International Conference

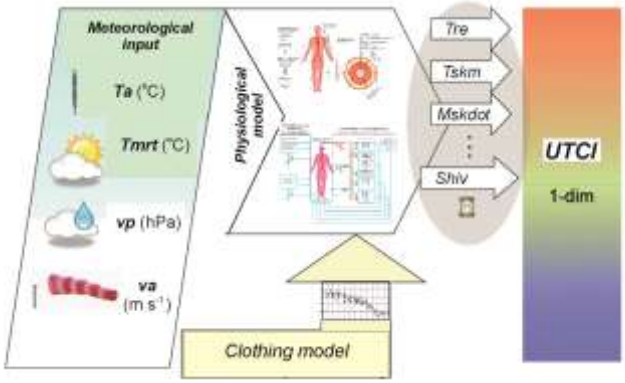
# UTCI - ASSESSMENT MEASURE IN HUMAN BIOCLIMATOLOGY - 10 YEARS OF APPLICATION

# and

# 1ST EUROPEAN BIOMETEOROLOGISTS' REGIONAL MEETING

Warsaw, 22-24 May 2019

# BOOK of ABSTRACTS



*In 2019 we celebrate two important anniversaries:*

- **20 years of the start of UTCI research**. In 1999 at the ISB Congress in Sydney the Commission for developing the Universal Thermal Climate Index UTCI was established. Starting from 2006 the members of Commission worked within COST730 Action „Towards a universal thermal climate index UTCI for assessing the thermal environment of the human being". The leader of both groups was prof. Gerd Jendritzky.

- **10 years of finalizing UTCI programme**. In 2009 the COST Action 730 has successfully completed and UTCI, a new tool in biometeorological and bioclimatic research, was proposed. The results of research were presented at the Conference in WMO Office in Geneva. After that first international school of UTCI was organised in Warsaw.

The last 10 years brought widespread use of UTCI in many research and practical application in the fields related to the thermal environment of people. The present Conference will be the platform for open discussion of the benefits and problems when using UTCI in various branches of research.

The key activity of International Society of Biometeorology is to provide an international forum and platform for the promotion of interdisciplinary collaboration between meteorologists, health professionals, biologists, climatologists, ecologists and other scientists. The progress in all branches of biometeorological research are discussed globally, at International Congresses of Biometeorology, as well as regionally. This year Warsaw is the place of the 1$^{st}$ regional meeting of European biometeorologists. It gives opportunity to discuss principal problems of European biometeorology and to create international research networks in specific topics.

In this brochure you will find abstracts of 54 oral presentations and posters which will be discussed during the Conference and Meeting. The abstracts are organised according to their appearance in the Programme.

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## *Session 1*

### UTCI application – basics, caveats, new developments

Peter Bröde

Leibniz Research Centre for Working Environment and Human Factors, Dortmund, broede@ifado.de

Since its release in 2009, the Universal Thermal Climate Index (UTCI) has become a widely used tool for applications and research on biometeorology. However, some issues related to usage and interpretation still seem to require further clarification. This is suggested by ongoing requests from users received by the author acting as contact for the published operational procedure and the project website (www.utci.org), as well as during his contribution to the current revision of VDI Guideline 3787-Part 2.

After briefly reviewing the structure and elements of UTCI and its operational procedure, this paper will therefore reinforce the UTCI usage guidelines regarding the most frequently encountered topics:

(i) the domain of definition for UTCI input parameters,
(ii) the input of wind speed 10 m above ground,
(iii) the simplified UTCI approximation by the regression polynomial compared to using the lookup-table,
(iv) the asymmetry of the UTCI assessment scale, and
(v) its interpretation concerning human physiology and thermal comfort, respectively.

This will be supplemented by presenting recent developments on extending UTCI to consider varying levels of activity, exposure duration and clothing configurations.

### A new paradigm to quantify the reduction of physical work capacity in the heat

Josh Foster, James Smallcombe, Simon Hodder, Lucy Dorman, Ollie Jay, George Havenith

Loughborough University Design School, Environmental Ergonomics Research Centre,
J.Foster2@lboro.ac.uk, G.Havenith@lboro.ac.uk

PURPOSE: The perceived workload of a worker is linked to their heart rate (HR). In physical occupations, workers tend to show relatively stable HR's, which implies a stable self-paced cardiovascular strain, which integrates stresses of both work and climate. This pacing behaviour directly affects physical work capacity (PWC). Based on this, we developed a new method to study PWC, i.e. productivity in moderately-heavy physical work, related to climate by using a constant cardiovascular strain protocol.

METHOD: A heterogeneous sample of sixteen young adult males performed ten experimental trials each consisting of 1-hour treadmill walking exercise at a HR clamped at 125 b·min$^{-1}$. After a reference trial without heat stress (15°C, 50% rh, UTCI = 15.5°C, WBGT = 12°C), the remaining trials were conducted at the same fixed target HR for 1-hour in UTCI ranges of 25 to 62°C (WBGT's of 21 to 41°C) by variations in both temperature and humidity. The total energy generated (above resting) in each heat-stress experimental trial was expressed as a percentage of that achieved in the reference condition, enabling quantification of the change in PWC (%).

RESULTS: Reductions in PWC were equally sensitive to UTCI ($R^2$ = 0.87) and WBGT ($R^2$ = 0.88), showing a sigmoidal relation. Losses of 25, 50, and 75% PWC were observed at UTCI of 35, 42, and 50°C, respectively. Equivalent losses in PWC were observed at WBGT of 29, 34, and 39°C, respectively.

CONCLUSION: The new approach allows for computation of a new formula to predict changes in PWC as a result of climate change. The UTCI and WBGT appear to be equally sensitive thermal indices in this regard. Our ongoing work incorporates solar radiation, wind, clothing insulation, and hours worked.

Funding was provided by 'Heat-Shield', European Union's Horizon 2020 research and innovation programme under the Grant agreement no. 668786.

**Physiological and perceptual responses to a self-paced work simulation as a function of UTCI**

Josh Foster, James Smallcombe, Simon Hodder, Lucy Dorman, Ollie Jay, George Havenith

Loughborough University Design School, Environmental Ergonomics Research Centre,
J.Foster2@lboro.ac.uk , G.Havenith@lboro.ac.uk

PURPOSE: In physical occupations, workers tend to pace their work based on the combined physiological stress of the metabolic rate and the thermal environment, resulting in a relatively stable working heart rate. In hot environments, the workload therefore decreases to keep the heart rate at an acceptable level. As a function of UTCI, the physiological and perceptual responses to a self-paced work simulation have never been described.

METHOD: A heterogeneous sample of sixteen young adult males performed ten experimental trials, each consisting of 1-hour treadmill walking exercise at a HR clamped at 125 b·min$^{-1}$. After a reference trial without heat stress (15°C, 50% rh, UTCI = 15.5°C), the remaining trials were conducted at the same fixed target HR for 1-hour in UTCI ranges of 25 to 62°C achieved through variations in both temperature and humidity. Rectal and skin temperature were taken as the average of the last 5 minutes of each trial. Thermal sensation (-50, extremely cold, to +50, extremely hot) was taken as the final value of each 1-hour trial.

RESULTS: Our analysis demonstrated a negative relation between physical work performed and UTCI ($R^2$ = 0.87). While UTCI was a strong predictor of mean skin temperature ($R^2$ = 0.96), it did not predict rectal temperature ($R^2$ = 0.01) or sweat rate ($R^2$ = 0.01). About 70% of the variance in thermal sensation could be explained by UTCI ($R^2$ = 0.69), where it tended to plateau above 50°C.

CONCLUSIONS: During our self-paced work simulation, an elevated skin temperature initiates a reduction in workload before significant heat strain arises. The relationship between thermal sensation and UTCI could be used to re-evaluate the descriptive boundaries associated with the current UTCI scale.

Funding was provided by 'Heat-Shield', European Union's Horizon 2020 research and innovation programme under the Grant agreement no. 668786.

## Comparison of estimated values of clothing insulation with the UTCI clothing model

Jin Ishii

Meijo University, Faculty of Science and Technology, Department of Architecture,
ishii@meijo-u.ac.jp

In the UTCI-clothing model, clothing insulation is defined in relation to ambient air temperature. In this model, when air temperature rises to 30°C, the clothing insulation falls below 0.5 clo. In Japan, it is common air temperature reaches to 30°C in summer. Clothing ensembles estimated from below 0.5 clo seem to be light clothes and inappropriate for work. Many Japanese probably wear more clothing on summer weekdays.

The purpose of this study is to compare estimated values of clothing insulation with the UTCI clothing model. The values of clothing insulation were estimated by photographic images of clothes worn by pedestrians. This estimation method was developed by Maruta and Tamura. The photographing from fixed observation point was conducted at a pedestrian overpass. The observations were conducted on a clear day and weekday afternoon at intervals of approximately 15 days through a whole year. Meteorological data were obtained at local meteorological observatory near the observation point.

The estimated mean values of clothing insulation in this study ranged from 0.59 clo to 1.55 clo. The estimated values of clothing insulation tend to higher than the UTCI-clothing model all around. The estimated values of clothing insulation tend to remain the same value, when air temperature rises above 30°C. Japanese may wear more clothing than the UTCI clothing model in summer. Consequently, UTCI may underestimate heat stress in Japan.

## Biometeorological forecast chain to develop thermal comfort/discomfort maps for Italy according to the UTCI

Alessandro Messeri[1,3], Marco Morabito[1,2], Alfonso Crisci[2], Gianni Messeri [2,4], Giulio Betti[2,4], Bernardo Gozzini [4], Simone Orlandini[1,3]

[1]Interdepartmental Centre of Bioclimatology, University of Florence, alessandro.messeri@unifi.it
[2]Institute of Biometeorology, National Research Council, Florence,
[3]Department of Agrifood Production and Environmental Sciences, University of Florence,
[4]LaMMA Consortium – Weather Forecaster and Researcher at Laboratory of Monitoring and Environmental Modelling for Sustainable Development, Florence,

Climate change is leading to an increase in the frequency and severity of hazard events such as heat waves and cold spells across the globe and particularly in Europe. These changes have a direct effect on human health and in particular on the vulnerable people such as the

elderly, children, workers or people suffering from chronic diseases. Despite this, nowadays weather forecast services provide little information about the effects of this particular class of hazards and only few specific weather service based on biometeorological forecast are actually available.

The reliability of the Universal Thermal Climate Index (UTCI) as a heat-related health risk indicator in Europe is already widely demonstrated in recent literature. The aim of the present study is to illustrate the reliability of a comprehensive biometeorological forecast service based on UTCI for operative warning purposes in Italy.

To increase accuracy of the basic biometeorological parameters, Global Forecast System (GFS) at 0.5° are used as initial condition to feed Limited Area Model (LAM) configured to work at high spatial resolution (12 km) by using all schemes and parameterizations suited to perform a more realistic simulation of the earth boundary layer, taking into account the soil and surface interactions. Hourly maps of thermal comfort/discomfort according to UTCI are provided with a forecast up to 5 days. Potentially, this operational chain could easily be implemented in more performed models (i.e. the 3-km ECMWF) and could also be used in specific UTCI health warning systems for vulnerable people.

