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Extreme Storm Surge Events in the Mediterranean: Variations in a Changing Climate

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Motivations

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The Mediterranean is a **climate change hotspot** and one of the most **densely populated** coastal regions in the world.

Reliable scenarios are needed to design **effective adaptation** and **risk reduction** strategies.

Using a **large ensemble** allows us to quantify internal variability and uncertainties in **future projections**.

Extreme storm surge events can cause **severe impacts** on coastal communities, infrastructure, and cultural heritage.

Rapallo, Ligurian Sea, 29 October 2018

Objectives

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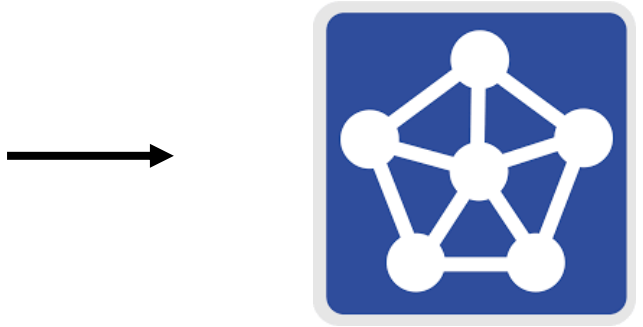
- **Modelling**:
  - Set up a **high spatial and temporal resolution** storm surge model across the **entire Mediterranean basin** using **Delft3D software**.
  - Develop a **hindcast dataset** (**45 years, 1979-2023**).
  - Develop a large ensemble of future storm surge projections up to the **end of the XXI century**, considering atmospheric forcing from **17 GCMs-RCMs** combinations, based on the **RCP8.5 climate change scenario**.
- **Data analysis**:
  - Analyses on **Extreme Surge Levels** and **variation in Return Periods**.



Modelling of hydrodynamic processes through the resolution of the Navier Stokes equations for an incompressible fluid, under the shallow water and the Boussinesq assumptions.

The Model

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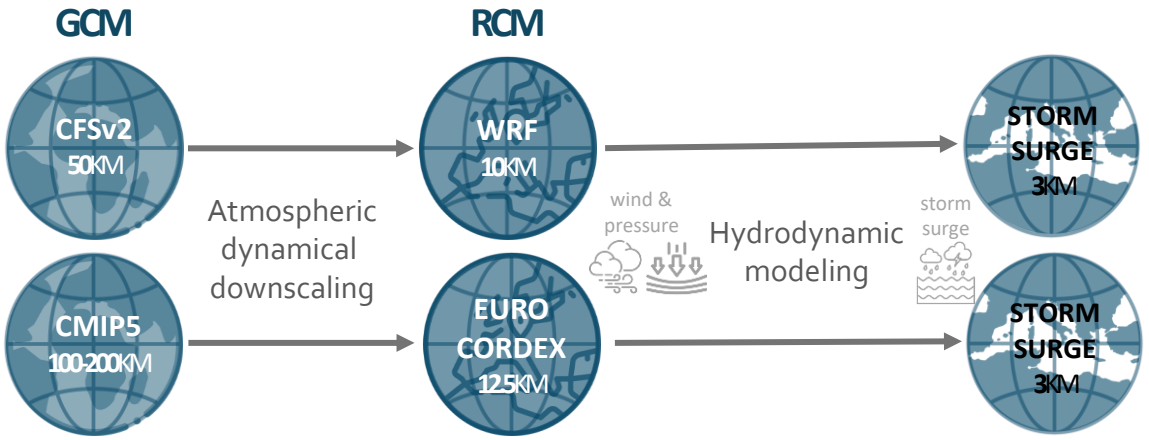
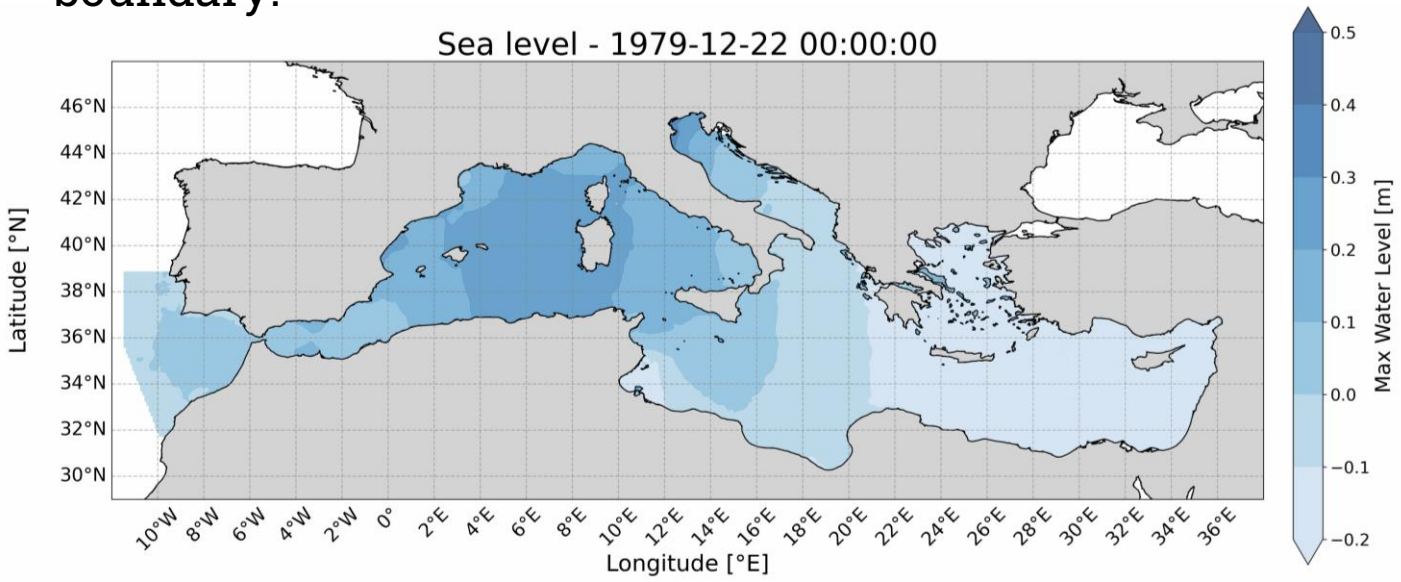
- Structured **grid** at **3km resolution** (more than 308’000 grid points).
- **Atmospheric forcing** at:
  - **10 km** spatial resolution – **1 hour** temporal resolution (**HINDCAST**).
  - **12.5 km** spatial resolution – **3 hours** temporal resolutions (**PROJECTIONS**).
- Specific parametrization for the Wind Drag Coefficient.
- **Single depth-averaged layer** in the vertical direction.
- **Inverse Barometer Effect** at the Atlantic Ocean open boundary.





