

Smart Control of the Climate Resilience in
European Coastal Cities



Session 2: Data-Driven and Nature-Based Adaptation – Tools for Today and Tomorrow

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ECCA-2025 Rimini – 17 June 2025

RED Risk – LaMMA – MBI – UNIPI – UCD – CNR –
TERO - ATU - SAMU - ENT



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Take Home Messages

- ◆ In **SCORE**, the complete **Disaster Risk Financing (DRF) modeling chain was developed**, including: climate change data research and downscaling; development of hazard, exposure, and vulnerability models; flood loss and risk assessment; development of DRF strategy and guidelines.
- ◆ The implementation of a comprehensive DRF framework that includes **understanding risk** and **planning its reduction, transfer, and retention** are essential **to develop a sustainable DRF strategy** and **to strengthen resilience**.

1-Selection of weather, marine and climate data

- ✓ Collect climate data and information from the main climate services and initiatives available across Europe.
- ✓ **Open, free** and **reliable climate data** are needed.

The main services and collaborative initiatives identified:

- Copernicus Climate Change Service (**C3S**) and the Climate Data Store (**CDS**)
- Copernicus Marine Environment Monitoring Service (**CMEMS**) portal
- European Marine Observation and Data Network (**EMODnet**) initiative



1-Selection of weather, marine and climate data

Examples of selected dataset

ERA5 family for “**historical**” period, e.g.

- ERA5 hourly data on a single level.
- ERA5-Land

EURO-CORDEX and Med-CORDEX for future “**projections**”, e.g.

- Water level change time series for the European coast from 1977 to 2100
- Surface wave time series for the European coast from 1976 to 2100.

Climate Data Store [Datasets](#) [Applications](#) [User guide](#) [Live](#) [Background](#)

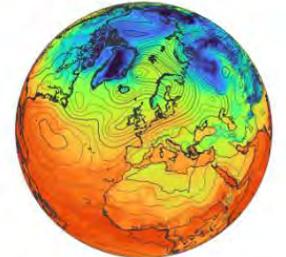
ERA5 hourly data on single levels from 1940 to present

[Overview](#) [Download](#) [Documentation](#)

ERA5 is the fifth generation ECMWF reanalysis for the global climate and weather for the past 8 decades. Data is available from 1940 onwards. ERA5 replaces the ERA-Interim reanalysis.

Reanalysis combines model data with observations from across the world into a globally complete and consistent dataset using the laws of physics. This principle, called data assimilation, is based on the method used by numerical weather prediction centres, where every so many

ERA5 2 metre temperature and Mean sea level pressure
1 January 2023 at 00:00 UTC



-40 -30 -20 -10 0 10 20 30 40
2 metre temperature (°C)

2-Downscaling of identified data to the local scale



From Global (Regional) scale...

- The scale of the earth system
- Typical scale: 1000 km - 50 Km
- The climate service scale

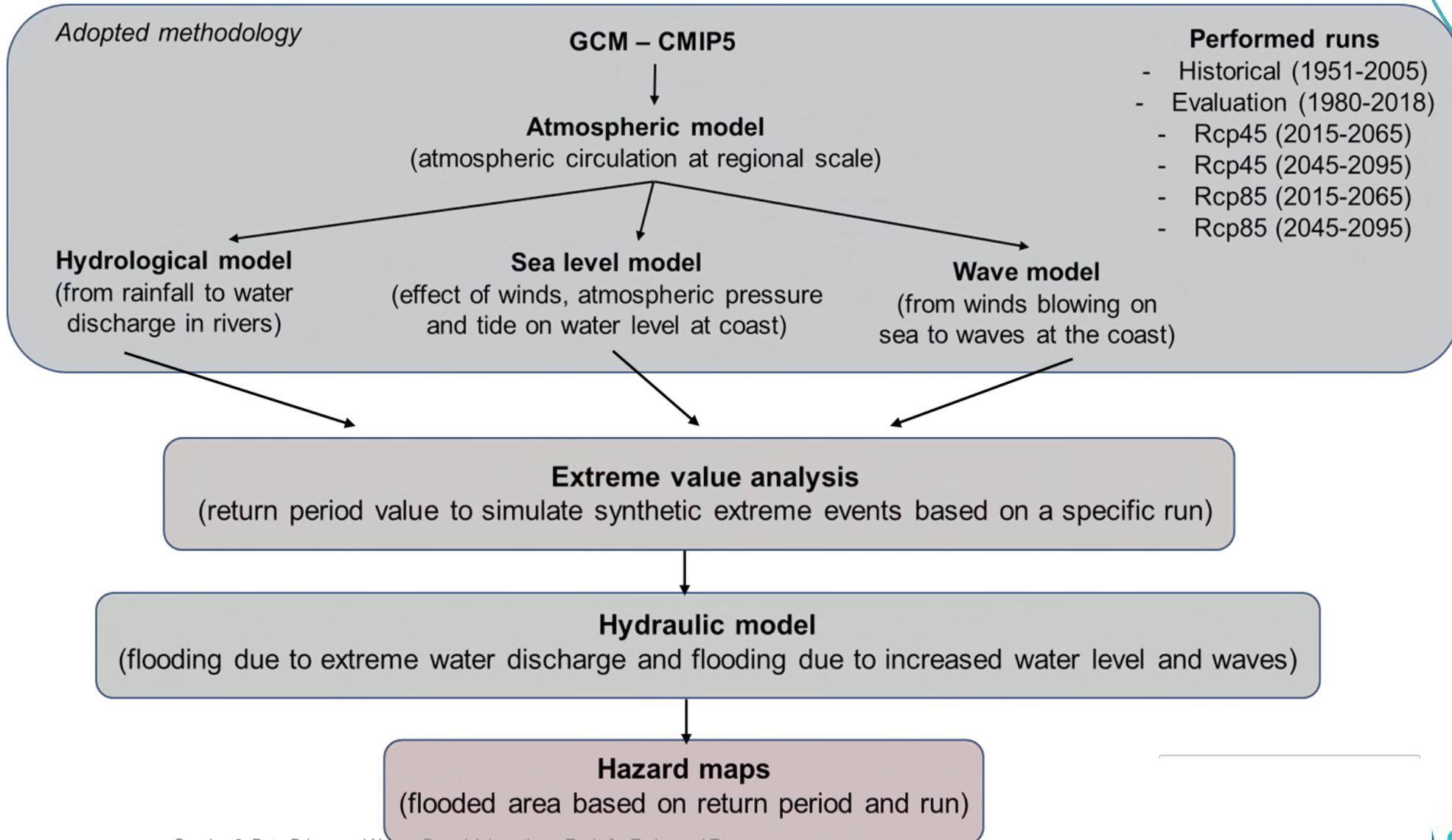


... to local scale!

- The scale of everyday life!
- Typical scale: 1 km - 10 m
- The scale of the actions for climate change resilience : urban models, flooding points, etc.

2-Downscaling of identified data to the local scale

State-the-art, open-source advanced models



Downscaling

Urban-scale

1-Data selection

2-Down scaling

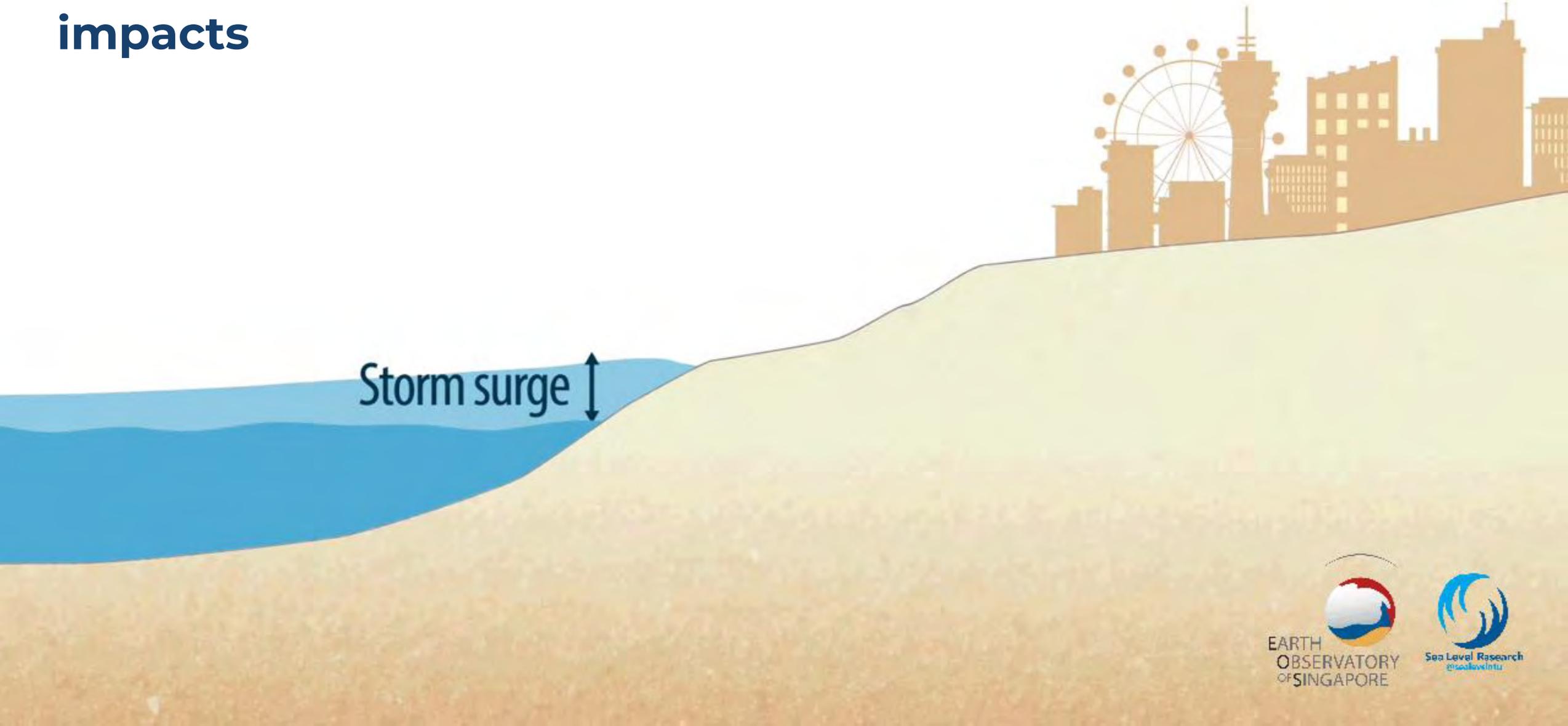
3-Hazard maps

4-Exposure, vulnerability

5-Risk and losses

6-Financial strategies

Relative Sea level rise as driver for extreme events impacts



3-Flood hazard maps

CCLLs
Massa
Oarsoaldea
Vilanova i la Geltrú

Perils	
Fluvial flooding	Current
	Post-EBA
Coastal flooding	

Climate scenarios	
Baseline	
RCP 4.5	2015-2065
	2045-2095
RCP 8.5	2015-2065
	2045-2095

Return periods (years)
5
25
50
100
200
500

In catastrophe modeling, the **return period (RP)** is the average interval (in years) between events of a specified severity, calculated as the reciprocal of the event's annual exceedance probability.

