On the applicability of urban canopy parameterization in building grey zone

Anurag Dipankar

Song Chen [1] chen_song@nea.gov.sg
Anurag Dipankar [2] anurag.dipankar@c2sm.ethz.ch

1. Centre for Climate Research Singapore, Singapore
2. Institute for Atmospheric and Climate Sciences, ETH Zürich

With increasing interest in urban meteorology and related services, the need to appropriately represent the urban environment in climate/weather models is given. These (regional) weather/climate models typically use a km-scale horizontal grid, which is not sufficient to resolve the flows around the buildings. Effecets of the urban environment on the atmosphere above are represented through a bulk approach using the Urban Canopy Parameterization (UCP) schemes. All existing UCPs use the repeating canyon-roof representation that assumes homogeneous distribution of buildings within the grid box. It is commonly accepted that the assumption of homogeneity holds at km-scale grid resolution but issues may arise at sub-km scale. This led Barlow et al. (2017) to use the term "building gray zone", analogous to "turbulence gray zone", to describe the scale(s) at which we need to resolve the large building blocks.

While there are such discussions in the existing literature, no systematic study has been done to pin-point the resolution at which the said assumption of homogeneity really breaks down. This is the motivation of the present work. Using a novel approach that allows one to separate the model grid from the grid used by the UCP, we show that indeed using UCP at sub-km scale grid resolution, as opposed to km-scale, leads to significant differences in the near surface variables and boundary layer structure. Although these differences the significant, they may still be small to affect the scientific findings of the previous works that have used conventional UCPs at sub-km scale gird resolution.

Our aim through the present work is to raise concerns over this issue so that the community is cautious when using conventional UCPs at sub-km scale resolutions or interpreting results from such simulations.

Urban high-resolution temperature downscaling based on satellite imagery, weather station data and NWP model data

Nico Bader

Nico Bader [1] nico.bader@meteoblue.com
Sebastian Schlögl [1] sebastian.schloegl@meteoblue.com

1. meteoblue AG, Switzerland

Today, more than half of the world’s population lives in urban areas and the proportion is projected to further increase in the near future. The increased number of heatwaves worldwide caused by the anthropogenic climate change may lead to heat stress and significant economic and ecological damages. Therefore, the growth of urban areas in combination with climate change can increase future mortality rates in cities, given that cities are more vulnerable to heatwaves due to the greater heat storage capacity of artificial surfaces towards higher longwave radiation fluxes.

Typically, the initial condition of urban air temperature field in NWP models are not represented well, as standard WMO stations are typically located outside the city, where air temperatures normally are lower than in the city center. Hence, NWP models tend to underpredict the air temperature in urban areas by about 1 K as the coarse resolution of the NWP model cannot resolve the urban heat island effect good enough. This study focuses on the analysis of the year 2020 for 15 European cities. It quantifies the statistical downscaling model improvement over an NWP model by a) including dense air temperature measurements in the urban and rural areas, b) including satellite derived variables as model input and c) including both dense air temperature measurements and satellite derived variables.

In a city with a dense air temperature network (a), the bias can be reduced to almost 0 K representing the urban heat island effect by air temperature measurements in the city. Including satellite derived variables as model input (b) the downscaling approach ensures to decrease the MAE by 0.4 K and to better represent the standard deviation. Extending the downscaling approach with a dense measurement network (c) the MAE is further reduced by taking better account of dynamic processes.

Dense air temperature networks in cities help to better understand the micro-scale air temperature field in an urban environment. These air temperature data train a statistical high-resolution air temperature downscaling model for urban environments in 10 m horizontal resolution. Complemented with official measurement stations, the statistical model can be transferred to other cities and used operationally to calculate hourly micro-scale air temperature fields. In addition to air temperature measurement data, the model is further forced by surface texture parameters from the polar-orbiting satellites Sentinel-2 and Landsat-8, high-resolution digital elevation models, and output parameters from meso-scale NWP models.

The statistical model approach enables to resolve high-resolution temperature fields in the past, making it possible to calculate high-resolution urban heat island maps. Furthermore, real-time temperature fields can help to significantly enhance the initial conditions for NWP models, thus improving forecast models in urban areas. A downscaling of a forecast can help decision-makers to identify local temperature effects easier.

Numerical simulation of summertime heat islands and nocturnal ventilation by drainage winds in Aschaffenburg, Germany

Saskia Buchholz

Meinolf Kossmann [1] meinolf.kossmann@dwd.de
Florian Steigerwald [1, 2] florian.steigerwald@dwd.de
Heike Schau-Noppel [1] heike.schau-noppel@dwd.de
Saskia Buchholz [1] saskia.buchholz@dwd.de
Oleg Panferov [2] o.panferov@th-bingen.de

1. Deutscher Wetterdienst, Department Climate and Environment Consultancy, Offenbach, Germany
2. TH Bingen - University of Applied Sciences, Bingen am Rhein, Germany

To support the City of Aschaffenburg in its development of a climate change adaptation strategy, numerical simulations of air temperature and wind fields under calm and cloudless summertime weather conditions were carried out using the three-dimensional urban climate model MUKLIMO_3. Aschaffenburg, the home of about 70.000 inhabitants, is located in hilly terrain in northwestern Bavaria, Germany at the exit of the Aschaff river valley. The model results with a spatial resolution of 50 m were used for the identification of urban heat islands and for the localisation of rural areas serving as the source areas of cold air during nighttime. Furthermore, the ventilation of heat prone urban quarters by nocturnal cold air flows has been examined via analysis of trajectories and volume fluxes of airflow in the lowest 50 m above ground.

Model results reveal pronounced heat islands in built-up areas. The maximum heat island intensity of about 4 K is simulated in the late evening in the city centre, which is in agreement with results from mobile measurements of a previous study. The strongest potential for nocturnal cold air formation is found in open country areas on various hill slopes around Aschaffenburg. While the nocturnal flow regime is initially dominated by thermally-driven down-slope winds and country breezes, a northeasterly down-valley wind in the Aschaff valley is established later in the night. The spatially complex and temporally variable drainage winds contribute to the nocturnal cooling of built-up areas and the heat island intensity is reduced to about 1 K before dawn.

Additional simulations of hypothetical urban development scenarios were carried out to study the effects of increased horizontal or vertical building density on the heat island development and nocturnal ventilation. Early in the night, the trajectory analysis revealed little changes in the ventilation of Aschaffenburg, because the stronger urban heat island and hence stronger forcing of country breezes partly compensates the effect of enhanced aerodynamic roughness due to increased building density. Later in the night, the amplification of the heat island intensity subsides and the increase in building density results in a noticeable reduction in ventilation.

Impact of green roofs on urban climate (ADAM Project)

Saskia Buchholz

Margarita Skoryi [1] margarita.skoryi@dwd.de
Saskia Buchholz [1] saskia.buchholz@dwd.de

1. German Weather Service

Cities and municipalities are facing a variety of challenges in the future. As climate change and its impacts will progress over the century, heat waves and droughts are predicted to increase in duration and intensity. Hence, adaptation measures have to be taken to ensure the wellbeing of the urban population regarding these alterations.

The expansion of green infrastructure is one possibility to counteract heat stress and the urban heat island during summer months. Through increased evaporation and transpiration due to more areas with vegetation and unsealed surfaces, as well as shading by trees, the air temperature can decrease, which has a positive effect on human thermal comfort.

The focus of the ADAM project, which is financed by Deutsche Bundesstiftung Umwelt (DBU), lies on the impact of green roofs on the urban climate. The city of Essen was chosen as model region for the urban climate model simulations with the microscale urban climate model MUKLIMO_3. In addition to the general input data that the model needs green roof specific data was generated on the basis of the spectral analysis of digital orthophotos. These include the spatial distribution of the green roof type i.e. extensive or intensive green roof and area for the current state and a maximum potential greening. A third state without any green roof is computed as a reference to the other two simulations. The potential cooling effect is then analysed by the change in air temperature, perceived temperature and both the latent and sensible heat fluxes.

Demonstration pavilion for microclimate mitigation measures

Marc Vonlanthen

Marc Vonlanthen [1] marc.vonlanthen@hefr.ch
Raphaël Compagnon [2] raphael.compagnon@hefr.ch
Jean-Michael Taillebois [2] jean-michael.taillebois@hefr.ch
Matias Caesari [2] matias.cesari@hefr.ch

1. Haute École d'Ingénierie et d'Architecture de Fribourg, Energy institute
2. Haute École d'Ingénierie et d'Architecture de Fribourg, Transform institute

Adapting to urban heat islands is one of the main challenges of today's urban planning. In practice, however, urban planners are confronted with many constraints (cultural heritages, transport and energy infrastructures, civil engineering) that may hinder the implementation of mitigation measures.

In this context, we present a concrete urban planning project conceived from the perspective of a microclimatic measurement demonstration pavillon (DP) at the street level. This DP was realized with the collaboration of the city of Fribourg, the cantonal climate plan and several local companies. The construction costs were covered by various financial supports, including a crowdfunding campaign. The latter was also intended to allow the awareness and the adhesion of the general public to this project.

