Impacts of air pollution on cultural heritage

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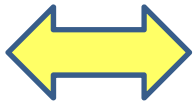
The effects of climatic and pollution factors on cultural heritage

Climatic and Pollution Parameters

- ✓Climatic parameters
  - -Temperature
  - - Relative Humidity
  - - Wind
  - - Rain
  - - Sea Salt
- ✓Air Pollution
  - - NO_x
  - - SO_2
  - - O_3
  - - PM_{10}
  - - $PM_{2.5}$
  - - BC



Materials

- ✓Stone
- ✓Wood
- ✓Metals
- ✓Glass

The effects of climatic and pollution factors on cultural heritage

Statua di Madama Lucrezia a Piazza San Marco (Roma)

Chiesa di S. Filippo (Torino)

Material loss of *stone materials*

Foro Romano (Roma)

Surface recession (R)

$$R^* (\mu m/year) = 4 + 0.0059 \cdot [SO_2] \cdot RH_{60} + 0.054 \cdot [H^+]\ Rain + 0.078 \cdot [HNO_3] \cdot RH_{60} + 0.0258 \cdot PM_{10}$$

*Multiassess Project: *Model for multi-pollutant impact and assessment of threshold levels for cultural heritage* (Multiasses)- *Report* 2005

The effects of climatic and pollution factors on cultural heritage

Corrosion of *metals*

Bronze Fontana delle Tartarughe a Piazza Mattei (Roma)

Copper Tempio Maggiore Israelitico - Sinagoga (Firenze)

Surface recession (R)

$$R^* (\mu m/year) = 0.15 + 0.000985 [SO_2] \; Rh_{60} \; e^{f(T)} + 0.00465 \; Rain [H^+] + 0.00432 \; PM_{10}$$

f(T) = 0.060(T-11) when T<11°C, -0.067(T-11) otherwise

Mass Loss (ML)

$$ML^* (g \, m^{-2}) = 0.0027 [SO_2]^{0.32} [O_3]^{0.79} Rh \exp\{f(T)\} \; t^{0.78} + 0.050 \; Rain [H^+] \; t^{0.89}$$

f(T) = 0.083(T-10) when T<10°C, otherwise -0.032(T-10)

*Multiassess Project: *Model for multi-pollutant impact and assessment of threshold levels for cultural heritage* (Multiasses)- *Report* 2005

The effects of climatic and pollution factors on cultural heritage

Blackening of ***stone materials***

Paratie a Piazza S. Marco (Venezia)

Colosseo (Roma)

Vittoriano (Roma)

$$R/R_0 = exp(kC_{PM}t)$$

R, R_0= final and initial reflectance
k= blackening coefficient
C_{PM}= particulate matter concentration
(**PM_{10} or $PM_{2.5}$**)

Multiassess Project: *Model for multi-pollutant impact and assessment of threshold levels for cultural heritage* (Multiasses)- *Report* 2005

ISPRA activities

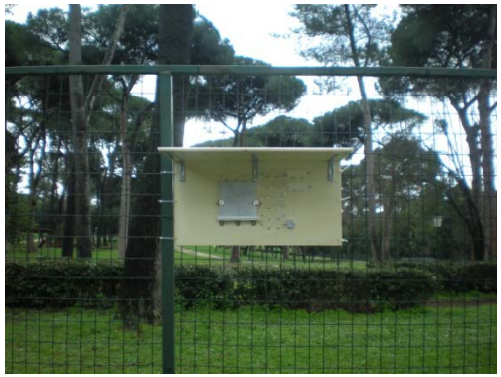
ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

Collaboration ISPRA and ISCR
(National Institute for Conservation and Restoration)

2003-2004

2010-2011

2013-2015



Objectives

Characterization of potential decay risk due to air pollution in the environment surrounding the works of art

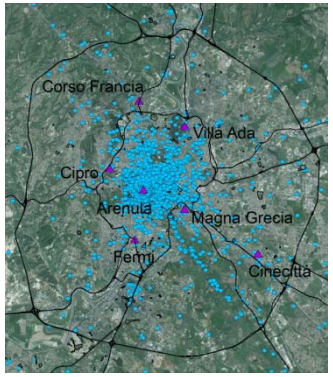
to plan rigorous and frequent maintenance activities to improve the conservation conditions of the cultural heritage

