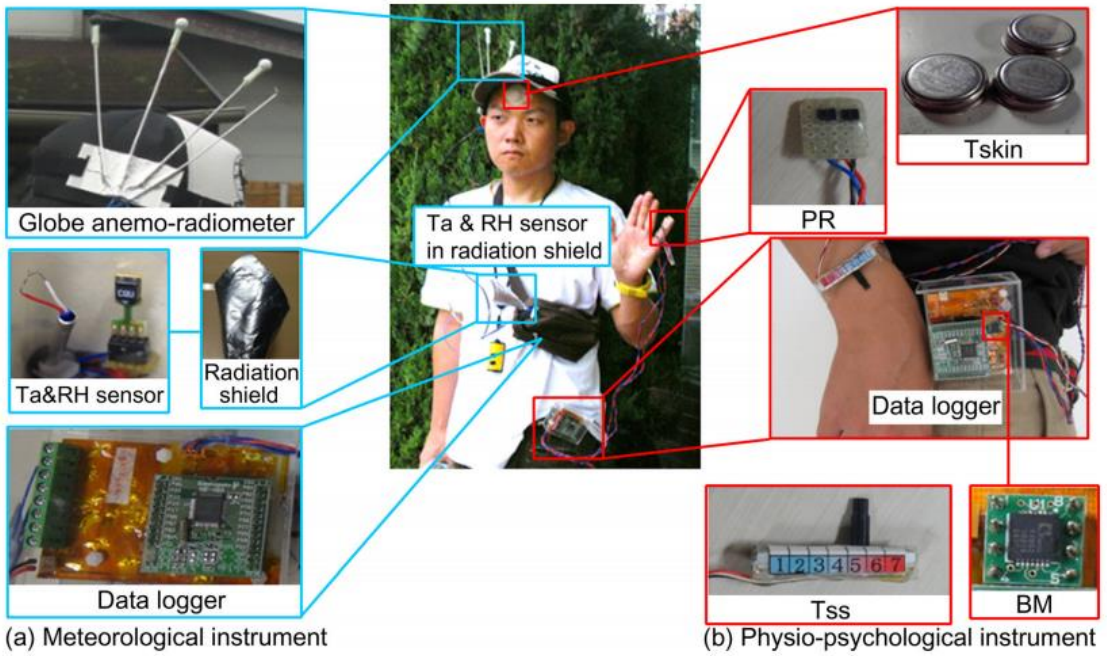


Fig. 1 Wearable measurement system

On the use of wearables for assessing urban heat exposure

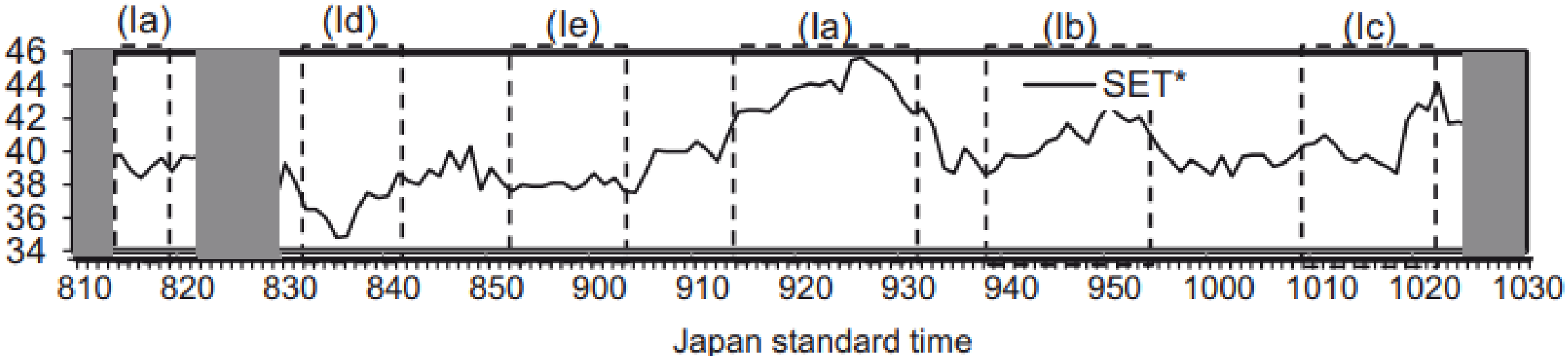
EXAMPLES
WEARABLES

Int J Biometeorol (2015) 59:503–515
DOI 10.1007/s00484-014-0864-y

ORIGINAL PAPER

Outdoor thermal physiology along human pathways: a study using a wearable measurement system

Makoto Nakayoshi · Manabu Kanda · Rui Shi · Richard de Dear



On the use of wearables for assessing urban heat exposure

EXAMPLES
WEARABLES

Environmental Research Letters

LETTER • OPEN ACCESS

Project Coolbit: Can your Watch Predict Heat Stress and Thermal Comfort Sensation?

To cite this article: Nazarian et al. 2020, *Environ. Res. Lett. 16 109222*

View the article online for updates and enhancements.

3

Behavioral characteristics:
Momentary assessment of comfort sensation, activity, and location

1

Environmental Factors
(T_a, RHa, …)

2

Physiological response
(T_{sk}, RH_{sk}, Heart rate, resting met rate)

#ProjectCoolbit

Nazarian et al. 2020b (ERL)
Jayathissa et al. 2019

METHODOLOGY

Controlled Environment

Assessment of the Physiological Data Collection

Semi-Controlled Environment

Assessment of Outdoor Environmental Data Collection

Non-Controlled Environment

Assessment of Data Collection during Daily Activities and Creating Analytics Platforms

#ProjectCoolbit

Nazarian et al. 2020b (ERL)
Jayathissa et al. 2019

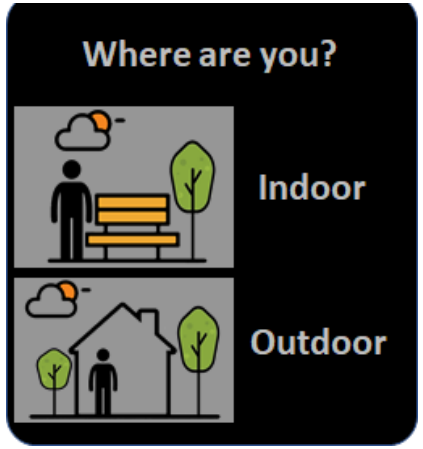
METHODOLOGY

Controlled Environment

Semi-Controlled Environment

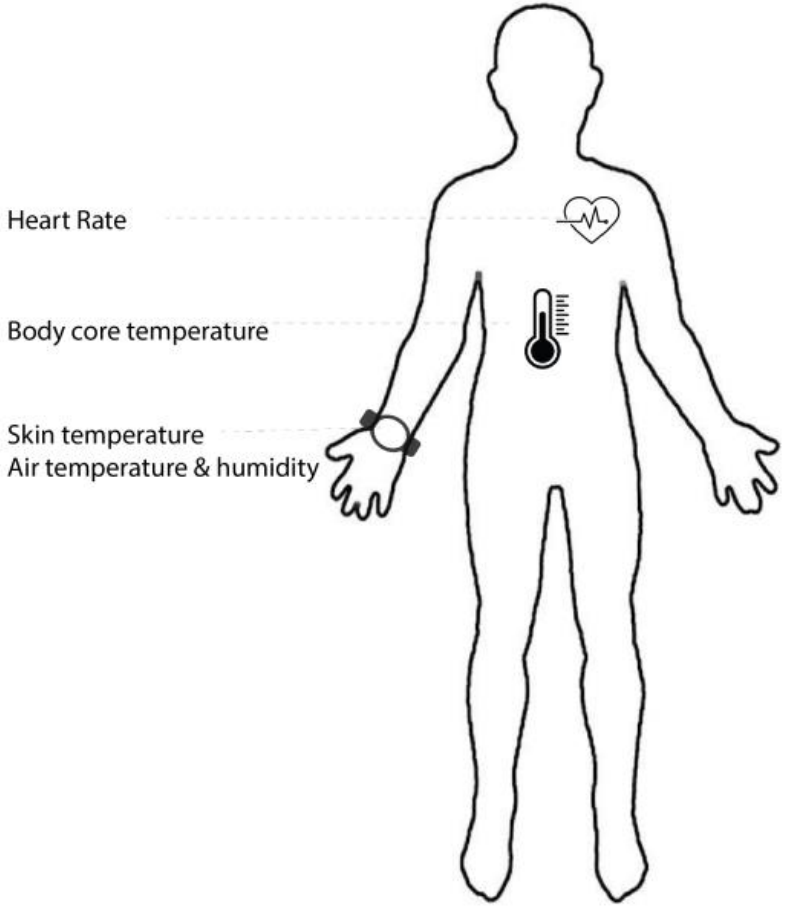
SG: 62 Participants/15 sessions over 6 days
SYD: 27 participants over 3 days
PHNX: 6 participants – 1 day pilot

