Mapping climate change and cultural heritage

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1 Introduction

Climate change is currently attracting interest both at research and policy levels, but the focus tends to be on issues such as agriculture, lakes and forests. Cultural heritage, in particular built heritage, archaeological sites and cultural landscapes, has not yet been dealt with in programmes or publications either at the EU or global level [1].

Up to now, climate change has never been taken into consideration as a factor threatening cultural heritage [2], which is a non-renewable resource to be transmitted to future generations [3, 4].

The Noah' Ark Project funded by European Commission demonstrates a novel synergy between climate change and cultural heritage research. This project aims to fill the gap existing in studies on the effects of future climate variations on cultural heritage, confronting for the first time the problems arising from the impact of climate changes on Europe's built heritage and cultural landscape [5].

Initial work has identified the most significant climate parameters affecting cultural heritage. Outputs from Hadley Models (HADCM3 and HADRM3) have been used to provide a picture of the European climate from 1961 to 2099.

These data are employed to produce hierarchical maps aiming to present broad regional future threats to European monuments and buildings over the next 100 years, i.e. climate maps, heritage climate maps, damage maps, risks maps and thematic maps.

2 Climate models

Climate parameters used for future projections are extracted by the models of the Hadley Centre (U.K.): HadCM3 and HadRM3.

HadCM3 is an Atmosphere-Ocean General Circulation Model. Its grid resolution is 2.5 × 3.75 degrees (i.e. 295 × 278 km at 45 N latitude).

HadRM3 is a Regional Climate Model. It encompasses a European region at a much higher resolution than the HadCM3 model. The temporal span is from 2070 to 2099 and it is based on a grid of equal-area cells, 50 × 50 km (i.e. 0.5 × 0.5 degree at 45 N latitude).

The model output used for our analysis has relied on A2 scenarios, which are based on a very heterogeneous world, in which the underlying theme is that of strengthening regional cultural identities, with an emphasis on family values and local traditions, high population growth, and less concern for rapid economic development.
The selected geographical area is centred on Europe and covers a region of 33.75W – 67.50E latitude and 80N – 25N longitude for the general model, and 30W – 55E latitude and 72N – 35N longitude for the regional one.

The daily outputs of HadCM3 and HadRM3 have been used to elaborate variables critical to the built cultural heritage. The monthly, seasonal and yearly means of the following parameters have been produced:

Temperature derived parameters

Temperature range: $\max(T_1..T_n) - \min(T_1..T_n)$ where T_i = daily mean

Thermal shock: number of events when $Tmax(i)-Tmin(i) > X$ °C
where X = 7, 10, 15, 20 °C

Freeze-thaw cycles: number of cycles, a cycle occurs when
$T(i) > 1 \wedge T(m) < -3 \wedge T(n) > 1$
where T(i), T(n) and T(m) are daily means and $i < m < n$

Water derived parameters

Precipitation Amount

Rain days: total number of rainy days

Extreme rain: number of events when $P(i) > 20$ mm, where P(i) is the daily precipitation amount

Consecutive number of rainy days: number of events

Mean Relative Humidity

Relative Humidity range

Relative Humidity shocks

Wind derived parameters

Wind speed: mean $(W_1..W_n)$ where W is the daily mean

Wind speed counts: number of events when $Wmax > X$m/s
where X = 7.5, 10, 15, 20 Wmax is the daily maximum

3 How can climate change be mapped for cultural heritage?

Using the HadCM3 data output, 30-year mean maps have been produced relative to 1961-1990 (Recent Past), 2010-2039 (Near Future) and 2070-2099 (Far Future), to provide three different pictures of several of the above mentioned parameters during the 1961-2099 period in the European area. The project has also generated difference maps between the 2010-2039 map and 1961-1990 map and between 2070-2099 map and 1961-1990 map, in order to quantify the changes that will occur in future respect to 1961-1990 (taken as reference). In addition, the 30-year mean maps relative to 2070-2099 have been produced using the HadRM3.

These data are utilized to produce hierarchical maps aimed at presenting broad regional future threats (Figure 1).

At the simplest level climate change has been mapped in terms of traditional climate parameters relevant to cultural heritage (e.g. yearly precipitation, rainfall intensity, frost).They represent the basis for the other types of maps and are functional to their preparation (Figure 2).