1-Data selection

2-Down scaling

3-Hazard maps

4-Exposure, vulnerability

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6-Financial strategies

Urban scale flood model

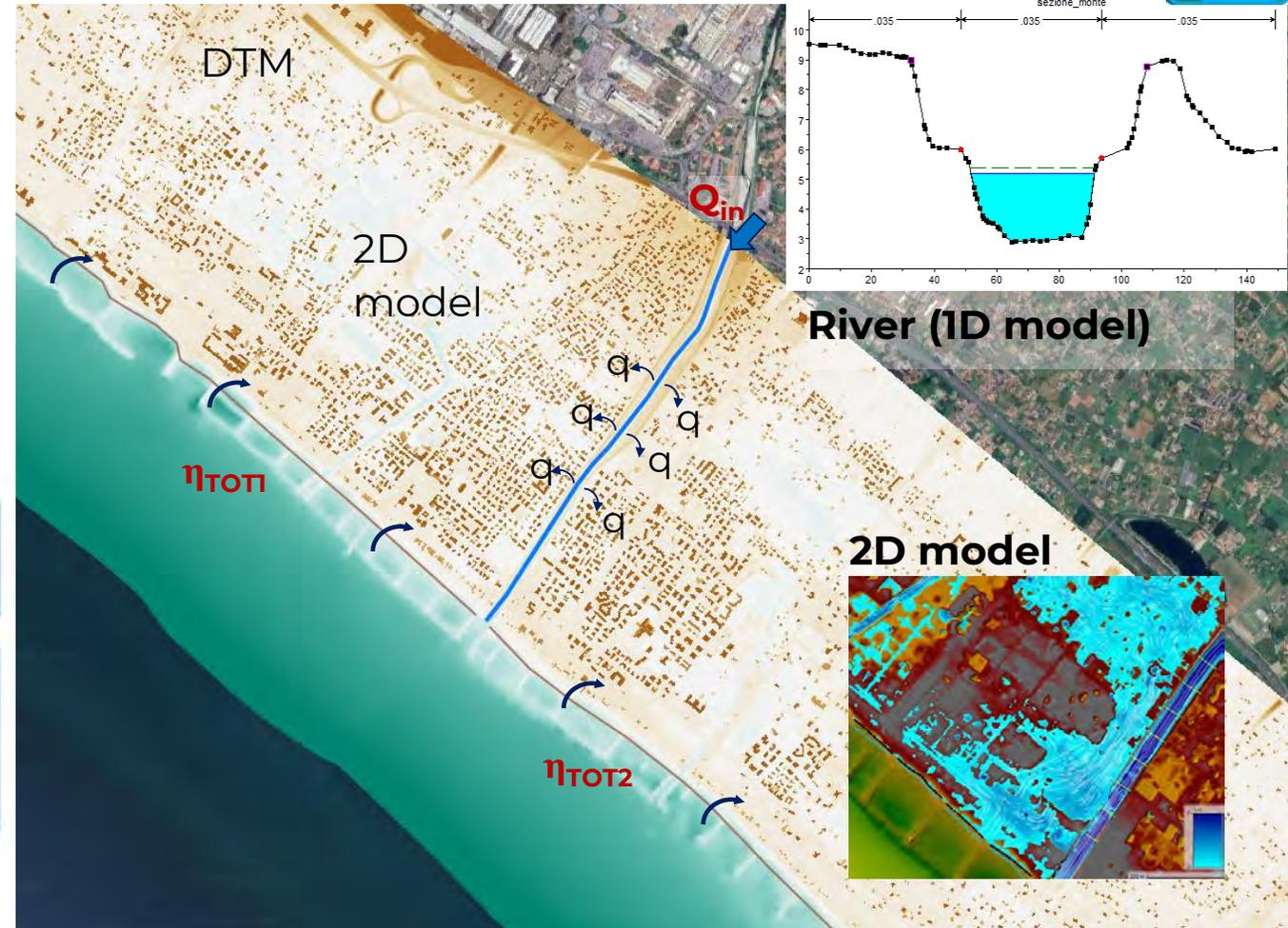
URBAN SCALE FLOOD MODELING

Riverine flood

- River discharge
- Relative Sea Level Rise

Coastal flood

- Storm surge
- Relative Sea Level Rise
- Tide
- Wave runup



1-Data selection

2-Down scaling

3-Hazard maps

4-Exposure, vulnerability

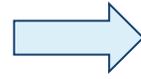
5-Risk and losses

6-Financial strategies

Massa hazard maps – Fluvial flood



Implementation of EBAs



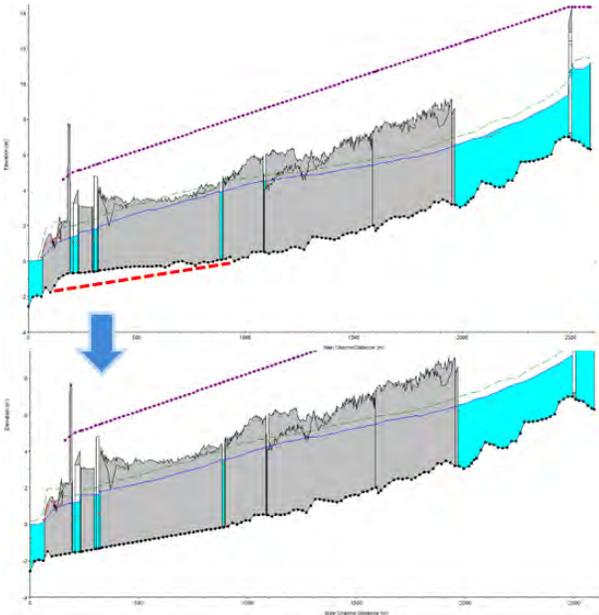
Hazard reduction

Massa

- Riparian reforestation
- Floodplain enlargement

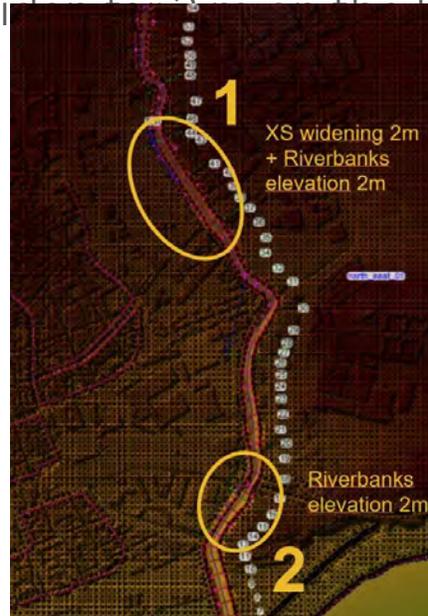


Riverbed excavation



Vilanova i la Geltrù

- Green overbanks elevation
- Widen for 2 m on the right side
- Widen for 2 m on the left side



Oarsoaldea

Reverse EBA exercise modelling what it would be like if the existing EBA did not exist and the river park was a built-up area



Hazard reduction



Risk reduction

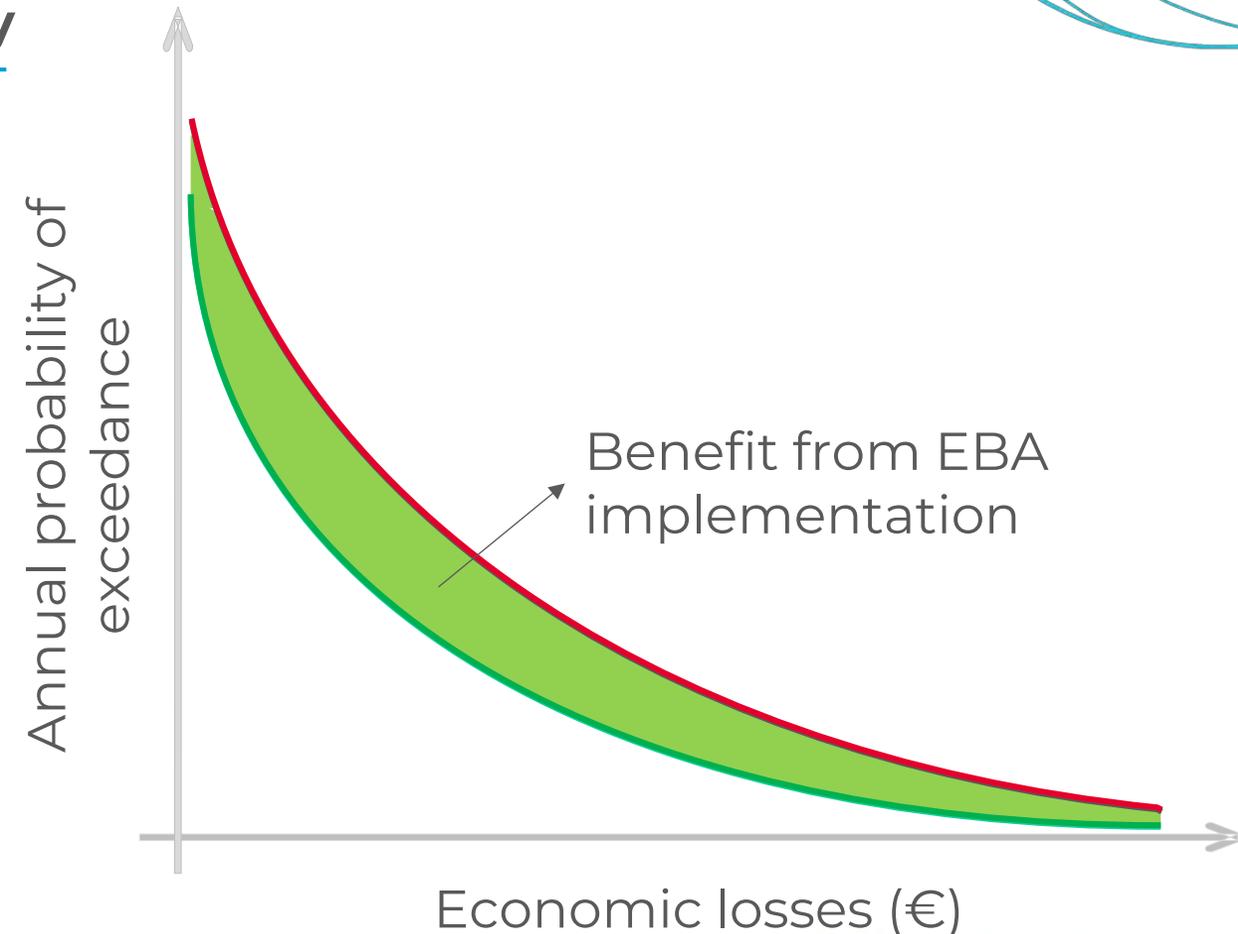
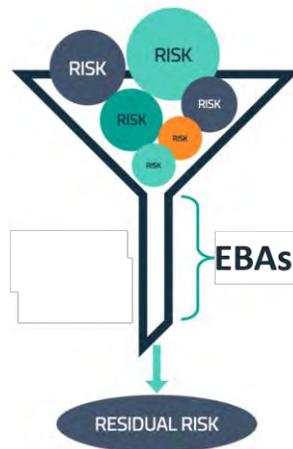