This DP has a floor area of about 50 square meters and integrates relevant measures in terms of optimizing urban comfort for users. The roofs and facades are vegetalised, the shading is optimized, phase change materials are included in the infrastructure, water flows and misting systems are used, and porous ceramics are cooled by water evaporation. In addition, the choice of materials according to established sustainability criteria as well as energy autonomy through solar panels on the roof constitute the guiding framework of the project. The modular construction of the DP allows it to be easily moved to relevant urban areas and stored for colder seasons.

In addition to the mere implementation of mitigation measures, the DP was designed to contribute to social cohesion and user friendliness. Up to 20 people can be seated at the same time and enjoy the infrastructure that encourages communication and relaxation. A special effort was made to raise awareness among the population by means of didactic sheets informing about the mitigation measures of the DP and QR codes referring to data and to general information on urban heat islands.

For scientific purposes and to quantify the effect of the microclimate DP, measurement campaigns of relevant parameters (air and globe temperatures, wind speed, solar irradiation) were conducted indoors and remotely for comparison. These parameters should also allow the determination of thermal comfort indices reflecting the impact on users.

During the summer of 2021, the DP was exhibited at 4 sites in the city, in collaboration with the municipality. These sites were selected based on a previous study conducted by the authors. This study allowed to map the heat islands and to predict their evolution under different climate scenarios. In addition, in order to reinforce the awareness and social cohesion component of our approach, partnerships have been established with summer cultural events. These collaborations have allowed us to demonstrate the important synergies that street furniture can offer, not only from the perspective of mitigating urban heat islands.

Following the strong media impact of the DP, various follow-ups are planned for the summer of 2022. The automation of the measurements and the digitalization of the information will be reinforced. In addition, new sites are being discussed. Indicators to evaluate the social impact of this furniture should also be developed.

Modelling mean radiant temperature in complex urban areas using a convolutional network approach

Ferdinand Briegel

Ferdinand Briegel [1] ferdinand.briegel@meteo.uni-freiburg.de
Osama Makansi [1]
Thomas Brox [1]
Andreas Christen [1]

1. University of Freiburg, Germany

We present a novel method to model mean radiant temperature (T_{mrt}) in complex urban areas using a special type of fully convolutional networks - U-Net - for image to image processing. T_{mrt} is a driving factor of daytime human thermal comfort and underlies great spatial and temporal variabilities at scales of metres, especially in complex urban areas. Various micro scale (building-resolving) models exist to model T_{mrt} in urban settings. However, these models are computational expensive, albeit to varying degrees. This means, study area and time span modelled might be limited depending on spatial and temporal resolution. While this is sufficient for case studies where micro-level processes are modelled for different neighbourhoods in limited time periods, accurate micro-level calculations over long-time periods are not possible (e.g. downscaling global climate projections). To overcome these computational drawbacks of physical models, we present a U-net approach for modelling T_{mrt} in complex urban areas.

U-Nets were first used for biomedical image segmentation and need fewer training data as comparable architectures. U-Nets are special types of encoder-decoder networks, allow precise image to image processing and have recently been successfully applied to mesoscale meteorological tasks such as short- to medium-range forecasting of 500-hPa geopotential height, precipitation nowcasting or T_a downscaling. Training a neural network requires representational training data. In this study, T_{mrt} (at 1.1 m a.g.l.) is modelled by SOLWEIG for 62 areas of the City of Freiburg, Germany (each 500x500 m^2 at 1 m^2 spatial resolution) and for 51 days. Training data is sampled randomly after clustering. The spatial and temporal input of SOLWEIG are in turn used as input features for the U-Net. The U-Net is trained on 56 areas and on 46 days and tested on the remaining areas and days. In addition, data from a T_{mrt} measurement campaign in 2008 is used to validate SOLWEIG and U-Net model output. As evaluation metric (loss function) mean absolute error (MAE) is used.

First results indicate that the proposed U-Net approach is capable to model T_{mrt} in complex urban areas sufficiently. A correlation of > 0.9 and a MAE of 1.53°C between SOLWEIG and the U-Net is observed. Results show a higher MAE during day than night, which can be partly explained by the difference of absolute T_{mrt} values at day and night, but also by more complex prediction conditions during day: cloud cover and thus varying radiation, but also low sun angle in the morning / evening. In addition, computing times for T_{mrt} map predictions are significantly lower than then of physical models.

Excess Mortality in 8 Swiss Cities during the Summers 1947, 2003, 2015 and 2018

Christoph Kestenholz

Christoph Kestenholz [1] christoph.kestenholz@gmail.com
Kaspar Staub [2] kaspar.staub@iem.uzh.ch
Ana Maria Vicedo Cabrera [1] anamaria.vicedo@ispm.unibe.ch

1. University of Bern, Institute of Social and Preventive Medicine (ISPM)
2. University of Zurich, Institute of Evolutionary Medicine (IEM)

Heat is considered today amongst the deadliest environmental hazards of great public health concern. Climate change is already amplifying current health impacts due to the increase in the frequency and severity of heat extremes, and it is expected that these will further increase as warming progresses. Heat is of particular relevance for public health in Switzerland. Recent epidemiological investigations found that heat is an important driver of mortality and morbidity in this country. However, no evidence exists on the health impacts of historical heat events before 2003 such as the one in 1947. The comparison of health burdens between these different events would help understanding the role of potential adaptation mechanisms and acclimatization, changes in demographic exposure and climate.

We here aim to quantify the excess mortality during the warm summers of 1947, 2003, 2015 and 2018 and during the specific heatwave episodes in 8 Swiss cities.

Basel reported the largest average-summer excess mortality in 1947 (12%) compared to the rest of cities with estimates below 6%. Similar burden around 15-10% is also reported in the other summers in 2003 (Basel, Geneva and Winterthur), 2015 (Biel) and 2018 (Bern). However, considerably larger excess mortality can be observed during specific heatwave periods. Overall, our results indicate that the heatwave in summer 1947 was particularly harmful for the population in Basel (33% excess mortality) followed by Lucerne (38%), Bern (23%) and St Gallen (20%), while it seemed to have little impact in other important cities such as Geneva, Lausanne, Winterthur or Zurich with excess mortality below 8%. In comparison with the other heatwave periods in 2003, 2015 and 2018, the heatwave in 1947 was the most devastating one in the cities of Bern, Lucerne and St Gallen. Conversely, 2003 heatwave was the one with the largest death toll in Basel, Geneva, Lausanne and Winterthur, while the episode in 2018 was the most devastating one in terms of excess mortality in Zurich (43%). Our study helps to compare recent and historical health impacts by heat stress and provides explanations what factors might change the impact between the past and the recent heatwaves.

Identifying local heat hotspots in Zurich - an urban morphology study

Dominik Strebel

Birgit Sützl [1] bsuetzl@ethz.ch
Dominik Strebel [1] strebdom@ethz.ch
Andreas Rubin [1] rubina@ethz.ch
Aytaç Kubilay [1] akubilay@ethz.ch
Jan Carmeliet [1] cajan@ethz.ch

1. ETH Zürich, Chair of Building Physics, Switzerland

Heat stress in the urban environment is the result of complex interactions between the different components of the built-up system and the atmosphere. Different surface materials, heterogeneity in size, shape, density and arrangement of buildings, all influence the uptake and transport of heat. Due to this extensive parameter space, numerical simulations of the urban microclimate often revert to simplified parametric morphologies like urban street canyons. To be able to simulate heat mitigation measures in a more realistic set-up, this ongoing research project aims to identify typical building morphologies that are associated with higher outdoor temperatures than comparable neighbourhoods.

The study uses summer daytime surface temperatures from the Landsat 8 high-resolution satellite data, averaged over the years 2013 - 2021, to identify urban neighbourhoods with potential for high heat stress. The surface temperature data shows clear cooling effects from water bodies and medium- to large-scale vegetated areas, while extensive railway infrastructure and large outdoor sports facilities with artificial turf induce high surface temperatures.

However, the impact of different building morphologies is less clear and requires further analysis. Several surface-cover and morphology parameters at neighbourhood scale are derived from building-resolved data, such as the impervious plan area index, plan- and frontal area indices of buildings, mean and maximum height of buildings, sky view factor, etc., and correlated to the average surface temperature of that neighbourhood. The data analysis indicates some distinct correlations between the urban morphology and surface temperature. Ongoing investigations further apply clustering algorithms, aiming to identify typical morphology features of urban neighbourhoods with higher levels of heat stress.

In this project we hope to learn valuable lessons for the design of new urban developments, for identifying possibilities and risks in urban densification, and for the adaptation of existing urban neighbourhoods to heat stress.

