IHcantabria
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European Coastal Flood Hazards

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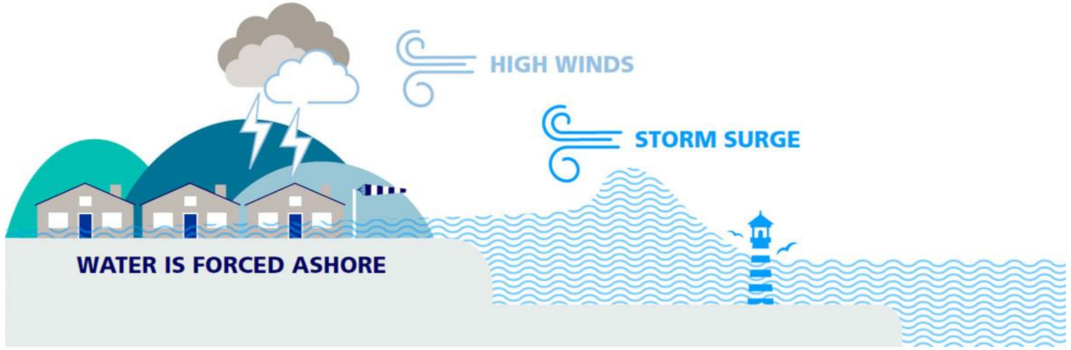
25th of September, 2025

LARGE-SCALE COASTAL FLOODING

Coastal zones → Coastal impacts + climate change → Increase in population → Impacts to assets → Decision-making and coastal management



Large-scale
vs
Local-scale

Homogeneous
vs
Generalized

2014 Storm – El Sardinero (Santander, Spain)

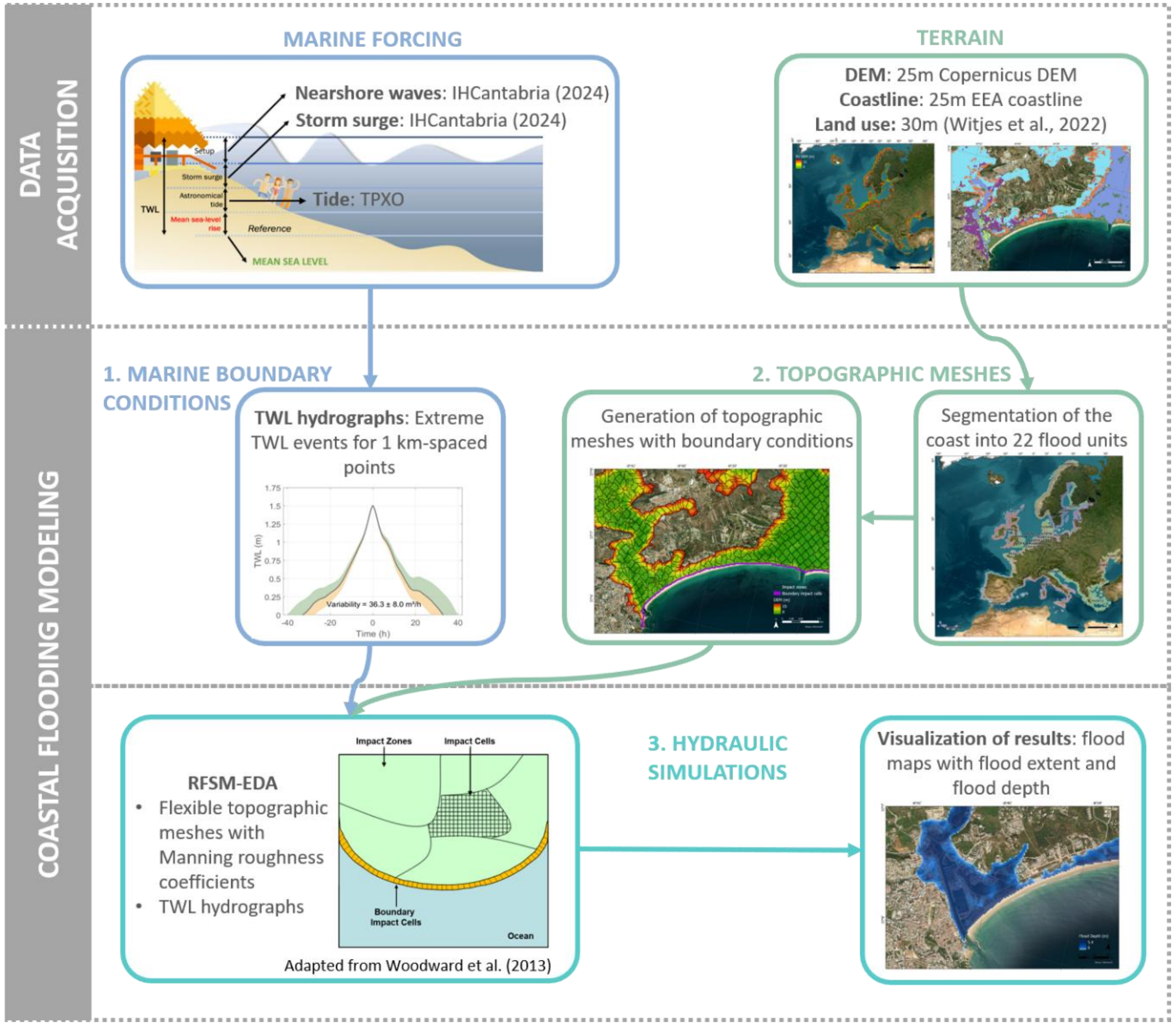
OBJECTIVE

To improve the characterization of **large-scale** coastal flooding with a focus on the generation of **flood maps**

Development of a homogeneous approach that considers climatic and morphological spatial variability

1. Marine forcing conditions
   - Coastal storm characterization
   - Location-specific hydrographs
2. Process-based flood modeling
   - Continental-scale

Pilot case: **Europe**

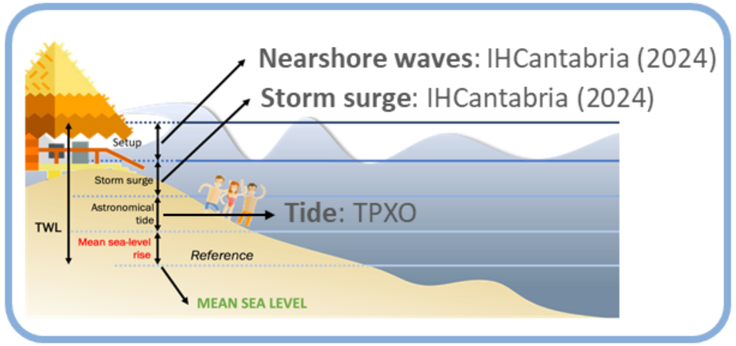


CoCliCo coastal climate core services | HORIZON 2020 | Comisión Europea

R+D+i for sustainable development

Financiado por la Unión Europea NextGenerationEU | Gobierno de España Ministerio de Ciencia e Innovación | Plan de Recuperación, Transformación y Resiliencia | Gobierno de Cantabria | Año Jubilar Lebaniego 2023·2024

