Il contributo del CNR allo studio del Comune di Venezia e Università Iuav di Venezia sugli effetti dei cambiamenti climatici sul patrimonio culturale veneziano

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Consiglio Nazionale delle Ricerche

Università di Bologna

Patrimonio Culturale a rischio – Cambiamenti climatici

European Commission, Directorate-General for Education, Youth, Sport and Culture, *Strengthening cultural heritage resilience for climate change: where the European Green Deal meets cultural heritage*, 2022

LACUNE ED OSTACOLI

There is a lack of:

- awareness of cultural heritage in the context of climate change in policymaking and integration of cultural heritage into mainstream climate change policies at EU and Member State levels;
- knowledge about the scale and dimensions of climate change damage and loss of cultural heritage;
- a coherent methodology for obtaining reliable information, quantitative data (e.g. showing how many sites are under immediate and long-term threats) and deep knowledge about rates and forms of decay affecting indoor, outdoor and underwater tangible heritage, loss of intangible heritage and future climate prospects at local level;
- incentives / tax reductions / support specifically for cultural heritage to adapt to or mitigate the effects of climate change at EU and national levels;
- resources (financial and human) at all levels of cultural heritage bodies to research, develop policies and implement actions to protect cultural heritage;
- quantitative data on the costs and economics of adaptation/mitigation measures for cultural heritage in times of climate change at national and EU levels;
- a website or platform at European level to provide information on the state of the art and progress;
- an inventory and central entry point covering damage to / loss of / risk to cultural heritage as a result of climate change at national and EU levels (a heritage climate change risk map);
- a permanent task force or forum for discussion and mutual exchange;

POLITICHE CLIMATICHE

DIMENSIONE DEL DANNO

METODOLOGIA COERENTE DATI QUANTITATIVI

MAPPATURA DEI RISCHI

10 RACCOMANDAZIONI PER STATI MEMBRI UE

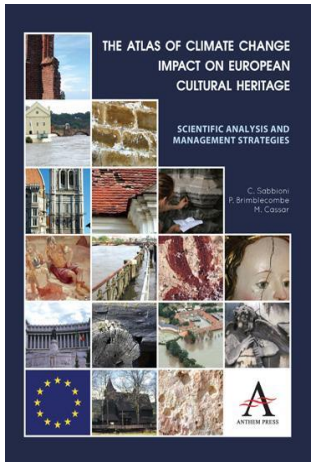
Table 1. Overview of national policies that mention cultural heritage

Country code	Country	National sustainability strategy	National climate adaptation plan	National recovery and resilience plan
AT	Austria	Yes	Yes	Yes
BE	Belgium	No	No	Yes
CH	Switzerland	No	No	No
CY	Cyprus	Yes	Yes	No
CZ	Czechia	Yes	Yes	Yes
DE	Germany	Yes	No	No
EE	Estonia	No	Yes	No
EL	Greece	Yes	Yes	Yes
ES	Spain	Yes	Yes	Yes
FI	Finland	No (4)	Yes	No
FR	France	No	No	No
HR	Croatia	Yes	Yes	Yes
IE	Ireland	Yes	Yes	No
IS	Iceland	No	No	No
IT	Italy	Yes	Yes	Yes
LT	Lithuania	No	Yes	Yes
LV	Latvia	Yes	Yes	Yes
MT	Malta	No	No	No
NL	Netherlands	Yes	No	Yes
NO	Norway	Yes	Yes	Yes
PL	Poland	No	Yes	Yes
PT	Portugal	Yes	Yes	Yes
RO	Romania	Yes	Yes	Yes
SE	Sweden	No (5)	Yes	Yes
SI	Slovenia	Yes	Yes	Yes
SK	Slovakia	Yes	Yes	Yes

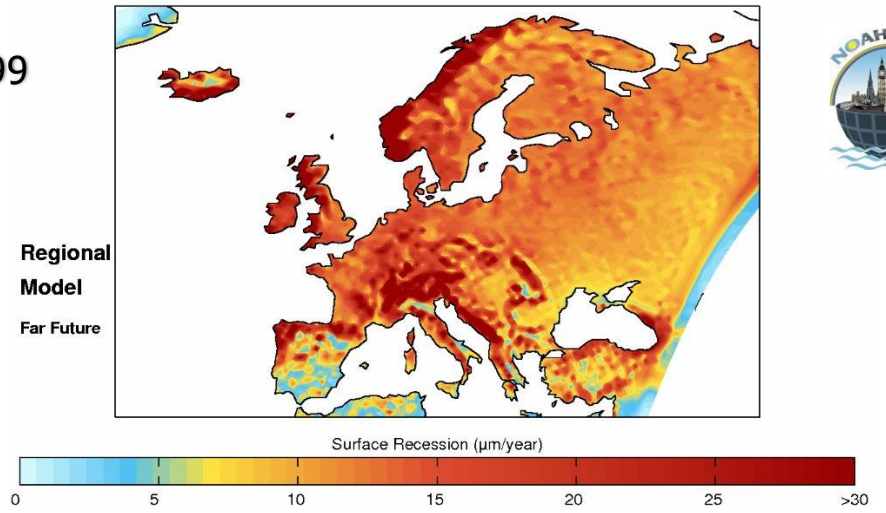
ITALIA FRA I PAESI CHE INCLUDONO PATRIMONIO CULTURALE NEI PIANI DI ADATTAMENTO AL CAMBIAMENTO CLIMATICO