Impact of mitigation measures for urban heat islands during heat wave conditions: Case study in Münsterhof, Zürich, using a coupled multiscale model

Aytaç Kubilay

Aytaç Kubilay [1]
Dominik Strebel [1]
Dominique Derome [2]
Jan Carmeliet [1]

1. ETH Zurich, Switzerland
2. Université de Sherbrooke, Canada

Studies show that heat waves are getting more frequent and intense with longer duration and at broader spatial scale. Effective mitigation strategies with careful planning are required to counter the impact due to heat waves, which can lead to very strong heat stress levels in cities when combined with local urban heat islands. However, in most cases, a variety of factors should be taken into account, which are very complex to predict. For example, use of trees to promote evapotranspiration may worsen conditions in cases with reliance on ventilation for heat removal, e.g. placing too dense trees along main ventilation corridors. Furthermore, increasing densification in cities may also lead to different conditions in terms of ventilation, heat load, and green spaces.

In this study, a multiscale approach with a coupled microclimate model is presented, allowing for the detailed analysis of the local impact of urban heat island mitigation measures. Mesoscale simulations with meteorological models provide boundary conditions to use in the microclimate model at neighborhood scale. At microscale, computational fluid dynamics (CFD) simulations are coupled with unsteady heat and moisture transport (HAM) in porous urban materials in order to take into account the dynamic heat and moisture storage in the built environment. This model allows for an accurate tracking of moisture content near surfaces available for evaporative cooling and for the calculation of drying rate and cooling potential. Trees are modeled as porous objects within the CFD domain including transpirative cooling based on the plant physiology.

A realistic case study is performed for Münsterhof, a public urban square, in the City of Zurich during heat wave conditions. The impacts of two different mitigation strategies, i.e. scheduled wetting of pavements and adding vegetation, on pedestrian thermal comfort are evaluated and compared with the existing situation. For each case, outside thermal comfort is evaluated at pedestrian level with the Universal Thermal Climate Index (UTCI). Results provide further insight in the exterior conditions to which pedestrians and buildings are exposed to in terms of both daytime conditions and night cooling.

Both mitigation measures show an improvement in thermal comfort in both conditions. The improvement resulting from the addition of trees is larger and lasts longer due to shadowing effects, even though a reduced ventilation is observed locally with an increased relative humidity due to the presence of trees. The cooling provided by trees is large enough to reduce the maximum thermal stress during day time, in some cases until moderate levels. During night time, trees reduce the sky view factor and lead to slightly worsened thermal comfort. Without any additional shadowing, cooling provided by scheduled surface wetting is more limited.

Beating the heat by taking urban form into consideration

Jonas Schwaab

Jonas Schwaab [1] jonasschwaab@ethz.ch
Sonia I. Seneviratne [1] sonia_seneviratne@ethz.ch
Gianluca Mussetti [1] Gianluca_Mussetti@swissre.com
Edouard L. Davin [2] edouard.davin@wyssacademy.org

1. Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland
2. Wyss Academy for Nature, Climate and Environmental Physics, Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland

Urban form has a strong influence on the surface urban heat island (SUHI). It has been shown that sprawling cities, in contrast to compact cities, are often characterized by a low SUHI. The impact of urban form on SUHIs has been mainly analyzed in separate case studies. Analyzing a large dataset of high spatial resolution LST data for more than 290 cities in Europe, we show that the effect of urban form on urban heat depends on region and predominant land-cover in the surrounding of a city. Our results indicate that sprawling or polycentric urban forms do not necessarily benefit the urban climate. In Mediterranean cities, sprawl may even lead to the warming of urban areas, highlighting the importance of background climate when determining the role of urban form in heat mitigation. It is also crucial to consider the predominant type of land cover surrounding a city, since sprawl may be climatically more beneficial in forested than in agricultural areas.

New heat scenarios for Swiss cities

Annkatrin Burgstall

Annkatrin Burgstall [1] annkatrin.burgstall@meteoswiss.ch
Sven Kotlarski [1] sven.kotlarski@meteoswiss.ch
Ana Casanueva [2] casanuevaa@unican.es
Elke Hertig [3] elke.hertig@med.uni-augsburg.de
Erich Fischer [4] erich.fischer@env.ethz.ch
Reto Knutti [4] reto.knutti@env.ethz.ch

1. Federal Office of Meteorology and Climatology MeteoSwiss, Zurich, Switzerland
2. Meteorology Group, Department of Applied Mathematics and Computer Science, University of Cantabria, Santander, Spain
3. Faculty of Medicine (Regional Climate Change and Health), University of Augsburg, Augsburg, Germany
4. Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland

Our study introduces a straightforward approach to generate multi-model climate projections of intense urban heat, based on an ensemble of state-of-the-art global and regional climate model simulations from EURO-CORDEX. The employed technique entails the empirical-statistical downscaling method quantile mapping (QM), which is applied in two different settings, first for bias correction and downscaling of raw climate model data to rural stations with long-term measurements and second for spatial transfer of bias-corrected and downscaled climate model data to the respective urban target site.

The resulting products are daily minimum and maximum temperatures at five urban sites in Switzerland (Basel, Bern, Geneva, Lausanne, Zurich) until the end of the 21st century under three emission scenarios (RCP2.6, RCP4.5, RCP8.5). We test the second-step QM approach in an extensive evaluation framework, using long-term observational data of two exemplary weather stations in Zurich. Results indicate remarkably good skill of QM in present-day climate.

Comparing the generated urban climate projections with the existing Swiss climate scenarios CH2018 of adjacent rural sites allows us to represent the urban heat island (UHI) effect in future temperature-based heat indices, namely tropical nights, summer days and hot days. Urban areas will be more strongly affected by rising temperatures than rural sites in terms of fixed threshold exceedances, especially during nighttime. Projections for the end of the century for Zurich, for instance, suggest more than double the number of tropical nights (Tmin above 20 °C) at the urban site (45 nights per year, multi-model median) compared to the rural counterpart (20 nights) under RCP8.5.

Our results are an important add-on to the existing CH2018 products: they provide customized climate services and help protect those population groups and sectors that have been identified as especially vulnerable towards high temperatures in urban areas (e.g. the elderly; construction sector/working outside). As a “ready-to-use” product (bias-corrected, high-resolved), the generated urban scenarios are directly applicable to climate change impact assessments. They are available via the CH2018 web atlas under "Indicators at stations". For the city stations, select the station at the bottom of the list with the addition "CITY CENTER".

Canopy Layer Urban Heat Island – an urban induced feature in regional temperature patterns

Heinke Schlünzen

Heinke Schlünzen [1] heinke.schluenzen@uni-hamburg.de
Sue Grimmond [2] c.s.grimmond@reading.ac.uk
Alexander Baklanov [3] abaklanov@wmo.int
Alberto Martilli [4] alberto.martilli@ciemat.es
Valéry Masson [5] Valery.masson@meteo.fr
Shiguang Miao [6] sgmiao@ium.cn
Chao Ren [7] renchao@hku.hk
Matthias Roth [8] geomr@nus.edu.sg
Iain Stewart [9] iain.stewart@utoronto.ca

1. Meteorological Institute, CEN, Universität Hamburg, Hamburg, Germany
2. Department of Meteorology, University of Reading, UK
3. Science and Innovation Department, World Meteorological Organization (WMO), Geneva, Switzerland
4. Centro Investigaciones Energéticas, Medioambientales y Tecnológicas, CIEMAT, Spain
5. CNRM (Centre National de Recherches Météorologiques), Météo-France & CNRS, France
6. IUM, CMA, Beijing, China
7. Faculty of architecture, The University of Hong Kong, Hong Kong SAR, China
8. National University of Singapore, Department of Geography, Singapore
9. Global Cities Institute, University of Toronto, Toronto, Canada

Urbanization influences the local climate by changing the natural surface energy balance affecting the regional temperature field. One of the best-known and widely studied phenomenon is the canopy layer urban heat island (CL-UHI) which found in cities of all sizes. Specifically, night temperatures are often higher in urban areas than in the surrounding rural areas. The CL-UHI characteristics differ between cities, within a city and with time of the day and the season. Climate change induced warming in cities is similar to that experienced in rural areas, but modified by the CL-UHI.

Given the city-scale importance of CL-UHI, and in response to the request of the 18th World Meteorological Congress (Resolutions 32 and 61), experts from WMO GAW (Global Atmosphere Watch) Urban Research Meteorology and Environment (GURME) initiated in 2020 an expert team to develop a guidance on measuring, modelling and monitoring the CL-UHI. This guidance, available at https://community.wmo.int/meetings/launch-3-urban-reports, is a community-based document with more than 30 contributors providing expertise in different aspects of the CL-UHI. Topics covered include a clear definition of the CL-UHI and clarifications of what it is not, causes of the CL-UHI (e.g. meteorological and morphological influences), methods to assess the CL-UHI intensity (measurements, modelling approaches) as well as CL-UHI application examples. The guidance also explains why the CL-UHI mitigation is only part of an answer to reduce urban heat problems. The guidance could serve as a useful reference to meteorologists, climatologists, meteorological administrative staff, and others interested in the CL-UHI.