MARINE FORCING



TWL hindcast
1985 – 2021
1 km

WAVE CONTRIBUTION

Nearshore wave conditions

↓

DOW2

→

Foreshore slope

Sunamura (1984)
and normalized as Melet et al. (2020)
Spatially and temporally variable

$$\beta = 0.12\left(\frac{H_s}{T\sqrt{gD}}\right)^{-\frac{1}{2}}$$

tan α = foreshore slope
H_b = wave height
g = gravity
T = wave period
D = sediment grain size (250 µm)

→

Wave setup

Stockdon et al. (2006)
Static wave setup

$$\eta = 0.035\beta\sqrt{H_s L_0}$$

$$L_0 = \frac{gT^2}{2\pi}$$

H_0 = wave height
L_0 = wavelength
η = static wave setup
β = foreshore slope
T = wave period

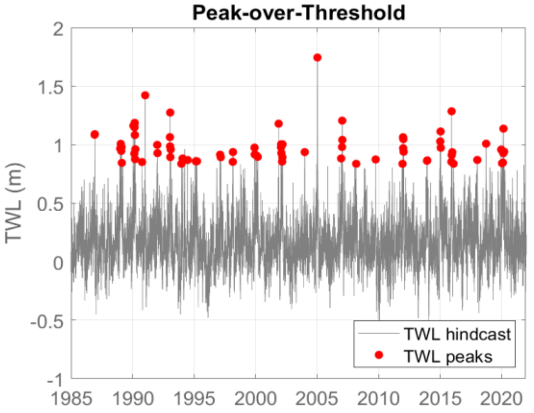
STILL WATER LEVEL

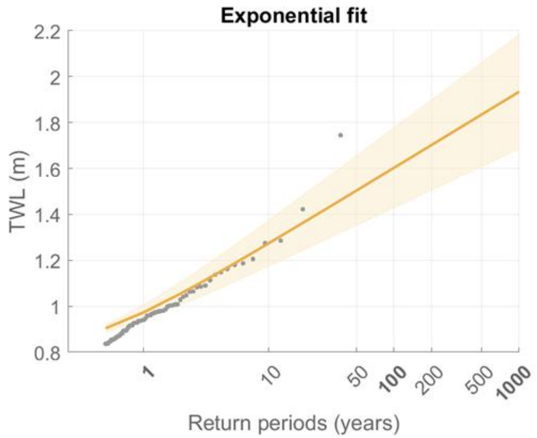
Astronomical tide → TPXO9

Storm surge → ERA5

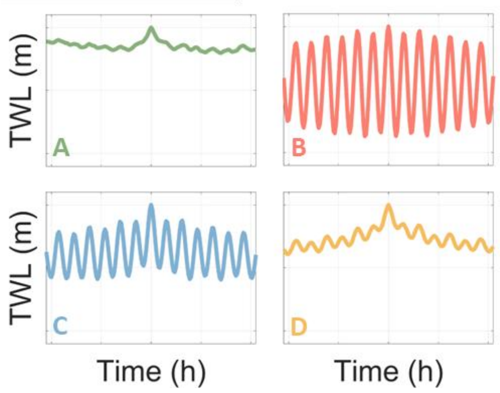
HYDROGRAPH DESIGN – KASTNA (EE)