Patrimonio Culturale a rischio – Cambiamenti climatici

Danno da variazioni graduali (clima – inquinamento)



2070-2099



Eventi climatici estremi
Piogge intense, Inondazioni, Siccità

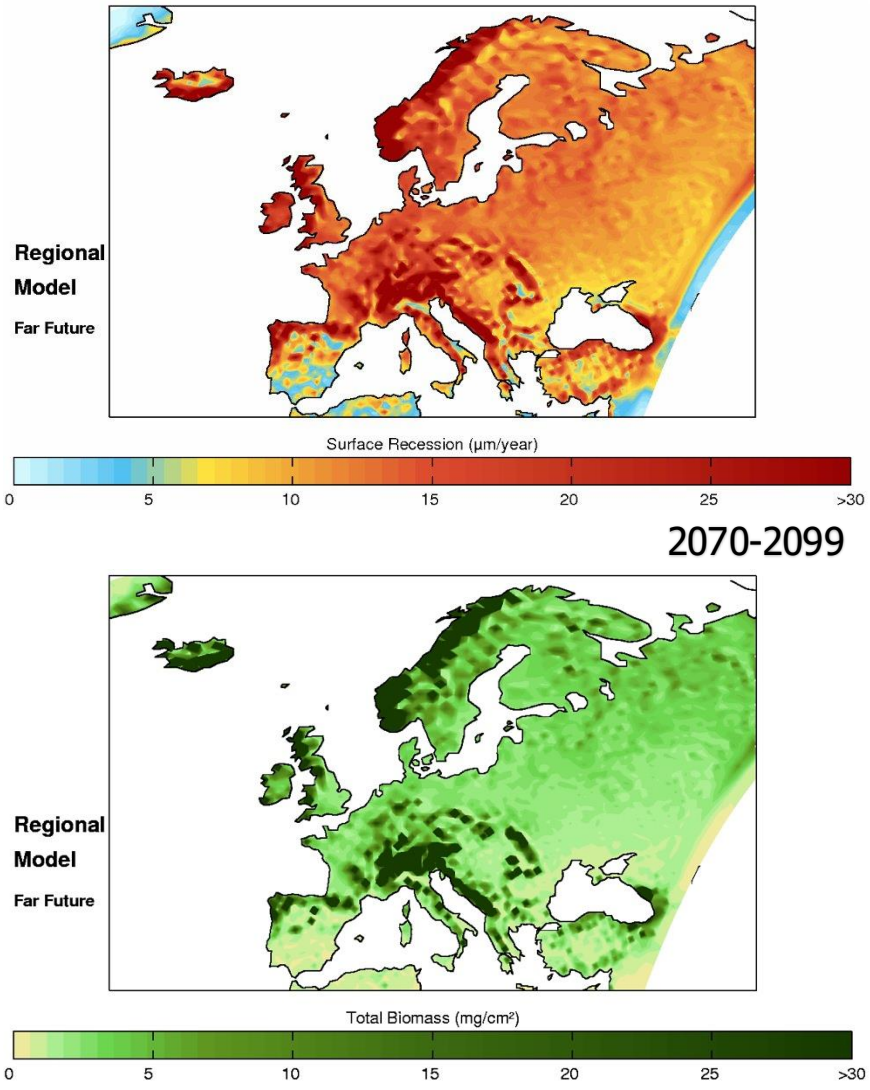
Emilia Romagna, alluvione 2023

Climatologia culturale

Variazioni graduali e continuative: funzioni di danno

Damage Process	Damage function/Risk expression	Valid for	Climate/ Pollution parameters
Surface recession	▪ Lipfert (1989); Bonazza et al; (2009) $L = 18.8 \cdot R + 0.016 \cdot [H^+] \cdot R + 0.18 \cdot (V_{dS} \cdot [SO_2] + V_{dN} \cdot [HNO_3])$ L=surface recession per year (μm·year⁻¹); 18.8=intercept term based on the solubility of $CaCO_3$ in equilibrium with 330 ppm CO_2 (μm·m⁻¹); R=precipitation (m·year⁻¹); 0.016=constant valid for precipitation pH in the range 3–5; $[H^+]$=hydrogen ion concentration (μmol·l⁻¹) evaluated from rain yearly pH; 0.18=conversion factor from (cm·s⁻¹) (μg·m⁻³) to μm; V_{dS}=deposition velocity of SO_2 (cm·s⁻¹); $[SO_2]$=SO_2 concentration (μg·m⁻³); V_{dN}=deposition velocity of HNO_3 (cm·s⁻¹) and $[HNO_3]$=HNO_3 concentration (μg·m⁻³). ▪ Kucera et al. (2007) $R = 3.95 + 0.0059 \cdot [SO_2] \cdot RH_{60} + 0.054 \text{Rain} \cdot [H^+] + 0.078 \cdot [HNO_3] \cdot RH_{60} + 0.0258 \cdot PM_{10}$ R = surface recession per year (μm·year⁻¹), $[SO_2]$ = SO_2 concentration (μm·m⁻³), RH_{60} = is the measured relative humidity when RH=60% otherwise 0, Rain = amount of rainfall (mm) and $[H^+]$ = H^+ concentration (0.0006–0.13 mg·l⁻¹), [HNO3] = HNO_3 concentration (μm·m⁻³), PM_{10} = particulate matter concentration (μg·m⁻³).	Marble and limestone with porosity lower than 25%	• Rain amount • Rain pH • Temperature • Relative humidity • Sulphur dioxide (SO_2) • Nitric acid (HNO_3) • Carbon dioxide (CO_2) • Particulate matter (PM)
