The role of trees in urban thermal comfort and SkyView Factor

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Determination of comfortable places in urban areas is one key issue for urban planning or design processes. In order to determine comfortable places of Erzurum in this study, measurements are made for six different types of tree in the city. These measurements are compared with the data obtained from meteorological station located in urban and rural areas. Additionally, fish-eye photographs at 1.5 m above ground are taken in this study for the calculation of Sky View Factor (SVF). In the context of this study, relationships between air temperature, human thermal comfort and different types of trees have been determined for the city of Erzurum. Meteorological measurements were made three times in one day for summer months and RayMan model was used for the analysis of these measurements. Trees used in this study were Fraxinus americana L (1), Pinus sylvestris L. (2), Salix babylonica L. (3), Ulmus glabra Huds. (4), Betula pendula Roth. (5), Malus hybrida (6). This study was made for defining that trees produce more comfortable conditions during summer months. The relationship between the air temperature under trees and SVF was in addition investigated. The effects of different types of trees on thermal comfort in urban areas for especially summer months were also determined.

It was stated from the ordination analysis that values of Sky view factor (SVF) are independent from azimuth and PET, which must strongly be related to Tmrt and SVF values are proportional to width of corolla and height of plant.

Keywords: Skyview factor, Trees, urban area

Developments and applications of thermal indices in urban structures by RayMan and SkyHelios model

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In order to analyze urban bioclimate and climate several input and output parameters are re-quired. For the quantification of thermal bioclimate assessment methods based on the human energy balance builds the basis of all the known thermal indices.

RayMan model can calculate mean radiant temperature and thermal indices (PMV, PET, SET*, UTCI and PT). For the calculation of mean radiant temperature, which in one of the most influencing parameters of thermal comfort on human, especially during summer conditions, many information about the radiation fluxes (short and long wave), wind speed and modifying factors (Sky View Factor, surface temperature, …) are required.

Some data and information can be obtained from measurement or simulated by micro scale models. This information in combination with shade, sunshine duration, wind speed and direction in simple and complex environments can be derived by RayMan and SkyHelios model. The models are able not only to calculate but also visualize climate and urban climate information based on grid data and vector data. The information can be derived for different spatial and temporal scales depending on the aim and the demands. In addition the Climate Mapping Tool can visualize most of the demanded urban climate data and data formats in combination with SkyHelios. In addition all three models are linked together and can exchange relevant inputs and information.

The application possibilities of the models cover several fields of human-biometeorology including urban climate issues for micro scale. Several possible applications for sky view factors, sunshine duration and thermal indices in complex urban environment will be shown.

Towards a city-wide analysis of mean radiant temperature at high spatial resolution – An example from Berlin, Germany

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Heat stress is expected to increase in the future due to global climate change. Many epidemiological studies show the close link between elevated air temperature and increased morbidity and mortality, which are not restricted to subtropical and tropical regions but also common in cities at higher latitudes like Berlin (52.5° N). Heat-stress risks are particularly high in urban regions, since urban climate modifications of regional weather conditions tend to increase heat-stress hazards.

In order to analyse heat-stress risks and hazards within a city, the mean radiant temperature is an important variable as it sums up long- and short-wave radiation that reaches the human body. Thus, the mean radiant temperature along with air temperature, atmospheric humidity and wind speed is used for the calculation of many biometeorological indices. In urban environments mean radiant temperature is highly variable due to the shadow patterns of objects. To calculate the mean radiant temperature, urban structures such as trees, bushes, courtyards, street canyons and buildings need to be parameterized or explicitly included. The former reduces the computation demand, but limits the possibility to derive planning measures to reduce heat stress. In addition, weather and climate influence the variability of the mean radiant temperature, because the atmospheric conditions are heterogeneous in large urban areas.

Therefore, the aim of this study is to calculate the mean radiant temperature for the case of Berlin while considering both micro-scale urban structures and meso-scale atmospheric conditions. For the computation of the mean radiant temperature we apply a version of the SOLWEIG model (Lindberg et al. 2011) that is able to use gridded meteorological input data. Digital surface models of buildings and vegetation with a spatial resolution of 1m provide the height of the micro-scale urban structures. The Central Europe Refined analysis (CER) serves as input for meso-scale atmospheric conditions.

We will discuss the resulting spatio-temporal pattern of the mean radiant temperature in view of the applied methodology as well as regarding actions to reduce heat stress.

Lindberg, F., C.S.B. Grimmond, 2011: The influence of vegetation and building morphology on shadow patterns and mean radiant temperatures in urban areas: model development and evaluation. Theor. Appl. Climatol., 105, 311-323.

Heat-related health impacts associated with the urban heat island and climate change in the West Midlands, UK.

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Heatwaves are associated with a range of adverse health effects, which can lead to emergency hospitalisations and mortality. In towns and cities, the Urban Heat Island (UHI) effect i.e. higher ambient temperatures in the city centre compared with surrounding suburban and rural areas, particularly at night, can exacerbate these health effects. The effects of UHIs are often amplified during anticyclonic summer weather conditions, which can cause or exacerbate heatwaves. Climate change projections often do not include the effects of the UHI, due to difficulties in resolving urban scale features. This means that assessments of health effects using these projections may underestimate the actual magnitude of future heat-related health impacts.

Birmingham is the second most populous city in the United Kingdom, and observations indicate that it has a pronounced UHI. Recent modelling showed that replacing urban land categories in the West Midlands with rural ones led to a reduction in 2 metre temperature of around 3 degrees Celsius on average and up to 7 degrees Celsius during the heatwave of August 2003, compared with the baseline urban simulation. In addition, examination of the extent of horizontal advection of warm air away from the city centre indicated that temperatures downwind of Birmingham centre were up to 2.5 degrees Celsius warmer than those upwind.