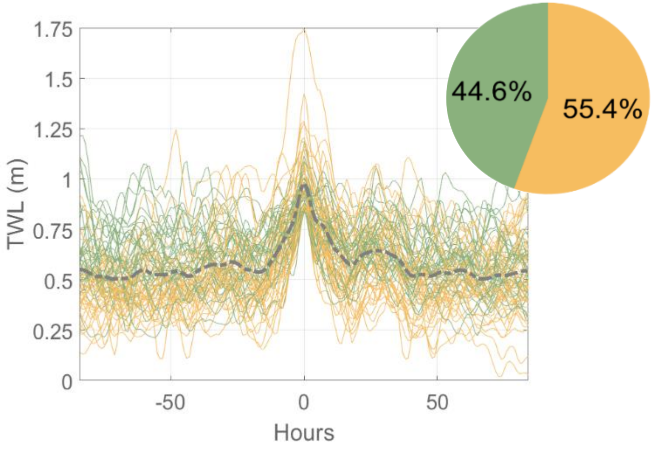
1. Extreme value analysis



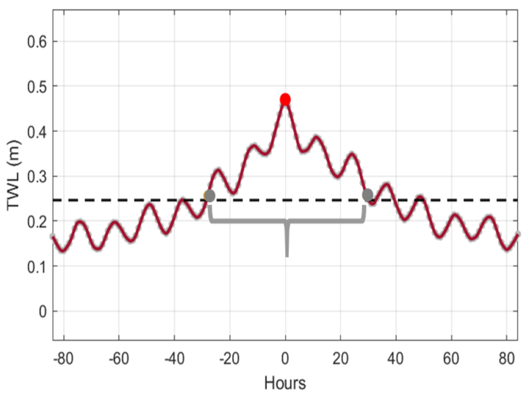


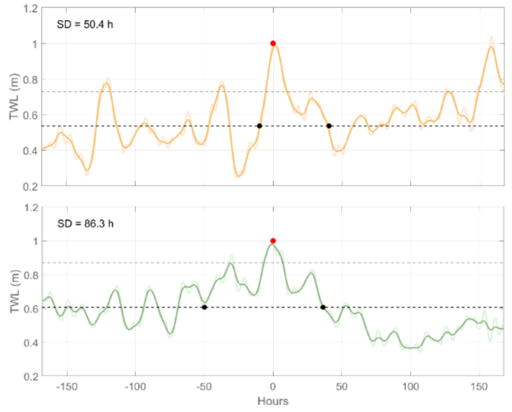
2. Individual storm classification



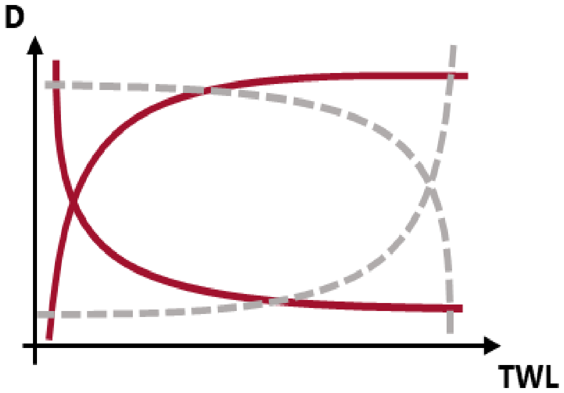


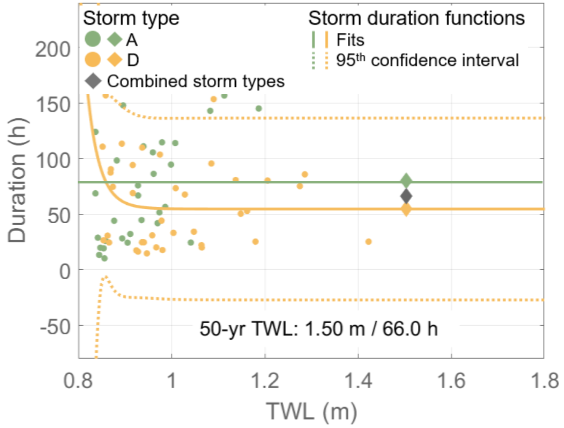
3. Individual storm duration





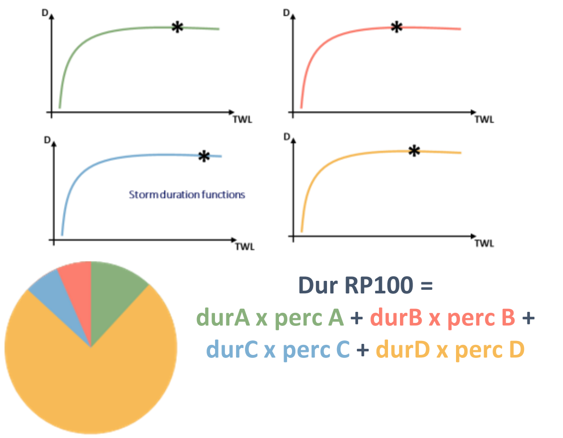
4. Storm duration functions

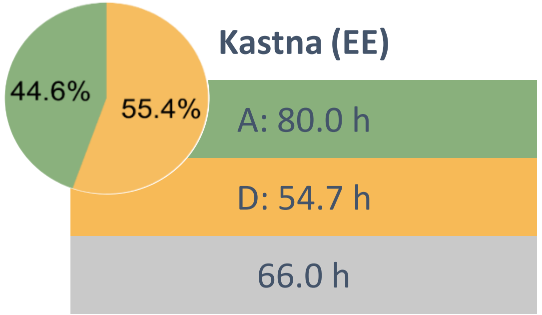




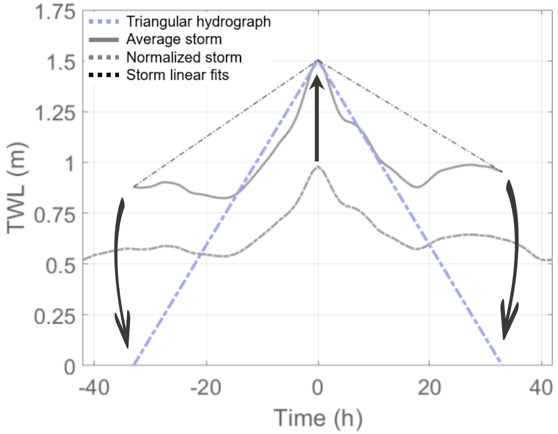
HYDROGRAPH DESIGN – KASTNA (EE)

