23rd International Congress of Biometeorology

International Society of Biometeorology

May 14-17, 2023

Tempe, Arizona, USA

ASU

ABSTRACT BOOK – TUESDAY, MAY 16

Thank you to sponsors and partners

GOLD LEVEL SPONSORS

Thank you to sponsors and partners

MAROON LEVEL SPONSORS

SPRINGER NATURE

HeatReady PHX
OFFICE OF HEAT RESPONSE AND MITIGATION

CoolSeal by GuardTop

COPPER LEVEL SPONSORS

Thermetrics

Life Is On Schneider Electric

PARTNERING SCIENTIFIC NETWORKS AND SOCIETIES

GLOBAL HEAT HEALTH INFORMATION NETWORK

EMS

Oral Presentation Abstracts

TUESDAY, MAY 16

Morning Parallel Sessions [10:30-12:00] **VENTANA ROOMS A, B, C**

Urban Biometeorology 4 - Special Session on Cooling Singapore	**VENTANA A**
Winston Chow	Cooling Singapore 2.0: Outdoor thermal comfort and the Singapore Green Plan 2030 Since 2017, the Cooling Singapore 2.0 Initiative (CS2.0) has evolved to assess and evaluate approaches to reduce the impacts of urban overheating in the dense city-state of Singapore. These include determining what combination of heat adaptation and mitigation methods are effective in reducing the city's heat exposure, which includes the important biometeorological aspect of minimising outdoor thermal discomfort and improving the thermal well-being for individuals living in Singapore. We review the initiative's achievements to this end, through (i.) analysing the outcomes from observational and modelling exercises over the past 6 years, and; (ii.) - integration of the initiative's results and recommendations pertaining to outdoor thermal comfort towards local policy as part of Singapore's overarching Green Plan 2030 to address broader climate change issues.
Sin Kang Yik	Sensitivity Analyses of Instruments for Microclimatic Measurements to Observe Park Cool Island in Tropical Climates: A Case Study in Singapore Many modern cities around the world today are experiencing urban overheating due to a combination of anthropogenic climate change and the urban heat island (UHI) phenomenon. This has resulted in urban areas experiencing higher ambient temperatures, which has extensive implications on energy demand, human-health and well-being in cities. Nature-based solutions (NBS) have been proposed to improve urban resilience, such as setting aside areas of green parks within a city. These parks provide a cooling effect known as the 'Park Cool Island' (PCI). This study deployed 18 MX2301A Honest Observer by Onset (HOBO) Temperature/RH Data Loggers around Bishan-Ang Mo Kio Park in the hot humid tropical city of Singapore to 1) measure the extent of PCI and 2) observe the differences in responses with and without a RS1 Solar Radiation Shield setup. We conducted the experiment during September 2021 to December 2021 without radiation shields, and January 2022 to November 2022 with radiation shields. Ten MX2301A sensors were set up inside a public park, and eight in the surrounding urban high-rise area. Further, we spatiotemporally analysed the study area using ArcGIS Pro, and observed lower air temperature (Ta) observed within the park compared to the surrounding urban areas. The dataset with the radiation shields recorded lower ranges of Ta and relative humidity (lower maximums and higher minimums). These results aim to reveal the extent of the PCI in tropical cities, and how effective parks and greenspaces are in reducing urban temperature. The study is further capable of informing the effectiveness of using these measurement apparatus to observe micro-climatic variables, while also complimenting the lacking literature on UHI and heat mitigation in tropical environments.

	Inferences obtained from this case study could also be useful in improving outdoor thermal environment in cities using NBS.
Graces Ching	Performance evaluation of ENVI-met for seasonality in a tropical urban medium-sized park Rapid urban development and climate change has resulted in urban overheating in many cities across the world. Singapore, a tropical city-state in Southeast Asia, is no exception to this phenomena. Nature-based solutions (NBS) through the provision of publicly accessible urban green parks is increasingly a popular measure to improve urban resilience and mitigation against heat within cities, given its space constraints. The 2030 Singapore Green Plan aims to expand green spaces by up to 1000 hectares as a continual effort to pursue its “City in a Garden" vision. To assist in the effective execution of such ambitious plans, the relevant agencies have explored various models that can help optimise the deployment of green spaces. ENVI-met (version 5.0.3) is a robust microclimate model that can be used for planning and estimating the cooling benefits from implementing park expansion in dense cities. We evaluate the model performance by simulating Bishan-Ang Mo Kio (BAMK) Park, a medium-sized 62 hectare linear park situated in a densely populated residential area. In other studies, simulations have input boundary conditions for specific days which may not be representative of the seasonality of the area. In this study, our simulation was forced using seven weather types that are representative of the meteorological conditions of Singapore’s tropical hot-humid climate. This allows us to investigate the extent of park cool island for a tropical urban medium-sized park, accounting sufficiently for typical days in the Southwest (SW), Northeast (NE) monsoon and intermonsoon periods. The model is validated using field measurements collected between January 2022 to December 2022. These results show that while ENVI-met is a useful model to project air temperature outputs for urban planning considerations, it is important to input representative boundary conditions and validate the model to account for the seasonality in the respective study areas.
Yuliya Dzyuban	Thermal walk for outdoor thermal comfort evaluation of urban spaces in an Asian city People living in cities spend a significant period of their lives outdoors. Outdoor thermal comfort heavily determines people’s usage of outdoor spaces and the quality of life in cities. For cities along the tropical equatorial region, extreme heat is a complex urban challenge and it is necessary to assess outdoor thermal comfort for designing and planning guidelines. Our study investigates the relationship between human thermal comfort, urban geometry and microclimatic conditions to better evaluate environmental conditions outdoors. An hour-long thermal walk was carried out in Singapore on a hot and cloudless day. Participants were equipped with Fitbit and iButton devices to measure their physiological states and tasked to record their heat perceptions on several stops and segments along the route via a thermal sensation questionnaire. Concurrent microclimatic measurements were obtained with the use of SMaRTy, a mobile biometeorological cart during the traverse. Preliminary results show evidence of alliesthesia and pleasure with changes to urban geometry and presence of vegetation coverage, with preference towards shading against direct sunlight. The novel methodology applied in this study contributes to the understanding of dynamism of human thermal sensation under various outdoor spaces, and suggests improvements to the environment in which people feel the most thermally comfortable outdoors.