We present results of a health impact assessment during heatwave periods, based on numerical simulations of the UHI in Birmingham and the West Midlands Metropolitan region using the regional meteorological Weather Research and Forecasting (WRF) model, with an urban canopy scheme. We find that heat-related health impacts associated with the UHI effect are significant and that the heat-health burden will increase in future, based on published temperature projections for the UK. These findings can be used to better quantify the current heat related health impacts relating to the UHI as well as future impacts under climate change scenarios. It may also be used to inform future adaptation measures to protect populations from heat in urban environments.

A contribution to the summertime heat improvement in a marathon course by application of radiate and airflow simulation

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Tokyo Olympic Games will be carried out at midsummer of 2020. Therefore a risk of heat exhaustion has been overstated when decision making of outdoor play is revealed. Summertime heat environment focused for the Olympic course in the heart of Tokyo has been discussed in this research. A comprehensive tool considering radiate and wind flows was developed to simulate the thermal impacts to athletes and audiences by taking the measures such as radiation shelter, planting trees and evaporative cool mist.

A Multiscaler Thermal Analysis of Urban Playgrounds

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The ways in which many playgrounds and parks are designed are not conducive for thermally safe and active play by children. Children are more sensitive and vulnerable to heat-related illnesses than the average adult, mainly due to their small body mass-to-surface-area ratio. This results in thermoregulatory difficulties during physical activity in the warm-hot ambient temperatures. Notably, the mean radiant temperature influences surface temperatures of playground equipment, and hence the dangers of burns and heat stress are present, particularly in predominantly sunny climates. Impacts are important to understand due to current and future urban heating and climate effects, urban land use change, growth of urban areas, and a lack of bioclimatic design in warming cities. Urban climate models cannot resolve human-scale or playground-scale effects, and remote sensing (RS) data, although better, also misses subgrid variability that occurs on the scale of centimeters within a playground.

The objective of this study is to address 'touch-scale' (hand based) surface temperatures on the order of centimeters, assessing the variability within the various subgrids in order to develop a framework linking the three scales of data. We utilize two sets of surface temperature data collected mid-day in Phoenix Arizona: 1) MASTER (MODIS/ASTER) overflight RS data at a 7m resolution, and 2) in-situ touch-scale data at < 1cm resolution using infrared thermometry. Within Phoenix – the U.S. metropolitan area with the highest summer temperatures – select neighborhood data is focused on two playgrounds within one neighborhood from July 2011 and Sept 2014 (air temperatures of 38^oC). Within-grid variability is assessed to determine the distribution of surface temperatures above or below the mean of remotely sensed data.

Results demonstrate the RS MASTER data for the neighborhood and two parks generally fitting a normal distribution curve, while the touch-scale data has a positive, or right, skew to the higher temperatures due to the presence of materials with high thermal conductivity (metal and plastic slides, metal bars, plastic seats, rubber or artificial turf). These touch-scale values were 20–40^oC greater than the 7m grid mean from the RS data within the playgrounds, reaching maximum magnitudes of 72–87^oC (dark slides, rubber surfaces); under shade however, these surfaces were 23–38^oC cooler.

This study demonstrates that for select surfaces, RS data is sufficient (e.g., roads, roofs, parking lots); however, in playgrounds and other neighborhood locations, this resolution is not accurate enough to quantify extreme and dangerous temperatures. Touch-scale measurements were largely different than remotely sensed temperatures in the playgrounds, yet nearly identical for sand and concrete surfaces. This information provides a paradigm for linking point measurements with RS grid measurements, and a quantitative framework addressed various scales in urban climate research. Applying information to public safety and children's health, illness and injury due to extreme heat can be avoided, and playgrounds can be designed for thermally safe and active play.

Indoor-outdoor environmental coupling and exposure risk to extreme heat and poor air quality during heat waves

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Mortality and morbidity associated with extreme summer heat and poor air quality continues to be one of the most pressing human health challenges in cities and is likely to be exacerbated in the future due to urban growth and climate change. While traditional epidemiological studies of the health effects of heat and air quality focus on outdoor environmental measurements, typical urban residents spend more than 85% of their time indoors—and some of the most vulnerable populations (e.g., the elderly) spend an even higher fraction of time indoors. While the indoor environment is coupled with the outdoor environment there are key differences both in terms of air quality and thermal conditions. With respect to thermal environment, for buildings without air conditioning, this coupling includes variations in indoor air temperature that depend on building construction characteristics, location within building (e.g. top floor, south façade), occupant behavior, internal loads, ventilation, and infiltration. Indoor air quality, on the other hand, is driven by the relative magnitude of each mode of air exchange (e.g. infiltration vs. filtered mechanical ventilation) and emissions and secondary reactions of air pollutants indoors. Hence, there is a need to better understand the relationship between indoor and outdoor environments, and how this relationship is affected by occupant behavior and building construction and management practices. In the case of air conditioned and mechanically ventilated buildings a scenario of particular interest is that of coincident heat waves and power outages producing very unhealthy indoor environments.

This presentation will discuss a newly funded research project that addresses these issues, with an emphasis on eldercare facilities. It will introduce some of the key mechanisms that drive differences in indoor and outdoor conditions and present some early findings related to risks of coincident heat waves and power outages or equipment failures in buildings.

Effect of urban pollution on indoor air quality in energy-efficient buildings in the UK

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UK government has launched the target for reducing its greenhouse gas (GHG) emissions by 80% below 1990 levels by 2050. However, half of the CO2 emissions results from building sector. Naturally, promotion of energy efficiency measures for the new-built as well as refurbished buildings is the key factor to achieve such ambitious and stringent goal of carbon reduction apart from low-carbon power generation and behavioral change. Increasing the air-tightness and therefore reducing heat loss in winter is one of the important energy-efficient measures being implemented in the UK. There are two views currently in relation to the impact of insulation and airtightness on the indoor air quality and health. One believes increases in air-tightness will degrade the indoor air quality due to the insufficient ventilation, and the other holds the view that higher airtightness will minimize indoor exposure by providing more protection from the ingress of outdoor pollutants. These two views sound contradictory but both are based on reasonable ground. In this paper, we hope to shed some lights on this issue by using UK as a case study. We developed a simple one-compartment model to investigate how the urban pollution in different urban districts in London affects the indoor air quality in London dwellings. The results reveal that the current trend toward more airtight dwellings by adopting Passivhaus standard in UK may have two sides. It can greatly improve indoor air quality for the buildings located the urban centers with low or light indoor sources by enhance the protection of ingress of outdoor pollutants. However, it may cause problems in some rural dwellings with high indoor pollutant source.

