Strengthening resilience of urban heritage under climate change

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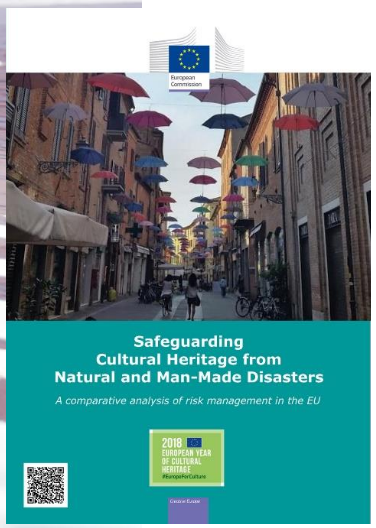

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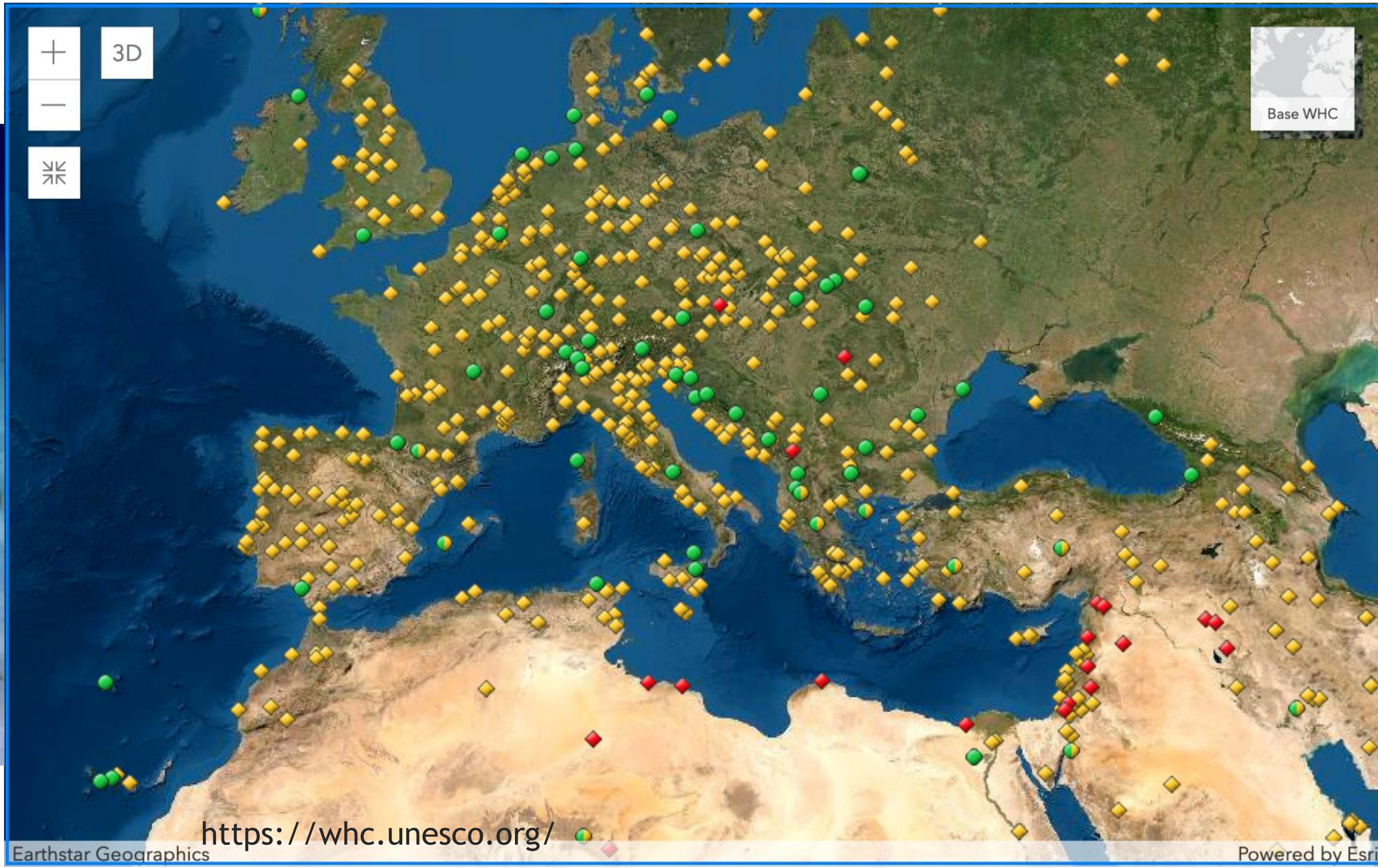
Bonazza et al., *Safeguarding …EU*, 2018