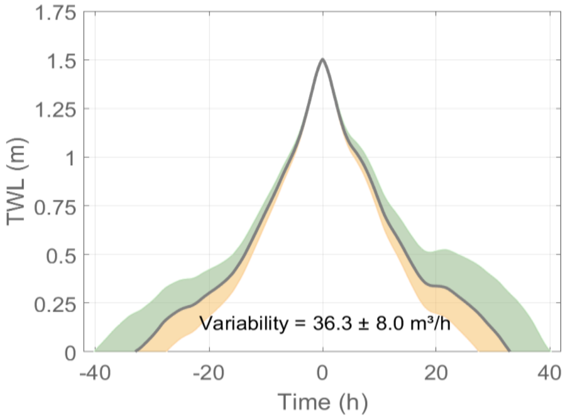
5. Estimation of RP storm duration



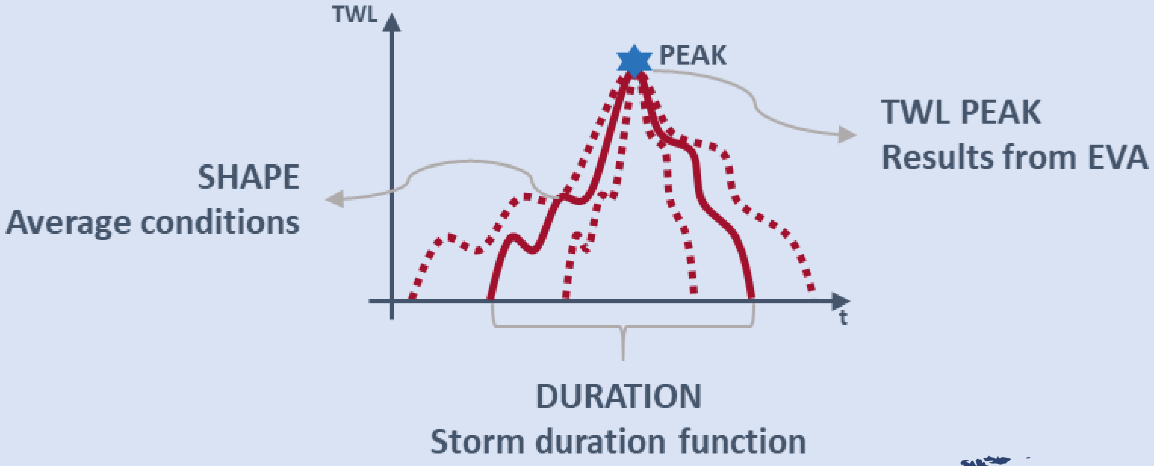


6. Hydrograph design





MARINE FORCING CONDITIONS
LOCATION-SPECIFIC HYDROGRAPH



OUTCOME

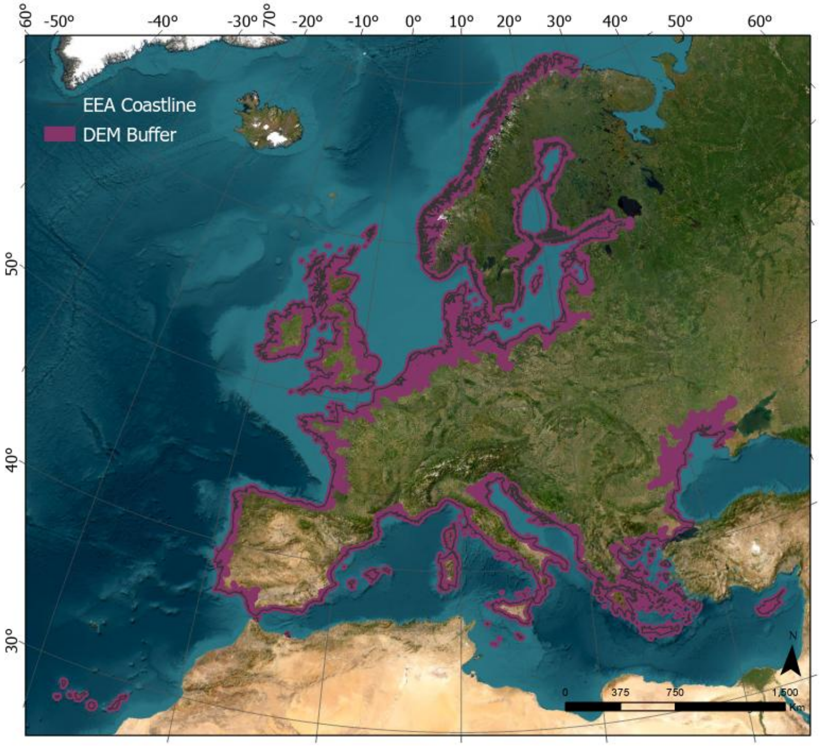
- 51,010 points
- 1 km resolution
- Individual storm types
- Combined storm type scenarios

