“Changes in extreme storm surge events in Southern Europe”

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MOTIVATION OF THIS STUDY?

- ✓ For many **coastal** engineering applications (flooding, coastal management, etc…), knowledge of climate **variability** and **changes** in sea level is important.
- ✓ Storm surge is a key component of sea level.
- ✓ **Extreme** events have immediate **impact** on the coast.

- ➢ How can we **characterize** the **extreme** events?
- ➢ Are the **extremes** storm surge events **changing**?
- ➢ Do these changes have a **spatial pattern**?
- ➢ Are they changing in **frequency** or **magnitude**?

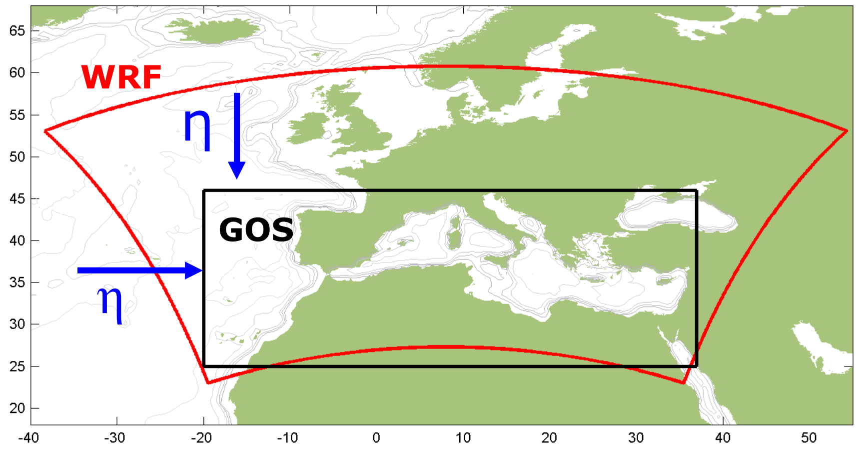
MAIN GOALS

- ❑ Development of a **methodology** to estimate extremes of storm surge
- ❑ Assessment of the **50-year return level**
- ❑ Analyse significant **trends** in **frequency** and **magnitude** of severe storm surges over Southern Europe

High resolution storm surge hindcast for Southern Europe. *GOS* (*Global Ocean Surge*).

MODEL DOMAIN

- Southern Europe
- Horizontal resolution of 1/8º (~ 13 Km).
- The bathymetry was extracted from the **ETOPO 2** database.



NUMERICAL MODEL

- The storm surge simulation has been performed using the Regional Ocean Model System (ROMS) (Shchepetkin and McWilliams, 2005).
- Barotropic mode (2D)

BOUNDARY CONDITIONS

Inverse barometer effect

ATMOSPHERIC FORCING

- **Hourly** meteorological data of **wind** and atmospheric **pressure**
- ROMS model was forced with an atmospheric dynamical downscaling (Seawind Project, (Menéndez et al., 2011))
- SeaWind: WRF forced with NCEP reanalysis (1948-2009, Δx~ 30 km)

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Hourly dataset of **62-years** of storm surge in Southern Europe with a horizontal resolution of **1/8º (~13 km)**