CULTURAL HERITAGE AT RISK
MEDITERRANEAN REGION A CLIMATE CHANGE HOTSPOT

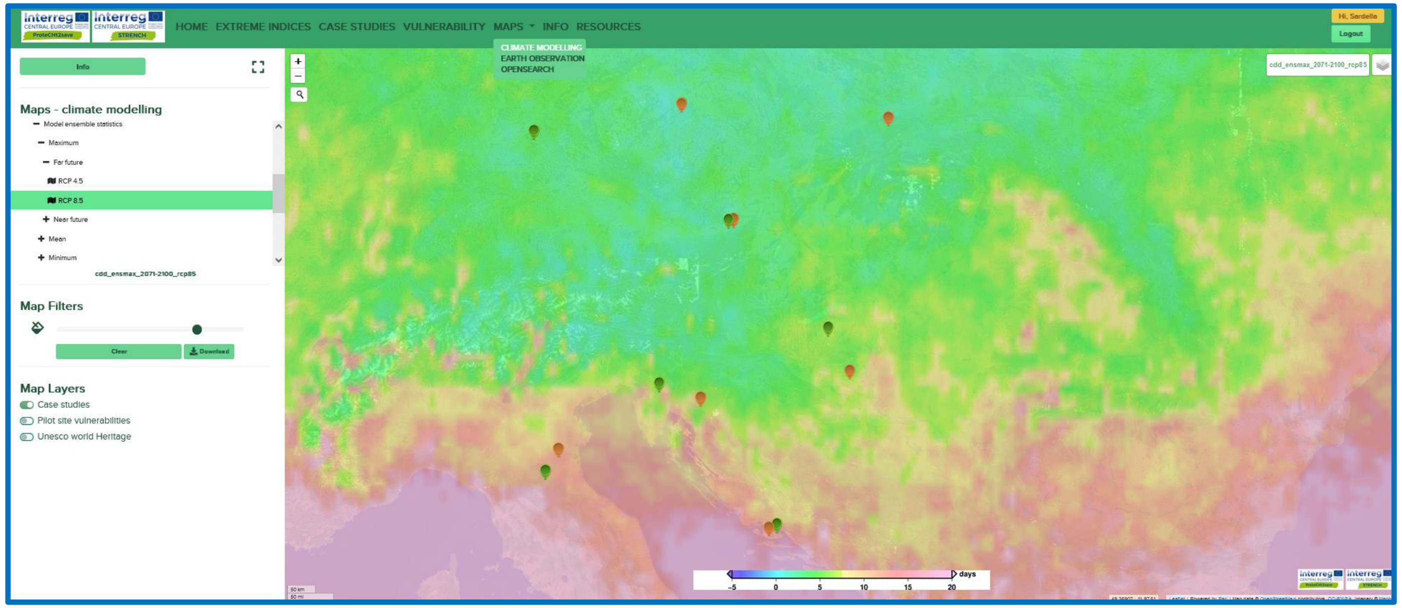
Coastal regions remain crucial as areas of increased exposure to risk and increasing vulnerability towards climate change (high confidence, IPCC AR6 WGII 2022)

