# Impact of climate change in the marine environment of the Iberian Peninsula

**Mariana Bernardino,**
**Marta Gonçalves, Carlos Guedes Soares**

**CENTEC- Center for Marine Technology an Ocean Engineering, IST, Lisbon, Portugal**

# CLIMENA

CLimate change Impacts on the Marine Environment of the North Atlantic

- ✓ 3 year national project funded by FCT (Portuguese foundation for Science and Technology)
- ✓ Collaboration with the Portuguese Institute for the Sea and the Atmosphere Portuguese Mett Office)
- ✓ Started 1st October 2018
- ✓ It's a follow up of the CLIBECO exploratory project (EXPL/AAG-MAA/1001/2013)

- ✓ The main objective of CLIMENA is to study the impacts of climate change in the North Atlantic wind and wave climate with special focus on the coast of the Iberian Peninsula.

- ✓ Aims to:
  - ✓ extend the simulations done in exploratory project CLIBECO
  - ✓ evaluate changes at different spatial and temporal scales
  - ✓ relate to large scale atmospheric regimes
  - ✓ study the impacts of marine climate change on different areas
    - ✓ routing of maritime transportation
    - ✓ assessment of wave and wind resources

# Data and models

## Reanalysis

ERA-Interim from ECMWF
ERA5

## Climate simulations

EC_Earth RCP8.5 simulation – EC-Earth is a global climate model system based on the weather forecast model of the ECMWF in its seasonal prediction configuration as the base of climate model.