Human Biometeorology 1	VENTANA B
Konrad Rykaczewski	Theory-guided improvement of cylindrical radiation thermometers for cost-effective mean radiant temperature measurements for a diverse population In extreme heat conditions, radiation accounts for a large fraction of the human heat load. In urban contexts, the radiative contribution to the heat load is highly variable due to multiple direct and reflected short- and longwave sources. Capturing this variability, which is needed to predict personal heat balance, comfort, and safety, requires accurate and cost-effective radiation thermometers that can be installed at multiple sites. In addition, such devices should provide measurements representative of a diverse population. Based on our measurements[1] and that of multiple other groups, it is increasingly apparent that commonly employed acrylic globe thermometers do not provide accurate measurements in outdoor settings and are not representative of the shape of the human body, among other drawbacks. Here we argue that improved cylindrical radiation thermometers (CRTs) provide a substantial advancement over globe thermometers. First, we show that the projected radiation area factors for cylinders represent well those of most adults in the United States (albeit in rotationally symmetric form)[2]. Second, we propose physics-based improvements to the CRTs based on our extensive measurements with multiple sensors and radiation thermometers[1]. In particular, we discuss the physical impact and provide theory-driven ideas for lessening the effects of a thermally insulating external CRT coating, the temperature measurement location, and convective heat loss corrections, including air turbulence effects. We also demonstrate that using two CRTs with differing albedos allows for the decoupling of short and longwave radiative fluxes[3]. Outputs from this work will drive important future research and applications to more easily measure the entire heat load on a human in more urban locations rather than temperature and humidity alone. [1] Vanos et al. International journal of biometeorology 65 (2021): 967-983. [2] Rykaczewski et al. International journal of biometeorology 66 (2022): 2357-2367. [3] Rykaczewski et al. Building&Environment, 208, (2022): 108636.
Cameron C. Lee	Developing a universal mortality-calibrated metric for human thermal comfort The nonlinear u- or j-shape to the temperature-mortality relationship is well known from prior research. This relationship differs by location, with warmer climates generally having higher ‘optimal’ temperatures and a greater response to cold, while people in colder climates have lower optimal temperatures and a greater response to heat. Furthermore, abnormally cold days will often have the opposite impact on mortality in summer (decreased mortality) compared to winter (increased mortality), and vice versa for abnormally warm temperatures. In addition, the thermal comfort of a population is due not only to temperature, but also other meteorological factors, namely radiation, humidity and wind speed. Such factors are often incorporated into temperature-related mortality research by using the apparent temperature (AT), Wet-bulb Globe Temperature, or the Universal Thermal Comfort Index. While these measures of human thermal comfort take multiple factors into consideration, none of them are explicitly calibrated on cumulative lagged mortality, nor do they consider the spatiotemporal variability that is known to impact the temperature-health relationship. The underlying hypothesis of this research is that a ‘modified apparent temperature’ that accounts for all of the aforementioned factors, but is specifically calibrated on empirical mortality data should be a better indicator of human thermal comfort than

	what is currently available. To test this hypothesis, we utilize artificial neural networks to learn the nonlinear, lagged, seasonally- and latitudinally-dependent temperature-mortality relationship using data across the USA. Preliminary results are encouraging, showing mortality spikes to be, on average, 2.8x more likely on days with a high mortality-adjusted temperature factor (MAT), compared to just a 1.7x risk for comparable AT extremes. Some locations exhibit risks of 6.7x on extreme MAT days. With the ambitious objective of the research, we mean this to be a starting point for a wider effort to create such a metric at a global scale.
Ankit Joshi	Predicting human thermal response: heat balance equation vs thermoregulation model Extreme weather (heatwaves and cold spells) caused by climate change are beyond the body's thermoregulation ability to cope with and pose a significant threat to human health. Therefore, behavioral adaptation (e.g., clothing, shelter, heating, ventilation, and air conditioning systems) are vital for human to maintain a normal core temperature. Thermoregulation models for the assessment of heat/cold stress can be very useful tool to mitigate the adverse health effects of climate change. In this study, we compared the predicted core and mean skin temperatures by two different methods (a) models based on heat balance equation and (b) an advanced thermoregulation model. The predicted heat strain (PHS) model (ISO7933), developed based on the heat balance equation, was used to predict the human thermal response. The numerical model of human thermoregulation was developed by considering the passive system (heat transfer within human body and to environment) and active system (vasodilation, vasoconstriction, sweat, and shivering). The predicted human thermal responses were compared with the data from the human subject study (Tamb: 20 to 30°C, RH: 47 to 86%, activity level: 3.5 METs, thermal resistances: 0.5 to 2.0 clo, evaporative resistances: 20 to 122 Pam2/W). The thermoregulation modelling approach showed higher accuracy in the predicted core and mean skin temperatures due to detailed consideration of higher spatial resolution (15 body segments) along with heat transfer via blood flow and through complex clothing ensembles. The average RMSD (root mean square deviation) of predicted core and mean skin temperatures were 0.21°C (maximum RMSD = 0.33°C) and 0.56°C (maximum RMSD = 1.03°C), compared to average standard deviation in measured data 0.26°C and 0.58°C, respectively. The advanced thermoregulation models are very useful tool to assess the heat and cold stress in extreme weather events, especially for populations frequently exposed to extreme weathers.
Andreas Matzarakis	Normalisation of thermal indices in the context of urban environments The evaluation of the thermal impact, based on thermal indices (depicting human thermoregulation) is most important in order to allow for a safe and risk-minimised but also human-adapted urban planning. This contribution demonstrates the thermal vulnerabilities, strengths and similarities of the indices. Min-Max-Normalisation was applied to relate and spatially compare the indices, independently of the physical unit and range. Subsequent regression analysis revealed the relationship between each index in turn. In this context, the indices were calculated for the urban district Rieselfeld in Freiburg, Germany, using the numerical, urban microscale model SkyHelios. The model is suitable to predict the meteorological outdoor conditions of future building- and local climate- scenarios. Our investigation showed that the different thermal indices are not so different and differ mainly in the areas where the modification of radiation and wind is most prominent. These are also precisely the zones in which automated clothing becomes a key driving factor and differs among the indices. We want to emphasise, that in future it will be necessary to compare not only

	the thermal indices with each other, but also the underlying implementations of the indices and the higher-level urban microscale models. This will increase confidence these models, providing additional information for future action in heat action plans.
Charles Simpson	Do drought and urban dryness really protect against heat stress? Questionable conclusions from problematic metrics Several recent studies have suggested that because heat stress increases with humidity, droughts can be protective, and irrigation or urban greening could actually be harmful in terms of human health and thermal comfort. Such studies use heat metrics such as wet-bulb temperature or Steadman's heat index; but the many existing metrics do not operate on a common scale and do not necessarily have a one-to-one mapping with each other, making direct comparison difficult. We show that the conclusions of some of these studies are based on poor choices of heat metrics, and the opposite conclusion would have been drawn if a different heat metric were chosen. We argue the wet bulb temperature is especially inappropriate as a heat metric for these studies. We demonstrate a novel method for comparing the sensitivity to temperature and humidity of heat metrics that do not operate on a common scale by using partial gradients. By choosing heat metrics that are over-sensitive to humidity, researchers are biasing their studies towards finding that moisture is harmful even in relatively dry conditions. This is potentially dangerous as it incorrectly forecloses interventions which use moisture (directly or indirectly) to reduce heat in cities, and which can reduce heat-related mortality and morbidity. Therefore, researchers need to be more critical in their choice of heat metrics. This has significant implications for the evaluation of irrigation and urban greening as adaptive responses to climate change and urban heat.