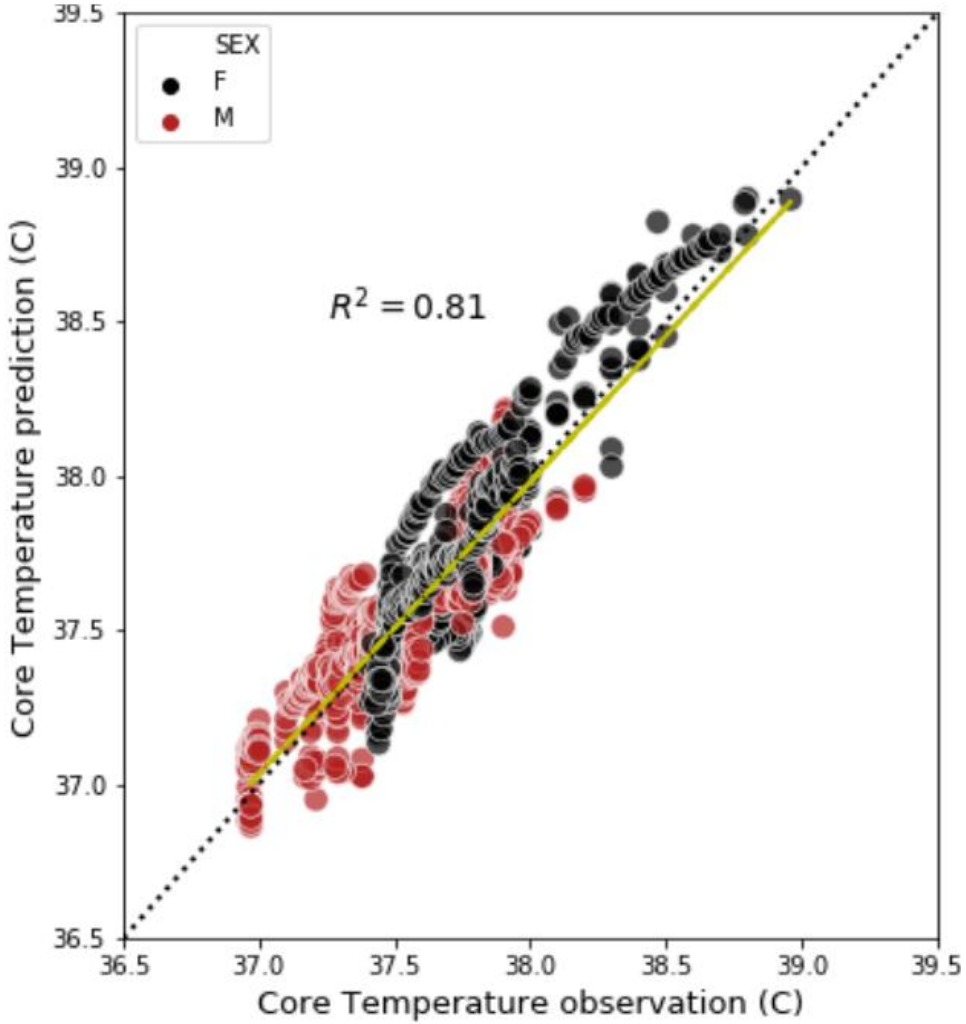
Non-Controlled Environment



On the use of wearables for **predicting heat stress**

EXAMPLES
WEARABLES



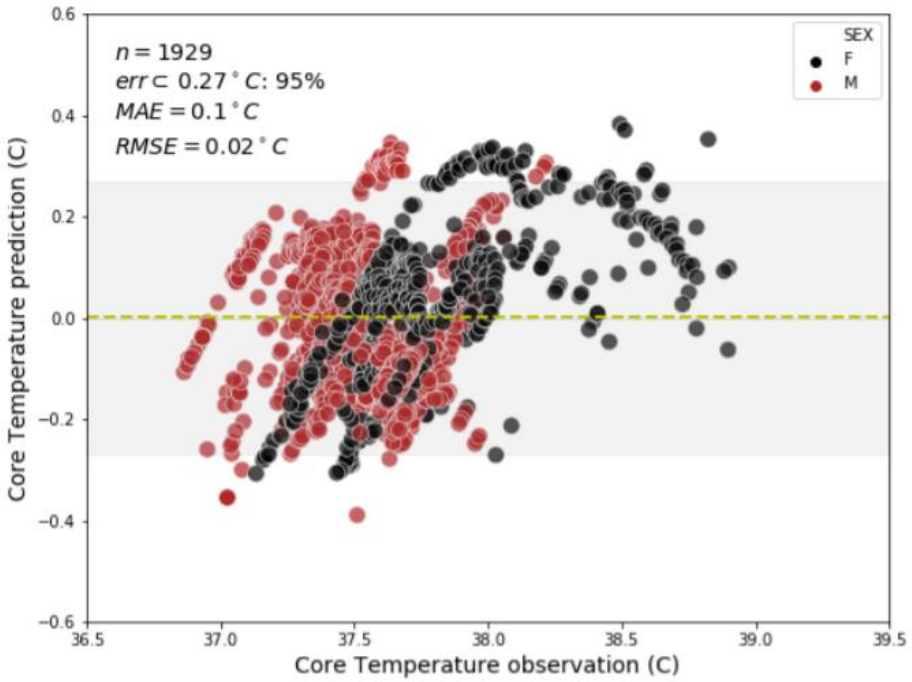


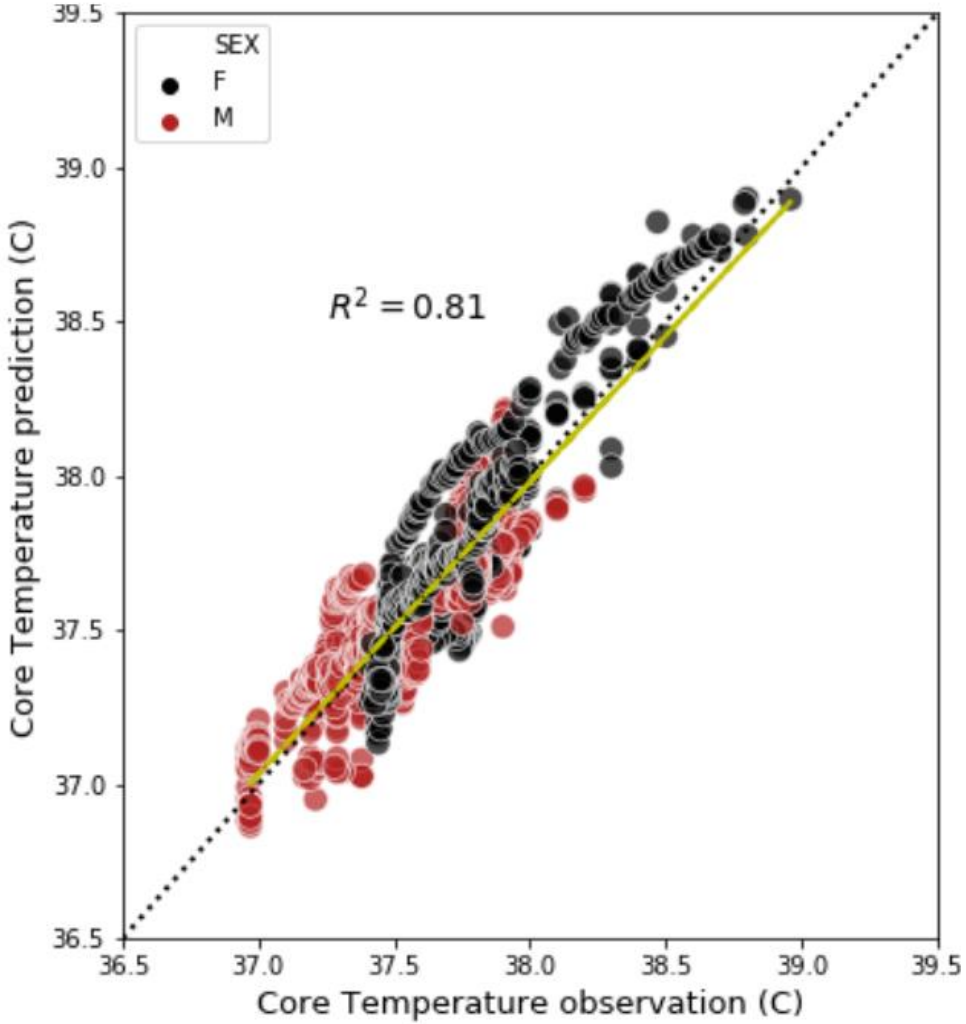
#ProjectCoolbit

Nazarian et al. 2020b (ERL)
Jayathissa et al. 2019

On the use of wearables for **predicting heat stress**

EXAMPLES
WEARABLES





Using **HR, skin temperature, and air temperature at wrist**, 95% of predicted core temperature falls within ±0.3 °C of measured data.

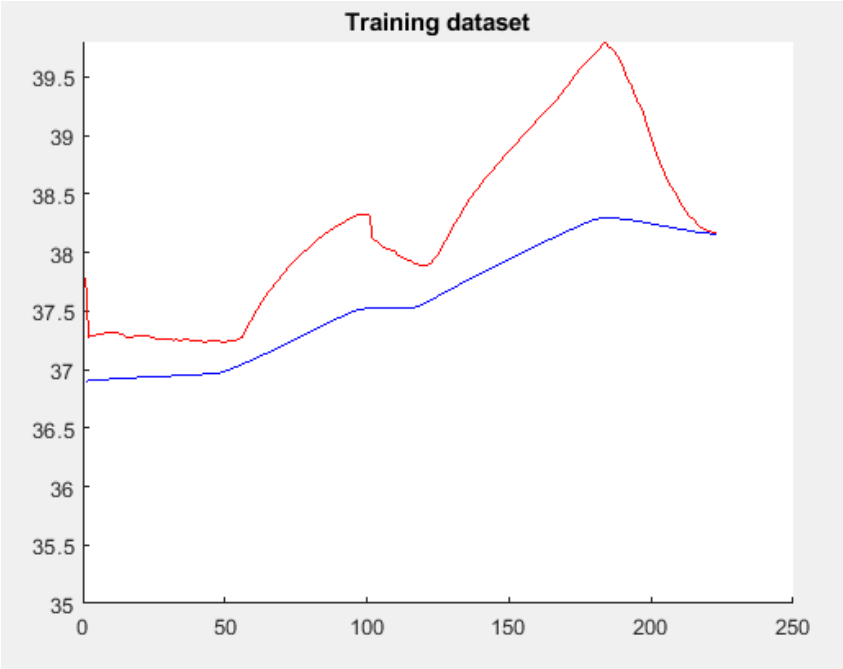
Ongoing: data from additional 35 participants is obrained to test predictions using both Kalman Filter and Recurrent neural network.

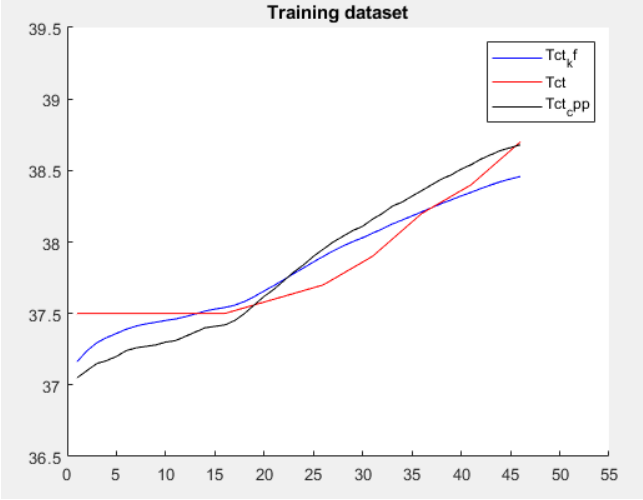
#ProjectCoolbit

Nazarian et al. 2020b (ERL)
Jayathissa et al. 2019

On the use of wearables for **predicting heat stress**

EXAMPLES
WEARABLES





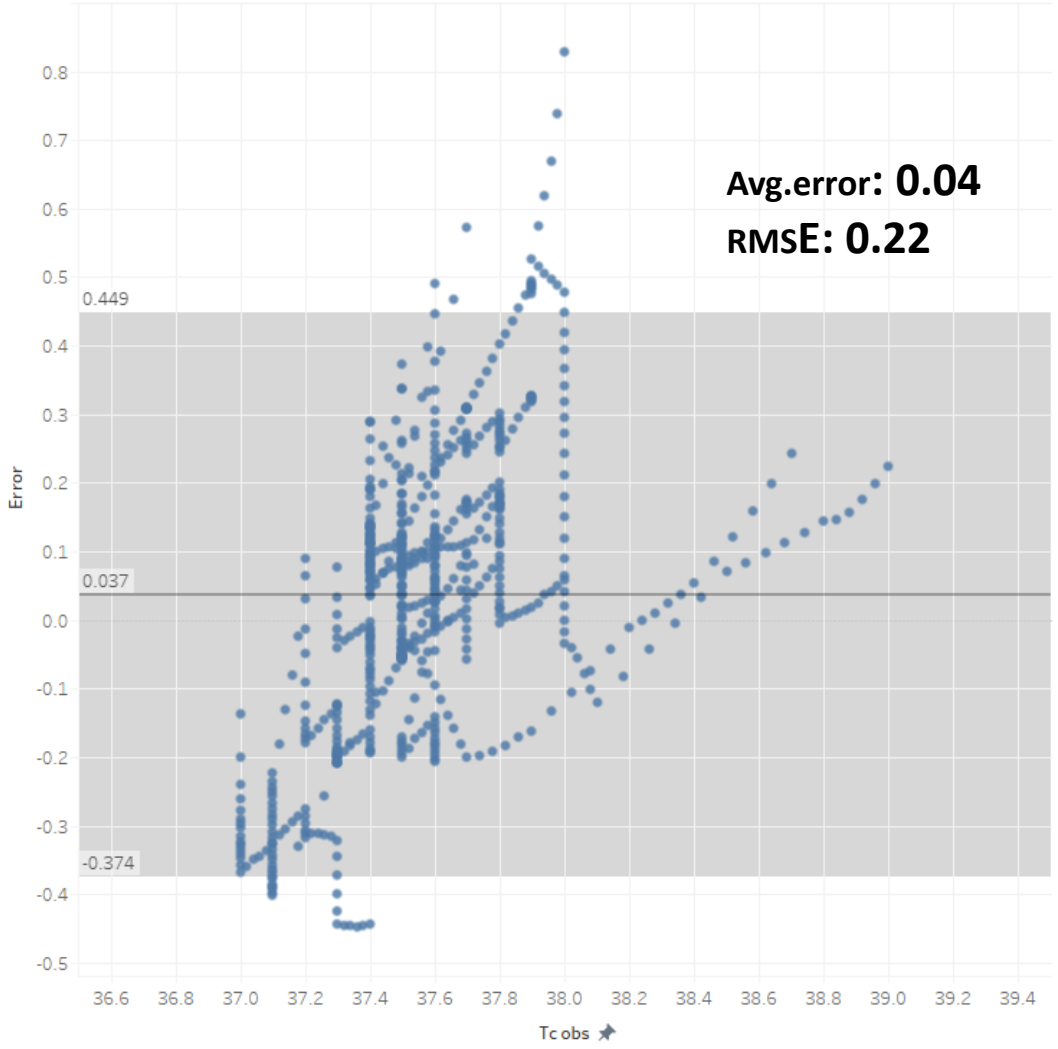
Applying the trained algorithms (Kalman Filter and ANN) to a sample group of **healthy young adults (all male)** performing a set of **intense activities** did not perform as well, particularly for higher core temperatures.

#ProjectCoolbit

Nazarian et al. 2020b (ERL)
Jayathissa et al. 2019

On the use of wearables for **predicting heat stress**

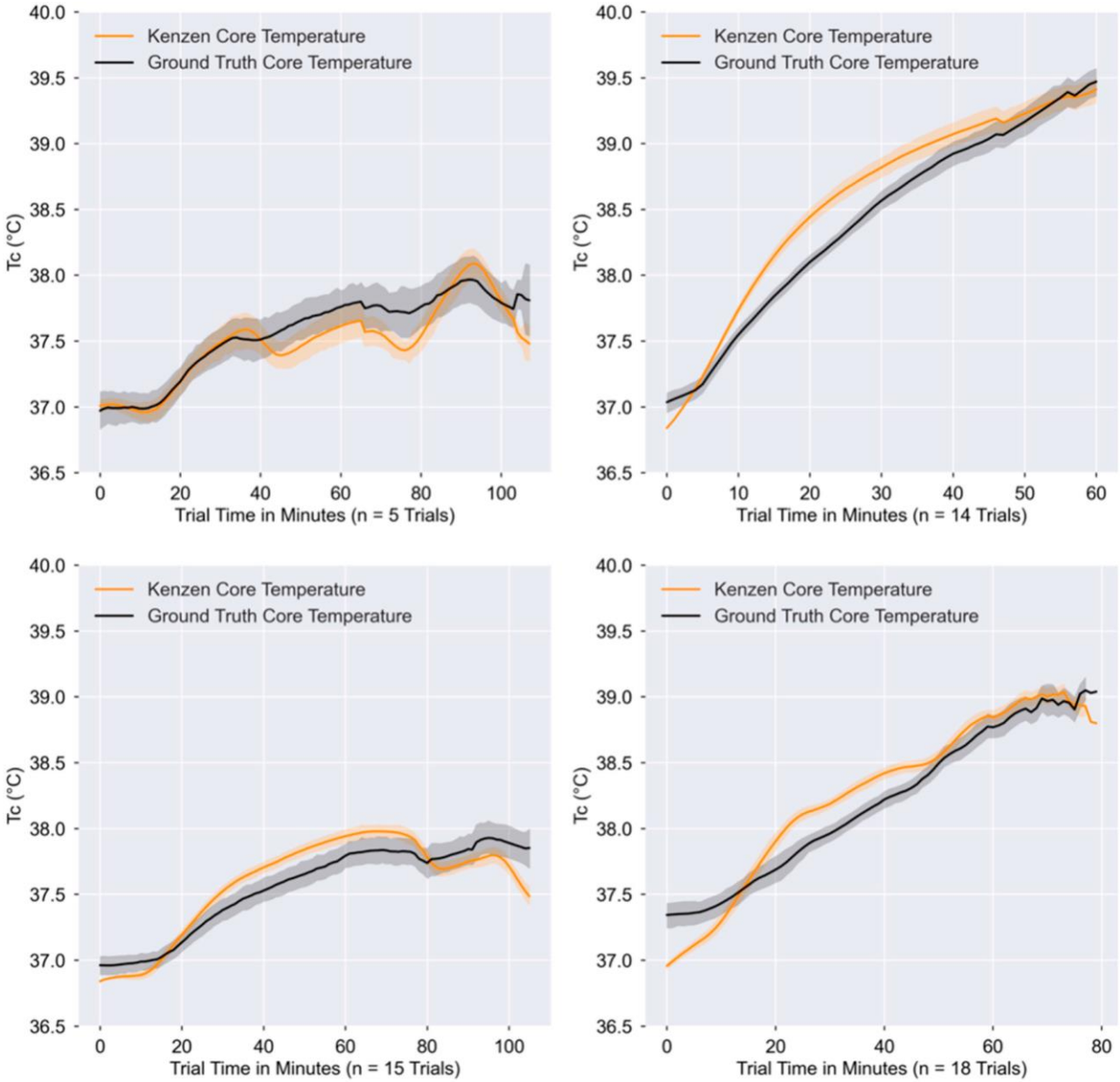
EXAMPLES
WEARABLES



Therefore, to complement the training with physics-based modelling, we are currently assessing how the **trained algorithm** can be **combined with a two-node thermophysiological model** to improve the accuracy of Tc prediction.