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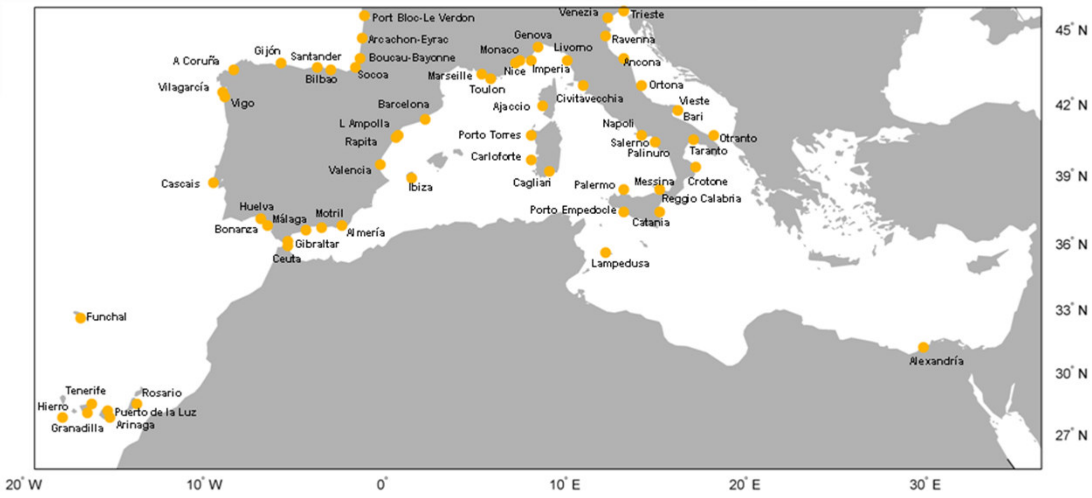
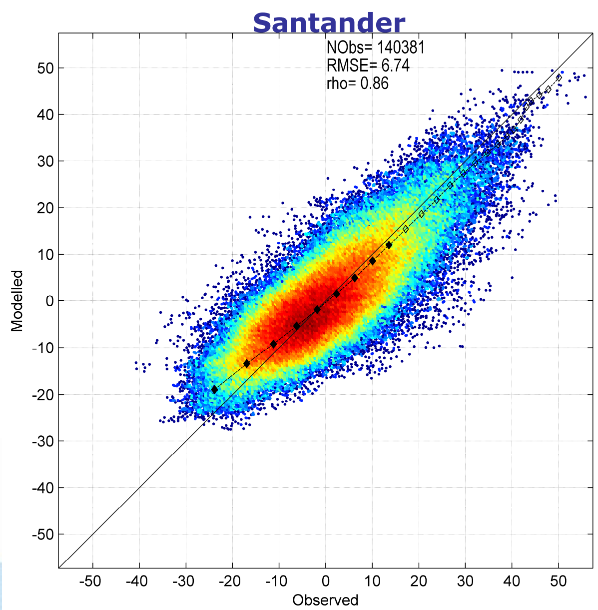
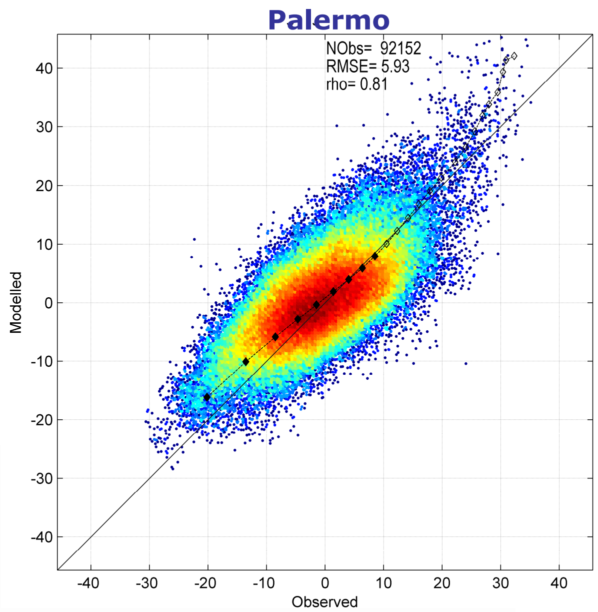
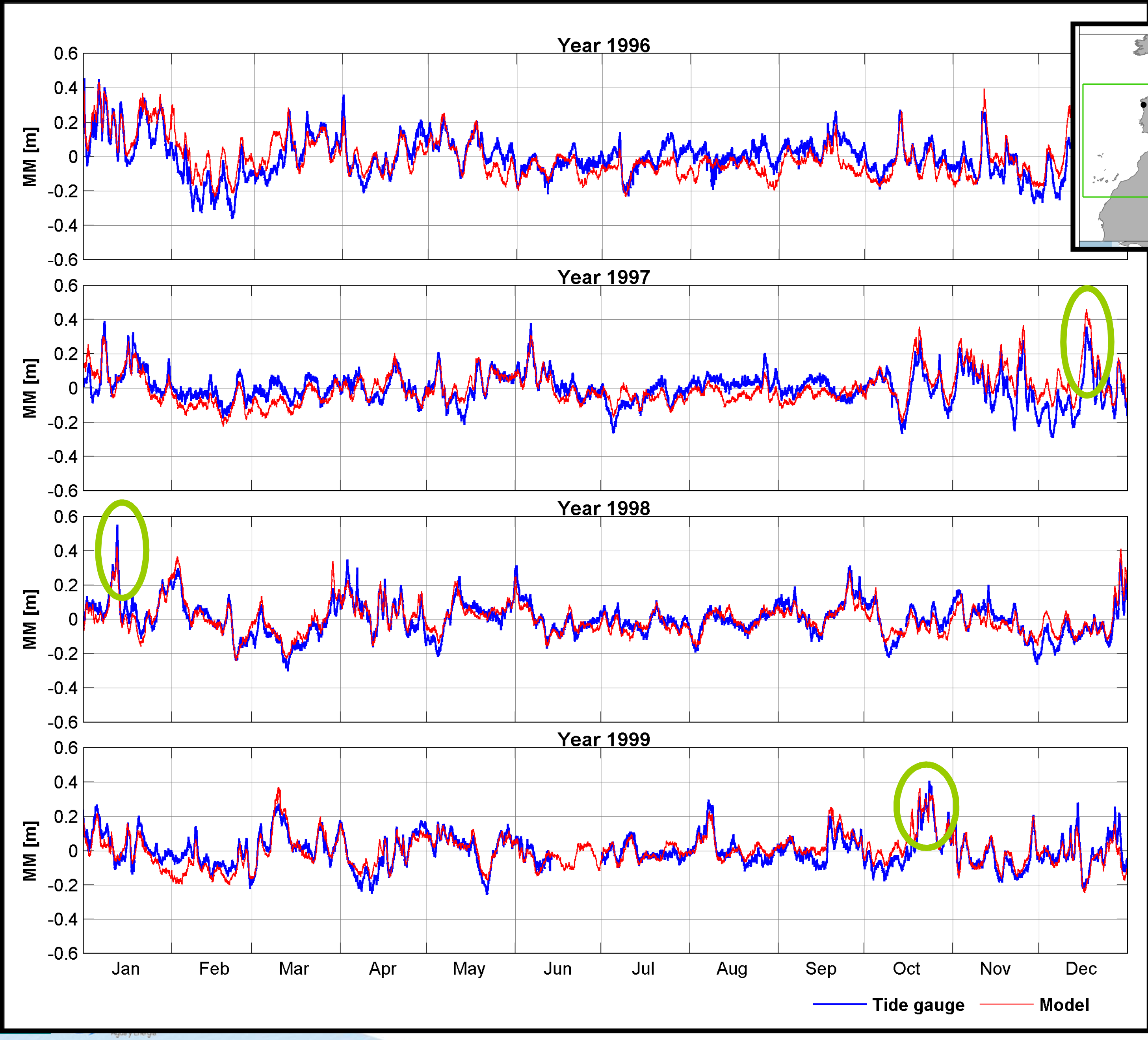
VALIDATION

- Tide gauges (PdE, SONEL, ISPRA, UHSLC)
- Satellite altimetry data (Ssalto/Duacs products, distributed by **Aviso**, with support from Cnes)

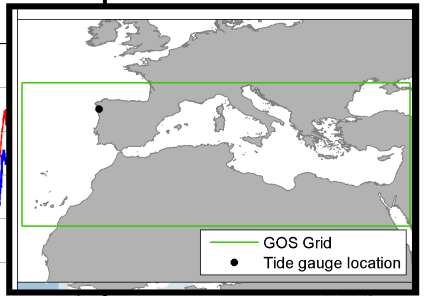






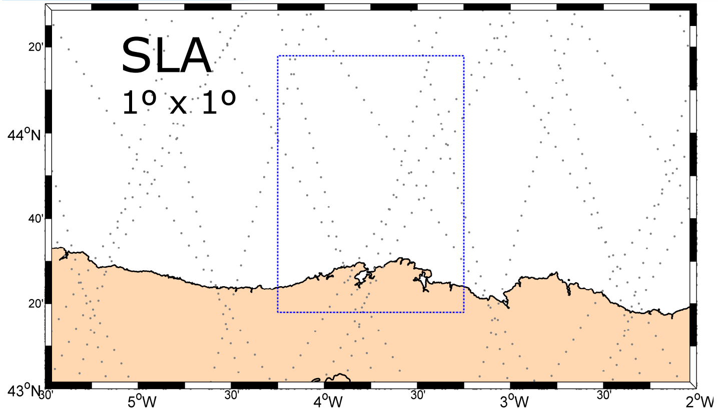


Year 1996
Year 1997
Year 1998
Year 1999
MM [m]
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Tide gauge
Model