4-Development of exposure and vulnerability

$$\text{Risk} = \text{Hazard} \times \text{Exposure} \times \text{Vulnerability}$$

In the context of SCORE:

- **Baseline risk** – before implementation of EBAs
- **Residual risk** – after the implementation of EBAs



1-Data selection

2-Down scaling

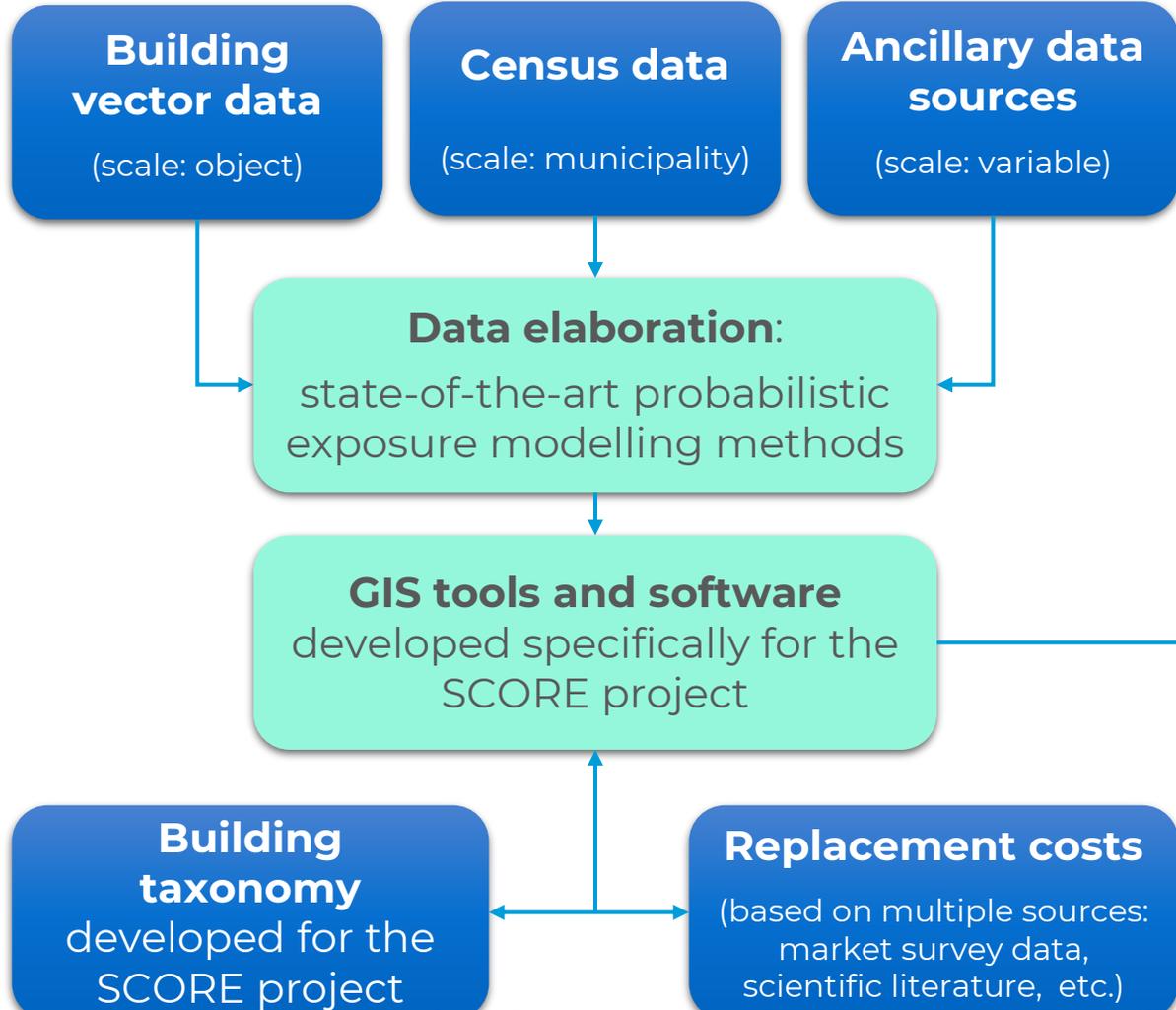
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4-Exposure, vulnerability

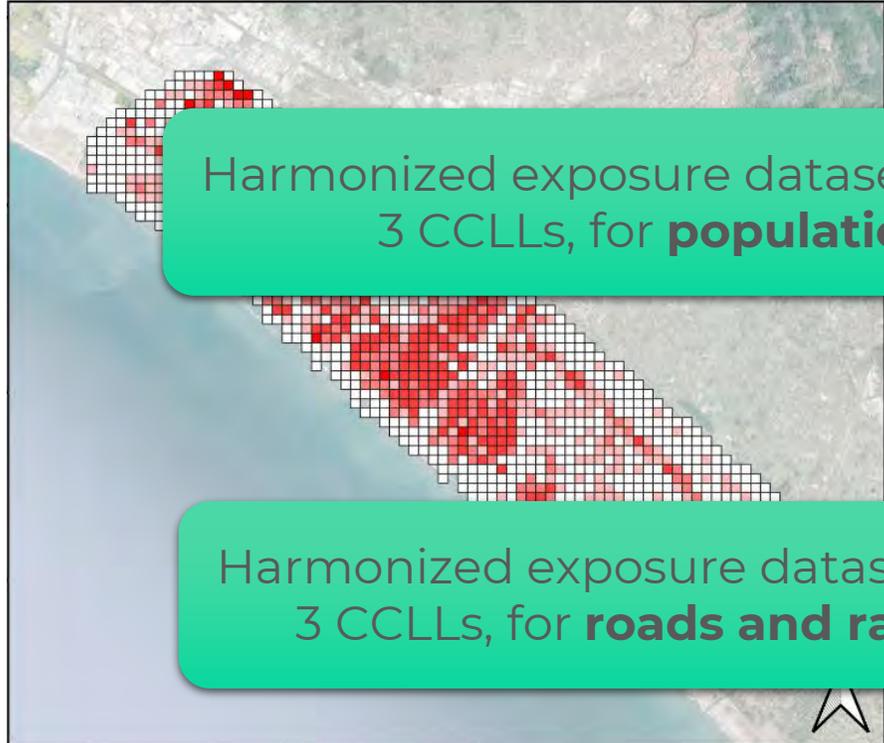
5-Risk and losses

6-Financial strategies

Exposure datasets



Harmonized exposure datasets for the 3 CCLLs, for **multiple building types of different occupancy classes**



Example output: Massa CCLL



1-Data selection

2-Down scaling

3-Hazard maps

4-Exposure, vulnerability

5-Risk and

6-Financial strategies

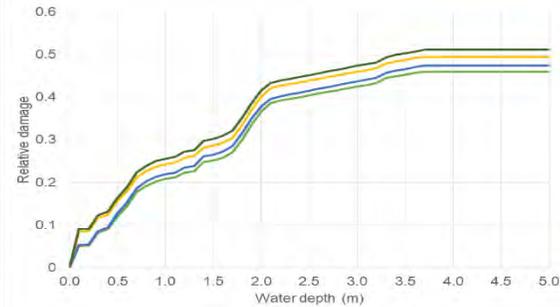
Vulnerability models

Buildings

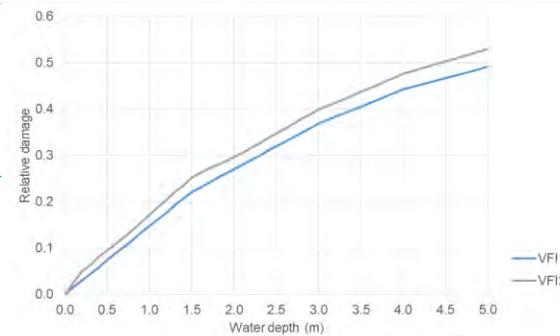
INSYDE (Dottori et. al 2016)



JRC (Huizinga, et al., 2017)



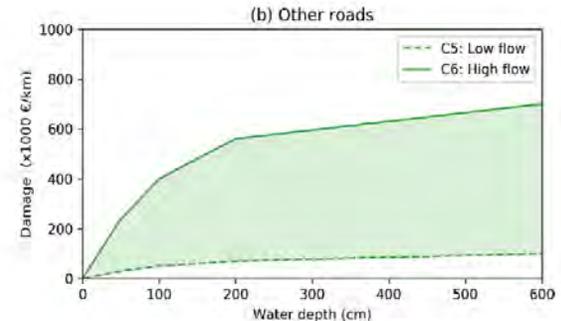
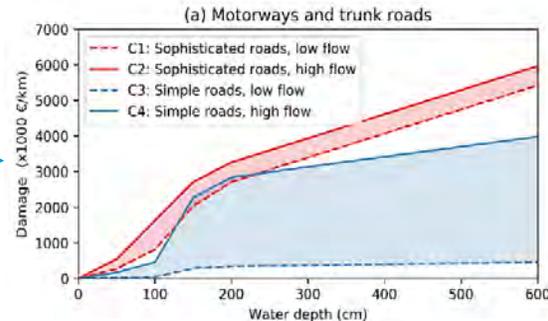
Vulnerability function code	Taxonomical classes
VFR1	RESMIX_RC RESMIX_OTH PUBLIC_RC
VFR2	RESMIX_MSN PUBLIC_MSN
VFR3	RESMIX_RC_B RESMIX_OTH_B PUBLIC_RC_B
VFR4	RESMIX_MSN_B PUBLIC_MSN_B



