CONFERENCE ON CULTURAL HERITAGE AND CLIMATE CHANGE

HOW CAN CULTURAL HERITAGE BE MANAGED IN TIMES OF CLIMATE CHANGE?

27. - 28.02.2023

DOMINICAN MONASTERY
KASERNSTRASSE 4, 96049 BAMBERG

2 FLOOR, NR. 317 «EHEMALIGE BIBLIOTHEK«

organised by Dr. Kristina Holl

OTTO-FRIEDRICH-UNIVERSITÄT BAMBERG
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Tagungsförderung der Frauenbeauftragten der Universität Bamberg

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CONFERENCE PROGRAMME

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Towards better policy decisions: defining the role of cultural heritage in climate adaptation

Constanze Fuhrmann
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Dr. Johanna Leissner
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The unprecedented speed and scale of climate change are severely threatening cultural heritage. Human-induced climate change is linked to weather and climate extremes in many regions which pose great risks and damage to heritage sites and assets around the globe. For example, significant cultural heritage sites are situated along coastlines and are endangered by rising sea levels with a high probability of permanent loss or damage. In spite of these grave risks, policies on climate change action in many cases do not include cultural heritage and the specific threats it faces. While political actors proclaim cultural heritage to be an important pillar of shared identity with many benefits for society, it is often neglected in climate change and adaptation planning at the national and international levels. At the same time, climate science also has been negligent in including cultural heritage in the global discussion on promising mitigation and adaptation strategies. This leads to a situation where cultural heritage and climate change action are not sufficiently thought together to achieve the best possible outcomes in protecting our collective past. What is needed is not only an inclusion of cultural heritage in the wider climate change discussion but also a better understanding of the distinct role cultural heritage itself can play in mitigating and adapting to a changing climate. In this paper, two trailblazing research endeavours will be set into context to outline the current state of the discussion around integrating cultural heritage both in the scientific and political debate with a special focus on climate adaptation.

The research of the project "Connecting Culture, Heritage and the IPCC", funded by the German Federal Environmental Foundation, covers the inclusion of heritage in recent IPCC reports, risk terminologies developed by UNESCO, ICOMOS, IUCN, ICOM, ICCROM and potential ways of integrating climate and heritage efforts as well as approaches to the identification, monitoring, and comparison of climate change risks and vulnerability of heritage. In 2020, a political mandate was given to the topic of climate change and cultural heritage for the first time: The Cultural Affairs Committee of the Council of the European Union adopted the mandate to set up the EU Open Method of Coordination (OMC) expert group of Member States on "Strengthening cultural heritage resilience for climate change". Experts from 25 EU Member States and three associated countries examined the state of play, identified gaps in knowledge and structural deficiencies at EU and Member State level and enhanced exchange and discussions around climate change and cultural heritage. The paper will interpret the research findings of both projects with a special focus on climate change adaptation. This allows outlining of current best practices and recommendations for both the heritage community as well as policymakers on how to devise strategies and approaches to climate change adaption of cultural heritage. It will also highlight the role that heritage itself can play in adapting to climate change impacts.

Defining vulnerability and exposure in risk assessment frameworks for climate change and cultural heritage

In the face of unprecedented climatic change, it is vitally important to develop rigorous risk assessment frameworks for cultural heritage. Determining the effects of climate change on cultural heritage must not be limited to solely analysing the changing prevalence of climatic hazards. For example, it is insufficient to identify which coastal heritage sites will be submerged in 2050 due to rising sea levels, without also considering the local, regional, and national significance of these sites and the associated loss and damage to relevant communities. Thus, heritage value needs to be incorporated into climate change risk assessments. This paper presents a systematic review of recent scholarly and grey literature on approaches to climate change risk frameworks for heritage. Of particular interest is 1) the scope of the frameworks, specifically identifying holistic risk assessments that look at the cumulative impacts of climate change on a national or regional scale rather than at the level of an individual site; 2) how the four components of the risk framework used by the Intergovernmental Panel on Climate Change (IPCC), hazard, exposure, vulnerability, and response, have been utilised in the historic environment; and 3) the divergent ways in which these terms have been defined and applied.

The mechanisms by which vulnerability and exposure have been incorporated into cultural heritage risk frameworks are important for ensuring the discipline moves past hazard maps for cultural heritage. While primarily focused on risk assessments for historic buildings and archaeological sites, the refinement of both impact frameworks and key terminology directly affects the management of indoor cultural heritage and heritage more broadly. Ultimately, this paper synthesizes the state of the field in terms of vulnerability and exposure assessments for heritage and recommends a joined-up approach with the IPCC's risk framework. Finally, it considers the feasibility of applying this method to heritage in England.

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Dr. Scott Allan Orr
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Keynote: Risk assessment for cultural heritage in times of climate change

Jonathan Ashley-Smith PhD

An independent teacher, researcher and consultant in the field of cultural heritage risk.

His recent work has highlighted his concerns about the decline in practical conservation skills and the unthinking rigidity of conservation ethics. His current obsession is 'uncertainty'. In 2019 he spent three months at the Getty Conservation Institute researching this subject. Several of his recent papers deal with uncertainty in conservation decision-making.