https://www.artworksforchange.org



https://whc.unesco.org/

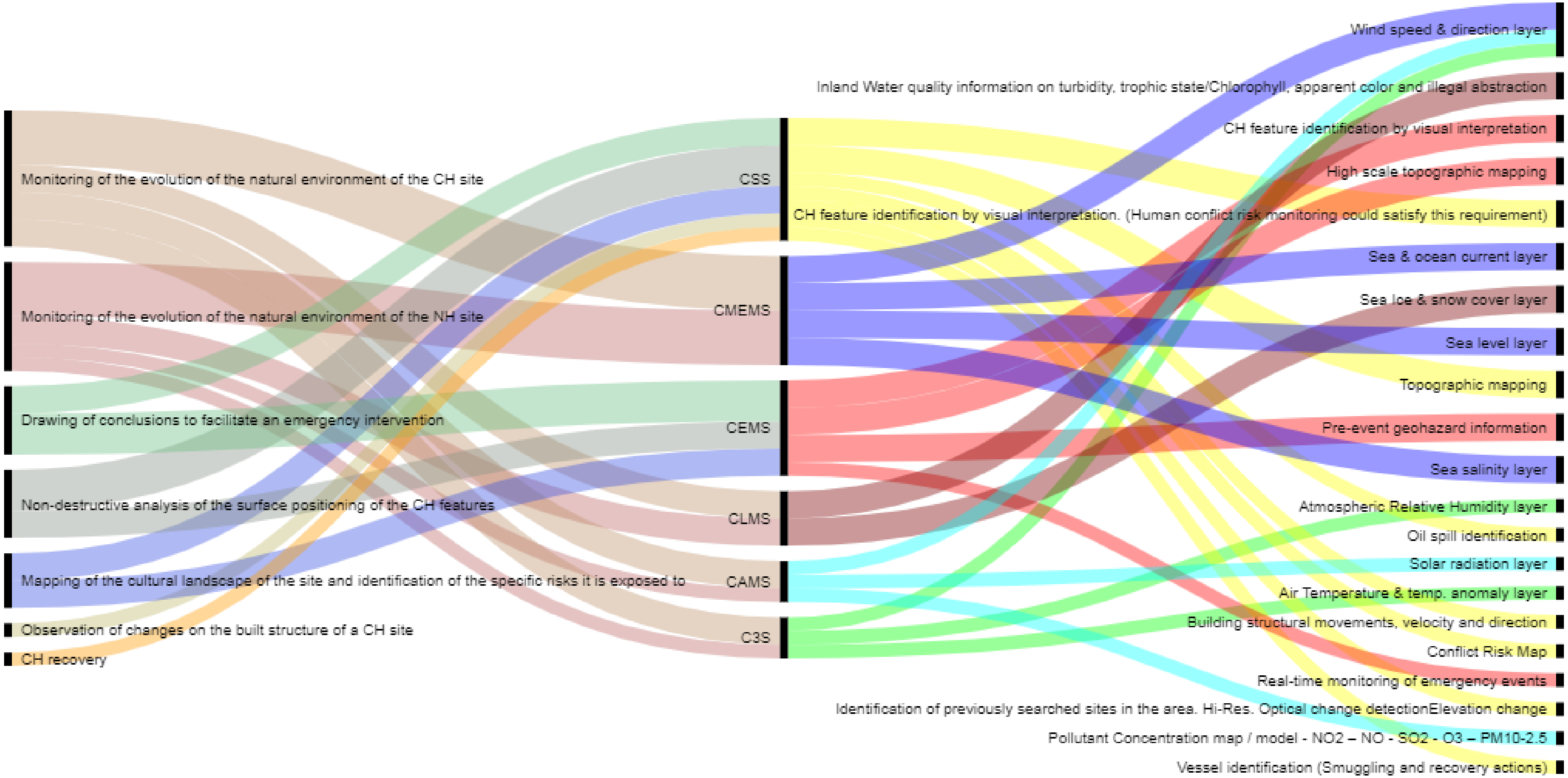
RISK MAPPING TOOL FOR CULTURAL HERITAGE PROTECTION



- ✓ Knowledge: observed/projected impacts
- ✓ Climate models: downscaling
- ✓ Earth Observation: Task Force Copernicus CH
- ✓ Environmental Monitoring (in situ)
- ✓ Vulnerability assessment
- ✓ Hazard Mapping
- ✓ Damage quantification
- ✓ Risk indices

Sardella et al., *Atmosphere, 2020*
Caciotti et al., *Climate Risk Management, 2021*
Bonazza et al., *IJDRR, 2021*

Copernicus CH TF: Matching the requirements with current Copernicus capacity



Link between high level user needs (monitoring domains), Copernicus Core services and user requirements satisfied

Bonazza et al., *Sustainability 2022*

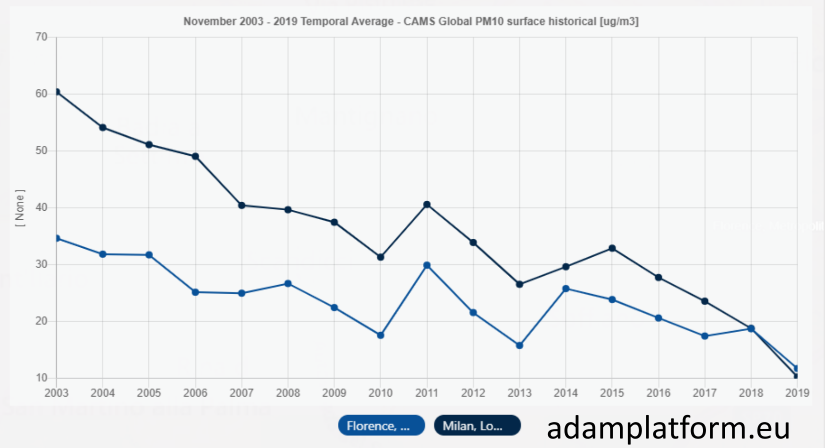
Copernicus CH TF: Gap Analysis
Matching the requirements with CAMS and C3S capacity

Requirement	C3S/CAMS	Spatial resolution	Update frequency	Monitoring domain
Hydrological changes & network changes layer	C3S	10 –30m	Yearly	Monitoring of the evolution of the natural environment of the CH site Monitoring of the evolution of the natural environment of the NH site
Atmospheric Relative Humidity layer	C3S	5-10 km	Daily	Monitoring of the evolution of the natural environment of the CH site Monitoring of the evolution of the natural environment of the NH site
Solar radiation layer	CAMS	10 km	3h – 1d	Monitoring of the evolution of the natural environment of the CH site
Air Temperature & temp. anomaly layer	C3S	10 km	6-12 h	Monitoring of the evolution of the natural environment of the NH site
Wind speed & direction layer	C3S/CAMS	10 km inland	Daily	Monitoring of the evolution of the natural environment of the CH site
Pollutant Concentration map / model - NO2 – NO - SO2 - O3 – PM10-2.5	CAMS	1-5 km 10km	Daily	Monitoring of the evolution of the natural environment of the CH site Monitoring of the evolution of the natural environment of the NH site

Vidorni et al., *EPJ PLus, 2019*
Bonazza et al., *Sustainability 2022*

-Climate/Pollution parameters
-Spatial resolution

Blackening function
$R=R_0 \cdot exp\ (-k_s PM_{10} t))$ [Kucera 2005]