Vulnerability function code	Taxonomical classes
VF11	INDCOM_RC INDCOM_MSN INDCOM_STL PRTBLD_RC PRTBLD_MSN PRTBLD_STL
VF12	INDCOM_RC_B INDCOM_MSN_B INDCOM_STL_B PRTBLD_RC_B PRTBLD_MSN_B PRTBLD_STL_B

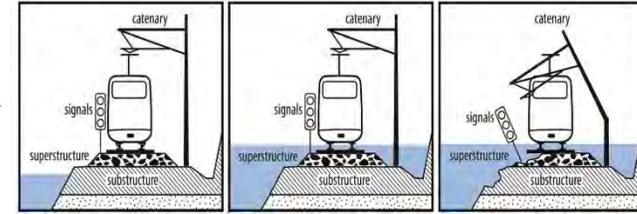
Roads

van Ginkel, et al., (2021)



Railways

RAIL (Kellermann, et al., 2015)



Damage class 1 | Damage class 2 | Damage class 3



1-Data selection

2-Down scaling

3-Hazard maps

4-Exposure, vulnerability

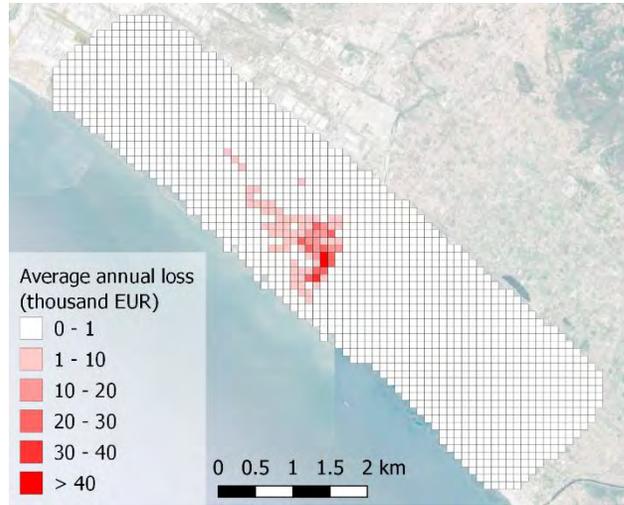
5-Risk and losses

6-Financial strategies

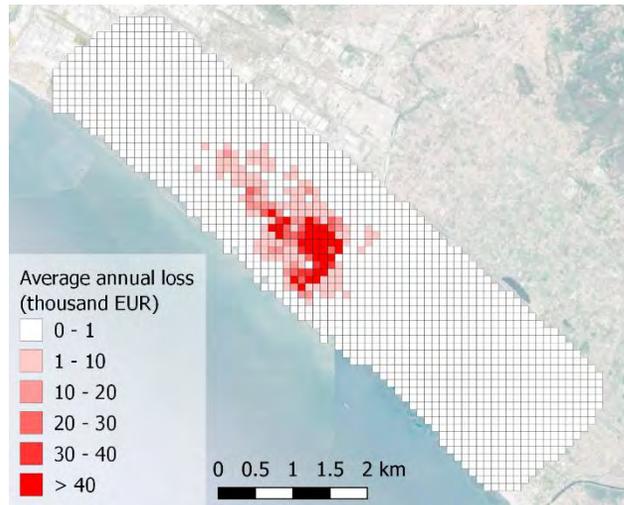
5-Risk and losses

Example output: Massa CCLL

Historical baseline

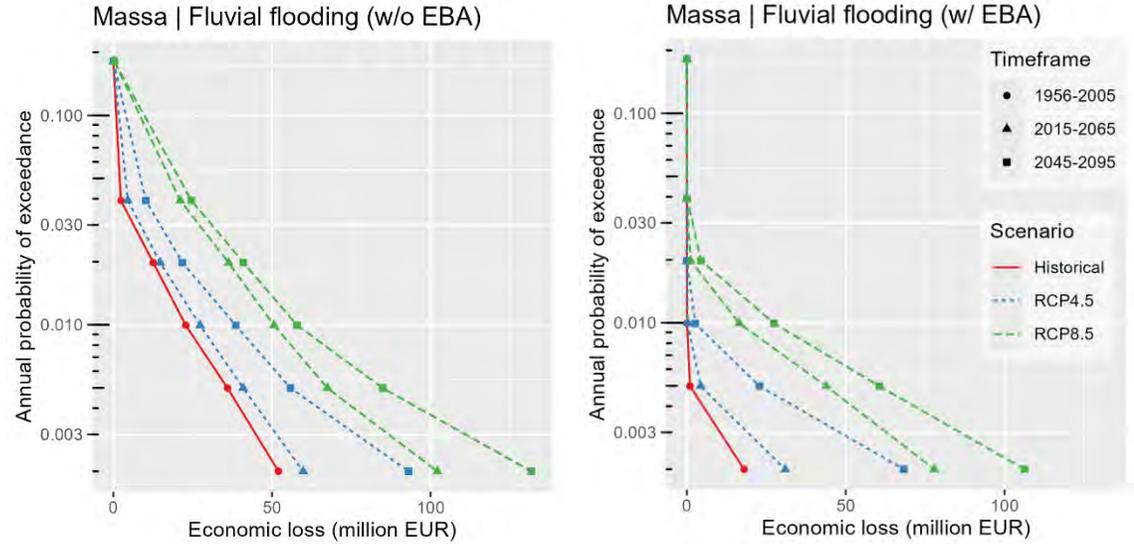


RCP 8.5 2045-2095

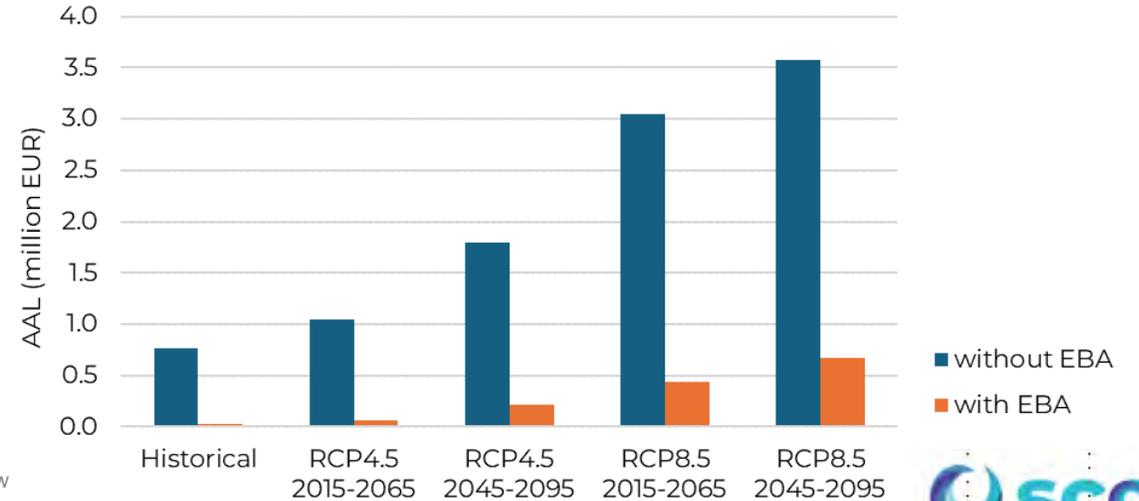


Spatial distribution of average annual losses due to fluvial flooding (without EBA)

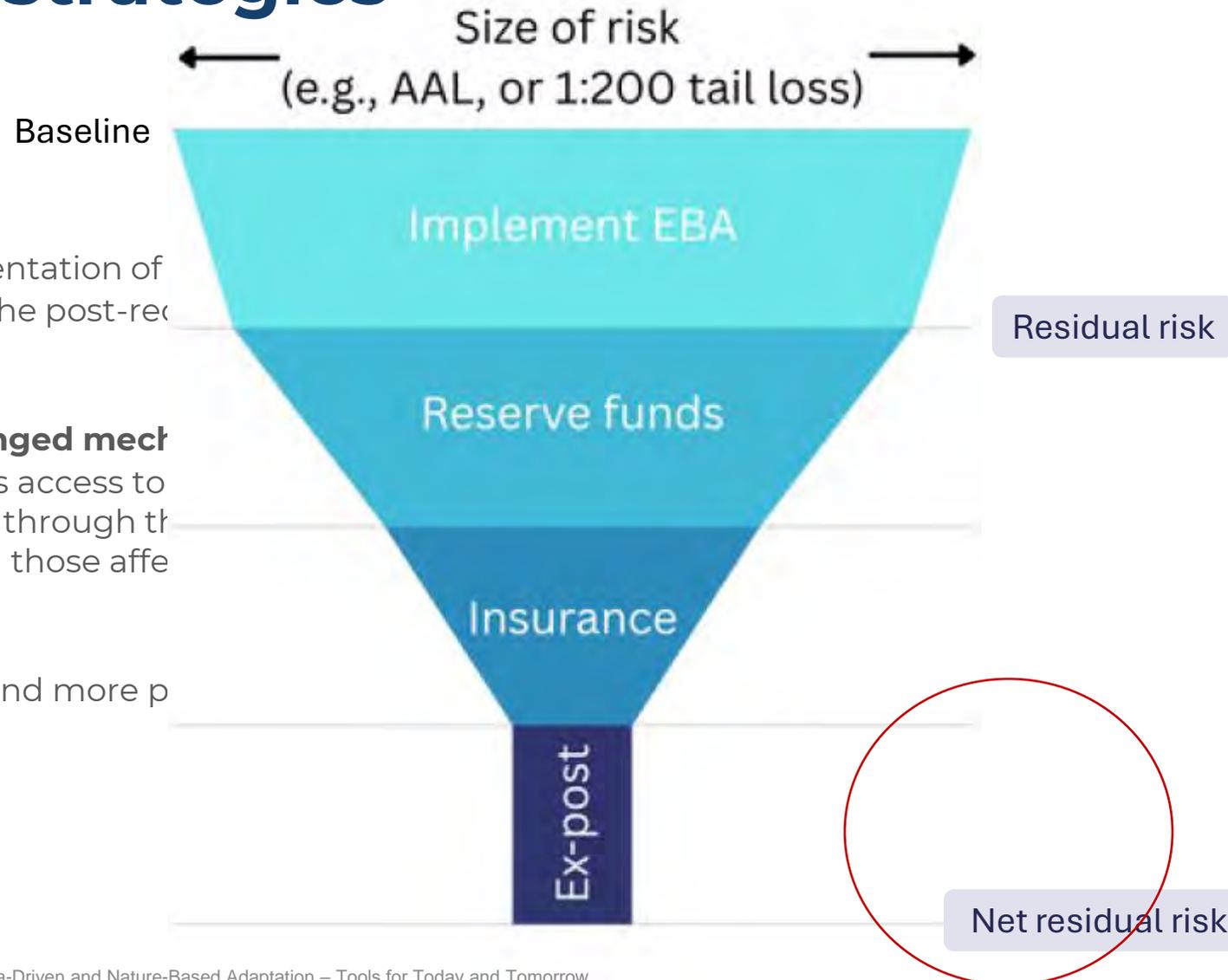
Fluvial flood risk curves



Average annual losses (AAL) due to fluvial flooding for each climate scenario and EBA situation



6-Financial strategies



- ◆ **Reduction.** Implementation of measures to compute the post-rec (residual risk).
- ◆ **Retention.** Pre-arranged mechanisms that provide risk holders access to The resources provided through the instruments come from those affected by the disaster.
- ◆ **Transfer.** Insurance and more parametric solutions.