Nowadays the problems of climate change, sustainability, risk and uncertainty have become topics of everyday conversation. These frequently used words and phrases have different meanings to different audiences. Often the people who debate climate change seem not to recognize or accept this multiplicity of meanings. This leads to the development of fixed attitudes that do not allow discussion of the inherent uncertainties. Risk assessment involves the consideration of possible future events, and discussions about the changes in state and value of heritage items brought about by these events. We cannot always accurately predict the future. Thus, the assessment of risks necessarily involves uncertainty. This uncertainty is made worse by the different interpretations of words like state and value. The use of science and mathematics to aid in the assessment of risk does not eliminate uncertainty, indeed it may add to it. However, the quantitative approach can offer ways to visualize and evaluate the degree of unpredictability. Conventional risk assessment involves looking at a single agent of deterioration and a single object or object type. The scenario in which the selected hazard and selected object might interact must be specified and the outcome must be predicted. For a complete assessment of risks to a whole collection, this process must be repeated for all the object types and all the hazards. This is a laborious enterprise, which surprisingly became a popular pastime in museums and other heritage organisations at the start of this century.

The statement that climate change might be detrimental to heritage buildings, and to the collections within them, needs to be evaluated. It might be simpler to think of the risks to necessary heritage activities, rather than considering risks to objects or collections. Assuming we can state what the business of a museum is, we can then list the facilities that are needed to run that business. This is a shorter list than the different types of objects. The list of ways that climate change might harm these facilities is also quite short. Thus, in theory, it should be relatively simple to create a management plan to mitigate or avoid the deleterious effects of predicted climate change. That is if the prediction of future local climate resulting from global climate change can be achieved. That is when all the uncertainties have been identified and quantified.

KEYNOTE: The use of historic climate analysis and microclimate monitoring for the long-term preservation of cultural heritage: a data-driven approach

In the field of Heritage Science, analyzing the microclimate has always been of extreme importance for the implementation of effective preventive conservation strategies. In fact, in many cases, the knowledge of the outdoor/indoor microclimate may support the decision process in conservation and preservation matters, because the microclimate and its variations are the main unavoidable responsible for the decay in the constituent materials of historical buildings. For this reason, monitoring campaigns are often established for collecting climatic data and gathering knowledge about selected case studies. First, due to sensors' errors, lack of continuous data-check and possible remoteness of the historic building location, the collected timeseries could be corrupted and, therefore, need to be properly reconstructed and/or filled. Second, indoor microclimatic conditions need to comply with the guidelines provided by international standards and protocols, to avoid or, at least, limit the climate-induced decay of historic materials and objects; this is generally obtained to stabilize microclimate conditions by using HVAC systems properly. Third, there is a general lack of globally-applicable damage functions and tools for assessing the climate-induced risk of heritage building assets/objects/works of art. Lastly, the ever-increasing global warming and the need for energy- and money-saving approaches, in times of climate change and deep energetic crisis, may have a severe impact on the field of heritage science and conservation, further limiting the funds and energy provisions to stabilize microclimate in museums and historic buildings.

In this framework, data-intensive strategies seem to be the quickest and cheapest approaches for striking up a pathway towards sustainable and effective cultural heritage preservation. As a matter of fact, already existing data collected during the years, together with unintentionally collected ones for preventive conservation (e.g., outdoor weather forecasts, satellite data), can be used to build up a complete dataset from which to extract common features and trends that could help in predicting future scenarios of risk and in implementing adequate and prompt preservation strategies. This possibility is of paramount importance. For the intended task, machine learning algorithms can once trained, be extremely supportive as they permit handling huge amounts of data automatically. In addition, if these algorithms are combined with well-established fracture mechanics and mechanics of materials approaches, it is ideally possible to indirectly estimate the residual life of the materials and their damage state accumulated during decades (or even centuries) of climatic history. Moreover, the prediction of future scenarios paves the way to an optimized use of HVAC systems to ensure safe microclimatic conditions, and for both limiting energy and money consumption, thus contributing to revising ASHRAE and CEN standards in the light of sustainability. Finally, these opportunities can trigger effective decision-making processes and guide preventive conservation actions well in advance, to avoid irreparable damage to valuable and unique cultural heritage.

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Preventive solutions for Sensitive Materials of Cultural Heritage – The EU-Horizon 2020 project SensMat

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Preventive conservation (PC) has emerged as an important approach for the long-term preservation of sensitive cultural heritage (CH), notably for mobile artefacts, those displayed or stored in harsh environments and for small and medium-sized museums. SensMat aims to develop and implement effective, low cost (<20–30€ for basic platform), eco-innovative and user-friendly sensors, models and decision-making tools, as well as recommendations and guidelines to enable prediction and prevention of degradation of artefacts as a function of environmental conditions.