→ MeteOcean DICCA (hindcast, 1979-2023)

→ Climate Models (projections, up to 2100)

Hindcast

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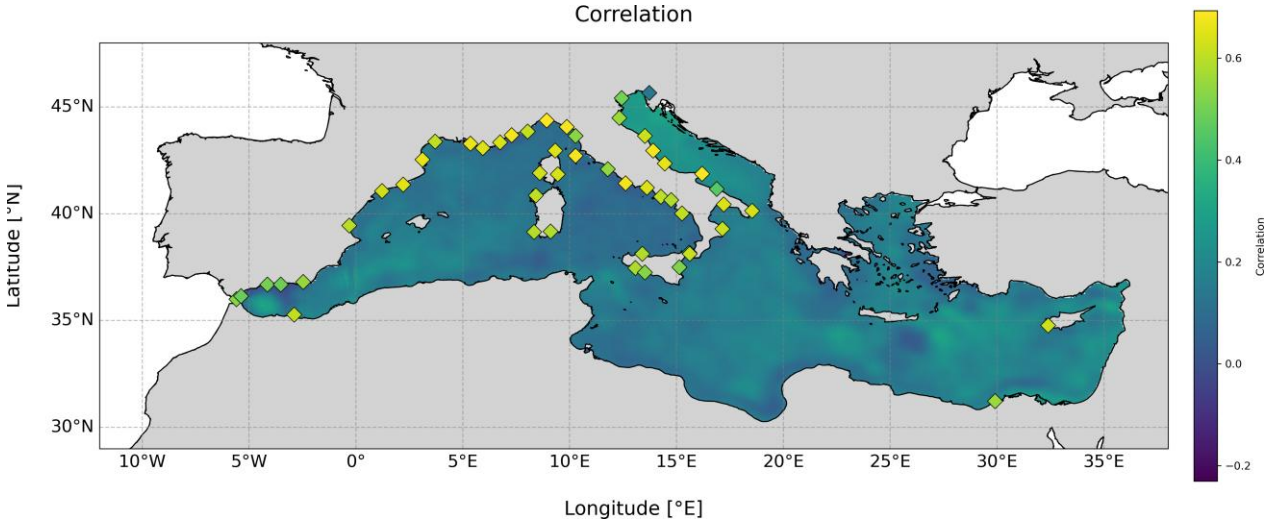
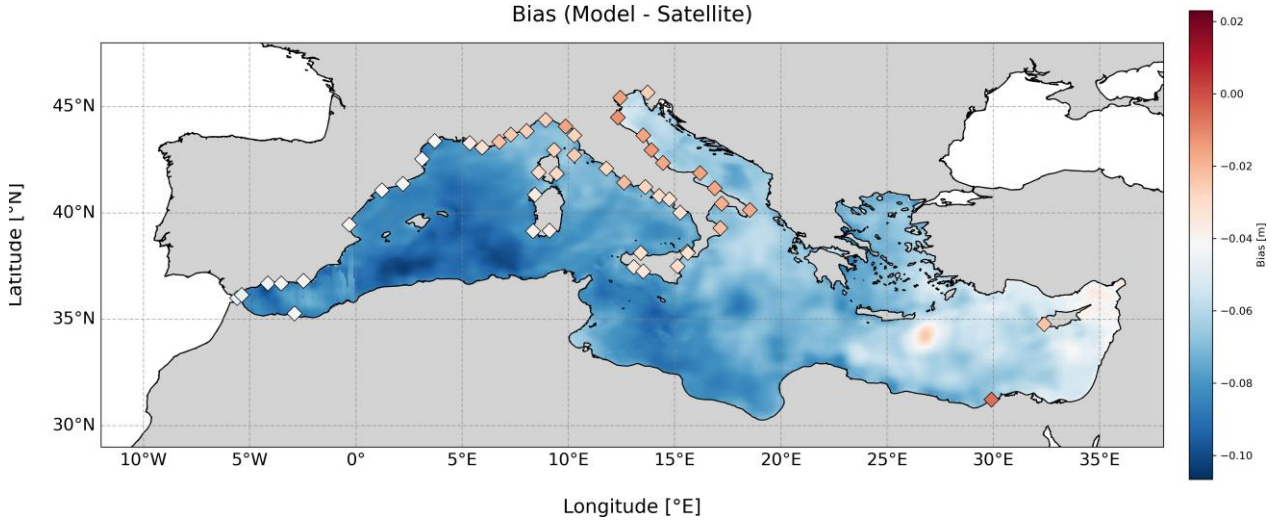
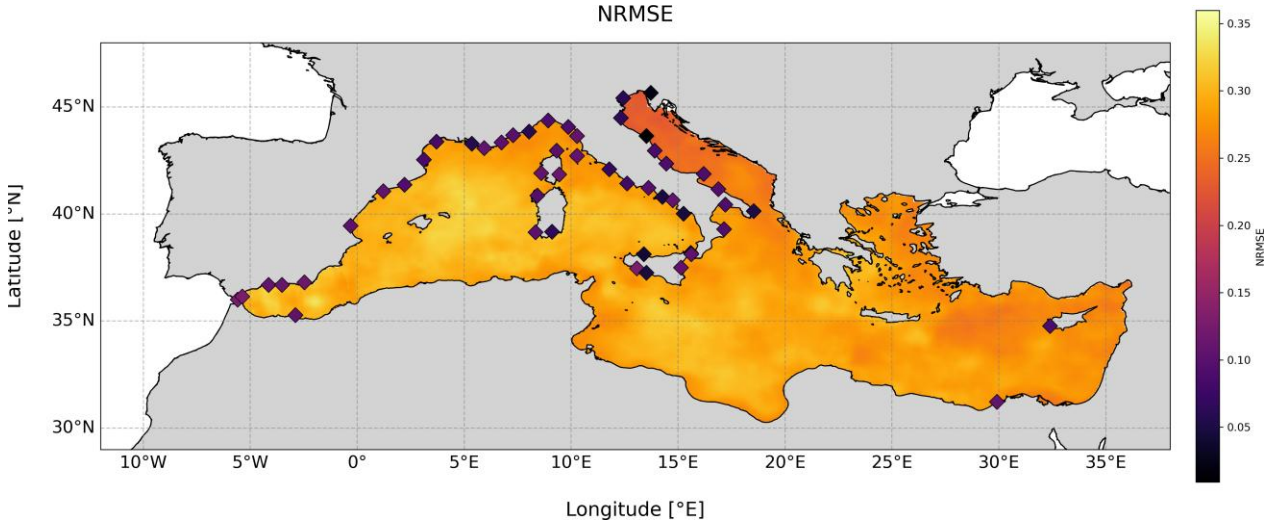
45 years dataset (1979-2023)







- **Hindcast Validation:**
  - **Tide gauges**: 51 stations from GESLA3 dataset (hourly resolution).
  - **Satellite data**: daily averages from CMEMS (available since 1993).