Soiling/ Blackening	▪ Kucera (2005) $R = R_0 \cdot \exp(-k_s \cdot PM_{10} \cdot t)$ R = reflectance after time t; t = time; R0 = initial value of reflectance; k_s = rate constant for blackening and PM10 = particulate matter concentration = 10 (μg·m⁻³). ▪ Brimblecombe and Grossi (2009) $-dR/dt = (R_0 - R_p)\, Vd_{EC} \cdot EC/\tau$ dR=rate of change in reflectance of the material (clean stone); t=time; R_0=reflectivity of the clean stone; R_p=final reflectance of the crust; Vd_{EC}=deposition velocity of elemental carbon; EC=elemental carbon concentration (μg·m⁻³); τ=folding density (surface concentration of elemental carbon required to reduce the reflectivity by a factor e). ▪ Brimblecombe and Grossi (2009) $R_t = (R_o - R_c) \cdot \exp(-k_s t) + Rc$ R_t=rate of reduction in reflectance; R_0= initial reflectance of the clean stone; R_C=reflectance of the deposited material; t=time; k_s=soiling constant.	Carbonate stones in general (sedimentary and metamorphic), mortars	• Rain amount • Temperature • Relative Humidity • Sulphur dioxide (SO_2) • Particulate matter (PM) • Carbon fractions of particulate matter (PM): elemental carbon (EC) and organic carbon (OC)
Biodeterioration Biomass accumulation	▪ Gòmez-Bolea et al. (2012) $B = \exp(-0.964 + 0.003P - 0.01T)$ B=Biomass accumulation (mg·cm²); P=annual precipitation (mm); T=annual mean temperature (°C).	Siliceous stones	• Rain amount • Temperature
Thermoclastism	▪ Bonazza et al., (2009) $\sigma_T = E \cdot \alpha \cdot (\text{daily}\Delta T_{air} + 20°C)/(1 - \nu)$ σ_T=Maximum thermal stress (MPa); E = Young's modulus (GPa); α=Thermal expansion coefficient (K^{-1}); ΔT_{air}=T_{airmax}-T_{airmin} (°C); ν=Poisson's ratio.	Marble	• Surface Temperature • Temperature
Salt crystallization	▪ Evaluation based on cycles per year/season of temperature and relative humidity (Sabbioni et al, 2010; Grossi et al., 2011; Menendez 2018)	Porous stones in general	• Relative Humidity • Temperature