Climate and Society 3 — VENTANA C

Adriaan Van der Walt	Trend analysis of cold extremes in South Africa: 1960–2016 Extreme cold events (“cold waves”) have disastrous impacts on ecosystems and human health. Evidence shows that these events will still occur under current increasing mean temperatures. Little research has been done on extreme cold events, especially in developing countries such as South Africa. These events pose a significant threat due to the low adaptive capacity, urgent development needs and relatively inadequate infrastructure in South Africa. This study presents annual and seasonal, spatial and temporal trend analyses of extreme cold temperature events for the period 1960–2016. We apply the World Meteorological Organisation Commission for Climatology and Indices Expert Team on Sector-Specific Climate Indices (ET-SCI) to South Africa for the first time, with comparison to the World Meteorological Organisation Expert Team on Climate Change Detection (ETCCDI) indices previously used in South Africa. The extreme cold indices are calculated using the RClimDex and ClimPACT, respectively. Trends were calculated using the non-parametric Mann-Kendall test, Spearman Rank Correlation Coefficient and Sen's slope estimates. A decreasing trend is found for annual cold spell duration and cold wave frequency, at rates of 0.10 days.day-1 and 0.02 events.day-1, respectively. Seasonally, the coldest day temperatures increased in autumn, with increases of 0.02°C. day-1 for the period 1960–2016. Regionally, increasing trends in annual cold spell duration days were evident in stations located in the Western Cape, Eastern Cape, and North-West Province, at a rate of 0.03 days.day-1. Increasing trends in cold waves were observed for stations in Northern Cape, Gauteng, KwaZulu-Natal and the Eastern Cape Province, at a rate of 0.01 events.day-1.

	These results contribute to the awareness and recognition of the incidence and duration of extreme cold events in South Africa, seeing that studies suggest that anomalously cold events may persist in a warming world.
Adam Kalkstein	Winds of Change: The Impact of Regional Sea Surface Temperatures on Spatial and Temporal Trends in Tornadoes across the United States Tornadoes pose a serious threat to human health and well-being and have been responsible for over 19,000 fatalities in the United States since the late 1800s. There have been well-documented spatial and temporal changes in tornadoes across the United States, with the most pronounced being a clear geographical shift to the southeast, away from the traditional "Tornado Alley." Recently, the mechanisms driving these observed changes have come into better focus and can partially be attributed to factors such as changing sea surface temperatures, atmospheric moisture, instability, and beyond. Despite an increasing body of literature concentrated on tornado trends across the United States, many unknowns remain, especially concerning smaller-scale features that might be contributing to the changes. Here, we first conduct a brief spatial and temporal analysis of tornado observations across the United States to clarify how and where trends are most prominent. Next, we examine regional sea surface temperatures in the Gulf of Mexico and corresponding surface meteorological conditions across the southeast United States to determine if sea surface temperature anomalies in certain locations of the Gulf of Mexico are more closely associated with surface meteorological changes and tornado counts. A better understanding of how regional sea surface temperature anomalies impact tornado outbreaks can hopefully lead to improved forecasting.
David M Hondula	Spatial Analysis of United States National Weather Service Excessive Heat Warnings and Heat Advisories Public heat alerts are important risk communication tools, but there has been no systematic analysis of how frequently they are issued or how patterns in alert frequency relate to regional climatology or heat–health impacts. We compiled and analyzed all excessive heat warnings and heat advisories (collectively, heat alerts) issued by the U.S. National Weather Service for 2010–19. Heat alert frequency was correlated to climatological indicators derived from reanalysis data aggregated to Weather Forecast Office (WFO) polygons and to estimates of heat-attributable mortality for 134 metropolitan areas. The type of heat alerts used and the frequency with which they were issued were highly variable. Across 77% of the country, heat advisories were the primary product issued. The median location experienced 2.3 heat alert days per year. Regions with the highest frequency (approaching 25 heat alert days per year) included the southern Midwest and Great Plains, as well as the desert Southwest. The 95th-percentile daily maximum heat index was the climatological indicator most strongly correlated with heat alert frequency across all WFOs ($r = 0.71$). Locations that issued heat alerts more frequently than would be expected based on climatology were primarily located along the Pacific coast; those that issued heat alerts less frequently than expected were in southern Texas and southern Florida, the latter of which includes multiple cities with high rates of heat-attributable mortality. Our results suggest that the public may be receiving mixed signals about the severity of the heat hazard, with some hotter locations particularly underserved by heat risk messaging.

Kelton Minor (VIRTUAL)	Extreme weather and human sentiment: Global evidence from 7.7 billion social media posts Climate change is increasing the magnitude of heat and precipitation extremes, posing diverse risks to mental well-being on a planetary scale. The spatial and temporal extent of many regionally intensifying stressors – including heatwaves and extreme precipitation events – demand new approaches for monitoring their complex human impacts and subclinical psychosocial responses. Here we link the lexical content of 7.7 billion tweets from 190 countries and over 43,000 unique counties with daily data on meteorological conditions and climate extremes in order to conduct a global natural experiment from 2015 to 2021. Exposure to plausibly random precipitation extremes and heatwaves consistently worsened expressed sentiments during the recent record compared to control days in the same location and time of year. A record reduction in the rate of positive online expressions from extreme precipitation and a record increase in the rate of negative expressions during heatwaves were both observed in 2021. Additionally, the 2021 Pacific Northwest heatwave in North America and the Western European extreme rainfall events both amplified negative sentiment and reduced positive sentiment by amounts far greater than the historical average heatwave and extreme precipitation effects observed between 2015 and 2020. Since climate change is shifting the extreme tails of most regional temperature and heavy precipitation distributions rightwards, the impact of more severe extremes on overt emotional states may far exceed those registered in the recent past, pending further adaptation.
Vera Vinogradova (VIRTUAL)	Heat waves on the territory of Russia and their impact on the population according to climate change scenarios for the middle of the 21st century According to IPCC 6th Assessment Report, the global surface temperature will continue to increase until at least mid-century under all emissions scenarios. Global warming comes with increasing frequency of extreme heat waves. The risks posed by extreme high temperatures are determined by changing climate but also depend on socioeconomic factors such as population density, urbanization level. We provide estimates of current and future population exposure to heat waves in Russian regions under the projection scenarios introduced by IPCC for the mid-21 century. Data from three CMIP6 models for scenarios SSP1-2.6 («soft») and SSP5-8.5 («hard»), which start in 2015 and assume different levels of radiation exposure by 2100, were used. Two indices were used, which together reflect the magnitude and duration of heat waves in summer: maximum daily temperatures and number of very warm days, i.e. number of days with maximum temperature above the 90th percentile of observed temperature in the base period. We also used estimates of the population of Russian regions according to Rosstat data for 2020 and forecast figures for 2050. Changes in the exposure of the population to the effects of heat waves are associated with both climate change and population changes. From our estimates, by the 2050, the area exposed to maximum daily temperatures above 30°C increases in Russia by 1.6–2.2 times from 12 to 18.7–26.7% covering most of European Russia and much of the southern Urals and Siberia. The aggregate population exposure increases by 1.8–2.5 times under the soft and hard scenarios respectively. Against the overall population decline, the growth in exposure is mainly driven by climate factor. The projections show a stronger exposure to extreme temperatures, especially for the Black and Caspian Sea regions and the Caucasus, where the absolute maximum summer temperatures exceed 35°C and 40°C.