Influence of physical properties of vertical wall surfaces on human thermal sensation based on field measurements and microclimate simulation

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In recent years, various countermeasures, such as greening, reflective painting, and ventilation paths, have been launched against Urban Heat Island phenomenon. One of the major purposes of these countermeasures is to create acceptable or tolerable thermal environments inside a warmed urban area. Thus, the performance of countermeasures should be assessed based on human thermal sensation as well as air temperature reduction. Previous studies have shown that radiation has a great influence on outdoor thermal sensation in summer. Therefore, the physical properties of building cladding materials in relation to radiation are important factors for thermal sensation in pedestrian space. Furthermore, considering the shape of the human body, the physical properties of vertical wall surfaces have more influence on thermal sensation in pedestrian spaces than those of horizontal wall surfaces. However, the properties of building cladding materials for walls have been mainly studied for reducing the heating and cooling loads of indoor spaces. Thus, knowledge of the influence of the modification of physical properties of building cladding materials on outdoor thermal sensation must be accumulated.

In order to clarify the influence of the modification of physical properties of building cladding materials on outdoor thermal sensation, field measurements were carried out at the COSMO (Comprehensive Outdoor Scale MOdel) site, Japan, in the summer of 2011. Three types of vertical wall surfaces, i.e., concrete, greening, and high reflective material, were set up, and surface temperature, air temperature, wind velocity, and three-dimensional radiant heat transport near each wall were measured. Additionally, the radiation and conduction simulations were conducted for the same area as the field measurements. Measured data was used to validate the simulation.

Calculated values of surface temperature agreed fairly well with the measured value in terms of peak position. The estimated absorbed radiation by a human body at the center of the canopy layer was compared. Although slight discrepancies between calculated and measured values were observed, these differences fell within 5% of the total absorbed radiation value.

The surfaces made of greening and high reflective material were found to almost always be cooler than the concrete surface, but the high reflective surface heated the ground and wall surfaces of neighboring buildings more than the others since it reflected more short-wave radiation. It was estimated that a human body standing near the high reflective surface would absorb the radiant heat more than when standing near the concrete, and among the three cases compared here, the radiant environment was evaluated to be the worst for the high reflective surface.

Thermal comfort conditions of urban spaces in a hot-humid climate of Chiangmai city, Thailand

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Urban spaces are most important to promote liveable cities because they accommodate pedestrians and various outdoor activities which contributing to urban livability and vitality. Thus, the urban microclimate is an important issue to determining the quality of urban spaces, especially in rapidly growing Asian cities in tropical climates. The aim of this study was to investigate thermal sensation for occupants of outdoor and semi-outdoor urban environments in wide range of hot-humid tropical climate conditions. The measurement period was conducted during the daytime from 8 am to 4 pm on April within the year 2014, which is the most representative a hottest month of summer in Chiangmai city. Thermal environment conditions of two different types of urban spaces were evaluated based upon the measurement of major climatic parameters, while the thermal acceptability of subjects was captured concurrently using a questionnaire survey. The respondents were conducted in a wide range of air temperature (34.8±3.2°C), relative humidity (40.7±7.3%), wind velocity (0.7±0.3m/s) and mean radiant temperature (40.3±8.8°C) for the climatic conditions in summer. The Thermal Sensation Vote (TSV) of the respondents were expressed on a 7-point scale ranging from -3 (very cold) to +3 (very hot), whereas the respondents were asked to rate their overall thermal comfort level (or acceptability) to determine the responses of individuals regarding the outdoor climatic conditions, along with personal parameters (e.g., age, gender, weight and height) and characteristics (e.g., clothing, activity etc.) of respondents.

A total of 296 questionnaires were collected in the outdoor (72.3%) and semi-outdoor (27.7%) urban spaces during the survey, which was carried out on days with suitable weather and avoid rainy days. Metabolic rate and clothing insulation were estimated in accordance with ASHRAE 55-2004. As only respondents who were sitting (1.2 met) and standing (1.4 met) were included during the survey. The average clothing values was found to be 0.55±0.20clo. In the meantime, the evaluation of PET (Physiologically Equivalent Temperature) index using the RayMan model was utilized to calculate the thermal comfort conditions in this study. The majority of the respondents (99.8%) stayed under trees or buildings shaded conditions. The 56.8% of the respondents were males. The average weight and height was 57.7±10.5 kg and 162.6±6.76 cm.

According to survey results, 28.97% and 26.83% of the respondents voted for neutral (TSV=0) in outdoor and semi-outdoor urban spaces respectively. The thermal neutrality was derived by solving the simple linear equations for a mean sensation vote of zero, which are determined by analyzing the relationship between the Mean Thermal Sensation Vote (MTSV) and PET values. The results found that, the neutral sensation PET temperatures (MTSV=0) of outdoor and semi-outdoor spaces were 27.1 °C and 28.5 °C, respectively. And the acceptable thermal conditions (by ASHRAE Standard 55 corresponded with minimum standard of 80% acceptability) ranges were 31.0-23.1°C (difference, 7.9°C) and 32.0-22.4°C (difference, 9.7°C), respectively. Compared with the thermal acceptable range between both spaces was found that the thermal acceptable range in the semi-outdoor environment is much higher than the outdoor environment, indicating that occupants in different spaces have different thermal requirements. The results of corresponding neutral acceptability temperatures for outdoor and semi-outdoor environments were 27.0°C and 27.2 °C, respectively. Compared with the neutral temperature differentiation in terms of sensations and acceptability temperatures for the both outdoor and semi-outdoor environments were 0.1°C and 1.3 °C, respectively. The results demonstrated that occupants of semi-outdoor spaces expect more unacceptable neutral thermal conditions than occupants of outdoor spaces. Thus, the comparison results can be explained that occupants who considered their thermal environments in semi-outdoor environment difficult to control are accepting of thermal environment conditions in summer, even if they are feeling comfort. Based on the results of thermal sensation and acceptability analysis in this study can contributes toward creating and improving comfortable urban spaces in hot-humid contexts to enhance the quality of urban life and achieving a liveable city in tropics such as Chiangmai.