Two approches

1. Monitoring campaigns

Case study:

Rome (within the Great Ring Road)

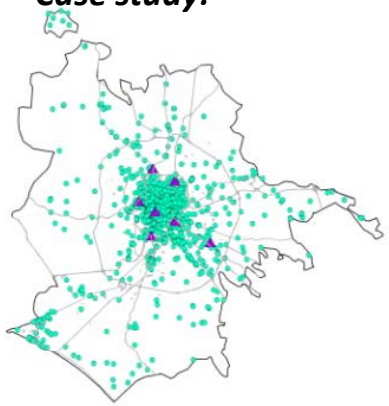


Data used: pollution concentrations from the air quality monitoring network

2. Damage assessment through the aplication of dose-response functions

Case study:

Rome

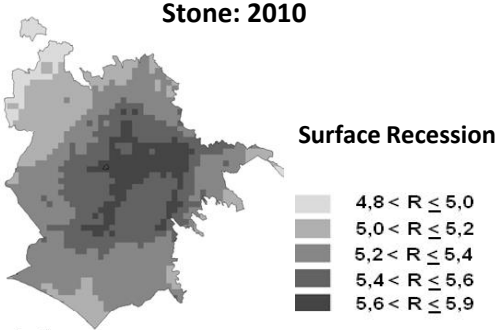


Data used: pollution concentrations (PM_{10}, NO_2, O_3) from models

2. Damage assessment through the aplication of dose- response functions

Rome

Stone: 2010

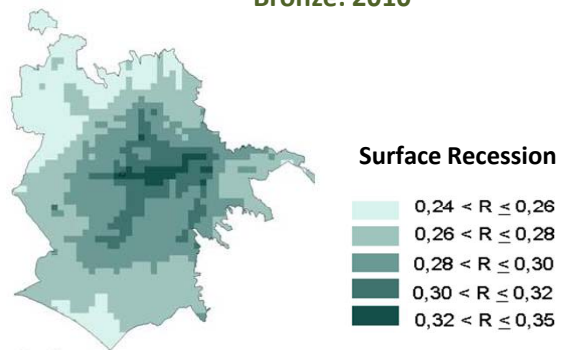


Resolution: 1 km

Surface Recession (μm/year)

$$\text{Recession (μm/year)} = 4 + 0.0059 \cdot [SO_2] \cdot RH_{60} + 0.054 \cdot [H^+] \text{ Rain} + 0.078 \cdot [HNO_3] \cdot RH_{60} + 0.0258 \cdot PM_{10}$$

Bronze: 2010



Resolution: 1 km

Surface Recession (μm/year)

$$\text{Recession (μm/year)} = 0.15 + 0.000985 \cdot [SO_2] \cdot Rh_{60} \cdot e^{f(T)} + 0.00465 \cdot \text{Rain} \cdot [H^+] + 0.00432 \cdot PM_{10}$$

The surface recession was estimated using PM_{10}, NO_2 and O_3 concentrations from FARM model (ARPA Lazio)

Possible use of CAMS products and needs

Elaboration of Territorial Risk for cultural heritage at national, regional and municipal levels

Territorial Risk*

$$R_t = n \times H_t$$

n= number of monuments

H_t= territorial Hazard represented by the damage (estimated applying the dose response functions or by pollutant concentrations when dose-response functions cannot be applied)

