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# TRENDS AND VARIABILITY OF WAVES UNDER SCENARIO RCP8.5 IN THE MEDITERRANEAN SEA

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#### BACKGROUND

Trends in sea states are particularly relevant in coastal and off-shore engineering





- $\longrightarrow$  Stability of features (such as dunes) depends on the significant wave height ( $H_s$ )
- Coastal defenses are designed using Hs with a prescribed probability of exceedance which may be affected by long-term trends



#### What do we know so far about trends in wave climate?



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#### LONG-TERM TREND DETECTION AND QUANTIFICATION

Trends are often detected through the Mann-Kendall test

 $x = [x_1, ..., x_n]$ 

$$Z_{MK} = \frac{1}{\sqrt{\sigma^2}} \begin{cases} S+1 & , S>0 \\ 0 & , S=0 \\ S-1 & , S<0 \end{cases} \qquad S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n \delta_{j-k} \\ \sigma^2(S) = \frac{1}{18} \left[ n\left(n-1\right)\left(2n+5\right) - \sum_{p=1}^g t_p\left(t_p-1\right)\left(2t_p+5\right) \right] \end{cases}$$



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Observed Test Statistic



#### LONG-TERM TREND DETECTION AND QUANTIFICATION

"the p-values can be viewed as a continuous measure of the compatibility between the data and the entire model used to compute it, ranging from 0 for complete incompatibility to 1 for perfect compatibility, and in this sense may be viewed as measuring the fit of the model to the data"

Greenland et. al., 2016



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## COMPARISON BETWEEN *b* AND $p_{MK}$ - data employed

http://www3.dicca.unige.it/meteocean/hindcast.html



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### COMPARISON BETWEEN *b* AND $p_{MK}$ - AM $H_s$



! The use of b is sound also for time series with non-linear trends

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# HISTORICAL TRENDS IN THE MEDITERRANEAN SEA - SPATIAL DISTRIBUTION







#### WAVE CLIMATE PROJECTION - THE IPPC SCENARIOS



lon/lat resolution: 11 km historical: 1970-2005 projection: 2006-2100



**RCP 8.5** 



EUR-11

- CLMcom-CCCma-CanESM2\_r1i1p1-CCLM4-8-17
- CLMcom-MIROC-MIROC5\_r1i1p1-CCLM4-8-17
- MPI-M-MPI-ESM-LR\_r1i1p1\_SMHI-RCA4
- NCC-NorESM1-M\_r1i1p1\_SMHI-RCA4
- SMHI-CNRM-CERFACS-CNRM-CM5\_r1i1p1-RCA4
- SMHI-IPSL-IPSL-CM5A-MR\_r1i1p1-RCA4
- SMHI-MOHC-HadGEM2-ES\_r1i1p1-RCA4

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#### wave fields over the Mediterranean Sea

CLMcom-CCCma-CanESM2\_r1i1p1-CCLM4-8-17





#### **TREND ANALYSIS - the Innovative Trend Analysis (ITA)**

Şen, 2011

 $x = [x_1, ..., x_n]$  $X_1 = [x_1, ..., x_n/2]$  $X_2 = [x_{n/2+1}, ..., x_n]$ × negative trend ×. Х 1



### **TREND ANALYSIS** - annual mean *H*<sub>s</sub>



time frame: 2010-2100

- $b \simeq -1 mm/yr$
- $\Delta H_s \simeq -9 cm$

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#### TREND ANALYSIS - AM $H_s$



#### time frame: 2010-2100

- $b \simeq -2.5 mm/yr$
- $\Delta H_s \simeq -23 cm$

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2

0

4.6

4.8

5.4

5.2

5

H<sub>s</sub><sup>max</sup> [m]



### TREND ANALYSIS - annual mean $T_m$



6

4

2

0 4.7

4.75

4.8

T<sub>m</sub><sup>mean</sup> [m]

4.85

4.9

- $b \simeq -1 ms/yr$
- $\Delta T_m \simeq -0.1s$

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4.95





#### TREND ANALYSIS - AM $T_m$



#### time frame: 2010-2100

- $b \simeq -2ms/yr$
- $\Delta T_m \simeq -0.2s$





time frame: 2010-2100



#### **TREND ANALYSIS - spatial distribution of AM trends**



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time frame: 2010-2100



#### **TREND ANALYSIS - spatial distribution of mean data trends**



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## **CONCLUSIONS AND FINAL REMARKS**

- *b* is a reliable index to assess long term trends of time series
- different wind models lead to different wave fields though characterized by consistent trends
- $H_S$  and  $T_m$  are characterized by trends similarly distributed over the basin
- on average waves intensity in the Mediterranean Sea is expected to decrease
- further investigations need to be performed on waves direction and spectral partitions

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## Thank you for listening

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