Visitor perception of thermal comfort in two contrasting public landscape gardens during extreme heat events

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Previous work on outdoor human thermal comfort has focused on local residents. Our study examines the differences in thermal perception between local residents and international visitors to botanic gardens. This information is important because it improves researcher understanding of tourism climatology. In addition, our study analyses visitor thermal perception stratified by postcode, that reveals the impact of acclimatisation. Data gathered during the Australian summer of 2013/2014 included visitor surveys and meteorological data. During that summer 2204 and 1122 visitors were surveyed in the Royal Botanic Gardens (RBG) Melbourne (a large heavily irrigated traditional botanical garden with many exotic species) and Cranbourne (a large, mostly un-irrigated native garden) respectively. Furthermore, a network of 11 automatic weather stations was established in both gardens during the summer season (18 December 2013 to 26 March 2014). A mobile weather transect was also maintained using the "Garden Explorer" in the RBG Cranbourne. Our study shows that thermal perception is different between local residents and foreign tourists. In particular, European tourists felt hotter than Australian and Chinese visitors in the RBG Melbourne. Moreover, local residents differed in their thermal perceptions between those who visited the RBG Melbourne and Cranbourne. This difference is likely due to the different garden designs and microclimates between the two gardens, even though the weather conditions were similar. As the fieldwork involved multiple heatwave days exceeding 40 °C, it provides new insight into the thermal perception of visitors from different countries of origin under very hot conditions. This information can inform garden landscape succession planning to incorporate thermal comfort in urban planning.

Impact of urban morphology on microclimatic conditions and outdoor thermal comfort – a study in mixed residential neighbourhood of Chennai, India.

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The urban built geometry alters the microclimate significantly which in turn affects the outdoor thermal comfort. The outdoor thermal comfort depends on the ability of the materials to absorb solar radiation (albedo) and the geometrical arrangement of the buildings and its morphology. The aim of this study is to investigate the influence of the built geometry and its morphology on the outdoor thermal environment in a mixed residential neighborhood in the hot humid city of Chennai. The study is twofold. Firstly, the impact of built geometry on the microclimatic conditions was assessed through field measurements and secondly a questionnaire survey on thermal sensation was conducted to study the subjective response of the users to the outdoor thermal environment. The field measurements included the monitoring of meteorological parameters such as air temperature Ta, relative humidity RH, wind speed v and mean radiant temperature Tmrt. Outdoor thermal comfort conditions were assessed through the physiologically equivalent temperature (PET) index, at different built morphology. The influence of various built parameters such as Sky view factor (SVF), street geometry/ aspect ratio, building materials, green cover, etc., on microclimatic conditions and the thermal sensation were assessed. This study also attempts to identify the appropriate urban morphology to improve pedestrian comfort conditions in the hot humid city of Chennai.

Outdoor thermal comfort under photovoltaic canopies – a seasonal field study at Arizona State University

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Shade plays an important role in designing pedestrian-friendly outdoor spaces in desert cities. To improve thermal comfort through shading at a pedestrian mall, Arizona State University (ASU) set up three 10 m high photovoltaic canopy structures on its Tempe campus next to the busiest central hub of student life, the Memorial Union (MU). The goal of this research is to quantify the impact of the installed photovoltaic canopies on microclimate and thermal comfort at the mall, using field observations and surveys. Our main objectives are threefold: (1) assess outdoor thermal comfort under photovoltaic canopies and in unshaded locations in a desert urban environment for different seasons and times of day; (2) investigate the relationship between measured and perceived comfort; (3) explore the determinants of thermal sensation, including non-climatic factors.

We installed six stationary, shielded temperature and humidity sensors underneath ASU's photovoltaic canopies next to the MU and in nearby sun-exposed and tree-shaded locations, logging at a frequency interval of 5 minutes for a full year. Additional transect measurements were conducted hourly from 7:00 AM to 10:00 PM during a typical day in each season under clear and calm weather. Observations underneath the stationary sensors included globe temperature, Wet Bulb Globe Temperature (WBGT), wind speed, solar radiation, and surface temperature. During the transect observations, more than 1000 people were surveyed in the shade and sun close to the stationary sensors about their thermal comfort, perception, preference, recent sun exposure, activity, and adaptation level. We calculated Mean Radiant Temperature (MRT) and comfort indices from the microclimate observations to statistically link thermal sensation votes and perceived comfort to the thermal environment. We explored correlations between survey responses and the thermal environment and investigated the relative significance of environmental, personal, and psychological factors for all seasons, different times of day, and in shaded and unshaded locations. This study will give insight into the relative importance of climatic and non-climatic factors that drive thermal comfort and highlights the importance of shade for the design of more walkable outdoor spaces in desert cities.

