Results of the EU project Climate for Culture : future climate-induced risks to historic buildings and their interiors

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Results of the EU Project *Climate For Culture:* Future Climate-induced Risks to Historic Buildings and their Interiors

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Abstract

The EU funded *Climate for Culture* (CfC) Project is finalized to forecast the impact of climate change on either indoor or outdoor Cultural Heritage and advise on related risks. CfC has produced high-resolution thematic maps over Europe to highlight the expected changes and related risks for a number of key materials, building types, deterioration mechanisms for the near and far future based on two emission scenarios as developed by IPCC. The procedure to obtain a thematic map is as follows: to simulate outdoor climate change; to pass from outdoor to indoor climate change through building simulation and case studies measurements; to use damage functions and literature results to evaluate potential risk for buildings and objects; to map the above results for advice and stakeholders use. This methodology has produced 55,650 thematic maps of future climate induced risks to historic buildings and collections in their interiors. The results can be used for climate change impact assessments and for planning adaption and mitigation measures in view of preventive conservation or other applications, e.g. human health, energy consumption, cultural tourism. This paper presents some of the main project outcomes.

Keywords: Climate Change, risk maps, preventive conservation, Cultural Heritage

1. THE CLIMATE FOR CULTURE PROJECT

Climate Change is one of the most critical global challenges of our time. This factor, coupled with the increasing demand our society makes on energy and resources, has forced sustainable development to the top of the European political agenda. Scientific research shows that the preservation of the cultural heritage of Europe is particularly vulnerable to all three of these factors. As a non-renewable resource of intrinsic importance to the European identity, it is necessary to develop more effective and efficient sustainable adaptation and mitigation strategies in order to preserve these invaluable cultural assets for the long-term future. More reliable assessments will lead to better prediction models, which in turn will enable preventive measures to be taken, thus reducing energy and the use of resources.

In the general perception, gale winds and heavy rains will likely affect outdoor monuments; museums should substantially be prepared to use more fuel for air conditioning and less for heating. The EU funded NOAH'S ARK project [1] has considered this problem for outdoor monuments and buildings and has produced a first risk atlas based on future simulations. This has provided very useful information concerning the cultural heritage at risk. However, so far nobody has a clear idea about the indoor conservation needs, i.e. if the museum collections will undergo an acceleration of the physical and chemical deterioration processes, if the risk of moulds and insect infestation will be increased or reduced and so on.

The *Climate For Culture* (CfC) project will consider not only monuments and buildings exposed to future weather injuries (e.g. precipitation, dryness, temperature, humidity, time of wetness, repeated freezing thawing or salt crystallization cycles), but the future of building interiors, collections, and various types of cultural objects and materials. CfC has connected high-resolution climate change evolution scenarios with whole building simulation models to identify the most urgent risks for specific building types and climate regions over Europe.

The CfC project has implemented high resolution regional climate model REMO with 10 km X 10 km spatial resolution [2] and it has used these results as input to assess deterioration rates and damage potentials. The innovation lies in the elaboration of a more systematically and reliable damage/risk assessment which will be deduced by correlating the projected future climate data with whole building simulation models and damage assessment functions.

Laboratory tests, in situ measurements and investigations at cultural heritage sites throughout Europe, and computer simulations have allowed a precise assessment of the real damage impact of climate change on cultural heritage at regional scale. Sustainable (energy and resource efficient) and appropriate mitigation/adaptation strategies, have been developed and applied on the basis of these findings simultaneously.

All the above results have been incorporated into thematic maps related to the outdoor and indoor deterioration mechanisms, the risk assessment and an evaluation of the economic costs and impacts that have been forecasted until 2050 and 2100 based on two IPCC emission scenarios.

To this aim, the first step was to achieve a reliable assessment of the impact of climate change through an improvement of the prediction models, then the development of a methodology to assess the climate-induced risks on materials and building envelopes which in turn can enable preventive measures to be taken from stakeholders, thus reducing the consumption of energy and resources.

The CfC project has also considered the analysis of uncertainties deriving from combining projections of future climate, building simulations and damage functions; although the effective communication of uncertainty is a challenging task, even when full probability distributions are known.

The analysis of the uncertainties related to the project outcome include uncertainties in: risk maps, forcing conditions and the used climate model, significance of the climate change pattern, building simulation, damage functions. The above analysis is necessary to assess the confidence limits that should be related to future scenarios and that should be considered and should underlie any decision support system or any decision-making activity.

2. RISK ASSESSMENT

Within the CfC project, the risk assessment process is carried out through a sequence of simulations [3]:

- Outdoor climate change simulation
- Indoor simulation to pass from outdoor to indoor climate change through building simulation and case studies measurements
- Risk assessment to using damage functions and literature results to evaluate potential risk for buildings and objects both outdoors and indoors.

This assessment method is carried out for:

- a grid of 474 European and Mediterranean locations as reported in Figure 1 [Fig.1] for each of the following items.
- three 30-year time windows i.e. for the **near future** (2021-2050), the **far future** (2071-2100) and the **recent past** (1961-1990) as reference period
- Two different moderate emission scenarios from the Intergovernmental Panel on Climate Change (IPCC) [4 and 5], respectively: **A1B Scenario** from IPCC's 4th report based on a higher CO_2 emission increase assumed until 2050 and a decrease afterwards. **Representative Concentration Pathway (RCP) 4.5 Scenario** based on long-term, global emissions of greenhouse gases, short-lived species, and land-use-land-cover which stabilizes radiative forcing at 4.5 watt m^{-2} (approximately 650 ppm CO_2 equivalent) in the year 2100 without ever exceeding that value [4].
- 16 generic building types, each of them different in volume, window area, assemblies and moisture buffering capacity as a combination of: **Volume**: small/large building; **Area**: small/large window; **Structure**: heavy weight/light weight; **Moisture Buffering Performance** (MBP): Low/High

2.1 Indoor Climate Simulation

Indoor climate and risk maps have been produced for all of the 16 generic building types as shown in Table 1 [Tab.1] through an innovative indoor simulation method based on the State Space Model (SSM). The SSM is an inverse modeling approach [6] that is applied in compiling a transfer function (TF) able to simulate the thermo-hygrometric performance of simplified building models with the characteristics of the generic buildings summarized in Table 1. Such an innovative approach allows for a very fast simulation of indoor temperature and vapor pressure [7] for each generic building type over all the European climate locations.

The results show high accordance between the indoor simulation obtained via this combined approach and the full building simulation made using WUFI® Plus.

One of the major results obtained by the CfC Project is the use of the SSM approach to overcome the whole building simulation drawbacks as the required long elaboration run time and the extended set of detailed information.