Elena Grigorieva (VIRTUAL)	Social vulnerability to Cold climate exposure: Alaska as a case study Human health and well-being depend on the complex influence of many factors, one of which is the thermal state of the climatic environment. The thermal load on human body is an important indicator of climatic discomfort, especially in the extraordinary cold conditions of the Arctic, where extremely low temperatures are combined with strong winds. The purpose of the study is to evaluate social vulnerability to cold climates in Alaska as the northwestern-most state of the USA. Social vulnerability Index as a combination of climatic exposure, social sensitivity and adaptivity was estimated separately for seven Public health regions. Climatic exposure was expressed by Universal Thermal Climatic Index (UTCI) in the categories of cold and very cold thermal stress. Social sensitivity was presented as a combination of indicators showing groups of population mostly vulnerable to cold temperature extremes. Adaptive capacity was assumed as the ability of society to couple with a cold environment and was represented by social infrastructure and socio-economic indicators. UTCI data for 30 locations in Alaska were based on historical reconstructions of ERE5-HEAT at the Copernicus Climate Data Store for the period 2014-2019. Social and economic data on the population of Alaska are available from the US Census data. Health data such as statistics for cardio-vascular and respiratory disease for the same period can be found on the state Department of Health website data and statistics page. The results show that Northern Alaska and Interior are exposed to the highest level of climatic discomfort, but Anchorage has the best conditions for adaptation to them. The results of the interdisciplinary research on estimation of social vulnerability are a useful tool in warning stakeholders and decision makers when developing appropriate intervention procedures in the field of the health monitoring, minimizing population losses and guaranteeing social security for the Arctic communities.

Early Afternoon Parallel Sessions [1:30-3:00] VENTANA ROOMS A, B, C

Urban Biometeorology 5	**VENTANA A**
Charles Simpson	Multi-scale analysis towards personal heat exposure assessment in Southeast England Withdrawn
Rui Li	Repurposing Mesoscale Traffic Models for Insights into Traveler Heat Exposure Climate change is poised to increase people's heat exposure significantly, yet there remain limited insights into how individuals experience heat in conjunction with behavior and infrastructure. We developed a simulation platform - Icarus - to estimate travelers' heat exposure at both personal and population scales at the interface of travel behavior, microclimate, and the built environment. We first applied Icarus to the Phoenix metropolitan region as a case study using three different temperature measurements: air temperature (Tair), mean radiant temperature (TMRT), and wet bulb globe temperature (TWBGT). The case study analysis shows that travel patterns (such as trip duration and the trip start time) for different demographic groups affect personal and population heat exposure. Different temperature measures also resulted in widely varying estimates of

	personal heat exposure. We then estimated the effectiveness of active trip heat exposure mitigation under built environment and travel behavior change using TMRT, Activity-based travel model (ABM), transportation network, Local Climate Zones, and supplemental data. Active trips reduced TMRT by an average of 1.2°C to 3.7°C based on different scenarios when the networks were fully converted to the cool corridors as a built environment change. The marginal benefit of the cooling decreased from over 1,000 trips/km when less than 10 km of corridors were converted to less than one trip/km when all corridors were transformed. The results revealed that heavily traveled corridors should be prioritized with limited resources, and the best cooling results come from environment and travel behavior change together. This study provides the ability to inform urban design and planning changes by measuring the cooling benefits of active trips.
Negin Nazarian	Project Coolbit: can your watch measure ambient air temperature? Urban overheating, exacerbated by rapid urbanization and global climate change, is one of the key environmental challenges facing our cities. While there are widespread efforts for collecting highresolution datasets, there is still a lack of human-centric monitoring of urban heat focusing on the immediate environment of individuals as they go about their lives in cities. Project Coolbit aims to address this limitation by utilizing wrist-mounted wearable devices, such as smartwatches, to measure and crowdsource ambient air temperature. The wearable monitoring method (introduced in Nazarian et al. 2021) combines environmental and physiological responses to provide a more holistic understanding of the human experience in urban areas. Sensors placed on smartwatches are used to measure air temperature and relative humidity at the wrist, as well as the skin temperature and heart rate of individuals. These measurements are then compared with data captured by a highly-accurate mobile weather station - the MaRTy cart capturing 6-directional radiation and wind speed in addition to ambient temperature and relative humidity – and a prediction model for ambient air temperature is proposed based on the wearable datasets. The mobile weather station also allows us to quantify the biases in air temperature prediction, particularly as mean radiant temperature and wind speed are not captured by wearable devices. The ability to predict air temperature using wearable devices offers a new, more comprehensive, and personalized way of measuring urban heat impacts in cities. This information can further be used to better understand the thermal environment and design urban spaces to mitigate the effects of urban overheating. Ultimately, the data collected through Project Coolbit will help to understand the spatial variability of air temperature in urban environments and provide valuable information to create more livable, sustainable cities.
João Vasconcelo	Assessment of the thermal comfort in Lisbon through the application of roving missions In Urban Climatology the use of roving missions is a way to observe, collect, and evaluate environmental, physiological, and psychological data at the street level. In Lisbon, for this effect, a mobile compact weather station equipped with several sensors, a data logger, and a GPS is being used to measure and collect the city environmental conditions. The roving missions in Lisbon are intended to evaluate the pedestrian thermal comfort in different times of the day and in different types of urban areas such as compact, open and green spaces. For this purpose, the environmental data, namely the UTCI and the PET indices will be used to evaluate the outdoor human thermophysiological comfort. They will

	be analysed on a spatial level, according, for example, to the local climate zones, to the HW ratio, to the urban volumetry, to the compactness and the urban density. Further variables, such as a shading model and the mean radiant temperature will also be calculated for usage in a Linear Mixed Model. This model will allow the understanding of how the different urban morphology characteristics influence thermal stress conditions. In addition, surveys are being applied to volunteers during the roving missions as to understand their thermal perception and sensation. The results will be evaluated according to the seasons, weather types and the urban morphology. The goal is to build a georeferenced and replicable method able to monitor and map urban microclimate variations. This new microclimatic knowledge, together with the assessment of natural-based solutions, may be helpful for heat stress mitigation policies for the urban environment.
Dragan Milosevic	Application of Mobile Micrometeorological Carts (MMCs) and remote sensing for assessment of biometeorological conditions in Novi Sad (Serbia) The climate risk profile and climate change projections indicate that Serbia will face a high probability of continued temperature increase, which will be intensified in urban areas due to the urban heat island effect. To develop heat mitigation strategies and guidelines for Serbian cities, detailed spatial and temporal micrometeorological data are needed. These data are crucial for tracking extreme heat and evaluating heat mitigation potential of different urban solutions. Novi Sad Urban Climate Research Team has developed Mobile Micrometeorological Carts (MMCs) to track the heat that affects the health, comfort and well-being of local population. MMCs are equipped with sensors for air temperature, relative humidity, wind speed and direction, globe temperature, global radiation, and six-directional short- and long-wave radiation measurements with detailed spatial and temporal resolution (2 minutes). Field campaigns were conducted in Novi Sad (Serbia) on hot days during the summer of 2022 to quantify biometeorological conditions across the city. Micrometeorological data were obtained using: 1) Two MMCs; 2) Six Kestrel 5400 Heat Stress Trackers; and 3) LANDSAT remote sensing images of Novi Sad. MMCs were used to obtain data at pre-defined locations on selected routes, while Kestrel Heat Stress Trackers were deployed in specific microclimate zones. In addition, remote sensing data from LANDSAT were used to obtain the land surface temperature distribution in the city. Biometeorological conditions and heat mitigation potential were obtained by comparing biometeorological data at the reference location (e.g., sun-exposed urban squares) with biometeorological data at natural locations (e.g., under different street trees, in urban park), shaded locations by urban form (e.g., street canyons) or shaded locations by engineered/lightweight solutions (e.g., building overhangs). Based on collected data, the biometeorological conditions and heat mitigation potential of different urban solutions and strategies were quantified.