Assessment of the temperature-mortality association in Switzerland based on individual death records and daily air temperature at a fine spatial resolution

Benjamin Flückiger

Martina Ragettli [1, 2] martina.ragettli@swisstph.ch
Benjamin Flückiger [1, 2] benjamin.flueckiger@swisstph.ch
Marloes Eeftens [1, 2] marloes.eeftens@swisstph.ch
Danielle Vienneau [1, 2] danielle.vienneau@swisstph.ch
Martin Röösli [1, 2] martin.roosli@swisstph.ch
Kees de Hoogh [1, 2] c.dehoogh@swisstph.ch

1. Swiss Tropical and Public Health Institute, Basel, Switzerland
2. University of Basel, Basel, Switzerland

Epidemiological studies investigating the relationship between heat and health, typically rely on either information from the nearest weather station or on coarse gridded temperature predictions, thereby ignoring small-scale intra-urban variations related to heat islands.

The aim of this study was to assess the temperature-mortality association accounting for small-scale variability in temperature exposure in Switzerland during the warm season (May to September) 2003 to 2016. We used individual death records from the Swiss National Cohort (SNC) that included 300’295 deaths due to natural causes during the study period. The SNC is a long-term cohort based on linkage of national census and mortality data for the whole Swiss population. We linked the daily individual death records based on their residential address to daily air temperature estimates (daily mean, minimum and maximum) from a temperature model specially developed for this study. Temperature was modelled based on a two-stage approach using random forest. First, we imputed missing values caused by cloud-cover in satellite-derived MODIS land surface temperature at a 1x1 km resolution. Second, we used the gap-filled MODIS data to explain spatiotemporal variation in the measured ground-based air temperature data at a 100x100m resolution across Switzerland using a range of predictor variables, including meteorological parameters, NDVI, impervious surface and altitude. The effect of heat on mortality in Switzerland was then assessed by applying distributed lag non-linear models in an individual case-crossover design.

The two stage approach to model temperature was successful for capturing fine scale variability across Switzerland. Stage 1 models achieved an overall R^2 of 0.98 and a RMSE of 1.49°C (independent validation), and the stage 2 model performed well for all years with R^2 and RMSE ranging from 0.94 to 0.99 and 1.05°C to 1.86°C, respectively. Significant temperature-mortality relationships were found for all three temperature indicators. Hot days defined as the 98th percentile of warm-season daily mean, maximum and minimum temperature distribution were associated with an increase in mortality risk by 18% (95% confidence interval CI: 15%-22%), 21% (17%-25%) and 11% (8%-14%) compared to the respective median warm-season temperature, respectively.

This is a national epidemiological assessment on heat-related mortality accounting for small-scale exposure variability. The fine spatial resolution of exposure estimates allowed us to capture urban heat islands and typical weather phenomena caused by Switzerland’s complex topography. Further analyses on modifying effects of various environmental (e.g. urban heat islands) and individual risks factors (e.g. socio-economic status) of heat-related mortality are underway.

Exploring vulnerability to heat and cold across urban and rural populations in Switzerland.

Evan de Schrijver

Evan de Schrijver [1, 2, 3]
Dominic Roye [4, 5]
Antonio Gasparrini [6, 7, 8]
Oscar Franco [1]
Ana Vicedo-Cabrera [1, 2]

1. Institute of Social and Preventive Medicine (ISPM), University of Bern, Bern, Switzerland
2. Oeschger Center for Climate Change Research (OCCR), University of Bern, Bern, Switzerland.
3. Graduate school of Health Sciences (GHS), University of Bern, Bern, Switzerland
4. Department of Geography, University of Santiago de Compostela, Santiago de Compostela, Spain
5. CIBER of Epidemiology and Public Health (CIBERESP), Spain
6. Department of Public Health, Environments and Society, London School of Hygiene & Tropical Medicine, London United Kingdom
7. Centre on Climate Change and Planetary Health, London School of Hygiene & Tropical Medicine, London (LSHTM), London, United Kingdom
8. Centre for Statistical Methodology, London School of Hygiene & Tropical Medicine, London United Kingdom

Heat- and cold-related mortality risks are highly variable across different geographies, suggesting differential distribution of vulnerability factors between and within countries, which could partly be driven by urban-to-rural disparities. Identifying these drivers of risk is crucial to characterize local vulnerability and to design tailored public health interventions to improve adaptation of populations to climate change. We aimed to assess how heat and cold mortality risks change across urban, peri-urban and rural areas in Switzerland and to identify and compare what factors are associated with increased vulnerability within and between different area typologies.

We estimated the heat- and cold-related mortality association using the case time-series design and distributed lag non-linear models over daily mean temperature and all-cause mortality series between 1990-2017 in each municipality in Switzerland. Then, through multivariate multi-level meta-regression, we derived pooled heat and cold-mortality associations by typology (i.e. urban/rural/peri-urban) and assess potential vulnerability factors among a wealth of demographic, socioeconomic, topographic, climatic, land use and other environmental data.

Urban clusters reported larger pooled heat-related mortality risk (at 99th percentile, vs. temperature of minimum mortality (MMT)) (relative risk=1.17(95%CI:1.10;1.24, vs peri-urban 1.03(1.00;1.06), and rural 1.03 (0.99;1.08)), but similar cold-mortality risk (at 1st percentile, vs. MMT) (1.35(1.28;1.43), vs rural 1.28(1.14;1.44) and peri-urban 1.39 (1.27-1.53)) clusters. We found different sets of vulnerability factors explaining the differential risk patterns across typologies. In urban clusters, mainly environmental factors (i.e. $PM_{2.5}$) drove the heat-mortality association, while for peri-urban/rural clusters socio-economic variables were also important. For cold, socio-economic variables drove vulnerability across all typologies, while environmental factors and ageing were other important drivers of vulnerability in peri-urban/rural clusters, with heterogeneity in the direction of association.

Our findings suggest that urban populations in Switzerland may be more vulnerable to heat, compared to rural locations, and different sets of vulnerability factors may drive these associations in each typology. Thus, future public health adaptation strategies should consider local and more tailored interventions rather than a one-size fits all approach.

Urban heat analysis - from meso to micro scale

Michael Schmutz

Michael Schmutz [1] michael.schmutz@meteotest.ch
Jan Remund [1] jan.remund@meteotest.ch
Anne-Kathrin Weber [1] anne-kathrin.weber@meteotest.ch

1. Meteotest AG, Switzerland

We developed a model based approach which allows covering urban heat analysis from mesoscale down to micro scale [1] based on the large eddy simulation model system PALM-4U [2].

Three model domains with distinct spatial resolutions and horizontal extents are nested in order to resolve relevant scales in one model setup. The mesoscale domain is resolved with a cell size of 50 m and covers an area in the order of magnitude of 10^4 m. At this scale a coarse representation of the topography and land cover is incorporated and the domain is coupled to the dynamic input from the COSMO weather forecasting system. This allows exposing the mesoscale domain to real weather conditions including regional meteorological characteristics (e.g. local wind systems). The local scale domain is represented by a 10 m grid size and horizontal dimensions in the order of 10^3 m. At a resolution of 10 m the fine grid enables to represent a detailed topography and simple 3D building structures which is especially relevant for the analysis of nocturnal cold air drainage or heat stress indices of larger areas. The micro scale domain is finally made up of 1 m grid cells and an area in the order of 10^2 m. With 1 m grid cells it is possible to model complex 3D building structures as well as 3D Vegetation elements and the landscape architecture with a variety of land use classes. Physical properties of different surface types or buildings can be defined individually. The static input data of the model, i.e the topography and the surface properties can be included from national surveys (e.g. swissALTI3D, swissBUILDINGS3D, swissTLM3D in Switzerland).

The 3D output of the model allows the creation of urban heat related services like climate maps or planning information for cantonal or communal authorities. The high resolution micro scale domain is of special interest for the analysis of specific building or areal projects for urban planners or architects. The information derived from the model output can be transferred into straight forward recommendations for action and support sensitizing planners and architects to mitigate urban heat effects. For the analysis of new building projects 3D data from CAD Software can be incorporated in order to evaluate the performance of a planned areal during extreme summer heat events. This also offers the opportunity to run the model with different scenarios, i.e. variations of building projects in order to examine the effectiveness of certain heat mitigation actions like bright building surfaces, green roofs or vegetated landscapes. As such it is not only possible to model the current state to which the project will be exposed but also the final state including the effects of the project itself on the micro (bio-)climate. By examining different scenarios it is possible to iteratively improve the heat mitigation strategy and create optimal climatic conditions for the citizens.