2.2 Risk Simulation

Levels and fluctuations of temperature (T) and relative humidity (RH) are the main environmental drivers of risks for both building envelopes and collections taken into account in producing the CfC risk maps.

Outdoor forcing factors that may generate some form of damage or risk for the building exterior are related to climate changes and extreme events.

Indoor forcing factors that may generate some form of damage or risk for objects and/or building envelopes are related to levels and fluctuations of indoor temperature and relative humidity.

Risks are directly related to mechanisms governed by physical, chemical or biological variables, e.g. freeze-thaw cycles, crystallization-dissolution cycles, mould infestation.

The production of indoor damage/risk maps has been performed using the SSM for generic building simulation connected with the use of damage functions/tolerable ranges or risk indices collected from literature or developed within the project for various types of material/risks [8].

Damage functions and/or thresholds link the changes of the variables describing the forcing factors to a specific risk of damage. A traffic light code is used to calculate the risk for each degradation mechanism. Three risk levels are defined: **safe** (i.e. green color in the risk map legend), **attention** (i.e. orange color in the risk map legend) and **risk** (i.e. red color in the risk map legend). The level of risk is defined according to the number of events that have exceeded, or the time elapsed above, some specific risk thresholds.

The risk maps produced within CfC project can either show the risk levels for any of the three time windows (i.e. recent past, near future and far future) or the change in risk from one time window to another (i.e. difference between near future and recent past or difference between far future and recent past). The difference maps will show whether a risk is increasing or decreasing and how much per each location over Europe.

3. HOW TO APPLY OUTDOOR AND INDOOR DAMAGE/RISK MAPS IN PREVENTIVE CONSERVATION

3.1 Selected Materials

Various types of materials have been used to build cultural heritage objects, buildings or sites. Within the CfC project the climate change impact on movable and immovable cultural heritage has been evaluated for mechanical, chemical and biological risks (related to T and RH environmental changes) for a number of key materials that have been commonly used in this field, or that need consideration because might be at risk under certain unfavorable circumstances:

- Stone and masonry
- Wood and veneers
- Painted wood
- Paper
- Silk
- Color photographs
- Metal

3.2 Outdoor Risk Maps

The first column in Figure 2 [Fig.2a and Fig.2b] includes some selected materials exposed to the outdoor environment (e.g. stone and masonry buildings and/or wood and metal). Each selected material is exposed to one or more risk types (e.g. mechanical, chemical and biological), given in the second column. In addition, the same example considers also other challenges for buildings: an evaluation of the energy demand, or the risk for natural hazards (i.e. extreme events). For each material, and for each risk type, a map has been drawn to represent how the main forcing factors that contribute to the risk assessment are distributed over Europe (third column). Of course, these are only particular examples to elucidate the methodology that the final user can apply to be informed of the most critical factors (including sea level rise) that are predicted in his/her region in terms of thematic risk maps.

3.3 Indoor Risk Maps

Once the outdoor climate has been simulated, the produced data serve as input for the building simulation (section 2.1) and to generate the indoor climate and its future scenarios. From the knowledge of the indoor climate and the damage functions for some selected materials (section 2.2), it is possible to calculate the future risks for conservation, and map the outcome over Europe.

Some examples useful to explain the use of indoor risk maps are reported in Figure 3 [Fig.3].

4. SOME RESULTS AS AN EXAMPLE OF THE VARIOUS OUTCOMES

4.1 Outdoor Climate Maps:

Within the CfC project, four climatic zones have been individuated over Europe taking into account similar thermo-hygrometric variations (see Figure 4), the outcomes evaluation will refer to such zones [Fig.4].

The main predictions concerning the expected **temperature** differences in the near and far future with reference to the recent past, under the A1B emission scenario are reported in Figure 5a and 5b [Fig.5a and Fig.5b]. These differences are positive (i.e. greater than zero, in mathematical terms) in all the 4 climatic zones in Europe, with maximum changes in Northern Europe, inland of Northern Africa, Central Spain, Greece and Turkey. The prediction under the RCP4.5 emission scenario (Figure 5c and 5d) is similar to A1B for the near future but there is a decrease in temperature change in the respective climatic zones for the far future [Fig.5c and Fig.5d].

The expected changes in **yearly total precipitation**, in percentage terms, evaluated for the A1B emission scenario for the near and far future are visible in Figure 6 [Fig.6a and Fig. 6b]. In both periods, the predictions highlight no or small change 0-20% in Climate Zone I and II respectively Northern Europe (i.e. European Russia, Poland and Scandinavian Peninsula) and Central-Eastern Europe (i.e. Germany, Austria, Switzerland, Hungary, Czech Republic, Slovakia, and Ukraine). In Climate Zone III and IV, respectively European Atlantic Coast (i.e. Island, UK, Ireland and France) and Mediterranean regions, the prediction highlight a mixed situation with both negative and positive changes up to +50% in Egypt, Libya and Eastern Algeria and -50% in central Portugal, Morocco and Western Algeria.

4.2 Outdoor Risk Maps:

One of the outdoor climate risk features projected as future change respect to the recent past, is the tropical nights index, i.e. the number of nights in a year with daily minimum temperature Tmin>20℃. This climate variabl e may be useful to evaluate health risks for the population as well as the potential increase in energy consumption. In the far future (Figure 7) [Fig.7], under the emission scenario A1B, the projection highlights an increase homogeneously distributed over the whole Mediterranean region with maxima of +60 days/year on the Provence (France) and the Black Sea coasts. Extreme conditions with an increase up to +110 days/year are expected on the Egyptian and Libyan coasts.

4.3 Indoor Climate Maps:

Coupled simulations of climate and buildings allow assessing the future changes in respect to the recent past (i.e. 1961-1990 period) for air temperature, relative humidity and humidity mixing ratio inside buildings. 16 buildings have been simulated changing their hygro-thermal and geometric characteristics over the different European climate zones. Figure 8 reports the future difference in indoor temperature range for the building type 1 (i.e. heavyweight, small building with small window area) respect to the recent past.

Figure 8a [Fig.8a] highlights near future changes respect to the past: higher positive (>0, in mathematical terms) increase in temperature range in Sweden and Norway, Denmark, Holland, central Romania, Alps, Italy, former Yugoslavia and Greek coasts; a negative decrease (<0, in mathematical terms) in the rest of Europe. In the far future [Fig.8b] the projections identify two macro-areas: the first includes the Northern Europe, Germany and Poland and it highlights a decrease in indoor temperature range up to 5℃; the second macro-area constituting the Western and Southern Europe, highlights an increase up to 4℃ in indoor temperature range.