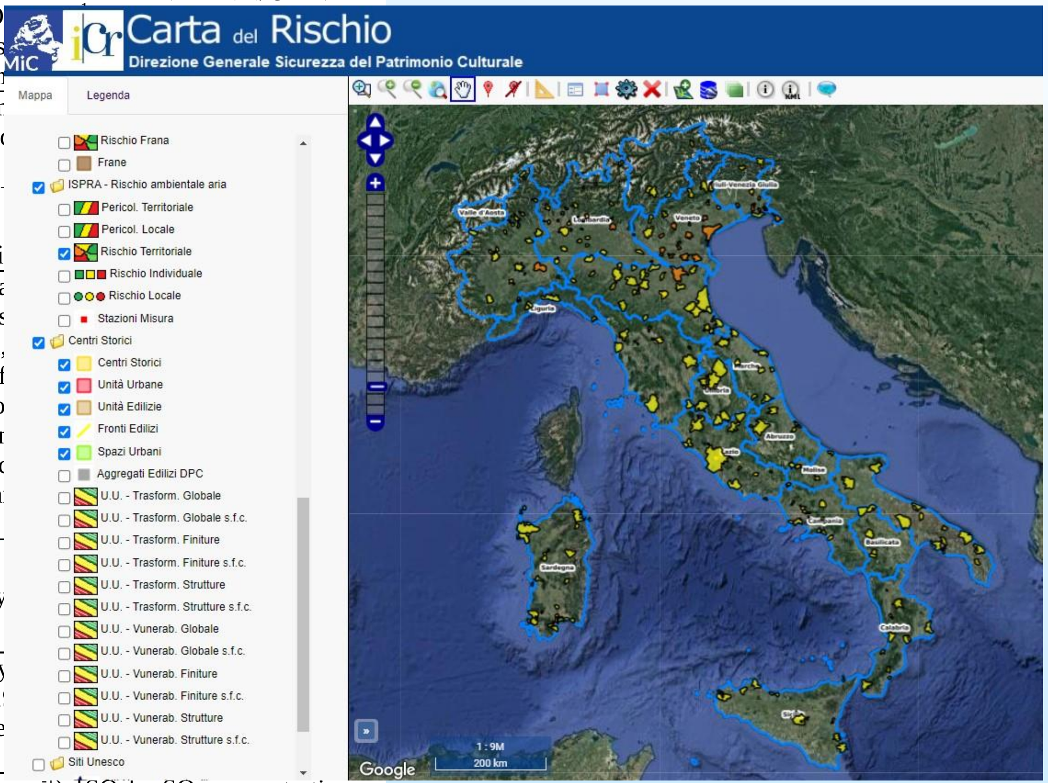


adamplatform.eu

Surface recession: damage functions

Reference	Function	Variables involved
Lipfert (1989)	L= 18.8·R + 0.016·[H^+]·R + 0.18 (V_{dS} [SO_2] + V_{dN} [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 concentration (µg m^{-3}) ; V_{dN} = depos [HNO_3] = HNO_3 concentration (µg m
Livingston (1992)	$\Delta[Ca^{2+}] = \Delta[SO_4^{2-}] + \{10^{-11.6}(1/\gamma_{r0}[H^+]_{r0} + 1/\gamma_0[H^+]_0) - 1/2[H^+]_{r0} - [H^+]_0)\} + \{10^{-11.6}(1/\gamma_0[H^+]_0 + 1/\gamma_r[H^+]_r) - 1/2([H^+]_0 - [H^+]_r)\}$	$\Delta[Ca^{2+}]$ and $\Delta[SO_4^{2-}]$ = differences in Ca^{2+} and SO_4^{2-} between rainwater and hydrogen ion concentration (mol l^{-1}) anthropogenic pollutants ($10^{-5.6}$) ; [H concentration (mol l^{-1}) of rain; [H^+]$_{ro}$ l^{-1}) of the runoff; γ = activity coeffici
Webb et al. (1992)	Stone loss (moles) = $ADV_{dS}C_{SO2}$ + ($K_HK_1P_{CO2}/2[H^+]_r$) $3\Sigma(A_iR\text{-}E_{vap})$ + ($[H^+]_i/2$) $3\Sigma(A_iR)$	C_{SO2} (µm m^{-3}) = mean SO_2 concentra (D), V_{dS} = deposition velocity (cm s stone, A_i = rainfall interception area, mean hydrogen ion concentrations of respectively, E_{vap} (mm^3) = volume o sample, K_H and K_1 = equilibrium co in equilibrium with atmospheric conc constant and first dissociation consta rainfall (mm).
Baedecker (1992)	Stone loss (mmoles/l) =0.16[1.0-0.015T+0.0000922T^2]/0.683+0.49[H^+]	T = temperature (°C) and [H^+] = hy
Tidblad et al. (1998); Tidblad et al. (2001)	R = 2.7[SO_2]$^{0.48}$exp{f_{Pl}(T)}$t^{0.96}$ + 0.019Rain[H^+]$t^{0.96}$ f_{Pl}(T)=-0.018T	R = surface recession per year (µm y (1-83 µm m^{-3}), T = temperature (2-1 (327-2144 mm) and [H^+] = H^+ conce time (1-8 years).
Kucera et al. (2007)	R = 3.95 + 0.0059[SO_2]RH_{60} + 0.054Rain[H^+] + 0.078[HNO_3]RH_{60} + 0.0258PM_{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}), [HNO_3] = HNO_3 concentration (µm m^{-3}), PM_{10} = particulate matter concentration (µg m^{-3}).