SensMat [1] developed and implemented effective, low cost, eco-innovative and user-friendly sensors, models and decision-making tools, as well as recommendations and guidelines to enable prediction and prevention of degradation of artefacts as a function of environmental conditions. Multi scale materials and environmental modeling were used to develop deterioration models in certain environments and validate the developed tools. An Integrated Software Framework use the data as input to generate indicators specifically designed to support Cultural Heritage professionals and operators. The presentation will give an overview on the main results of the project. The focus will be multi scale modelling and validation measures.

[1] EU-Horizon 2020 project SensMat - Preventive solutions for Sensitive Materials of Cultural Heritage, Grant Agreement No. 814596. www.sensmat.eu

IoT for sustainability and efficiency in preventive conservation at the Anthropology and Ethnology Museum of Florence

New technologies are increasingly used to understand the risks to collections of museums and other cultural institutions. Also, climate monitoring and control strategies to reduce the risks to heritage objects in their conservation environments are recently been based on the more flexible object-based approach proposed in the European Standard EN 15757:2010 and the 2019 review of ASHRAE Applications Handbook, which propose the overcoming of the more traditional rigid relative humidity (RH) and temperature (T) values of 50% and 21°C. Furthermore, the contribution of the Internet of Things (IoT) to the implementation of tailored, appropriate climate control systems is becoming increasingly significant due to the progress in sensor and data transmission technologies together with the development of cloud computing. Yet, museum and conservation practice does not integrate climate parameters with information about mechanical behaviour and deformation of sensitive, reactive materials such as wood, limiting access to informed restoration or preventive activities. The present work aims to reduce the gap between technological research and museum and conservation practice, by applying an affordable and attractive IoT architecture for cultural institutions. Built on previous research, it proposes an integrated collection of climatic data and conservation information, based on historic climate studies according to international standards, and on the conservation needs of hygroscopic materials.

To do so, an experimental analysis of different types of smart sensors communicating to gateways for data transfer to the cloud with remote and continuum access has been implemented. his approach has been used in the study and the care of a museum collection rich in hygroscopic material, the Anthropology and Ethnology Museum in Florence. our case studies have been chosen and studied from a conservation perspective among the objects preserved in the museum. Moreover, the historic climate in the halls hosting the case studies has been determined based on a monitoring campaign. The same IoT platform used to collect conservation and climatic data has been used to tailor a climate control system. Real-time remote access to the data was given to the museum staff and conservators, the appropriate alarm logic with immediate feedback to the conservators was implemented, and active climate control was introduced and successfully validated. By using IoT architecture to monitor and control the conservation state of the objects, curators, conservators and all the professionals involved in the care of the collections can change the setpoints and time use of some of the climate modules and reduce energy and water demand. These would make climate specifications more flexible and affordable, and tailored to the most sensitive materials.

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Long-term measurements of climate in the dome of Xanten and measurements on historic surfaces to predict damage risks on historical windows and mould risk on several historic altars

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University Rhein-Waa

Johannes Schubert
Cathedral builder Xanten

Dr. Hans-Jürgen Daams
Hajuveda-Heritage

The current and future assessment of the indoor climate in Xanten cathedral and their effect on damages to historical furnishings requires an extensive measurement strategy throughout the cathedral and on respective objects inside the cathedral. In cooperation with the university of Rhein-Waal, this has been done now for more than three years. Details are reported in a separate presentation by Prof. Rolf Becker. This paper is focusing on in-situ measurements of historical surfaces. The valuable stained glass from the Middle Ages and the historical Petrus Altar are selected as examples of measurements and risk assessment. The impact of climate and sun on the protective glazing was measured for a period of 3 years. Data were collected for temperature and relative humidity inside the air gap, the air directly close to the historical glazing inside the church and the surface temperatures of the glazing inside the airgap and inside the church. Measurements were done using the IoT-Instrument Custos-Aeris from iXtronics GmbH, which is easily assembled within minutes and connects the data to the internet Cloud using an LTE Connection. Data analysis directly links thermodynamic risks with possible damage root causes like drying out, embrittlement, shrinkage of the gel layer and exponential increase in glass corrosion, mould and damage to the fixative. Diagrams are created for all directly measured data and the dew point.

On top based on intelligent data analysis diagrams are created to show the behaviour of the system over years with respect to being in the optimum and outside the optimum thermodynamic condition. The optimum area indicates most probably no damage to the window. Outside of the optimum area, new diagrams are linked to show the possible damages that can happen to the window. The same system is used at the Petrus Altar to measure air and material thermodynamic conditions. But on top of the system Custos-Mucoris is used to directly measure and warn the user if mould starts to grow. This system is using an objective and camera to take pictures from the surface. Using artificial intelligence the system is able to detect mould right at the beginning of growth when the diameter is exceeding 1 mm. In order to train the convolutional neural network more than 6000 pictures of mould were used to achieve a detection accuracy of almost 100%. The system is linked to the cloud by using WLAN or an LTE-connection. Measurements are carried out now for almost three years with permanent and automatic control of the surface of the Petrus altar. The same system is installed in the Dome of Münster inside the organ. It will be especially interesting to continue the measurements until February to see the effect of stopping the heating system in Xanten.