TERRAIN

1. Data collection

DEM: Copernicus 25m

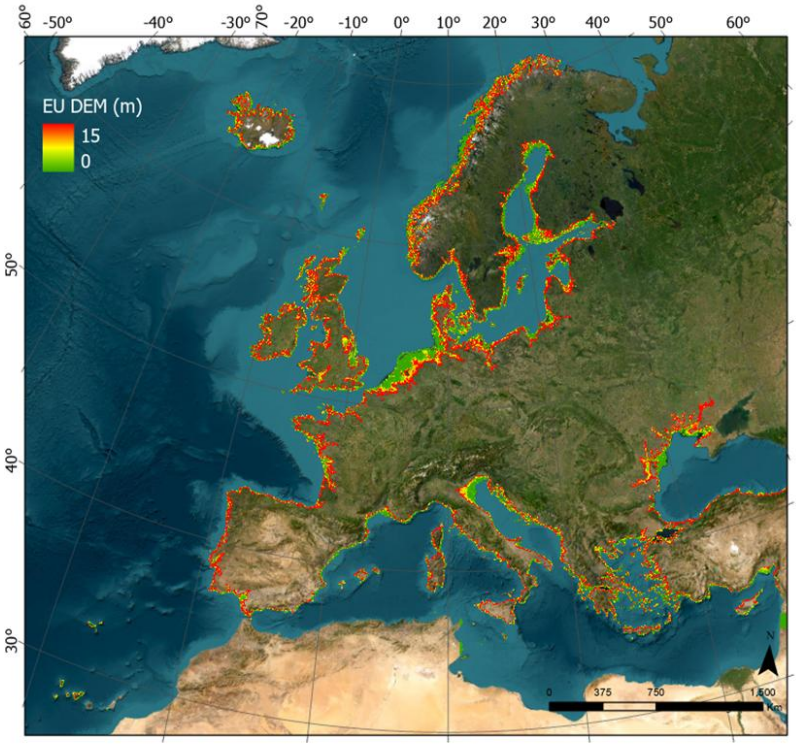
Coastline: EEA 25m



2. Floodplain definition

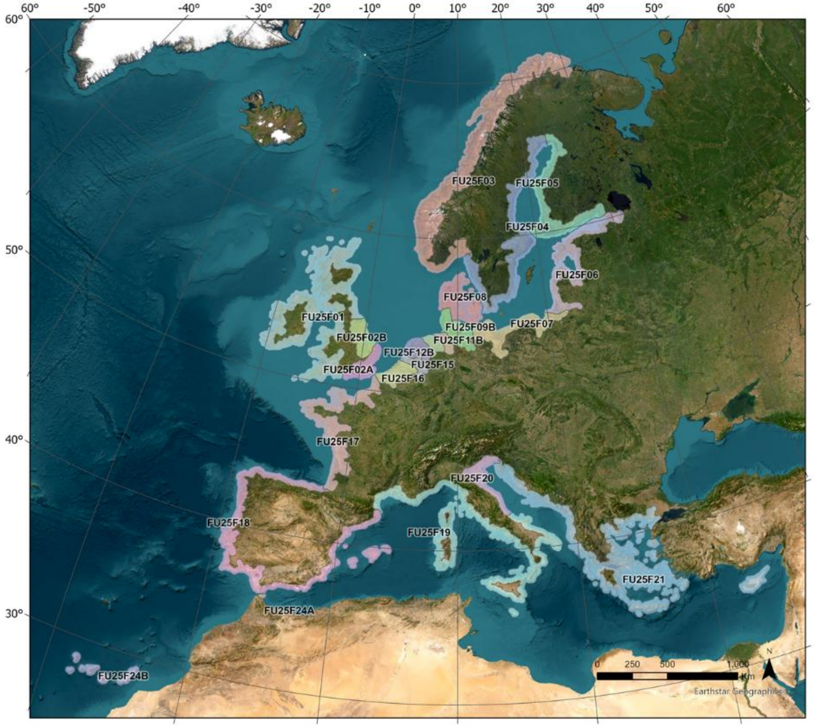
Elevation: 0 – 15m

Hydraulic connection to the sea



3. Pre-processing

Coastal segmentation to address computational limitations

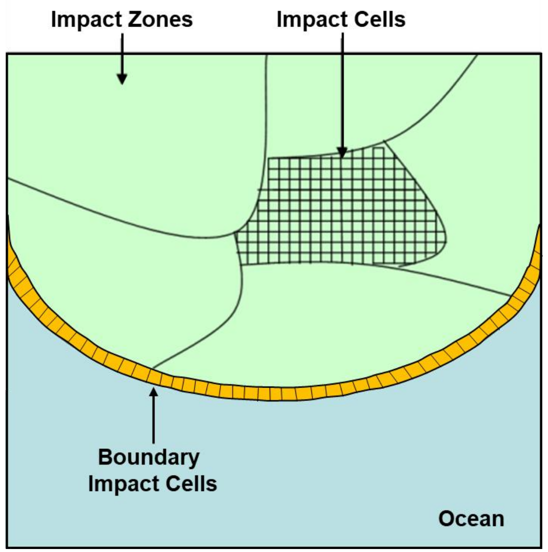


TOPOGRAPHIC MESHES

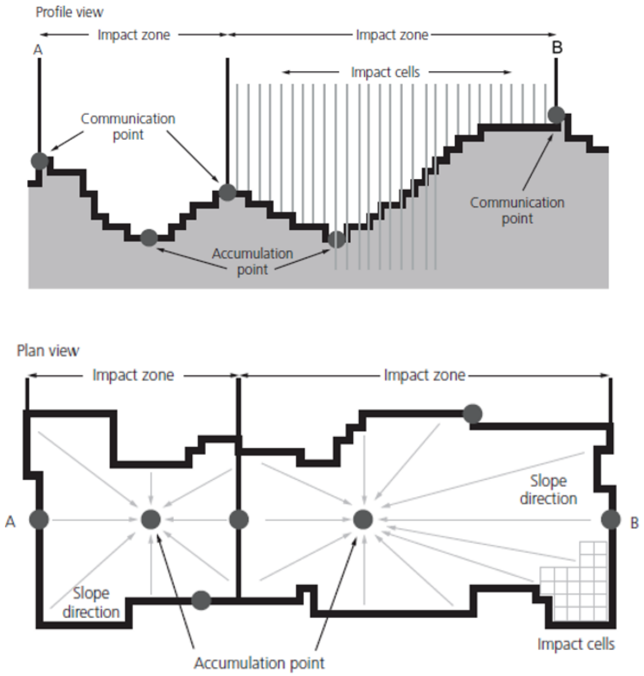
RFSM-EDA (Jamieson et al., 2012)

Rapid Flood Spreading Method – Explicit Diffusion wave with Acceleration term

- Very fast execution
- Adaptive time step + local inertia
- Sensitivity to Manning's roughness coefficient
- Analysis of flood evolution



Adapted from Woodward et al. (2013)



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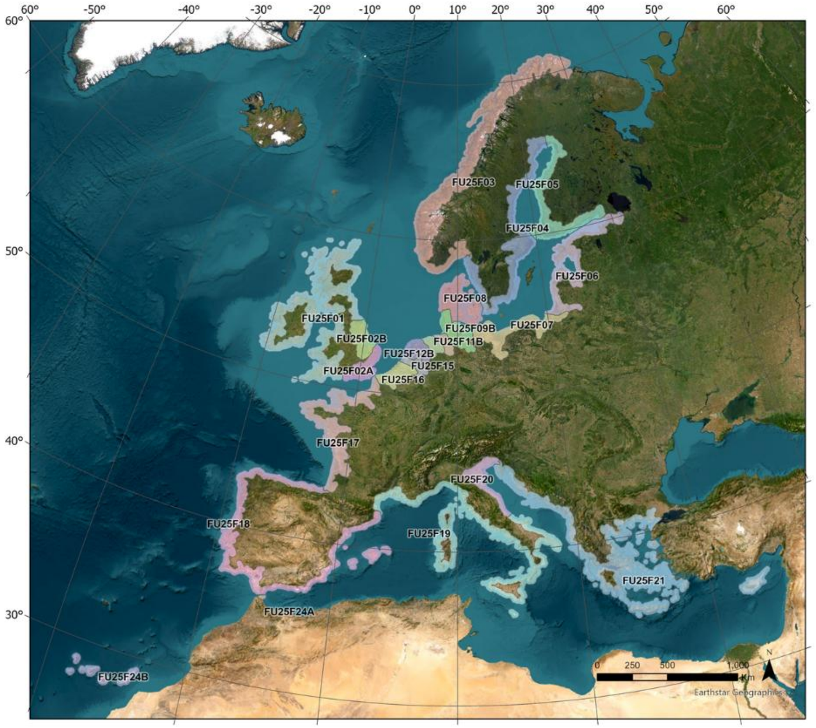

Computational limitation (512 GB RAM):

- 1.35×10^{10} m²
- 43GB ASCII file
- 450,000 impact zones

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Gobierno de España, Ministerio de Ciencia e Innovación
Plan de Recuperación, Transformación y Resiliencia
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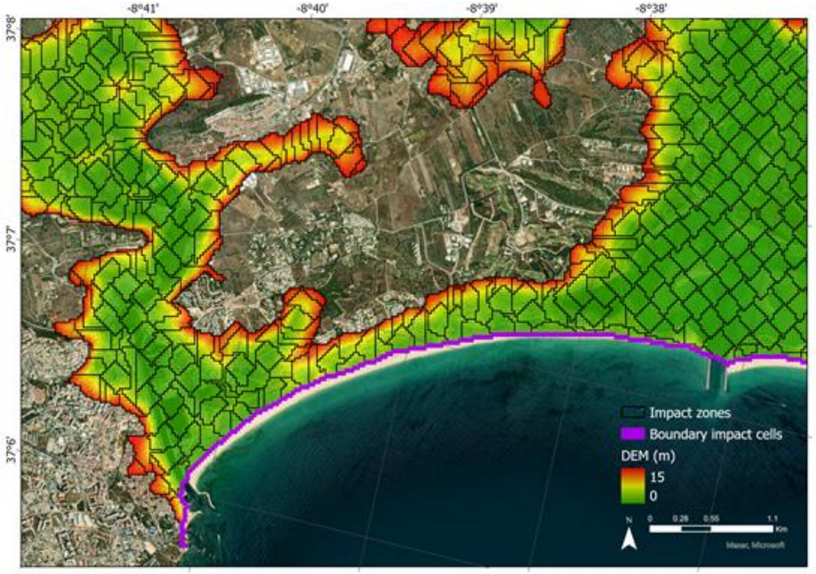
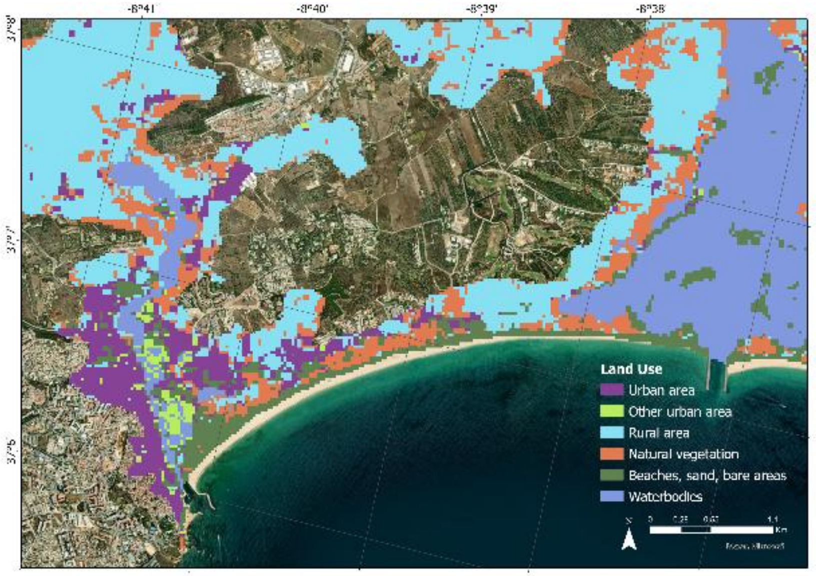
TOPOGRAPHIC MESHES – LAGOS (PT)