Bonazza et al., STOTEN, 2009



Carta Rischio - Italy

Courtesy of Raffaela Gaddi, ISPRA

RISK MAPPING TOOL FOR CH: CLIMATE EXTREME EVENTS

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Regional scale

Hazard mapping

Impact linked to hydrometeorological extreme events

- Climate extreme indices (ETCCDI)
  - *Precipitation (Rx5day, R20mm, ..)*
  - *Temperature (Tx99p, TR, ...)*
- Climate modelling
  - *E-OBS dataset*
  - *Global and Regional climate models (GCM/RCM)*
    - *Single Model / Model ensemble statistics*
- Climate reanalysis by earth observation datasets
  - *Copernicus ERA5 / ERA Land*
  - *NASA GPM IMERG*
- Climate Maps
  - Past 1986-2015 (E-OBS) - *25Km*
  - Near future (2021-2050) - *RCPs 4.5/8.5 - 12Km*
  - Far future (2071-2100) - *RCPs 4.5/8.5 - 12Km*
  - Past 1950 - 2021 (ERA5) - *25Km*
  - Past 1981 - 2021 (ERA Land) - *10Km*
  - Past 2000-2021 (IMERG) - *10Km*
- Historic changes and future scenarios at European level

Hazard prone areas

Building scale

Vulnerability assessment

- **Criticalities**
  Managerial & Physical
- **Vulnerability**
  Susceptibility + Exposure - Resilience

Local scale

Preparedness strategies

Implementation/Integration

Pilot Sites (local/building)

Territorial level

Increase resilience of cultural heritage

- *Cultural landscapes*
- *Archaeological sites*
- *Small ruined villages*
- *Monumental complexes*
- *Historic buildings*

Mitigation and preparedness enhance effective responses to calamitous events

- *Flood of large basin*
- *Flash flood*
- *Heavy rain*
- *Wind storm*
- *Landslides*
- *Drought periods*

Sendai Priorities
1. Understanding disaster risk
2. Strengthening disaster risk governance
3. Investing in disaster risk reduction for resilience
4. Enhancing disaster preparedness

Actions
1. Raise awareness
2. Establishment of priorities
3. Promote collaboration
4. Downscale future hazard scenarios
5. Asses vulnerability
6. Link the cause to the effect
7. Monitor the impacts
8. Training