Assessment of human thermal perception and local adaptation to urban climate change in hot-humid climates – the case of Dar es Salaam, Tanzania

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The sultry condition is typical to coastal urban areas in the tropics and the associated impacts of climate change are likely to exacerbate the conditions to the level of limiting the local human thermal comfort. In order to better understand the local thermal adaptive capacity and provide a plausible interpretation of thermal index values, micrometeorological measurements accompanied by human thermal sensation interview surveys at two outdoor public spaces (i.e. an urban park and a beach) were conducted in Dar es Salaam, Tanzania. The surveys based on the ASHRAE seven (7) point scale; while the values of the Physiologically Equivalent Temperature (PET) and Universal Temperature Climate Index (UTCI) were calculated using the RayMan model. Additional measurements were also done in various local climate zones (LCZ) in order to model the thermal effects of several adaptation measures and varying meteorological parameters in the ENVI-met model. The meteorological data from the nearby synoptic station were used to compare and calibrate the local measurements. By using regression analysis of the thermal sensation votes and thermal index values, the thermal acceptable range of human thermal comfort in Dar es Salaam could be between 23 – 31 °C PET. Since many of the urban neighbourhoods are within the lightweight low-rise local climate zone mainly due to the fact that nearly 70 percent of Dar es Salaam is unplanned, then shade provided by trees and parks could be suitable for local adaptation particularly for outdoor thermal comfort of pedestrians.

Assessment on thermal environment and comfort within urban open spaces: A Case of Tropical City, Nagpur, India

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The habitability of urban open spaces is highly dependent on the thermal comfort experienced by the users of the open spaces. A study of spatial and temporal variation of microclimatic parameters in some open spaces used as parks or playgrounds in a tropical city Nagpur was conducted during summer 2010-2012. The thermal comfort experienced by the users was measured along a seven point voting scale based on ASHRAE guidelines to generate the Outdoor Thermal Sensation Vote (OTSV). The ANOVA of the microclimatic parameters and the resulting thermal sensation reveals that surrounding building geometry, vegetation and ground cover affect the variation in microclimatic parameters and in go the thermal sensation. The study suggests a thermal mapping approach for designing or redesigning the open spaces and parks for improving their frequentation and use.

Evaluation of building-scale heat-stress analysis system (BioCAS) based on mortality observation in Seoul

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Biometeorological Climate impact Assessment System (BioCAS) was developed by combining models on building-scale climate analysis, biometeorology, and excess mortality by heat stress. It can provide urban planners with gridded data relevant for local climate assessment at 25 m and 5 m spatial resolutions. The influence of building morphology and vegetation on mean radiant temperature Tmrt was simulated by the SOLWEIG model. Gridded hourly perceived temperature PT was computed using the Klima-Michel Model based on the estimated Tmrt. Daily maximum perceived temperature PTmax was then applied to an empirical-statistical model that explains the relationship between PTmax and excess mortality rate rEM in Seoul. The resultant rEM map quantifies the heat stress at the building scale.

Each component model of BioCAS was compared to the observation. For the evaluation of the temperature deviation, observed data from automatic weather stations in Seoul were utilized. For the evaluation of Tmrt from the SOLWEIG model, three dimensional radiations (shortwave and longwave components) in and around urban canyon and tall trees were observed. For the assessment of mortality increase by heat stress, mortality differences among districts in Seoul were compared to the estimated rEM. BioCAS can assess the urban heat stress in terms of mortality changes brought specifically by the placement and volume of buildings. Additional research such as indoor climate assessment, vegetation cooling impact, and local population structure will further improve the system.

Estimation of DALY loss due to heat stroke and sleep disturbance caused by air temperature rise in Tokyo, Japan

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Residents in urban areas are now confronting two kinds of warming which are global warming and urban heat island. The former is caused by an increase in concentration of greenhouse effect gases and the latter is caused by urbanization. The air temperature rise effect of urban heat island is not small compared to global warming. The world 11-year average air temperature has increased by 0.90 degrees during the last 100 years. The Japanese 11-year average air temperature has increased by 1.38 degrees. However, the 11-year average air temperature rise of Tokyo during the same period leads to 3.03 degrees.

Such high air temperature rise has posed various environmental problems in the society. Human health is one of the problems. High daytime air temperature considered to lead to heat stroke while high night air temperature can pose sleep problems. However, only health damage due to heat stroke has been remarked and some countermeasures including an alerting service have been installed in Japan. The reason is considered as follows. Damage of heat stroke can be quantified by using public statistics of deaths or the number of patients transported by ambulance. These statistics are made every year by Japanese or local governments. Meanwhile, there is no statistics related to sleep in Japan. Many previous studies have assessed damage on sleep by nighttime air temperature rise. However, their assessed values could not be compared with damage of heat stroke and ignored in the society.

This study aimed at developing damage functions of heat stroke and sleep disturbance at the same measure and estimating the current damages caused by air temperature rise.

We adopted the disability-adjusted life year (DALY) as the measure for heat stroke and sleep disturbance in this study. DALY was developed by World Health Organization (WHO). It is the sum of the years of life lost (YLL) and the years lost due to disability (YLD). YLL is calculated to multiply the number of deaths by the standard life expectancy at age of death in years. YLD is calculated to multiply the number of incident cases by the disability weight and the average duration of the case until remission or death. The numerical values or functions about heat stroke are known by the previous studies or public statistics. Regarding sleep disturbance, we have already developed the disability weight based on interview to experts. Here we quantified the relationship between the number of cases (sleep disturbance) and the nighttime air temperature based on the past epidemiological studies conducted in 2006 and 2007.

Then, we estimated the current health damage about heat stroke and sleep disturbance in Tokyo using the above DALY loss functions and the meteorological data. The society tends to deem heat stroke as the most important damage caused by urban air temperature rise. However, our result showed that the current DALY loss by sleep disturbance in Tokyo is also important and should not be ignored.

Inhalation cancer risk assessment in Krasnoyarsk city

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This work investigates the inhalation cancer risk caused by air pollution in Krasnoyarsk city, an industrial city in eastern Siberia. For risk assessment we used data from the state's network of urban air pollution monitoring stations.

The pollutants which give the greatest contribution cancer effect for human health have been selected, such as benzene, formaldehyde, benzo[a]pyrene, ethylbenzene.