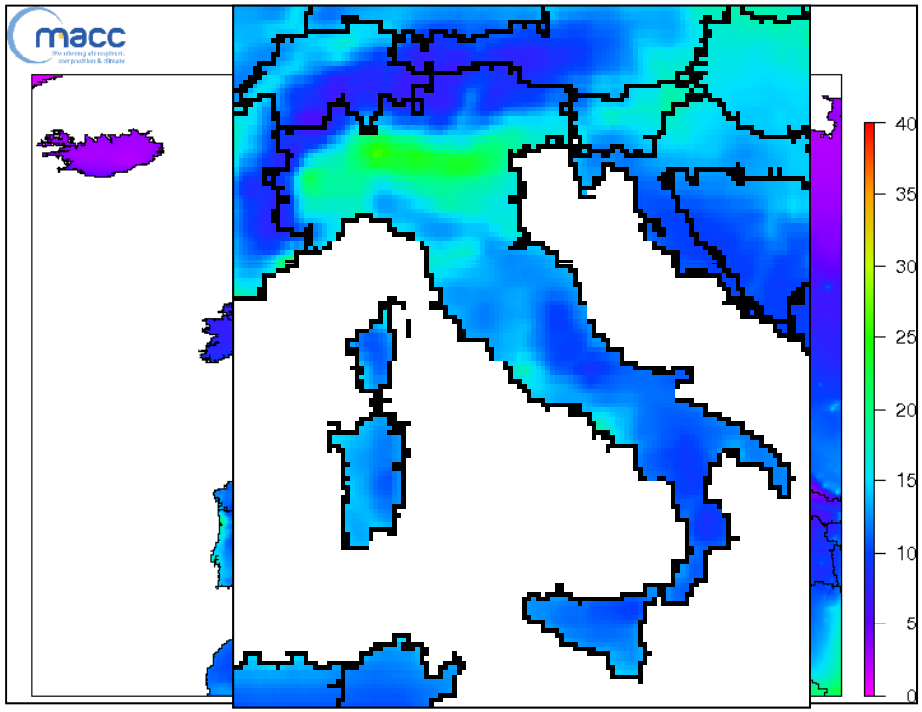
* Risk Map of Cultural Heritage, ISCR, 1995

Possible use of CAMS products and needs

1. Territorial Risk assessment at *national* level

- Cultural heritage from Vincoli in Rete data base: national level

Source: Vincoli in Rete database (ISCR)
http://vincoliinretegeo.beniculturali.it/vir/vir/vir.html?token=20968cd



Source: Copernicus http://www.copernicus-atmosphere.eu

Possible use of CAMS products and needs

Data required at national level

From Regional Models

Analysis and reanalysis data of the following parameters (annual average) :

- ✓SO_2
- ✓NO_2
- ✓O_3
- ✓PM_{10}

➡ **Material loss**

- ✓PM_{10}
- ✓$PM_{2.5}$

➡ **Blackening**

⇩

Territorial Risk:
$R_t = n \times H_t$

⇔

Cultural heritage distribution in Italy

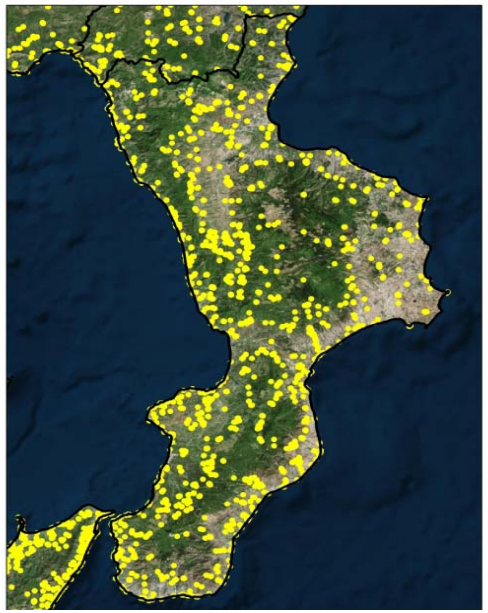
Source: Vincoli in Rete database (ISCR)