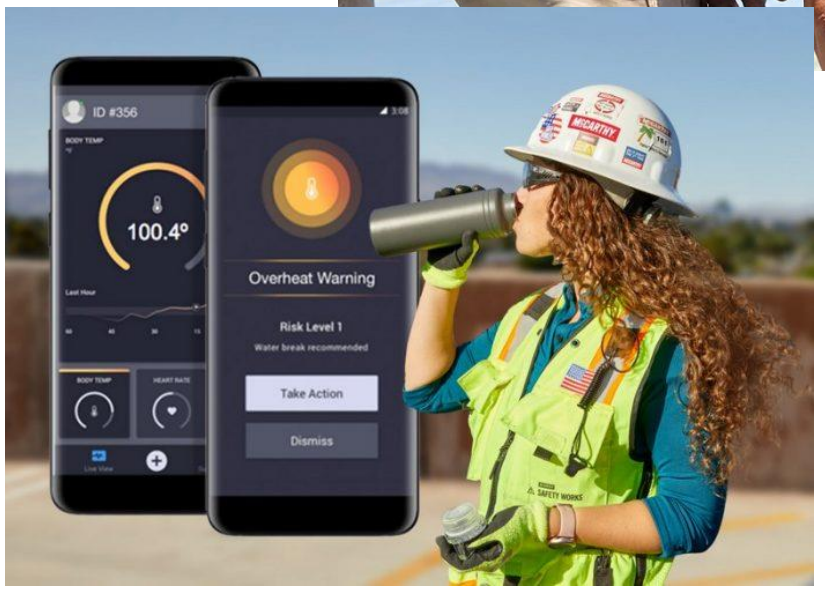
#ProjectCoolbit

Nazarian et al. 2020b (ERL)
Jayathissa et al. 2019



Moyen, N.E., Bapat, R.C., Tan, B., Hunt, L.A., Jay, O. and Mündel, T., 2021. Accuracy of Algorithm to Non-Invasively Predict Core Body Temperature Using the Kenzen Wearable Device. International Journal of Environmental Research and Public Health

Real-time Tc prediction using HR, skin and ambient temperatures, skin and ambient relative humidity, and step rate



A Heart Rate Based Algorithm to Estimate Core Temperature Responses in Elite Athletes Exercising in the Heat

de Korte et al 2022. *Frontiers in Sports and Active Living*

101 elite athletes performed an exercise test in simulated **hot and humid environmental** conditions

To obtain a reliable prediction method for heat strain, **more comprehensive coverage of human activities** are needed. Moreover, Tc alone cannot determine negative impact of heat on humans.

Subgroup	No. of observations	Pearson's r, p-value	RMSE (°C)	Mean bias (°C) (LLoA - ULoA)
Total cohort (n=101)	5025	0.86, p<0.001	0.35±0.18	0.15 (-0.29-0.60)
Sex				
Females (n=52)	2789	0.86, p<0.001	0.35±0.18	0.13 (-0.33-0.59)
Males (n=49)	2256	0.86, p<0.001	0.36±0.19	0.18 (-0.26-0.62)
Sport disciplines				
Endurance (n=27)	1397	0.90, p<0.001	0.33±0.14	0.04 (-0.49-0.56)
Mixed (n=28)	1273	0.85, p<0.001	0.37±0.21	0.23 (-0.21-0.66)
Power (n=11)	556	0.85, p<0.001	0.38±0.19	0.20 (-0.31-0.71)
Skill (n=35)	1799	0.86, p<0.001	0.36±0.18	0.18 (-0.22-0.57)

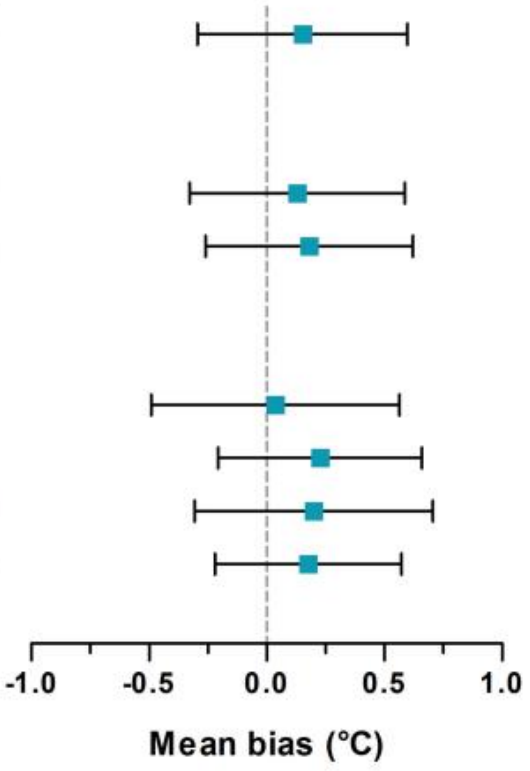
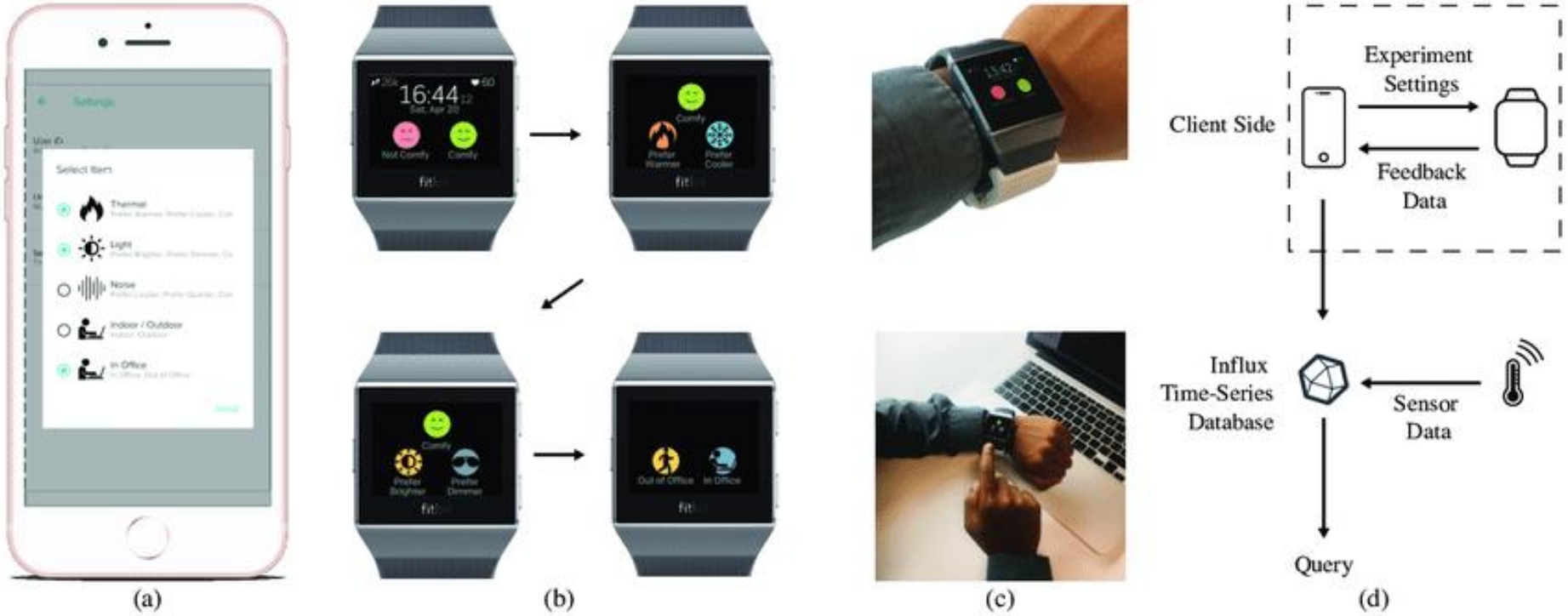


FIGURE 4 | Subgroup-specific Pearson correlation coefficients between T_{c-est} and T_c, root mean square errors (RMSE) weighted for participant and exercise test duration across T_{c-est} and T_c, and the mean bias for T_{c-est}. Mean bias is presented with the lower limit of agreement (LLoA) and the upper limit of agreement (ULoA).

Humans as sensors:
Predicting urban heat exposure impacts

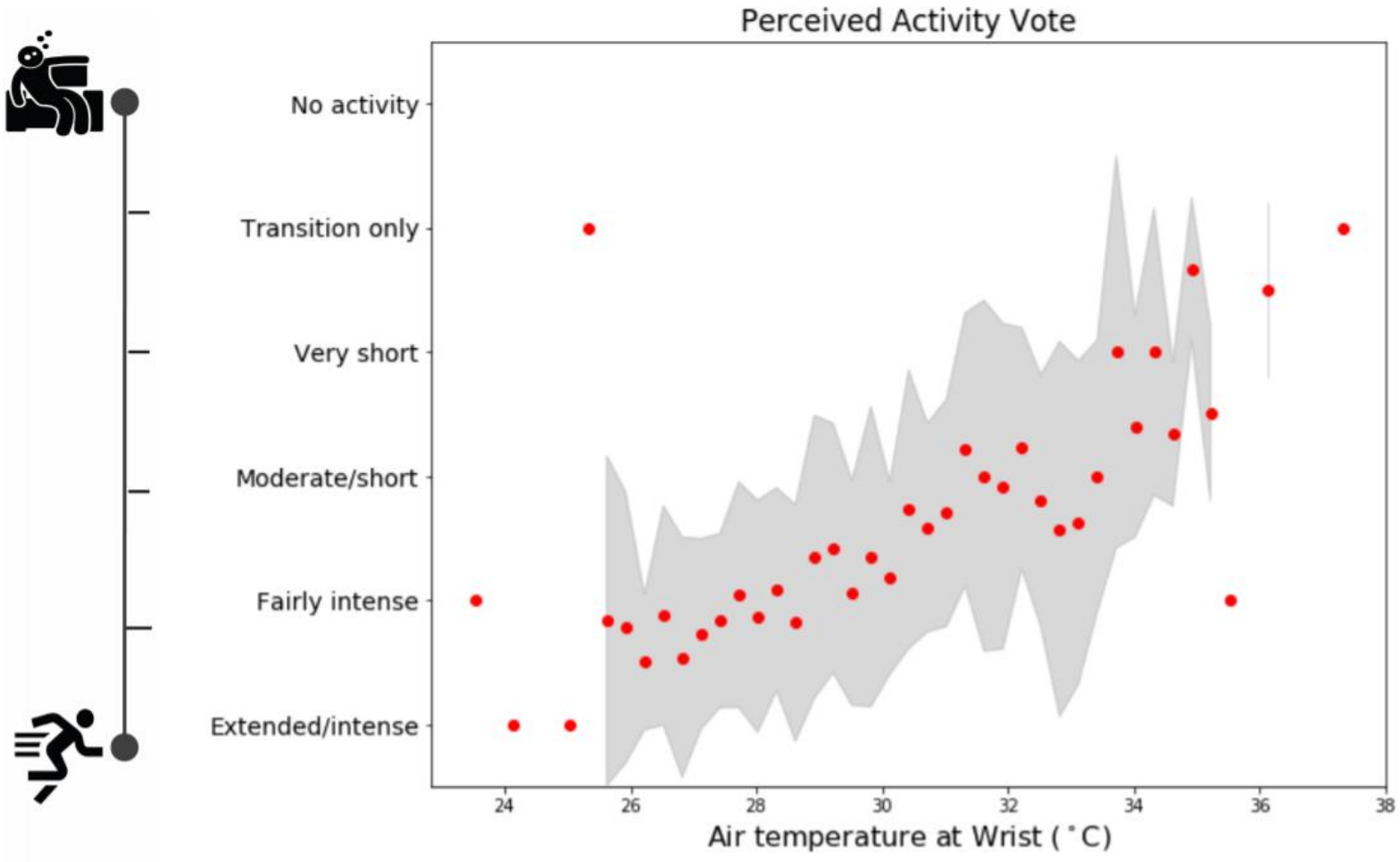


Additionally, direct feedback can be obtained through continuous and unobtrusive data collection

#ProjectCoolbit

Nazarian et al. 2020b (ERL)
Jayathissa et al. 2019

Humans as sensors:
Predicting urban heat exposure impacts



Direct connection between **air temperature at the wrist** ($T_{a,w}$) and the **perceived activity level** (PAV) of individuals was drawn. We observe that with increased $T_{a,w}$, the desire for physical activity is significantly reduced, reaching 'Transition only' PAV level at 36°C

Is urban heat obesogenic?