Dynamics of these substances concentrations were analysed from 1982 to 2013. It was shown that changes of the concentrations of benzene, benzo[a]pyrene and ethylbenzene connect mainly with changes in emission of the industry and traffic. While the formaldehyde concentrations are defined by the level of air pollution in generally. At the same time formaldehyde concentrations depend on change of urban meteorology. For the last 30 years average air temperature in Krasnoyarsk increased on 1.9°C. Increasing of air temperature leads to growth of intensity of photochemical reactions that increase formaldehyde levels. Photochemical reactions leads to increase of formaldehyde concentration by factor of ten during the summer. The contribution of various factors to air pollution levels was estimated.

For each substances a time of toxic effect exposure was calculated. It was used the logarithmic model for this calculation. It was shown that time exposure for formaldehyde and benzene was reduced during 30 years. It is connected with increasing their concentration in urban air.

Cancer risk estimated for various organ targets. Verification of the received results was carried out by comparison with statistics of cancer of specific organ's targets of the city's inhabitants.

EFFECTS OF URBAN AIR POLLUTION ON HUMAN HEALTH, PLANTS: A CASE STUDY BIJAPUR CITY, SOUTH INDIA

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In any well planned urban set up, industrial pollution takes a back seat and vehicular emissions take precedence as the major cause of urban air pollution. Currently, in India, air pollution is widespread in urban areas where vehicles are the major contributors except in a few other areas with a high concentration of industries and thermal power plants. Attributed to location of industries in non residential areas and enforcement of air pollution standards by the Pollution control board, industrial air pollution could be considered less deleterious than vehicular pollution. Rapid urbanization and modernization has led to an unprecedented increase in the number of vehicles in the city. Against 1.9 million vehicular populations in 1990 in Delhi, it rose to nearly 3.6 million in the year 2001 and road-length by merely 14 per cent (from 22,000 Km to 25,000 Km) respectively. Similar increase in vehicles in all the urban centers of India is a reality; leading to deleterious effect on the health of the people as well as plant communities' .A study has been carried out to know the effects of urban air pollution on human health, plants in Bijapur city of South India

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Changing weather factors implication on the prevalence of malaria in Ado-Ekiti, South west, Nigeria.

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The impact of weather factors on human health has been greatly realized in recent times; the effects these variables have on malaria prevalence have been of particular interest because the disease is a public health burden and its transmission is sensitive to changing weather and climate as a result of urban development. .This study explored the impact of weather and climate and its variability on the occurrence and transmission of malaria in Ado Ekiti, a tropical rain forest area of south-west Nigeria. We investigate this supposition by looking at the relationship between rainfall, relative humidity, minimum and maximum temperature, and malaria in Ado Ekiti. This study uses monthly data of 8 years (2005-2012) for both meteorological data and record of reported cases of malaria with different age groups.

We evaluated a simple statistical model that permitted valuable and novel insights into the simultaneous/single effects of weather factors (rainfall, relative humidity, maximum and minimum temperature on malaria prevalence. The results from temperature and relative humidity threshold shows significantly that malaria prevails more between the temperature range of (30.1-32)°c and relative humidity of (60.1-80)% than any other temperature and relative humidity threshold. Malaria prevalence among children <5 years old was higher than that of adults.. Also surveys conducted among the people in the station revealed that, the interplay of poverty and other socio-economic variables have intensified the vulnerability of this community to the impacts of this disease. The results improved our understanding of how temperature and humidity shifts affect the distribution of at-risk regions, as well as how rapidly malaria outbreaks take off within vulnerable populations The result of this study will also help individuals, government, policy makers and professionals in guiding against or planning ahead for possible outbreak of malaria.

Keywords: Disease, prevalent, public health, malaria, weather, climate

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A Field Assessment on Natural Ventilation and Thermal Comfort of Historical District: A case of the Wugoushui Settlement in Taiwan

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Due to the urban and town development, it is common to see historical buildings and new buildings intermingled with one and another inside historical regions in Taiwan. With the increase of new buildings, natural ventilation becomes harder, which leads to the impact on the preservation of historical building and the reduction of thermal comfort for residents. Besides, problems of new buildings' construction and design affect the developments of cities and towns in historical district, which has existed for hundreds of years.

The Wugoushui settlement is located in Pingtung County, the southernmost part of Taiwan, and its hot season of a year is pretty long and belongs to warm and humid tropical climate. In 2008, the Pingtung County Government officially registered and announced Wugoushui as traditional settlement and meanwhile, provided the maintenance and preservation for buildings in this region on government subsidies.

This paper is based on one-year-long field experiments of Wugoushui settlement. Residents in Wugoushui settlement continue constructing new buildings near by the traditional buildings. With the fact that constructions of new buildings results in huge impact on the circumstances of natural ventilation and thermal comfort, which have been for hundreds of years, the simple weather station is set up to collect the data of local microclimate. In addition, four representative traditional architectures were selected to be measured their indoor and outdoor temperature, humidity, wind speed, wind direction and thermal radiation both in winter (December to February) and in summer (May to September). The measurement time of each building is one week and every data record is kept every minute. Besides, residents were asked to fill out the comfort survey. Based on these data, the distributions of indoor and outdoor thermal environment as well as the thermal comfort of living space under the condition of the natural ventilation are assessed. Finally, focused on the indoor living space of historical districts in southern Taiwan, there are two main suggestions given in the essay: First, a provisional comfort zone in summer is planned and proposed. Second, the preliminary suggestions for the design and norms of new buildings in historical district are provided.

Neonates in Ahmedabad, India during the 2010 heat wave: a climate change adaptation study

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Health effects from climate change are a growing international concern with urban areas at particular risk due to urban heat island effects. The potential burden of disease on vulnerable populations in non-climate controlled settings has not been well-studied. This study compared neonatal morbidity in a non-climate controlled hospital during the 2010 heat wave in Ahmedabad to morbidity in the prior and subsequent years. The outcome was neonatal intensive care unit admissions for heat, as a diagnosis of exclusion. During the months of April, May, and June, 13.0% of all neonatal intensive care unit admissions were for heat versus 4.2% and 2.5% in 2009 and 2011 respectively. A daily maximum temperature increase of two degrees was associated with a heat-related admission odds ratio of 1.59 (95% CI 1.05 – 2.04). Lower floor location of the maternity ward within hospital which occurred after the 2010 heat wave showed a protective effect. These findings demonstrate the importance of simple surveillance measures in motivating a hospital policy change for climate change adaptation – here relocating one ward – and the potential increasing health burden of heat in non-climate controlled institutions on vulnerable populations.