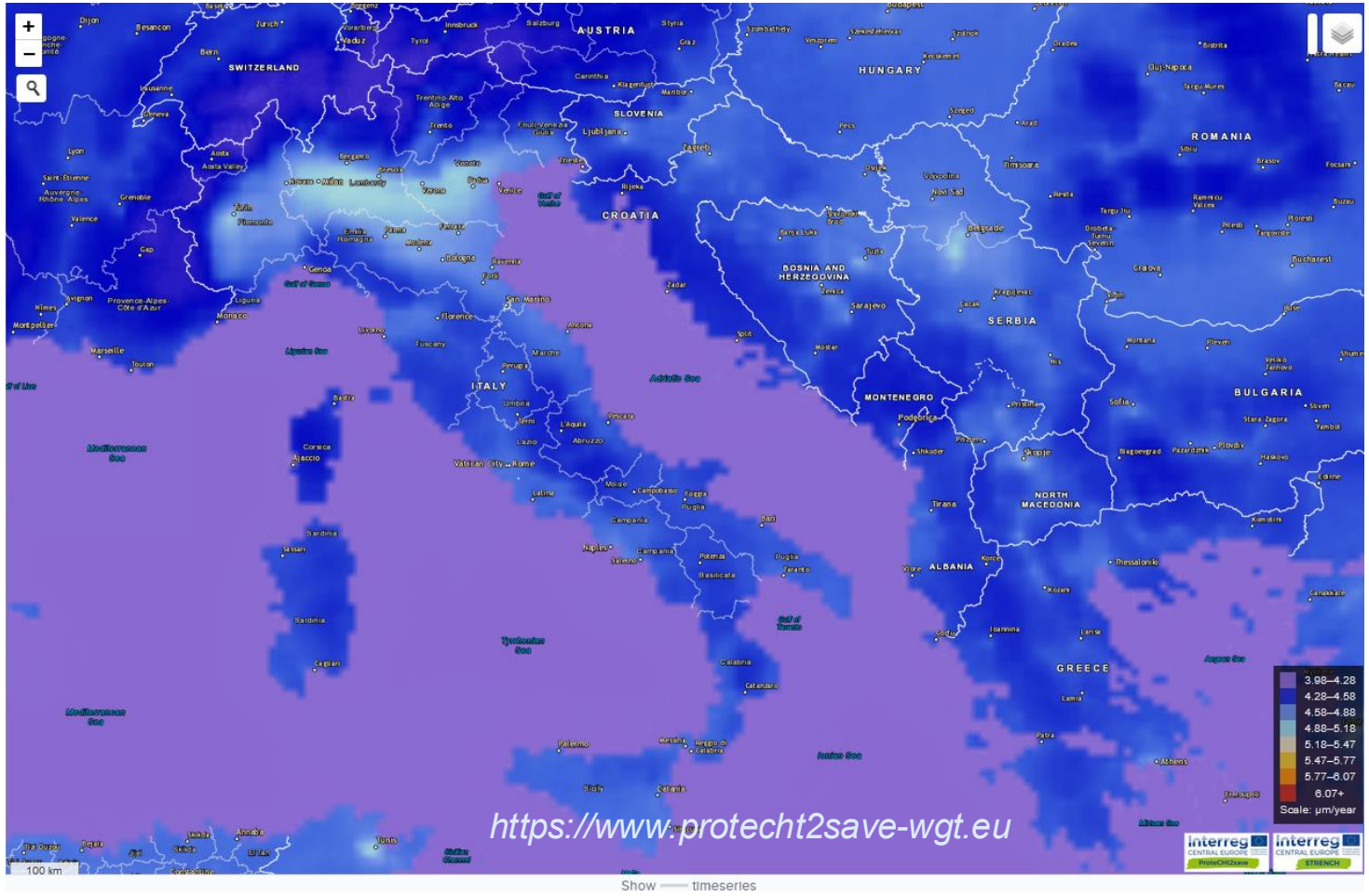
Bonazza & Sardella, *Heritage*, 2023



Patrimonio Culturale a rischio – Inquinamento

Recessione superficiale

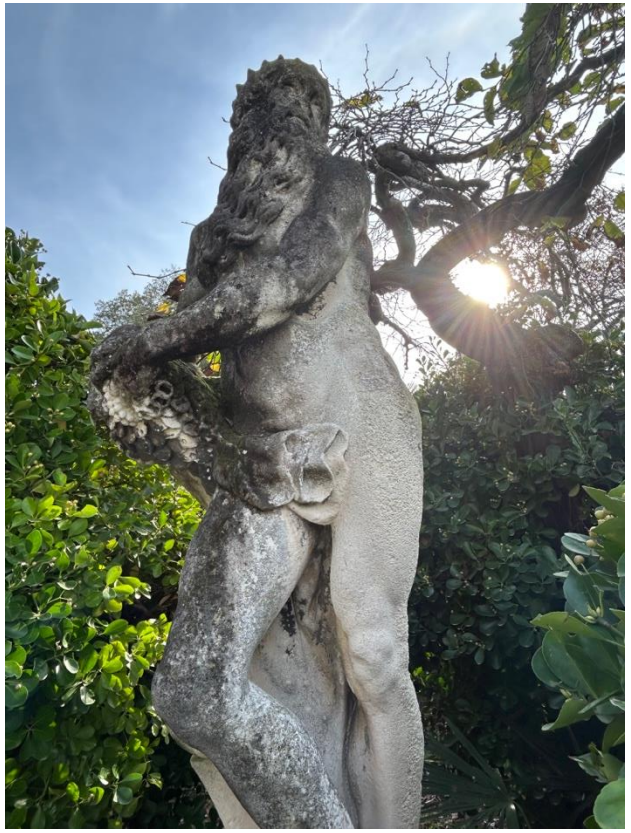
$R = 3{,}95 + 0{,}0059[SO_2]RH60 + 0{,}078[HNO_3]RH60 + 0{,}0258PM_{10}$