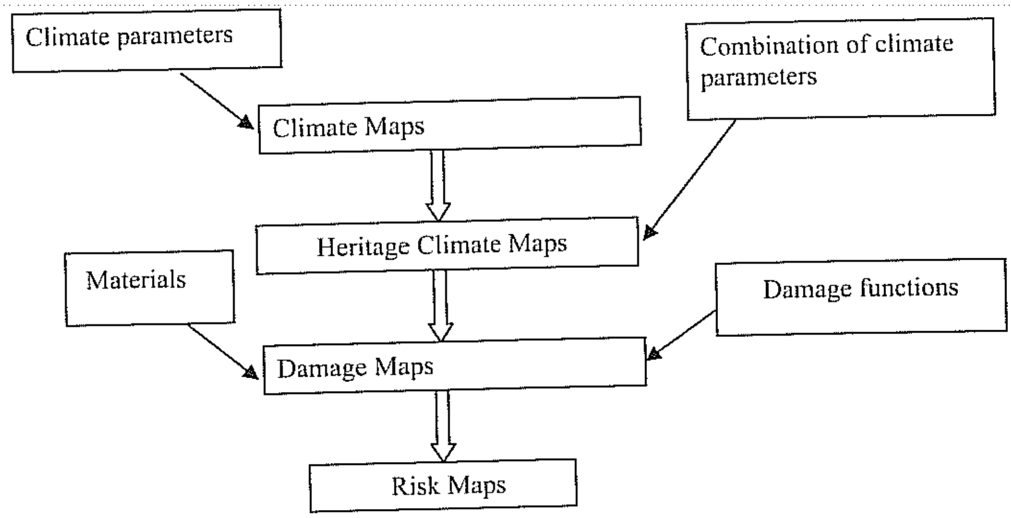

Figure 1: Scheme of the hierarchical maps produced for illustrating climate change future threats to the built heritage

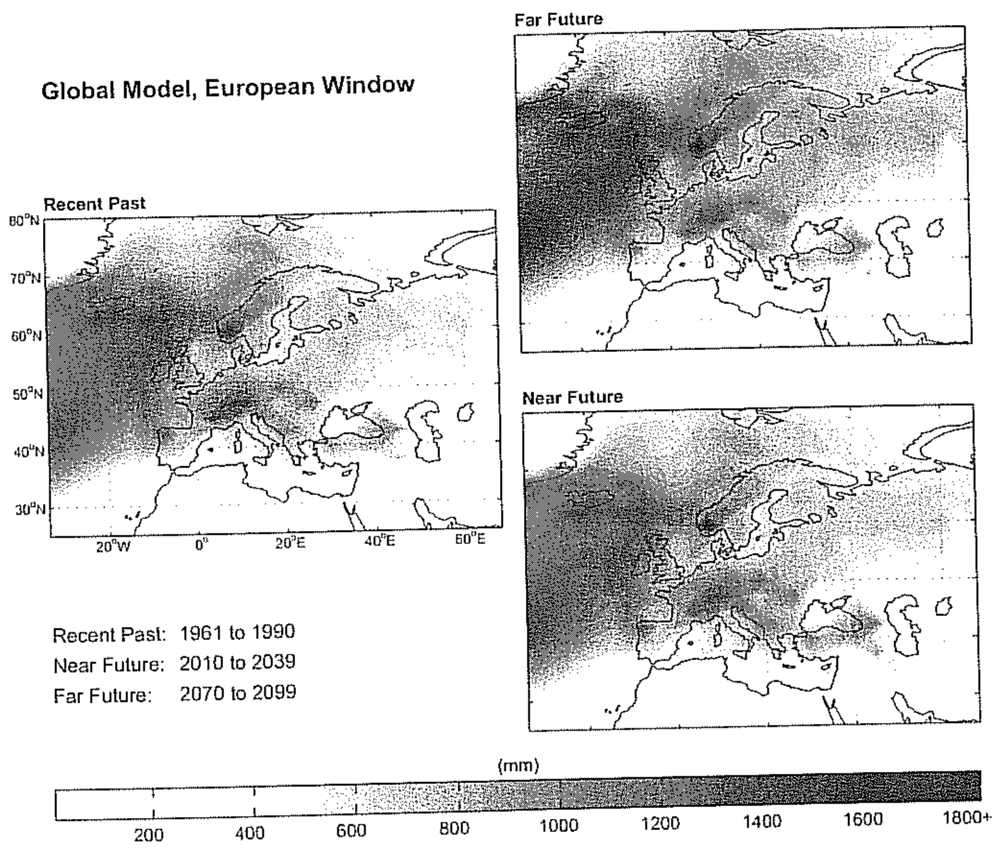

Figure 2: Yearly precipitation projections in Europe for the different periods analysed: recent past, mid future and far future – HADCM3 model

Furthermore climate parameters have been combined to produce specific heritage climatologies, e.g. wet-frost, based on rain followed by intense freezing.