Human Biometeorology 2	VENTANA B
Jennifer Vanos	Extreme Heat in a Changing Climate: A New Approach to Assess Human Survivability and Livability Extreme heat can have devastating impacts on human health, causing avoidable deaths and adverse impacts on work and life. Most studies projecting future limits to human habitability due to increasing extreme heat use a wet-bulb temperature (Tw) threshold of 35°C and assume inevitable death from heat stroke after six hours, missing critical physiological and behavioral variability. More robust methods are needed to establish global survivability and livability under increasing heat stress. This study applies human heat exchange principles across two subpopulations (younger and older adults), with or without sweat rate impairments due to aging or chronic disease. Three or six hours of constant heat exposures are used to project 1) heatstroke death (survivability) using a physiologically-relevant critical core temperature (43°C); and 2) the maximum safe work capacity (livability) before unchecked rises in core temperature occurs. Livability estimates are made across combinations of projected air temperature, relative humidity, and solar radiation under contemporary and projected climates globally. Survivability results show that the Tw=35°C habitability assumption is implausible for heat exposure in hot-dry conditions, whether shaded or sunlit, yet is plausible for humid and shaded conditions. The physiological limit to survive for young adults corresponds to a Tw ranging from 18.5–29.9°C for young adults and 16.1°C–26.9°C for older adults, which is 5.1–16.5°C lower than the 35°C assumption. Climate projections show a greater decline in livability in dry climates through end-of-century, indicating a consistent and declining ability to perform safe activities in the future. Findings indicate that heat-health risks—from livability to survivability—are likely greatly underestimated in many regions, particularly hot and dry, and for older adults. Including the complexities of the human body in heat-health climate projections provide a more robust and realistic assessment of risks for supporting increasing investments in heat adaptation for vulnerable groups and regions.
Daniel J. Vecellio	Skin wettedness as a limiting factor to heat stress compensability The evaporation of sweat excreted onto the skin is the most important contributor to body cooling and maintaining thermal equilibrium during exposure to extreme heat. The proportion of the body that is covered by sweat at any given time is defined as skin wettedness. A maximum skin wettedness value of 1.0 (full body coverage) is considered attainable for acclimated individuals, but that value drops to 0.85 for unacclimated persons. A popular, theorized upper threshold for human thermoregulatory tolerance to extreme heat (a wet-bulb temperature of 35°C) assumed free evaporation from a body fully covered in sweat, however, empirical laboratory studies have found that that threshold overestimates human heat stress compensability. One reason for this downward shift in thermoregulatory capacity may be due to sub-optimal skin wetting, leading to a decreased ability to dissipate heat at maximum efficiency. Here, we examine variability in calculated skin wettedness values across a range of temperature and humidity regimes (warm-humid to hot-dry) and across two separate metabolic rates (minimal

	activity [MinAct]: 83 W/m2; light ambulatory [LightAmb]: 133 W/m2) given the known connections between sweating, air temperature, and exercise intensity. Additionally, we use partitional calorimetry to determine what physiological and ambient factors control the magnitude of skin wettedness in different environments and work rates.
Adriaan Van Der Walt	Daytime heat stress across southern Africa according to the Universal Thermal Climate Index (UTCI): an analysis of the climatology and trends for 1979-2021 The 6th Assessment of the Intergovernmental Panel on Climate Change projects increasing thermal-associated morbidity and mortality under anthropogenically-induced warming. Over 100 indices exist to quantify thermal stress, and among these, the Universal Thermal Climate Index (UTCI) was developed for regional investigations of outdoor thermal stress influences on human health. Although by definition a universal index, current applications are mainly limited to Europe. Over Africa, the UTCI use has been hampered by a lack of available requisite input variables from ground-based meteorological stations. To overcome this, a gridded dataset, derived from ERA5 reanalysis, of UTCI equivalent temperatures was developed by the European Centre for Medium-Range Weather Forecasts. Using this dataset for daily maximum UTCI values, we explore spatiotemporal patterns and changes over annual and monthly scales across southern Africa from 1979-2021. Across these scales, five of 10 UTCI thermal stress categories were observed, ranging from slight cold stress to very strong heat stress. Annually, moderate and strong heat stress spanned an 85.7% extent, with the remaining area characterised by thermosphysiologically acceptable conditions. During summer months (December-March), moderate to very strong heat stress spanned roughly 98%, whereas during winter months (June-August) moderate to strong heat stress spanned 34.3% (July) to 62.2% (August). Interannually, a clear El Niño Southern Oscillation influence on thermal stress was evident during summer months, with El Niño (La Niña) phases extending (reducing) heat stress incidences by up to 4.6%. Over the study period, heat stress increased at statistically significant rates in many instances, with the strongest, most widespread increases during the September and October spring months, where UTCI equivalent temperature trends increased by up to 0.9°C.decade-1. The results reveal regions vulnerable to day-time heat stress and increases thereof, highlighting where and when preparedness and response plans regarding heat stress should be considered for outdoor work and leisure activities.
Gisel Guzman Echavarria	A Physiological-based Weather Categorization of Extreme Heat Days in the U.S. to determine Regional Personal Cooling Needs Climate-classification systems provide information about the average atmospheric state in a location for various purposes. Common systems are not practical for understanding and preventing heat illness or determining appropriate city- and individual-level cooling strategies. In warm-humid weather, the body's evaporative cooling capacity is a limiting factor in achieving thermal equilibrium, but convective heat loss may be effective. Conversely, evaporative cooling is more effective in warm-dry weather, yet a person's sweating capacity is limited, and dry-heat heat gain dominates. Here, we assess differences in human thermo-physiological response to heat, either by heat or moisture/humidity magnitude, to