## UTCI field measurements in an urban park in Florence (Italy)

Petralli Martina[1], Giada Brandani[1], Alessandro Messeri[1], Luciano Massetti[2], Marco Morabito[2], Simone Orlandini[1]

1) Centre of Bioclimatology – Department of Agrifood production and Environmental Studies – University of Florence, Martina.petralli@unifi.it
2) Institute of Biometeorology – National Research Council

The aim of this study is to evaluate the human thermal (dis)comfort in different green areas settings in the city of Florence by using the Universal Thermal Climate Index (UTCI). Field measurements of air temperature, solar radiation, relative humidity, wind speed and black-globe temperature were collected during several hot summer days in various settings of the Cascine Park, the biggest urban park of Florence (Italy). UTCI values have been calculated at human height over various land surfaces (asphalt, gravel and grassland) directly exposed to the sun or shaded by a big linden tree.

Results showed significant differences of UTCI values among the studied land surfaces shaded by the linden tree, while no significant UTCI differences were observed among soil surfaces directly exposed to the solar radiation. Future studies are needed to investigate how the shading effect of different tree species is able to influence the thermal (dis)comfort based on different land surfaces.

## *Session 2*

### Operational UTCI forecasting for heatwave-related health hazards

Claudia Di Napoli[1], Hannah Cloke[2], Fredrik Wetterhall[1], Christel Prudhomme[1], Florian Pappenberger[1]

[1]European Centre for Medium-range Weather Forecasts, claudia.dinapoli@ecmwf.int
[2]University of Reading

The excess mortality in areas affected by severe and prolonged episodes of summer heat such as the 2003 European heatwave revealed the importance of putting in place Heat Health Warning Systems (HHWSs) to mitigate the negative impacts caused by hot weather extremes on human health.

A heatwave-associated HHWS is being developed as part of the pan-European multi-hazard early warning system constructed within the HORIZON2020 ANYWHERE project (EnhANcing emergencY management and response to extreme WeatHER and climate Events). The ANYWHERE HHWS is the first HHWWS based on the forecast of the Universal Thermal Climate Index (UTCI), a state-of-the-art biometeorological index representing the heat stress induced by the atmospheric environment on the human body [1]. As UTCI forecasts have been recently proved skilful in predicting hazardous heat stress levels at the medium range (i.e. up to 10 days) [2], the ANYWHERE HHWS builds on the UTCI forecasts computed daily at the European continental scale using air temperature, humidity, wind and radiation from ECMWF numerical prediction models.

The potential of the UTCI as a predicting tool for heat-related health hazards has been assessed from historical bioclimatological data [3] and it will be here presented. The significance of the ANYWHERE HHSW from a health perspective will also be explored and discussed within an operational context.

[1] Błażejczyk K. et al. (2013). Geographia Polonica, 86(1): 5–10
[2] Pappenberger F. et al. (2015). International Journal of Biometeorology 59(3): 311–323
[3] Di Napoli C. et al. (2018). International Journal of Biometeorology, 62(7): 1155–1165

### The predictability of heat-related mortality in Prague, Czech Republic during summer 2015 – A comparison of selected thermal indices

Aleš Urban[1], David M. Hondula[2], Hana Hanzlíková[1,3], Jan Kyselý[1,4,5]

[1] Institute of Atmospheric Physics, Czech Academy of Sciences, urban@ufa.cas.cz
[2] School of Geographical Sciences and Urban Planning, Arizona State University
[3] Institute of Geophysics, Czech Academy of Sciences
[4] Faculty of Environmental Sciences, Czech University of Life Sciences
[5] Global Change Research Centre, Czech Academy of Sciences

We compared selected thermal indices in their ability to predict heat-related mortality in Prague, Czech Republic during the extraordinary summer 2015. Relatively novel thermal indices – Universal Thermal Climate Index and Excess Heat Factor (EHF) – were compared

with more traditional ones (Apparent Temperature, simplified Wet-Bulb Globe Temperature (WBGT), and Physiologically Equivalent Temperature). The relationships between thermal indices and all-cause relative mortality deviations from the baseline (excess mortality) were estimated by Generalized Additive Models for the extended summer season (May–September) during 1994–2014. The resulting models were applied to predict excess mortality in 2015 based on observed meteorology, and the mortality estimates by different indices were compared.

Although all predictors showed a clear association between thermal conditions and excess mortality, we found important variability in their performance. The EHF formula performed best in estimating the intensity of heat waves and magnitude of heat-impacts on excess mortality on the most extreme days. Afternoon WBGT, on the other hand, was most precise in the selection of heat-alert days during the extended summer season, mainly due to a relatively small number of "false alerts" compared to other predictors. Since the main purpose of heat warning systems is identification of days with an increased risk of heat-related death rather than prediction of exact magnitude of the excess mortality, WBGT seemed to be a slightly favourable predictor for such a system.

## Influence of thermal environment determined according to UTCI on mortality in Polish cities

Magdalena Kuchcik

Climate Impacts Laboratory, Institute of Geography and Spatial Organization, Polish Academy of Sciences, mkuchcik@twarda.pan.pl

Both, very strong heat and cold stress lead to the rise of mortality. The question was - at what value of UTCI a significant increase in mortality does start and how big is it? A basis for a study were: daily number of deaths from all causes, from circulatory and respiratory system diseases over the years 1975-2014, from 8 Polish cities Białystok, Gdańsk, Cracow, Lublin, Łódź, Poznań, Warsaw and Wrocław. All deaths were broken down by sex (male, female) and age (under or above 65 years of age). The meteorological data comprised daily mean, minimum and maximum air temperatures and data from 12 UTC (air temperature, air humidity, wind speed, air pressure, cloudiness), which were applied to calculate Universal Thermal Climate Index (UTCI). The impact of UTCI on mortality was modelled by cubic regression splines and the results were presented in the graphs.

The 40-years period, 1975-2014, includes time of significant climate changes, very cold and extremely hot periods.

In Wrocław, Poznań and Łódź, under cold stress there wasn't any rise of mortality, and in Warsaw, Krakow and Lublin the increase of RR did not exceed 10% under very strong and extreme strong cold stress. In turn the burden of moderate heat stress caused a significant increase in the risk of death, reaching even 10% in Warsaw, Poznań and Łódź. Under strong heat stress most of the cities other than Gdańsk and Lublin experienced a 10-20% rise in RR. When the heat stress was very strong (UTCI above 38.0°C), the risk of death was elevated by more than 20%, and even more than 30% in the case of Warsaw.

**Influenza related hospital admissions and atmospheric circulation in Spain: an statistical approach for the period 2003-13**

Pablo Fdez-Arroyabe[1], Alberto Martí-Ezpeleta[2], Dominic Roye[2,3], Ana Santurtun[1]

[1] University of Cantabria, Geography Department, Santander, Spain, pablo.fdezarroyabe@unican.es
[2] University of Santiago de Compostela, Geography Department, Santiago de Compostela, Spain
[3] Porto University, Geography Department, Porto, Portugal
[4] University of Cantabria, Faculty of Medicine, Santander, Spain

The study of the interaction between atmospheric processes and respiratory diseases is a frequent topic of research world-wide. The effect of weather on infectious respiratory diseases such as influenza responds to a clear seasonality in the temperate areas. In this research, a statistical approach based on non-lineal models is developed to analyse the relationship between influenza cases and daily circulation weather types in Spain for the period 2003-13. The proposed methodology is based on a synoptic approach in which relative risk is estimated for a catalogue of different circulation weather types. Medical data of influenza related hospital admissions have been facilitated by the Spanish Ministry of Health for the study period by postal code. Meteorological information has also been obtained from the National Center for Atmospheric Research (NCEP/NCAR reanalysis data and from the Spanish Agency of Meteorology (AEMET) in order to produce a catalogue of weather types based on the Jenkinson and Collison method.

The overall RR is higher when SW circulation is affecting the Iberian Peninsula while the statistical risk of having influenza-related hospital admission is clearly lower with East and Southeast circulation types in Spain. A specific study is developed also at a regional scale, considering 17 administrative units call Autonomous Communities in which Spain is divided. At this level, each weather type generates a different RR on hospital admissions being geographical heterogeneity and spatial variability of meteorological factors the main characteristic to explain variety of RR values and statistical significance.

**UTCI and the health measures for adaptation to climate change: Bulgarian experience**

Zoya Mateeva

Department of Geography, National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, zoyam@abv.bg

Ten years after creation of the UTCI index it increasingly appears a tool for solving various issues related to the assessment of thermo-physiological comfort of man. This stems both from the qualities of UTCI as a complex physiologically relevant index and from the growing need to assess bioclimatic conditions and resources. This need expands and intensifies in parallel with an increase in the multidirectional impacts of climate change on human life and economic activity, among which impacts on human health occupy a leading position. The health is a subject of a number of direct and indirect effects of climate change, for reduction of which the World is developing special adaptation measures. They are an essential part of the government strategies for adapting to the changes of climate, thus extending the opportunities for using UTCI too.

The purpose of this study is to assess the possibilities of UTCI application in the process of practical implementation of health sector adaptation measures. For this purpose, the study uses as an example the National Adaptation Strategy of Bulgaria, whose development was completed just in the beginning of 2019.

Achieving this goal is done by analyzing the adaptation modules with respect to the potential for applying of UTCI in their accomplishment. As a result, a scheme has been constructed showing the possibilities of using UTCI in various aspects of human health adaptation to climate change.

The results are useful for objective assessment of human being bioclimatic comfort in order to maintain its range of optimal parameters, protecting him from dangerous weather effects, as well as for more efficient use of bioclimatic resources and conditions under the changing climate. Moreover, the application of UTCI in adaptation procedures of human health sector provides new opportunities for improvement of the index itself for the purposes of different practical and applied activities.

## *Session 3*

### Motivations to use water for thermal comfort: the influence of evaporative mister systems on thermal comfort in outdoor eateries

Jennifer Vanos, David Hondula, Ariane Middel, Harrison Ambrose, Alana Kaiser, Mary Wright

Arizona State University, jvanos@asu.edu

Thermal comfort (TC) is an important determinant of quality of life and economic vitality in cities. Successful deployment of strategies to improve TC may become a more important part of cities' planning and sustainability efforts with projections of continued urban growth and climate change. In hot, dry climates, both shading and misting (for evaporative cooling) are commonly deployed strategies to improve comfort and well-being. A case study was performed in the extreme summertime climate of Phoenix, AZ in summer 2016, with the following objectives: 1) quantify the influence of shade and misters on outdoor restaurant attendees' TC, 2) to further understand the restaurant manager perspectives on water-comfort trade-offs. We employed four metrics: air temperature ($T_a$), mean radiant temperature (MRT), the Universal Thermal Climate Index (UTCI), and the Physiological Equivalent Temperature (PET). Microclimate measurements ($T_a$, windspeed, relative humidity, globe temperature) were taken at five restaurants midday in four environmental conditions: mist with and without shade, shade only, sun only. Within-metric analyses, rather than between, were performed.

Across all days, sites, and conditions (sun and shade), misters improved TC. The $T_a$ and MRT were on average 3.9°C and 7.6°C lower in misted locations, respectively, which contributed to lower average PET (-6.5°C) and UTCI (-4.4°C) values. The most effective way to improve TC was through the use of shade plus mist, whereby the PET and UTCI were reduced by 15.5 and 9.7°C, respectively. Facility managers identified customer comfort as the most important factor in mister use. Patio mister use also considerably increased seating capacity. Finally,

aesthetics of misters encouraged use, while cost and environmental concerns were less important.

Gaining knowledge on both the economic costs of mister usage in addition to the benefits to restaurant attendance linked to TC can advance the understanding of active urban water use for TC.