EURO-CORDEX

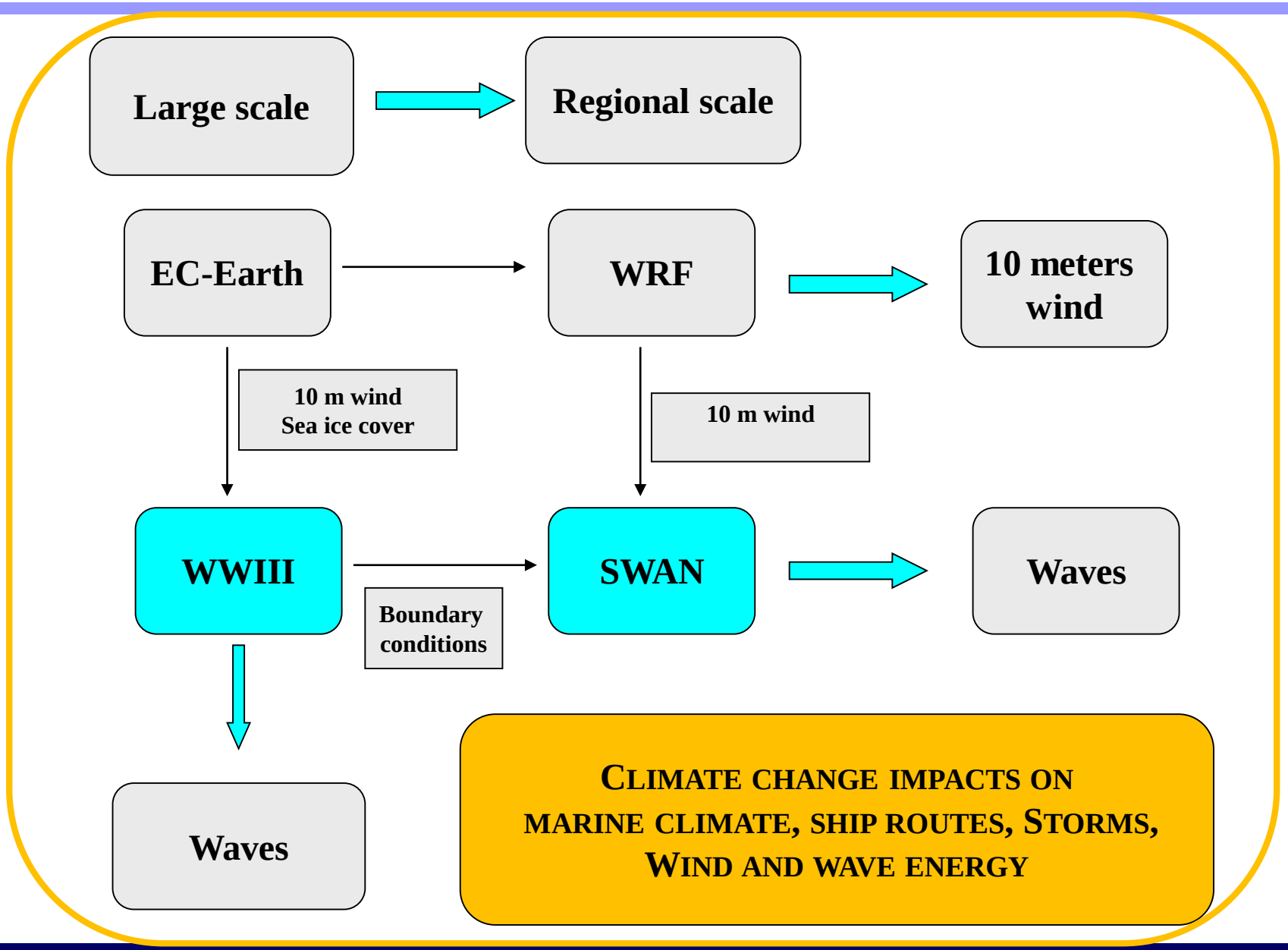
## Meteorological model

IFS- Integrated forcasting system (ECMWF)
WRF- Weather Research & Forecasting – mesoescale model

## Wave models

WWIII – for large scale wave simulations
SWAN – for coastal wave simulations.

# Climate simulations



# North Atlantic wave simulations

To perform the large scale wave simulations

WAVEWATCH III (WW3) (Tolman 2016) - third generation wave model developed at NOAA/NCEP

**Domain**: North Atlantic , Global

**Spatial resolution:** 0.5º by 0.5º

**The wave spectrum** was discretized using 32 frequencies, being the lowest frequency equal to 0. 0373 Hz (increment factor=1.1) and 24 directions.

**Forcing:** EC-EARTH ( historical, RCP8.5)

10 meters wind components and ice cover

**Simulations**

30 years present climate (1979-2008)

10 years future climate (2031-2040)

# Regional Wave Modelling

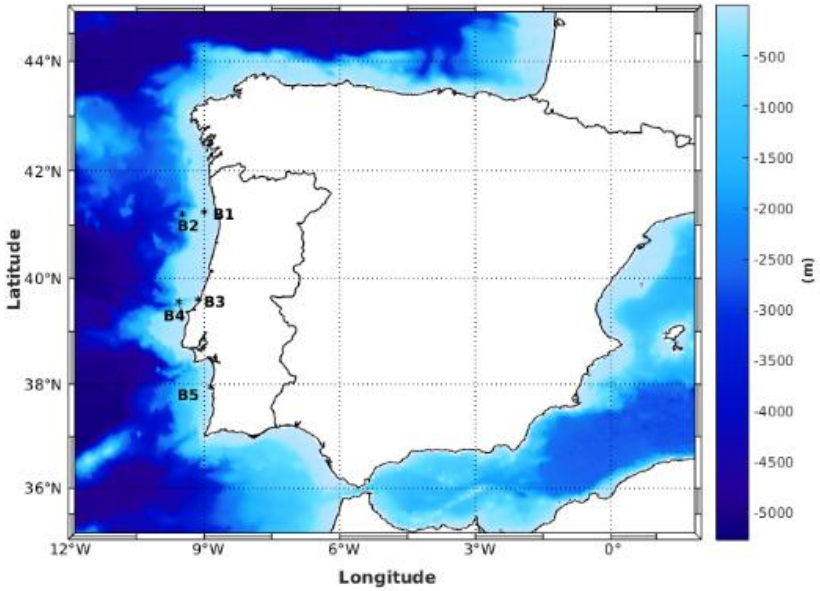
➢While WW3, was used to generate waves for the entire North Atlantic basin, the SWAN model was used to study the evolution of the waves in the Iberian Peninsula

➢The SWAN model is a third-generation phase-averaged wave model based on the action balance equation.