	create a physiology-based climate classification using a biophysical human heat balance model. The classification is applied to major U.S. cities. “Heat typologies” were classified into four categories, from “very hot and dry” to “very hot and humid.” Using data from HadISD weather stations and simulated radiation from NSRDB, we estimate the percentage of time when the hottest 10% of the daytime hours fall into each heat category (using a 2000-2020 baseline). Focusing on heat stress mitigation, we explored different criteria to separate the impact of moisture (based on the thermodynamic processes) and magnitude of heat stress (based on the physiological feasibility of cooling via sweat evaporation). The human-heat exchange model applied to healthy adults reveals that a region can experience multiple types of heat throughout its warmest weather. However, in the eastern half of the U.S., the dominant heat category is hot and humid, while dry heat prevails in the west. Further, there is a sub-estimation bias in heat stress severity when disregarding radiation exposure in the analysis. Findings align with physiological theory and are intended to create tailor-made criteria for personal heat stress and strain mitigation strategies under present conditions with potential to expand the classification globally.
Konrad Rykaczewski	Impact of Human Body Shape on Convective and Radiative Heat Transfer Predicting the human thermal comfort and safety requires a quantitative knowledge of the convective and radiative heat transfer between the human body and its surrounding. Our current understanding of these process is mostly based on measurements or simulations of adults with “average” bodies. However, most of us are not "average" and what an "average" body shape is varies across regions and cultures. To this end, we have developed sixty human body models that represent the 1-99 percentile body mass index (BMI) and height diversity of the adult population of the USA [1] and have simulated their convective and radiative heat exchange with the surrounding. As a metric of the radiative heat exchange, we simulated the effective and projected radiation area factors for all the manikins. We found that appreciable relative differences from the average models only emerge for manikins with BMI above 80th percentile. However, these differences only occur at low zenith angles and are small as compared to variations induced by, for example, the zenith angle increase. For the convective part, we developed a coupled turbulent flow and convective heat transfer simulation and benchmarked it against prior literature. With representative airflow with 2 m/s and 5% turbulence intensity, the height of the manikins had a negligible impact while an increase in the BMI led to a nearly linear decrease of the heat transfer coefficient. Evaluation of the local coefficients revealed that those also nearly linearly decreased with BMI, which correlated to an inversely proportional local area (i.e., cross-sectional dimension) increase. However, even the most considerable difference that exists between 1st and 99th percentile BMI manikins is less than 15% of heat transfer coefficient of the average manikin. Thus, it can be concluded that the impact of the human body shape on the convective heat transfer is minor.

Climate and Society 4	VENTANA C
Mary Munoz Encinas	HeatReady Schools as a complementing tool for FEMA Safer, Stronger, Smarter: A Guide to Improving Natural Hazard Safety. The White House's School Infrastructure Toolkit FEMA P-1000 Safer, Stronger, Smarter: A Guide to Improving School Natural Hazard Safety provides guidance on school operations (before during and after an event) and on the physical protection of school facilities. Extreme heat, the deadliest weather event in the United States, is not considered in this list of natural hazards. The FEMA School Toolkit's focus is on disasters that pose a direct threat to the structural integrity of schools' buildings, showing a gap in the available information in the area supportive measures for staff and students, which allow schools to prepare for and properly function during a natural disaster. This gap can be addressed by the HeatReady Schools Tool, which aims to establish what a HeatReady school is and how it operates effectively in preventing, mitigating and adapting to the complex effects and challenges of extreme heat. HeatReady Schools provides a template that complements FEMA's school guide's comprehensive approach, in order to equip schools with tools and resources to be able to prevent, adapt to, mitigate, track, and respond to the effects of extreme heat. The HeatReady Schools tool used along with the general FEMA guidance on natural hazard protection for schools could provide a more complete picture of adapting schools for disasters relevant to their community.
Ariane Middel	Science-Policy Disconnect: Perspectives on Co-benefits, Trade-offs, and Disservices of Heat Mitigation Strategies Written communication of and between scientists and practitioners is key to building resilience against human health threats such as extreme (urban) heat. Urban heat mitigation demands transformation in ways of thinking and asks to involve actors from outside academia. The goal is to create usable science by crossing traditional boundaries using a diverse range of actors and agencies to integrate the best available knowledge into policy-making. Scientists and practitioners as two relevant stakeholders in the process of the creation of usable science are expected to have diverse and potentially competing views on urban climate governance including heat mitigation strategies and how they are communicated. The disconnect between the understanding and communication of the same topic between science (basic; knowledge producers) and practice (applied; knowledge users) is considered the basic-applied paradigm or science-policy disconnect. This work showcases the results of a systematic literature and content analysis to determine the science-policy disconnect in the written word and understand the different perspectives on the environmental, social, and economic impacts of green infrastructure (GI) and reflective pavement (RP) as heat mitigation strategies in the scientific peer-reviewed literature and US urban practitioner literature. The study identifies the impacts for GI and RP provided by each stakeholder and compares the findings between the strategies and stakeholders. The outcomes of this study add to the understanding of GI and RP, and to the understanding of options to bridge the science-policy disconnect on heat mitigation strategies, thus contributing to urban climate governance. Identifying these differences and integrating knowledge from different agents is critical to inform future

	transformational ways of thinking to inform the creation of usable science in urban climate and urban climate governance.
Elizabeth Doran	Understanding Heat Risk Perception and Adaptive Capacity in the General Population of the Northeast Extreme heat has been the leading cause of weather related mortality in the United States for the past thirty years with vulnerable populations including the elderly, young, and low income considered particularly vulnerable. While extreme heat events receive a significant amount of attention, the majority of heat related illness and death occurs outside of those events. Despite this general scientific understanding of the risks and impacts, as the climate continues to rapidly warm differentially around the country, regional differences in the public perception of risk and tolerance for adaptive action have been less well studied. The Northeast US, for instance, is one of the fastest warming regions of the country and also has a relatively older population, older housing stock that lacks air conditioning and rural development pattern compared to generally hotter parts of the country or large urban centers. To better understand the public perception of extreme heat, risk tolerance and adaptive action in the general population of the Northeast, an online stratified survey of Vermonters was conducted in the late summer of 2022. Questions were designed to leverage insights from the social-psychological theories of behavior change including the theory of planned behavior and the transtheoretical model. Findings provide insight into the public's perception of extreme heat, use of National Weather Service heat warning information, existing strategies for short term exposure mitigation and potential for long term adaptive actions. Findings can inform program design and intervention strategies including outreach campaigns to reduce the public health burden from heat.
Melissa Guardaro	The Promise of Resilience Hubs Frontline communities are the most impacted by climate change, are under-resourced and overburdened by climate disturbances and take longer to recover from these events. Resilience hubs, trusted community spaces that provide regular programming, can spring into action during a crisis to keep neighbors safe. Further, they can ease the complexity of recovery by activating robust mutual aid networks and by acting as a conduit for information and resources. The term "resilience hub" is an evolving concept. The goal of a resilience hub is to have the community design their neighborhood destiny, with cities in the helper seat. This requires a shift in power dynamics with stakeholders trusting that communities know what is best for themselves, have the knowledge to solve these issues, and have the capability of managing funding, which they control, to execute their ideas. The promise of resilience hubs is to shift the dynamic from a community that is highly impacted by disturbances and disasters, waiting on government resources to address these issues, to one that grows stronger with each event. Using urban heat as an example, resilience hubs can operate as cooling centers during extreme heat and provide refrigeration for medications and distribute food and water during heat waves and blackouts. Neighbors learn who is most vulnerable while distributing heat health safety information and can plan to watch out for them during the next heat wave. The resilience hub can be the central point to understand evidence-based heat mitigation

	and adaptation solutions; neighbors can then decide which is most appropriate for them and advocate accordingly. Funding becomes important to not only restore losses during climate events but also to build a stronger future and a higher quality of life for all community members.
Morgan Rogers	Cool by Design: A case study on design attributes contributing to heat burdens in schools and residential areas Extreme heat is a major public health and climate justice issue facing Californians. Children as a population are more vulnerable to the health impacts of heat exposure, and children in low income neighborhoods and communities of color in particular are disproportionately impacted by extreme heat. This study examines how urban design influences the human experience of heat in Pacoima, a neighborhood in San Fernando Valley of Los Angeles, which is listed among the 25% most vulnerable areas within California by CalEPA. We examine conditions both in a residential block and in a school, where children spend most of their time during the week. To analyze design factors contributing to or decreasing the heat burden in both study areas, we took field measurements of several urban heat indicators and developed microclimate models based on these measurements. We found the primary factor in reducing heat burden is shade. While both the residential block and the school had low shade coverage, lack of shade was especially pronounced in the school with less than 20% shade coverage throughout the day and less than 10% during the midday recess period. This study suggests that school design does not provide cooling in high use areas or times of day, leaving children vulnerable to extreme heat, especially during recess. Increasing shade will be a critical design strategy in reducing the heat burden both in the neighborhood and within the school.