## Better design of outdoor spaces in high-density cities: The influence of environmental perception on outdoor thermal comfort

Kevin Ka-Lun LAU, Sum Ching CHUNG

Institute of Future Cities, The Chinese University of Hong Kong, kevinlau@cuhk.edu.hk

In high-density cities, outdoor spaces are scarce but important to urban living, particularly the health and well-being of urban inhabitants. Well-designed outdoor spaces provide a comfortable environment for urban dwellers and encourage the use of outdoor spaces, improving the well-being of urban inhabitants. Previous studies showed that there are large variations in thermal comfort conditions in different urban settings. Therefore, urban designers must consider these variations when designing outdoor spaces in cities. However, the subjective perception of thermal comfort and how it is affected by people's perception of environmental quality has not been well studied.

The present study aims to investigate the effect of perceived environmental quality on overall thermal comfort as well as sensation of meteorological conditions (i.e. air temperature, humidity, wind, solar radiation) in high-density cities. It was found that the subjective thermal sensation is significantly correlated with UTCI and air temperature.

The results of binary logistic regression analysis showed that overall thermal comfort is significantly associated with thermal, humidity, wind and solar radiation sensation. It is also significantly associated with satisfaction of aesthetic and air quality. On the other hand, thermal and wind sensation is significantly associated with satisfaction of air quality in the survey locations. This suggests that the relationship between overall thermal comfort and subjective perception of meteorological conditions is influenced by how people perceive the environmental quality of the outdoor spaces. It also reiterates the importance of the three approaches of thermal comfort (i.e. thermo-physiological, psychological, and heat-balance of human body) suggested by Höppe and hence psychological adaptation is important in the assessment of outdoor thermal comfort.

## Interdependency of estimated (objective) and perceived (subjective) comfort using the UTCI model in tropics: the case of Singapore

Ata Chokhachian[1] , Daniele Santucci[2], Kevin Lau[3], Stefano Schiavon[4], Thomas Auer[1]

[1] Chair of Architecture Informatics, Technical University of Munich, Germany, ata.chokhachian@tum.de
[2] Chair of Building Technology and Climate Responsive Design, Technical University of Munich, Germany, daniele.santucci@tum.de
[3] Institute of Future Cities, The Chinese University of Hong Kong, Hong Kong, kevinlau@cuhk.edu.hk
[4] Centre for the Built Environment, University of California, Berkeley, CA, USA, schiavon@berkeley.edu

Microclimate among further key factors has a fundamental influence on how people occupy and use public spaces in dense urban environments. Respectively, comfort evaluation of outdoor spaces is essential due to the fact that they accommodate daily pedestrian flows and various outdoor activities, also they contribute largely to urban livability and vitality.

Since its definition, the UTCI has been used as the most effective metric to quantify outdoor comfort conditions. This study investigates on the effectiveness of UTCI to evaluate comfort in dense urban environments in tropical climate employing field measurements combined with individual perception and physiological sensing techniques.

The applied method investigates the verification of correspondences between physiological and psychological response to varying environmental condition in Singapore´s outdoor spaces, focusing on the transient experience from outdoor to indoor (conditioned and non-conditioned), shaded and mechanically ventilated spaces.

Based on a data oriented approach, this study questions the interdependency of estimated (objective) and perceived (subjective) comfort using the UTCI model.

The results in tropical climate reveal that there is a gap between the thermal sensation ("feels like") temperature and individual perception of outdoor conditions.

Significant changes in thermal sensation votes were found when transiting between indoor (air conditioned) and outdoor spaces. Our results showed that exposure to high temperature causes thermal stress in different transient pattern. Although the subjects expressed cool sensation when transiting from outdoor into indoor, such heat stress is not relieved by short-term exposure to cooler environment and will amplify the increase in hot sensation once the subjects were back into the outdoor space. In addition, thermal comfort under transient conditions is strongly affected by the sky condition and air temperature.

## Comparing comfort ranges of UTCI for two tropical cities in Brazil

Eduardo Krüger, Thiago José Vieira Silva, Simone Queiroz da Silveira Hirashima, Eduardo Grala da Cunha, Luísa Alcântara

Federal University of Technology of Paraná, ekruger@utfpr.edu.br

Both, global climate change and urbanization trends will demand adaptation measures in cities. Large agglomerations and impacts on landscape and natural environments due to city growth will require guided densification schemes in urban areas, particularly in developing

countries. Human-biometeorological indices such as UTCI could guide this process, as they provide a clear account of expected effects on thermal sensation from a given change in outdoor settings. However, an earlier step should optimally include an adequacy test of suggested comfort and thermal stress ranges with calibration procedures based on surveys with the target population.

This paper compares obtained comfort ranges for two different locations in Brazil: Belo Horizonte, 19°S, Cwa climate type and Pelotas, at 32°S, with a Cfa climate type, thus with a pronounced difference in local latitude between cities. In each city, a set of outdoor comfort field campaigns has been carried out according to similar procedures, covering a wide range of climatic conditions over different seasons of the year. In Belo Horizonte, the sample obtained comprises 1691 thermal votes with measurements in four different locations over four campaigns. In Pelotas, the sample was considerably smaller (ongoing research) and comprises 257 votes distributed in ten measurement campaigns at five different points.

Obtained results indicate a reduction of neutral temperatures around for 2°C (UTCI units) as a possible latitude and local climate effect for the southernmost location. Comfort ranges, however, suggest a broader band for Pelotas than in Belo Horizonte, possibly resulting from the wider range of microclimatic exposure inhabitants of Pelotas are exposed to throughout the year. A very low UTCI value was found in Pelotas for a thermal sensation vote -1 (13°C for binned data), which was lower than the suggested bands for the index. A possible explanation for that is a longer exposure to cold conditions as buildings seldom are provided with heating systems.

## UTCI as an output of NWP model ALADIN (CHMI)

Martin Novák [1, 3], Radmila Brožková [2]

[1] Czech Hydrometeorological Institute, Regional Office in Usti n.L., Czech Republic, novakm@chmi.cz
[2] Czech Hydrometeorological Institute, Praha, Czech Republic
[3] Jan Evangelista Purkyne University in Usti n.L., Faculty of Environment, Usti n.L., Czech Republic

The Universal Thermal Climate Index (UTCI) is very interesting tool for a biometeorological forecasting. The index describes thermal comfort/discomfort as the concurrent effect of four components of the external environment – air temperature, air humidity, wind speed and radiation. The complex character of this index is main reason behind its difficult prediction by classical meteorological methods.

The CHMI Regional Forecasting Office in Usti nad Labem asked the Numerical Weather Prediction Department (NWPD) of the Czech Hydrometeorological Institute (CHMI) for extension of the list of computed characteristics for UTCI calculation in order to develop new CHMI biometeorological forecast model. As the first step, the NWPD added the mean radiant temperature among routinely calculated outputs of the ALADIN model during 2018.

The subsequent step will be an implementation of the UTCI to the ALADIN model. The NWPD will upgrade ALADIN model (CHMI) with better resolution of 2.3 km (current version is 4.6 km) and more accurate orography description. The NWPD plans to start the new version of

ALADIN model in February 2019. This version already includes an UTCI calculation and CHMI is going to use this index for i.e. improvement of current biometeorological forecasts and bioclimatological mapping of the Czech Republic and other interesting subregions such as mountains, cities and spa. The UTCI will be also used for national heat health warning system (as the part of Integrated Warnings Service System).

The poster includes an introduction of the UTCI outputs from new ALADIN model and its basic characteristics for points, (sub)regions, time series etc.

**Variability of bioclimatic conditions in the Western Sudetes with a special consideration of UTCI index**

Bartłomiej Miszuk

Institute of Meteorology and Water Management – National Research Institute,
Bartlomiej.Miszuk@imgw.pl

One of the most important issues of mountainous region of the Western Sudetes is their variability in the context of bioclimatic conditions. It mainly concerns climate-tourism indices and heat loads that can be measured with the use of UTCI index. Previous research on bioclimate of the discussed region showed that lower located areas are characterized by regular heat stress occurrence in the Summer while in case of the summit zone cold stress can affect both human health and tourism, especially in the cold season.

The analysis was carried on the basis of IMGW-PIB meteorological data for multiannual period. The data was collected from IMGW-PIB stations in the region.

The main goal of the analysis was to evaluate variability in heat loads with the use of UTCI and examine how it correspond to the results of the indices related to the impact of climate conditions on tourism and recreation. In case of climate-tourism evaluation, WSI index for various forms of recreation was used. The results showed that values of UTCI and frequency of heat load classes in the lower zones of the mountains are similar to lowland region of the Lower Silesia. As a result, the usefulness of weather in the summertime is diminished, especially for active recreation forms. On the other hand, in the higher parts the frequency of cold heat loads significantly increases. In the summit zone about 50% of days in the cold season are characterized by extreme heat load. Consequently, it negatively affects the usefulness of weather for tourism and recreation. It also concerns ski tourism. In this case the highest usefulness of weather is shifted to Spring season where snow cover is still high while the frequency of extreme heat loads is lower if compared to Winter. The results of the research can be used in tourist information folders.

**Bioclimatic conditions of Lublin based on the UTCI Index**

Mateusz Dobek, Agnieszka Krzyżewska, Sylwester Wereski

Department of Hydrology and Climatology, Faculty of Earth Sciences, University of Maria Curie Skłodowska, mateusz.dobek@umcs.pl

The aim of this paper is to present the biometeorological conditions in the center and suburbs of Lublin using the bioclimatic index UTCI and appropriate thermal loads.

Meteorological data regarding air temperature, wind velocity, relative humidity of air and cloud cover were used. The source of the meteorological data is the meteorological station of the Department of Hydrology and Climatology UMCS located on Pl. Lithuanian in the center of Lublin and the IMGW Lublin Radawiec station located 13 km from the city center, in rural areas.

Obtained results allowed to analyze the frequency of occurrence of specific classes of index size in the diurnal course and at 12 UTC in the last 40 years. The most frequent periods in which biometeorological situations incriminating the body and days with thermal comfort were determined. The obtained results showed differences in thermal loads in urban areas and beyond.

## *Session 4*

### Prediction of outdoor comfort enhancement in hot and dry climates using human-biometeorological UTCI charts with focus on wind and shading strategies

Wolfgang KESSLING, Martin ENGELHARDT

Transsolar Energietechnik, kessling@transsolar.com

This paper is about findings using UTCI as design parameter in outdoor comfort design in tropical as well as hot and dry climates. Strategies to enhance outdoor comfort have been studied with detailed modeling of environmental and human parameters and have been rated with UTCI. Predictions have been compared to human perceptions in some field studies in Singapore, Cayman Islands, and the Middle East. Backed up by these findings, the authors suggest that the sensitivity of the UTCI in particular for low wind speeds in tropical conditions and shade with reduced MRT in hot and dry conditions shall have further attention by the community developing an updated UTCI index.

In total there are 8 major parameters used which define the comfort perception in outdoor situations: direct and diffuse solar radiation, long wave radiation, air temperature and humidity, wind velocity, activity and clothing. Assessing the combined effect, advanced human-biometeorological parameters such as UTCI can be well used for outdoor comfort design. For purpose of outdoor comfort design detailed dynamical simulation models have been developed to study performance e.g. of fixed or operable shading, wind, vegetation and materials. Prediction are available e.g. on an hourly basis. These findings have been compared to measurements taken in field studies, where the same set of parameters was measured and compared to the modeling as well as observed human perceptions. The findings indicate that the cooling effect is underestimated with UTCI in tropical conditions. People showed a higher response and preference in particular at lower wind velocities. This suggest revisiting the UTCI index to improve the applicability for outdoor comfort design in the tropics.