Bonazza et al., *IJDRS, 2021*

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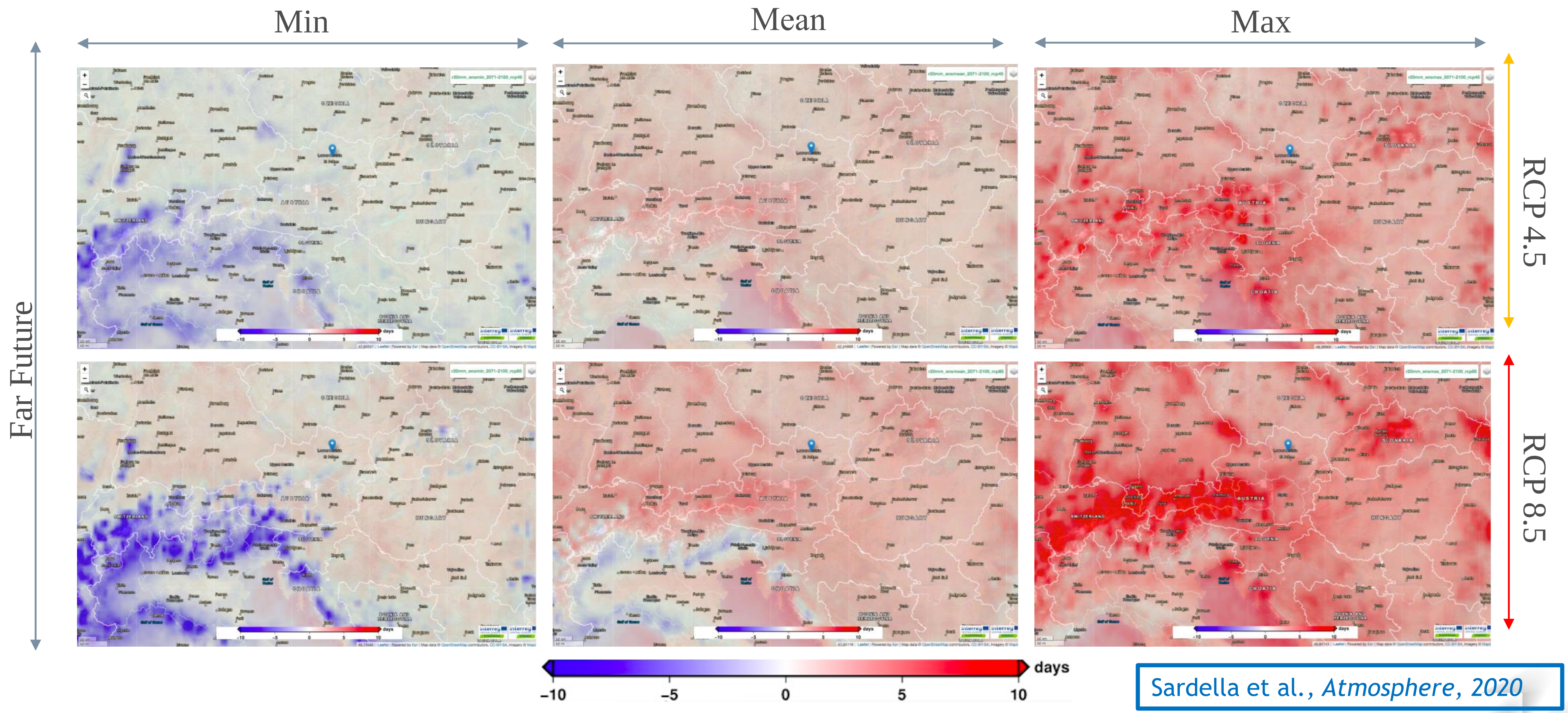
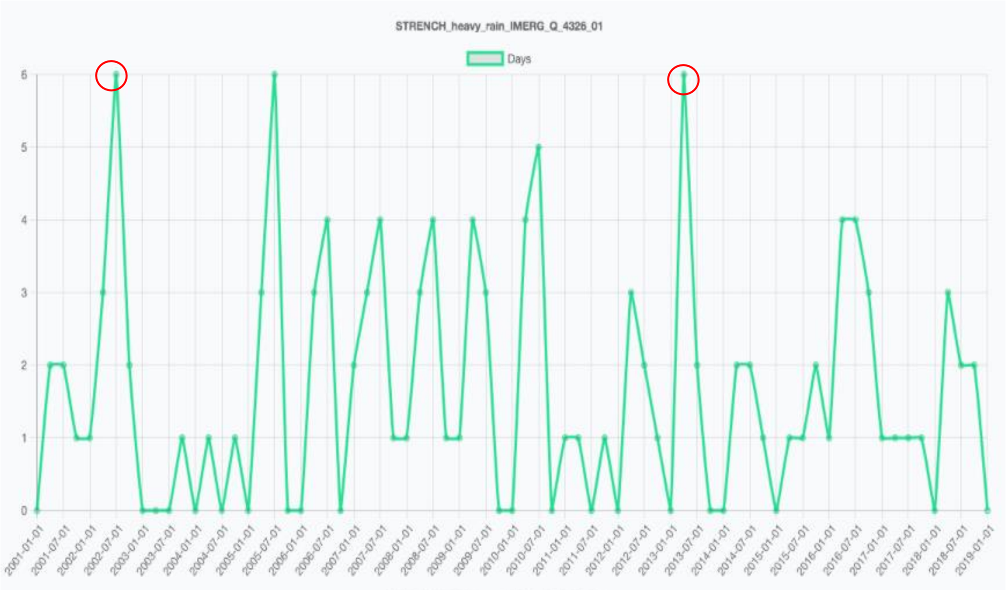
MAPPING THE RISK_ HEAVY RAIN

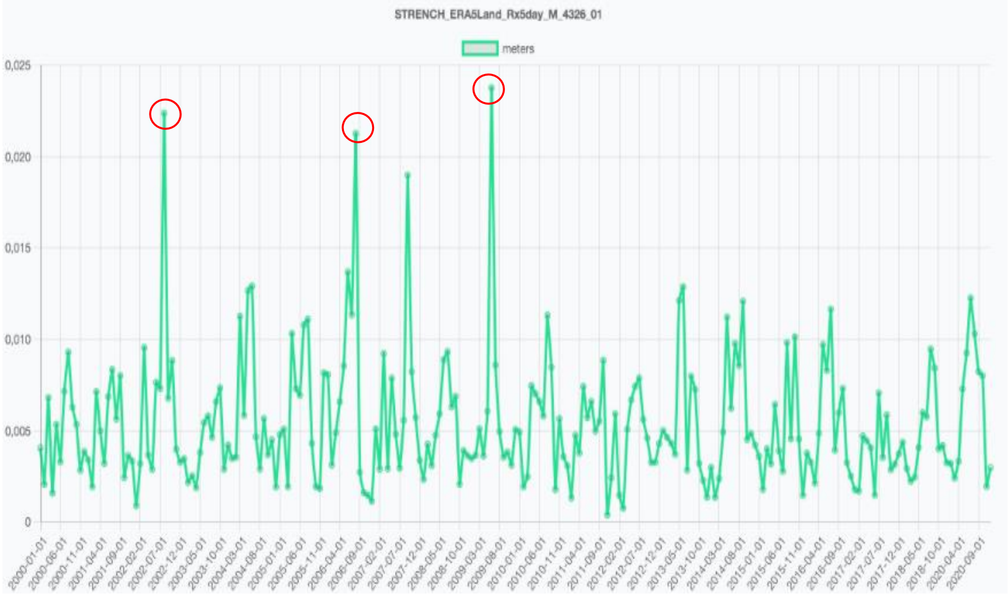


Sardella et al., *Atmosphere*, 2020

ETCCDI **R20mm**_Number of days in a year with precipitation greater than or equal to 20 mm/day