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[2] https://palm.muk.uni-hannover.de/trac

Assessing the heat mitigation potential of a water misting system in the city of Zurich

Saskia Drossaart van Dusseldorp

Saskia Drossaart van Dusseldorp [1] dros@zhaw.ch

1. ZHAW Zentrum für Aviatik

In the beginning of July 2022, the city of Zurich has launched the project *AltoZürrus* to investigate the use of a water misting system as a remedy for urban heat islands. It is installed on Turbinenplatz in the Zürich West district and consists of a ring with a diameter of 9 meters, mounted 5 meters above ground, to which 180 high-pressure nozzles are attached. When the ambient temperature exceeds a preset threshold, water is passed through the ring under high pressure and sprayed through the nozzles to form a fine mist, which evaporates rapidly, extracting heat from the surrounding air, and thereby cooling its environment.
While this concept is not new, and misting systems are frequently used for cooling terraces and patios in warmer regions, scientific studies on their effect on temperature are sparse and inconclusive, whit cooling effects found in a range between 0.5 and over 20°C, highly depending on the experimental setup and operational and environmental conditions (Ulpiani, 2021). Studies addressing the spray mist’s effect on particulate matter (PM) concentration show an even larger span, which ranges from a significant decrease of particle concentration in industrial applications (Pollock & Organisack, 2007), to an increase in environmental particle concentration by up to a factor of 8 in an urban environment (Knight et al., 2022). Assessing the cooling efficacy and of the *AltoZürrus* cloud, as well as its effect on local PM concentration, consequentially requires measurements on site under operating conditions. To this end,13 sensors installed on Turbinenplatz, observing temperature and humidity during the operational period (mid July until end of September) in order to observe the clouds effect on the local temperature. Additional sensors, recording PM concentration by measuring the lung-deposited surface area, will be installed shortly after submission of this abstract. While the measuring period is still ongoing at the date of the conference, some first exploratory findings will be presented.

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Trends in Tropical Nights and their Effects on Mortality in Cantons and Cities of Switzerland

Vanessa Rippstein

Vanessa Rippstein [1, 2] vanessa.rippstein@bluewin.ch
Evan de Schrijver [1, 2, 3] evan.deschrijver@ispm.unibe.ch
Sandra Eckert [4, 5] sandra.eckert@unibe.ch
Ana M. Vicedo-Cabrera [1, 2] anamaria.vicedo@ispm.unibe.ch

1. Oeschger Centre for Climate Change Research (OCCR), University of Bern, Switzerland
2. Institute of Social and Preventive Medicine (ISPM), University of Bern, Switzerland
3. Graduate school of Health Sciences (GHS), University of Bern, Switzerland
4. Centre for Development and Environment (CDE), University of Bern, Switzerland
5. Institute of Geography (GIUB), University of Bern, Switzerland

Increasing temperature and more frequent and severe heat waves in Switzerland are leading to increasing heat-related health burdens. Especially, high nocturnal temperature, usually associated with the urban heat island effect, reduces the well-being of society. We aimed to assess the spatiotemporal patterns in the frequency, the exposed population to Tropical Nights (TN), and its effect on daily mortality in Switzerland.

We derived the number of TNs (night temperature ≥ 20°C) per district using population-weighted temperature series based on high resolution hourly mean temperature (ERA5-Land reanalysis data set) between 1969-2019. We assessed the change in TN frequency and the exposed population per district and decade through a spatiotemporal analysis. We then estimated the TN-mortality association by canton and districts of the 8 main cities using conditional quasi-Poisson regression and data on all-cause mortality at the district level between 1980-2019. The model accounted for long-term and seasonal patterns and daily mean temperature.

We found an overall increase in the frequency of TN and exposed population in Switzerland between 1969-2019, mainly in the areas of the main cities of Lausanne, Geneva, Basel, Lugano, and the region of Zurich and during the last two decades. Across cantons and cities, no clear spatial patterns were found in the level of vulnerability. In particular, TNs were associated with an increase of 37-22% in the risk of mortality in the cantons of Vaud (RR:*1.37 [95% CI:1.19-1.59]*), Zurich (*1.33 [0.99-1.79]*), Lucerne (*1.33 [0.95-1.87]*) and Solothurn (*1.22 [0.88-1.69]*), while a negative association was observed in the cantons of Ticino (*0.51 [0.37-0.7]*), Basel-Land (*0.4 [0.24-0.65]*) and Thurgau (*0.65 [0.5-0.85]*). A null association was found in the remaining Cantons. For the city-specific analysis, no robust results were found. But there was a trend of an increased risk in the cities of Lugano (*1.19 [0.78-1.8]*), Lucerne (*1.46 [0.85-2.49]*), and Winterthur (*1.34 [0.78-2.31]*). While the cities of Zurich (*0.83 [0.63-1.07]*), Geneva (*0.83 [0.69-1]*), Basel (*0.82 [0.65-1.04]*), and Biel/Bienne (*0.85 [0.55-1.32]*) showed a trend to a protective effect during TNs.

We found contrasting results on the vulnerability level between cantons and cities. Interestingly, TNs seemed to have a protective effect in the cities while they represent a risk at cantonal level (e.g., Zurich-Zurich, Vaud-Lausanne). It would suggest that there could be a gap between rural and urban residents’ sensitivity to heat, leading to larger adaptation in populations in cities. Our findings indicate that TN is a relevant health hazard for a large part of the Swiss population with potentially larger impacts in the future due to climate change and increasing urbanization.

The role of humidity in heat stress from a causal perspective

Sidharth Sivaraj

Sidharth Sivaraj [1, 2] sidharth.sivaraj@ispm.unibe.ch
Ana Maria Vicedo Cabrera [1, 2] anamaria.vicedo@ispm.unibe.ch

1. Institute of Social and Preventive Medicine, University of Bern, Switzerland
2. Oeschger Centre for Climate Change Research, University of Bern, Switzerland

The health burden associated with heat stress poses severe socio-economic concerns for many countries across the globe. The anthropogenic warming is only predicted to exacerbate and extend this burden in future. Urban centres, where the urban heat isle effect could be significant, require critical inputs concerning the complex pathways through which heat stress affects health, for devising better adaptation measures. While studies concerning physiological models have shown that high humidity leads to increased heat stress in humans, to date findings from epidemiological studies remain inconclusive on this matter. With the use of directed acyclic graphs (DAGs) as probabilistic graphical models, we aim to explore the assumptions and implications concerning the inclusion of humidity variables in the epidemiological assessments of heat related health impacts. From a Bayesian perspective, the DAGs represent a set of conditional independence assumptions about the underlying causal associations. We examine DAG networks for heat-health impact associations, where humidity variable is included as a confounder, a covariate, an effect modifier etc., and elucidate the underlying model assumptions. The same methodology is extended to analyse the implications for including different humidity variables in the model. For example, how the inclusion of relative humidity (negatively correlated with temperature) will impact the model compared to the inclusion of specific humidity (positively correlated with temperature). Similarly, the inclusion of combined heat – humidity indices such as wet-bulb temperature, heat-index etc. is also explored. We compare our insights from the DAG networks with the results from select epidemiological studies that have analysed the role of humidity in heat health impacts. This study serves as the first step towards a critical re-evaluation of the role of humidity in heat stress, and will develop a framework for addressing similar complex research questions in environmental epidemiology.

Urban climate change considerations for Singapore

Matthias Roth

Matthias Roth [1] geomr@nus.edu.sg

1. National University of Singapore, Singapore

Cites in warm or hot regions are strongly affected by the UHI which increases ambient outdoor temperature and decreases outdoor thermal comfort to possibly intolerable levels. The situation is exacerbated in equatorial/wet climates, where high day- and nighttime air temperature in combination with the high humidity characteristic of the wet tropics, present a particularly challenging living environment for urban residents. Such additional warming generated by the UHI on top of anthropogenic global warming is clearly undesirable. Singapore, located in the tropics next to the equator, is no exception to this. Rapid growth of the city has generated a nocturnal canopy-layer UHI intensity which has doubled in magnitude since 1965; at the same time the spatial extent of the nocturnal UHI has also expanded to accommodate a growing population and expanding industries, often at the expense of vegetated areas. Local growth and development aspirations are therefore likely responsible for a local temperature increase which is about twice that of the global temperature trend over land. Given the homemade nature of this local urban climate change, options exist to mitigate some of the unwanted warming, irrespective of (in)action at the global level regarding anthropogenic global warming. This presentation shows how Singapore has become a hot “little red dot” and reflects on its air temperature mitigation potential.

Climate Resilient Strategies and Green Sustainable Development Measures in the City Skopje, North Macedonia

Assoc. Prof. PhD Viktorija Mangaroska

Assoc. Prof. PhD Viktorija Mangaroska [114] vmangaroska@gmail.com
Full Prof. PhD Kosta Mangaroski [114] kmangaroski@yahoo.com

The City Skopje is located in the Republic of North Macedonia. It has good connections and favorable geographical location of the main roads and magistral roads, which developed a very large number of industries and agricultural production industries in the city. In the recent years, Skopje is dealing with issues such as: urban heat island, air pollution and climate urban resilient measures are key for the urban planners.