#ProjectCoolbit

Nazarian et al. 2020b (ERL)
Jayathissa et al. 2019

On the use of IR Thermography for assessing urban heat exposure

EXAMPLES
IR Thermography

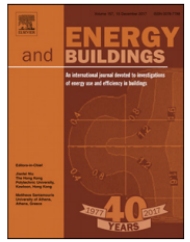
Energy & Buildings 176 (2018) 246–261

ELSEVIER

Contents lists available at ScienceDirect

Energy & Buildings

journal homepage: www.elsevier.com/locate/enbuild



Non-intrusive interpretation of human thermal comfort through analysis of facial infrared thermography

Da Li, Carol C. Menassa*, Vineet R. Kamat

Department of Civil and Environmental Engineering, University of Michigan, United States

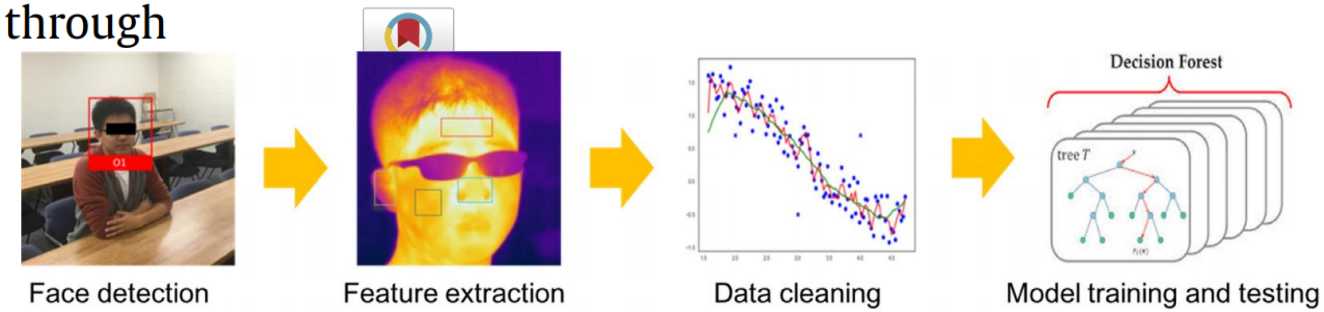
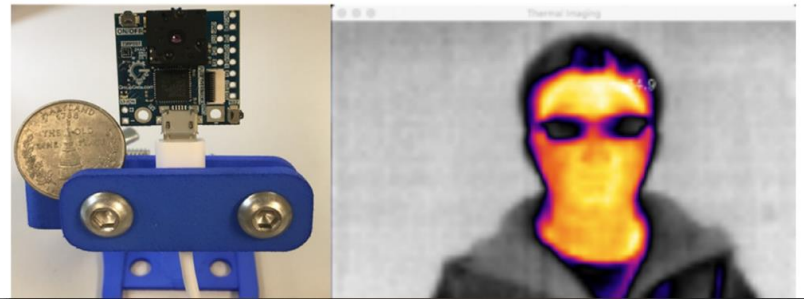


Fig 1. Overview of the non-intrusive thermal comfort interpretation framework.

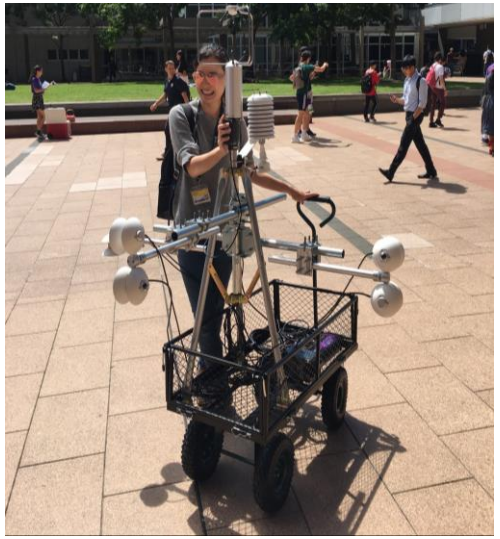
The results demonstrate that ears, nose and cheeks are most indicative of thermal comfort and the proposed framework can be used to assess occupants' thermal comfort with an average accuracy of 85%.

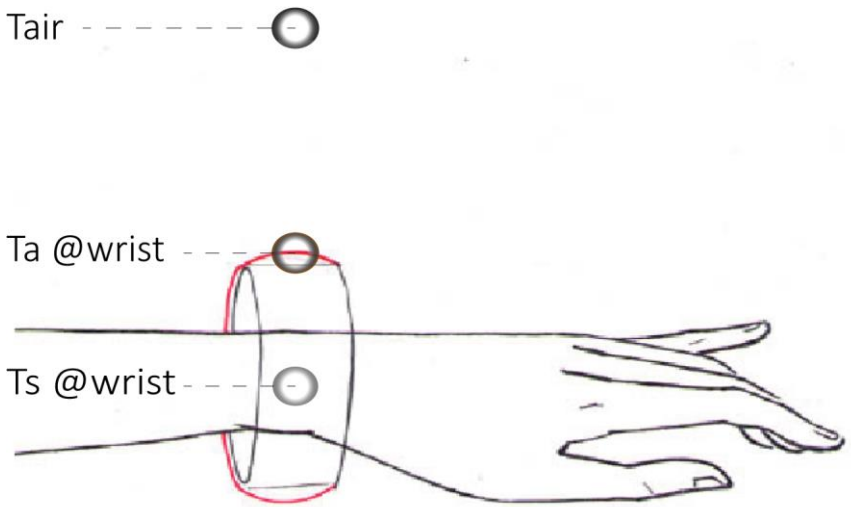


Li D, Menassa CC and Kamat VR (2019) Robust non-intrusive interpretation of occupant thermal comfort in built environments with low-cost networked thermal cameras. *Applied energy* 251. Elsevier: 113336.

On the use of wearables for **predicting air temperature**

EXAMPLES
WEARABLES



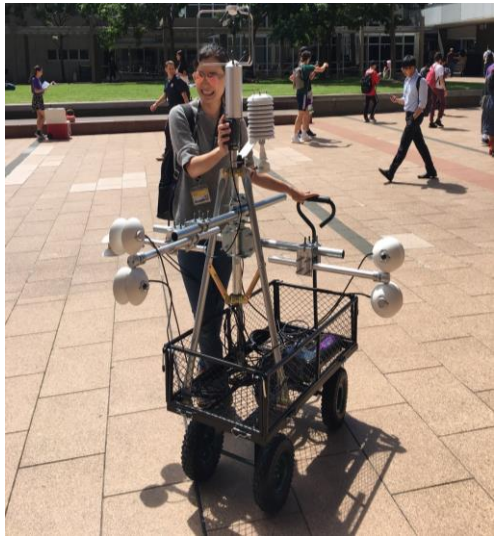


Air temperature at wrist is linearly correlated with **skin temperature** as well as **ambient air temperature**. This lays the foundation for creating a prediction model for ambient temperature based on wearable data.

Ta@wrist $\overset{?}{=}$ ***f*(Tair, Ts@wrist)** RH@wrist, HR)

On the use of wearables for **predicting air temperature**

EXAMPLES
WEARABLES

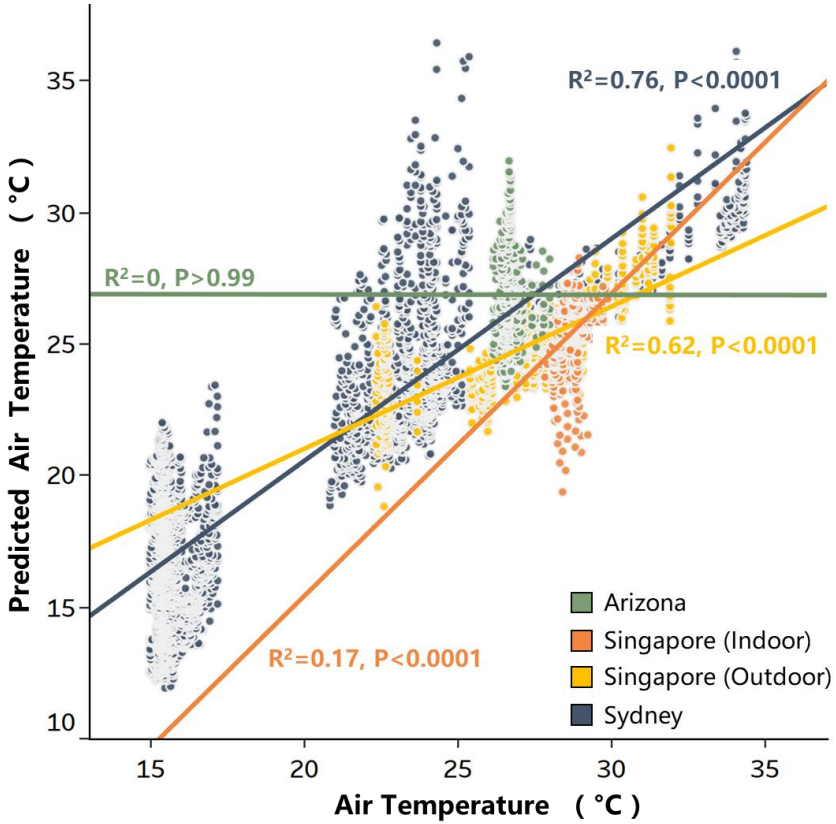


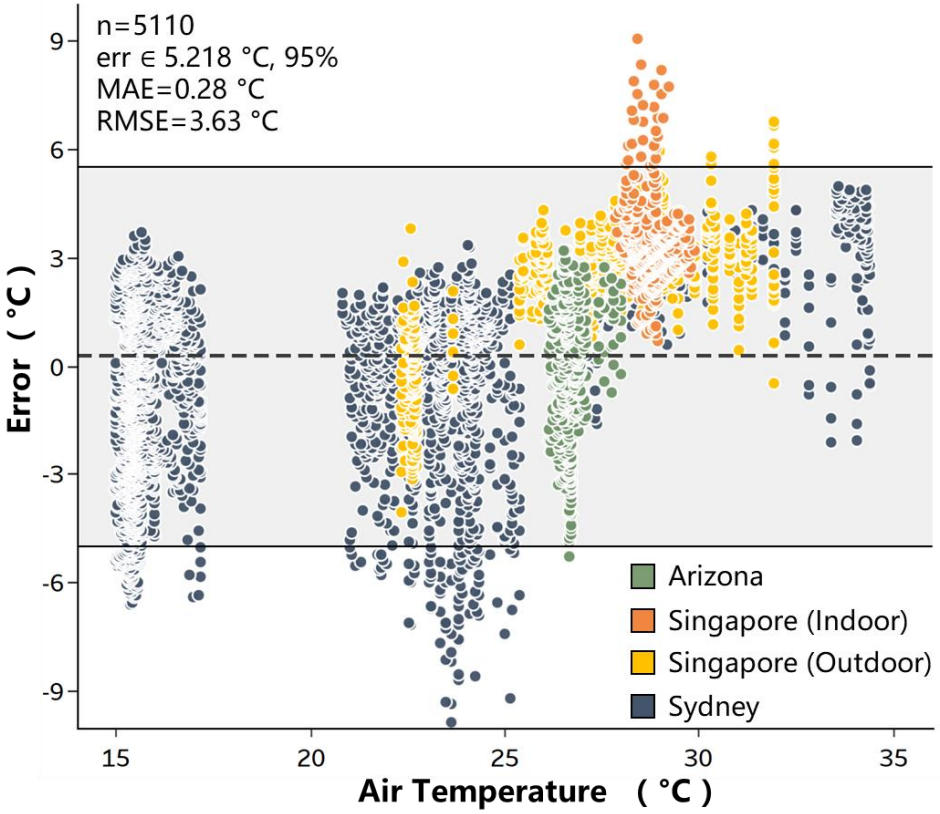
Multi-city analyses of air temperature prediction in different climate classes

On the use of wearables for **predicting air temperature**

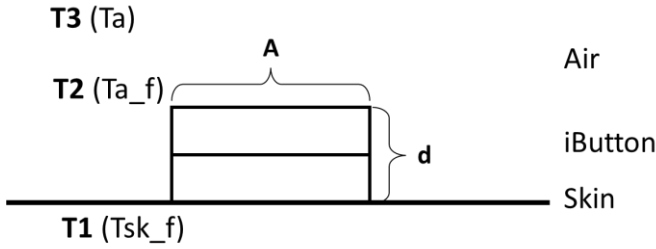
EXAMPLES
WEARABLES

Using multiple linear regression for prediction, prediction accuracy is low (**RMSE=3.6°C**) and **city/climate dependent.**





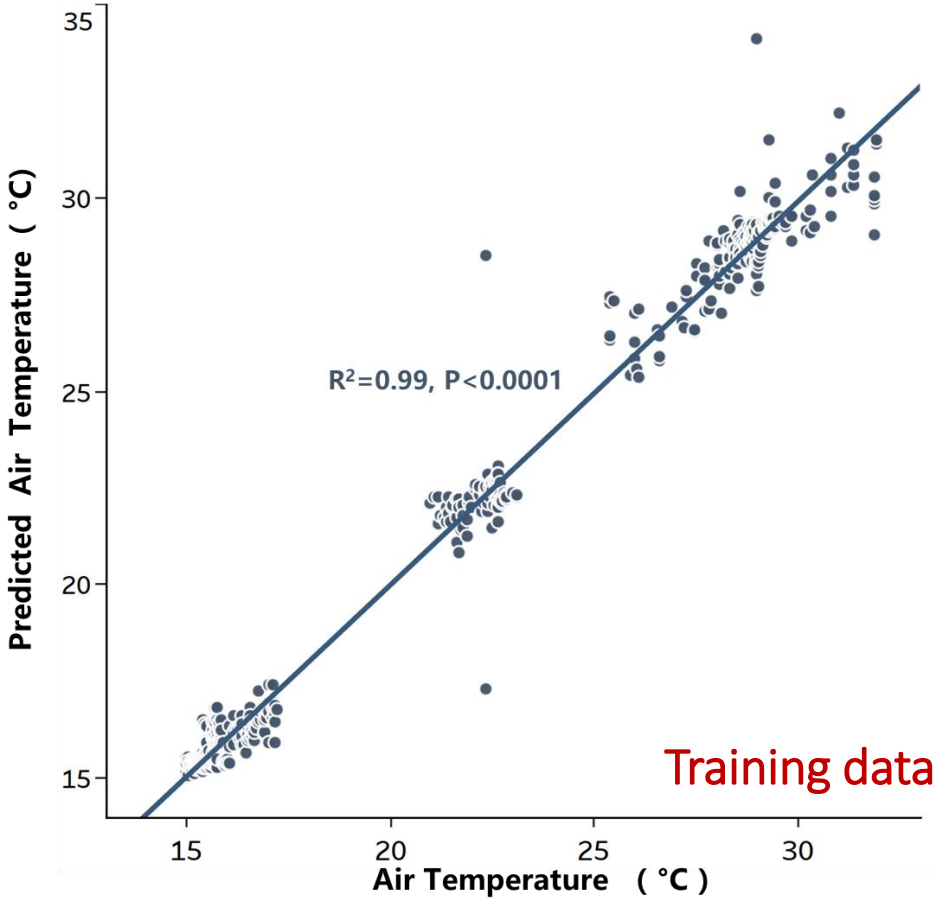
$$Ta = \frac{-k}{dh} \times Tsk_f + Ta_f\left(1 + \frac{k}{dh}\right)$$