**Weather influence on zoo visitation in Cabárceno (Northern Spain)**

Domingo F. Rasilla Álvarez, Sonia Crespo Barquín

Department of Geography, Urbanism and Spatial Planning, Universidad de Cantabria, Santander, domingo.rasilla@unican.es

The Cabarceno Zoo is widely recognized as one of the leading zoos in Spain and has become an important element of the tourism industry in Cantabria (Northern Spain), recording half a million visitors each year. With an extension of 750 hectares and more than 20 km of roads and walking trails, it occupies a former open pit mine in a karst landscape.

Since most of the activity of the visitors take place outdoors, the objective of this research is to assess the relationship between weather and zoo visitation, using two methodologies. First, we compare daily values of the most representative facets of tourism climatology, as well as several widely used bioclimatic indices, against the number of daily visitors to the zoo. Secondly, we compared those findings with the results from several surveys in order to highlight the perceptions of the visitors regarding the influence of weather in their activities.

Analysis of visitor statistics show remarkable weekly and seasonal cycles which potentially hidden such relationship, besides deep impact of the economic crises experienced by Spain from 2009 onwards. Consequently, we focus our analysis on the Eastern break (from Thursday to Sunday) and the peak season (August) from 2005 till 2018. Zoo visitation was more sensitive to daily weather variability during the Eastern break rather than the peak season, becoming precipitation the most influential variable (an overriding effect). No behavioural threshold associated with extreme hot temperatures is observed during the peak season, probably because of the typical mild west-temperate climate of the region. Analysis of the perceived preferences of the visitors emphasize the relevance of the atmospheric environment on the level of satisfaction of the visitors, but influenced by previous information (meteorological forecasting).

**UTCI variability during winter seasons in Poland in the 21st century**

Sylwester Wereski, Agnieszka Krzyżewska, Mateusz Dobek

Department of Hydrology and Climatology, Faculty of Earth Sciences and Spatial Management, University of Maria Curie Skłodowska, sylwester.wereski@umcs.pl

In this study spatial and temporal variability of the UTCI index during winter seasons in Poland in the 21$^{st}$ century was analysed. The data retrieved from Institute of Meteorology and Water Management – National Research Institute is from seasons 2001/02-2017/18 from 17 Polish weather stations, which represent all bioclimatological regions of Poland (according to Błażejczyk). The meteorological data used for calculation of UTCI was hourly values of air temperature, relative humidity, wind speed and cloudiness. Analysis of winter seasons is based on UTCI values from 12 UTC, however for detailed analysis of coldwave values from 24 hours were used. Winter is defined as December from previous year, January and February months from next year, so the study covers 2001/02 winter to 2017/18 winter.

The most frequent UTCI heat stress category was *moderate cold stress* with frequency varying from 46% in Łeba (Coastal bioclimatic region) to 66% in Zielona Góra (Central bioclimatic region); in mountain areas this class was less frequent (7-12%). The second-frequent class was *strong cold stress* with values from 11% in Zakopane (Carpathian region) to 43% in Suwałki (North-Eastern region). In mountain areas *very strong cold stress* and *extreme cold stress* occurred frequently (respectively 29-36% and 18-48%). Few cases of *extreme cold stress* were observed at other Polish stations. *Thermoneutral zone* was not recorded in the mountain area, however on other Polish stations it appeared with 0,1% in Suwałki (Coastal region) to 4,6% in Zakopane (Carpathian region).

The 2010/11 winter season was the coldest in the 21st century in Poland, because the highest number of cases from *strong* to *extreme cold stress* was recorded. Most cases of *extreme cold stress* were recorded during 2005/06 winter season, due to cold wave in January 2006.

**Adjusting monthly and daily datasets for UTCI calculations: example of Lithuania**

Justas Kažys[1], Donatas Valiukas[2]

[1] Institute of Geosciences, Vilnius University; Justas.kazys@gf.vu.lt
[2] Lithuanian Hydrometeorological Service under the Ministry of Environment

The main problem for using UTCI in climatological assessment is that hourly data are required for the calculations, while various datasets formed from monthly (at best daily) values. It is a huge difference to calculate UTCI using hourly, daily and monthly datasets. This situation is common practice for databases which hold only monthly (at best daily) values. An original method was created to adjust UTCI values: 1) the UTCI values were calculated for every hour and only then averaged for the month. This approach allows calculating “real” UTCI values and the data could be used for climatological assessment; 2) the average monthly values of different meteorological variables were calculated and only then these values were used for calculating averaged monthly UTCI values.

The hourly data from the period of 1993-2017 were taken from the Lithuanian Hydrometeorological Service archives. For the spatial UTCI values comparison data from 4 meteorological stations (Klaipėda, Telšiai, Dotnuva, Utena) in different regions in Lithuania were used. For the temporal comparison the five starting (1993-1997) and ending (2013-2017) years and five years with the highest and the lowest UTCI monthly values were analysed. Moreover, for better accuracy, day and night UTCI temperatures were calculated separately.

Results showed that UTCI values have small differences in spatial scale and huge differences in temporal scale. UTCI monthly values could be used for November-February period and for the night hours only with small adjustments of the data. However, for the rest of the months and for the day hours the usage of monthly UTCI values should be adjusted using individually developed coefficients.

**UTCI variability during summer seasons in Poland in the 21st century**

Agnieszka Krzyżewska, Sylwester Wereski, Mateusz Dobek

Department of Hydrology and Climatology, Faculty of Earth Sciences and Spatial Management, University of Maria Curie Skłodowska, agnieszka.krzyzewska@umcs.pl

The aim of this study is the analysis of the spatial and temporal variability of the UTCI index during summer seasons in Poland in the 21st century. The data are from 2001-2017 from 17 Polish weather stations, localized in different bioclimatic regions of Poland according to Błażejczyk division. The hourly data of air temperature, relative humidity, wind speed and cloudiness were obtained from the Institute of Meteorology and Water Management – National Research Institute. Based on those values, the UTCI index was calculated. Presented biothermal conditions are from 12 UTC, which is the most representative for the time of the highest human activity. However, for detailed analysis of heatwave UTCI values from 24 hours were used. Summer season is defined as June, July and August months.

In Poland in summer *thermoneutral zone* class occurs the most frequently (56-75% of the summer days), with the exception of mountain stations (Kasprowy Wierch, Śnieżka, where it has 30-35% frequency). *Moderate heat stress* is the class with the second highest frequency of occurrence from 18% to 29% with the exception of coastal and mountain areas.

No *extreme heat stress* class was recorded at 12 UTC in Poland. The most unfavourable conditions for humans were in Upland bioclimatic region (VI) represented by Kraków and Sandomierz stations, where cases of *very strong heat stress* occurred with about 10% frequency. The higest values of UTCI > 40°C were recorded in Kraków on 17.07.2007 and 29.07.2005.

In the 21st century in Poland, the year 2015 was the year with the highest number of cases of *very strong heat stress,* due to 2-weak mega-heatwave in August.

## *Session 5*

**Current Croatian heath waves prevention measures in comparison with UTCI heat waves**

Lidija Srnec, Dunja Plačko Vršnik, Krunoslac Mikec

Croatian Meteorological and Hydrological Service, lidija.srnec@cirus.dhz.hr

Current Croatian heath waves prevention measures have been operational for several years. The measures are coordinated by Ministry of health in collaboration with Croatian Meteorological and Hydrological Service, Croatian Academy of Medical Sciences, Croatian Institute of Public Health, Croatian Health Insurance Fund, Croatian Institute for Emergency Medicine, and many other institutes regarding health and civil protection. Critical meterological threshold values for heath waves are determined in correlation with mortality data. According to them during summer daily warnings are issued from DHMZ towards all partners in the prevention system. Depending on the strengths of the issued alarm, various protection measures are implemented.

In this study, heat waves will be discussed from the UCTI definition perspective. We expect this study can improve current Croatian heath waves prevention measures.

### Occurrence of extreme heat stress in Poland and its circulation conditions

Arkadiusz M. Tomczyk[1], Małgorzata Owczarek[2]

[1] Adam Mickiewicz University in Poznań, Institute of Physical Geography and Environmental Planning, Department of Climatology, atomczyk@amu.edu.pl
[2] University of Gdańsk, Faculty of Oceanography and Geography, Department of Meteorology and Climatology, m.owczarek@ug.edu.pl

The primary objective of the research was the determination of the atmospheric circulation favouring the occurrence of extreme stress of the human organism due to heat stress in Poland. The results was prepared based on data obtained from the Institute of Meteorology and Water Management – National Research Institute, and the National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR). The criterion of extreme stress of the human organism adopted in the paper covered conditions in which the Universal Thermal Climate Index (UTCI) value was higher than 32˚C.

The research showed a statistically significant increase in half of the analysed stations, and an increasing tendency or no changes in the remaining stations. Moreover, after 1990, conditions particularly strenuous for the organism were recorded (UTCI >40˚C) over a major part of the territory of Poland. The occurrence of days with extreme heat stress in Poland was related to the presence of high pressure systems blocking zonal circulation. The research permitted the designation of three types in which the pressure field showed common features, but differed in the location of anticyclonic systems.

### Seasonal Variation of the UTCI index and Heat Waves in Mostar (Bosnia and Herzegovina)

Milica Pecelj

Geographical Institute “Jovan Cvijić” Serbian Academy of Science and Arts, Belgrade, Serbia, milicapecelj@gmail.com
University of East Sarajevo, Faculty of Philosophy, Department of Geography, Pale, Republic of Srpska, Bosnia and Herzegovina
South Ural State University, Institute of Sports, Tourism and Service, Chelyabinsk, Russia

The idea of this study is the analysis of human-bioclimatic condition in Mostar (Bosnia and Herzegovina). Special emphasis is given to the Universal Thermal Index (UTCI) whose purpose is to evaluate degree of thermal stress that human body is exposed to.

Since Mostar is one of the warmest city in Bosnia and Herzegovina, we analyzed variation of UTCI index by seasons. In addition, the thresholds of extreme temperatures were analyzed in order to detect the frequency of heat waves and compare it with UTCI heat stress in the last 16 years. For this study, daily and hourly (07h and14h) meteorological data are collected for the period 2000-2016. Bearing in mind until now there is no bioclimatic analysis in Herzegovina based on heat budget indices, the study of seasonal variation of UTCI provide local features of Mostar bioclimate as a representative of the Mediterranean climate.

## Differentiation of the diurnal and seasonal course of heat load in air masses typical for Central Europe

Monika Okoniewska

Institute of Geography, Kazimierz Wielki University in Bydgoszcz, monika.okoniewska@ukw.edu.pl

The aim of the study is to compare the diurnal and annual heat load of an organism occurring in Central Europe depending on the advection of air masses.

Data from Warsaw (representing the Central European Lowland) from 1991-2000, from eight observation terms and included air temperature (°C), water vapour pressure (hPa), wind speed (m $s^{-1}$) and cloud cover (%) were used for the analysis. Based on the data, a Universal Thermal Climate Index (UTCI, °C) was calculated, which was then averaged for individual months and four types of atmospheric air masses.

In the study, the analysis of differences in diurnal average values of the Universal Thermal Climate Index (UTCI, °C) between polar maritime, arctic, polar continental and tropical air masses was performed, and the frequency of days with different types of heat load in individual air masses was determined.

Analysis have shown that under the conditions of Central Europe, the greatest diurnal variation of biothermal conditions occurs between continental polar and tropical air masses in spring and autumn. In addition, there was a significantly greater variation in biothermal conditions between the masses during daytime than night time, especially in the warm half of the year. The heat load that can be encountered in Central Europe varies from "extreme cold stress" during the night and early morning hours to "very strong heat stress" in the summer at noon. The extreme heat loads of the body are associated primarily with masses of polar continental, arctic and tropical air. The most comfortable conditions occur during the advection of polar maritime air masses.