TOPOGRAPHIC MESHES



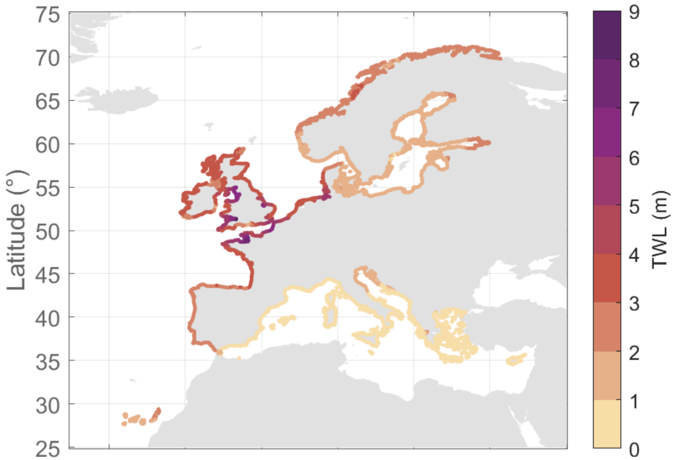
LAND USE



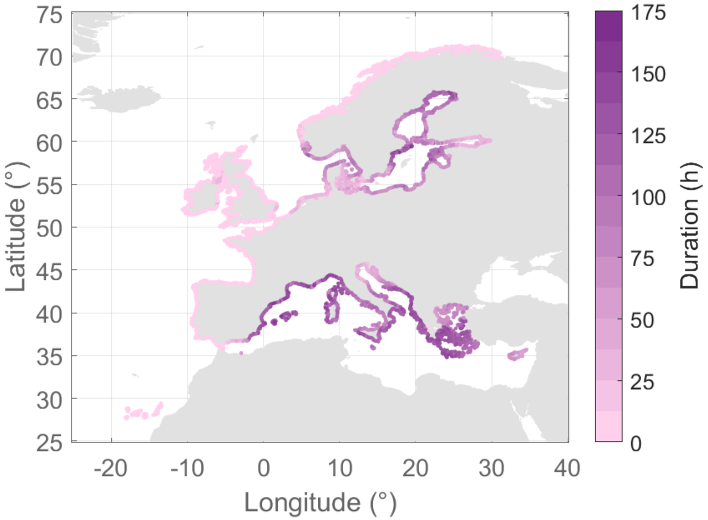
FLOOD MAP

EUROPEAN COASTAL FLOODING – 100yr TWL

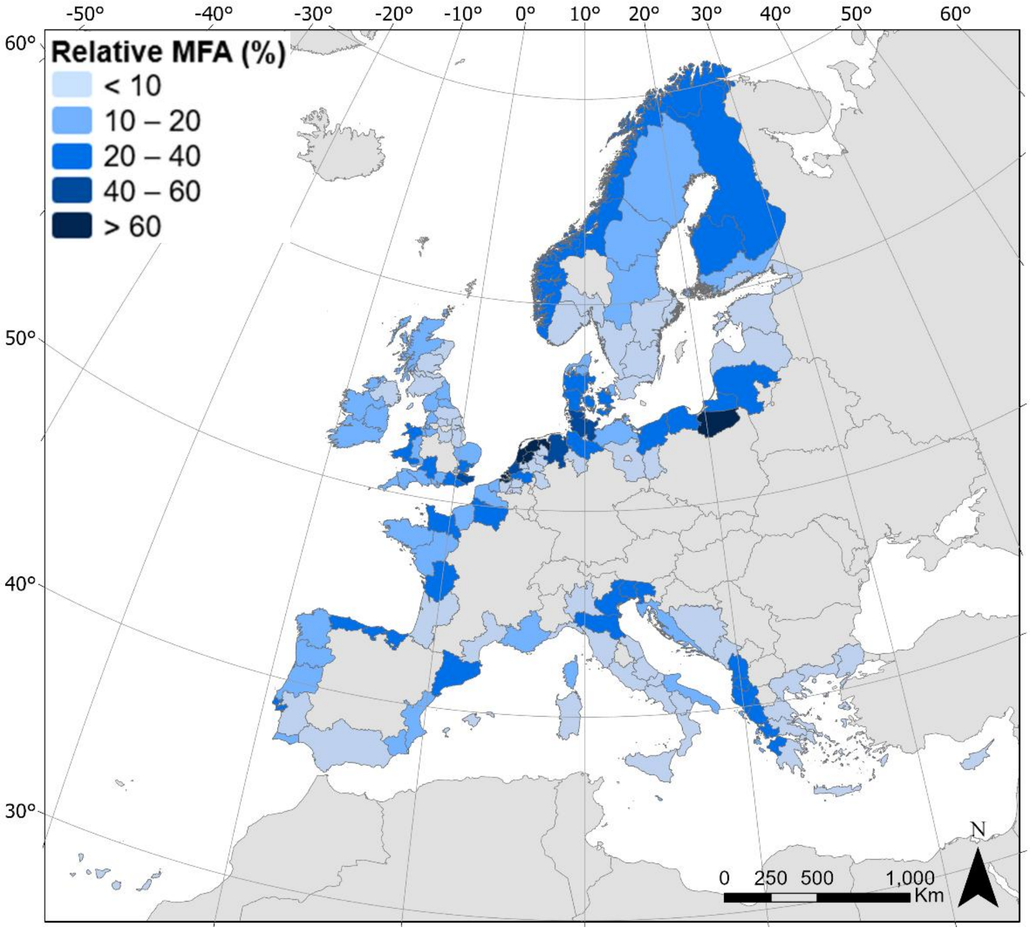
RETURN LEVELS



DURATION



RELATIVE MAXIMUM FLOODED AREA

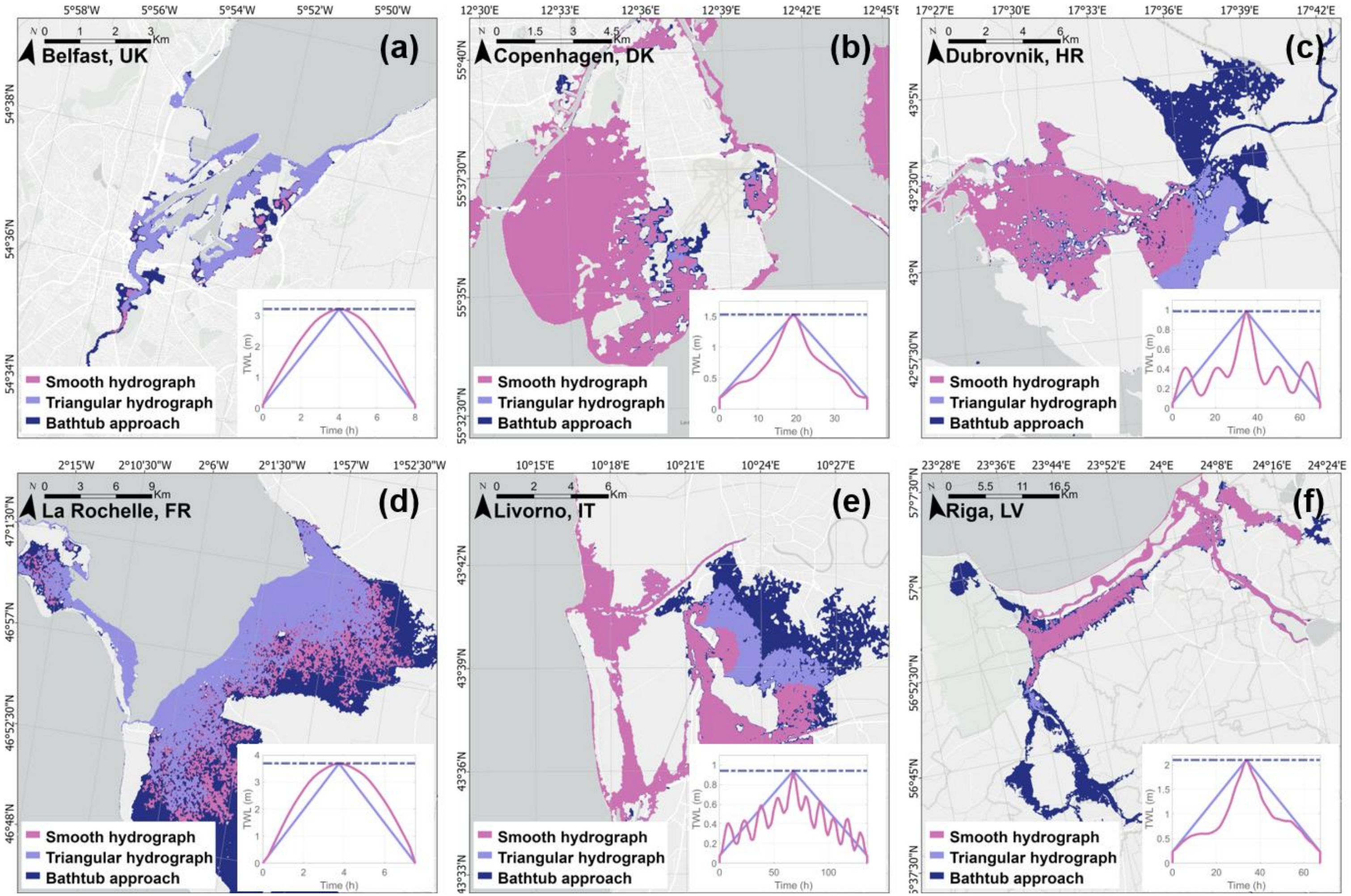


Study area	100-yr MFA (m2)
Europe	47871.67
Atlantic coast	31840.03
Baltic Sea	9289.10
Mediterranean Sea	6742.38

~ 22% of the EU floodplain

~ 28% of the Atlantic floodplain
~ 16% of the Baltic floodplain