Climate change and its effects on indoor museum pests (insects and fungi) in Austria

In summer 2021 a research project started at the Natural History Museum in Vienna, that aims at gaining a better understanding of how climate change will influence insect pests and fungi in museums, libraries and historic buildings in Austria. The project collects in-situ data on insects, fungi and indoor climate. We selected 20 Austrian heritage institutions (museums, modern storage depositories, historic buildings and historic libraries) and currently collect data for two and a half years. The main aim is to establish the statistical relationship between outdoor climate, indoor climate and pest abundance and activity. The investigated buildings differ in their indoor climate, some museums and storage depositories have a full climate control, others are only heated in winter, while many of the historic libraries have no heating in winter, cooling in the summer nor dehumidification. The warm summers in the last years have already impacted the indoor climate in some buildings with effects on the insects and fungi. Introduced and neobiotic species such as the grey silverfish Ctenolepisma longicaudatum will probably profit from higher temperature in the buildings and increases in humidity, for example during extreme weather events. The data collection in the 20 sites will be complemented by laboratory experiments, breeding insect and fungi species at different temperatures. Three model buildings (NHM, KHM and one modern storage) will receive a complex outdoor-indoor climate response model, to postulate the effects of different future climate scenarios (in 50 years) on the room temperature and RH.

With these results, we hope to better understand how future climate change will affect our buildings and objects, how buildings are best protected and how we can reduce damage from pests.

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Long-term surface monitoring of the wall-paintings in the former Dominican church in Bamberg

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The former Dominican Church of St. Christopher in Bamberg is a large mendicant church from the 14th and 15th centuries. The church contains an extensive and complex program of wall painting fragments, which were successively uncovered in the course of the 20th century. For the use of the former church as a venue for the Otto-Friedrich-University of Bamberg, a combined heating system consisting of underfloor and circulating air heating was installed between 1999 and 2015, and the interior was extensively renovated. During an inspection in 2019, a very dry room climate, as well as chipped fragments of the wall paintings on the floor, caught the eye. Based on «Structured-Light-Scanning» a concept was developed to check the state of preservation of the wall paintings at regular intervals with regard to the room climate. For this purpose, the generated 3D data from different points in time are virtually superimposed. Movements or changes on the surfaces are visualized with the help of false-colour representation. This makes it possible to accurately compare the surface at different points in time to detect even the smallest changes. In this way, it is possible to intervene at an early stage in the case of minor damage and to avoid restorations, which always means intervention in the historical substance. A high-resolution structured-light scanner (L3D, Carl Zeiss Optotechnik GmbH) was used for the investigation, which scanned the surfaces with two different resolutions at a point distance of 0.03 - 0.1 mm.

In this way, the surface could be examined in a non-contact and non-destructive manner. By repeating the scans two months later, the differences could be directly visualized. This technique can reveal the enlargement of cracks or even flake of entire paint layer packages. To interpret the measured movements, the results of the scans were set in relation with measurements of the indoor climate. The analysis of the interior climate of the church showed high fluctuations, especially in relative humidity, which averaged between 60 and 30% relative humidity. Since the former church was continuously heated to 20 – 21 °C every day during the measurement period, dry periods with less than 20 % relative humidity occurred especially in the winter months. Especially the short-term fluctuations were considerable: strong fluctuations up to 30 % relative humidity within a few hours occurred several times per week. Such climatic changes create stress situations for the wall paintings with resulting damage such as loosening and loss of substance. The effects of these moisture fluctuations were visualized with the 3D comparisons. Since fall/winter of 2022/2023, the university auditorium has only been heated to about 12 °C as a measure of energy conservation. This is to avoid damage due to too cold temperatures, but also extremely dry periods in the winter months. Further monitoring now takes place annually as part of courses offered by the Professorship of Materials and Preservation Science at the University of Bamberg.

Development of a monitoring concept for in-situ humidification, taking the example of a large-sized damaged wooden panel painting

Theresa Hilger
Manuela Hörmann
Julia Brandt
Bayerisches Landesamt für Denkmalpflege – AV Restaurierung

Projectpartners:
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TU München,
Care For Art

The global climate crisis is demonstrably leading to drier, hotter summers worldwide. This also affects the indoor climate of historic buildings. Whereas the relative humidity in these buildings in Central Europe tended to be too high in the past, climate change is incrementing dry periods. The preservation of works of art in these buildings is thus an essential but yet largely unexplored field of research. The sacristy of Freising Cathedral has been holding 1495 a large-scale panel painting as part of an altar. The heating system and wall drainage caused lower humidity and more damage to the paint layer since the mid-20th century. As a consequence, conservation treatments had to be carried out at ever shorter intervals. The support has shrunk, making it impossible to consolidate flaking paint without removing the material. Due to the climate crisis, the drying-related damage predicts future challenges for the interiors of historic buildings and preserving cultural heritage in historic buildings. In light of rising energy prices and the need to save energy, conventional air conditioning of historic rooms is increasingly utopian. In 2021, the Bavarian State Office for the Preservation of Historical Monuments, the Technical University of Munich, the University of Bamberg (Kompetenzzentrum für Denkmal-Wissenschaften und Denkmaltechnologien KDWT) and the company Care for Art initiated a research project funded by the German Federal Environmental Foundation (Deutsche Bundesstiftung Umwelt DBU).