➢The model describes the propagation of the waves from offshore to nearshore, considering a wide range of physical processes.

$$\frac{\partial N}{\partial t} + \nabla_x \cdot \dot{x} N + \frac{\partial}{\partial k} kN + \frac{\partial}{\partial \theta} \dot{\theta} N = \frac{S}{\sigma}$$

- Bathymetry
- Boundary conditions
- High resolution wind input



# SWAN parameterization tests

One year- 2003

Wind forcing WRF ( forced by ERA- Interim)
6 hour and 0.1º resolution

Boundary conditions – spectral information from ERA- Interim

OUTPUT:
Wave parameters fields – 6h
Selected locations:
Wave parameters
and spectra- 3h

Comparison with 3 buoys in the Portuguese coast

- Leixões
- Sines
- Faro

| Numerical squeme | Wave generation | | |
|---|---|---|---|
| | JASSEN | WESTH | KOMEN |
| S&L | 1 | 2 | 5 |
| BSBT | 3 | 4 | 6 |

HS

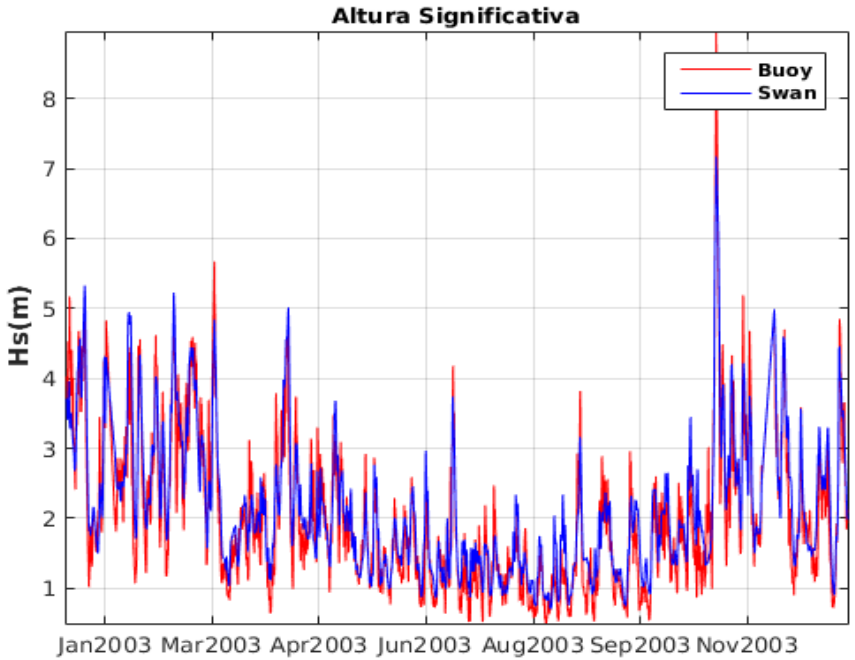
| | BIAS | | | RMSE | | | SI | | | R | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Experiment | LEX | SINES | FARO | LEX | SINES | FARO | LEX | SINES | FARO | LEX | SINES | FARO |
| 1 | -0,15 | -0,12 | -0,49 | 0,41 | 0,46 | 0,7 | 0,21 | 0,27 | 0,72 | 0,92 | 0,9 | 0,66 |
| 2 | -0,46 | -0,44 | -0,76 | 0,68 | 0,63 | 0,95 | 0,35 | 0,37 | 0,97 | 0,88 | 0,88 | 0,67 |
| 3 | -0,24 | -0,29 | -0,58 | 0,48 | 0,5 | 0,77 | 0,25 | 0,29 | 0,79 | 0,91 | 0,89 | 0,67 |
| 4 | -0,14 | -0,18 | -0,42 | 0,41 | 0,43 | 0,64 | 0,21 | 0,25 | 0,65 | 0,92 | 0,9 | 0,66 |
| 5 | -0,45 | -0,41 | -0,68 | 0,67 | 0,6 | 0,87 | 0,35 | 0,35 | 0,89 | 0,88 | 0,89 | 0,67 |
| 6 | -0,23 | -0,26 | -0,51 | 0,47 | 0,47 | 0,7 | 0,24 | 0,28 | 0,72 | 0,91 | 0,9 | 0,67 |