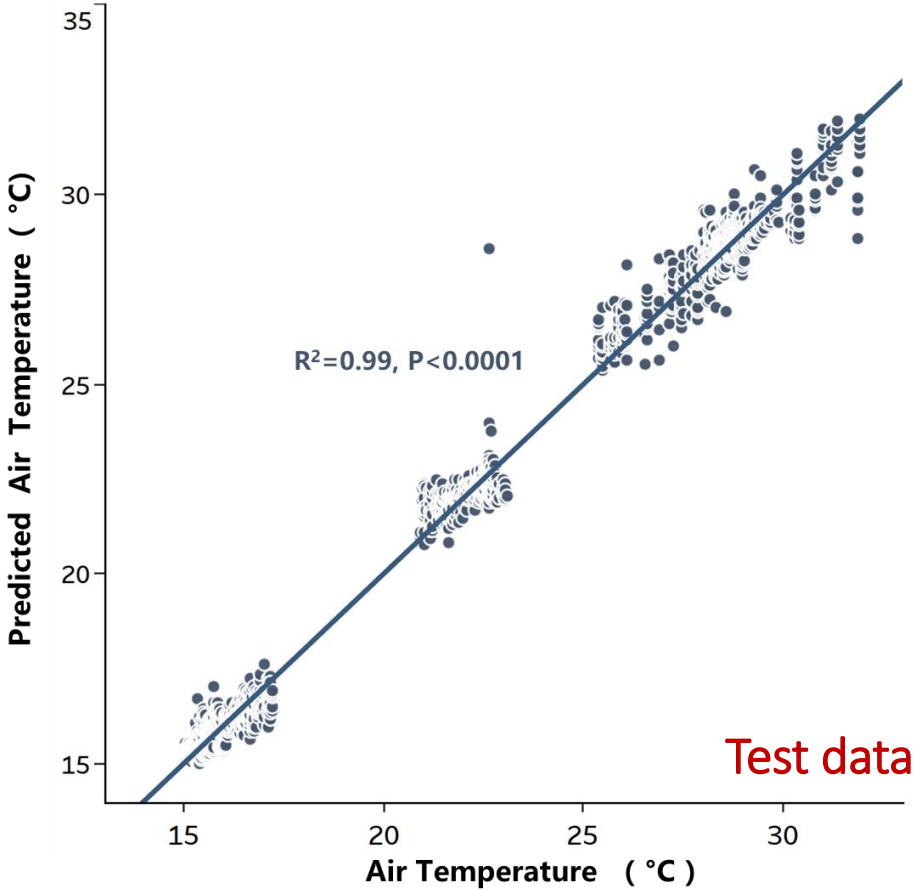


On the use of wearables for **predicting air temperature**

EXAMPLES
WEARABLES

Using Artificial Neural Network and analyzing the data **for each city/climate,** prediction accuracy is significantly improved (**RMSE 0.612°C** for **Sydney** with 80% training, 20% testing data)

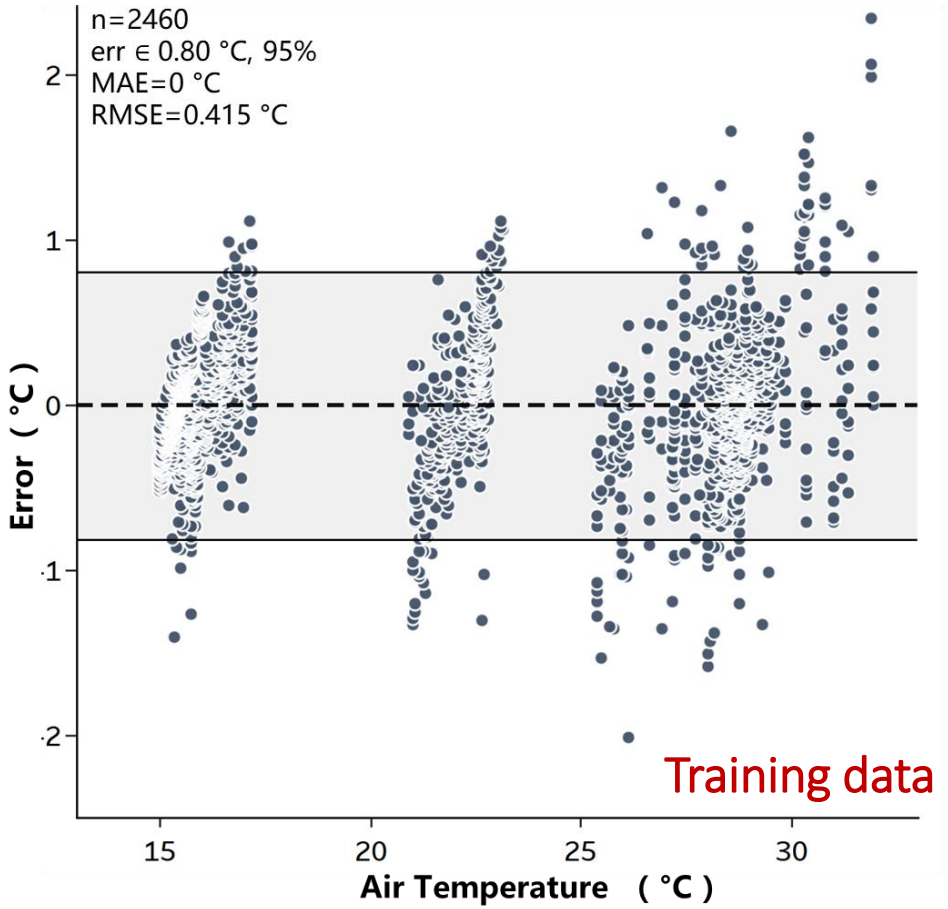


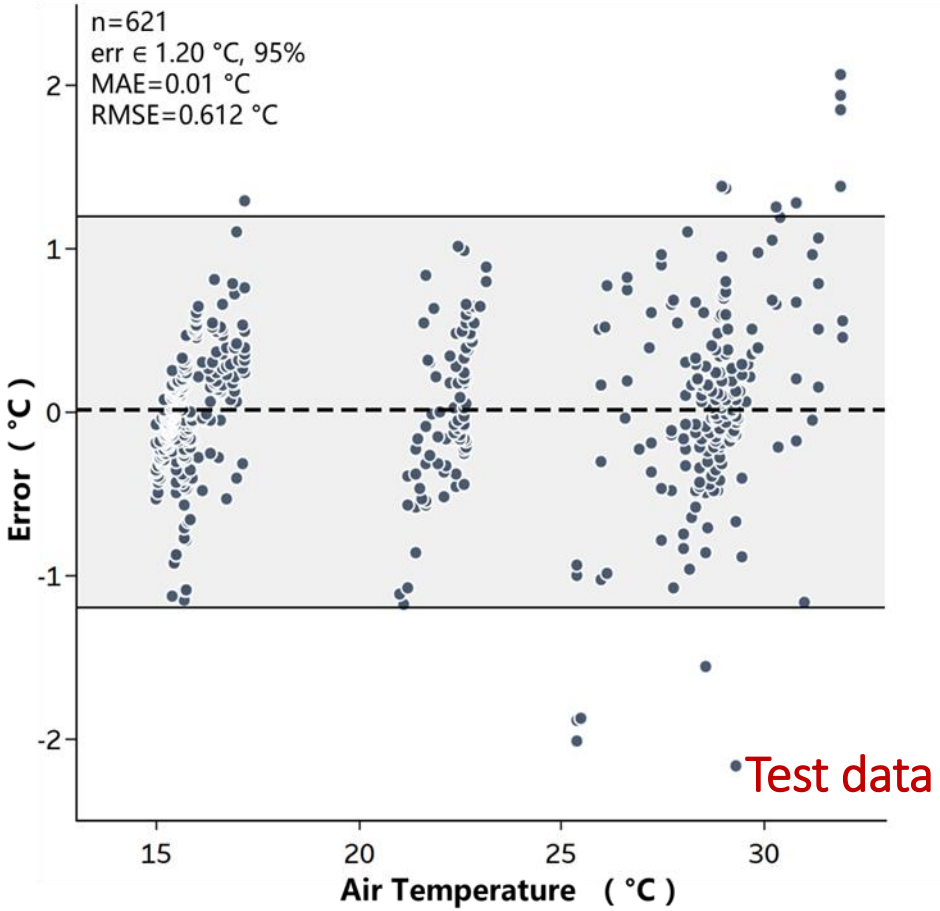


On the use of wearables for **predicting air temperature**

EXAMPLES
WEARABLES

Using Artificial Neural Network and analyzing the data **for each city/climate,** prediction accuracy is significantly improved (**RMSE 0.612°C** for **Sydney** with 80% training, 20% testing data)



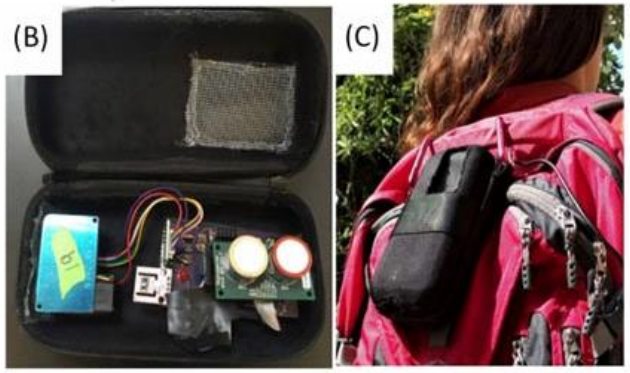


EXAMPLES
NEARABLES

Quantifying heat exposure urban spaces

How does heat exposure affect people's movement, lifestyle & behavior?

Real-time environmental monitoring



EXAMPLES
NEARABLES

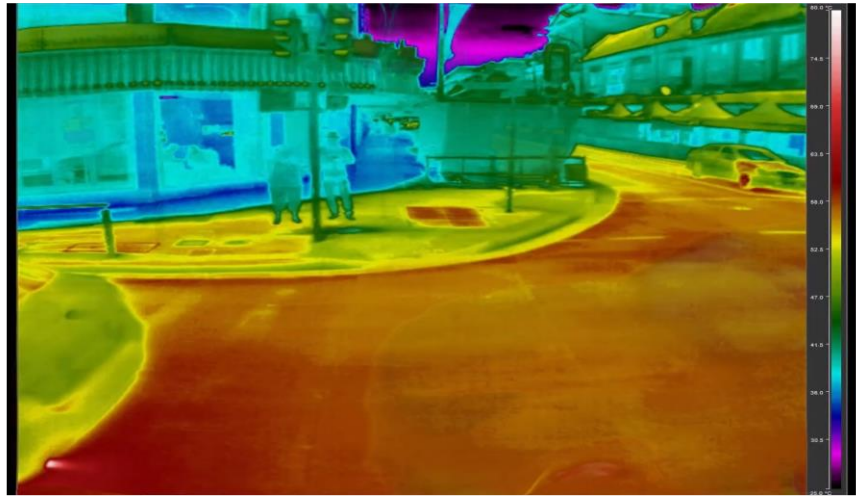
Quantifying heat exposure urban spaces

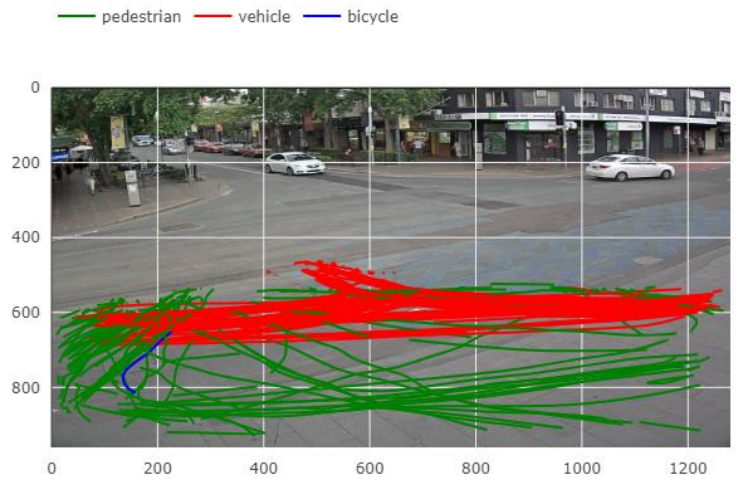
How does heat exposure affect people's movement, lifestyle & behavior?

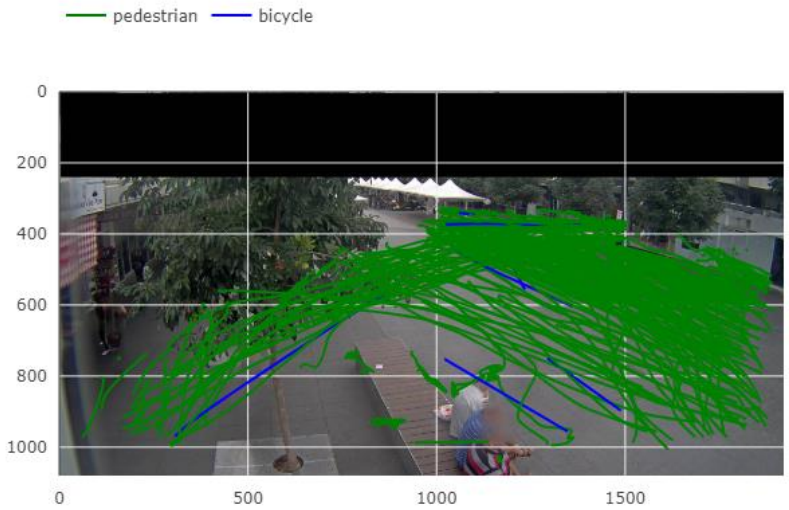
Real-time environmental monitoring

+

Video Analytics for Real-Time Occupancy Monitoring







smart infrastructure facility | UNIVERSITY OF WOLLONGONG AUSTRALIA

Barthélemy et al. 2019 - Edge-Computing Video Analytics for Real-Time Traffic Monitoring in a Smart City
Western Parkland City Sensor Network – Heat and air quality use case

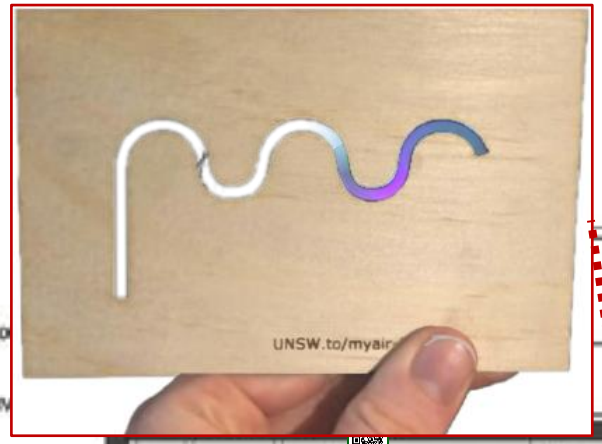
How is environmental quality in our educational building?