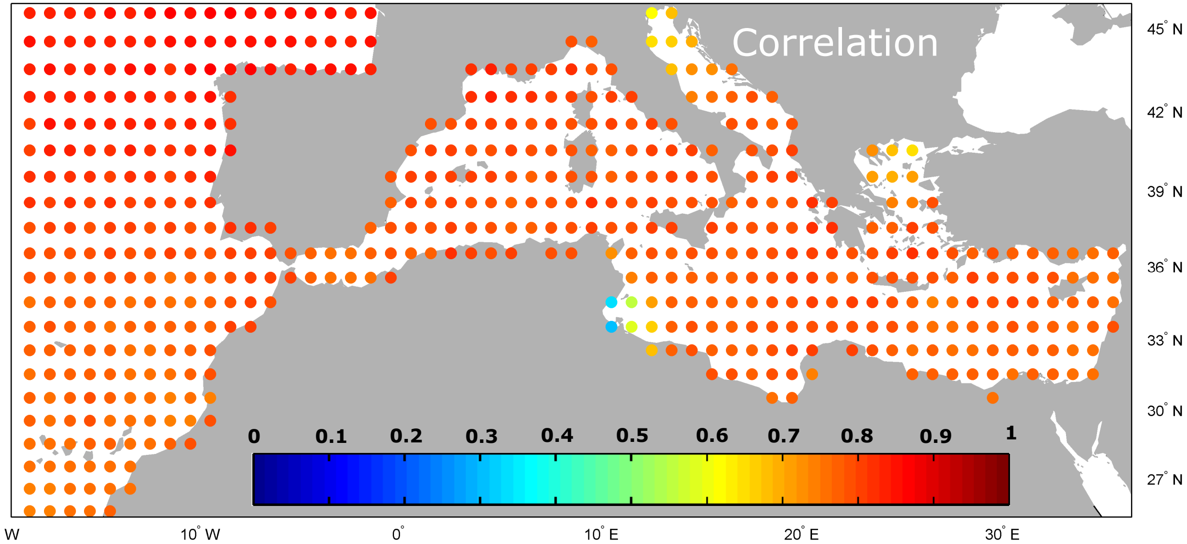


GOS Grid
Tide gauge location

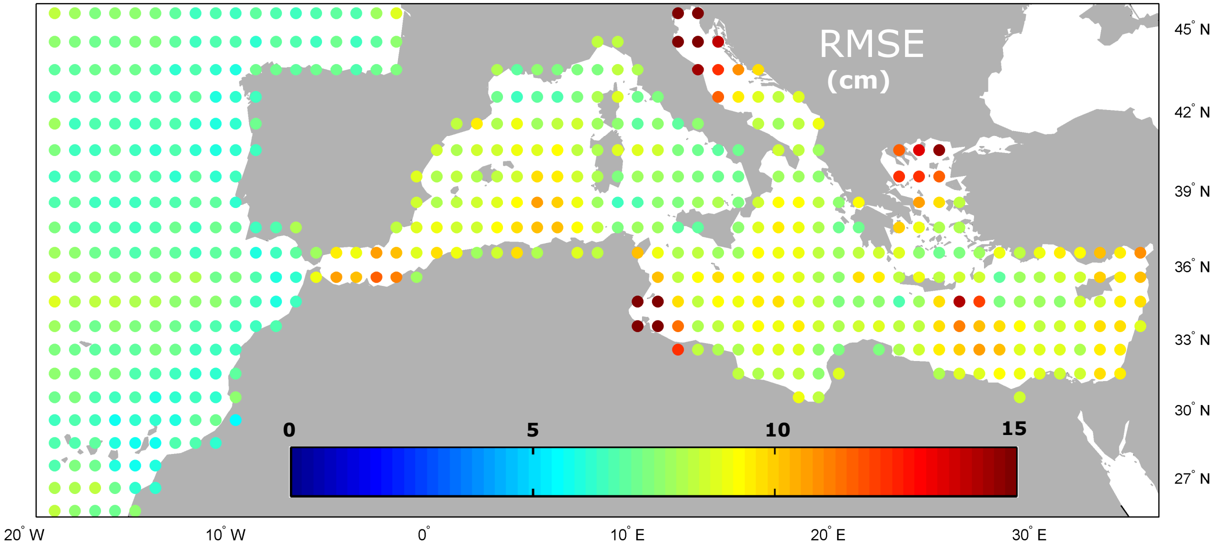
VALIDATION Satellite data (1992-2009)



SLA (7 different satellites, ~8 days period)
DAC (regular grid 0.25ºx0.25º, 6-hour interval)



Satellite (**SLA + DAC)** vs. **GOS**
(closest grid point in time and space)