## Intensity of heat load during selected weather events in 2015-2018 period in particular regions of the south-west Poland

Bartłomiej Miszuk

Institute of Meteorology and Water Management – National Research Institute,
Bartlomiej.Miszuk@imgw.pl

Increase in intensity of heat stress is one of the most important problems related to the impact of weather conditions on human health. The analysis on city adaptation plans in the context of climate conditions and their changes showed that such weather situations belong to the most important aspects affecting most of municipal social-economic sectors. Simultaneously, the region of the south-west Poland is one of the warmest area of Poland and is vulnerable to high frequency of days with heat stress if compared to other Polish regions. Various analysis on climate conditions have shown that a significant increase in air temperature has been noticed throughout the region. Besides, air temperature, growing tendency for the number of hot days, warm days and heat waves has been observed. This

provides to the intensification of heat stress in the discussed area what can have a serious impact on health issues, tourism and various types of recreation and outdoor activities.

The analysis was carried out on the basis of meteorological data from IMGW-PIB stations. It concerned both, 2015-2018 and multiannual (1971-2015) periods.

The main goal of the article was to assess the intensity of heat stress during selected weather events characterized by high air temperature values. Furthermore, a complex impact of weather on human organism was presented with the use of UTCI index. The research showed that during the most extreme thermal events the values of UTCI are classified into the highest heat load classes. Very extreme weather conditions occurred especially in summer 2015 when air temperature often exceeded 35$^{o}$C. The results of the analysis show that such weather events can contribute to serious threat to human health and life and should be taken into consideration in climate adaptation plans and in the investments which could potentially intensify heat load.

**Comparison of PET and UTCI values for three months of year 2018 in Zagreb and Split**

Lidija Cvitan, Ksenija Zaninović

Croatian Meteorological and Hydrological Service, cvitan@cirus.dhz.hr

Biometeorological conditions in Croatia are analysed in Croatian Meteorological and Hydrological service every month, upon the values of biometeorological index physiologically equivalent temperature (PET). The results are published monthly in Meteorological and Hydrological Bulletin, together with the results of the monthly weather analysis from the other aspects. UTCI parameter is not yet operationally in use in Croatia.

The intention was to compare PET values with analogous UTCI values, for three terms daily (7 a.m, 2 p.m. and 9 p.m.) over February, March and April 2018, for Zagreb in the mainland with continental climate, and for Split at the seaside with maritime climate. In almost whole Croatia average air temperature deviations of three months in 2018 from the corresponding multiannual averages 1961-1990 were in the following categories: cold in February, normal in March and extremely warm in April. For each daily term presented is thermal sensation according to PET and UTCI values, using the same values of PET and UTCI parameter as limits between categories of thermal sensation. Presented are also PET categories for average decadal PET values, as well as UTCI categories for average decadal UTCI values for each of three months 2018. In order to estimate the deviations of thermal sensation from the normal values in the referent climate period 1961-1990, determined are also decadal deviations of PET and UTCI values 2018 from average PET and UTCI values in 1961-1990 period for each of three terms.

## *Session6*

### UTCI and climate change adaptation plans in Portugal

João Vasconcelos[1,2], Ezequiel Correia[1], Marcelo Fragoso[1], António Lopes[1]

[1] Institute of Geography and Spatial Planning of the University of Lisbon
[2] Polytechnic Institute of Leiria, joaovvasconcelos@gmail.com

Under the elaboration of the Climate Change Adaptation Plan for the Lisbon Metropolitan Area (LMA) in Portugal, the UTCI was calculated for different periods (1971-2000, 2041-2070 and 2071-2100) and for two scenarios (RCP 4.5 and RCP 8.5) based on an Ensemble model built from two Regional Models (Cordex5).

UTCI in the period of 1971-2000 was relatively moderate, with no presence of days with extreme thermal stress (both cold or heat). There was a high frequency of days with absence of stress, as well as of days with slight and moderate cold stress.

Projections until the end of the century indicated a pronounced decrease in cold discomfort as well as a widespread worsening of heat discomfort.

While in the current period slight and moderate cold stress occurred on more than 75% of winter days, it will not exceed half of the winter days at the end of the century, according to RCP 8.5.

With regard to summer discomfort, a worsening of the conditions of moderate heat stress is projected in the same scenario. In August, more than half of the days at the end of the century will be days of moderate, strong, or very strong stress.

The projections also allow to identify an extension of the period of heat discomfort throughout the year. In the current period, the heat discomfort classes were only observed from June to September and they will occur towards the end of the century between the months of April and October.

LMA is projected to reduce -65 days of cold stress per year (RCP 4.5 scenario) or -75 days (RCP 8.5 scenario) by mid-century. Towards the end of the century the annual reduction projected days of cold stress is -77 days in the scenario of lower forcing and -109 days according to RCP 8.5.

### Influence of urban growth of the city Vienna on the thermal comport of its habitants

Philipp Weihs[1], Heidelinde Trimmel[1], Herbert Formayer[1], Christian Gützer[1], Imran Nadeem[1], Sandro Oswald[1], Stéphanie Faroux[2], Aude Lemonsu[2], Valéry Masson[2], Michael Revesz[1], Kristofer Hasel[1]

[1] University of Natural Resources and Life Sciences, Institute of Meteorology, Water-Atmosphere-Environment, Vienna, Austria, philipp.weihs@boku.ac.at
[2] CNRM, CNRS-Météo France, Toulouse, France (valery.masson@boku.ac.at)

Until 2030, the population within the metropolitan area of Vienna is expected to increase by 10%. This will cause the living space to be densified. However, already now the population is suffering from heat stress during the summer months.

Within the project URBANIA the influence of urban expansion on the heat island effect in the city of Vienna is investigated. The micro scale model Town Energy Balance (TEB) is coupled online and offline with the meso scale model (WRF). Further, measurements are taken in selected districts of Vienna and are used to validate the coupled model. Then this coupled model is used to simulate selected scenarios of urban expansion with regard to a changing climate in the future. The thermal comfort of the population is estimated by calculating the universal climate index (UTCI).

The meteorological conditions in Vienna already now show inhomogeneous spatial variations. For example, the thermal stress on the scale of UTCI varies by up to 6°C between different districts, which corresponds to the span of almost one category on the comfort scale.

Simulations of a historical heat period in 2015 show that densification of the living space may result in a slight increase of air temperature by less than 0.1°C in the city centre. However, optimised growth may result in a decrease of the air temperature by up to 0.1°C.

Micro-scale simulations show also that vegetation may have a cooling effect on the urban climate and that an increase in surface albedo may on the one hand cause a reduction in air temperature, but on the other hand a slight increase of the thermal stress for the population.

## UTCI forecasts in weather service of the Institute of Meteorology and Water Management - National Research Institute (IMGW-PIB) in Poland

Joanna Wieczorek

The Institute of Meteorology and Water Management – National Research Institute, Section of the Specialist Forecasts, joanna.wieczorek@imgw.pl

The assessment of a meteorological threats and their impact on human health is a significant challenge for a national meteorological services, especially in heat waves and cold spells warning system development. The way of providing information and knowledge, so that they are accessible, understandable and adjustable to the public possess another challenge. Development of a meteorological services, where basic forecasts are extended with detailed biometeorological products, seems to be important nowadays, especially from the perspective of public health protection and the adaptation to climate change.

UTCI is one of the indices used in official Polish Weather Service since 2012, in routine operational use form year 2015. The +48h forecasts (6h time resolution) of UTCI category and recommendations for 21 cities in Poland are available daily on www.pogodynka.pl/biometeo/utci. In ‘warm period’ of 2018 (May-September, 153 days) a strong heat stress (UTCI>32°C, SHS) at noon (12:00 UTC) occurred only few times and was differentiated regionally: Szczecin (7 days), Wroclaw (11), Lodz (6), Warsaw (8), Bialystok (8) and Rzeszow (3). The analysis was based on meteorological and radiation measurement data from IMGW network. For comparison – SHS in Warsaw only in July-August period occurred 13 times in 2015. In general, most of the cases of SHS in Poland are noted in period of July-August, but the first cases of strong heat stress usually appear in May, when a days with the significant cold stress are also possible.

A large diversity of the local climate in Poland and its seasonal variability possess challenges for the operation of the comprehensive national 'watch and warning' system. UTCI seems to be a good tool to support the decision-making process of meteorologist, however its operational use was limited due to the complex index calculation process so far. In some cases (eg. windy days in coastal regions – real heat load of inhabitants- Leba case) interpretation of UTCI values seems to be debatable. However, the search for new guidelines for warnings issuing should be discussed at least, especially when we consider problems as climate change and the actual adaptation of the population (greater tendency to internal and external migration) to the local climate.

**Information of IMGW-PIB on the healthy use of solar UV radiation**

Aleksander Curyło, Bogumił Kois, Julita Biszczuk-Jakubowska

Institute of Meteorology and Water Management - National Research Institute,
Aleksander.Curylo@imgw.pl, Bogumil.Kois@imgw.pl, Julita.Biszczuk@imgw.pl

Since the mid-1980s, when first time a significant depletion of ozone over Antarctica was observed, (ozone hole), interest in the subject of the impact of solar UV radiation on human health has grown rapidly. In many countries, UV monitoring measurement networks have been launched. At the Institute of Meteorology and Water Management (IMGW-PIB), UV monitoring measurements has begun since mid-1993. After some time, meteorological services began to inform about the risks of excessive sun exposure, and forecasts of the UV Index, the internationally defined quantity of the amount of UV sunlight, was in use. IMGW-PIB maps with UV Index forecasts began to be presented from 2000. With time, IMGW-PIB added to forecasts a presentation of the measurements in real time. It turns out that not only excess UV radiation can be harmful. Also, too little UV radiation can lead to health disorders and even serious illnesses. In Poland, this problem mainly concerns the autumn and winter months. During this period, UV radiation is so small that it is impossible, by exposing face and hands to the sun (normal for that period), to get the sufficient for health amount of vitamin D3. Deficiencies of vitamin D3 cause weakening of the human immune system and can be the cause of numerous colds during the winter. Therefore, in 2018, the IMGW-PIB on the website has introduced a forecast showing how many percent of daily human demand for vitamin D3 can be obtained at sun exposure.

The presentation will show a method of informing about UV radiation on the IMGW-PIB website. Passing the proper information on UV to the public will be also discussed. On one hand, you should protect yourself from the sun to prevent skin burns, but on other hand, remember that excessive protection against UV radiation lead to vitamin D3 deficiencies.

## Thermal evaluation of open-air art space by UTCI

Kazuo Nagano

Kyoto Prefectural University, info2014@nagano-lab.net

The thermal environment at outdoor museums depends inevitably on the weather, while the exhibition rooms in ordinary museums are air-conditioned to 20-22°C of air temperature and 50-55% of relative humidity to preserve artwork and maintain occupants' comfort. We should pay attention to the thermal effect on the occupants in outdoor spaces, although the durable and waterproof artwork is hard to damage. This study uses UTCI to evaluate the thermal environment of an open-air museum in Kyoto, Japan.

This small museum is made mainly of concrete and glass to form the overlapping decks and ramps descending below street level, cascading water walls and pools. We conceive that is an interpretation of the traditional stroll garden in Japan, where different scenes can be experienced one after another by sauntering down the path around a pond.