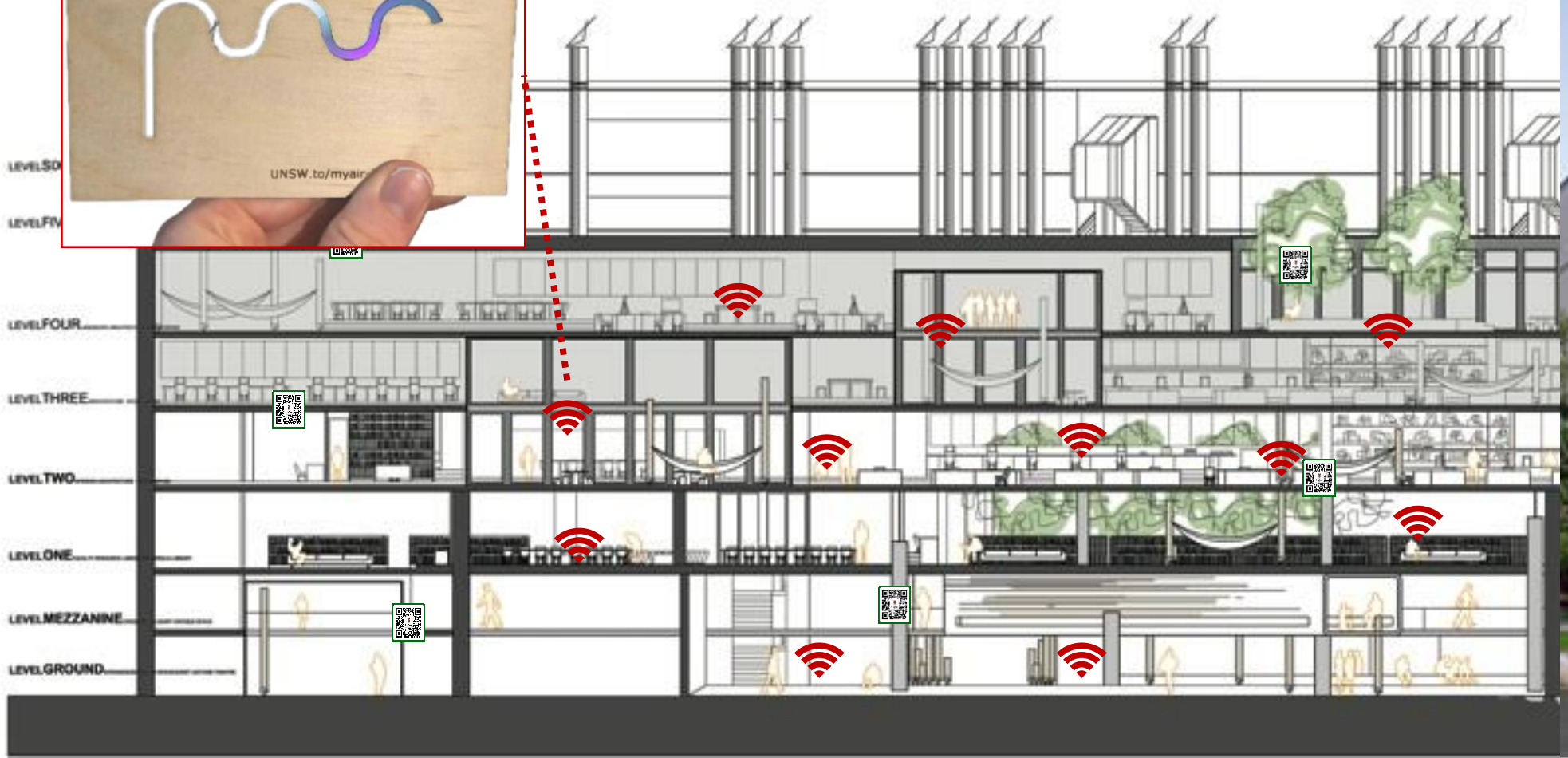
Design and Implementation of **IoT Living Laboratory**

UNSW SYDNEY

Built Environment

MyAir sensor for **indoor environmental quality**



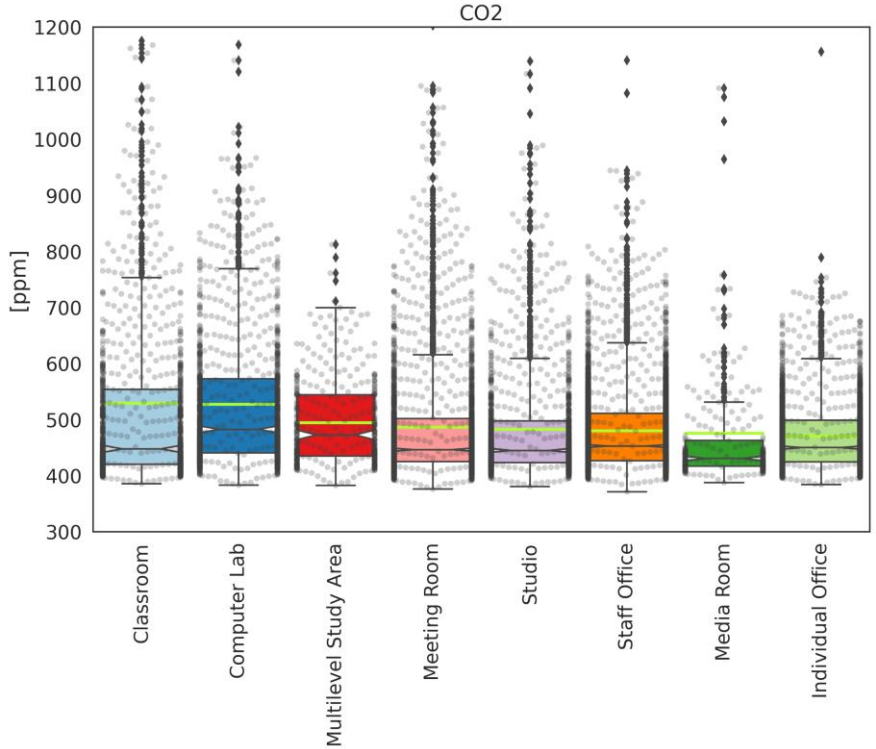


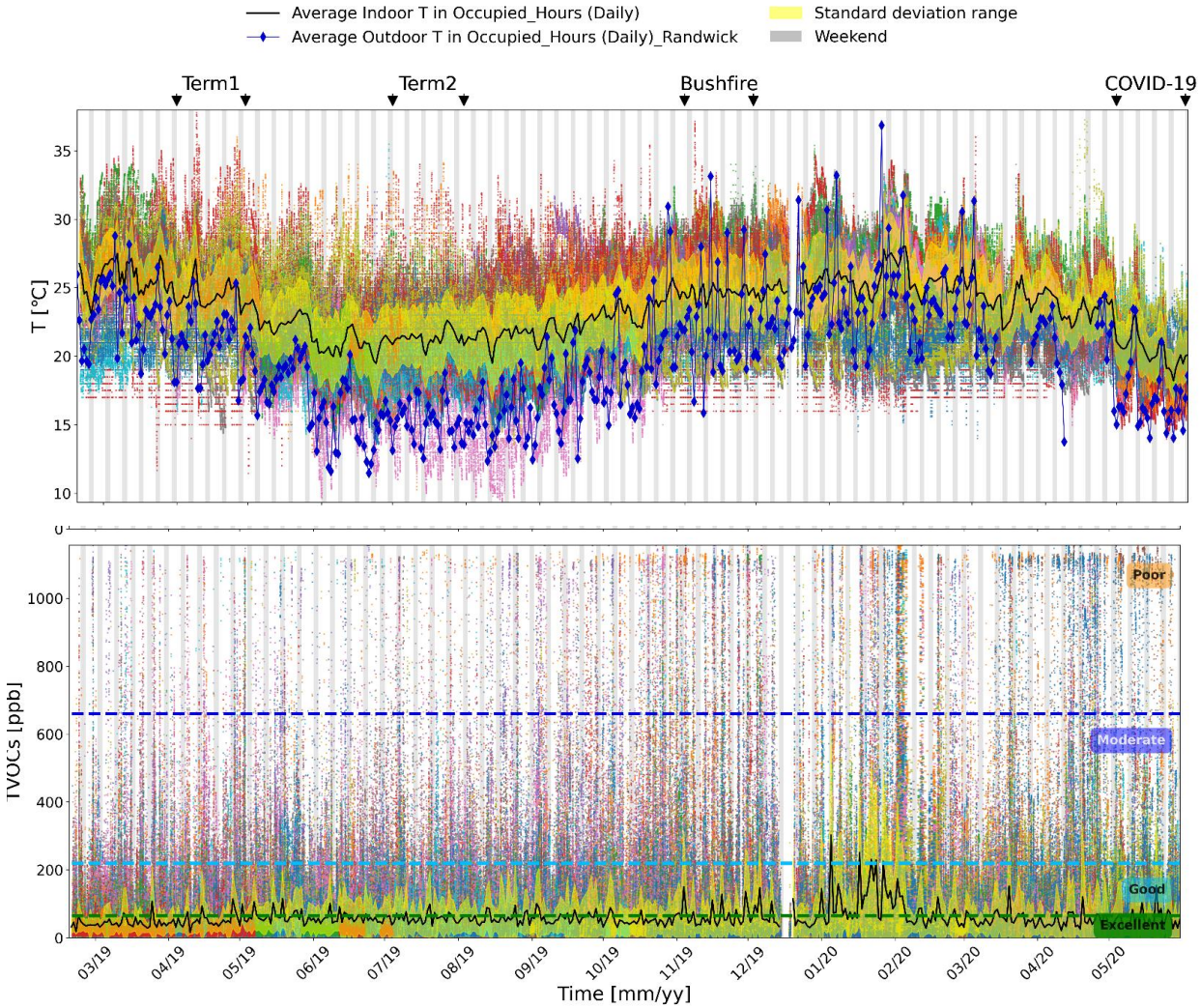
Design and Implementation of IoT Living Laboratory

UNSW SYDNEY Built Environment

How is environmental quality in our educational building?

Real-time, continuous, and capillary monitoring enable us to assess environmental quality in a range of room usage not only in standard occupancy, but also during extreme weather events and COVID-19 pandemic





Ulpiani et al 2021, Towards a Living Lab for Enhanced Thermal Comfort and Air Quality: Analyses of Standard Occupancy, Weather Extremes, and COVID-19 Pandemic, Frontiers in Environmental Science

How is environmental quality in our educational building?

Design and Implementation of **IoT Living Laboratory**

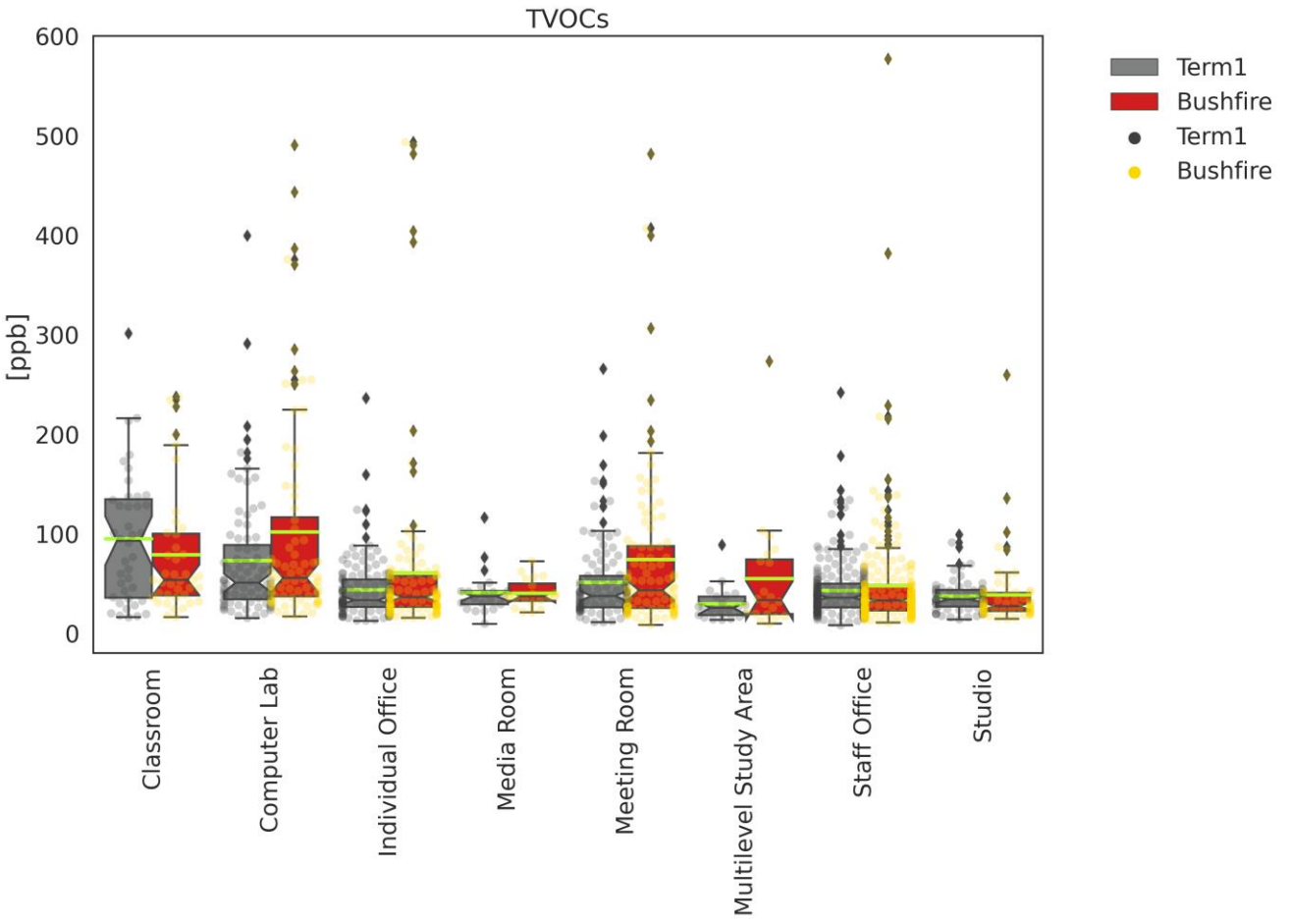
UNSW SYDNEY Built Environment

Key findings include

(i) passive ventilation systems based on manual interventions are most likely associated with sub-optimum environmental quality and extreme variability linked to occupancy patterns,

(ii) normally closed environments tend to get very unhealthy under periods of extreme pollution and intermittent/protracted disuse,

(iii) the elevation and floor level in addition to room use were found to be significant conditional variables in determining heat and pollutants accumulation.