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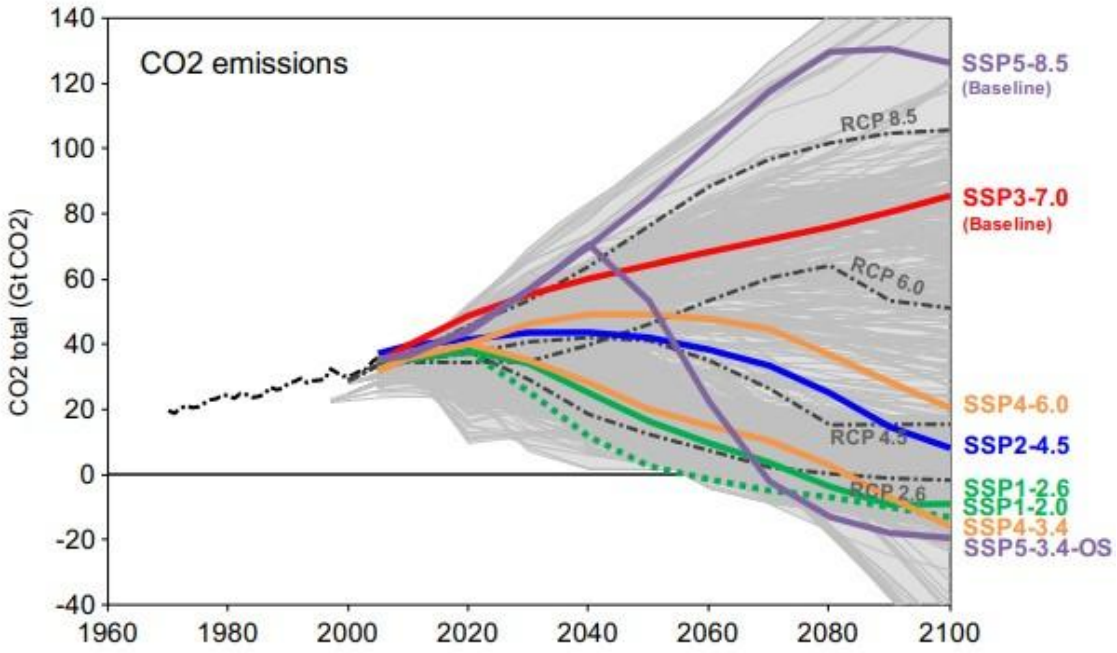
17 GCM-RCMs combinations:

GCM / RCM	CCLM4-8-17	RCA4	HIRHAM5	COSMO
CCCma-CanESM2	✓			
MIROC-MIROC5	✓			
CNRM-CERFACS-CNRM-CM5		✓	✓	
IPSL-IPSL-CM5A-MR		✓	✓	
MOHC-HadGEM2-ES		✓	✓	✓
MPI-M-MPI-ESM-LR		✓	✓	
NCC-NorESM1-M		✓	✓	✓
ICHEC-EC-EARTH		✓	✓	✓

RCP 8.5



- Baseline - **historical period** (1970-2005)
- **Projection** (2006-2100) → Allow assessment at **mid and end century**.