4.4 Indoor Risk/Damage Maps

A number of results are related to the simulation of mechanical, biological and chemical risks concerning nine selected materials that constitute building envelopes and/or the collections preserved indoors. Figure 9 highlights the mechanical risk for marble, stone and masonry due to future change in the frequency of salt crystallization cycles per year. Looking at Figure 9a [Fig.9a], for the near future under the A1B emission scenario, mixed situations are visible in Climate Zones I and IV, respectively Northern Europe and the Mediterranean Area with changes, respect to the recent past, ranging from -20 salt crystallization cycles/year in the Alps and in large part of Northern Europe, up to +10 salt crystallization cycles/year in the rest of Northern Europe, Southern Mediterranean and Spanish coast. In the far future (Figure 9b [Fig.9b]), the projection shows larger changes, i.e. up to -40 salt crystallization cycles/year in the Northern region (i.e. Climate Zone I) and in the Alps. A prediction of a decrease in number of salt crystallization means a lower risk of mechanical damages on masonry and stones, as opposed, an increase in frequency of salt-crystallization cycles (e.g. as in the rest of Europe with about +10 salt crystallization cycles/year more) means a slight increase of risk for such materials.

4.5 Energy Demand Maps

The prediction under the A1B emission scenario, related to the changes in energy demand in the near future respect to the recent past for a historic building with a strict climate control (Figure 10) [Fig.10a] highlights again two macro-areas over Europe. The first, shows a general saving of…… that can be estimated, for a building of 500 m^3 volume, up to 400 l oil/year in Northern Europe and up to ……equivalent to 100 l oil/year in central Europe; while the second macro-area shows a mixed situation with opposite trends in energy consumption. A maximum saving of corresponding to about 300 l oil/year is predicted for the the Alps whereas a maximum increase in consumption (i.e. W more corresponding to an additional consumption of 300 l oil/year) is expected in central Spain and Algeria. In the Far Future (Figure 10b) [Fig.10b] the macro-area distinction persists: from one hand there will be a saving in consumption of , (i.e. 1000 l oil/year less for a building with 500 m^3 volume) in Northern Region and of i.e. 800 l oil/year if this building is located in the Alps; from the other hand, the energy consumption will double in Spain and in Northern Italy reaching a maximum of ……600 l oil/year.

If we consider, under the A1B emission scenario, the energy demand in the Near and Far Future for a modern building envelope with a modern strict climate control (Figure 11), the above identified macro-areas still persist, but the prediction is quantitatively different compared to a historic building. In the Near Future (Fig.11a) [Fig.11a], for a modern building, a maximum saving of i.e. 60 l oil/year for a 500 m^3 volume is reached in Northern Europe. This saving decreases to i.e. 10 l oil/year in central Europe. In climatic zone III and IV i.e. Western Atlantic Europe and the Mediterranean Area, the mixed situations persist: from one hand a maximum of 40 l oil/year saved in Island, Northern Scotland and Alps; from the other hand, an increase in energy consumption up to 60 l oil/year in the Western Mediterranean, Iberian Peninsula, Libya, Egypt and Northern Italy. In the Far Future (Fig.11b) [Fig.11b], Northern Europe will save double in respect to the Near Future, while in Island, Ireland and Scotland an energy saving of about 120 l oil/year will be reached. In the Alps the energy saving will modestly increase reaching 60 l oil/year, while a maximum in energy consumption is predicted for Spain, Egypt, Northern Italy; The Mediterranean and Atlantic Coasts will have an increase in consumption of about 170 l oil/year.

5. CONCLUSIONS

To make the results understandable about a complex matter in a simple and friendly way for specialists and non-specialist users (e.g. researchers, conservators, policy makers, stakeholders), the risk assessment process has been developed with a problem-oriented approach which considers only one variable or aspect, at a time.

The project outcomes, concerning the future changes of indoor/outdoor climate variables, the main deterioration factors, the critical frequencies distribution and/or risks for building envelopes and collections have been presented in a simplified form as thematic maps over Europe.

The total number of thematic maps produced for the various types of materials, buildings, scenarios etc. is impressive: 55,650 high-resolution maps over Europe, as reported in the Project Deliverable 5.2 and in the Project Data Base [9]. These thematic maps include detailed information concerning potential deterioration and risk factors for indoor and outdoor, movable and immovable cultural heritage. The same basic information might be useful for other health or social application fields, e.g. cultural tourism, temperature changes and increased number of tropical days or energy consumption.

In this context, climate change may have negative, neutral or positive effects, depending on specific problems, aims, solutions and use. Research results offer a timely information to prepare adaptation and mitigation strategies, or to take advantage from the positive aspects whenever possible.

In this sense, the CfC project provides an informative tool aimed to assist policy makers, conservators, architects and any type of users in their difficult task, especially in view of an efficient strategy for management and preventive conservation of the European Cultural Heritage.

6. ACKNOWLEDGMENTS

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7. REFERENCES

1. Sabbioni, C., Brimblecombe, P. and Cassar, M. 2012. *The Atlas of Climate Change impact on European Cultural Heritage*. Anthem Press, New York.
2. Jacob, D., Mikolajewicz, U, Kotova, L., et al. 2012. *Climate for Culture – WP1 Deliverable 1.2.* Internal Project Report.

3. Bertolin, C., Camuffo, D. 2013. *Climate for Culture – WP5 Deliverable 5.1.* Confidential Project Report.
4. IPCC 2014. Climate Change 2013: The Physical Science Basis. Intergovernmental Panel on Climate Change, Fifth Assessment Report.
5. IPCC 2007. Fourth Assessment Report (AR4). Climate change 2007: Scientific basis. Available at: http://www.ipcc.ch/
6. Kramer, R. 2012. *From Castle To Binary Code – Inverse modeling for the prediction and characterization of Indoor climates and energy performances*. Msc-thesis. University of Technology Eindhoven.
7. Riedler, J. 2013. *Untersuchung Inverser Modellierung – Zur Bewertung der Einflüsse des Klimawandels auf Kulturgüter in Europa*. Bsc-thesis. Technischen Universität München (TUM).
8. Ashley-Smith J. et al. 2014. *Climate for Culture – WP4 Deliverable 4.2*. In print.
9. Bertolin C., Camuffo D., Antretter F., Winkler M., Kotova L., Mikolajewicz U., Jacob D., van Schijndel A.W.M., Schellen, H. Huijbregts Z., Martens M., Broström T., Leijonhufvud G., Sladek A., Mirtič M., Šijanec-Zavrl M. and Ashley-Smith J., 2014. *Climate for Culture – WP5 Deliverable 5.2*. Public Project Report. Available on request to the CfC Project coordinator.