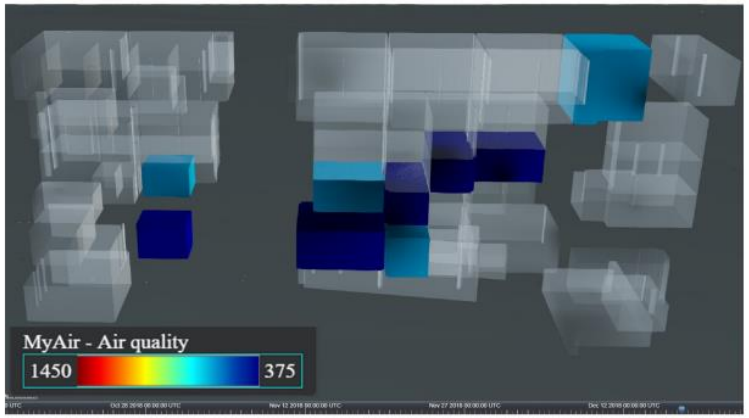


Ulpiani et al 2021, Towards a Living Lab for Enhanced Thermal Comfort and Air Quality: Analyses of Standard Occupancy, Weather Extremes, and COVID-19 Pandemic, Frontiers in Environmental Science

Design and Implementation of
IoT Living Laboratory

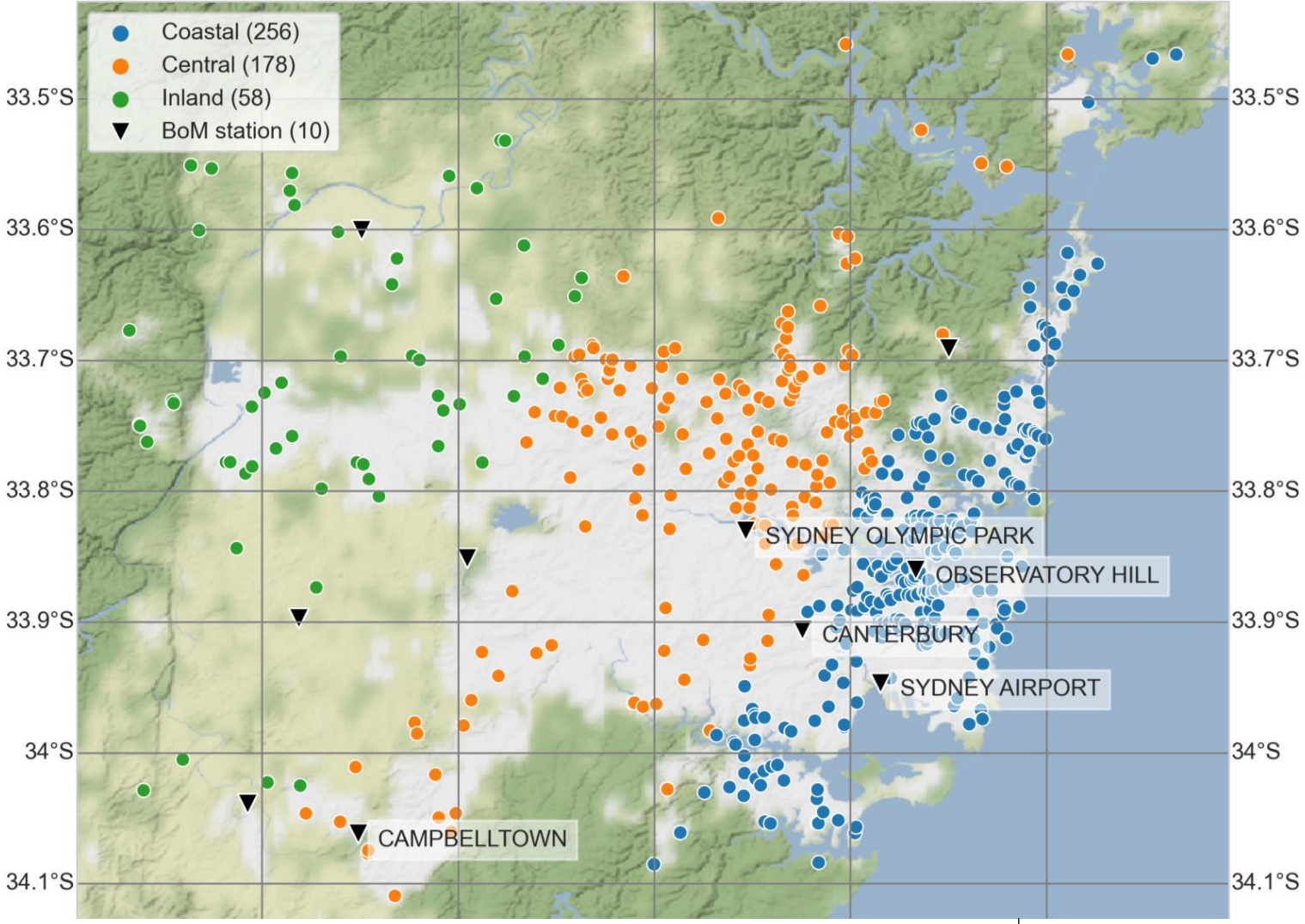
UNSW SYDNEY
Built Environment

Integration of real-time sensor data in the Digital Twin of UNSW Built Environment



Diakite et al 2022 (forthcoming), Towards a Living Lab for Enhanced Thermal Comfort and Air Quality: Integration of real-time sensor data in digital twins

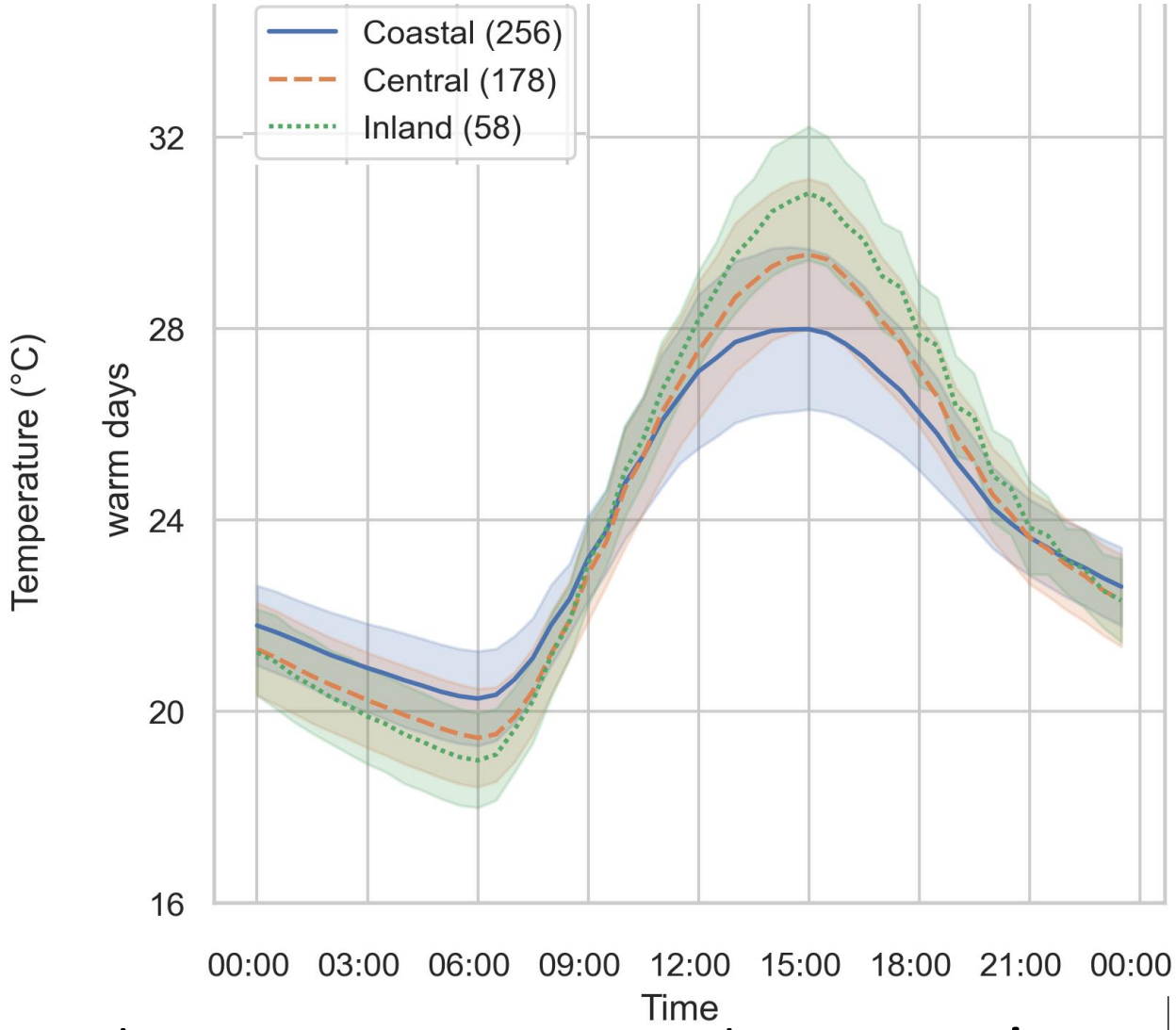
EXAMPLES
NEARABLES



Potgieter et al. (2021), **Combining High-Resolution Land Use Data With Crowdsourced Air Temperature to Investigate Intra-Urban Microclimate**, Frontiers in Environmental Science.

Crowdsourcing **Inter-** and **Intra-Urban** Temperature Monitoring using citizen weather station networks

EXAMPLES
NEARABLES

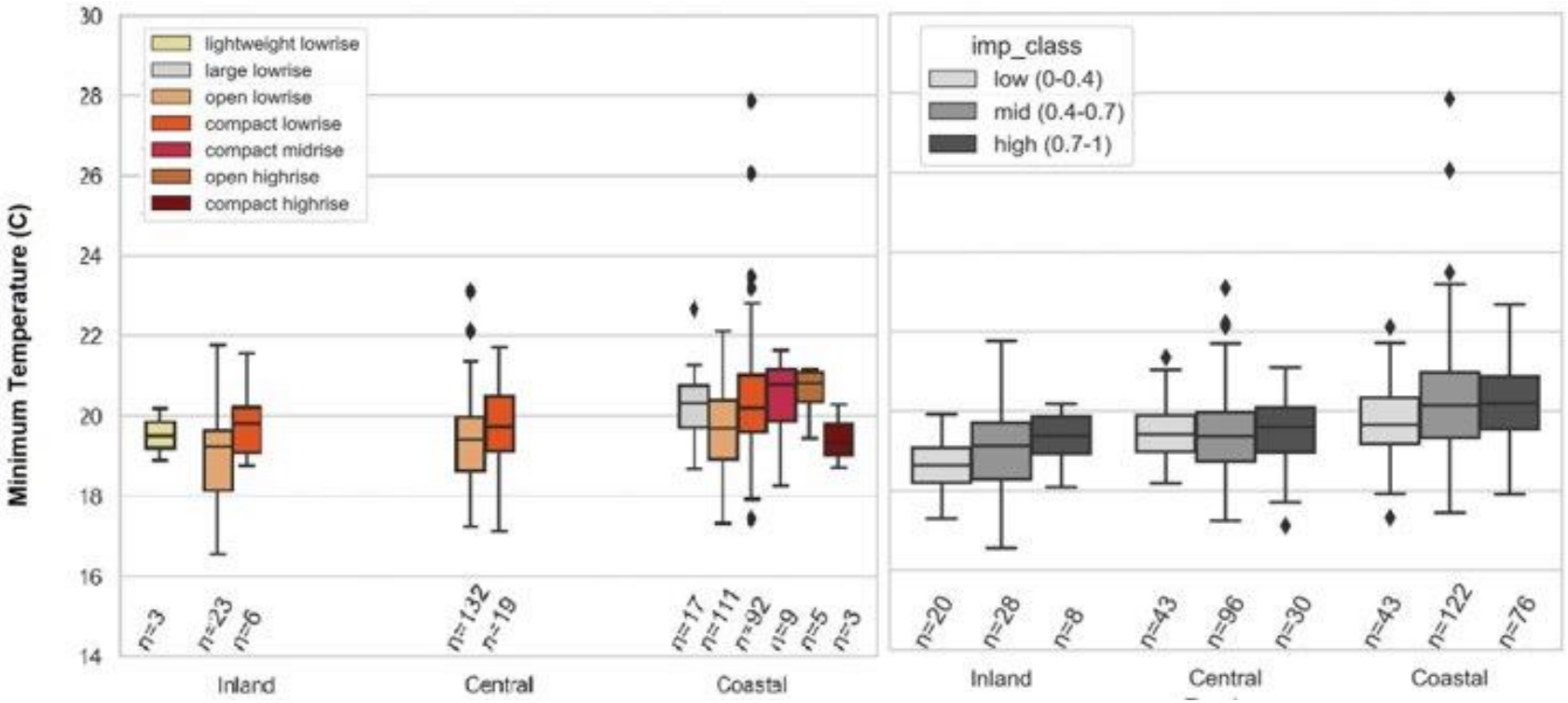


Potgieter et al. (2021), **Combining High-Resolution Land Use Data With Crowdsourced Air Temperature to Investigate Intra-Urban Microclimate**, Frontiers in Environmental Science.