Resolution: 10 x 10 km

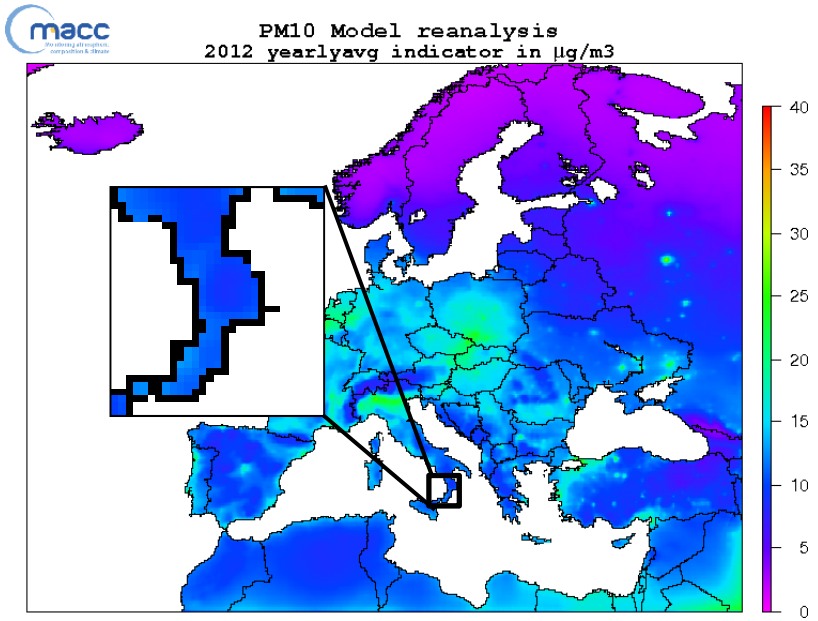
Possible use of CAMS products and needs

2. Territorial Risk assessment at *regional* level

Cultural heritage collected in Vincoli in Rete data base: regional level (Calabria)



Source: Vincoli in Rete database (ISCR)



Source: Copernicus http://www.copernicus-atmosphere.eu

Possible use of CAMS products and needs

Data required at regional level

From Regional Models

Analysis and reanalysis data of the following parameters (annual average) :

- ✓ SO_2
- ✓ NO_2
- ✓ O_3
- ✓ HNO_3
- ✓ PM_{10}

➡ **Material loss**

- ✓ PM_{10}
- ✓ $PM_{2.5}$

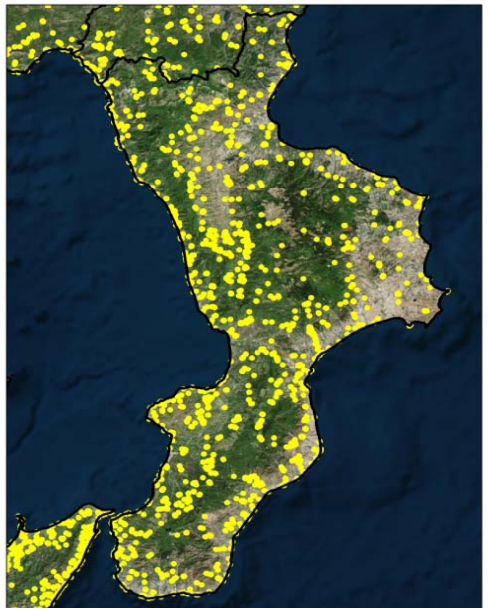
➡ **Blackening**

⇩

Territorial Risk: $R_t = n \times H_t$

⇔

Cultural heritage distribution at regional level (Calabria)



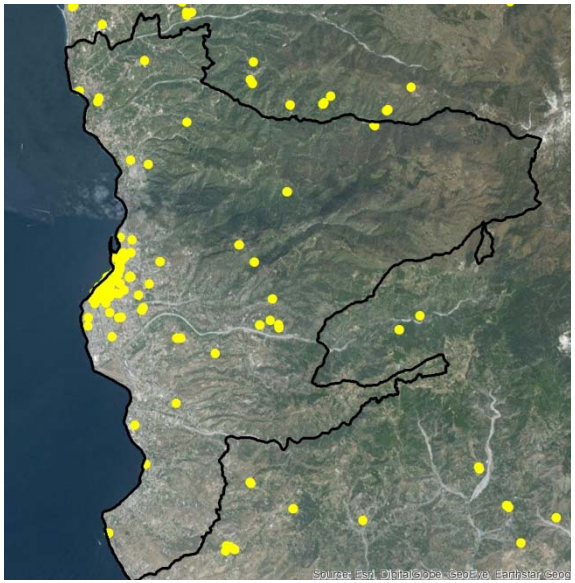
Source: Vincoli in Rete database (ISCR)