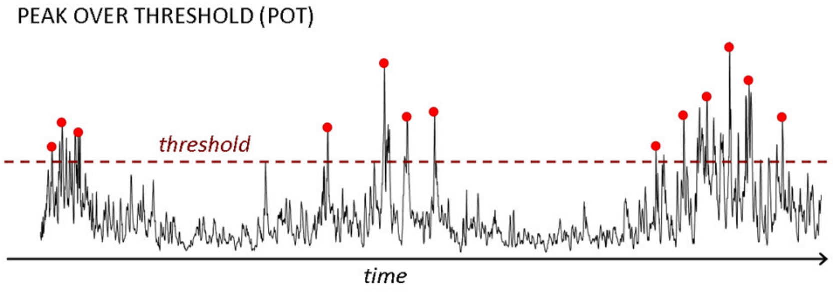


Identifying extreme events: POT

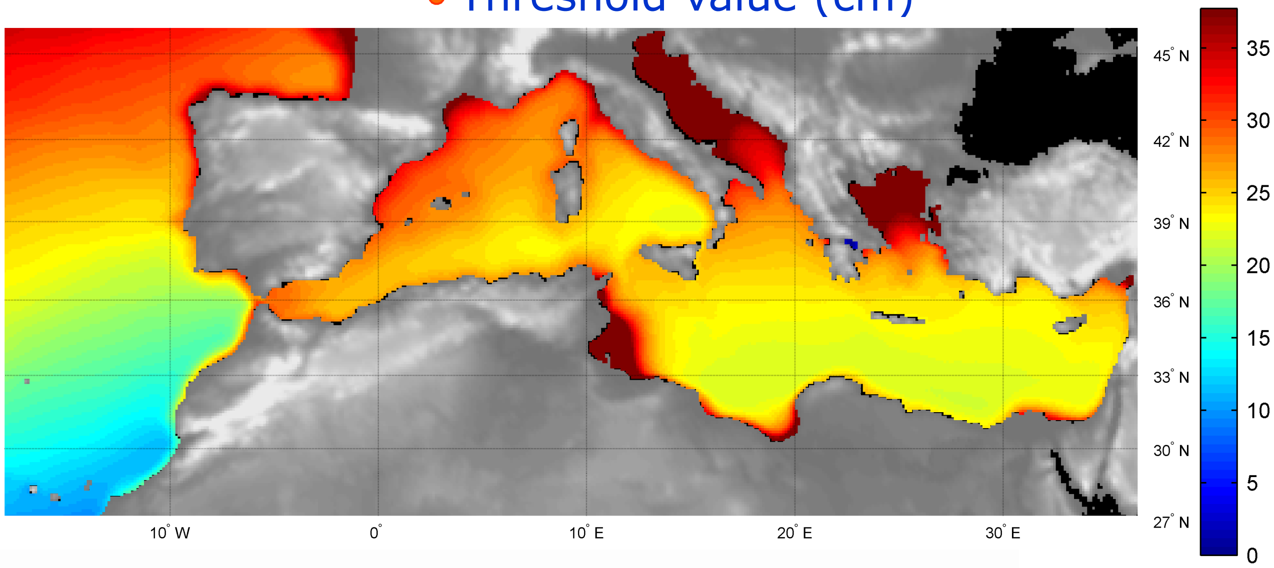
Threshold: 99.5%

Time span : 3 days

Extreme values description



- Threshold value (cm)



- Number of events per year
- Persistence over the threshold

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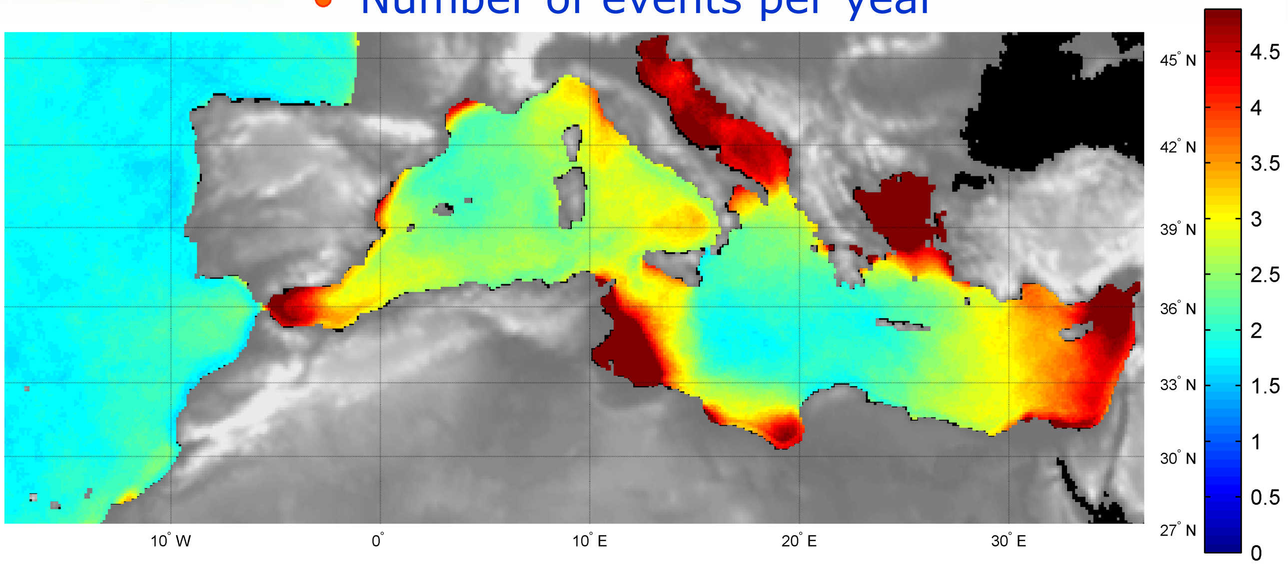
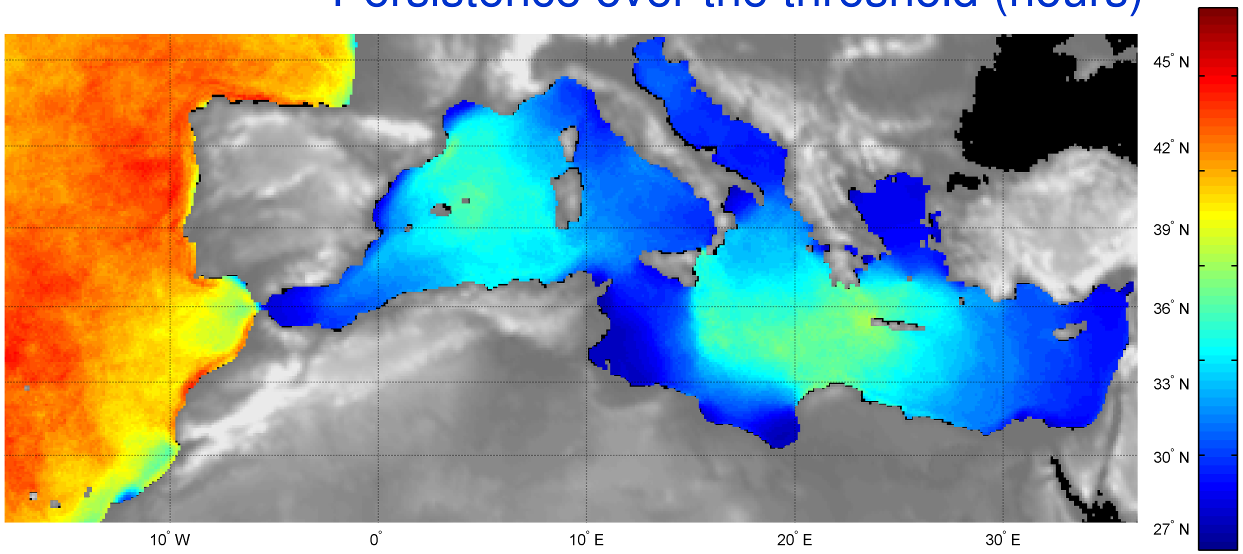