8. IMAGES AND TABLES

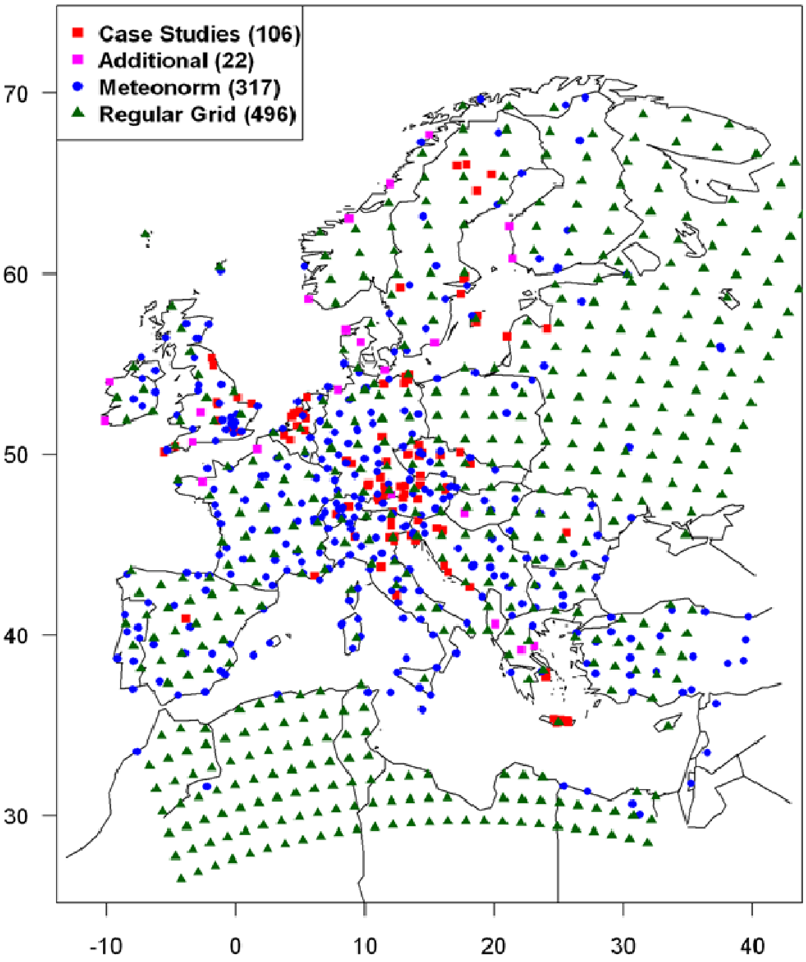

Fig. 1 Location of sites for which outdoor climate data are provided with hourly resolution for recent past, near future and far future

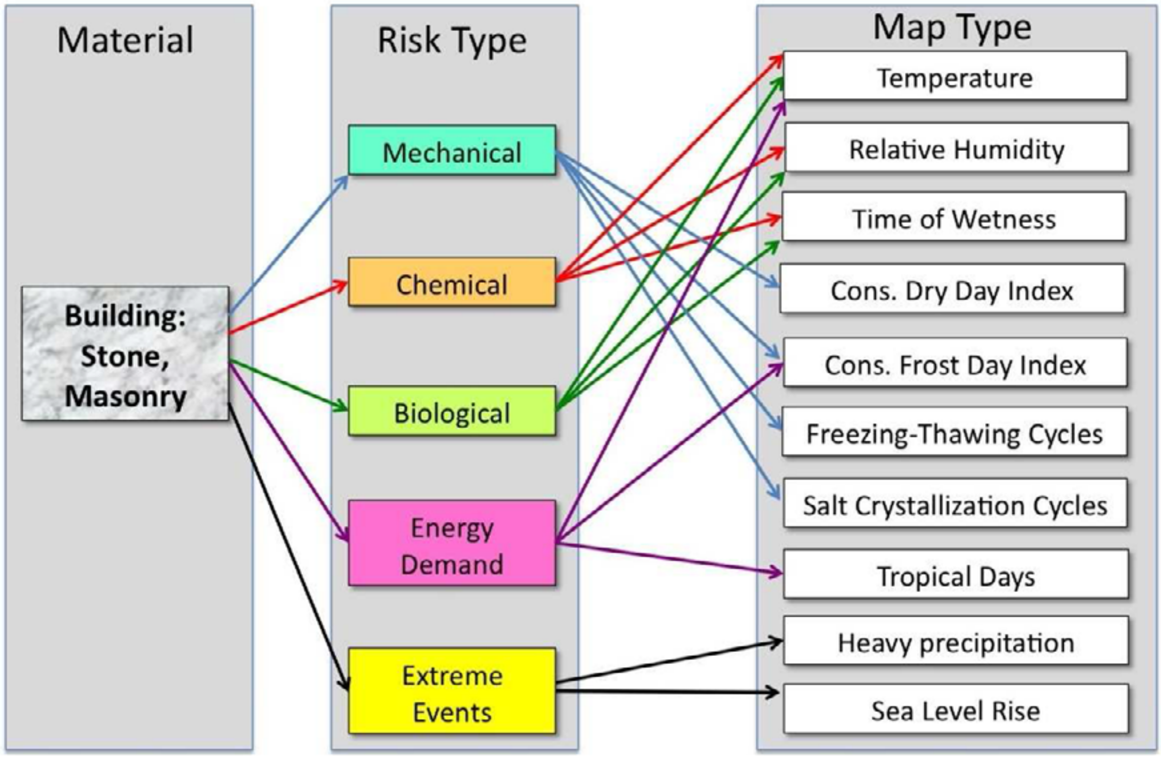

Fig. 2a An example elucidating the material oriented use of the climate risk/damage maps for a user potentially interested in stone and masonry buildings conservation outdoors.