1-Data selection

2-Down scaling

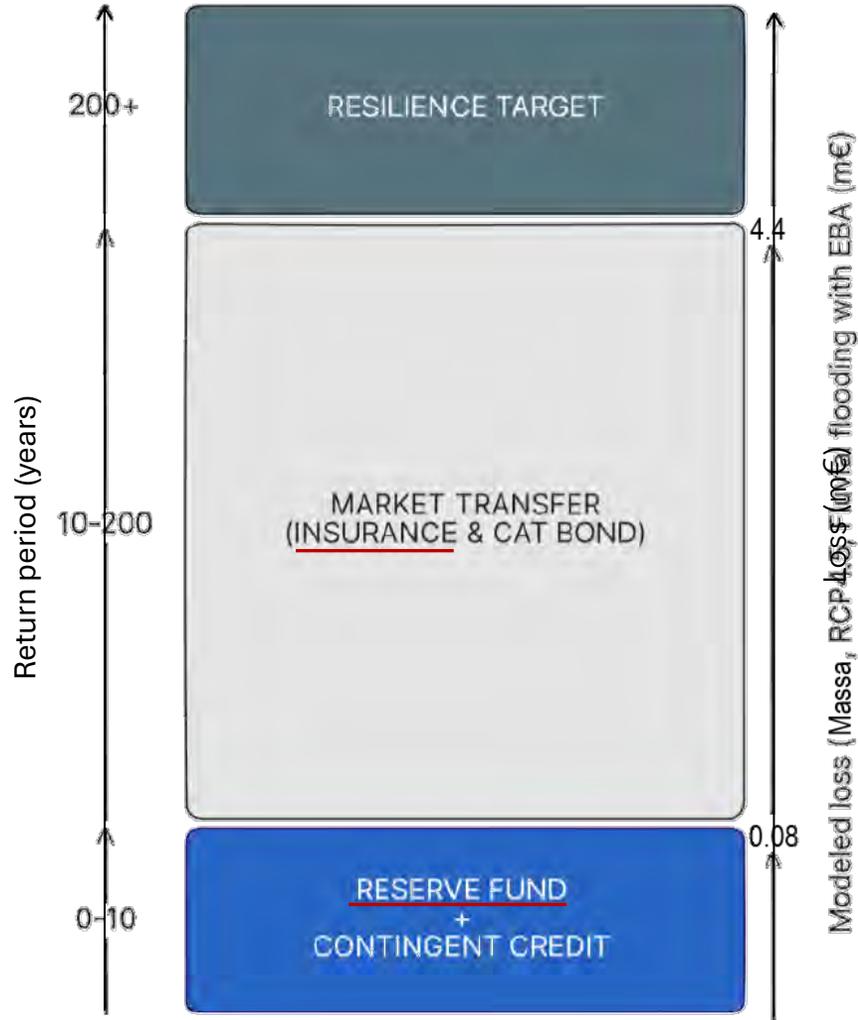
3-Hazard maps

4-Exposure, vulnerability

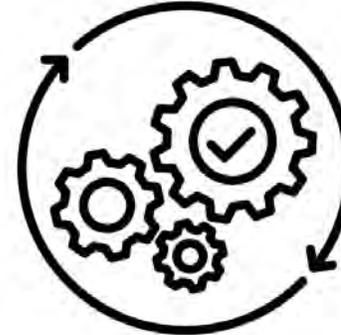
5-Risk and losses

6-Financial strategies

DRF Strategy



Risk assessment results + Input decision variables



Optimization engine (DSS tool)



Budget requirements



Financing gaps

Investing in Climate Adaptation

Enhancing Massa's Climate Resilience

Disaster Risk Financing (DRF) Guidelines Aims: This strategy provides financial guidelines to help manage the increasing risks of climate-related disasters.



Flood Risk in Massa

- **Hazards:** Historically dominated by fluvial floods, but coastal flooding is an increasing concern.
- **Loss Estimates:** Average annual flood losses range from €0.75 - €3.0M before any risk management action is implemented.
- **Fiscal Exposure:** With no pre-allocated national funds, Massa competes for regional civil protection funding, heightening vulnerability.

Key Recommendations for Managing Risk

1. Risk Reduction - Prioritise EBAs to reduce overall risk & financing costs. Implement *Ecosystem-Based Adaptations (EBA)* that reduce hazard exposure. In Massa, EBAs could cut average annual losses by 97%, reducing costs to €25,000.

2. Risk Retention - Reserve funds can cover frequent, low-severity losses. Thanks to the hugely successful risk-reduction layer provided by EBAs, risk retention would require modest savings, only a small fraction of the estimated budget.

3. Risk Transfer - Use parametric insurance for high-impact events. For rare, high-impact floods, parametric (index-based) insurance is recommended. Residual losses for rare (1-in-200 year) events can be covered for under €80K/year.



Disaster Risk Financing Guidelines

Making Every Euro Count

Disaster Risk Financing (DRF) Guidelines Aims: This strategy provides financial guidelines to help manage the increasing risks of climate-related disasters.

1) Prioritise Risk Reduction

Risk reduction, especially through Ecosystem-Based Adaptation (EBA), is the most cost-effective strategy. In Massa (IT), EBAs cut average annual losses by over 90%. Global evidence affirms that reducing risk up front lowers overall financing needs and should always be the first DRF layer.

3) Set Specific Resilience Targets

Resilience targets should reflect local priorities, risk appetite, and critical infrastructure. Engaging stakeholders ensures realistic goals, helping cities allocate between retained, transferred, or accepted risks effectively.

5) Diversify and Stay Flexible

A mix of instruments, reserves, insurance, contingent credit, and possibly bonds, enhances flexibility. As risks and markets evolve, annual reviews of DRF strategies ensure continued relevance and cost-effectiveness.

7) Risk Pools and Catastrophe Bonds

Though still rare, EU-level catastrophe bonds and risk pools hold promise. CCLs can lead innovation by exploring regional pooling and capital market solutions.

2) Use Exceedance Probability Curves

Loss exceedance probability (EP) curves are central to risk-layering. It identifies return-period losses (e.g., 1-in-200-year) to inform resilience targets and determine which risks to retain or transfer. Parametric (index-based) insurance can be tailored to match the local EP curve and offer fast payouts after major events.

4) Explore Contingent Credit

Contingent credit lines efficiently finance high- to moderate-frequency events, avoiding large reserve funds' opportunity costs. They provide post-event liquidity, balancing risk retention without the burden of indefinitely holding excess cash reserves.

6) Engage EU & National Institutions

CCLs should take the lead in initiating dialogue with their national, regional, and EU-level counterparts to emphasize the importance of evidence-based DRF, which is significantly more cost-effective and operationally efficient.

8) Reassess Regularly

DRF strategies must adapt to macroeconomic shifts, including insurance market cycles and funding conditions. Regular reassessment helps cities remain resilient and fiscally sustainable.

Potential impacts and applications

For all CCLs:

- ◆ Empower municipalities, researchers, and stakeholders in European coastal cities
- ◆ Make evidence-based decisions that enhance climate resilience and sustainable coastal management

For

- ◆ **Municipalities:** Enhance urban resilience planning through the accurate data produced
- ◆ **Researchers:** Facilitate development of predictive models for coastal and urban climate phenomena
- ◆ **Insurance Companies:** Improve risk assessment and policy pricing for flood hazards

The first SCORE letters mean "Smart Control"...

WITHIN SCORE TWO "SMART" DIGITAL TOOLS

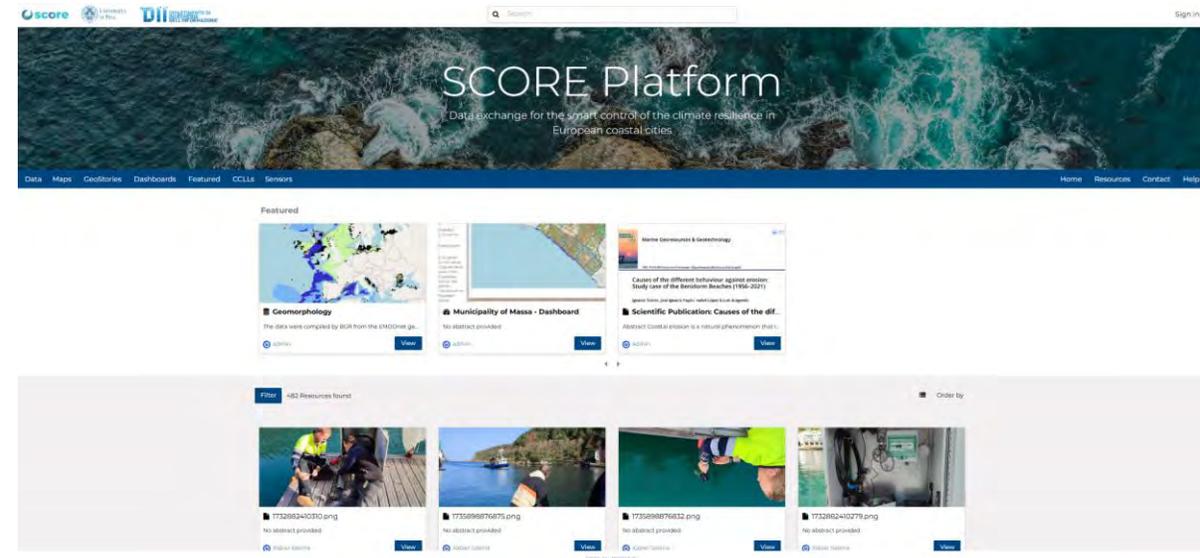
WHERE DEVELOPED:



The digital Twin - EWS



The SCORE data Platform



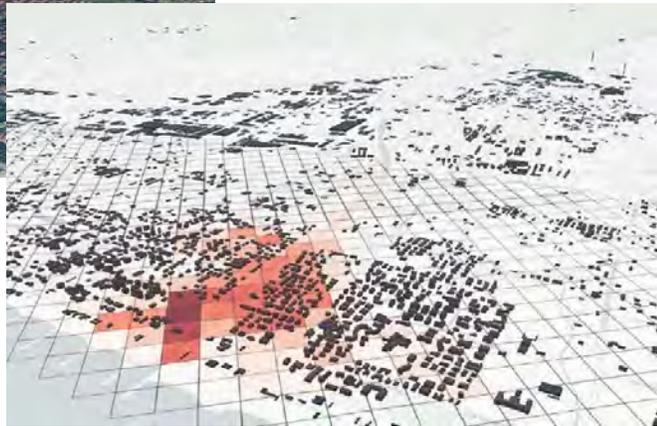
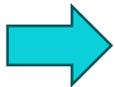
The Digital Twin and the Early Warning System (EWS)

Digital Twin: Support tool for Strengthening Coastal Cities' Resilience



← The Physical
Twin...