~ 17% of the Mediterranean floodplain

EUROPEAN COASTAL FLOODING – SENSITIVITY ANALYSES



- Modeling approach static vs dynamic flood modeling
- Hydrograph shape triangular vs smooth-shaped
- Storm type variability

Quantification of uncertainty

~ 22% of the EU floodplain

~ 10% EU uncertainty

EU 100-yr TWL flooded area 19.8 – 24.2% of the floodplain

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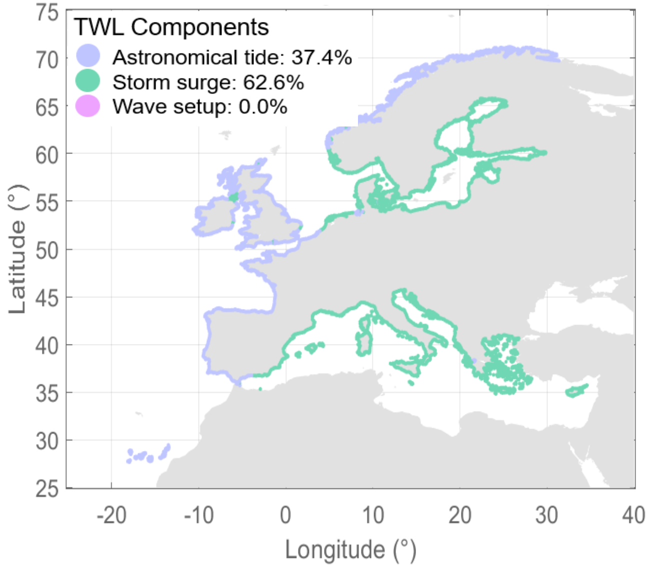
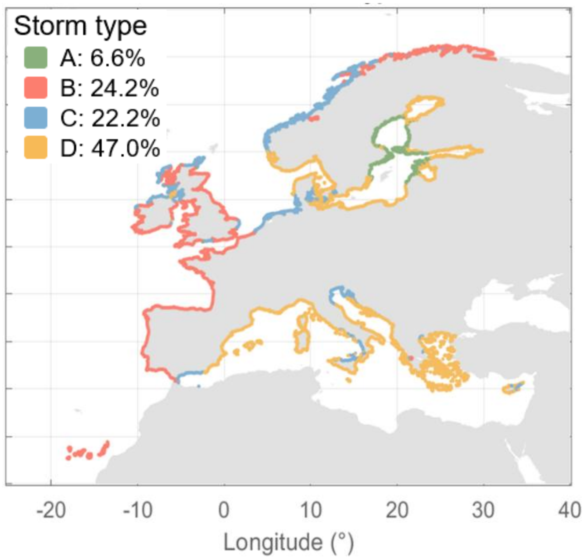
Plan de Recuperación, Transformación y Resiliencia