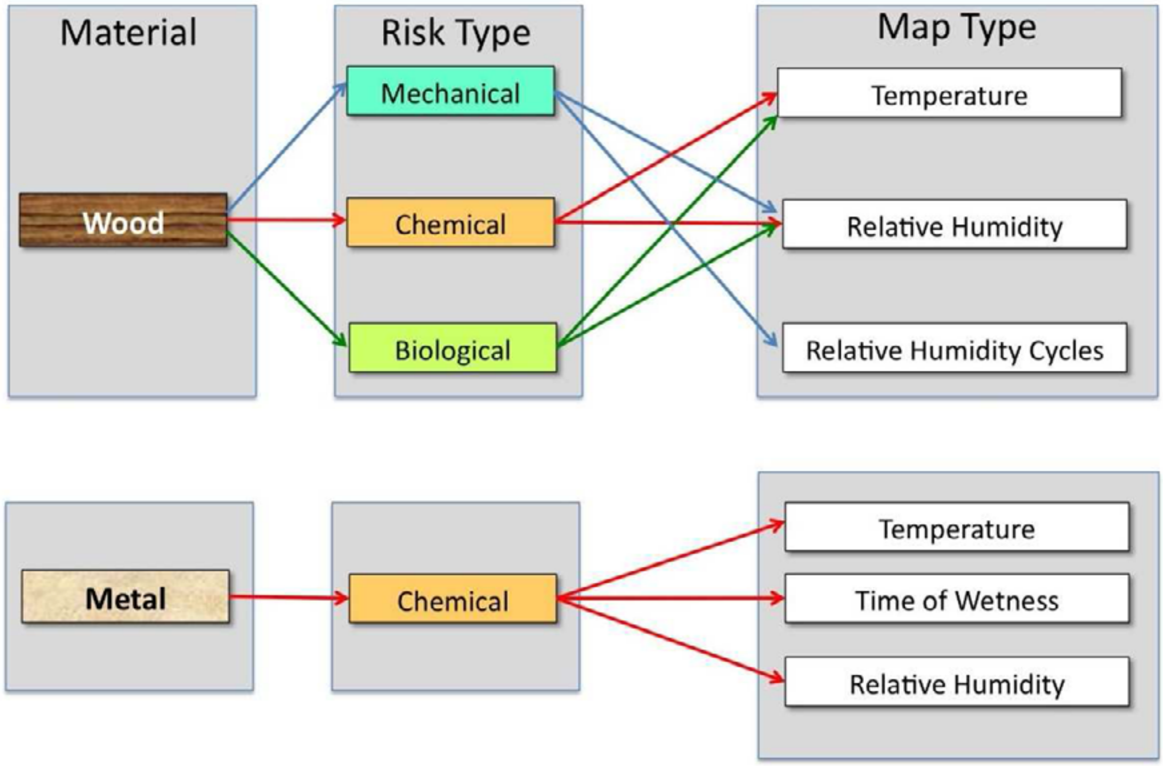

Fig. 2b An example elucidating the material oriented use of the climate risk/damage maps for a user potentially interested in wood buildings and metal conservation outdoors.

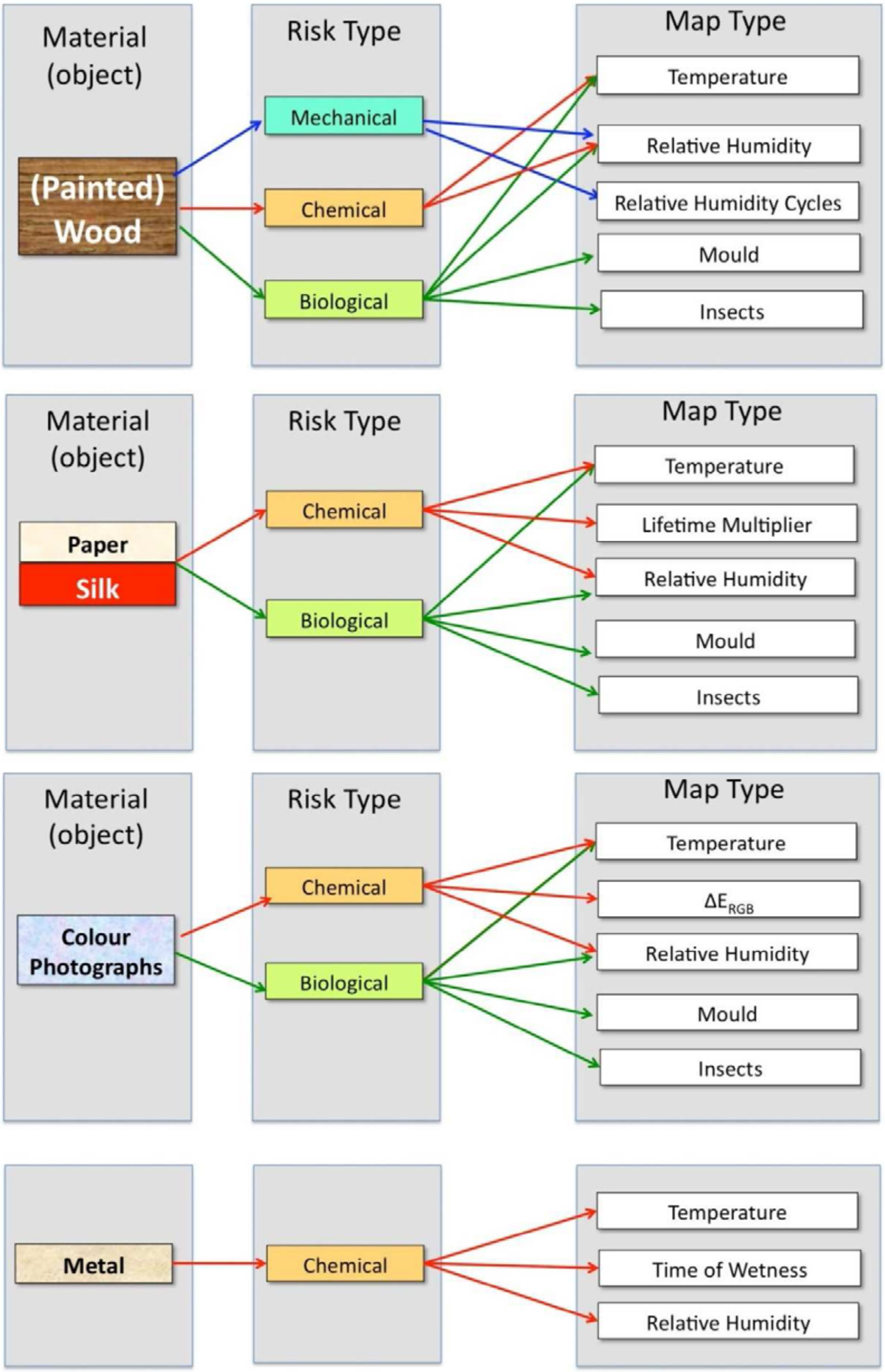

Fig. 3 An example elucidating the material oriented use of the climate risk/damage maps for a user potentially interested in indoor conservation of collection composed of several materials (e.g. painted wood, paper, silk, colour photographs and metal).