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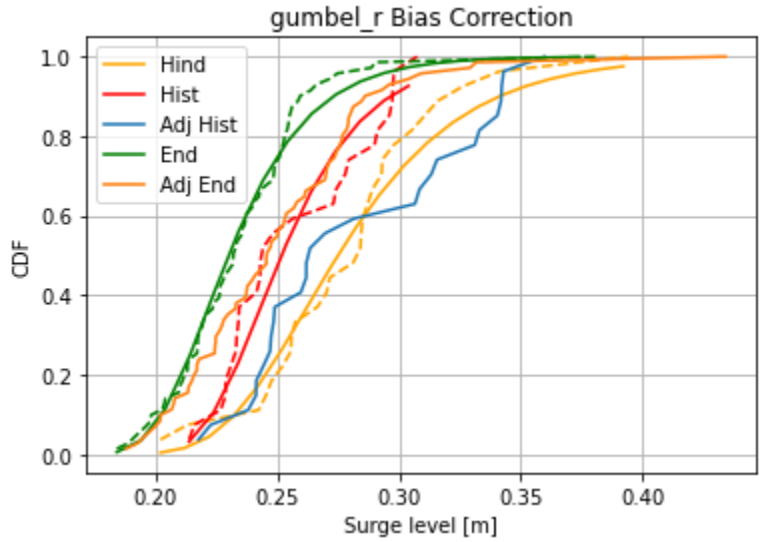
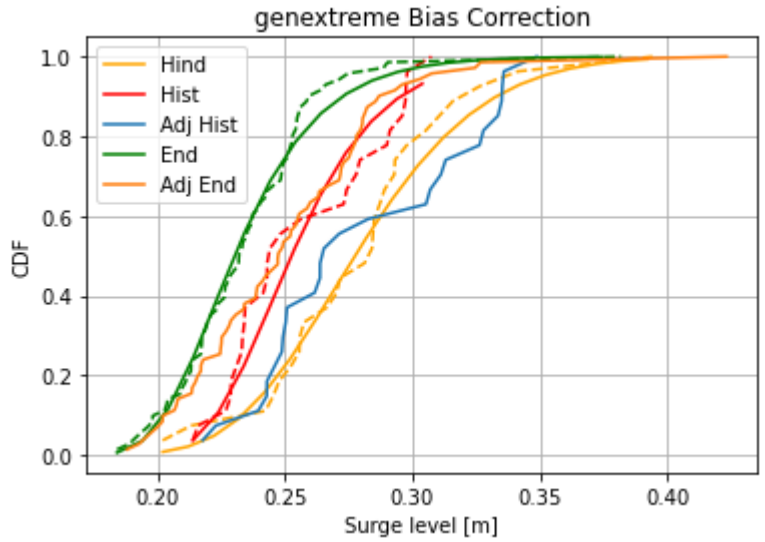
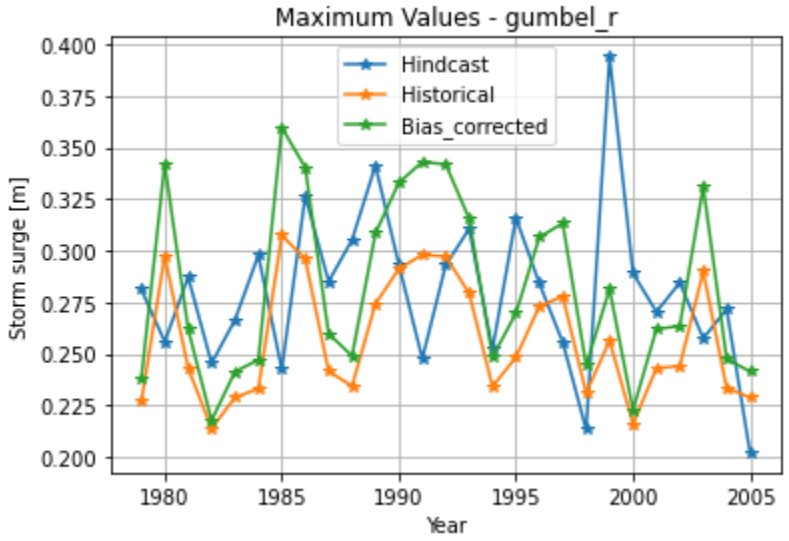
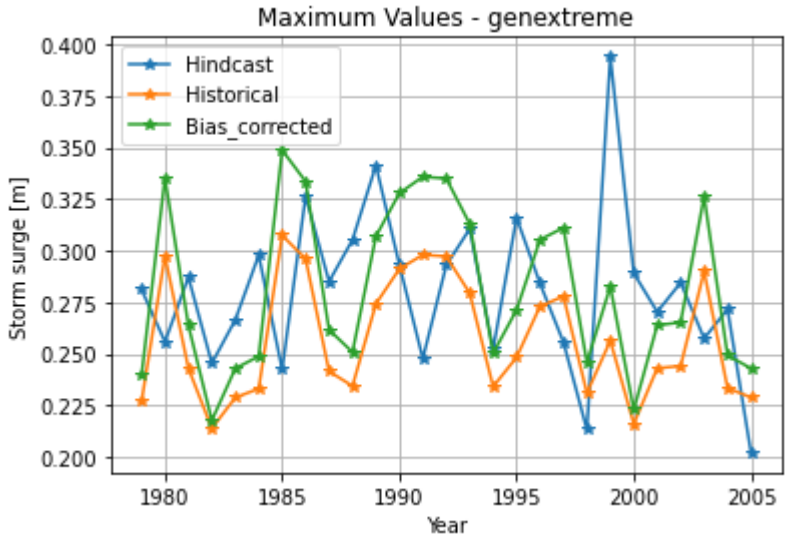
Bias Correction of the Annual Maxima









Quantile-mapping approach applied to annual maxima (1979-2005, 27 years):

for each grid point, the CDF of the **historical maxima is adjusted** to match the CDF of the maxima from the hindcast dataset.

Both **Gumbel** and **GEV** distribution are used.

The same distributional transformation is then applied to the future projections, under the assumption of **bias stationarity**.