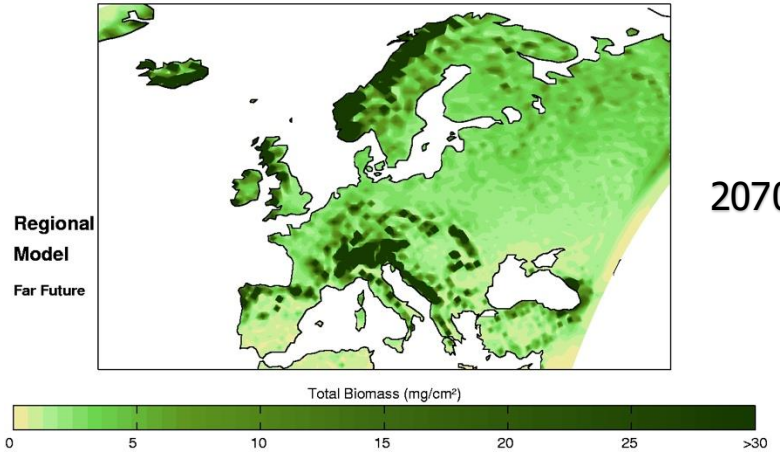


Mappa recessione superficiale (2021) – Dati IMERG, CAMS e ERA5Land

Impatti causati dalle variazioni graduali: Patrimonio costruito Venezia

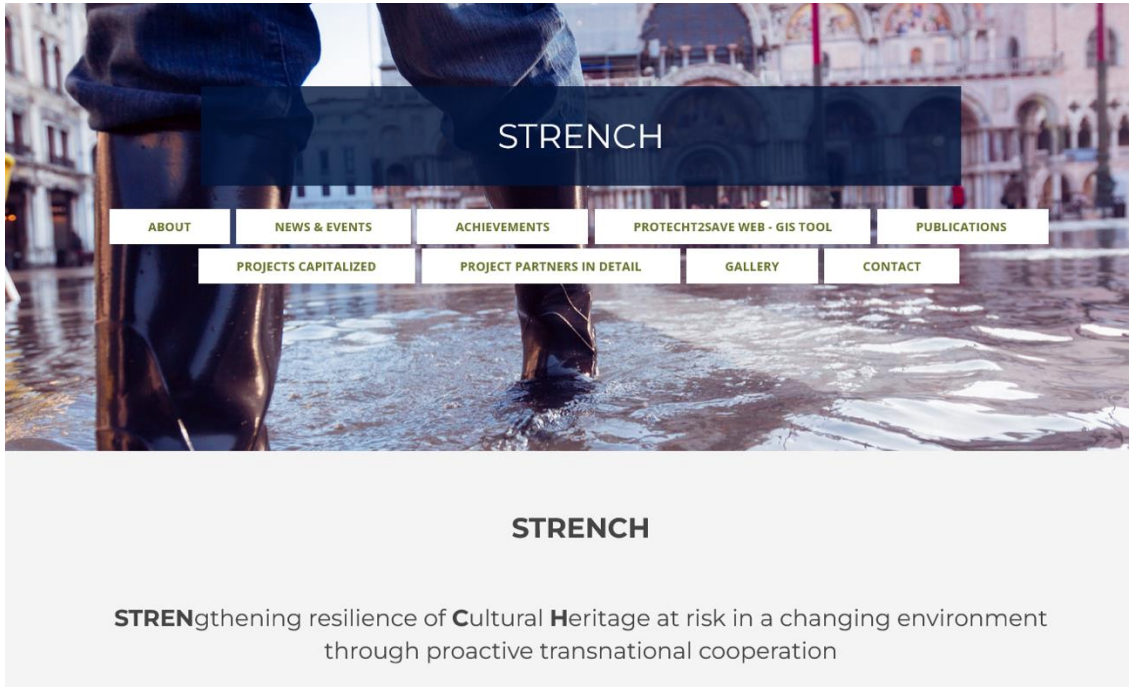
Processo di danno/Impatto	Materiali	Condizioni esposizione	Proiezioni 2070-2099
Recessione superficiale Formazione strati di degrado superficiali	Marmo e calcare compatto	Diretto dilavamento UR elevata NO_x, SO_2,PM elevata	Max 15-20 µm/anno
Termoclastismo (decoesione, disgregazione)	Marmo	Diretta esposizione a radiazione solare	>250-300 eventi di tensione interna del materiale superiori a 20 MPa.
Biodegrado	Rocce, mattoni, malte, intonaci	Aumento della T media, variazioni stagionali precipitazioni e concentrazioni inquinanti	Modifiche nei processi di accumulo di biomassa, tipologie specie biologiche
Cristallizzazione/dissoluzione sali (decoesione, disgregazione)	Materiali porosi (malte, arenarie, mattoni)	--------	> 30-35 cicli anno di UR intorno 75,5%





2070-2099

Interreg CE Projects ProteCHt2save and STRENCH: Ricerca scientifica vs necessità degli utenti



https://programme2014-20.interreg-central.eu/Content.Node/STRENCH.html

https://programme2014-20.interreg-central.eu/Content.Node/ProteCHt2save.html

Progetto Interreg CE INACO

Increasing the resilience of heritage sites in river basins

Climate change increases the intensity and frequency of hydrometeorological events, including landslides, flash floods, storms, heat waves or prolonged drought periods. Amongst other negative consequences, this endangers natural and cultural heritage sites close to river basins. The INACO project strengthens the resilience of these by deploying joint adaptation strategies. The partners also design and test new WebGIS-based solutions for heritage sites and tools for them to self-assess their vulnerability. Last but not least, specially trained risk managers are introduced in selected pilot regions.

interreg-central.eu/projects/inaco

COUNTRIES & REGIONS

AUSTRIA	Niederösterreich | Wien
CROATIA	Jadranska Hrvatska
CZECHIA	Praha
GERMANY	Bayern
HUNGARY	Dél-Dunántúl
ITALY	Emilia-Romagna
POLAND	Dolnośląskie
SLOVAKIA	Východné Slovensko