... the Digital
Twin!!



User Scenario Evaluation (USE):

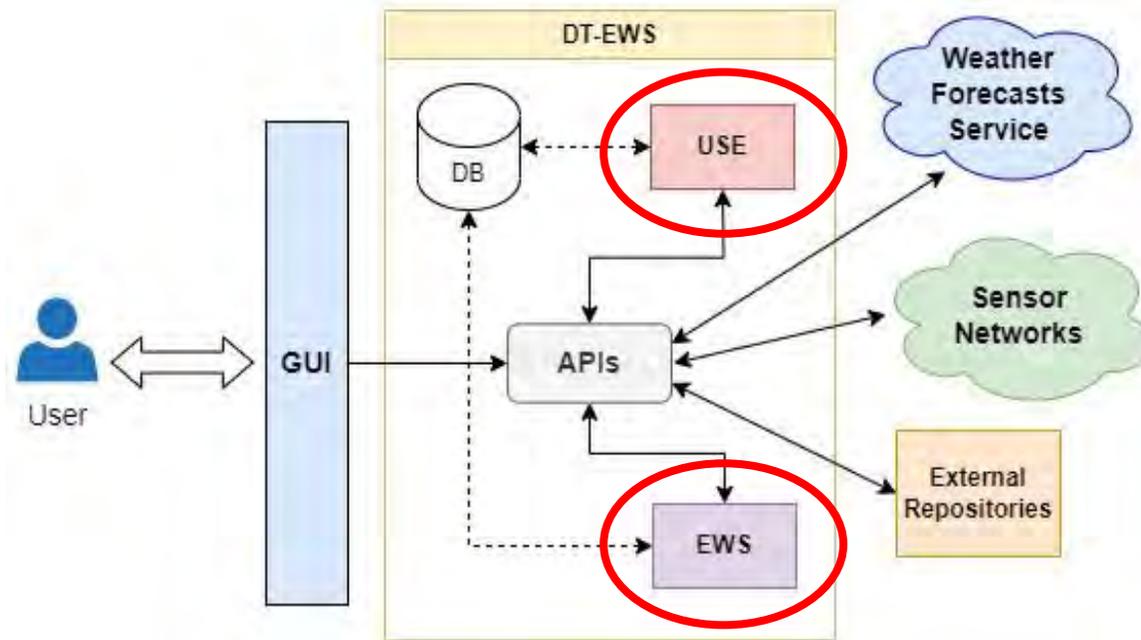
- Flood maps – Event simulation.
- Human and financial risk maps.
- Ecosystem-Based Adaptation (EBA) implementation simulation.
- Coastal erosion estimation.

Early-Warning Support (EWS):

- Alert sent in case of flooding or significant damage.
- Warnings in case of inconsistent data flows.
- Forecast flood maps.
- Forecast human and financial risk maps.

The Digital Twin and the Early Warning System (EWS)

System Architecture



Inside the Digital Twin:

- Digital data (*DSM/DTM models, land use maps, riverbed geometry, flood exposure maps*).
- The hydrological and sea state models (LISFLOOD-FP)
- The future scenarios data
- Sensors data (Institutional and SCORE Sensor)
- Forecast data

- **USE:** User Scenario Evaluation
- **EWS:** Early-Warning Support
- **DB:** Database

- **APIs:** Application programming Interfaces
- **GUI:** Graphical User Interface

The Digital Twin and the Early Warning System (EWS)

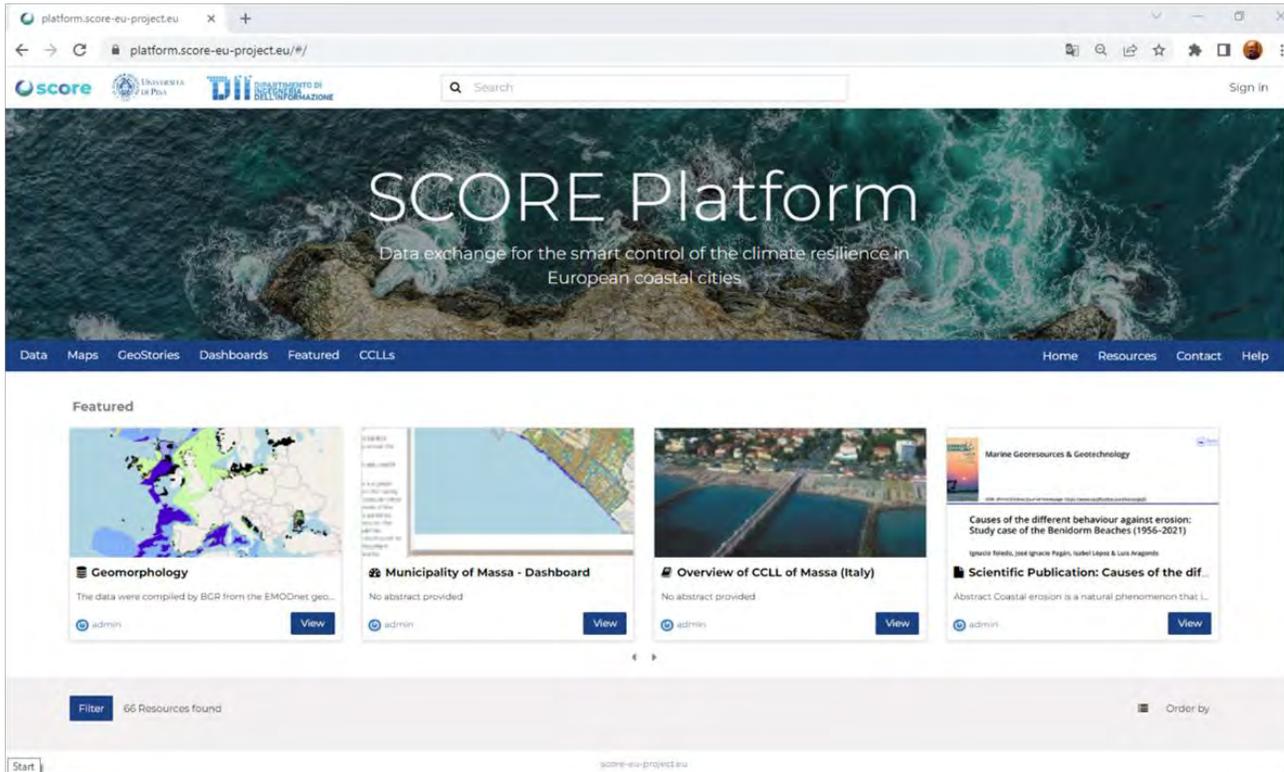
Digital Twin USE Output



The SCORE ICT data Platform (SIP)

Landing Page

<https://platform.score-eu-project.eu/>



SCORE project
Knowledge
Market Place

Concrete Resources:

- **Document:** generic resource representing unstructured data;
- **Spatial Dataset:** generic resource representing structured data;
- **Timeseries:** a dataset with temporal support.



Downstream Resource:

- **Maps:** a multiple spatial datasets and rich interactive map
- **Dashboards:** a virtual board where multiple widgets and maps are positioned
- **Geostories:** a vertically scrolling composition of media, maps and documents

The SCORE ICT data Platform (SIP)

Resource preview

Geostory

Ecosystem-Based ... Save Sync Edit Share

Marram grass plan

Planting vegetation on sand dunes for c...

Objective

Reduce flood risk and storm surges, support vegetation

Benefits

Increase biodiversity, flood risk reduction

Category

Coastal flood risk zones

Scale of Operation

1
Afforestation

2
Riparian ref...

3
Wetland res...

4
Saltmarsh a...

5
Flood plain ...

6
Dune and b...

7
Marram gra...

8
Coral reef re...

9
SUDS
BENEFITS

Search
68 Resources found

Home Resources Contact Help
Data Maps GeoStories Dashboards Featured CCLs

Order by
Municipality of Massa

Municipality of Massa

Massa is a coastal town of the Tyrrhenian Sea, located in the northern part of Tuscany. The altitude of the municipality's territory is mostly slightly above the sea level. Massa has 70,000 inhabitants and 9 km of coastal length. In a few kilometers there is a great variety of landscapes: from the sandy beaches that have been popular since the last century, to the peaks of the Apuan Alps, a true hiker's paradise. Also, we cannot fail to mention the world-famous marble quarries, particularly present and developed on the western side of the mountain territory, bordering the nearby municipality of Carrara.