The aim is to develop resource-saving methods to preserve artworks in their historical context even in drier climates. The Freising panel painting serves as a case study for the development of an in situ humidification method, which should subsequently ensure the necessary conditions for the preservation of the panel painting in situ without the use of additional energy. For the development of the method, it is first important to document the panel painting´s reactions to changes in relative humidity as accurately as possible. An elaborate measuring system for recording the wood moisture, the surface temperature and the geometric changes of the support depending on the room climate provide for the first time detailed information about the behaviour of centuries-old panel paintings. At the same time, climate chamber experiments and computer-aided hygrothermal simulations make it possible to predict the behaviour of the artwork in different climate situations. The lecture presents the setup and the installation of the innovative measurement system with a high-resolution structured-light 3D scanner, triangulation lasers, extensometers, time-lapse cameras, surface temperature sensors and wood moisture sensors. Special emphasis will be given to practical questions on how to fix the sensors to the painting. The initial measuring results presented will provide information about the behaviour of a complex system, such as a panel painting, in different climatic situations and lay the foundation for further measures.

Climatic effects on half-timbered heritage in the Franconian open-air museum Bad Windsheim

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Prof. Dr. Ralf Kilian
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In view of the effects of the global climate crisis and accompanying extreme weather events, the preservation of cultural heritage is facing new challenges. In particular, cultural assets such as historic buildings are under constant climatic influence with their surroundings and need to be adapted to the climatic changes. In this context, the present work deals with the effects of climatic influences on an especially vulnerable type of built heritage using the example of two half-timbered buildings of the Franconian open-air museum Bad Windsheim. After 20 years of standing in the museum grounds, both buildings showed visible damage to the exterior and interior walls and had already undergone several renovation measures. The focus of the investigations lies on recording and evaluating the material and structural vulnerability of the two buildings to local climatic conditions and possible extreme weather events. Aspects such as the different execution of the construction, as exposed or plastered timber frame, as well as the installation of a temperature-controlled wall heating system are examined for their impact on the resistance of the buildings to external influences. Non-destructive methods enabled the conduction of in-depth investigations of the climatic and building physics conditions during the six-month study period from October 2021 to March 2022. The west-facing rooms showed high ranges of relative humidity as well as temperature and were very similar to the values of the outdoor climate. This indicates that the west oriented interior rooms are exposed to the strongest influence of the exterior climate.

The result was consistent with the mapping of numerous damages on the interior and exterior walls. A comparison of the recorded interior temperatures of the two museum buildings highlighted the influence of the installed temperature control lines, which resulted in a much more stable and compact indoor climate with reduced extreme values. Over the winter period, minimum values of 3 °C were measured in the temperature-controlled building, whereas room temperatures of up to minus 4 °C were recorded in the unheated building. In particular, historical furnishings and materials were exposed to direct frost. Additional data, such as results of the passive thermography or the surface temperatures and humidity in the interior rooms, could be determined by means of point-by-point wall measurements. The observed damage patterns formed the basis for determining the effects of various weather phenomena in Bad Windsheim. A high risk is posed, for example, by frequent driving rain if the building is exposed and or the building fabric is already damaged. The severity of damage depends on the materials used and the type of materials used and the construction method. Thus, a generalize risk assessment for the specific vulnerability of halftimbered buildings is proposed. Preventive measures such as enclosing exposed truss walls over the winter months or the re-establishment of an intact water drainage system on the one hand reduce the risk potential of negative impairments by weather phenomena, on the other hand they increase the resistance to climatic influences.

The role of cultural heritage in climate resilience. Developing, testing and replicating cross-sectoral solutions for historic buildings to combine climate change adaptation and mitigation in mountainous regions.

The urgent need for adaptation measures to improve the resilience of European territories and communities has become clear with the acceleration of climate change1. For this reason, key strategies such as the EU Adaptation Strategy and the EU Green Deal have been developed. The main objective of the IMPETUS H2020 project, launched in October 2021, is to turn climate commitments into tangible actions. It develops a multi-scale, multi-level, and cross-sectoral set of solutions for climate change adaptation to speed up the transition towards a climate-neutral economy and society. The project aims to build communities of local actors able to assess future development scenarios based on objective data and to support strategic decision-making processes. IMPETUS Demo Sites cover 7 biogeographical regions of the EU (continental, coastal, Mediterranean, Atlantic, Arctic, boreal, and mountainous), demonstrating a full variety of present and future climate threats. Valle dei Laghi (NE Italy) represents the mountainous region, where the impacts of climate change are leading to an increase in current land and water use conflicts. Intangible heritage can play a key role in the context of global climate change in mountainous regions predominantly facing an increase in frequency and intensity of locally occurring natural hazards. Despite their high damage potential, these are known to the local communities, who have been dealing with such threats for decades/centuries and are experiencing some changes in recent times.