- Persistence over the threshold (hours)

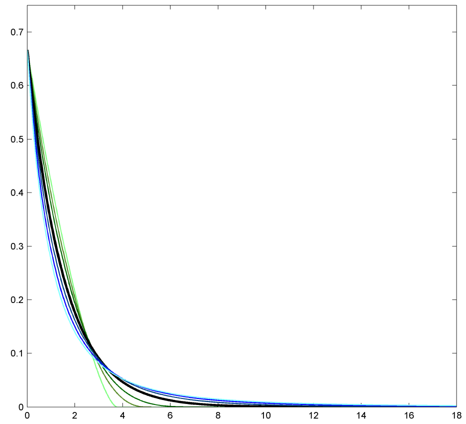


Extreme Value Theory

Statistical discipline that develops a set of techniques and methods to quantify and model the stochastic behavior of extreme events, either in magnitude or frequency.

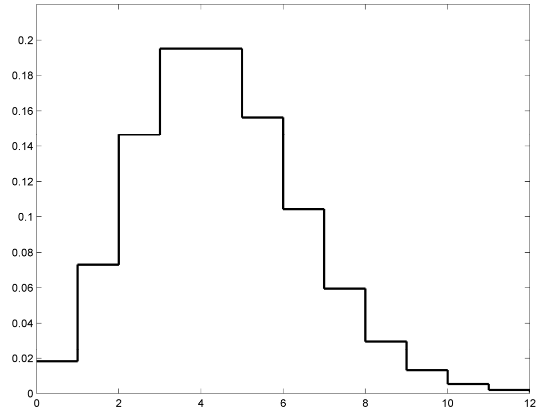
Pareto

(excess values over threshold)



Poisson

(exceedance times over threshold)



Pareto – Poisson model

$$F(x;\theta) = 1 - \left(1 + \xi \frac{x}{\sigma}\right)^{-1/\xi}$$

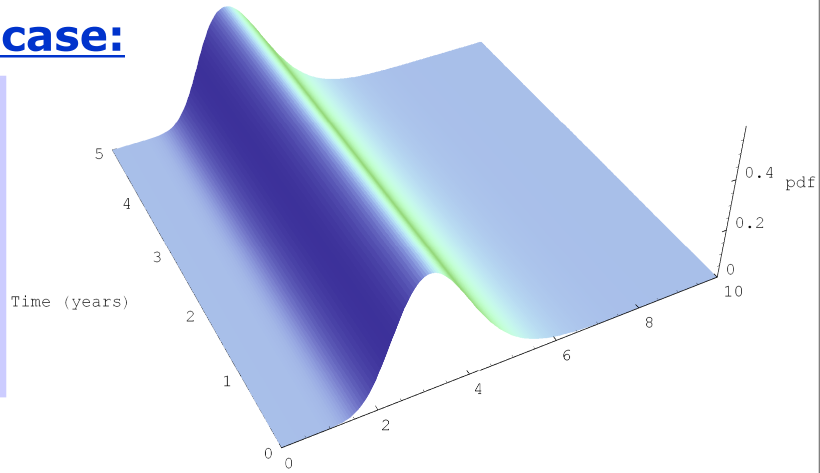
$$p(x;\theta) = e^{-\lambda} \frac{\lambda^x}{x!}$$

Shape parameter

Scale parameter

Stationary case:

$$\sigma = \sigma_0$$
$$\xi = \xi_0$$
$$\lambda = \lambda_0$$

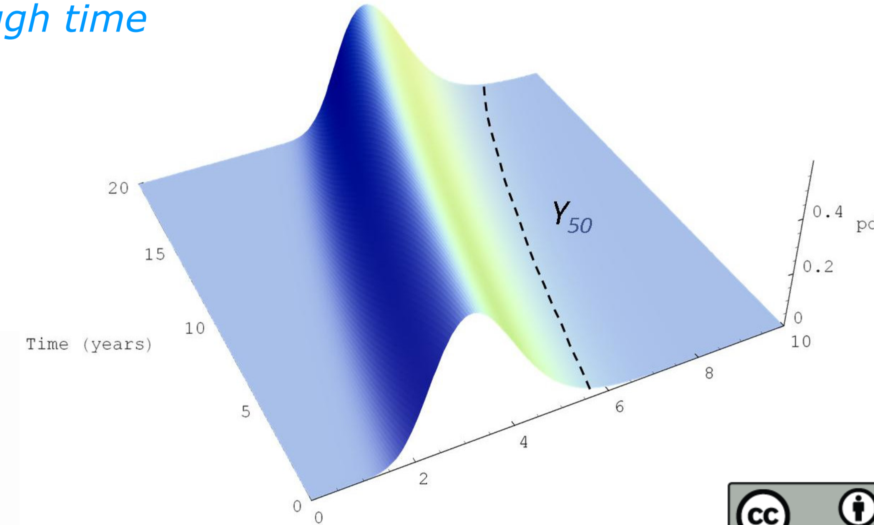


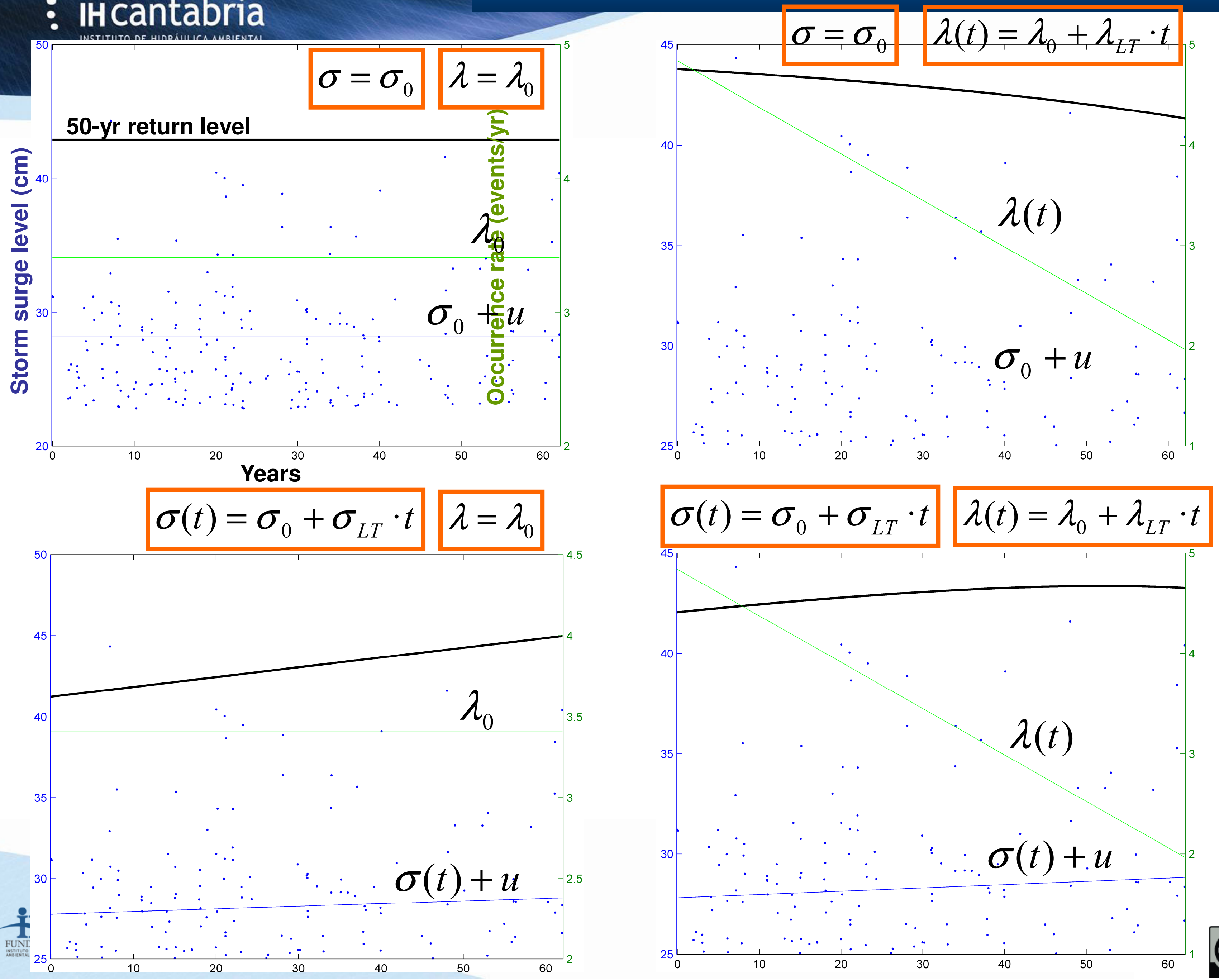
Maximum likelihood estimation

Time-dependent case:

The probability of an extreme sea level varies through time

$$\sigma(t) = \sigma_0 + \sigma_{LT} \cdot t$$
$$\xi = \xi_0$$
$$\lambda(t) = \lambda_0 + \lambda_{LT} \cdot t$$