Map Legend

Topology

- Corso d'acqua rappresentabile/fiume/canale
- Depuratore
- Boschi
- Colture
- Strada
- Edifici civili/sociali/amministrativi
- Edifici industriali/commerciali/capannoni

River - Massa

- river

Municipality of Massa

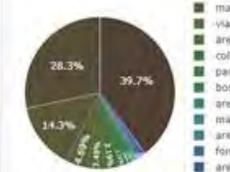
- Municipality of Massa



Type of river

el_idr_nom	al_dsede
FOSSO MAGLIANO	Su piano di campagna
FOSSO MAGLIANO	Su piano di campagna
FOSSO MAGLIANO	Su piano di campagna
TORRENTE MONTIGNOSO	Su piano di campagna
FOSSO DEL SALE	Su piano di campagna
FOSSO MAGLIANO	Su piano di campagna

Type of topology



- unita volumetrica
- area attrezzata del suolo
- area di circolazione veicolare
- manufatto civile, monumentale e di arredo urbano
- viabilità mista secondaria
- area di circolazione pedonale
- coltura agricola
- pascolo o incolto
- bosco
- area di mare
- manufatto industriale
- area bagnata
- forma naturale del terreno
- area verde

Geomorphology

admin: June 28th 2022

admin: June 28th 2022

admin: June 28th 2022

dataset: MODnet Geology project phase III between 2017 and between 10 000 and 5 000 000.

admin: https://www.emodnet.eu/

30 Session 2: Data-Driven and Nature-Based Adaptation – Tools for Today and Tomorrow



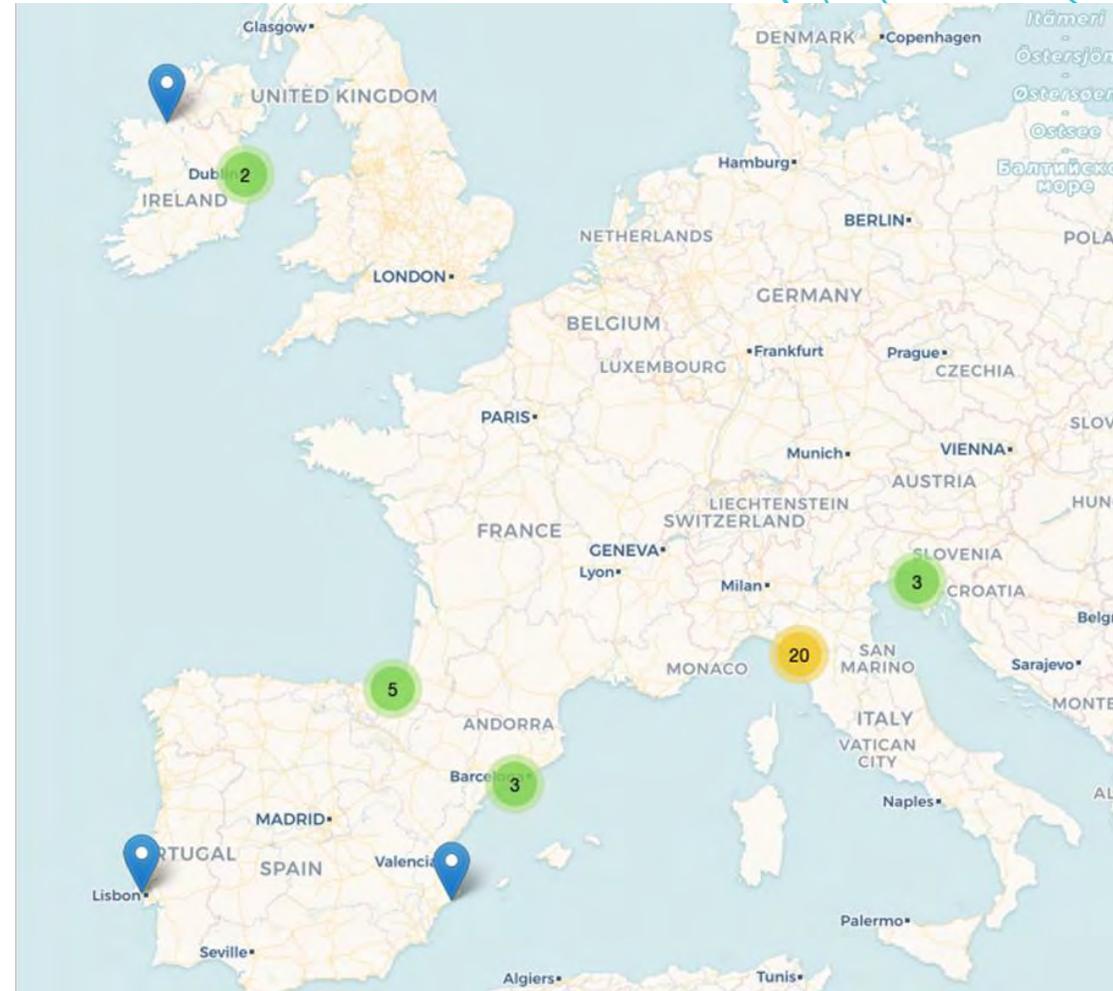
The SCORE ICT data Platform (SIP)

Sensor Service:

- **Collecting data** from both the institutional sensors and the SCORE citizen low-cost sensors used in WP4
- **Sharing the sensor data** to Early Warning Support and Digital Twin platform, WP8
- **Supporting citizen activities** by enabling the collection of field data within the CCLLs,
- **Connecting the CCLL sensors** with the SCORE ICT platform.

Data collection from Institutional & Professional Sensor Networks

CCLLs	Massa, Sligo, Oarsoaldea, Benidorm, Oeiras, Piran, Dublin, Vilanova
Stations	36
Data streams	75
Observations (measurements)	> 7.340.000



Thank you!



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- ECCA 2025, 17 June 2025

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Smart Pebbles Experiment Massa CCLL



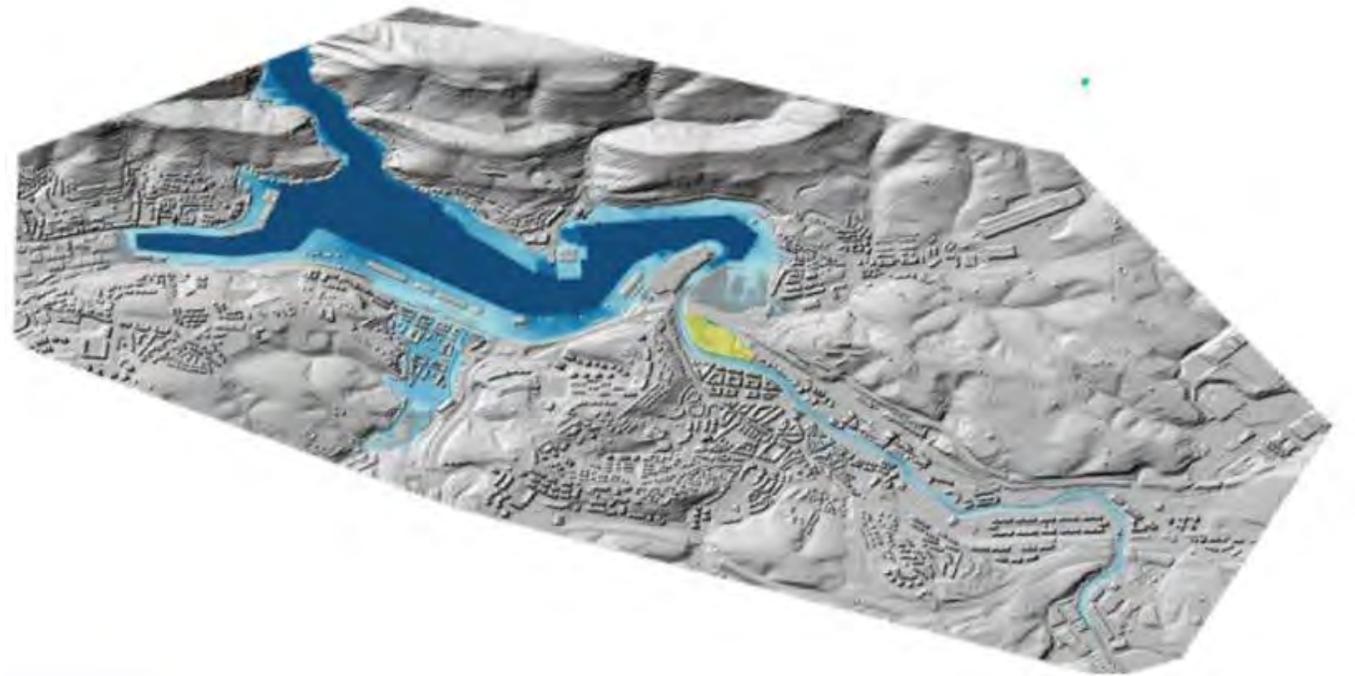
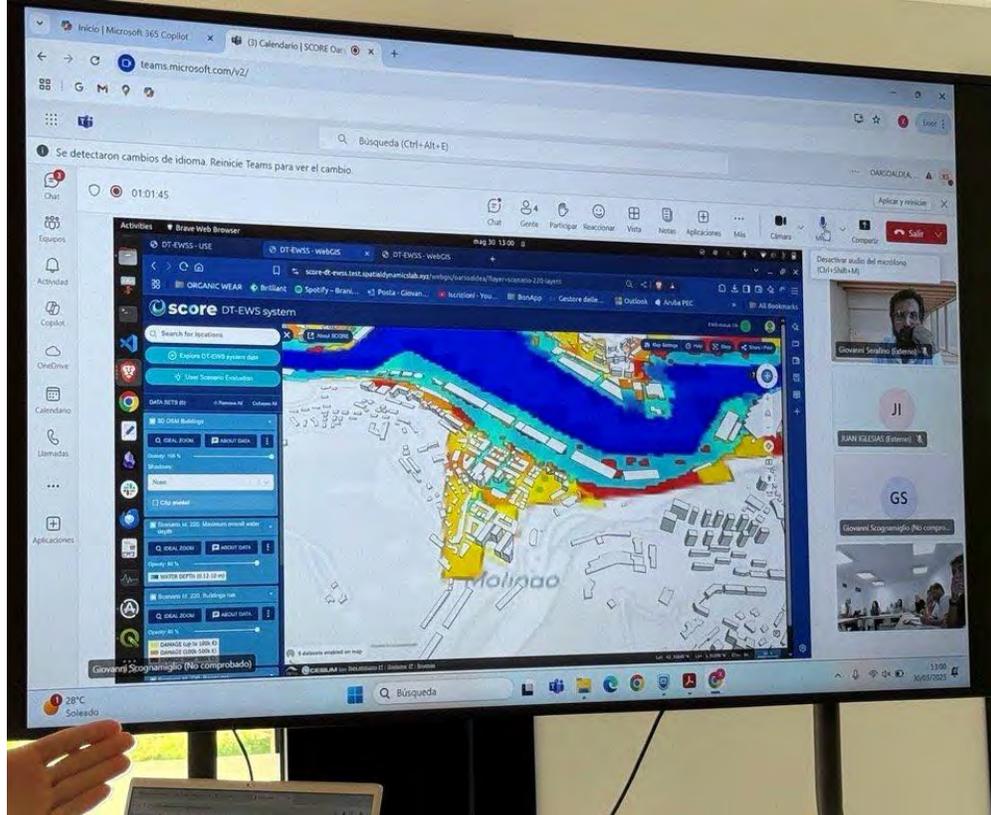
DT-EWS Local Presentation Event

OARSOALDEA CCLL



DT-EWS

OARSOALDEA CCLL



LOW-COST SENSORS

OARSOALDEA CCLL



FINANCIAL RESILIENCE STRATEGIES

OARSOALDEA CCLL

Investing in Climate Adaptation

Enhancing Oarsoaldea's Climate Resilience

Disaster Risk Financing (DRF) Guidelines Aims: This strategy provides financial guidelines to help manage the increasing risks of climate-related disasters.