At the local and regional levels, a thorough understanding of how to cope with risk has evolved. This endogenous local knowledge will be tapped into the demo site. The analysis of past climatic conditions together with an in-depth study of the locally built heritage leads to the identification of vulnerabilities in the conservation of the tangible heritage. The quantification of hygrothermal risks under future climate conditions is performed by means of numerical simulation. Simulated models recreate the geometry and materials of the existing masonries and offer the possibility to quantify the risks they are exposed to in terms of water accumulation, frost damage, and biological attack. In addition to that, hygrothermal and energy modelling offers the possibility of simulating several scenarios (past, present, and future climate as well as existing and retrofitted scenarios). Energy retrofit solutions can still achieve important energy savings and contribute towards carbon neutrality. However, these interventions need to be carefully considered from a hygrothermal and energy point of view so that the performance of possible interventions is fully understood and the risks of material damage and occupants' discomfort are assessed. Eventually, tools (such as risk misperceptions or performance coefficients) will be developed to foster societal awareness and facilitate win-win solutions for the adaptation & implementation of low-carbon measures for historic buildings. The focus of the work presented at the conference will be on the methodological approach and state of progress rather than final results.

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UAV-based analysis of drought induced beech tree degradation in landscape parks of SPSG in Berlin/Potsdam

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Historic parks and landscapes are cultural objects that are very worthy of preservation. They also represent a reference from past and present civilizations. In the course of climate change and resulting drought and extreme climate events, these cultural objects are under considerable threat to be severely damaged or destroyed. This works aims to develop a monitoring system and a spatially explicit analysis workflow that can be used to quantify and model drought-induced tree crown damages with a focus on beech trees in historic parks and landscapes of the Prussian Palaces and Gardens Foundation Berlin-Brandenburg. The first results are presented for the landscape parks regions “Klein Glienicke” and “Park Babelsberg” in the southwest of Berlin and Potsdam. We conducted UAV-based (unmanned aerial vehicle) flight campaigns with the Phantom 4 RTK (Real Time Kinematic) and Phantom 4 Multispectral RTK in the summer month of July and August in 2020, 2021 and 2022. Two methodological approaches were developed: individual tree crowns were delineated applying a watershed tree-crown object segmentation on the canopy height model and resulting tree crown objects were classified based on multispectral drone data into different defoliation classes using a deep learning convolutional neural network algorithm.

We differentiated four defoliation classes based on the training data. Additionally, a concept for mapping tree crown gaps based on a canopy height model was developed. Canopy height models were calculated from ultra-high resolution drone data and from survey data from the State Survey Offices Berlin and Brandenburg in 2018. Annual canopy loss was estimated at 4-5 hectare per year in the Babelsberg park region. The stand gap analysis was restricted to tree heights above 7 m height. The vegetation gap dynamics in the park Babelsberg were also identified as partly driven by tree pruning measures, whereas in the park region of “Klein Glienicke” no dead defoliated trees and defoliated tree branches are removed from the forest area. This led to a clear distortion of the statistics on area changes based on stock gaps. Overall, these approaches successfully demonstrated the potential of UAV data analysis for the detection of likely climate change-induced tree cover change in historic park areas. These findings clearly recommend the application of UAV data analysis also for other park areas. Analysis with more site-specific reference data will be conducted to link the UAV data-based change results with a better understanding of local processes.

A holistic model for predicting the impacts of climate change on indoor climate and air quality

The IPCC report from 2021 predicts an average global temperature increase of 1.4-4.4 °C by 2100, depending on the specific scenario, and more frequent extreme weather events are expected. The changing climatic conditions such as temperature, humidity, and pollutant concentration further affect the indoor microclimate by altering the physical properties of the building, the dynamics of the indoor air, the chemical/physical reactions of pollutants, pollutants emission strength, and even microbial growth. The question, therefore, arises to what extent the changed processes influence indoor air quality and the well-being of the occupants. Numerous IAQ simulation models have already been developed that focus on specific aspects. Nevertheless, there is still a need for a holistic model that combines all the main aspects and provides a complete picture of how climate change affects indoor air. Thus, a research project was motivated and funded by the German Environment Agency for developing the Indoor Air Quality Climate Change (IAQCC) model system. The IAQCC was constructed from five sub-models, each of which addresses one aspect:
1) The building physics model calculates the heat and moisture balance of the building zones and boundary conditions;
2) The emission model considers emissions of gas and particulate pollutants from e.g. furniture and occupant activities;
3) The chemical-physical model focuses on the key indoor processes, including aerosol dynamics, gas-phase reactions and SVOC sinks;
4) The mould growth model assesses the mold risk on indoor surfaces;
5) The exposure model evaluates the results of the individual sub-models and estimates the human exposure, including thermal comfort and exposure to gaseous, particle and microorganic pollutants. In addition to this expert model system, an interactive web information platform is created in order to raise awareness of the impact of climate change on the indoor environment and to transfer knowledge to a broad public in an easily understandable way. The web information platform is to be freely accessible and, through simple, intuitive usability, enable the user to engage with the topic in a game-like effect. The holistic model will allow long-term prediction of indoor climate and pollutant concentrations under various future climate scenarios, including different IPCC scenarios and emission reduction scenarios assuming different levels of air quality legislation. The results can provide a strong basis for future insulation, ventilation and IAQ improvement strategies and policies and may be also transferred to the cultural heritage area.