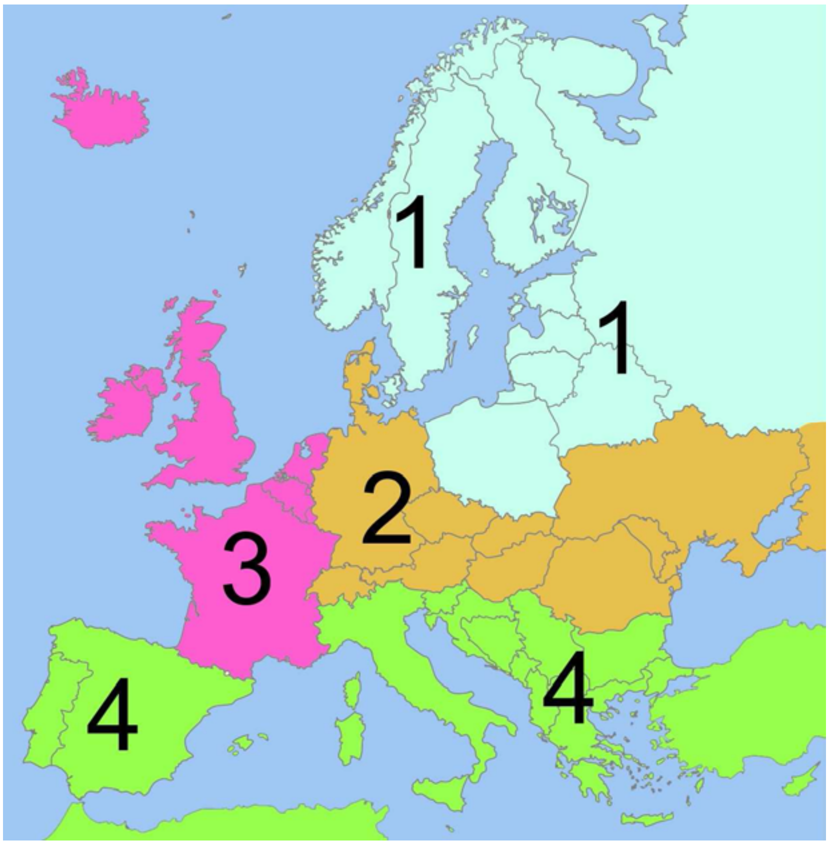

Fig. 4 Practical climate zoning for Climate for Culture outcomes evaluation

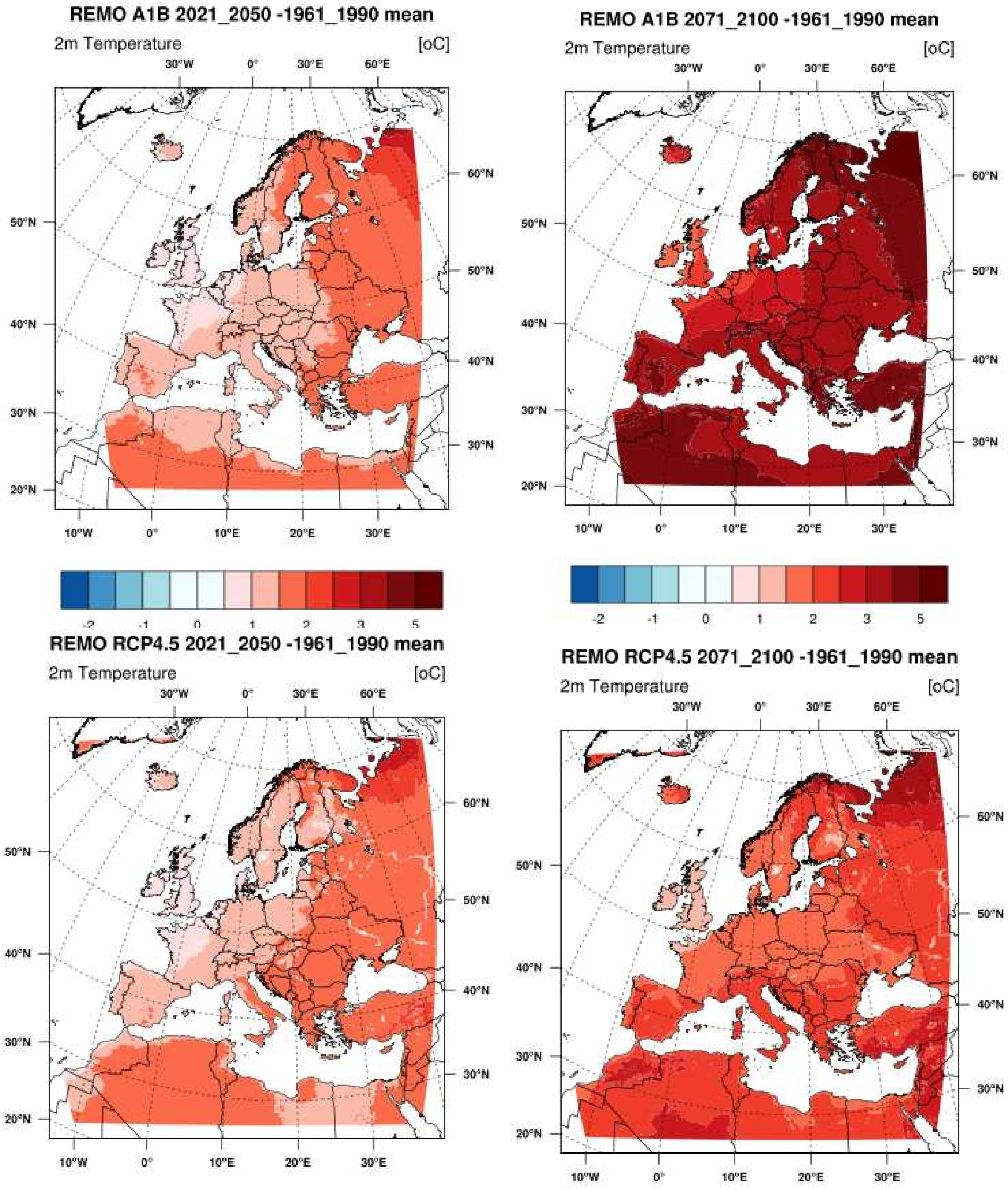

Fig. 5 Changes in air temperature at 2 m (°C) from the Recent Past to the Near Future (left side - 5a and 5c) and the same for the Far Future (right side – Fig. 5b and 5d). Simulations made under the A1B (top – Fig. 5a and 5b) and RCP 4.5 (bottom- 5c and 5d) emission scenarios.