1,99 million €
Project budget

11
Partners

8
Pilots

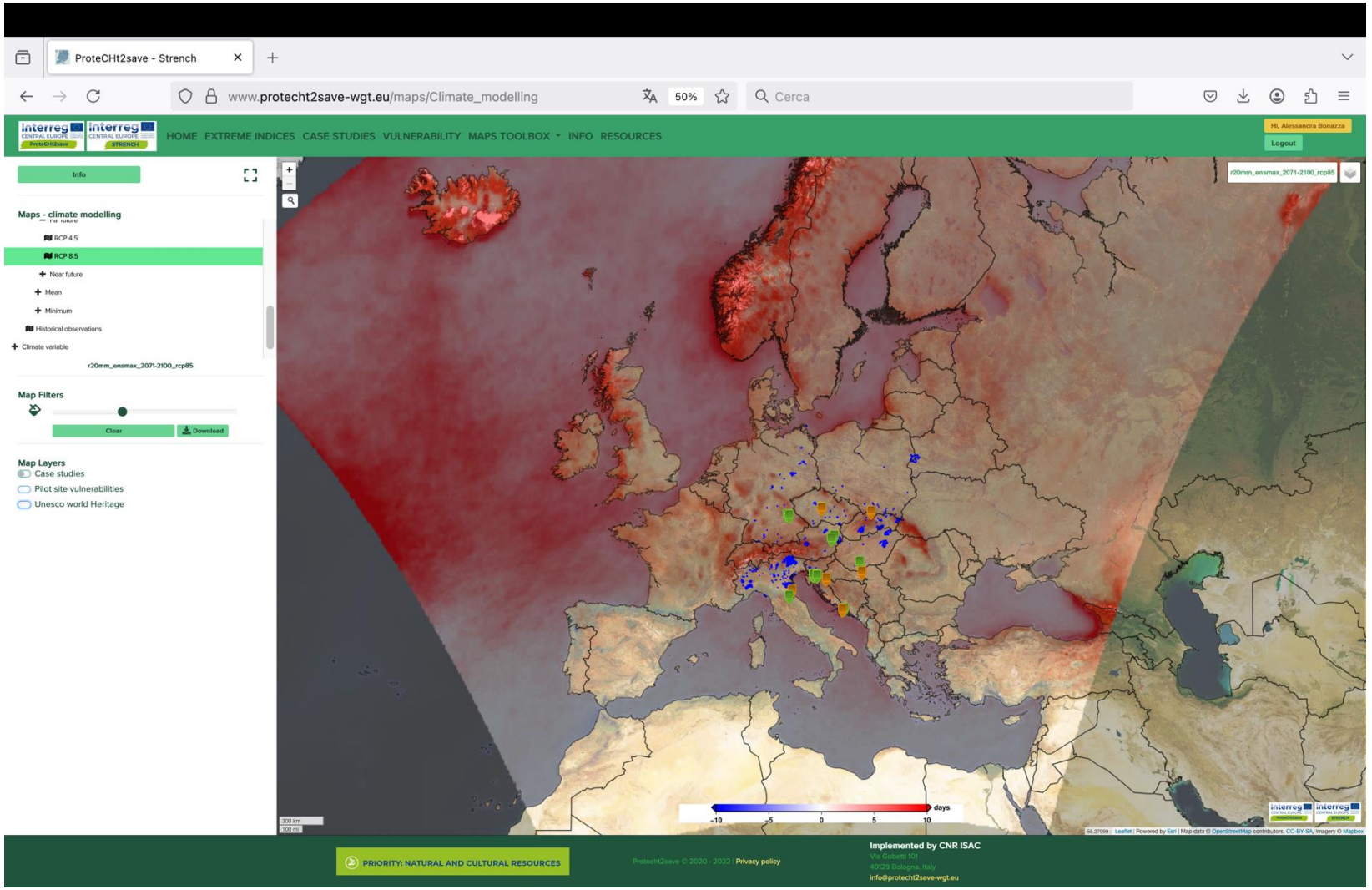
06.2024
Start date

11.2026
End date

80%
ERDF co-financing

Information based on application form | February 2024

Eventi climatici estremi: mappare il rischio



https://www.protecht2save-wgt.eu/

Mappe di pericolosità climatica a scala territoriale

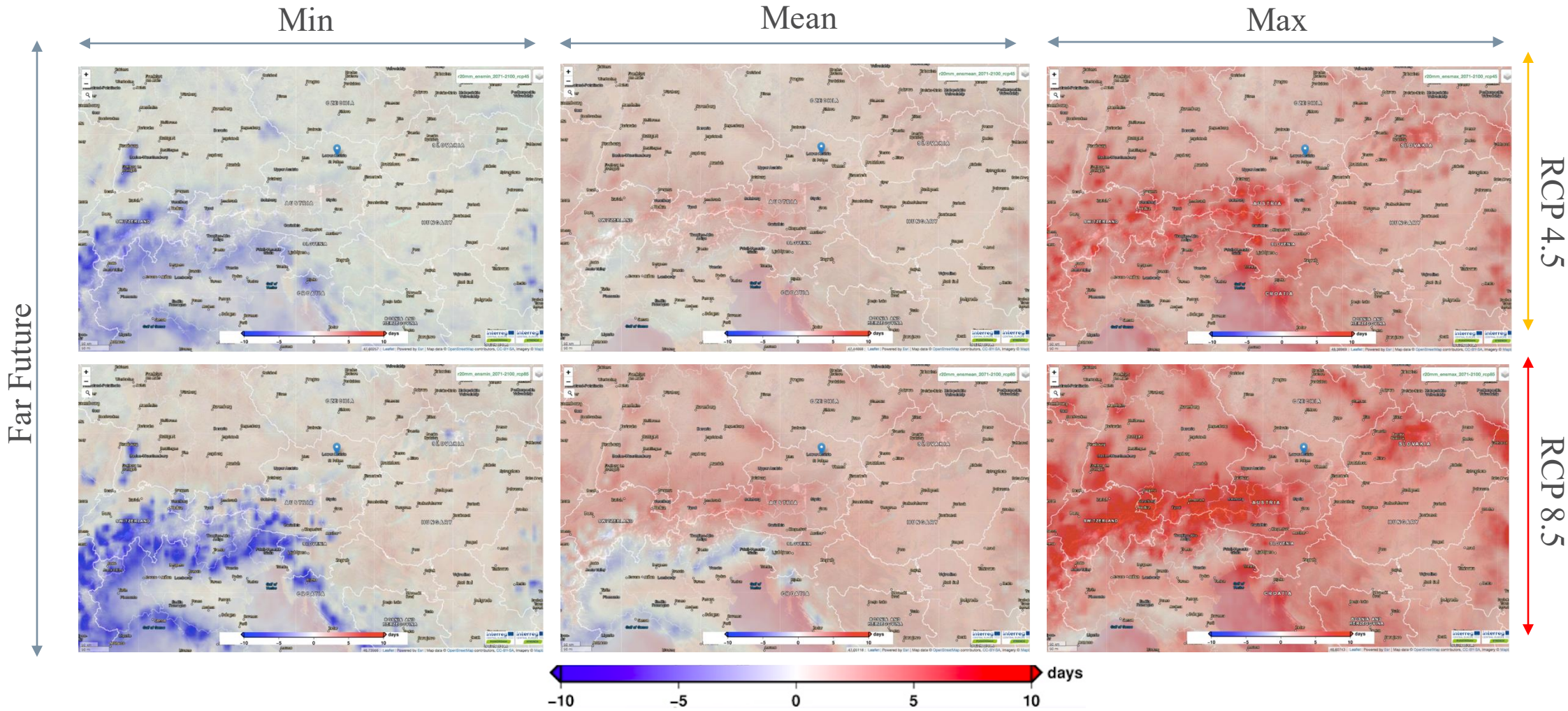
E-OBS dataset
Global and Regional Climate models (EuroCORDEX)