A further step has made use of climate parameters to determine the amount of damage occurring on building materials in future scenarios. The damage maps are based on damage functions, which quantitatively express the damage induced by climate parameters on building materials (e.g. dissolution induced by rain, crack propagation during freezing, salt weathering of porous stones).

Finally risk maps are based on the combination of two or more damage processes that can occur in different regions of Europe. This decay evaluation can then be translated into generalized risk maps that can inform decision makers of the type of risk most prevalent in a particular region.

Mapping provides a strategic tool for a sustainable management of the future threat to cultural heritage and opens up a challenging new area for interdisciplinary research.

4 Conclusion

4.1 European dimension

Few interests of European citizens are of such great importance as the problems associated with global warming or climate change. Climate change can occur over areas of varying extension, outdoor as well as indoor. In terms of practical consequences, global, regional and local climate changes need to be distinguished. There is an urgent need to develop and apply policies, strategies and measures to mitigate the impact of global climate change on cultural heritage at all the three levels. All European states and local administrations, as well as stake holders, need tools for impact mitigation on the relevant level, i.e. global or continental, regional or municipal, and at site or object level. This approach is also justified by the fact that global change effects are frequently intensified due to climate change effects generated at lower levels.

Finally, the increased stresses and shorter maintenance periods will generate an increased cost linked to climate changes, in the form of financial support for the restoration and conservation of the built cultural heritage. The project methodology and results predicting future scenarios regarding the protection of cultural heritage will be also useful to the construction sector: building managers in general will need to understand the probable impacts of climate change on their building stock.

4.2 Innovation and originality

The results achieved within the Noah's Ark Project will lead to:

- the determination of the meteorological parameters and changes most critical to the built cultural heritage;
- research aimed at predicting and describing the effects of climate change on Europe's built cultural heritage over the next 100 years;
- the constitution of a scientific basis for the development of mitigation and adaptation strategies for historic buildings, sites, monuments and materials that are likely to be worst affected by climate change effects and associated disasters;
- the development of electronic information sources and tools, including Climate Risk Maps and a Vulnerability Atlas, aiding heritage managers to assess the threats of climate change, in order to visualize the built heritage and cultural landscape under future climate scenarios and model the effects of different adaptation strategies;
- advice for policy-makers and legislators.

4.3 Impacts

The Noah's Ark project has contributed to closing the gaps existing in current EU policy on air quality and impact assessment, with particular reference to "Ambient and air quality assessment and management (Council Directive/EC), the EC CAFE Directive (Clean Air For Europe) and the Environmental Impact Assessment (EIA Directive/EC), favouring the inclusion of Cultural Heritage.

In Climate Change Reports, such as the European Topic Centre Air and Climate Change (ETC-ACC) Report for the European Environment Agency (EEA), and in the Intergovernmental Panel on Climate Change Report (2001 and 3rd Assessment Report), cultural heritage is not mentioned among the expected future impacts and vulnerabilities. Within this context the EC funded Project Noah's Ark has a pioneering added value.

An additional impact of this research will be its usefulness to the European Insurance Industry. This value is recognised by the industry through the participation as a partner in the project of the Ecclesiastical Insurance Group, specialized in the insurance of historic buildings, particularly churches. Their data show an upward trend in the cost of environmental impacts on buildings, from annual claims worth approximately 750 million Euros in the early 1990's, to close to 1.5 billion Euros for their annual average over the recent three-year period from 1999-2001. The exceptional flooding in the UK during 2000 resulted in insured losses more than 2.2 billion Euros. An improved understanding of the likely effects of climate change will enable a better business management. The research to test and improve drying-out scenarios for flooded buildings will lead to a more efficient drying out of buildings, and in the long run, lower costs, as damage to the historic fabric caused by inappropriate drying out strategies will be avoided. The research will also enable the time required for the drying-out of individual buildings to be more accurately estimated and planned, leading to better management of this process and its costs.

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6 European Project Details

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