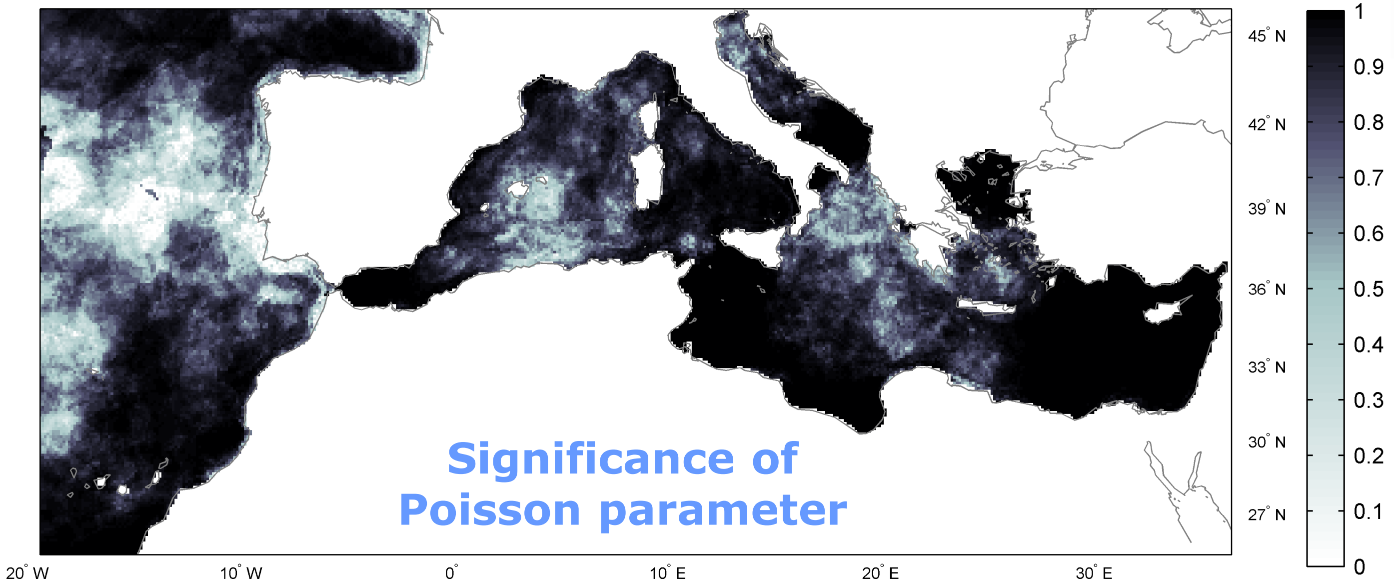


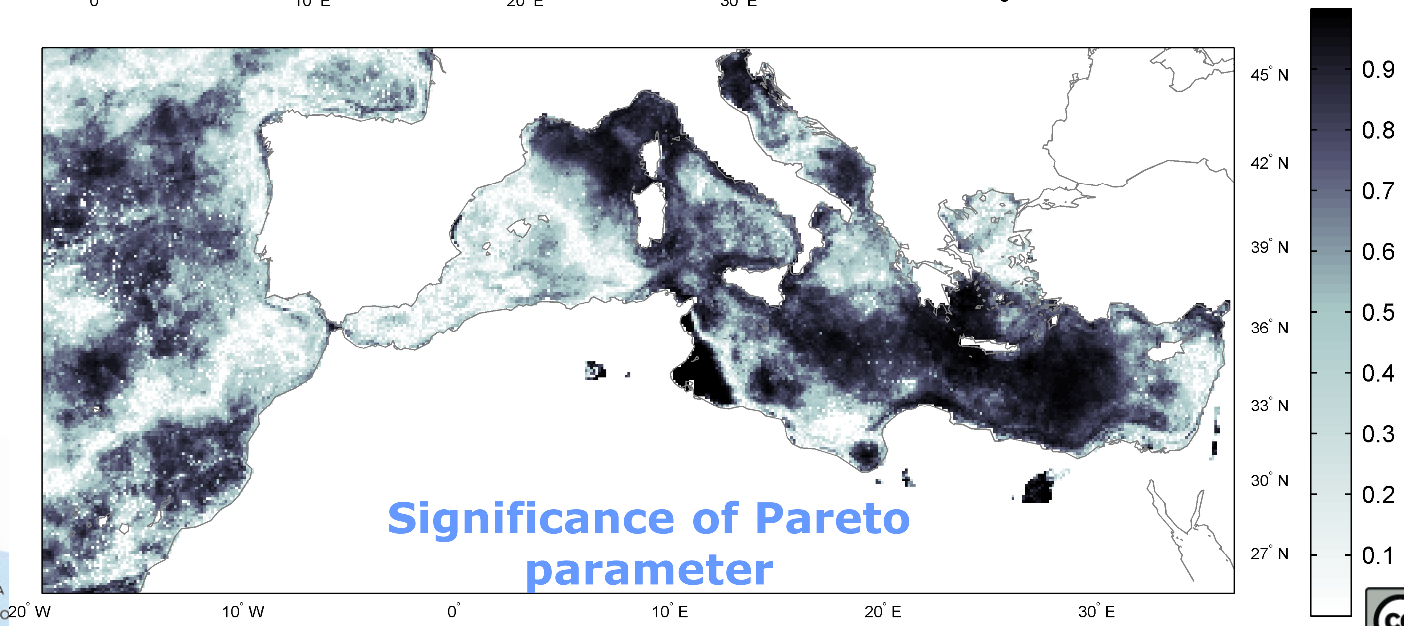

$\sigma = \sigma_0$
$\lambda = \lambda_0$
50-yr return level
λ_0
$\sigma_0 + u$
Storm surge level (cm)
Occurrence rate (events/yr)
Years
$\sigma = \sigma_0$
$\lambda(t) = \lambda_0 + \lambda_{LT} \cdot t$
$\lambda(t)$
$\sigma_0 + u$
$\sigma(t) = \sigma_0 + \sigma_{LT} \cdot t$
$\lambda = \lambda_0$
λ_0
$\sigma(t) + u$
$\sigma(t) = \sigma_0 + \sigma_{LT} \cdot t$
$\lambda(t) = \lambda_0 + \lambda_{LT} \cdot t$
$\lambda(t)$
$\sigma(t) + u$

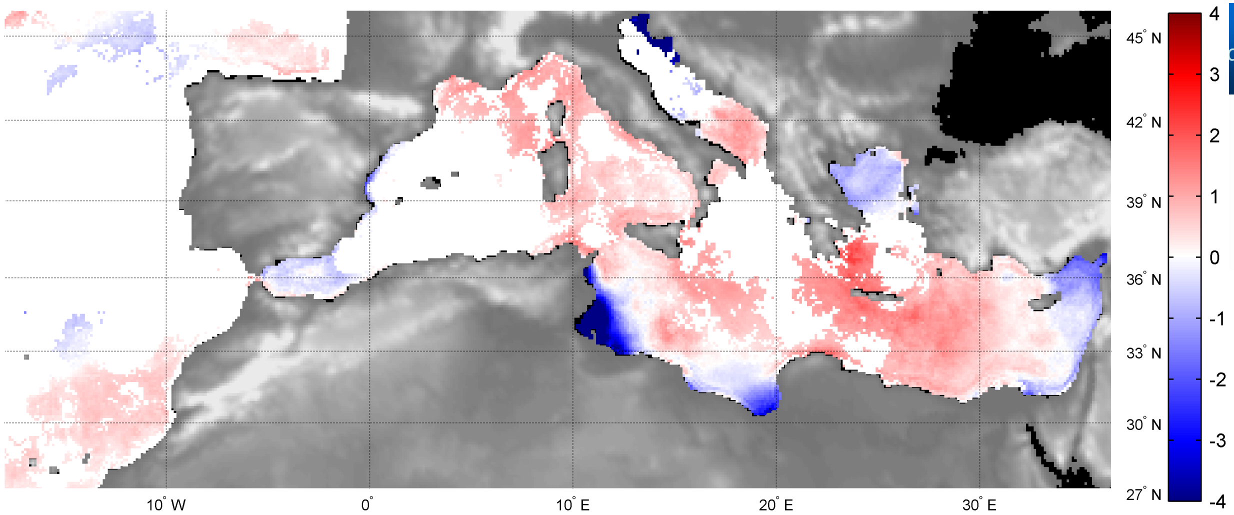
Stationary case

Vs.