Copernicus ERA5/ERA Land
NASA GPM IMERG
Climate extreme indices (ETCCDI)

INONDAZIONI, PIOGGE INTENSE, SICCITA'

Stima della vulnerabilità a scala locale

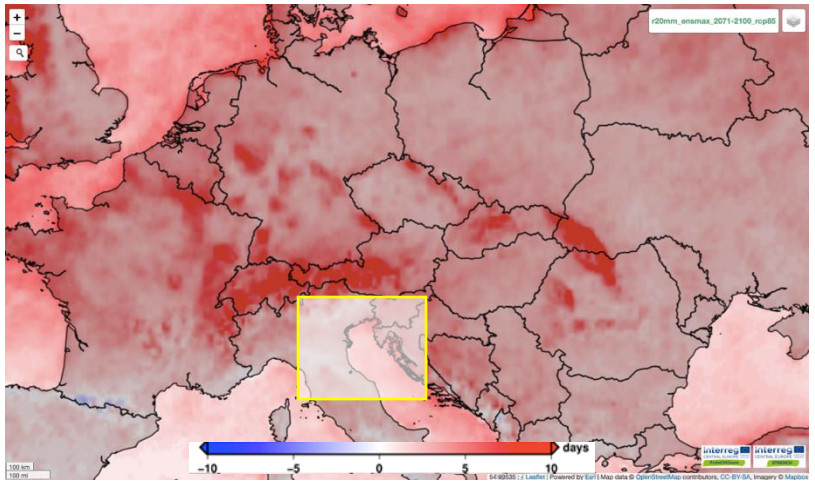
- ✓ Paesaggi urbani
- ✓ Centri storici

MAPPARE IL RISCHIO_ PIOGGE INTENSE

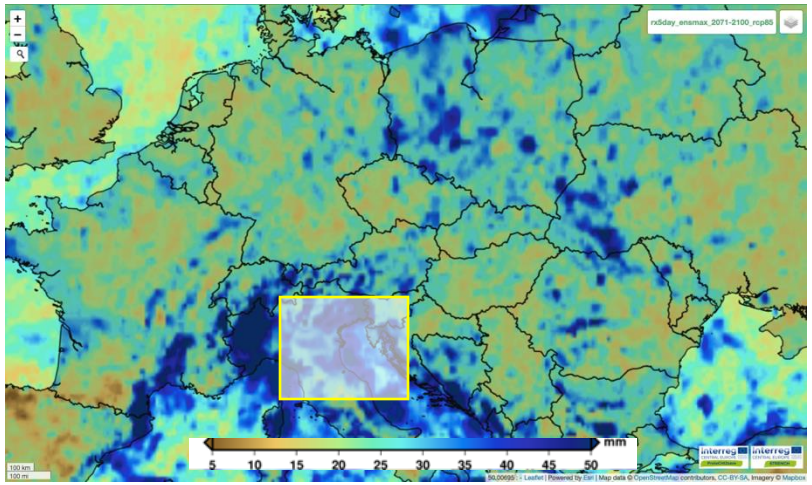


ETCCDI **R20mm**_Numero di giorni in un anno con precipitazioni maggiori o uguali a 20 mm/giorno