Late Afternoon Parallel Sessions [3:30-5:00] VENTANA ROOMS A, B, C

Plant Biometeorology 1	VENTANA A
Cameron C. Lee	Investigating multivariate surface air masses as drivers of tree growth Research examining the meteorological components impacting annual tree growth is often limited to using temperature, precipitation, and/or drought indices. However, drawing from other realms of biometeorology – especially human thermal comfort – we theorize that living organisms are less exposed to an individual weather variable acting in isolation, but rather more-so exposed to the entire suite of meteorological elements – an air mass (AM) – acting synergistically to impact the organism. To test this hypothesis on tree growth, this research utilizes the global-scale gridded weather typing classification to examine how AMs impact tree ring widths (TRWs) across 900 different sites in the Northern Hemisphere. Results show that TRWs are significantly impacted by the frequency of these multivariate AMs, especially in the period from July of the year prior to the tree ring's growth (Year-1) through June of the growth year (Year0). The

	two most important AMs are the Humid-Cool AM and the Dry-Warm AM, which exhibit average correlations of +0.4 and -0.4 with TRWs, respectively, for certain tree species. In addition, when compared to artificial neural network (ANN) models that utilize temperature and precipitation exclusively to predict TRW, the ANN models that instead used AM frequencies to model TRW proved superior at nearly 60% of the 900 locations, and for over 80% of the sampled species with adequate sample sizes (n>10). While the TRW database currently available tends to oversample the Northern Hemisphere, these results nonetheless form a foundation for future research to utilize AMs to improve predictions of tree growth, tree stress, and wildfire potential in forests around the globe. Moreover, it may be feasible to use TRWs as proxy records to reconstruct long-term records of AM frequencies back several centuries in well-sampled parts of the globe.
Geoffrey Henebry	Land Surface Phenologies in Grazed Montane Grasslands Observed at Multiple Scales: Challenges, Caveats, and Opportunities Are there optimal scales at which to observe land surface phenologies? Appropriate answers to this question must address the relevant scales including spatial, temporal, spectral, and radiometric resolutions as well as the type of biome, vegetation communities, land uses, and landscapes that constitute the specific targets of interest. Here we explore multi-scale observation and modeling of land surface phenologies in grazed grasslands in the highlands of rural Kyrgyzstan. We focus our attention on “NARYN”, an area for intensive observation (nominally 5m, ~2-3d) by the VENµS mission during 2018-2020. In addition to the rich VENµS time series, we pull in observations from Landsat (30m, every 8-16d) and the Planet-Fusion product (3m, 1d). Our LSP modeling framework fits to each vegetation index (VI) pixel time series a downward-arching quadratic function of thermal time rather than calendar time. We model LSP using three complementary VIs—NDVI, EVI2, and WDRVI—that had been smoothed using a Savitzky-Golay filter with window size of 5 or 7 observations. We calculate accumulated growing degree-days from MODIS land surface temperature products (1km, 8d composites) to measure thermal time. The modeling framework includes quality criteria, an iterative fitting phase, and modeling diagnostics. From the successful fits, we use the fitted parameter coefficients to calculated three phenometrics: PH, the modeled peak VI value; TTP, the thermal time to the VI peak; and HTV, the VI value at half the TTP. We generated the resulting phenometrics at 12 sites with the NARYN frame. At each site, we look at distributions of phenometrics associated with 50m radius buffer to examine how change of scales influence model fitting and phenometric values. We compare our results with the different phenometrics of the MODIS MCD12Q2 product. We discuss the challenges, caveats, and opportunities that multiscale LSP modeling presents.

Alison Donnelly	Characterizing temperate deciduous shrub and tree phenology Traditionally, phenological research in temperate deciduous forests tends to focus on upper canopy trees, due to their overwhelming influence on ecosystem productivity and function. However, since understory shrubs leaf-out before trees and remain green longer into the autumn season their contribution to ecosystem productivity, particularly, at the extremes of the growing season cannot be ignored. Furthermore, an extended growing season of non-native shrubs has been cited as providing a competitive advantage over native shrub species. In this study, we monitored (2017-2021) spring and autumn phenology of five tree species, four native and three non-native shrubs growing together in an urban woodland fragment in Wisconsin, USA, to determine how phenology differed between the plant groups. Our findings suggest that the phenology of non-native shrubs may not always differ from native species particularly in spring and differences between groups is site specific and determined by species composition. A longer time series is necessary to understand the long-term impacts of climate change on both native and non-native shrub phenology in the wild and how this might impact, species composition, plant functional groups and other organisms they support.
Claudia-Helena Giraldo-Escobar	Recording phenological observations in Eucalyptus species: an approach to capturing intrinsically complex and entangled data Complex is a term required to describe the diversity of flowering phenology within the Eucalyptus genus (eucalypts). Studying reproductive phenology in eucalypts requires a different approach than those used for northern-hemisphere temperate tree species. For instance, (1) the length of the reproductive phenological cycles in eucalypts can last 6-8 years versus the typical annual cycle; (2) eucalypts may flower several times during the cycle leading to multiple cycles (i.e., cohorts) occurring on a tree simultaneously; (3) flowering frequency varies from 6 months to four years or more; (4) flowering time does not always coincide with spring (i.e., flowering can initiate in different seasons depending on species or genotype); (5) in some species, the effect of warming temperatures leads to delayed flowering, contrary to the generalized advancement; (6) the duration of flowering is particularly long, a single flowering event may last 2-9 months; and, finally, (7) the intensity of flowering events varies greatly from year to year, cycle to cycle. Accordingly, we propose that phenological observations of eucalypts must record the abundance of assorted reproductive structures in a way that includes several development stages of flowers and fruits, which also must be discriminated by the cohort cycle. This will allow the researcher to reconstruct and predict the frequency, timing, and intensity of phenological events from the field and herbarium records to characterize the reproductive phenology in response to environmental variability and change.

Susanne Jochner-Oette	The network of the International Phenological Gardens of Europe – an update Climate change has vast impacts on nature and the best-known and classic example is the change in plant phenology. There is a strong statistical correlation between phenological onset dates and temperature measured prior to those events. Deviations from this relationship are often explained by genetic variations of different individuals of a tree species. To exclude this influence, Fritz Schnelle and Erik Volkert have established the network of the International Phenological Gardens of Europe (IPG), which presents a unique database that is investigated by various researches all around the globe. Gardens in this network receive trees and shrubs that were vegetatively propagated from plants in a mother garden. Until now, over 120,000 phenological observations of 23 species were collected and currently more than 60 active IPGs contribute to this database. In this presentation, we review the history, aims and potential of the IPG network and present some selected results. We demonstrate to what extent such data can illustrate the effect of climate change on different plant species, i.e., change in the timing of first flowering or leaf unfolding. As the scientific coordination of the network was recently passed over from the Humboldt University of Berlin (F.-M. Chmielewski) to the Catholic University of Eichstätt-Ingolstadt, we also present the new webpage and database for the entry of phenological data.