Identification of the Urban Heat island in Skopje analysis the thermal map of Skopje, temperature-profile analysis, micro-analysis based on thermal images of the central area. Based on the analysis, proposed are the climate mitigation measures: general mitigation measures: greening strategies, landscape, green roof, and cool pavements; anthropological measures of the citizens in Skopje, innovative green strategies and measures, as well as municipality action plan for climate resilience strategies.

The City Skopje needs to adapt the new trend of sustainable green measures in order to have revitalization and re-modernization of the green capacities of the city and especially the lake Treska which is becoming more popular eco-touristic location among young people. In this scientific paper specified will be sustainable green approach as a catalyst for new innovative ideas.

The results of this scientific paper will be analyzing the conditions, architectural design and the possibilities of the green architecture and green infrastructure, especially following the revitalizing efforts towards making bio-economic tourism and greening strategies influences in the thermal resilient modification and revitalization of the city Skopje.

Vulnerability to heat exposure and cardiovascular events in adults in the city of Madrid

Coral Salvador

Coral Salvador [1, 2, 3] coral.salvador@ispm.unibe.ch
Pedro Gullón [4, 5] pedro.gullon@uah.es
Manuel Franco [4, 6] manuel.franco@uah.es
Ana M. Vicedo-Cabrera [2, 3] anamaria.vicedo@ispm.unibe.ch

1. Centro de Investigación Mariña, Universidade de Vigo, Environmental Physics Laboratory (EPhysLab), Ourense, Spain
2. Institute of Social and Preventive Medicine, University of Bern, Switzerland
3. Oeschger Center for Climate Change Research, University of Bern, Switzerland
4. Universidad de Alcalá, Facultad de Medicina y Ciencias de La Salud, Departamento de Cirugía, Ciencias Médicas y Sociales, Grupo de Investigación en Epidemiología y Salud Pública, Alcalá de Henares, Madrid, Spain.
5. Centre for Urban Research, RMIT University, Melbourne, Australia
6. Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, Md, 21205-2217, USA

Heat is an important environmental and occupational hazard posing a great concern for public health, especially in densely populated urban areas. Most studies on heat-related health effects have focused on mortality but there is scarce evidence about the heat impact on cause-specific morbidity. Further vulnerability assessments are also needed, given the expected increase in extreme heat events in the future due to climate change, which is expected to continue disproportionately affecting vulnerable residents and intensify existing social and health inequalities. The aim of our study is 1) to explore the heat impact on the incidence of the first acute cardiovascular disease event in adults living in Madrid between 2015 and 2018, and 2) to analyse the influence of social conditions as potential risk modifying factors, ultimately identifying the most vulnerable populations.

Data on cardiovascular events was extracted from electronic medical records of 1442840 adults aged 40-75 living in the city of Madrid and free of previous cardiovascular disase. Data was shared by the primary care service research unit. We used daily maximum temperature as the exposure variable, which was provided by the State Meteorological Agency in Spain. We performed a case-crossover design using a conditional logistic regression model with a distributed lag non-linear model to analyse the association between daily maximum temperature and the first cardiovascular event during the summer months. We conducted stratified analysis by sex (female, male), age (40-64, 65-75), country of origin (Spain, other), deprivation status (low, medium, high), and specific first cardiovascular disease diagnosis (ischaemic heart disease with angina; ischaemic heart disease without angina; acute myocardial infarction; heart failure; transient cerebral ischemia; stroke and cerebrovascular accident).

The risk of suffering a first cardiovascular disease event increased by 15.3% (95%CI: 1.01, 1.317) in the total population for extreme heat (97.5th temperature percentile in Madrid) compared to the minimum risk temperature (range from 25th percentile to 90th percentile). Extreme temperature mostly impacted males (risk increased by 24.8%, 95%CI: 1.059, 1.471), not Spanish (risk increased by 86.9%, 95%CI: 1.028, 2.728), and individuals living under high deprivation conditions (risk increased by 22.8%, 95%CI: 1.031, 1.462). A higher impact was observed in older adults compared to young adults however the difference was not significant. According to the stratified analysis by specific groups of diagnosis, we observed a positive association for all specific cardiovascular causes, except for ischaemic heart disease without angina, being the association robust for transient cerebral ischemia. Days of extreme temperature increased the risk of having a (first) cardiovascular disease event in Madrid between 2015 and 2018, especially in males, no Spanish, and people living under high deprivation conditions. Local studies that allow better knowledge about how social disparities interact with and influence heat risks to health are crucial, especially considering future projections of climate change. Public health policies should pay more attention to vulnerable populations to reduce exposure, vulnerability, and risks associated with heat.

Effects of Dubai coastline extreme urbanization in land and sea on local near-surface climate variables

Emily Elhacham

Emily Elhacham [1] emily.elhacham@gmail.com

1. Tel Aviv University, Israel

Over a billion people currently live in coastal areas, and coastal urbanization is rapidly growing worldwide. The potential impact of such rapid coastal urbanization on the local climate is illustrated here by focusing on Dubai. Dubai is one of the fastest growing cities in the world over the last two decades. Its urbanization centers along its coastline – in land, massive skyscrapers and infrastructure have been built, while in sea, unique artificial islands have been constructed.

We explore the effects of this extreme urbanization on the near-surface climatic variables, based on MODIS data, Landsat and in-situ observations. Studying the coastline during the years of intense urbanization, we show that the coastal surface urban heat island has nearly doubled its size, expanding towards the newly developed areas. This newly developed zone also exhibited the largest temperature trend along the coast, exceeding 0.1°C/year on average.

Overall, we found that over land, temperature increases go along with albedo decreases, while in sea, surface temperature decreases and albedo increases were observed particularly over the artificial islands. These trends in land and sea temperatures affect the land-sea temperature gradient which influences the breeze intensity. The above findings, along with the increasing relative humidity shown, directly affect the local population and ecosystem, exacerbate the thermal comfort, adding additional burden to this area.

Heatwave Risk Perception and Emotions - Preliminary Results of a Cross-sectional Study in Pakistan

Farman Ullah

farman ullah [1] farmancus@gmail.com
Martina Valente [1] martina.valente@uniupo.it
francesco .barone adesi [1] francesco.baroneadesi@uniupo.it

1. CRIMEDIM - Center for Research and Training in Disaster Medicine, Humanitarian Aid, & Global Health, Università del Piemonte Orientale

Globally, over the last fifty years, the frequency and severity of heatwaves have been on the rise, thus seriously posing a great challenge to human health and societal well-being. Climate change is the leading cause of the increasing frequency and severity of extreme heatwaves all over the world even in places like the antarctica. In order to find out how people generally perceive, understand, behave, and adaptat during heatwaves, this cross-sectional study has been conducted in Pakistan. Heatwaves related risk perception was measured using the constructs of the famous Health Belief Model (HBM). Furthermore, this study aimed also to assess adaptation towards heatwaves both at individual and household level as well as to find out the psychological reactions during heatwaves. Data was collected using a standardized questionnaire at the household level from across Pakistan. Using a five-point Likert Scale technique, the questionnaire was made in such a manner that all the key components of the study were achieved properly. Moreover, the questionnaire was divided into consist of five (05) key sections. Part one was about the general heatwave awareness, part two assessed people’s heatwaves risk perception (using health belief model), part three measured people’s heatwave related emotional and psychological responses, part four assessed people’s adaptation to heatwave and part five collected data about the socio-demographic characteristics of the respondents. Furthermore, risk perception was measured using the two components of HBM i.e., Perceived Vulnerability and Perceived Severity by a total of seven statements each. Individual adaptation was measured using fourteen statements whereas households’ adaptation was measured using sixteen statements. A total of eleven items were used to measure psychological reactions during heatwaves. Demographic data such as age, gender, marital status, income, mother language, and living conditions were also part of the survey. Preliminary results of 496 respondents throughout Pakistan suggests high risk perception for urban communities compared to rural communities. Results also highlights that majority of the participants were already applying individual as well as households’ level adaptation. Analysis of the emotional responses showed mixed results based on the location of the respondent. In total, 341 respondents were from urban areas whereas 155 of the respondents were from rural areas. Ethnicity of the respondents showed that most of the respondents were belonging to the Pashto (176) speaking population followed by Urdu (98), Punjabi (97), Balochi (40), Sindhi (33) and others. Gender-wise, most of the respondents were male (367) compared to female (129) with majority of the participants having high level of education (Undergraduate and above).

Note: As the study is still ongoing, the results are subjected to changes as responses comes in on daily basis. Therefore, here we have presented some of the key results on each section. Moreover, further data analysis will show major trends among the population once we collect a reasonable sample.