PAST CALAMITOUS EVENTS_WACHAU REGION

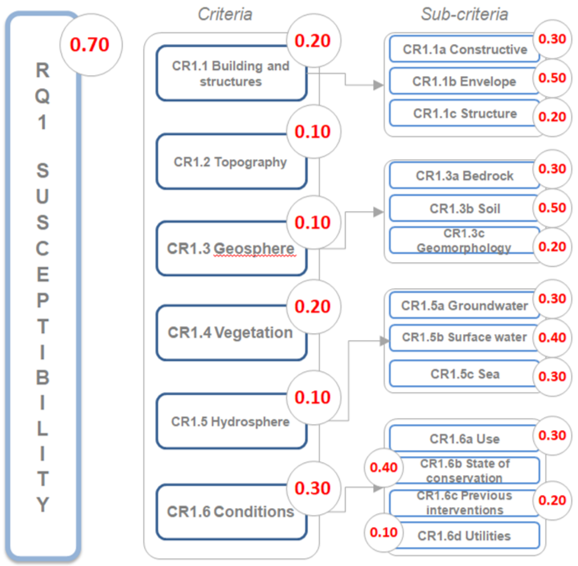


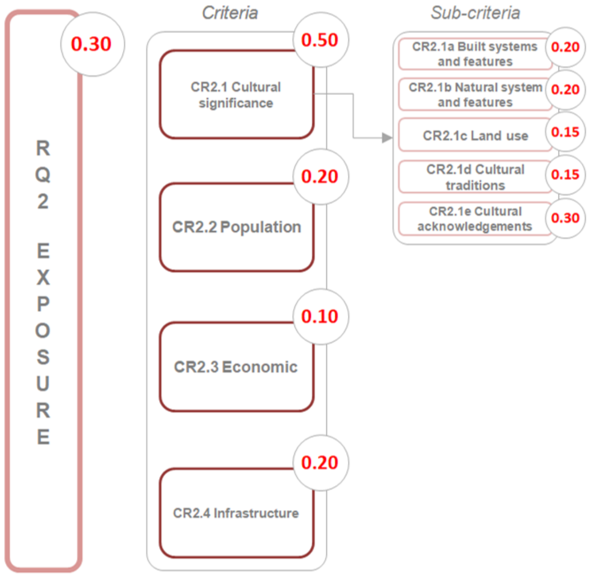


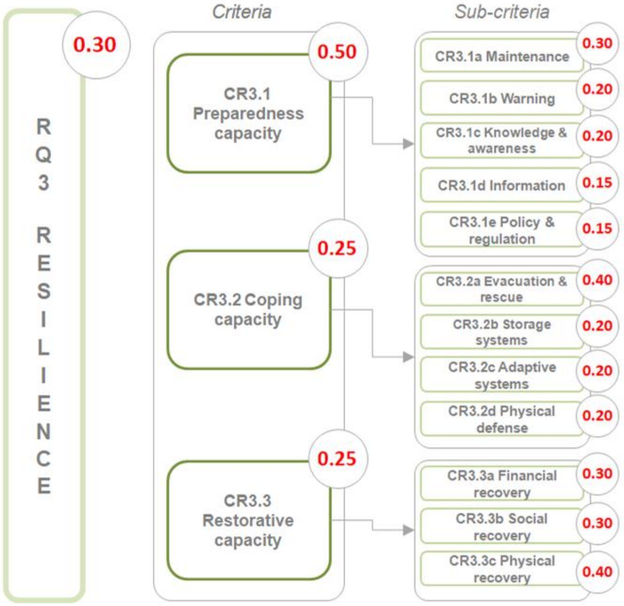
- R20mm values at seasonal scale derived from IMERG products
- Rx5day at monthly scale derived from ERA5Land products

Peaks of R20mm and Rx5day clearly visible in corrispondence of recorded catastrophic heavy rainfall and floods

Methodology for Vulnerability Ranking







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CULTURAL HERITAGE AT RISK
THE KNOWLEDGE OF THE PAST

Actions addressed to:

- ✓ Capitalization of existing knowledge/Harmonization of data
- ✓ User driven approach/stakeholders requirements
- ✓ Solving existing challenges in the territories
- ✓ Solutions for policy/decision makers and rescues bodies

DECISION MAKING FROM POLICY TO PRACTICAL APPLICATION

The integration of culture into urban policy and planning is increasingly recognised as critical to develope sustainable, resilient cities and features in international agreements such as the SDGs (limited evidence; high agreement). However, urban cultural policies are still limited (IPCC AR6 WGII 2022)

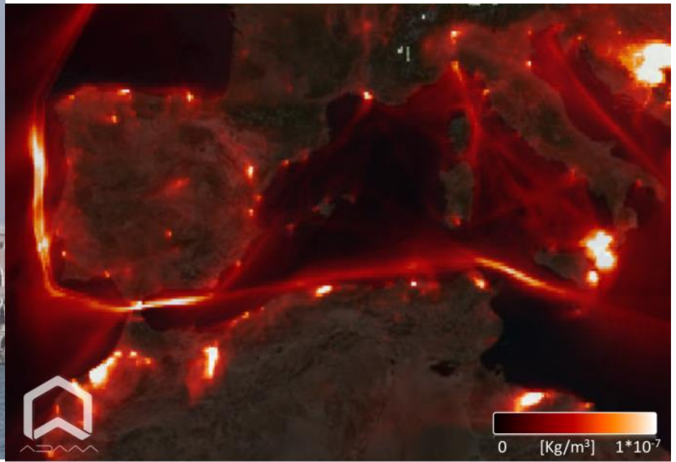
SENDAI FRAMEWORK FOR DISASTER RISK REDUCTION 2015-2030

Action Plan on the Sendai Framework – Implementation Priority Key Area 4

MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE

Italian National Strategy for Adaptation to Climate Change (SNAC)
Italian National Plan for Adaptation to Climate Change (PNAC)