Time-dependent case

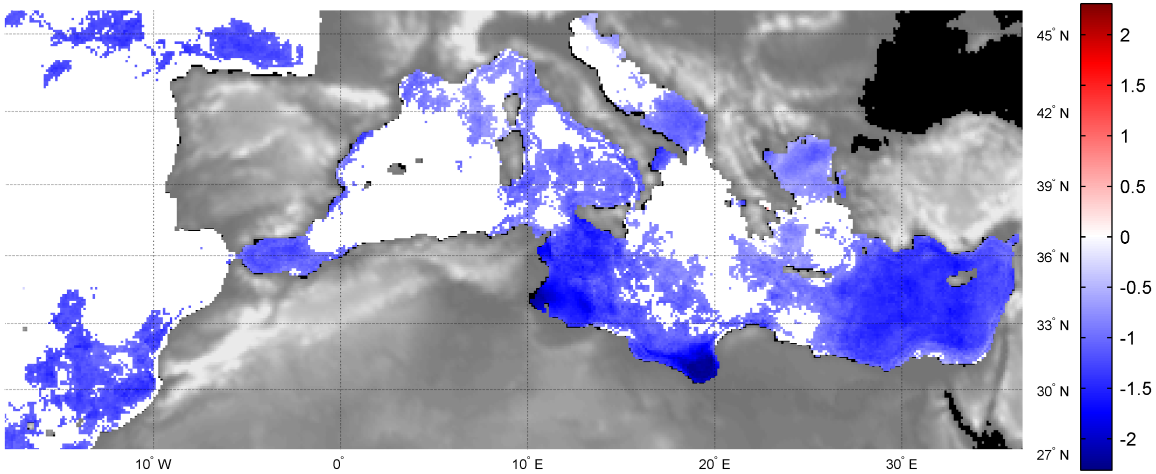






Trends in magnitude (mm/yr)

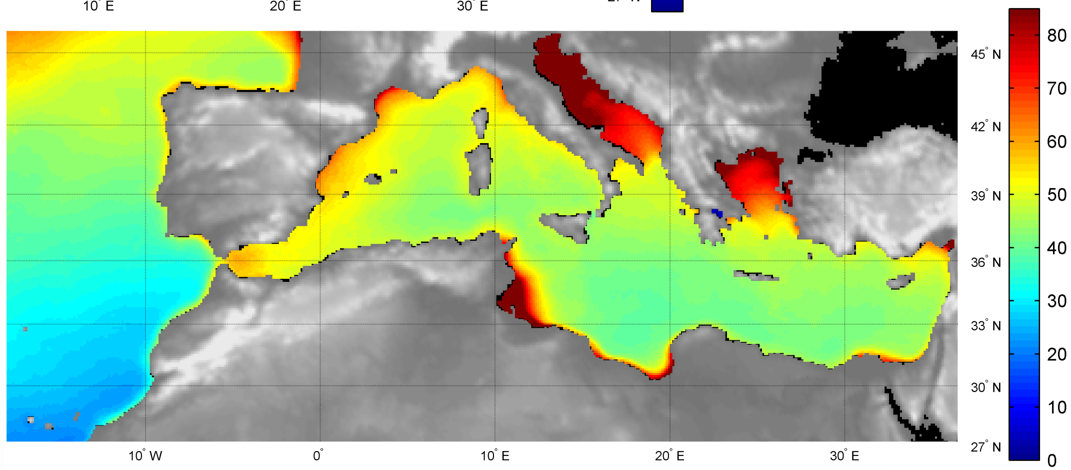
Trends statistically significant at 90%



Trends in frequency (%)

Fifty-year return level (cm)

$$Y_{50}(t) = u - \left(\left(\frac{\sigma_t}{\xi_0} \right) \cdot \left(1 - (\lambda_t \cdot 50)^{\xi_0} \right) \right)$$



Conclusions

- Trends in the **magnitude** of extreme values are around +- 2 mm/yr
- Positive trends are found in the majority of the domain

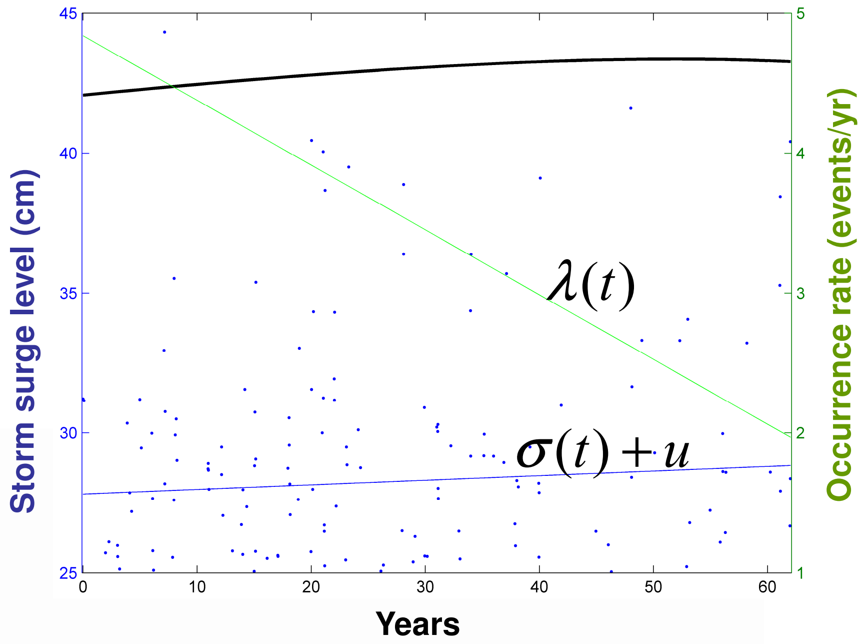
- Trends in the **frequency** of extreme events are around -2%
- Frequency trends are negative all over the domain

- Trends in **frequency** (related to Poisson) are more important than in **magnitude** (related to Pareto).

$$\lambda(t) = \lambda_0 + \lambda_{LT} \cdot t$$

$$\sigma(t) = \sigma_0 + \sigma_{LT} \cdot t$$

- Statistical framework presented to study extreme events



Thanks for your attention

Comments? Questions?

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