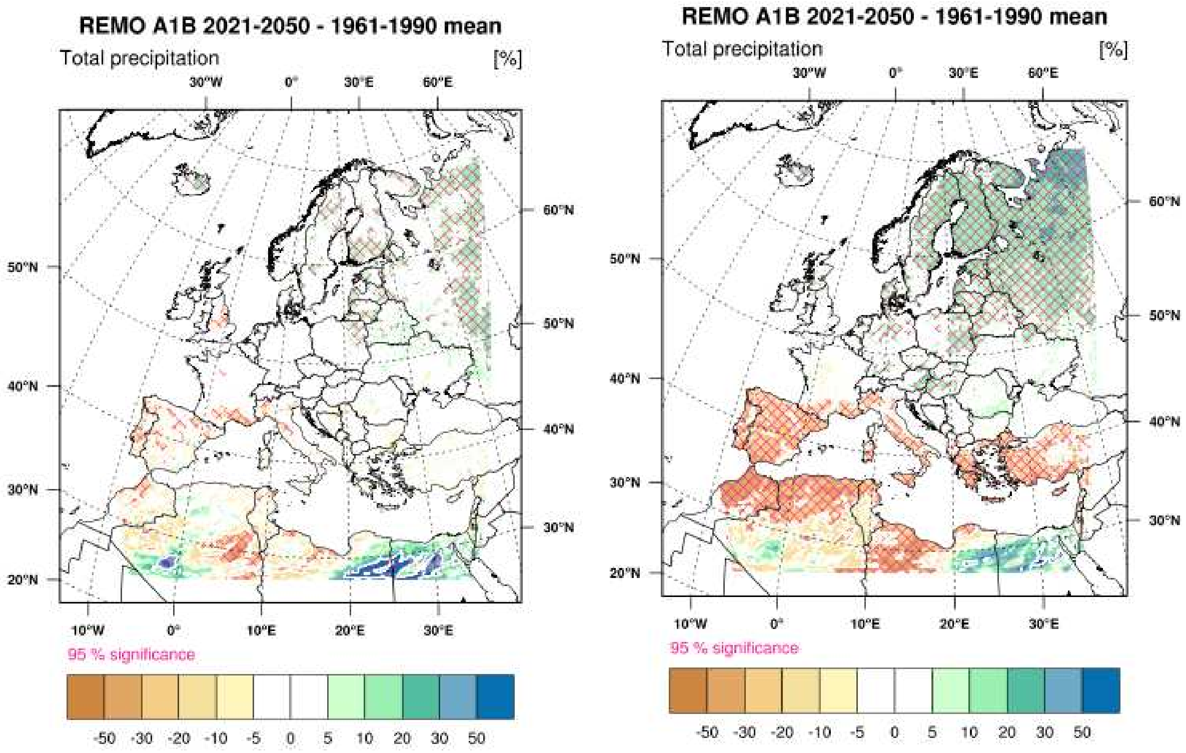

Fig. 6 Changes in yearly totals precipitation expressed in % as ratio between the Near Future and the Recent Past (Fig.6a on the left). The same but for the Far Future (Fig. 6b on the right). Simulations made under the A1B emission scenario.

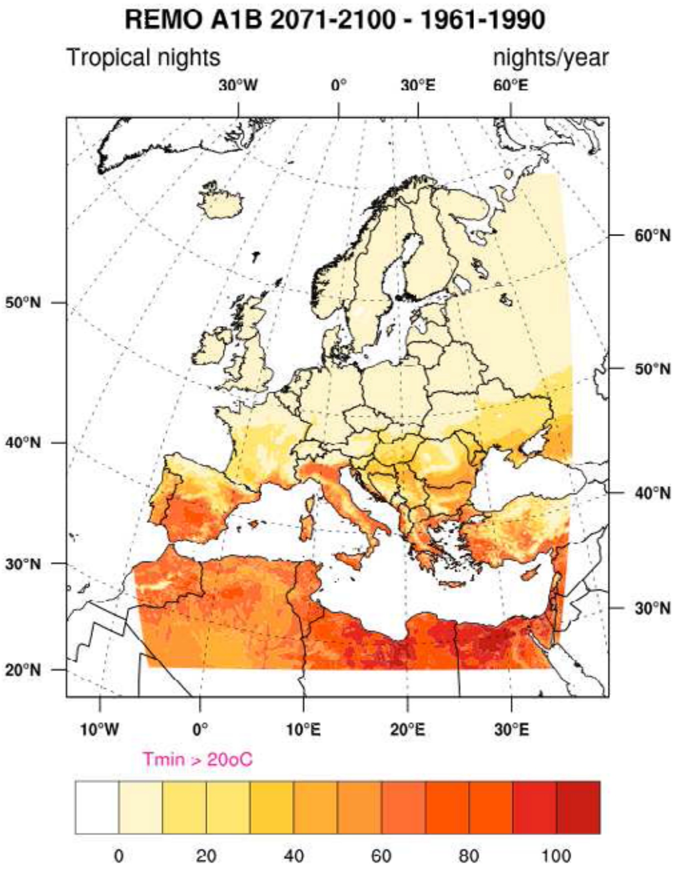

Fig. 7 Changes in number of days per year with minimum temperature exceeding 20°C calculated as a difference between the Recent Past and the Far Future. Simulations made under the A1B emission scenario.

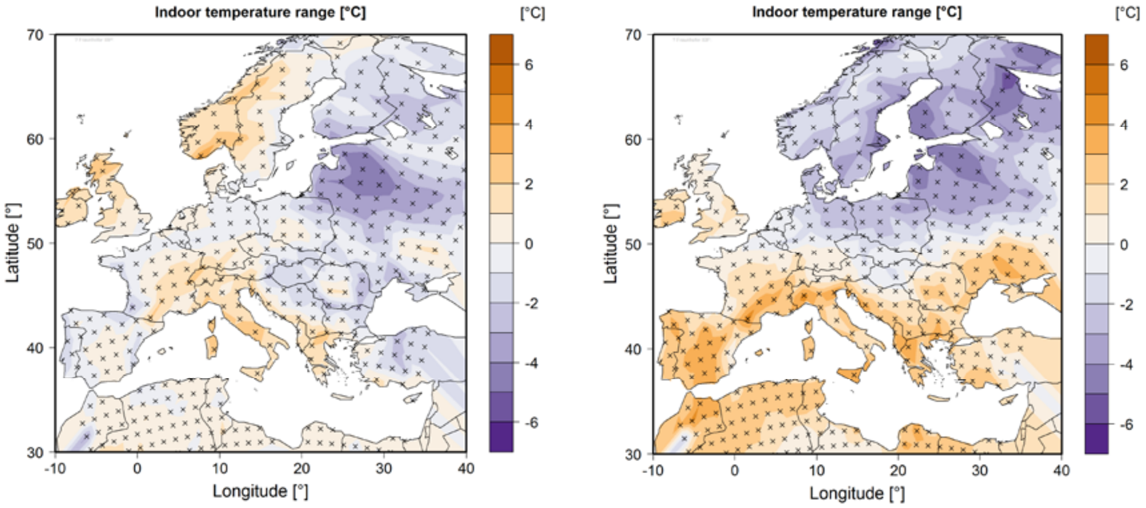

Fig. 8 Changes in yearly average of indoor air temperature range (°C) from the Recent Past to the Near Future (Fig.8a on the left side) and the same for the Far Future (Fig.8b on the right side). Simulations made under the A1B emission scenario.