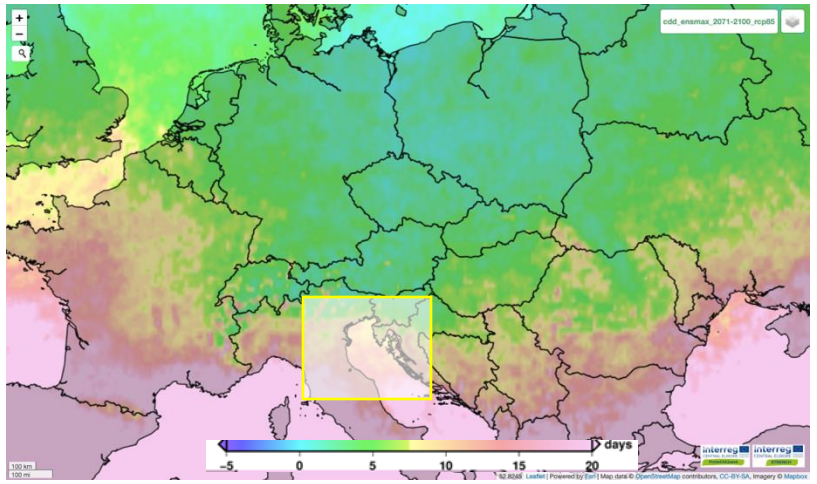
Eventi climatici estremi: mappare la pericolosità



R20mm (very heavy precipitation days)



Rx5day (highest 5-day precipitation amount)



CDD (consecutive dry days)

Projection: Ensemble max, far future (2071-2100), pessimistic scenario (RCP8.5)

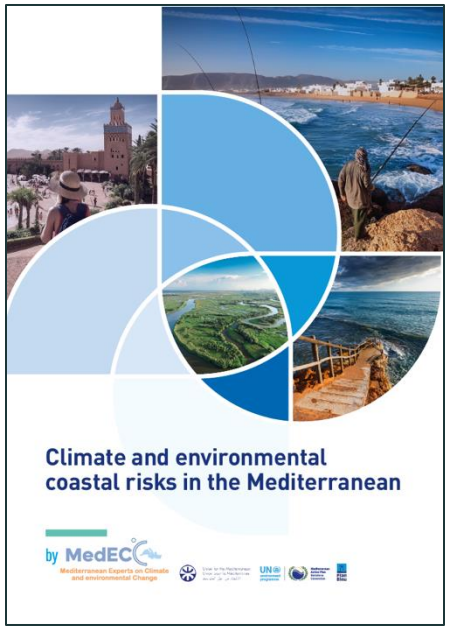
Implicazioni per il Patrimonio Costruito Venezia

Erosione e danni strutturali alle facciate di monumenti ed edifici storici in particolare se esposte a diretto dilavamento. Tale effetto è da ricondursi all'aumento della intensità e frequenza di eventi di piogge intense.

Intensificazione degli effetti del degrado biologico, cristallizzazione/dissoluzione di sali e presenza di umidità nelle murature a causa di allagamenti (interni-esterni).

Basilica San Marco
(Photo Procuratoria di San Marco)

Strategie di mitigazione/adattamento e riduzione del rischio



Strategia Nazionale di Adattamento ai Cambiamenti Climatici (Italia)

Piano Nazionale di Adattamento ai Cambiamenti Climatici (Italia)

Strategia di Adattamento Climatico di Roma Capitale

Action Plan on the Sendai Framework Implementation Priority Key Area 4

MedECC Special Assessment Report Climate and Environmental Coastal Risks in the Mediterranean
MedECC Second Mediterranean Assessment Report

EU funded Projects Climate change – Cultural Heritage

HORIZON EU Project ChemiNova "Novel Technologies for On-Site and Remote Collaborative Enriched Monitoring to Detect Structural and Chemical Damages in Cultural Heritage Assets" https://cheminova.eu

Interreg Central EU INACO "INnovative strategies for the Adoption of risk management plans to enhance the resilience of sensitive Cultural and natural heritage Objectives against climate hazards in river basin districts" https://www.interreg-central.eu/projects/inaco/

H2020-MSCA-RISE-2020 SCORE "Sustainable COnservation and REstoration of built cultural heritage" https://score-project.net/

EC H2020-MSCA-RISE-2019 TECTONIC "TEchnological Consortium TO develop sustaiNabIlity of underwater Cultural Heritage" https://www.tectonicproject.eu/

DG-EAC READY- Resilience for Heritage in the Face of Disasters, Climate Risks and Complex Emergencies

National Projects Climate change – Cultural Heritage

Dipartimento per la Tutela del Patrimonio Culturale, Italian Ministry of Culture - Piano Straordinario Nazionale di Monitoraggio e Conservazione dei Beni Culturali Immobili

PNRR CHANGES SPOKE 7 – PROTECTION AND CONSERVATION OF CULTURAL HERITAGE AGAINST CLIMATE CHANGES, NATURAL AND ANTHROPIC RISKS

PNRR ECOSISTER FOR SUSTAINABLE TRANSITION IN EMILIA-ROMAGNA