Crowdsourcing **Inter-** and **Intra-Urban** Temperature Monitoring using citizen weather station networks

EXAMPLES
NEARABLES

Combining crowdsourced air temperature with urban data assist us in quantifying the importance of urban design (form and fabric) on microclimate variability

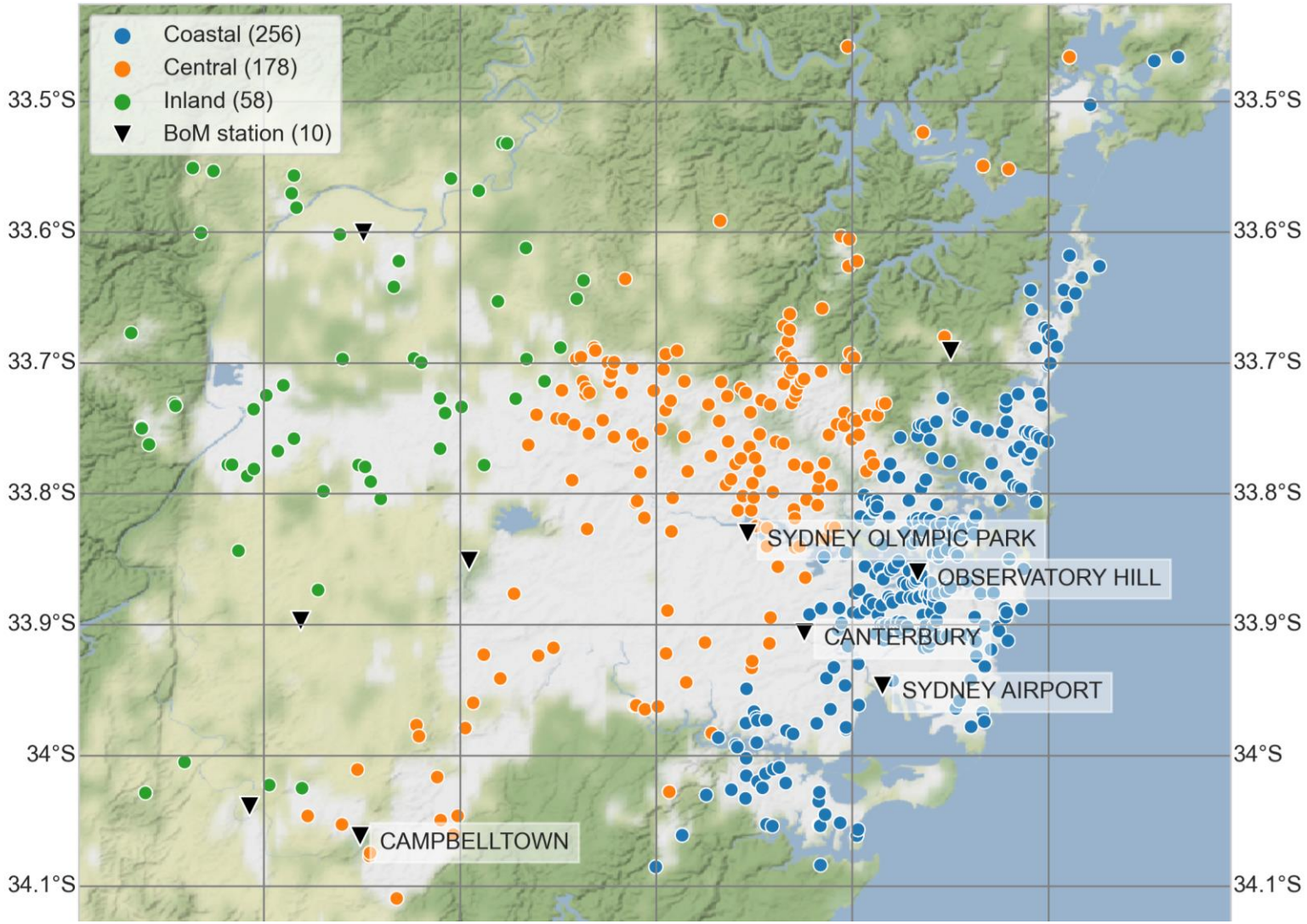


Minimum temperature data, split by distance from the coast for LCZs on the left and impervious surface on the right

Potgieter et al. (2021), **Combining High-Resolution Land Use Data With Crowdsourced Air Temperature to Investigate Intra-Urban Microclimate**, Frontiers in Environmental Science.

EXAMPLES
NEARABLES

Are all urban areas represented similarly in crowdsourced data?

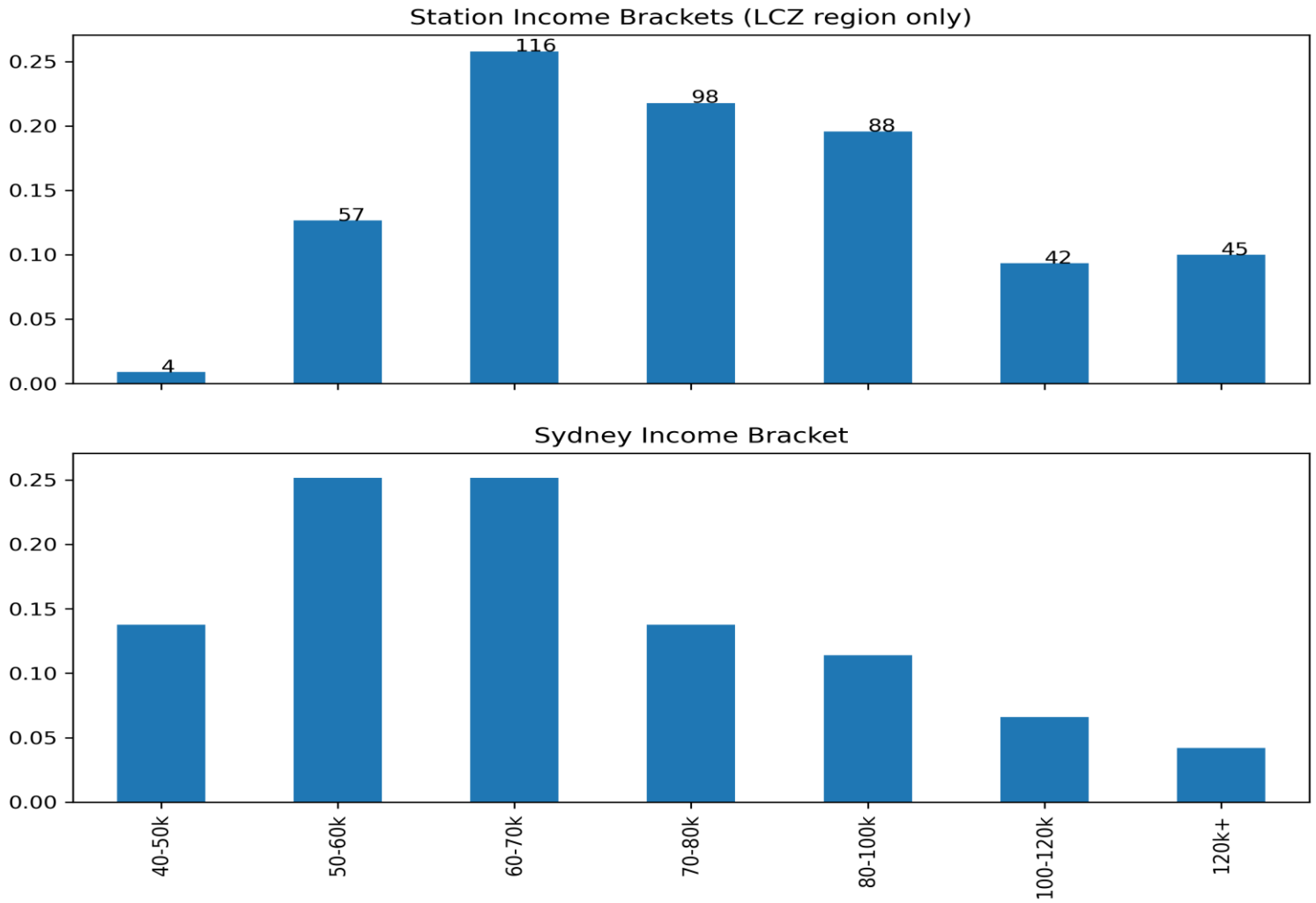


Potgieter et al. (2021), **Combining High-Resolution Land Use Data With Crowdsourced Air Temperature to Investigate Intra-Urban Microclimate**, Frontiers in Environmental Science.

EXAMPLES
NEARABLES

Ongoing research:
Quantifying urban climate justice in Australian Cities.

Are all urban areas represented similarly in crowdsourced data?



Article | Open Access | Published: 25 May 2021

Disproportionate exposure to urban heat island intensity across major US cities

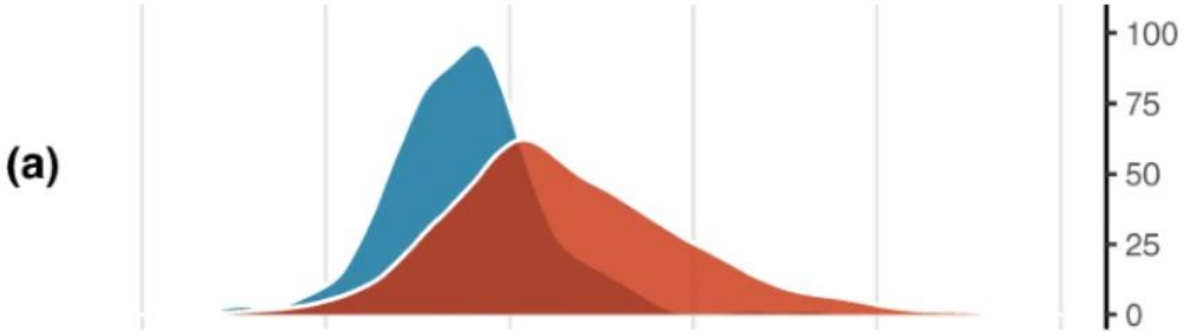
Angel Hsu, Glenn Sheriff, Tirthankar Chakraborty & Diego Manya

Nature Communications **12**, Article number: 2721 (2021) | Cite this article

13k Accesses | **8** Citations | **1792** Altmetric | Metrics

"The average person of color lives in a census tract with higher SUHI intensity than non-Hispanic whites in all but 6 of the 175 largest urbanized areas in the continental United States."

Fig. 1: Distribution across cities of mean summer daytime surface urban heat island (SUHI) intensity by sociodemographic group.



CHALLENGES & RESEARCH QUESTIONS

How can IoT, crowdsourcing, and ubiquitous data provide meaningful personal heat exposure data?

"The most critical gap in the IoT deployment strategies for urban climate assessment arguably pertains to the quality of the sensors and the collected data." Pantelic et al. 2022

"One of the critical gaps in IoT environmental sensing arguably pertains to the quality of the sensors and the collected data as a universally accepted set of procedures, standards, or guidelines for standardization and quality control is yet to be developed." Nazarian et al. 2022

- low-cost sensors
  - poor calibration
    - sensor drift
  - poor instrumental setup (ex. lack of radiation shield)
  - Different installations

- Change in user context (during realistic use)
  - realistic microclimatic effects

- Data accessibility
  - Integration of collected data

- Integration of human factor
  - Assessment of urban climate justice
    - personal recommendation systems

Changing by Alisa Singer

"As we witness our planet transforming around us, we watch, listen, measure … respond."

Thank you & looking forward to see you in Sydney

Critical questions & comment?

n.nazarian@unsw.edu.au

@NazarianNegin

Climate-resilientcities.com

Sydney, Australia selected to host ICUC-11 in 2023

The next International Conference on Urban Climate **(ICUC-11)** will take place in **Sydney, Australia from August 30 to September 3, 2021**. The Board of the International Association for Urban Climate (IAUC) selected the team in Sydney with its proposal "Cities as Living Labs: Climate, Vulnerability, and Multidisciplinary Solutions" on April 4, 2019. The Board's decision follows the results of a membership consultation in March. In the membership consultation, a strong preference for Sydney emerged. From a total of 240 voters, 64% ranked Sydney their first choice, followed by 19% that ranked "Hong Kong" first and 17% that ranked "Beijing" first.

The University of New South Wales (UNSW) who will host ICUC-11 has also received support from the American Meteorological Society (AMS) Board on the Urban Environment (BUE) to run ICUC-11 together with the Symposium on the Urban Environment (AMS-BUE). UNSW will collaborate with other Australian Universities and Research Institutes in hosting this conference. Dr. Negin Nazzarin, who leads the organising committee, welcomes the IAUC community to Sydney: "We greatly appreciate the vote of confidence from the IAUC members. We truly believe that Sydney is an ideal venue for bringing in the diverse and international Urban Climate community, and look forward to welcoming all members in Sydney, Australia, for the 11th International Conference on Urban Climate (ICUC-11) in 2021."

ICUC-11 will be hosted on the campus of UNSW. The Sir John Clancy auditorium offers tiered seating for up to 945 participants in plenary sessions. The adjacent Matthews Pavillions will provide a contemporary semi-enclosed space for exhibitions, poster display and catering. A number of nearby theatres and lecture rooms will offer spaces for concurrent sessions and workshops.

The board congratulates the team from Sydney which will make a highly attractive venue for our flagship meeting. The board also greatly appreciates the work and willingness by all candidate teams to host ICUC-11, including Beijing and Hong Kong who each developed very attractive proposals, but were ultimately unsuccessful.