Projections

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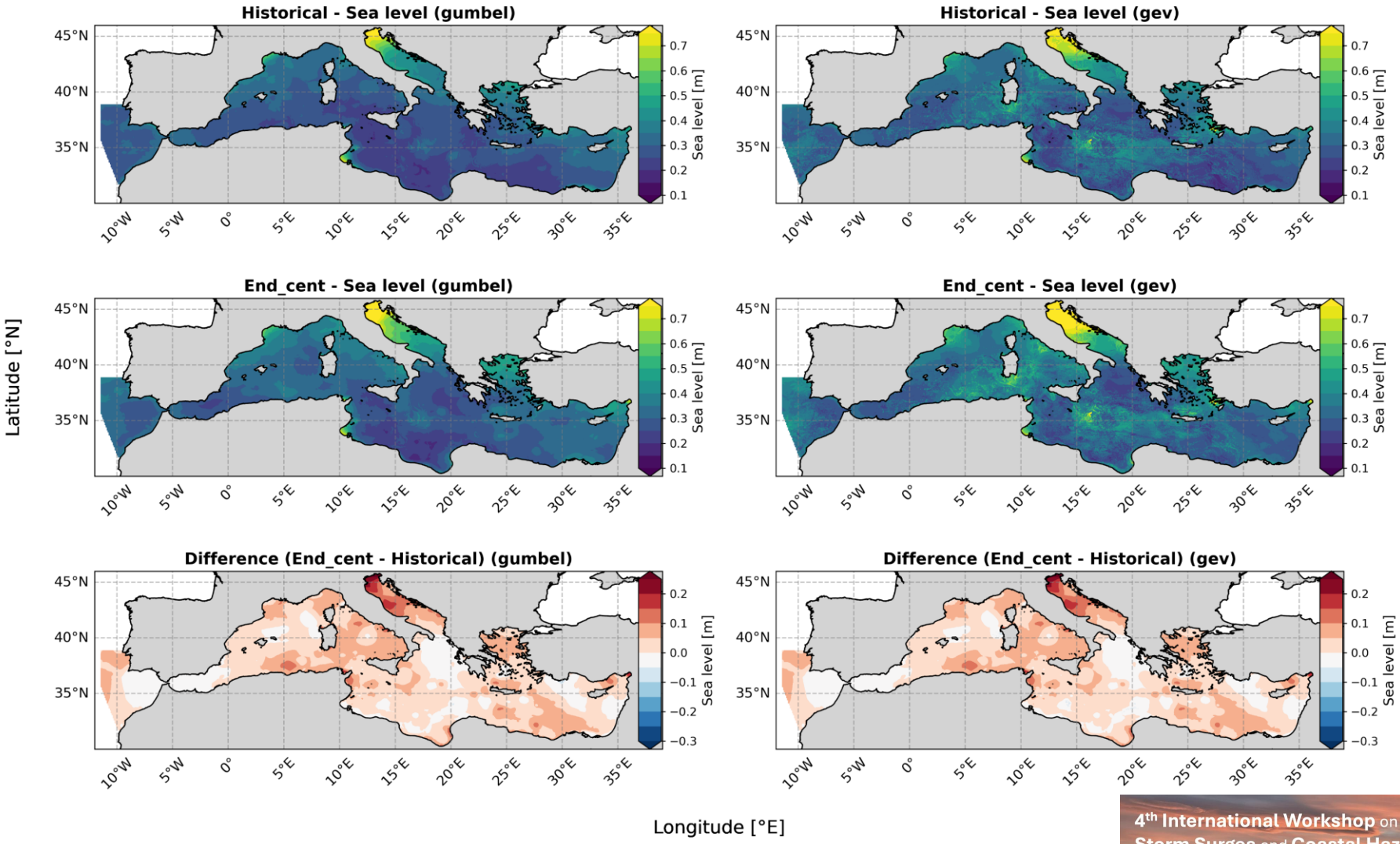
EUR-11_CLMcom-CCCma-CanESM2_r1i1p1-CCLM4-8-17_v1_6hr



RL Variations