Thermal comfort comparison and evaluation in different climates

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The response to heat stress in cities in moderate and tropical climates can be quite different. According to the thermal adaptation and to a certain expectation regarding the thermal conditions, thermal comfort ranges change, once psychological and sociocultural processes play an important role in thermal comfort evaluation. The aim of this study was to validate the results of investigations in different climates (Brazil and Germany) using the same method to compare the limits of heat stress and to study the response from the subjective evaluation of thermal sensation to measured data. This can be seen as a realistic way of determining heat stress and can therefore be an instrument for planners to identify heat sensitive areas in the open space and develop strategies to mitigate those.

The presented methods and results were derived during measurement campaigns with microclimatic data and interviews of adult persons in Belo Horizonte /Brazil and Kassel / Freiburg in Germany. The subjective variables were data concerning perception and preferences of thermal sensation, using a seven-point scale. As thermal index derived from measurements the physical equivalent temperature PET was used and combined with the seven-point scale very hot, hot, warm, neutral, cool, cold and very cold.

In this study the index PET was chosen due to different reasons. The first reason is that – compared to other indices – it was adapted to outdoor settings. The second reason is that it is internationally used which provides comparability. In addition to its wide distribution it is furthermore continuously developed by several work groups.

Urban design need strategies and concepts for urban planning in order to mitigate the impacts of urban heat load. These strategies have to consider urban climate conditions of hot and cold seasons, but also have to take into account that in colder climates people want to have warm periods for short time, while in hotter climate people long for cool. The thermal index PET showed lower values for the scale very hot in Brazil than in Germany. For city design of open spaces in colder climates some warm places should be kept as long they do not lead to heat storage, for hot climates, as expected, shadow is important at any case. The PET neutral comfort value range in Belo Horizonte is from 15 to 30 oC PET and the hot range starts at 31 oC, while in Kassel neural range is from 18 to 28 oC PET and hot range starts with 35 oC PET.

How to transform the standing man from a box to a cylinder – a modified methodology to calculate mean radiant temperature in models and field studies

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Mean radiant temperature (Tmrt) has shown to be an important meteorological variable in studies of human comfort and health. The Tmrt is calculated as the surface temperature of a standing man approximated as a cylinder emitting the same amount of longwave radiation as all short- and longwave radiation fluxes received from the surrounding four cardinal points and down- and upwards. The calculation was introduced by Höppe in 1992 and has then been used both in models (e.g. SOLWEIG) and field studies. However, the formula by Höppe describes in fact a man shaped like a box and not a cylinder, which has resulted in some peculiar features noticed in studies of Tmrt such as a secondary daytime minimum and an influence of the orientation of the field equipment.

A methodology to change the box man to a cylindrical man is proposed. It will remove the peculiarities that have been observed in earlier studies. The methodology is based on the partition of the observed shortwave fluxes in direct and diffuse radiation. The minimum shortwave radiation of the four cardinal points is used as diffuse radiation since it is monitored by a sensor that is not sunlit. By subtraction of this quantity the horizontal direct fluxes are obtained. Calculation of the resultant flux of the sunlit sensors and adjustment for solar angle gives the direct shortwave radiation. The surface of the standing man (as a cylinder) perpendicular to the direct radiation must be determined and the direct shortwave radiation received by the standing man can be calculated. Then the sum of the shortwave fluxes can be calculated. The diffuse and longwave fluxes can be calculated according to the Höppe formula since they differ little with direction. In the SOLWEIG model the direct shortwave radiation is used as an input. Thus the calculation according to the new methodology is easy to apply, only the solar position needs to be added.

The new methodology is tested by model calculations with SOLWEIG and field studies in both high-latitude Gothenburg, Sweden and low-latitude Ouagadougou, Burkina Faso. The secondary minimum disappears. In Gothenburg at a site with SVF=0.95 the noon depression of Tmrt by the Höppe formula was about 2 °C and there was an overestimation of 1.5-1.7 °C two-three hours before and after noon.differences in summer. In Ouagadougou data from an open site (SVF=0.83) in the dry season the differences were slightly smaller. Sites with lower SVF and much reflected direct shortwave radiation differed less from the Tmrt obtained with the Höppe formula.

Watts in a comfort index: Evaluating pedestrian energy exchange and thermal stress in urban environments

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The thermal environment in cities is commonly, and habitually, described in terms of temperature. In some cases it is near-surface air temperature, and in others it is a mean radiant temperature, often embedded within a physiologically equivalent temperature or similar comfort index which is used to quantify, in degrees, the thermal effects of the environment on a person. While temperature is indeed our most familiar and intuitive measure of thermal states, it is important to remember that the human body’s thermal endings are not in fact sensors of temperature – but rather of heat flow, monitoring the rate of heat gain or loss from our body due to radiation, convection and evaporation.

This paper describes the validation and implementation of an alternative approach for assessing the thermal environment in urban spaces, using the Index of Thermal Stress (ITS). Rather than attempting to portray the effects of sun, wind, temperature and humidity as a single point on an imaginary thermometer, the ITS is based on an accounting of the individual energy exchanges between a pedestrian's body and the surroundings – expressed in watts – and the physiological response that is required for the body to maintain thermal equilibrium. Calculated values of this index, based on measurements in a hot-arid urban setting, were found to correlate closely with subjective thermal sensation as expressed in questionnaire responses by pedestrians in the same set of locations. While a number of personal and experiential factors were found to impact thermal perception, the "neutral point" was found to correspond in a variety of different circumstances to a physical situation in which the dissipation of heat from a person's body was precisely in balance with that person's internal metabolic heat production (ITS=0).