Global station-based daily maximum wet-bulb temperature dataset

Jianquan Dong

Jianquan Dong [1, 2] djquan@pku.edu.cn
Stefan Brönnimann [1] stefan.broennimann@giub.unibe.ch
Jian Peng [2] jianpeng@urban.pku.edu.cn
Yuri Brugnara [1] yuri.brugnara@giub.unibe.ch

1. Institute of Geography and Oeschger Centre for Climate Change Research, University of Bern
2. College of Urban and Environmental Sciences, Peking University

The wet-bulb temperature (WBT) comprehensively characterizes the temperature and humidity, and the daily maximum WBT could be effectively used in assessing humid heat stress and its effect. Because meteorological stations might be susceptible to non-climatic influences, it is difficult to provide complete and homogeneous long-term series. However, the inhomogeneity and missing data is often ignored. Currently, there still lacks the global station-based daily maximum WBT datasets. In this study, based on the sub-daily dataset of HadISD and integrating the reanalysis dataset, the daily maximum WBT series of 1834 stations were homogenized by using the Climatol. The dataset of global station-based daily maximum WBT from 1981 to 2020 were produced. Compared with other datasets including WBT, the average bias was lower than 0.5 degrees. We solved the problem of station-based dataset with many missing values and possible inhomogeneous breakpoints. The GSDM-WBT dataset can effectively support the research on climate change and its impacts, especially the analysis of humid heatwaves.

Radiation-correction of low-cost temperature stations in an urban context

Julien Anet

Julien Anet
Curdin Spirig

Global warming will be one of the largest societal challenges to be addressed over the course of the 21st century. In urban areas, different factors may be contributing to an amplification of the warming effect. Among others, especially high surface roughness inhibiting efficient ventilation, lower albedo due to a high fraction of dark surfaces, little vegetated areas and a high Bowen ratio due to non-permeable surfaces will promote the formation of an urban microclimate, the urban heat island (UHI). Quantifying the UHI effect should be the prioritized by city authorities, as this allows a focalization of heat mitigation strategies to improve the quality of life as well as the health of city dwellers. Heat mitigation measures may comprise de-pavement of surfaces, enlarging green spaces, correctly orientating new buildings within cold air density flows, and others. In collaboration with meteoblue AG, ZHAW has been operating a low-cost urban temperature network in Zurich and Basel, with a total of nearly 500 stations for a duration of 3 years. While quality assurance at night-time is relatively straightforward, this is less the case at daytime. The large heterogeneity of the station network in terms of urban climate zones as well as individual radiation errors of the stations made it indispensable to postprocess all the data. To this end, we developed a radiation correction algorithm based on station-based direct sunlight exposure as well as average incoming shortwave radiation and mean station error. Using reference stations in Zurich city to train the algorithm, we were able to reduce the root mean square error (RMSE) from 1.98 K to 1.47 K and the mean average error (MAE) from 0.96 K to 0.58 K in Basel. In Zurich, the training dataset allowed reducing the RMSE from 1.48 K to 0.92 K and the MAE from 0.92K to 0.29 K. As a tradeoff, while the algorithm may restrain the individual station dynamic to a certain degree, unrealistic temperatures (up to 6 K of radiation error) can be efficiently corrected. Once applied onto the entire dataset, the postprocessed data can then be used for other derived products (land use regression, model nudging, etc.).

Discussing the applicability of complex simulations versus for urban planning problems

Curdin Spirig

Curdin Spirig[1] spiu@zhaw.ch
Stefan Fluck[1] fluf@zhaw.ch
Saskia Drossart van Dusseldorp[1] saskia.drossaartvandusseldorp@zhaw.ch
Julien Anet[1] anet@zhaw.ch

1. ZHAW Zentrum für Aviatik

The second warmest summer in Switzerland since the beginning of systematic temperature measurements in 1864 has brought the effects of anthropogenic climate change back into public awareness after the COVID-19 pandemic. And because global greenhouse gas emissions are still rising despite the ambitious climate targets of various countries, this summer was only a harbinger of what is to come in the future. The predicted climate change will hit cities particularly hard because of the intensification of heatwaves in combination with the urban heat island effect (UHI). The temperature difference due to the UHI can be a few degrees during the day, but up to 10°C at night (up to 8° for Zurich). To counteract this, there are various urban planning measures that could be implemented, but since urban microclimate is a complex system of numerous intricated processes, it is difficult to predict the resulting effect of any alternation, which can, in the worst case, even be opposite to what was desired. Complex urban climate simulations can help to make more informed decisions in this regard. Using our own simulations from the Zurich region and findings from the scientific literature, it is discussed if such simulations make sense and what should be taken into account.

Where can we cool down? Chasing the urban heat in Bern with different methods

Moritz Burger

Moritz Burger[1,2] moritz.burger@giub.unibe.ch
Moritz Gubler[1,2,3] moritz.gubler@giub.unibe.ch
Achim Holtmann[4] achim.holtmann@tu-berlin.de
Stefan Brönnimann[1,2] stefan.broennimann@giub.unibe.ch

1. Institute of Geography, University of Bern
2. Oeschger Centre for Climate Change Research, University of Bern
3. Institute of Lower Secondary Education, Bern University of Teacher Education
4. Chair of Climatology, Institute of Ecology, Technische Universität Berlin

Mean summer air temperatures as well as the likelihood for prolonged and more intense and more frequent heatwave periods are increasing across Europe due to the ongoing anthropogenic warming. Cities are especially prone to the alteration in summer air temperatures and extremes due to the so-called urban heat island (UHI) effect, which leads to even higher temperatures in urban environments, especially during calm nights after sunny and radiative intense days. The UHI effect causes various negative impacts for cities and its residents regarding public health (e.g. increased fatigue, cardiovascular problems), environment (e.g. increased vulnerability of urban trees) or economy (e.g. cooling costs, reduced productivity of people).

To plan adequate adaptation measures to counteract these negative effects and cool down the city, detailed knowledge about the intra-urban air temperature variability within a city is crucial. Different methods to estimate the temperature distribution in cities exist, such as measuring with in-situ data, numerical climate modeling or geostatistical modeling. In Bern, a very dense low cost air temperature network has been installed since the summer of 2018[1] and different models to investigate the urban heat have already been set up. This includes a geostatistical model to estimate nighttime UHI intensity means for heatwave periods[2] and another geostatistical model to estimate absolute temperature fields for every single night during summer[3], both having a spatial resolution of 50 m. Additionally, two numerical urban climate models have been applied: The non-hydrostatic microscale model MUKLIMO 3 with a resolution of 50m[4] and the high resolution (10 m) PALM 4-U urban climate model which is able to resolve large eddy simulations within the modeling process. In this project, we want to compare the different methods and evaluate the capability of them to realistically predict the nighttime urban air temperature distribution in a city with complex terrain. To do so, we will investigate one night of a heatwave in summer 2018 (30th of July to 31st of July), with all models and validate their spatial and temporal performance in order to assess their potentials to contribute to urban planning initiatives and adaptation plans to make cities cooler in a warming world.

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[3] Burger, M., Gubler, M. and Brönnimann, S. (submitted). Modeling the intra-urban nocturnal summertime air temperature fields at a daily basis in a city with complex topography.

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Modeling nocturnal air temperature fields at a daily basis

Moritz Burger

Moritz Burger[1,2] moritz.burger@giub.unibe.ch
Moritz Gubler[1,2,3] moritz.gubler@giub.unibe.ch
Stefan Brönnimann[1,2] stefan.broennimann@giub.unibe.ch

1. Institute of Geography, University of Bern
2. Oeschger Centre for Climate Change Research, University of Bern
3. Institute of Lower Secondary Education, Bern University of Teacher Education

In Bern, Switzerland, mean summer temperatures have risen more than 1.5 °C within the last 40 years[1]. In same time period, the sealed and built-up areas have constantly augmented which furthermore aggravated the urban heat island effect, leading to even a stronger warming within the city.

In recent years, there has been an increased awareness that action must be taken in order to reduce the urban heat island effect and its negative implications. To be able to plan and implement such adaptation measures, detailed knowledge about the intra-urban distribution of the temperature is crucial. In Bern, a low cost urban temperature measurement network with 70 to 90 stations is operated since 2018, recording the urban temperatures on a very fine scale[2]. Since there is a small bias during daytime and the urban heat island is mainly a phenomena between sunset and sunrise, the nighttime data of that measurement network is of major interest.

One key research question concerning that data is to obtain two-dimensional information out of the point data, which needs the implementation of an interpolation method. Since detailed and publicly available data on land use exists for Bern, land use regression (LUR) modeling is a promising method, which has already been applied successfully to investigate heatwave periods[3] in the city of Bern. In this project, we want to further develop the method by including meteorological variables and thus calculate daily maps. To do so, we test different model structures and cold air drainage proxies. In this poster, we present and discuss the structure of the modeling process and one model output. The aim of the overall project is to compute an urban temperature dataset of the last 16 years and to create a basis to enable urban planners and city administrations to straightforwardly include heat related questions in their daily work.