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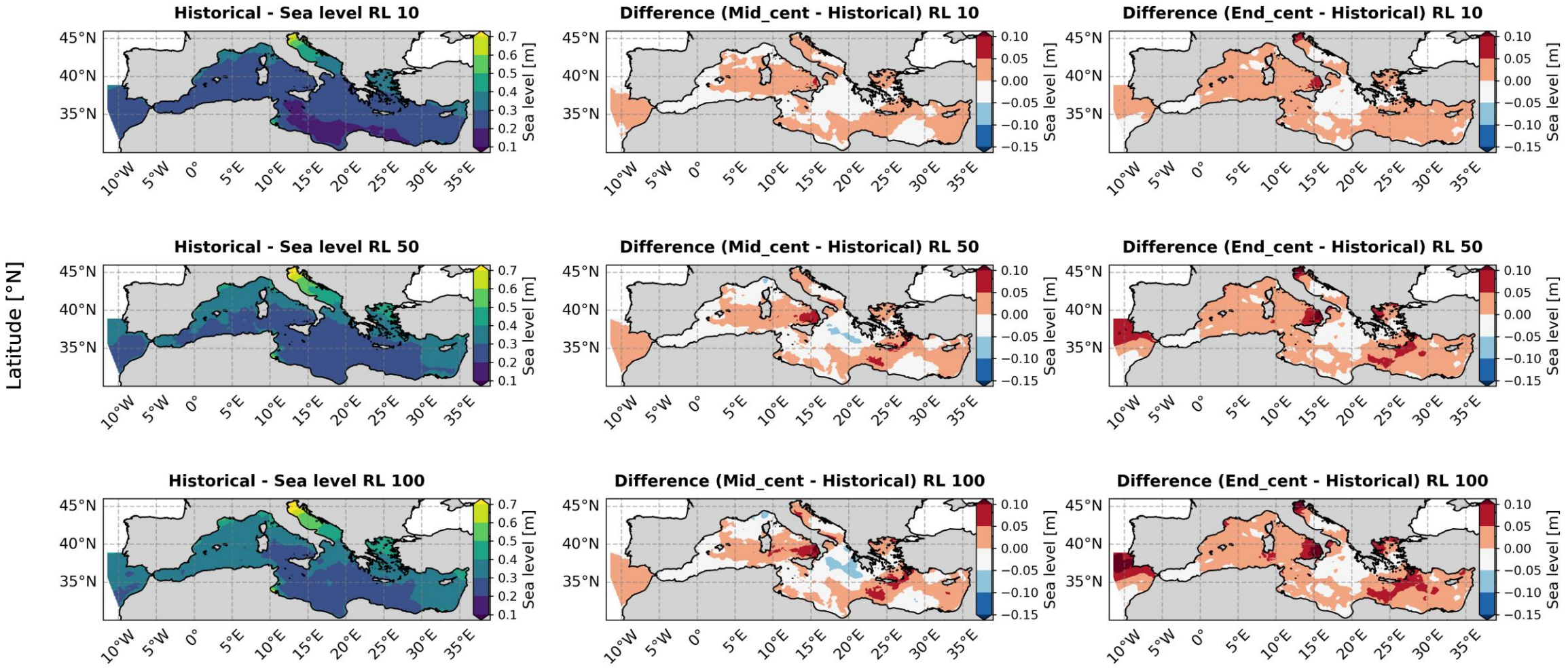
Return Levels - EUR-11_CLMcom-CCCma-CanESM2_r1i1p1-CCLM4-8-17_v1_6hr