A series of experimental studies has made use of this ITS model to analyze the thermal effects of variations in street canyon geometry, of shade trees, and of vegetative ground cover, and to evaluate the "cooling efficiency" of irrigated landscaping by comparing its potential to reduce bodily heat gain with the latent heat value of water loss through evapotranspiration. Finally, a case study of a Mediterranean coastal urban park examined the ways in which thermal discomfort is perceived by local residents, and results indicated that the expressed thermal preferences of the park's users align robustly with predictions based on ITS.

SHORT-TERM ACCLIMATIZATION EFFECTS IN AN OUTDOOR COMFORT STUDY

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The ‘Alliesthesia’ concept suggests that stepping from thermal homogeneity to more dynamic and uncontrolled states (as in outdoor settings) should create immediate responses that would diminish with time of exposure. Also according to this concept, once the subject remains for a given time within a thermally static environment, with no “opportunity for the body to interpret the ‘usefulness’ of a stimulus for thermoregulation”, there is a greater chance that he will more effectively experience thermal perception under sudden dynamic conditions. Thus, if there is a means of ensuring thermal homogeneity for a given time period, short-time acclimatization could be tested over different time steps of exposure to the outdoor environment. The present research investigates short-term acclimatization effects on a subject’s thermal sensation and perception. For ensuring thermal homogeneity and almost steady-state conditions prior to the subject’s exposure to the outdoors, a climate chamber is employed, where subjects (N=16) remain for five consecutive hours under nearly thermal comfort conditions (PMV= approx. 0) in two office-like rooms. Standardized clothing is adopted on each subject and a metabolic rate of approximately 2.3 Met is assumed after subjects walk around the external precincts of the chamber within a short period of time, so that a direct comparison to estimated thermal votes can be made. Two different configurations are adopted for the indoor environment as regard visual clues on weather changes throughout the 5-h period inside the chamber, which might influence subjects’ thermal expectations: open, unobstructed view to the outside and closed shutters. In addition, three different time steps are tested: immediately after leaving the air-conditioned space, after 15 minutes and after 30 minutes outside the chamber. The pilot study took place during several days with varying outdoor conditions. The climate chamber (Laboratory for Occupants’ Behaviour, Satisfaction, Thermal Comfort and Environmental Research, LOBSTER) is located in Karlsruhe, Germany (49°00'N), at the Karlsruhe Institute of Technology (KIT). The tests performed evaluate the effects of the time spent outdoors and the subject’s expectations of outdoor meteorological conditions against predictions of the outdoor thermal comfort index UTCI (Universal Thermal Climate Index).

Physiological Response of Human Body and Thermal Sensation for Irradiation and Exercise Load Changes

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In outdoor environment, radiation and exercise state is not always steady, and it is necessary to take into account the unsteady environment in order to predict human thermal sensation. In this study, we firstly conduct subject experiments to understand the influence of periodic change of irradiation to thermo-physiological response of the human body. Experiments were conducted in climate chamber set to 28 degree Celsius and 50% RH. The artificial light source displayed 67 metal halide lamps into a plane of 1.0 m x 2.0 m form. We performed two conditions in the same subjects on separate days for irradiation period of 18 and 6 minutes. The total experiment time was 36 minutes with both conditions. The change of skin temperature was expressed in primary delay system. High correlation was seen in the change of skin temperature and the change of thermal sensation. It was found out that the change of skin temperature was an important factor to estimate the thermal sensation under the unsteady irradiation. In this study, we secondary conduct subject experiments to understand the influence of unsteady excise to thermo-physiological response of the human body. Experiments were conducted in climate chamber set to 28 degree Celsius, 50% RH or 30% RH. Subjects were given excise load of 90 W by ergometer for 9 minutes and subsequently keep rest state for 3 minutes. The subjects performed 3 cycles in the experiment. Mean skin temperature of subjects decreased just after an exercise start and gradually rise to rest period. Eardrum temperature rose during exercise. Heart rate rose after exercise started and decreased during a rest period. The rate of change of the heart rate and the thermal sensation showed high correlation. Regression equation of thermal sensation and physiological value obtained from the experiment showed high correlation. In this study, subject experiments were carried out finally in the outdoor space where roadside trees affected. A walk and standstill were repeated. Based on the results obtained from the above-mentioned subject experiments, the evaluation of the measured results was carried out, and the possibility of the unsteady thermal seansation prediction in the everyday life was suggested.

The prediction of outdoor human thermal states in non-uniform thermal loads

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Considering thermal states or thermal sensation is the good idea for assessing the thermal environment around humans. Human thermal states can be obtained by using thermal load of human in general and many thermal indices were developed based on steady-state human energy-balance model. However, there are so many no steady states and complex situations exist in reality. For example, our environment is surrounded by various materials with various properties and they play an important role for creating non-uniform outdoor thermal environment. Thus, the present study addresses the effect of non-uniform thermal load on human thermal state.

The authors first performed measurements for understanding of physical environment. Then, measurements were performed with human participants to grasp the relationship between human thermal states, human thermal perception, and thermal environment conditions in the proximity of a human body. In order to simulate the outdoor non-uniform thermal load, regional thermal load was applied on human surface directly by using own making thermal module. The surrounding weather factors (air temperature, humidity, air speed, solar and infrared radiations) and the physiological response of the human body (temperatures on skin and core, heart rate, inhale and exhale gas, sweat) were measured at the same time. Thermal perceptions were also asked. The results show that regional thermal load by warming or cooling had strong relationship with regional thermal sensation, and this led whole body thermal sensation. Each body parts had different thermal sensitivity. The authors established totally well-described thermal load model.

For an application, human thermal state assessment was experimentally and numerically performed in typical street environment. The authors tried to establish the new way of evaluating non-uniformity of environment and human by using non-uniform human thermal load method as an energy balance evaluation was successfully proposed. The results showed that our method could be a good thermal states prediction for non-uniform complex outdoor environment conditions.