The meteorological observation and the measurement of human psychological responses were conducted from 1 to 2 p.m. on sunny days in August, October, and December. One observer walked through eight points inside and outside the museum to measure the air and globe temperatures, humidity, wind velocity, and solar radiation. The forty university students walked with the observer and reported their impressions at each observation point by responding to 30 seven-point scales including thermal sensation.

The results showed that the subjects felt thermally neutral at the points by the cascades, even when the UTCI indicated 36.5°C. It means that the view and sound of falling water, which are not thermal elements, can get rid of extremely hot feelings. Therefore, the contemporary cascades have the same function as traditional ornaments "shishi-odoshi" and "suikinkutsu" in Japanese gardens, which emit cool sounds and conjure relaxing sensation. However, those also raise the risk of heat stroke and other health problems, as UTCI indicates.

## Variability of bioclimatic conditions in Szczecin in the context of thermal seasons of the year

Agnieszka Mąkosza, Jadwiga Nidzgorska-Lencewicz

West Pomeranian University of Technology in Szczecin, Department of Meteorology, Botany and Landscape Architecture, agnieszka.makosza@zut.edu.pl

Climate change is an empirical fact evidenced by subsequent IPCC reports. Urban areas are particularly vulnerable to climate change as the intensified negative effects of global warming are frequently observed there, including the extreme phenomena such as heat waves additionally intensified by UHI. In the context of the above, it would be worthwhile to perform a retrospective evaluation of bioclimatic conditions as their variability is yet another obvious manifestation of climatic variations.

The aim of the present paper is to characterise and evaluate temporal variability of bioclimatic conditions and frequency of particular thermal stress classes in the context of thermal seasons of the year in Szczecin.

The assessment of bioclimatic conditions was conducted with the use of Universal Thermal Climate Index (UTCI). The present elaboration is based on hourly values of the following meteorological elements: air temperature (°C), relative air humidity (%), wind speed ($m \cdot s^{-1}$), and cloud cover (%). The meteorological data were obtained from the Institute of Meteorology and Water Management – National Research Institute (IMGW-PIB) in Szczecin and cover the period 2000-2018. Variability of bioclimatic conditions is considered per periods corresponding to thermal seasons of the year as identified by the Gumiński method on the basis of monthly air temperature values.

**Long-term variability of bioclimatic conditions in Warsaw agglomeration (Poland)**

Katarzyna Rozbicka, T. Rozbicki

Warsaw University of Life Sciences WULS-SGGW, Faculty of Civil and Environmental Engineering,
Katarzyna_rozbicka@sggw.pl

The area of the research in this work is Warsaw agglomeration located in the central-eastern part of Poland. It is the largest city in terms of population (over 2.7 million) and also one of the most attractive and most visited by tourists. The aim of this study is long-term (1980-2016) temporal and spatial analysis of bioclimatic conditions on the example of 3 stations representing various types of areas of the Warsaw agglomeration. One of them is located in city area and two ones are located outskirts of the city. To determine seasonal variability of biometeorological conditions, its effects on humans, the occurrence and the possibilities of practicing various forms of recreation and outdoor activities the Universal Thermal Climate Index (UTCI) and Subjective Temperature Index (STI) were used among others. The STI index was used to determine the types of weather occurring in the studied area. For 10-day intervals the Climate-Tourism-Information-Scheme (CTIS) was prepared, which presents the probability of weather components occurrence important for both residents and tourists.

The results of UTCI analysis shows increasing trend in all stations, more intense in case of stations located outskirts of the city than in station located in the city. A significant variation in the frequency occurrence of particular thermal load in different periods and months was noted. In the station located in the city an increase in frequency of unfavorable thermal loads as heat stress was found whereas in the stations located outskirts of the city an increase in cold stress was found. The main limitations for outdoor leisure activities are associated with biothermal conditions. In winter frequently occurring cold stress and in summer heat stress can be particularly disturbing to elderly and children and non-acclimatized tourists.

**The temporal and spatial variability of Universal Thermal Climate Index (UTCI) in Toruń, Central Poland**

Andrzej Araźny

Nicolaus Copernicus University in Toruń, Department of Meteorology and Climatology, andy@umk.pl

The paper presents the specifics of bioclimatic conditions in Toruń using the UTCI. The Universal Thermal Climate Index (UTCI) is expressed as a reference environment's equivalent ambient temperature (°C) that provides the same physiological response in a reference person as the actual environment (Błażejczyk et al. 2012, Weihs et al. 2012). Physiological response to the meteorological input is calculated based on a multi-node model of human thermoregulation (Fiala et al. 2001), which is augmented with a clothing model.

The temporal variability of UTCI in Toruń was described based on data for the years 1966–2018. Extreme UTCI values ranged from very strong heat stress to very strong cold stress. The article also includes an evaluation of the spatial variability of UTCI in Toruń and suburbs on the example of 2012 data. Meteorological data was taken from ten automatic stations in various cover and land-use types. The greatest variation in UTCI was found between the city centre (point LO1 in the mediaeval Old Town) and a suburb (Koniczynka, in an agricultural land-use zone) (Araźny et. al. 2016).

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## *Session 1*

### A Web-based support system for data-driven biometeorological research

Benjamín Arroquia-Cuadros[1], Ángel Marqués-Mateu[2], Laura Sebastiá[2], Pablo Fdez-Arroyabe[3]

(1) Valencia International University,
(2) Universitat Politècnica de València,
(3) Universidad de Cantabria, pablo.fdezarroyabe@unican.es

Biometerological research requires considerable amounts of spatially distributed data that come from multiple sources and are available in different specialised formats. A first issue that researchers in several disciplines (i.e. public health, agriculture or environmental sciences to name a few) have to face with is the preprocessing of those highly specific datasets to fit their needs. An easy-to-use and practical system to collect data in the proper format may be therefore of interest for the research community. In this study we developed a support system to collect, format, and visualise biometeorological data using well-known Web technologies.

We sought a multidevice design with API access based on two main components: the front-end side for visualisation and interaction purposes and the back-end side for information management related tasks. The variable of interest in this case study is the difference of atmospheric oxygen (DAO) which is known to be related to several health and environmental problems. The system collects the data from publicly available repositories run by the National Oceanic and Atmospheric Administration (NOAA), specifically the temperature, pressure and relative humidity variables. After downloading the data, the system transforms the raw datasets into georeferenced arrays and conducts a series of computations with the goal of making a global raster map of the variable of interest. The map is a key component of the Web graphical user interface (GUI) with which interested users can view and request specific datasets and start the data processing for their research quickly.

The current version of the GUI allows graphical interaction to download time series from a specific site by pointing the geographic location with the mouse as well as raster maps, either global or by user-defined extent, in different tabular and geospatial formats. These functionalities allow scientists to properly prepare the data to conduct longitudinal and spatial analyses.

## Bioclimatic conditions of Lower Silesia Voivodeship in 1966-2017

Arkadiusz Głogowski, Krystyna Bryś

Institute of Environmental Protection and Development, Wrocław University of Environmental and Life Sciences, Arkadiusz.glogowski@upwr.edu.pl, krystyna.brys@upwr.edu.pl

Paper present the temporal and spatial characteristics of the bioclimatic conditions of the Lower Silesia Voivodeship. The daily timed values (12UTC) of meteorological elements in the period 1966-2017 from seven synoptic stations (Jelenia Góra, Kłodzko, Legnica, Leszno, Wrocław, Opole, Śnieżka) were used as the basis for the calculations. Data used in paper came form IMGW-PIB (Institute of Meteorology and Water Management). In order to assess the bioclimatic conditions, a thermal stress index UTCI (Universal Thermal Climate Index) that is calculated with the use of BioKlima 2.6 software was applied. Śnieżka was analysed separately because of her such different conditions.

During the analysed period, frequency of days with extreme cold thermal and very strong cold stress on Śnieżka were about 48%. In other six station, located in Lower Silesia Voivodeship, dominated factor was slight cold stress and no thermal stress (53 %).During the analysed period days with thermal stress related to cold stress occurred more frequently than those with thermal stress related to heat. First half of analysed period mean values of air temperature and UTCI are lower with about 1°C, mean humidity was higher with about 3%. Mean values of cloudiness and wind speed was similar in both periods.

## Bioclimatic conditions of Chornohora and Tatry Mts. (northern Carpathians) and air circulation

Oleh Skrynyk[1], Krzysztof Błażejczyk[2], Jarosław Baranowski[2]

[1] University of Warsaw, Faculty of Geography and Regional Studies, o.skrynyk@uw.edu.pl
[2] Climate Impacts Laboratory, Institute of Geography and Spatial Organization, Polish Academy of Sciences

Chornohora and Tatry Mts. are the highest ridges in northern Carpathians. Chornohora is the highest mountain ridge in the Ukrainian Carpathians with 6 peaks of an altitude over 2,000 m above sea level. This 30 km long massif is a climatic barrier on NW-SE line. However, High Tatras ridge runs along W-E line and its long is also about 30 km. The distance between both ridges is about 250 km. The climate of this part of Carpathians is formed by similar air masses and thus classification of air circulation types by T. Niedźwiedź covering the period from 1873 up to the present can be applied. In the last 2 decades both, Chornohora and Tatry are popular destinations for tourists preferring climbing, skiing and mountain walking.

The aim of the paper is to compare principal features of bioclimate from the point of view of thermal stress experienced in elevated locations and at the bottom of ridges. To assess bioclimatic condition the study bases on average, maximum and minimum UTCI values within the period 1986-2015 and on the frequency of three selected thermal stress categories (<-13°C, 9-26°C and >32°C) for 2 weather stations in Chornohora (Pozhyzhevska, 1451 m a.s.l. and Yaremcha, 585 m a.s.l.) and 2 stations in Polish Tatras (Hala Gąsienicowa,

1520 m a.s.l. and Zakopane, 850 m a.s.l.). Midday meteorological data of cloudiness, air temperature and humidity and wind speed were applied to calculate UTCI.

Bioclimatic conditions of compared ridges have several similarities and differences. In general Chornohora region is warmer than Tatry. However, elevated sites of Chornohora is characterised by more extreme thermal stress conditions especially during advection of arctic air masses.

## Evaluating urban vegetation scenarios to mitigate urban heat island and save building's energy in dense built-up areas in Mega city Cairo

Amir Aboelata, Sahar Sodoudi

Institute of Meteorology, Freie University Berlin. Urban Climate research group.
Eng.amir_ahmed@yahoo.com

Cairo as a mega city witnessed during last 20 years huge rate of urban sprawl and green areas decreasing. Person's portion from green areas decreased between 1995-2015 from 6m/person to 4cm/person. This leaded to high temperature in Cairo compared to its adjacent sub urban and rural areas by 6-8K, which this phenomena is known as Urban Heat Island (UHI).

Intense hot summer days lead to more energy consumption through air conditioning in indoor spaces. This research seeks to find out best vegetation ratio, which could be used to mitigate UHI, enhance thermal performance in outdoor spaces and save building's energy.

A small area from Cairo downtown has been chosen to represent on of the hottest spots. ENVI-met model has been used to simulate the current case compared with three new scenarios; 30% trees of outdoor spaces, 50% trees of outdoor spaces and 30% trees + 70% grass of outdoor spaces. The output of modeling concluded to new measurements of air temperature, wind speed and humidity for each scenario. Therefore, Designbuilder has been used to estimate building's energy according to each scenario. This study showed that 50% Trees Scenario within whole area is the best scenario to mitigate urban heat island. Further result shows that scenario of 50% Trees for the whole area except the street oriented North West – South East (330°) with aspect ratio 1:1 is the best scenario to improve thermal performance and save energy consumption.