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Application of hygrothermal building simulations to determine potential damage to historic buildings caused by climate change

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The frequency of extreme weather events, such as prolonged heat waves, extreme drought or storm events, is increasing more and more. These changes in climatic boundary conditions also have an impact on our cultural assets. The German research project KERES focuses on the protection of historic buildings and monuments as well as man-made historic gardens and landscapes. For these cultural assets, the project investigates expected damage as well as measures to prevent and manage acute damage situations.

In order to take into account future climate developments up to the year 2100, the project uses ensembles of future climate projections from regional climate models based on the RCP 8.5 emission scenario and evaluates them for specific locations in Germany. These generated climate datasets are then used as climatic boundary conditions for specialized impact models such as hygrothermal building and component simulations as well as urban microclimate simulations in order to predict the future behaviour of cultural assets and possible damage. The approach of considering simulation ensembles, which is well established in climate science, is also applied to the detailed impact models in KERES in order to increase the robustness of the findings. Two of five studies in Keres are presented in this paper: Charlottenhof Palace in Potsdam and Sufferloh Chapel in Upper Bavaria. Common to both is that hygrothermal building simulation was used as the specialized impact model.

Damage effects from prolonged periods of heat and drought were the focus of Charlottenhof Palace. Effects from driving rain and the effect of hydrophobic treatment were the focus. Methodologically, the procedure was identical for both case studies: Hygrothermal building simulation models are created for both buildings and validated on the basis of collected indoor climate measurements. In addition, the provided climate change projections are checked for plausibility with historically recorded weather data from the immediate vicinity of the case studies. Ensemble simulations are then performed for three time periods: 1970-2000 (historical comparison period), 2035 - 2065 (near future), and 2070 - 2100 (far future). The ensemble here consisted of climate data from 10 regional climate models.

The simulation results of the case studies suggest an increase in indoor temperatures, in the frequency and duration of high-temperature events, and a sharp increase in absolute humidity. With regard to damage processes, there is also a reduction in the lifetime multipliers for the silk, paper and lacquer objects included in the evaluation. The investigations of the small chapel show that the building is impacted severely by wind-driven rain. A change in the protective plaster system and a simple wall heating system (Temperierung) show good results so far. However, the moisture problems are not yet completely solved and other options like improved climate control or simple measures like repeated maintenance are currently under discussion.

Benchmarking Energy Consumption and RH/T Environment - Key Performance Indicators for Memory Institutions

Climate change has finally arrived in our museums, archives and libraries. It manifests itself, for example, in increasing risk scenarios such as severe weather events, but also in their own ecological footprint, which often threatens to undermine their very own mission, the sustainable preservation of cultural heritage. Related to their area, memory institutions rank among the top-energy-consumers in the urban context. In addition to the gray energy embedded in buildings, a major obstacle on the way to more climate-friendliness is above all the excessive air conditioning, which has been traditionally more based on technical feasibility than on conservation needs. In May 2010, at the 38th Annual AIC Meeting in Milwaukee, a panel discussion, hosted in collaboration with the IIC, focused on the so-called Plus/Minus Dilemma. We distinguish, a.o., between gray and operational energy. The «gray energy» is difficult to estimate in the long term, since the non-renewable energy content of substitute materials or systems is difficult to predict. In addition, there still needs to be more tools to assess the gray energy occurring during demolition and disposal, especially for historic buildings. The ratio of embodied gray energy to operational energy depends on numerous factors. With increased service life, operating energy gains in importance. On the other hand, with the trend towards better energy efficiency, gray energy will regain importance in the overall life cycle of buildings. Energy consumption is therefore an important Key Performance Indicator (KPI) in the climate crisis. A database for benchmarking the energy consumption of memory institutions, which we compiled over recent years together with partners from Germany and abroad, now includes more than 100 institutions. On average, memory institutions consume 373 kWh/m^{2}a (median at 342 kWh/m^{2}a) as operational energy. We need to consider, that the area information is not standardized and in many cultural institutions associated with ambiguities. While transparency in this debate is outmost importance and many cultural institutions are openly sharing their consumption data e.g.via their websites, some still remain reluctant to share these. Another KPI for memory institutions, especially helpful for identifying energy saving options, is the classification of the real humidity and temperature conditions in standardized climate classes according to national and international standards and recommendations. Since autumn 2022, the Rathgen-Forschungslabor is offering the evaluation of indoor climate for grant recipients of the Federal Government Commissioner for Culture and Media (BKM) and beyond. Relative humidity (RH, %) and temperature (T, °C) recordings submitted to the institute over an annual period are classified and ranked according to ASHRAE 2019, Bizot Green Protocol 2014, Deutscher Museumsbund 2022, and for archives /libraries according to DIN ISO 11799 (2017) and B DIN 67700 (2017). This contribution will report on our experiences with soliciting and evaluating data for both KPI´s over the first winter of the looming energy crisis.