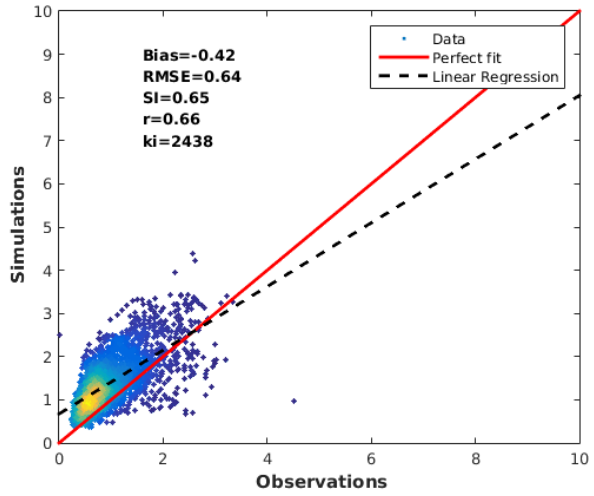
TM02

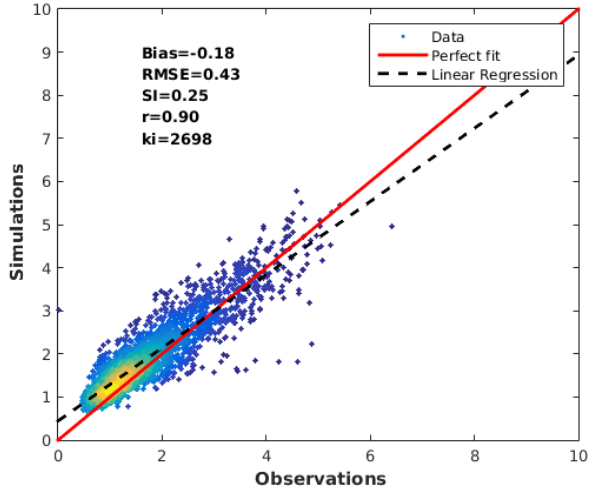
| | BIAS | | | RMSE | | | SI | | | R | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Experiment | LEX | SINES | FARO | LEX | SINES | FARO | LEX | SINES | FARO | LEX | SINES | FARO |
| 1 | 0,57 | 0,04 | -1,02 | 1,25 | 1,17 | 1,63 | 0,19 | 0,18 | 0,36 | 0,78 | 0,81 | 0,65 |
| 2 | 0,76 | 0,37 | -0,67 | 1,65 | 1,53 | 1,32 | 0,25 | 0,24 | 0,29 | 0,64 | 0,71 | 0,72 |
| 3 | 0,3 | -0,21 | -1,06 | 1,57 | 1,54 | 1,74 | 0,24 | 0,24 | 0,38 | 0,7 | 0,75 | 0,72 |
| 4 | 0,57 | 0,07 | -0,92 | 1,25 | 1,16 | 1,57 | 0,19 | 0,18 | 0,35 | 0,78 | 0,81 | 0,65 |
| 5 | 0,81 | 0,45 | -0,53 | 1,66 | 1,54 | 1,22 | 0,25 | 0,24 | 0,27 | 0,64 | 0,71 | 0,71 |
| 6 | 0,32 | -0,14 | -0,92 | 1,56 | 1,52 | 1,66 | 0,24 | 0,24 | 0,36 | 0,7 | 0,75 | 0,71 |

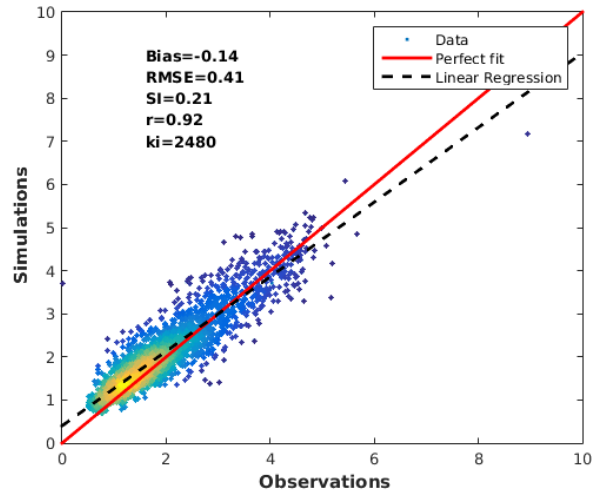
# SWAN parameterization tests

| Numerical squeme | Wave generation | | |
|---|---|---|---|
| | JASSEN | WESTH | KOMEN |
| S&L | 1 | 2 | 5 |
| BSBT | 3 | 4 | 6 |