Human Biometeorology 3	**VENTANA B**
Chris Fuhrmann	Using a web-based tool to forecast local variations in wet bulb globe temperature Extreme heat is the leading cause of weather-related morbidity and mortality globally. Though many different groups are vulnerable to extreme heat, outdoor workers and athletes are particularly susceptible due to increased metabolic heat production and frequent outdoor exposure. This has led to the development of heat mitigation strategies and safety guidelines, an increasing number of which utilize wet bulb globe temperature (WBGT) to estimate environmental heat stress. WBGT accounts not only for the effects of air temperature and humidity, but also wind speed and radiation, which includes both solar and infrared radiation. On hot days there is often considerable variability in WBGT across short distances, from 10s to 100s of meters, due to differences in insolation (e.g., shading) and surface characteristics (e.g., topography, tree cover, surface roughness, proximity to water). The Southeast Regional Climate Center (SERCC) has developed a web-based tool for forecasting WBGT that is increasingly used in high school athletics to assess risk for heat stress and set activity guidelines. Field work, however, has revealed a need for more granular estimations of WBGT to account for local variability in heat exposure. In this presentation, we share results from field work that illustrate local variations in WBGT within rural, urban, and suburban environments in the Southeast U.S. We show how the incorporation of these local variations into the SERCC WBGT tool improve the accuracy of WBGT forecasts.

Joseph Karanja	Thermal Discomfort for Unhoused Communities using different Tent Materials The unhoused population is highly predisposed to severe atmospheric conditions translating to increased health outcomes. The homeless population in Maricopa County, Arizona accounts for approximately 40% of heat-related deaths, which could further rise given the projected increases in heat frequency, duration, magnitude, and intensity. One of the coping mechanisms for the homeless is to cover their tents as a means of cushioning against extreme heat. This research conducted a 3-day experiment using six different tent cover materials that are frequently used namely; mylar, white bedsheet, tarp, sunbrella fabric, aluminum foil, and a control tent that did not have additional cover material. Two kestrel drop sensors per tent were programmed to collect readings every 5 minutes and the tent averages were compared to the control tent. The models used were controlled for ambient temperature, time of the day, wind speed, relative humidity, and wind chill. Considering the daytime, all the tents had higher temperatures compared to the control tent and ambient temperature conditions. However, during nighttime, sunbrella, tarp and bedsheet had lower temperatures compared to ambient temperatures, but all the tents had higher temperatures than the control tent. These findings suggest that additional tent cover materials result in increased heat risk. Further, the findings are crucial for rescue missions, local governments, public health officials, and general donors from the public to avoid adding cover materials during the summer as it worsens heat vulnerability for the unhoused. Local government officials should pay attention to the tent cover materials as a first step in safeguarding the unhoused populations from disproportionate heat-health outcomes.
Milica Pecelj	Assessment of Outdoor Thermal Comfort in Belgrade (Serbia) During Marathon Performance It is well-known that weather and climate have a great influence on marathon running performance. Participating in such outdoor urban event requires tremendous physical effort and expose athletes to various thermal conditions. Heat stress is certainly one of the most common challenges. This article discusses the thermal conditions during the marathon performance in Belgrade from 1990 to 2019. The aim of the study is to determine the level of heat stress for each day of each year that the marathon race was occurred and how it relates to the best result achieved for each year. The research is conducted using Wet Bulb Globe Temperature (WBGT) and Universal Thermal Climate Index (UTCI) indices based on an hourly (14:00 CET) meteorological data set for particular days when marathon performance was occurred.
Leonardo Brandão do Prado	Outdoor thermal discomfort: A case study of street vendors in the periphery of Rio de Janeiro In the field of extreme event attribution (EEA), increasing global warming made cities much more vulnerable to hazards such as heat waves and extreme heat. People who work indoors have access to thermally controlled places and are less exposed to extreme heat climate events. However, in Brazil, the number of people working outdoors continues growing in cities like Rio de Janeiro and São Paulo. This study focuses on street vendors in the periphery of Rio de Janeiro and evaluates how exposed to extreme weather events those people were during their work in 2021. To achieve this objective, five alternative meteorological stations were used to measure temperature and humidity in different neighborhoods during 2021. We used the Pandas library in Python to manage the data and identify thermal comfort classes during the work schedule (6:00 a.m. and 6:00 p.m.).

	This study used an effective temperature index adapted to tropical weather. We found that street vendors were exposed to 2794 hours of thermal discomfort in one year, of which 2444 hours were in thermal heat discomfort (55,7% of the total hours). It was possible to verify that the scale of “comfortable”, which represents the other 44,3% was inflated to atmospheric systems that cause cloudy and rainy days with an average duration of 2,3 consecutive days. More than thermal discomfort, the continuous hours of heat exposure associated with social vulnerability enhance health problems for these workers that already have bad eating habits and drinking water access. As widely discussed, state interventions such as: urban climate mitigation approaches like shading, ventilation, green infrastructure, thermal properties of surfaces, and albedo could help these people. Nonetheless, the city hall has historically neglected the suburban areas to the detriment of the most valued regions of the city.
Sam Chambers	Heat-Related Death as a Function of Physical Exertion and Border Policy in Southern Arizona Late-breaking submission; no abstract.
Henno Havenga (VIRTUAL)	Healthy Environments for Athletes, a pilot study to understand environmental impacts on endurance athletes in South Africa. Every year, since 1921, the Comrades Ultra Marathon has taken place between the cities of Pietermaritzburg and Durban in South Africa. In the last two decades, over 10000 participants have started the 89km event, making this the largest ultra-marathon event in the world. In 2022, the event resumed after an hiatus as a result of COVID-19, the event was subsequently moved from it's traditional date in mid-June, too late August, which promoted some caution on the possible changes to the expected weather condition. To better understand the event day conditions, weather stations, particulate matter measurements and a pollen counter were placed at key positions, close to timing mats and medical facilities along the route. This allowed the first measurements of environmental conditions at a very local level for the Comrades marathon, along with data from medical tents, we hope to relate specific environmental conditions to incidences of injuries along the route. The paper presents the novel measurement campaign and the newly formed Healthy Environments for Athletes (HEAT) project to be conducted in South Africa with support from local sport bodies. The project aims to improve awareness and early warnings to ensure safe participation of athletes in local conditions.

Climate and Society 5: Special Session on Heat Wave Ranking **VENTANA C**
Short presentations with panel discussion

Greg Wellenius	Moderator
Yuval Baharav	Why categorization? Impetus and worldwide implications
Laurence S. Kalkstein	Heat wave categorization based upon human health outcomes: Results from year one pilot projects.
Rebecca Rose	Pilot results for Seville categorization: evaluation
Eleni Myrivili	Real-world application of a categorization system: utilization in Greece
Peter Mitchell	How categorization is perceived by the general population