[1] Burger, M., Gubler, M., Brönnimann, S., Vicedo-Cabrera, A. and Winkel, M (2022). Berns Westen im (Klima-) Wandel. Wie sich Stadtentwicklung und Klimawandel auf das sommerliche Mikroklima auswirken. Fachbeitrag zu Berner Geographische Mitteilungen 2022 (Reihe G Grundlagenforschung G99). Bern: Geographica Bernensia 10.4480/GB2022.G99

[2] Gubler, M., Christen, A., Remund, J. and Brönnimann, S. (2021). Evaluation and application of a low-cost measurement network to study intra-urban temperature differences during summer 2018 in Bern, Switzerland. *Urban climate*, *37*, 100817.

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Compound day and night heatwaves in Swiss cities will be longer and more frequent in the future

Saeid Ashraf Vaghefi

Saeid Ashraf Vaghefi[1,2] saeid.vaghefi@geo.uzh.ch
Veruska Muccione[1] veruska.muccione@geo.uzh.ch
Raphael Neukom[1,3] raphael.neukom@geo.uzh.ch
Christian Huggel[1] christian.huggel@geo.uzh.ch
Nadine Salzmann[3,4,5] nadine.salzmann@slf.ch

1. University of Zürich, Department of Geography
2. Eawag: Swiss Federal Institute of Aquatic Science and Technology, Dübendorf
3. University of Fribourg, Department of Geosciences
4. WSL Institute for Snow and Avalanche Research SLF, Davos Dorf
5. Climate Change, Extremes, and Natural Hazards in Alpine Regions Research Center CERC, Davos Dorf

Climate change is making extreme weather events such as heatwaves, floods, and droughts more frequent and intense. Swiss cities will be confronted with extreme heat events of increasing severity and should urgently step up their adaptation efforts.

Compound concurrent hot day and night (CCHDNs) extremes that combine daytime and nighttime heat are of greater concern for health than individual hot days or hot nights. These types of heatwaves will become more long-lasting and pervasive in Swiss cities in the future (near future: 2020-2050 and far-future: 2070-2100).
We utilize a bottom-up exploratory modeling approach to investigate how adaptation options and various unfolding future scenarios alleviate the impacts of the heatwaves and affect the frequency and intensity of CCHDNs.
We defined three metrics for heatwaves analysis:

1. The number of concurrent hot days and nights: Annual number of days where the threshold for both hot days and hot nights is exceeded
2. The frequency of CCHDN events: Annual number of instances where the threshold for both extreme hot days and nights is exceeded for at least two days in a row.
3. The Length of CCHDN events: Length of consecutive days where the threshold for both extreme hot days and nights is exceeded

We found more frequent and lengthier hot days and nights in cities under all emission scenarios, notably significant under high emissions scenarios (RCP8.5). The highest decadal increase of CCHDNs occur in i) Lugano with 65.8 days in the historical period and 110 (371) days in the near-future (far-future), ii) Geneva with 48 historical days to 108 (362) days in the future, iii) Basel with 48 days in the historical period and 74 (217) days in the future, followed by iv) Bern with 15 historical days and 44 (213) and v) Zürich with 14 historical days and 50 (217) days in the near-future and far-future, respectively.

We projected That the frequency of compound extreme heatwaves (exceeding both historical thresholds of night and day temperatures) might increase by 3.5–7.8-fold and become 3.3–5.3-fold lengthier in all cities of Switzerland in the far-future.

Our findings undermine the need for Swiss cities to adapt to extreme heatwaves by reducing daytime heating, improving the cooling at night and strengthening the resilience of the population towards more severe heatwaves. By implementing proper adaptation option decision-makers in different organizations and sectors could manage the climate risks to a level that is acceptable to their sectors.

Student Research for an Improved Urban Climate

Saba Baer and other Geography students at the University of Bern

Saba Baer[1] saba.baer@giub.unibe.ch

1. Institute of Geography, University of Bern

Within the framework of the course "Research in Geography" in the spring semester 2021, groups of Geography students at the University of Bern performed small, interdisciplinary research projects under the general umbrella "Bern - sustainable city". Several groups analysed challenges - and possible solutions - related to urban heat, using air temperature measurements and thermal imaging. The poster presents a summary of their findings addressing temperature effects of green back yards, green balconies, green roofs, and urban green space.

FAIR NEtwork of micrometeorological measurements (FAIRNESS)

Stefan Brönnimann and COST Action CA20108

Stefan Brönnimann[1,2]

1. Institute of Geography, University of Bern
2. Oeschger Centre for Climate Change Research, University of Bern

For mitigating weather-induced agricultural losses, water resource management, and climate change adaptation, among many other problems, topoclimatic and micrometeorological data play a key role. Often, such microclimatic networks are not operated by national weather serivces, but within by local authorities, scientific projects, or consortia of institutions. There is no European network of such activities. COST Action FAIRNESS aims at building a knowledge share platform in order to facilitate exchange of expertise, of metadata and of data from such networks. One of the key foci are urban climate networks. FAIRNESS compiles an inventory of available and quality proven micrometeorological in situ data sets on the European level and beyond, it provides guidance on measurement and data management in order to meet FAIR principles and avoid temporal and spatial gaps. Best-practice examples of rural and urban FAIR data sets will be shown, and exchange between Action members, stakeholders, specialized user groups and the general public will be fostered.
This will help to fill knowledge gaps, standardize, optimize and promote new environmental-tailored measurement and control procedures, enhance research effectiveness and improve dissemination.

Assessing the effectiveness of urban heat mitigation measures

Moritz Gubler

Moritz Gubler[1,2,3] moritz.gubler@giub.unibe.ch
Moritz Burger[1,2] moritz.burger@giub.unibe.ch
Stefan Brönnimann[1,2] stefan.broennimann@giub.unibe.ch

Cities are especially prone to heat stress due to the Urban Heat Island (UHI) effect, which leads to higher temperatures within densely built-up areas. To combat the UHI effect and adapt them for present and future impacts of anthropogenic climate change, city administrations and urban planners are increasingly implementing urban heat mitigation measures such as unsealed surfaces or green infrastructure (e.g., tree plantings). However, the cooling effects of such measures are often site-specific and difficult to be derived from similar approaches in other cities. To assess the effectiveness of urban heat mitigation measures, different projects of the city of Bern, Switzerland, have been monitored by the Climatology Group at the Institute of Geography by measurements of air and surface temperatures before and after the implementation. Here, we present the results of multiple past and on-ongoing monitoring projects and discuss the applicability of the methodological approaches used.

Intercomparison and combination of low-cost urban air temperature measurement approaches

Moritz Gubler

Lukas Meyer [1, 2] lukas.meyer@giub.unibe.ch
Moritz Gubler [1, 2, 3] moritz.gubler@giub.unibe.ch
Fred Meier [4] fred.meier@tu-berlin.de
Stefan Brönnimann [1, 2] stefan.broennimann@giub.unibe.ch

1. Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland
2. Institute of Geography, University of Bern, Bern, Switzerland
3. Institute for Lower Secondary Education, Bern University of Teacher Education, Bern, Switzerland
4. Chair of Climatology, Institute of Ecology, Technische Universität Berlin, D-12165 Berlin, Germany

Measurements of urban air temperatures (T_{air}) are vital to successful adaptation and mitigation policies to increasing urban heat stress. However, in-situ measurements in cities are often scarce and costly, and therefore low-cost approaches are increasingly used to study urban T_{air}. This allows for inexpensive, yet still highly spatially and temporally resolved observations of urban T_{air}. Despite their merits, a common issue of such low-cost approaches is lacking data quality and potential measurement errors. In this case study, we compare three low-cost measurement approaches regarding their ability to capture intra-urban variability of T_{air} over a period of 24 hours in Bern, Switzerland: a) A network of 79 low-cost measurement devices (LCD), b) bicycle mounted mobile measurements (BCY), and c) 581 Netatmo citizen weather stations (CWS). As the BCY sensor is actively ventilated, it is used as the reference for intercomparisons with LCD and CWS. Compared to the BCY, the median difference of T_{air} for LCD is found to be slightly negative over the entire study period (-0.08 K) as well as during night-time (-0.10 K), and positive during daytime (0.05 K). As the LCD are known to exhibit a positive bias during the daytime, the good agreement of BCY and LCD is speculated to indicate a positive daytime bias in BCY as well. The CWS show a positive median difference of 0.67 K over the entire study period, 0.98 K during night-time, and a negative difference of -0.23 K during daytime. It is hypothesized that these biases result from incorrect siting of the CWS by their owners installing CWS to close to buildings or walls. At night, these emit thermal radiation which could lead to the positive bias whilst the negative bias during daytime might result from buildings shading the CWS. BCY and LCD both show a distinct pattern of nocturnal intra-urban T_{air} variability, which is less pronounced in the CWS measurements. Furthermore, the intercomparison of the three approaches across local climate zones reveals that CWS do not well represent forested areas. Whilst the bias sources of the individual approaches require in-depth investigation in future studies (e.g., external heat sources and measurement height for BCY, daytime short-wave radiation errors for LCD, and nocturnal thermal heating by nearby buildings for CWS), we conclude that combining the three measurement approaches can allow to reduce the shortcomings of each approach regarding spatial and temporal resolution or correct biases inherent to one approach.