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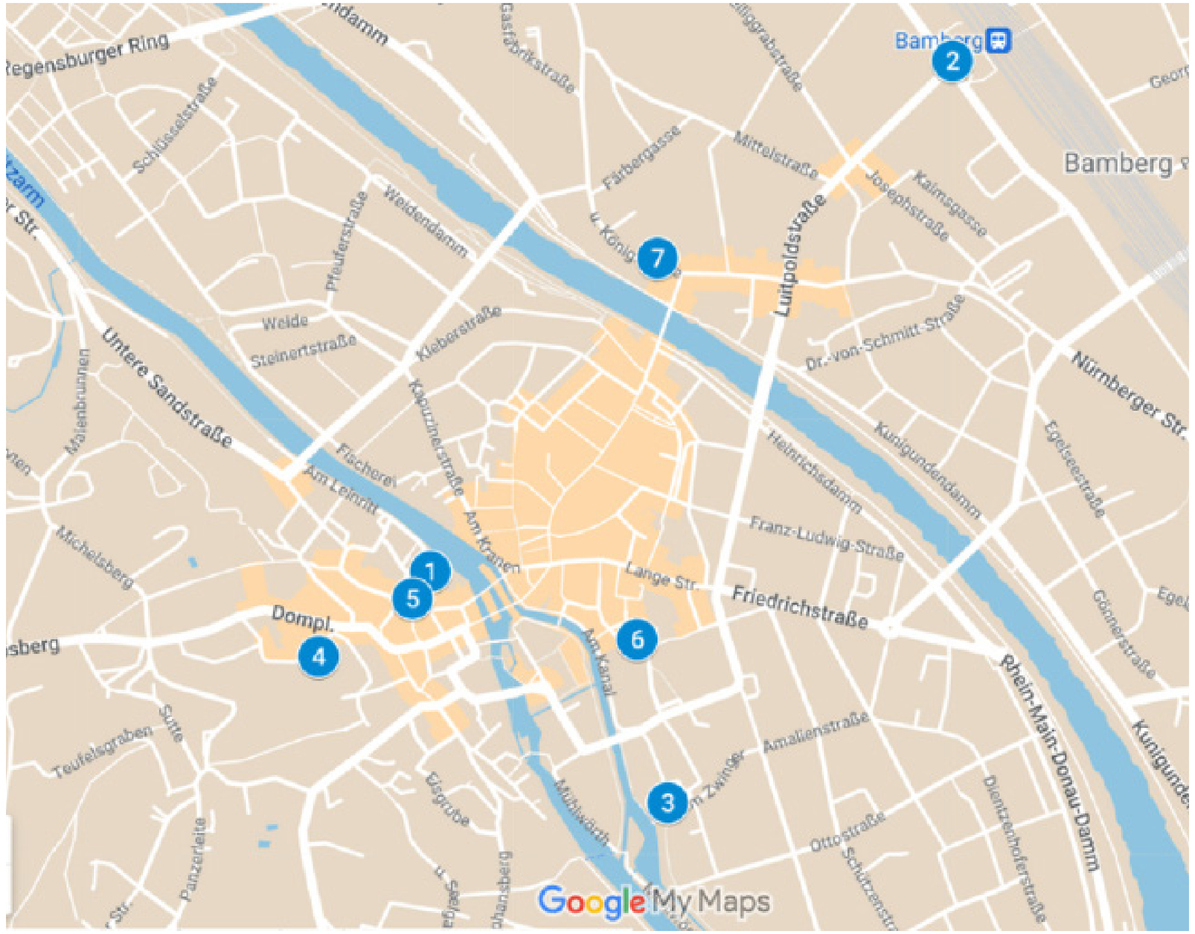
CONFERENCE LOCATIONS AND CONTACTS



1 - Former Dominican cloister,
Kasernstraße 4, 96049 Bamberg, 2 OG, Nr. 317 ehemalige Dominikanerbibliothek
2 - Central Station Bamberg
Center 96052 Bamberg
3 - Centre for Heritage Conservation Studies and Technologies (KDWT)
Am Zwinger 6
4 - Bamberg Cathedral
Domplatz
5 - Schlenkerla, Enduring family-run brewery specializing in smoked beer, also serving typical Bavarian food
Dominikanerstraße 6, 96049 Bamberg
6 - Hotel Ibis Altstadt
Theatergassen 10 Navigation:, Schillerpl. 2, 96047 Bamberg
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Imprint

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How can cultural heritage be managed in times of climate change?
Conference on Cultural Heritage and Climate Change at the University of Bamberg
27. - 28. February 2023

Website: https://www.uni-bamberg.de/restaurierungswissenschaft/conference-on-cultural-heritage-and-climate-change

Layout: Tetiana Golub