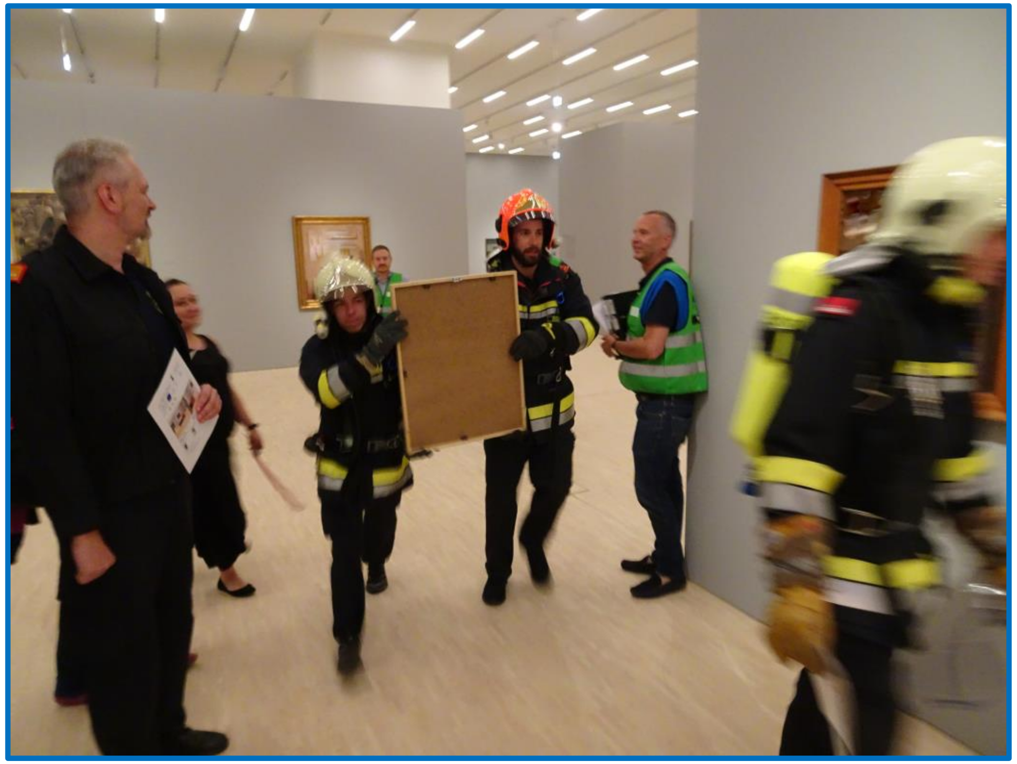
CAMS EU Regional SO_2 surface concentration (average 09/09/2020)



Fostering the adoption of a Mediterranean Emission Control Area (MedECA)

DECISION MAKING FROM POLICY TO PRACTICAL APPLICATION

Coordinated actions of recues services that should operate on the basis of pre-planned practical programmes (establishment of priorities of CH to be rescued, adequate risk assessments, training, familiarisation techniques previously carried out)



CULTURAL HERITAGE RESQUE TEAM

KEY ACTION: PREPAREDNESS

Bonazza et al., *Safeguarding …EU, 2018*

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EUROGEO WORKSHOP 2022

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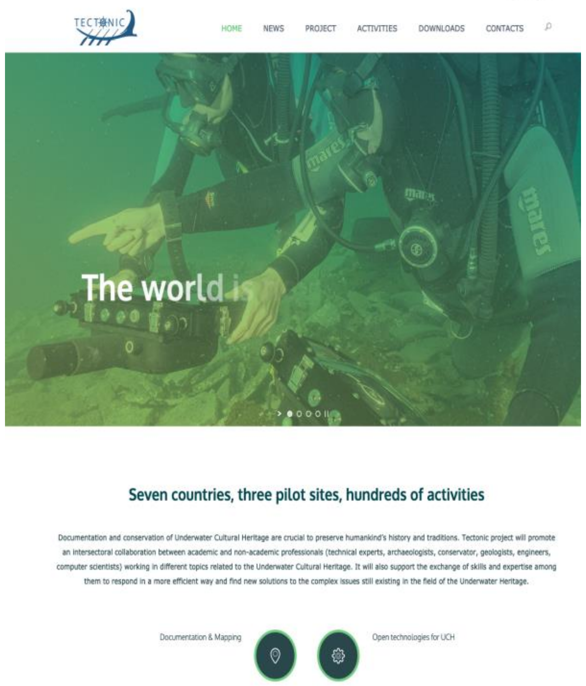

THANKS to ISAC team and Projects Partnership

ATHENS 7-9 DECEMBER 2022

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