Resolution: 5 x 5 km

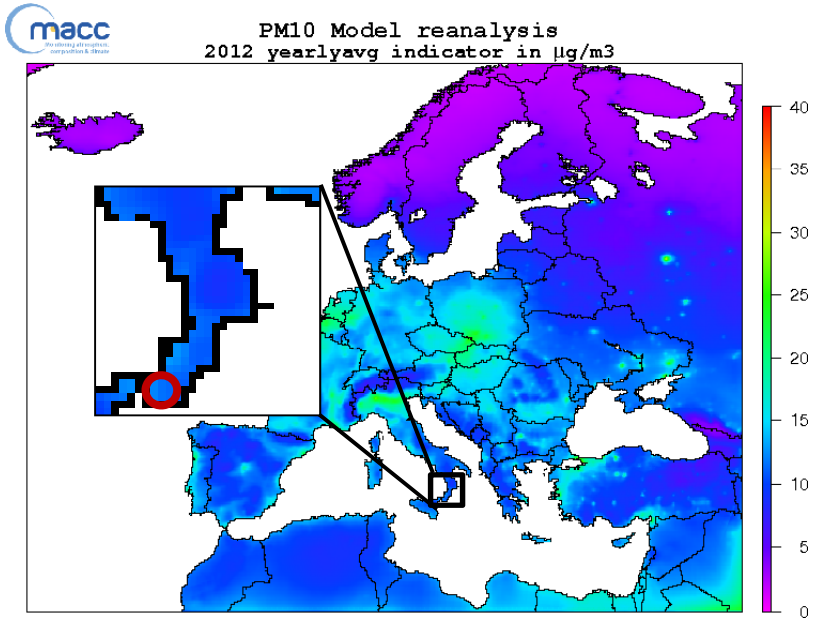
Possible use of CAMS products and needs

3. Territorial and Individual Risk assessments at *municipal* level

Cultural heritage collected in Vincoli in Rete data base: municipal level (Reggio Calabria)



Source: Vincoli in Rete database (ISCR)



Source: Copernicus http://www.copernicus-atmosphere.eu

Possible use of CAMS products and needs

Data required at municipal level

From Regional Models

Analysis and reanalysis data of the following parameters (annual average) :

- ✓ SO_2
- ✓ NO_2
- ✓ O_3
- ✓ HNO_3
- ✓ PM_{10}

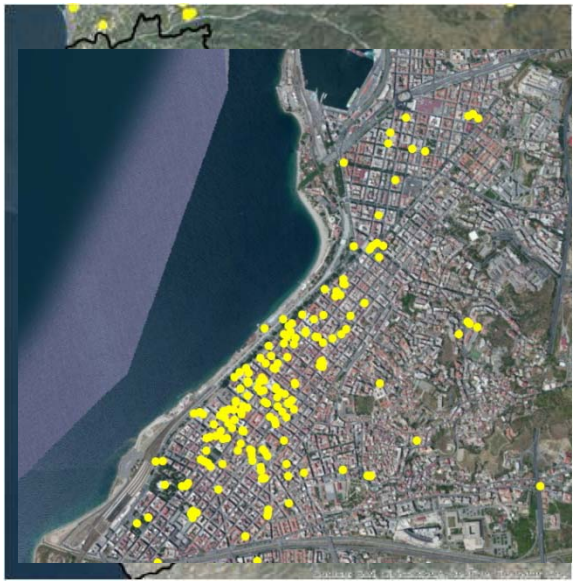
➡ **Material loss**

- ✓ PM_{10}
- ✓ $PM_{2.5}$

➡ **Blackening**

⇔

● **Cultural heritage distribution at municipal level (Reggio Calabria)**



Source: Vincoli in Rete database (ISCR)

⇩

Territorial Risk: $R_t = n \times H_t$

Individual Risk: $R_i = V \times H_t$

where V= vulnerability (conservation conditions of single monument)

Resolution: 1 x 1 km

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Thank you
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