Flood Risk in Oarsoaldea

- **Hazards:** Exposed to fluvial flooding, particularly within its dense urban areas.
- **Loss Estimates:** Baseline average annual losses are around €3.5 million. Frequent (1-in-10-year) events could result in €16 million in losses, while a rare (1-in-200-year) event could cause €31-38.5M in damages.
- **Fiscal Exposure:** A dedicated budget to address high frequency (1-in-10-year) losses is lacking, creating a critical protection gap.

Key Recommendations for Managing Risk

1) Risk Reduction - Prioritise Expanded Measures Beyond EBAs. Risk reduction must be prioritised. The implemented Ecosystem-Based Adaptation (EBAs) provide only modest reductions. Additional risk reduction options to be explored to meaningfully reduce the cost of forecasted risks.

2) Risk Retention - Use Reserve Funds Where Feasible. Without further risk retention capacity, the city may require ~€16 million/year in reserve fund capacity to absorb frequent event costs. Aim to cover these with adequate reserve funds, explore collaborative risk pools within the region, and event-contingent credit lines.

3) Risk Transfer - Use a Layered Insurance Approach. On top of traditional insurance, use parametric (index-based) insurance to cover excess risk - around €20 million in coverage is needed to reach its resilience goals.



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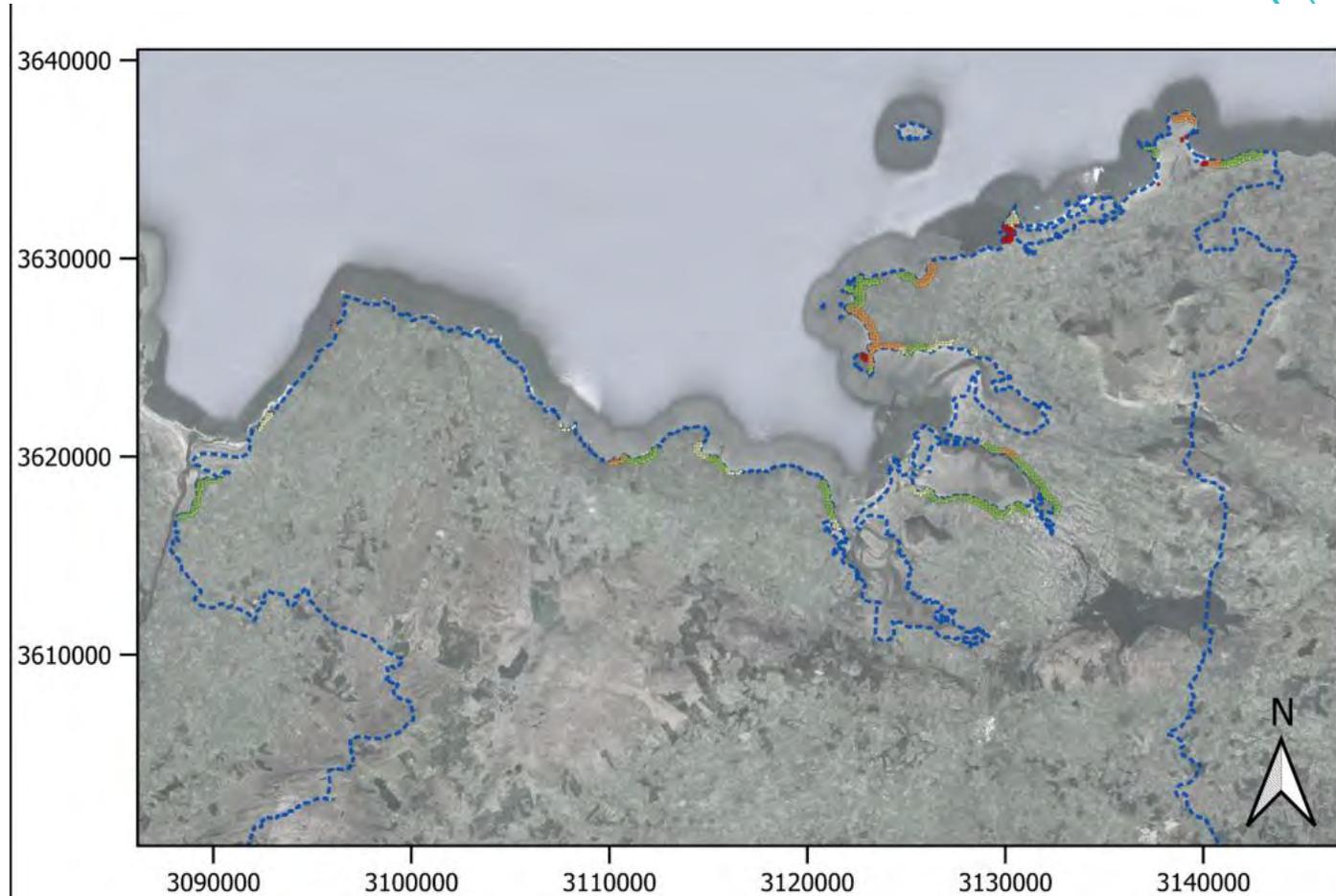
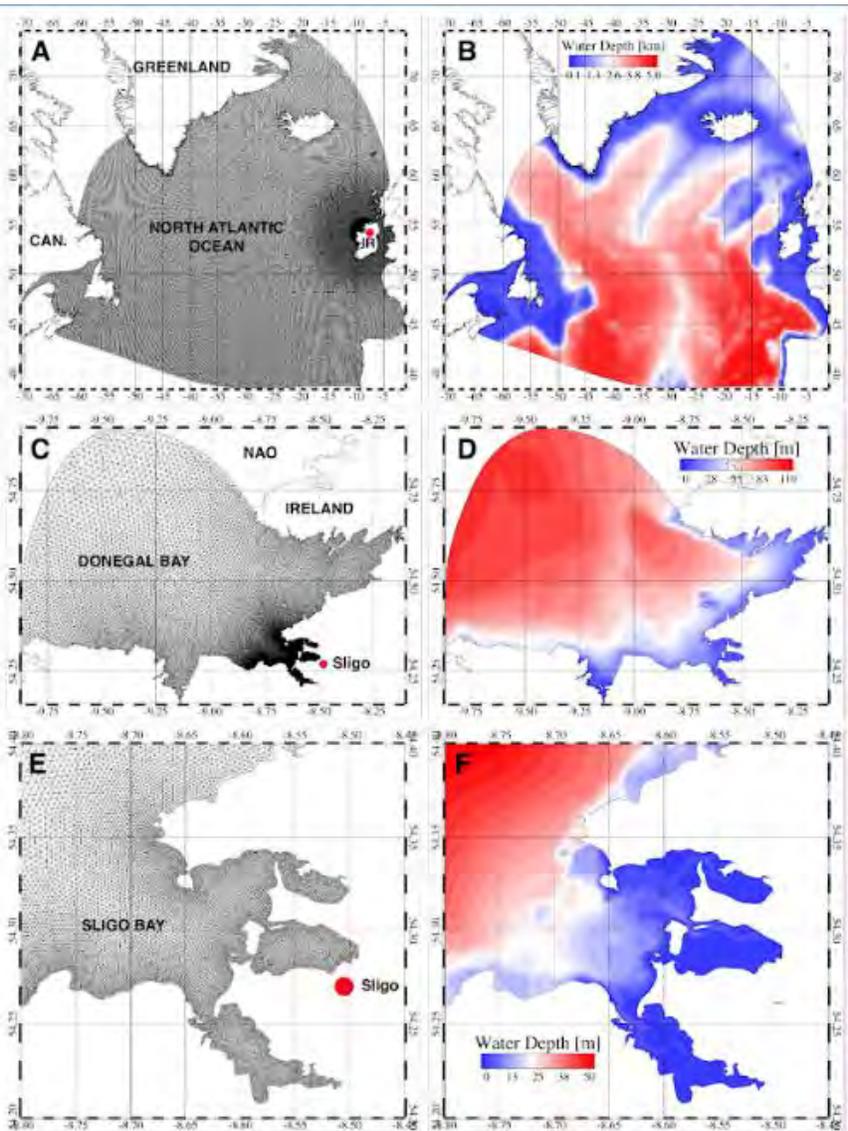
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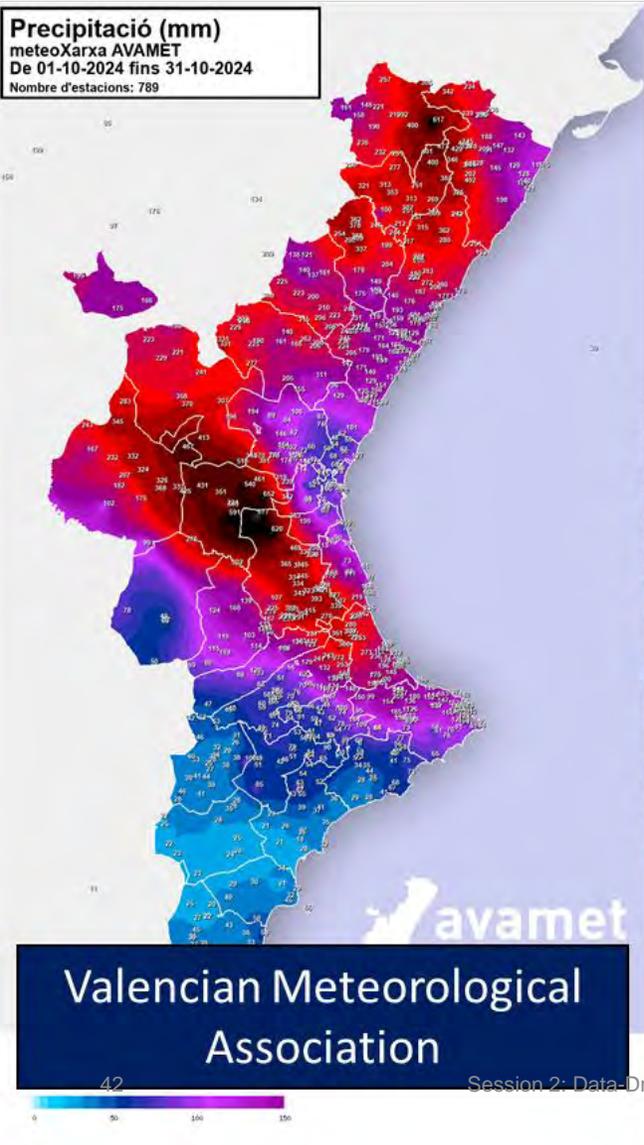
SLIGO CCLL



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Cameras with integrated AI



EBA Solutions



EBA Selection Workshop



Thank you!

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