## Measured and perceived effect of blue and green features at thermal comfort in urban squares

Lehnert, Michal[1], Jurek, Martin[1], Tokar, Vladimír[1] , Geletič, Jan[2]

[1] Palacký University Olomouc, Faculty of Science, Department of Geography, m.lehnert@upol.cz
[2] Global Change Research Institute of the Czech Academy of Sciences

Located in city centre, open, mostly impervious and usually very frequented – urban squares were identified as one of the most vulnerable localities by thermal stress. In cooperation with local municipalities we therefore focused part of our research to squares of Czech

cities. We calculated UTCI based on field measurement on at least three locations within the squares during the heat waves. The measurement sites were selected to enable evaluate the impact of blue and green features on thermal comfort. At the same time, we conduct extensive questionnaire survey of the perceived thermal comfort by inhabitants. The aim of our research is to evaluate physical (measured) and subjective (perceived) blue and green infrastructure to effectively plan adaptation measures.

## *Session 2*

### A European-scale assessment of the impact of climate change on labour productivity

Simon N. Gosling[1], Jamal Zaherpour[1], Dolores Ibaretta[2]

[1] School of Geography, University of Nottingham, Nottingham, UK, simon.gosling@nottingham.ac.uk
[2] European Commission Joint Research Centre, Seville, Spain

We present the first assessment of the impact of climate change on labour productivity at the multi-national level that uses multiple impact models with multiple climate models to estimate potential impacts across Europe. The assessment uses five impact models that describe observed relationships between labour productivity and temperature. Most of the impact models have been used in previous climate change impact assessments, individually, but never together. Therefore up until now there has been a dearth of understanding on the range of uncertainty in projections that may arise from using different impact models. Projections are presented for 25 climate-impact model combinations under two climate change scenarios: a high emissions scenario (RCP8.5) and a mitigation scenario where global-mean warming is 2°C relative to pre-industrial.

Under the high emissions scenario, by the end of the century, daily average outdoor labour productivity could decline by around 10-15% from present-day levels in several southern European countries, including Bulgaria, Greece, Italy, Macedonia, Portugal, Spain and Turkey. Impacts are lower for countries in northern Europe at around 2-4%, including Denmark, Estonia, Finland, Norway and Sweden. Limiting global warming to below 2°C could avoid a substantial proportion of impacts in the European countries that see the largest impacts without mitigation. With some climate-impact model combinations the declines in labour productivity can be up to 10 percentage points lower with mitigation when compared to without mitigation. The range in projected impacts due to using multiple climate models is comparable to the range in impacts from using multiple impact models with only one climate model. Therefore it is likely that past assessments of the impact of climate change on labour productivity have under-estimated the uncertainty range of projected impacts, and possibly the magnitude of potential impact itself.

## Influence of air circulation on thermal stress in Polish Carpathians

Agnieszka Halaś[1], Krzysztof Błażejczyk[2]

[1] University of Warsaw, Faculty of Geography and Regional Studies, aj.halas@student.uw.edu.pl
[2] Climate Impacts Laboratory, Institute of Geography and Spatial Organization, Polish Academy of Sciences

The bio-thermal conditions are poorly recognized for Polish part of the Carpathians and UTCI has never been used to analyze such a large mountainous area. Polish Carpathians are divided into the eastern and western parts due to the geological structure and altitudes, which create different conditions for the flow of the air masses above the mountain range. Therefore, for this part of Poland the classification of circulation types by T. Niedźwiedź covering the period from 1873 up to the present is commonly used.

The aim of the study is to investigate how the UTCI characteristics vary depending on the type of atmospheric circulation in different seasons and whether there is a difference between eastern and western parts of the Polish Carpathians. The analysis of bio-thermal conditions in the study was based on average, maximum and minimum UTCI values within the period 1986-2017 and three selected thermal stress categories (<-13°C, 9-26°C and >32°C) for five stations located along the mountain range: Istebna, Zakopane, Krynica, Dukla and Lesko.

The results showed that, the eastern and western parts of the Polish Carpathians differ not only in terms of geological structure or terrain, but also for bio-thermal conditions. The western part, despite higher altitudes, was characterized by higher average UTCI values over the considered period, while the eastern stations were characterized by higher extremes. The seasonal variation of UTCI in the Polish Carpathians will be presented in the paper.

## Medicinal properties of climate in Poland and the possibility of their use in treatment of selected diseases

Jakub Szmyd[1,2]

[1] Climate Impacts Laboratory, Institute of Geography and Spatial Organization, Polish Academy of Sciences
[2] Institute of Meteorology and Water Management - National Research Institute, Jakub.Szmyd@imgw.pl

In recent years there has been a noticeable growth in the demand for medical services in health resorts in Poland, as well as an increase in the number of communities applying for the status of a health resort. Currently, there are 46 spas in Poland and each year several new communities attempts to obtain such status. These phenomena are determined mainly by changes in the Polish population, especially in the age structure of residents. Polish society is intensively aging, which results in an increase in the number of people requiring treatment, including medical services in spa resorts. The growth of Poles' health awareness as well as increase in the wealth of Poles, which allows the allocation of more funds for pro-health activities, also contributes to the development of spa resorts.

The aim of the study is to identify areas in Poland where the medicinal properties of the climate are potentially the most advantageous. Diagnosis will be conducted in the general scope, as well as detailed, with regard to the selected diseases. A comparison of the selected areas with the location of health resorts in Poland will make it possible to determine whether the resorts are preferably located in terms of climate, as well as to verify whether the therapeutic profile of the resorts is well defined. The conclusions will also enable to indicate the optimal - conditioned by climatic factors – development directions for therapeutic activities in Polish spas.

The base for the analysis was data from 55 synoptic stations in Poland operated by Institute of Meteorology and Water Management-National Research Institute. From each station data from 3 main standard terms (6, 12, 18 UTC) and daily data for the decade 2008-2017 were used. About a dozen climate indicators regarding to 7 meteorological elements (sunshine duration, cloudiness, air temperature and humidity, wind speed, rainfall, fog) were applied in the study. Data on health resorts, including information about their therapeutic profile, were obtained from the Polish Ministry of Health.

## Weather suitability for outdoor tourism in two European regions

Milica Pecelj[1], Krzysztof Błażejczyk[2]

[1] Geographical Institute “Jovan Cvijić”, Serbian Academy of Science and Arts, milicapecelj@gmail.com
[2] Climate Impacts Laboratory, Institute of Geography and Spatial Organization, Polish Academy of Sciences, k.blaz@twarda.pan.pl

Tourism is an important branch of national economy both, in Poland and in Serbia. Outdoor tourism is strongly influenced by general features of climate and by actual weather. The aim of the present study is to assess suitability of weather conditions for various forms of outdoor tourism in different regions of Serbia and Poland. Köppen-Geiger climate classification will give the background of bioclimatic considerations.

The research base on daily meteorological data from the period 2001-2016 for 7 Polish (Hel, Toruń, Warsaw, Wrocław, Cracow, Jelenia Góra and Hala Gąsienicowa) and 6 Serbian (Novi Sad, Belgrade, Loznica, Niš, Vranje and Mt. Zlatibor) stations. They represent different touristic regions of compared countries. The weather conditions were assessed using Weather Suitability Index bases on bioclimatic weather classification proposed by Błażejczyk.

While the compared regions represent two main climate zones according to Köppen-Geiger classification: temperate (C) and cold (D) they also differ in weather characteristics. In general, in Poland the weather mostly suitable for outdoor tourism occurs from April till September then in Serbia the most suitable is period from September till April. In summer months in Serbian resorts the weather is available for active forms of outdoor tourism. However in Polish resorts we notes less days suitable for passive tourism forms, i.e. sun baths and air baths.

**The influence of thermal stress on physical and tactical activities of football players - the lesson from Russia'2018 World Cup**

Michał Zacharko[1], Marek Konefał[1], Paweł Chmura[1], Jarosław Baranowski[2], Marcin Andrzejewski[3], Krzysztof Błażejczyk[2], Jan Chmura[1]

[1] University School of Physical Education, Wrocław, Poland; marek.konefal@awf.wroc.pl
[2] Climate Impacts Laboratory, Institute of Geography and Spatial Organization, Polish Academy of Sciences,
[3] University School of Physical Education, Poznań, Poland

The present study attempts to assess changes in soccer players' physical and technical activity profiles due to thermal stress, measured by UTCI (Universal Thermal Climate Index) registered in training centres and during matches of the 2018 FIFA World Cup in Russia. The study material consisted of observations of 340 players representing 32 national teams taking part in the tournament. The measured indices included: physical activity: total distance covered [km], distances covered with an intensity of 20-25 km/h and >25 km/h [km], number of sprints performed; technical activity: number of shots, number of passes, pass accuracy [%]; and two physiological parameters: (EVL) evaporative water loss (g/h) during the match and (HR-E) heart rate effort (BPM) during the match (assuming a workload of 400 W/m$^2$). Relevant match data for these indices were retrieved from the official FIFA website, which was gathered using the advanced motion analysis system known as STATS® (Chicago, IL, USA). In addition, the ranking of national teams (from 1 to 32 places) and UTCI climate indicator were used in the research. UTCI was classified as: UTCI(–) - negative difference in UTCI between value registered at training centers and during the match, and UTCI(+) - positive difference in UTCI between value registered at training centers and during the match.

Statistical analysis show that an effect was observed in ranking of national teams ($F$ = 28.358; $p$ = 0.001), in total distance covered ($F$ = 14.928; $p$ = 0.001), distances covered with intensity 20-25km/h ($F$ = 5.505; $p$ = 0.019), numbers of sprints ($F$ = 4.739; $p$ = 0.030, number of passes ($F$ = 6.621; $p$ = 0.010). In all parameters the better result was recorded in UTCI(+). Analysis of the physiological parameters showed that the effect was observed in EVL ($F$ = 491.98; $p$ = 0.001) and HR-E ($F$ = 524.93; $p$ = 0.001). Larger parameter values were observed in UTCI(–).

The climatic conditions at training centres and in places the matches are played should be taken into account in preparations for future World Cup tournaments, especially those in hot countries. Situations where the climatic conditions at training centres are more difficult than those in which matches are played are more beneficial for increasing the physical and technical activity of the players.

**Potential meteorotrophy of air masses in Warsaw**

Katarzyna Lindner-Cendrowska, Grzegorz Kaliński

Faculty of Geography and Regional Studies, University of Warsaw, klindner@uw.edu.pl

Particular air masses in different seasons have divergent physical properties and therefore their influence on human wellbeing and level of meteorotrophy can vary greatly. The present study aims to investigate the possible impact of biometeorological conditions on morbidity in Warsaw, depending on the air mass type. As a case study, daily emergency hospital admissions due to acute myocardial infarction (I21 according to ICD-10) and other chronic obstructive pulmonary disease (J44) in Warsaw were analysed. The Spatial Synoptic Classification (SSC) was applied to divide air masses into biosynoptic types for each day of 5-year period 2013-2017 in Warsaw. Then frequency of thermal stress in each air mass in Warsaw was determined using the Universal Thermal Climate Index (UTCI), as well as the amount of sultry days was calculated.

For the majority of Warsaw medical centres, daily admission rate (AR) was calculated for particular air mass types, in two-year period (2013-2014). Conditional probability for various levels of AR in each air mass were analysed for each season separately. Our preliminary results reveal that MP air in Winter, as well as DT in Spring contribute to higher morbidity on myocardial infarction, while 50% higher AR due to chronic obstructive pulmonary disease was associated with DP air masses in Winter and Summer, DM in Winter and DT in Autumn.