KEY FINDINGS

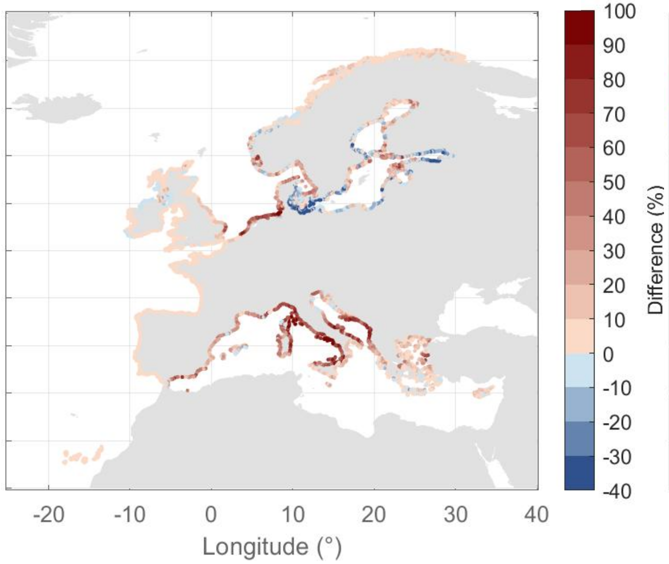
STORM CONDITIONS



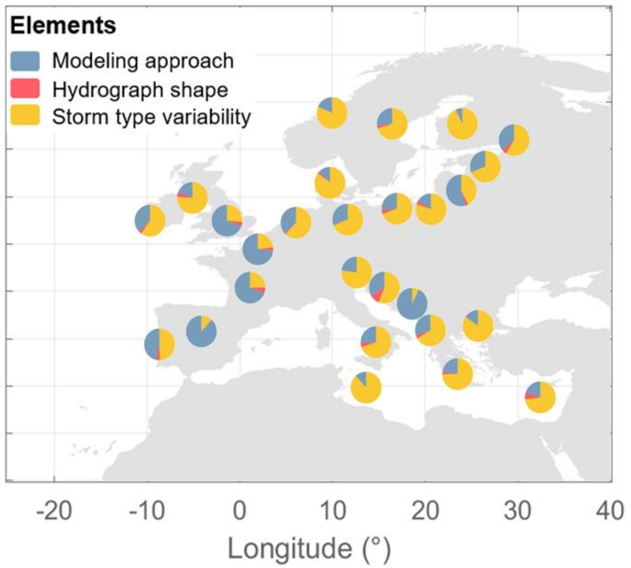
STORM CLASSIFICATION



STORM DURATION



COASTAL FLOOD MODELING SENSITIVITY



EXTREME TWL COASTAL FLOODING IN EUROPE

Atlantic coast	Baltic Sea	Mediterranean Sea
Tide-dominated storms	Storm surge-dominated storms	Mixed storms
Low hydrograph uncertainty	Lowest confidence of EVA results	Highest storm durations
Most sensitive to modeling approach	Most sensitive to storm type variability	Most sensitive to hydrograph shape

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CONCLUSIONS

Outcome

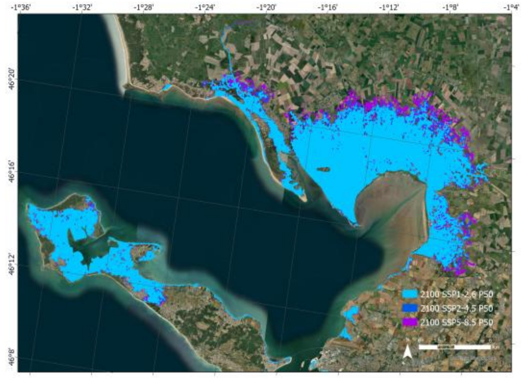
- Development of a **homogeneous methodology** to assess coastal flooding from storms considering the heterogeneity of a large-scale study
- Applicable to local and regional scale studies

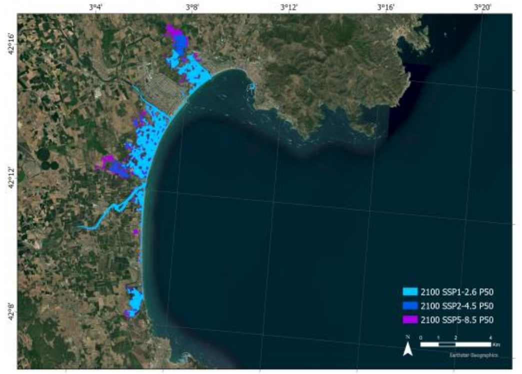
Europe Pilot Case

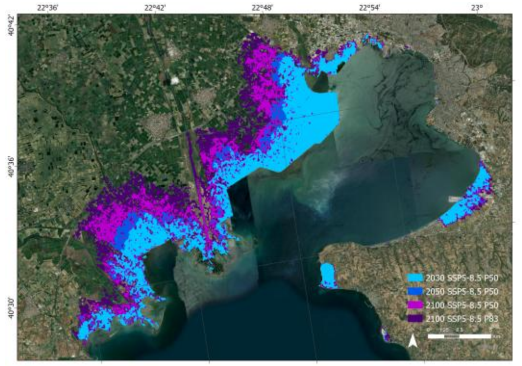
- Identification of **four storm types**
- Division of the study area into **three regions**
- Quantification of flood maps **uncertainty**

Associated publications

1. Cotrim, C., Toimil, A., Losada, I., Menéndez, M., and Lobeto, H.: **Assessing extreme total water levels across Europe for large-scale coastal flood analysis**, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2025-2998, 2025. *(under review – EGU NHESS)*
2. Cotrim, C., Toimil, A., Losada, I., Lobeto, H., and Menéndez, M.: **A framework for storm classification and hydrograph generation from total water level in Europe** *(under review – AGU Earth's Future)*
3. Cotrim, C., Toimil, A., Losada, I., Novo, S., and Suárez, I.: **Pan-European assessment of coastal flood hazards** *(in preparation)*







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