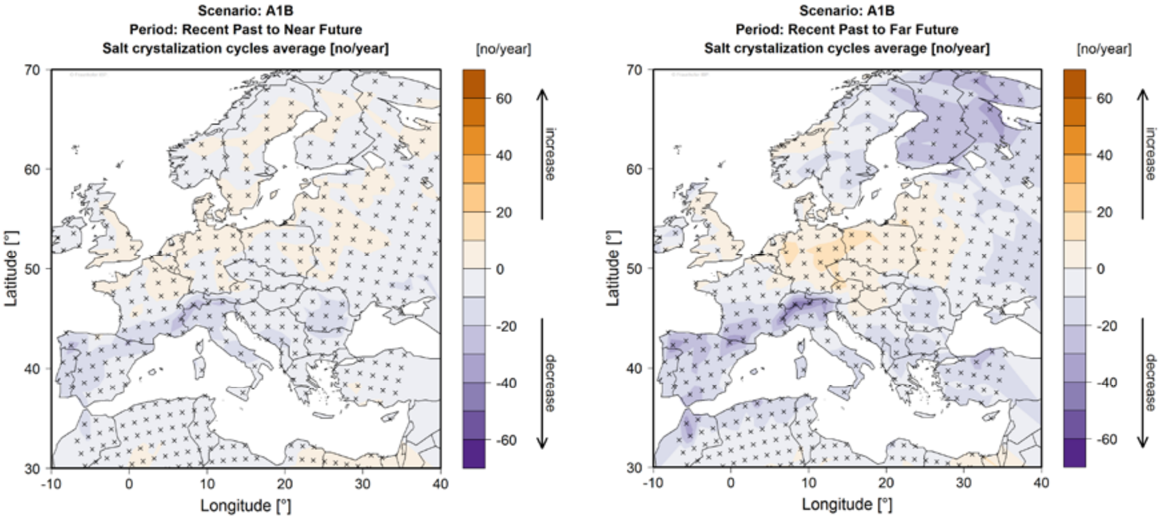

Fig. 9 Changes in yearly frequency of salt crystallization cycles from the Recent Past to the Near Future (Fig.9a on the left side) and the same for the Far Future (Fig.9b on the right side). Positive values for increasing risk; negative for decreasing.

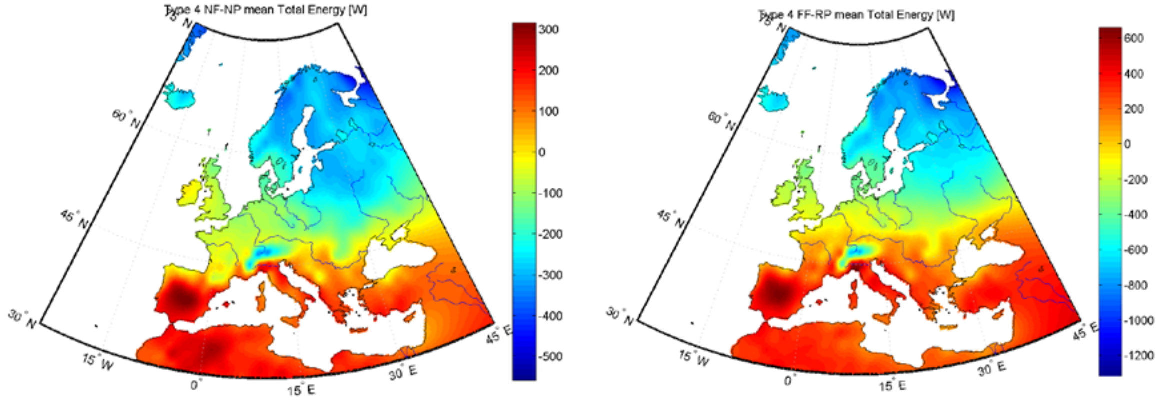

Fig. 10 Changes in energy demand (W) for a historic building with a strict climate control in the near future respect to the recent past (Fig.10a on the left) and in the far future respect to the recent past (Fig.10b on the right).

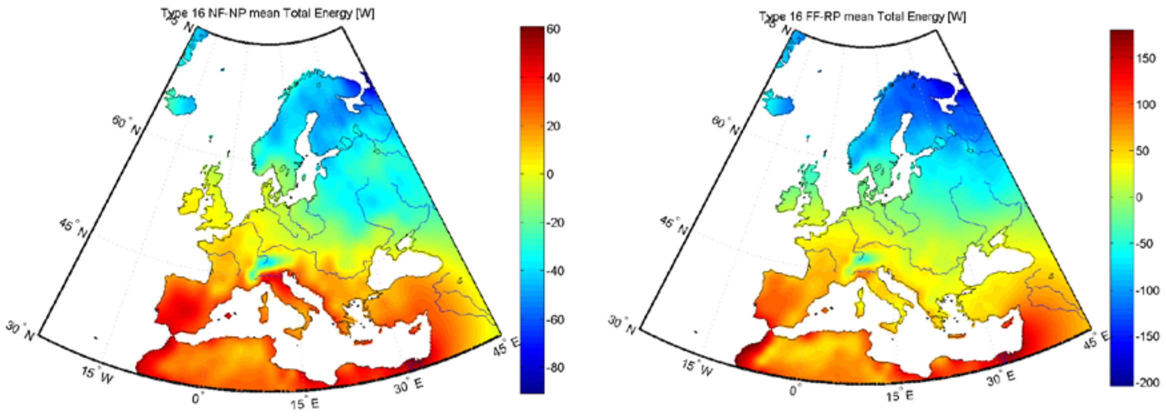

Fig. 11 Changes in energy demand (W) for a modern building envelope with a modern strict climate control in the near future respect to the recent past (Fig.11a on the left) and in the far future respect to the recent past (Fig.11b on the right).

Tab. 1 Extended nomenclature for Generic Buildings simulated within CfC Project as described in [3] - Appendix A.

	Heavyweight Building		Lightweight Building	
	Low MBP	High MBP	Low MBP	High MBP
Small Building, small window area	1	2	3	4
Small Building, large window area	5	6	7	8
Large Building, small window area	9	10	11	12
Large Building, large window area	13	14	15	16