**Weather-related subjective well-being in patients with coronary artery disease,**

Dalia Martinaitiene, Nijole Raskauskiene, Robertas Bunevicius

Laboratory of Behavioral Medicine of Neuroscience Institute of Lithuanian University of Health Sciences, Palanga, Lithuania, dalia.martinaitiene@lsmuni.lt

Increasing concern about climate change increases interest in studies on interaction between weather parameters and human health. Most of them have been carried out to determine association between certain weather conditions and increased mortality, morbidity, hospital admissions, calls or visits to emergency aid services and have been used as statistical data. However, relations between daily weather conditions and daily weather-related well-being have not been widely investigated, especially in patients with coronary artery disease (CAD).

We aimed to evaluate associations between the subjective well-being of patients with CAD and the weather parameters.

From June 2008 to October 2012 a total of 865 consecutive patients with CAD (mean age 60 years; 30% women) were recruited from the cardiac rehabilitation program at the Hospital Palanga Clinic, Lithuania.

In this study for the first time in Lithuania was developed and tested the psychometric properties of self-assessment diary for weather sensitivity in patients with CAD. All patients filled in diary every day from 8 to 21 days (average 15±3 days) about their well-being

(psychological, cardiac and physical symptoms) on the last day. Approximately 13327 measurements and results of questioning were documented.

The weather data was recorded in database eight times every day with 3–hour interval using weather station "Vantage Pro2 Plus" which was located in the same Clinic. The daily averages of the eight-time records for weather parameters were calculated and were linked to the same day diary data.

We found that well-being of patients with CAD were associated with weather parameters, specifically general well-being was better within the temperature range 9-15°C and worse on both sides of this range. Worsened general well-being was also associated with higher relative humidity and lower atmospheric pressure. Weather parameters can explain from 3 to 8% of variance of well-being in patients with CAD.

## *Session 3*

### Spatio-temporal modelling of biometeorological indices in street level using PALM-4U

Jan Geletič[1], Jaroslav Resler[1], Pavel Krč[1], Jana Řadová[1], Kryštof Eben[1], Dominik Froehlich [2]

[1] Institute of Computer Science of the Czech Academy of Sciences, geletic@cs.cas.cz
[2] Deutscher Wetterdienst

Growing urban population represents, together with climatic changes, new challenge for urbanists and local municipalities. People are strongly affected by their surroundings. Especially places with high percentage of impervious surfaces and concentration of people are uncomfortable for inhabitants during heat waves. In a real street, the thermal comfort of urban population is influenced by various factors, like surface materials, traffic volume, wind velocity, air temperature etc., while each surface has different physical characteristics. Although there are several approaches to spatio-temporal modelling of thermal comfort, most of them use parameterizations of surroundings and a simplified meteorology.

PALM-4U is the first model based on large-eddy simulation (LES) approach which has implemented a very detailed urban surface model (USM). The USM contains an energy balance solver for horizontal and vertical impervious surfaces and thermal diffusion in ground, wall and roof materials. Additionally, it includes a simple model to deal with anthropogenic heat sources.

One of the fundamental parts of PALM-4U represents the multi-reflection radiative transfer model (RTM). It calculates interactions of radiation with land and urban surfaces for short-wave and long-wave radiation and it also has an integrated model of absorption of radiation by resolved plant canopy (i.e. trees, shrubs). The recent version 3.0 of RTM is able to calculate spatial and temporal distribution of the mean radiant temperature (MRT). The calculation is based on the same principles and discretization schemes as the calculation of radiation interactions, thus representing a methodologically correct way of MRT derivation. The values of MRT, together with other modelled meteorological values, form a basis for integrated calculation of biometeorological indices (UTCI or PET) done in a new biometeorology module. In this presentation we will show first results of spatio-temporal modelling of biometeorological indices (UTCI and PET) using LES in Prague-Dejvice.

**Diurnal change in psychological and physiological responses to consistent relative humidity of 60 % rh to 80%rh**

Naoshi Kakitsuba, Qimin Chen

Meijo University, naoshi@meijo-u.ac.jp

Following the previous study (Kakitsuba, 2018, Roomvent2018, Finland), diurnal change in physiological and psychological responses to thermal environments at consistent relative humidity (Rh) was investigated in summer. Lightly clothed seven male and seven female subjects participated in the experiment where Rh was maintained at 60%, 70% and 80 % at air temperature of 28$^{o}$C from 9 h00 to 18 h30. Skin temperatures and local heat flux rates at four sites and tympanic temperature were continuously monitored at 2-min intervals throughout the experimental period. Body weight loss, oxygen consumption rate were measured during the periods of 9 h30-10 h30, 13 h30-14 h30 and 17 h30-18 h30. In addition, thermal sensation and comfort votes were recorded at the same time.

The results showed that the amount of heat loss was slightly greater than metabolic heat production in almost all cases. However, tympanic temperature and mean skin temperature increased from the morning to the evening in both groups. The subjects voted “warm” in the morning at 70% rh and 80% rh but voted “slightly warm” in the evening whereas they voted “slightly warm” at 60%. Two reasons are plausible for diurnal change in thermal sensation at 70% rh and 80% rh. The subjects were accustomed to high relative humidity towards evening, and voted due to diurnal change in cutaneous sensation threshold zone. In conclusion, these results indicated that high relative humidity of 70% or 80% rh may be acceptable in the evening in summer.

**Infra red skin temperatures compared to thermal comfort indices (UTCI, TE and ID)**

Gonçalves F. L. T., Santos, E. S.

Atmospheric Sciences Dept., IAG-University of São Paulo, fabio.goncalves@iag.usp.br

Thermal comfort indices have been used since earlier last century to analyse the relationship among human and animal comfort and environmental variables, mainly due to temperature and relative humidity. This work deals with a comparison between skin temperatures and different thermal comfort indices (UTCI, Effective temperature and Discomfort index).

The study selected a group of 20 elderly (over 65 years old) and tested them in a chamber with different temperatures (24 and 32$^{o}$C, corresponding respectively to the comfort and extreme indoor heat at our study region of São Paulo) and relative humidity (30% and 60%, also extreme indoor conditions). The Infrared camera (FLIR T640) was used in order to take pictures after the comfort tests (24$^{o}$C and RH of 30/60%) and after the heat tests (32$^{o}$C with the same RH values). Five face skin temperatures were performed in order to have a better overview of the heat effect on human skin body.

Pearson correlation was used to compare the differences (heat and comfort) between skin temperatures with comfort and heat tests and calculate their differences. These values were

compared to thermal comfort indices differences using correlation coefficients. The results have shown a high correlation among all indices and the average of skin temperature differences, over 0.70 with all indices. These results are quite interesting and we plan to perform this study with a larger population including questionnaires and IR pictures.

## Season and Indoor Air Conditions in Housing

Masatoshi Tanaka

Professor Emeritus of Fukushima Medical University, mtanaka@fmu.ac.jp

**Introduction** The climate in Japan is generally cool and dry in winter, and hot and humid in summer. Winter season is from December to February. January is the coldest month. Summer season are from June to August. July or August is the hottest month. Spring and autumn is moderate comfortable seasons. We researched the housing in Fukushima City, which is located in the North-East of Japan. Indoor air- conditioning is especially important to keep the health condition of the people.

**Methods** Room air temperature and humidity were measured and recorded in the living room and bed room. Thermal recorders were set up at a height of 0.5-1.5 m from the floor for each room, that is, living activity spaces. In winter, the $CO_2$ was measured and recorded in the kitchen. Measuring devices are Thermo-Recorders and $CO_2$ Recorders, with automatic recording systems (T&D Corporation, Japan).

**Results & Discussion** In summer, rooms were comfortable with the use of the air conditioner, but uncomfortable with no air conditioner. Natural ventilation was not satisfactory. As an example, in the living room of housing with air conditioners in August, the air temperature was 24-25°C and humidity was rather high at night. During the daytime, the air temperature was 26-27°C. Humidity level was 40-50% and Discomfort index (DI) was 70-75 levels.

Indoor air temperatures in the living rooms and bed rooms were similar; max average temperature over 29°C. Humidity was rather high. Discomfort index (DI) was about 80. DI is calculated with air temperature and humidity. Over 80 DI is discomfort as an indicator. So the thermal conditions at indoor housing are hot and humid, and not so comfortable.

In winter, the air temperature was 18-20°C at night, and the air temperature was 20-25°C during the daytime. Humidity level was 40-50%. Wind-chill index (WCI) was level 300 kcal/$m^2$/hr. WCI is calculated with air temperature and air velocity for evaluation of cold degrees. Wind-chill index 300-500 kcal/$m^2$/hr is cool and wind-chill index 150-300 kcal/$m^2$/hr is comfortable according to the evaluation of thermal conditions. Inside the housing are not so uncomfortable.

$CO_2$ concentration in the kitchen of each house was measured in the winter season. Mean of average $CO_2$ concentration was over 1200 ppm and maxim $CO_2$ concentration was over 3600 ppm. Allowable concentration of indoor carbon dioxide is generally 1000 ppm. $CO_2$ levels became to be high. Poor air quality occurs frequently inside air-tight and narrow spaces; therefore, adequate ventilation in the room is needed to keep good air quality. The thermal condition of living spaces and healthy air must be seriously considered.

**Long-term microclimate studies of peatlands as potential refugia of climate change**

Sandra Słowińska[1], Katarzyna Marcisz[2,3], Mariusz Lamentowicz[2,3], Krzysztof Błażejczyk[1], Michał Słowiński[4]

[1)] Climate Impacts Laboratory, Department of Geoecology and Climatology, Institute of Geography and Spatial Organization, Polish Academy of Sciences, s.slowinska@twarda.pan.pl
[2)] Laboratory of Wetland Ecology and Monitoring, Adam Mickiewicz University, Poznan,
[3)] Department of Biogeography and Paleoecology, Adam Mickiewicz University, Poznan,
[4)] Department of Environmental Resources and Geohazards, Institute of Geography and Spatial Organization, Polish Academy of Sciences,

Peatlands are unique environments, often acting as microrefugia of various taxa and climate change refugia (Morelli et al., 2016). They are also the largest natural terrestrial carbon store and need special attention in the face of the climate change challenges. The response of ecosystems to predicted climate change can be empirically estimated by experimental research simulations, as well as by long-term monitoring.

The functioning of peatlands depends on the appropriate groundwater table depth. Groundwater table fluctuations in ombrogenic and topogenic peatlands reflect interannual and seasonal changes in precipitation and thermal conditions. Unfavourable meteorological conditions (e.g. prolonged drought) within several years may cause tree encroachment, can affect the peatland ecosystem by changes in microclimatic and surface conditions.

We have been investigating interactions between abiotic and biotic factors of a small Sphagnum mire (ca. 6.0 ha) for over ten years now. The mire is located in transitional temperate climate and is the only place in Polish lowlands where glacial relict *Betula nana* occurs.

We observed that 2-3-year-old layout of unfavourable hydrometeorological conditions is sufficient to peatland started to overgrow. We have also examined the differences in microclimates and species composition of testate amoeba between open and shaded (by trees) plots.

The results of the study from the growing season 2012 showed that open plots were characterized by higher air temperature, despite often lower values of minimum temperature and increased vapour pressure deficit, what caused more frequent drying of surface moss layer. The cumulative value of growing degree days (GDD) showed that the coldest places were the shaded ones. Also, we have observed differences in dewfall occurrence, what has a significant contribution to the formation of microhabitat conditions. The mire was colder than the surroundings and ground frosts occurred there even in the summer.

Our results show that microhabitats changes affects on biological processes and should be taken into consideration in palaeoecological investigations.

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