RL Variations

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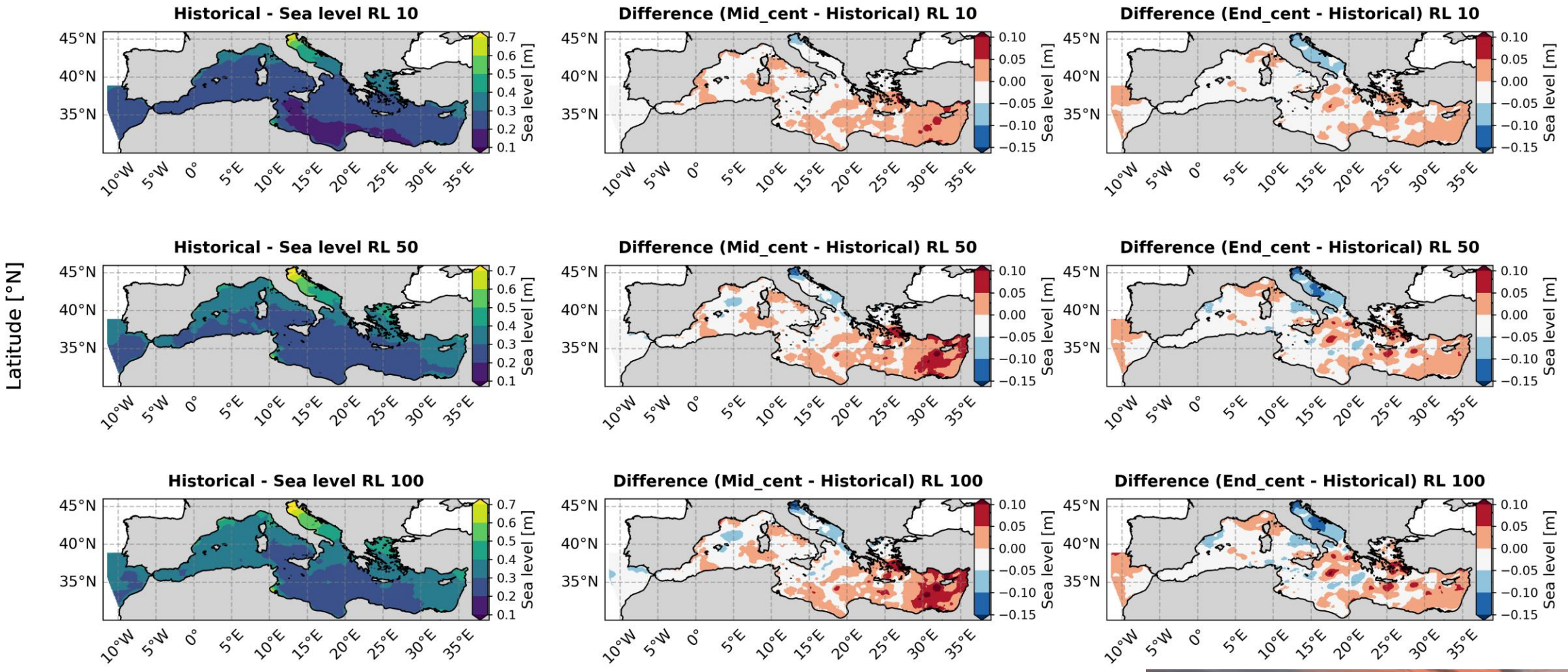
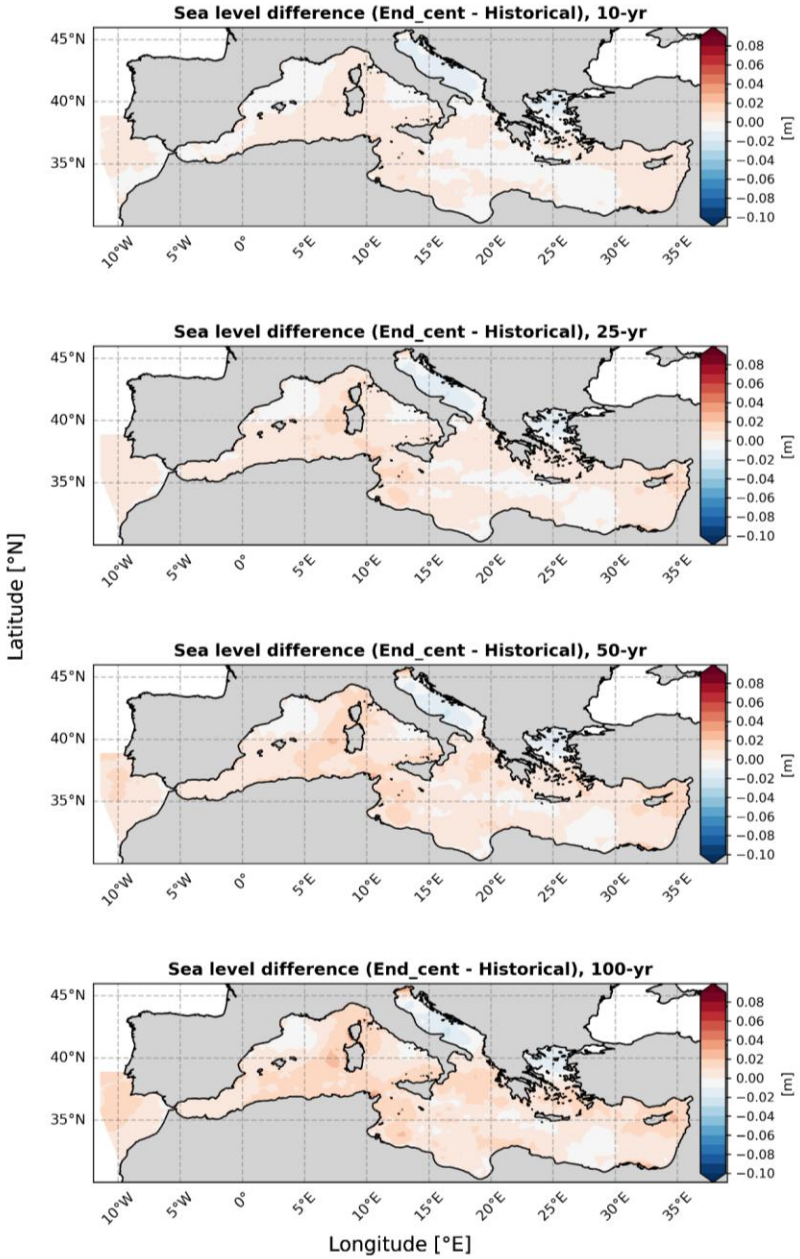
Return Levels - EUR-11_CLMcom-MIROC-MIROC5_r1i1p1-CCLM4-8-17_v1_6hr



RL Variations

Being all projections bias-corrected with respect to the hindcast, they are **directly comparable with one another**.

All the projections can be analyzed either **individually or in a pooled framework**, the latter providing a **substantially larger sample size for the assessment of extreme events** and a more robust basis for Extreme Value Analysis.



Difference in surge levels for return periods of 10, 25, 50, and 100 years between the **hindcast dataset** and the **ensemble of 17 developed projections**.

Conclusions

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- To protect coastal communities from the risks associated with extreme storm surge events, it is essential to develop **reliable scenarios** to design **effective adaptation** and **risk reduction strategies**.
- The developed **hindcast** dataset was considered a **reliable reference**, thanks to the validation performed, to assess future variations in storm surge.
- Considered individually, different projections provide varying, sometimes even **contrasting**, information due to intrinsic uncertainty.
- Based on the **ensemble** of the 17 developed projections, **no significant variations** in extreme storm surge events appear in the Mediterranean.

- The aim is to investigate more thoroughly the **influence** that **individual projections** have on the overall results.
- Investigate about the variation in the **frequency** of extreme surge levels.

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Thank you for your attention!

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