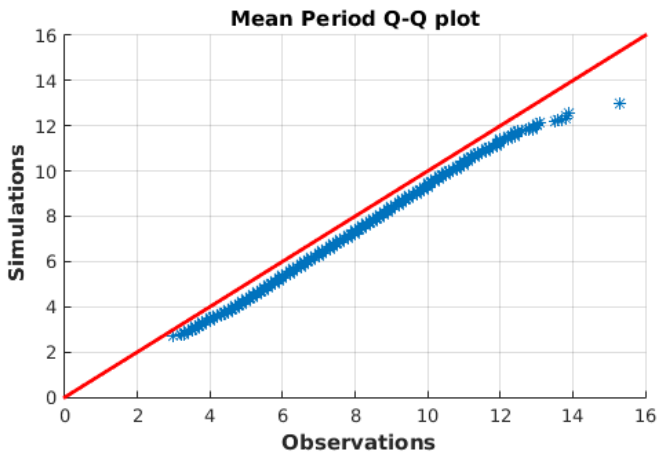



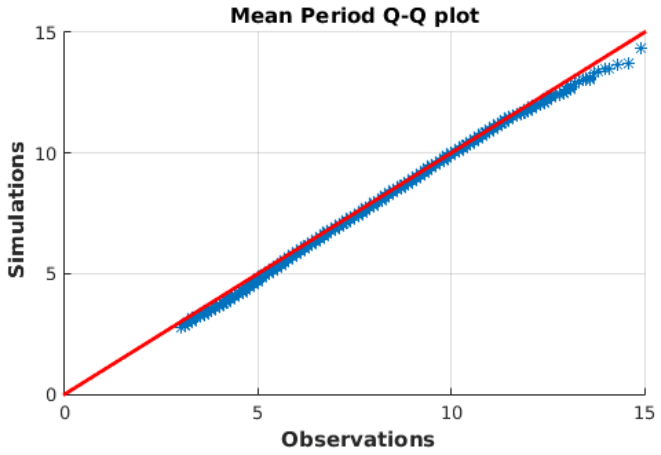



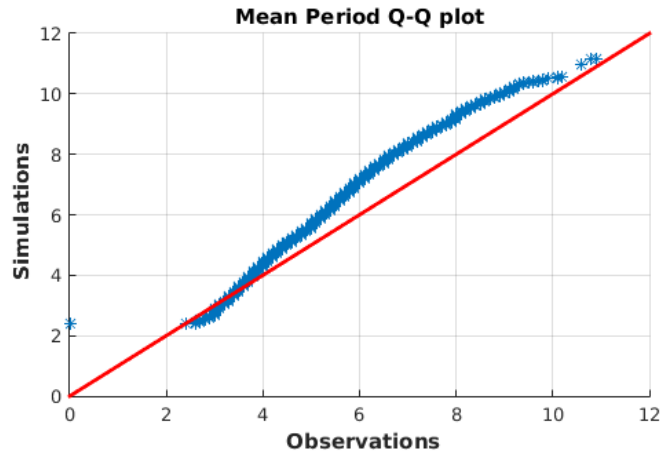



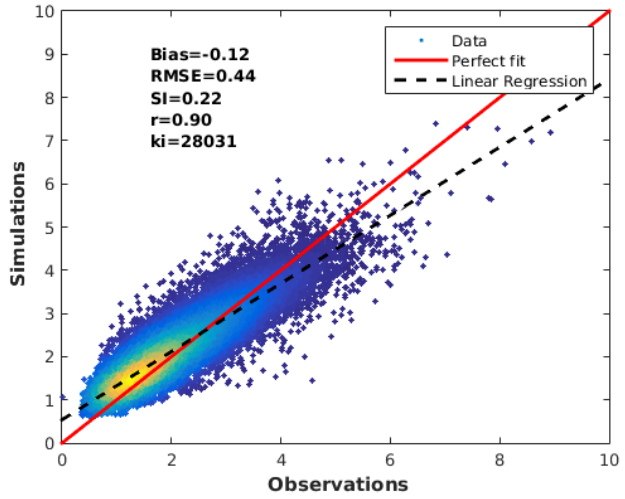
# Regional wave climate simulation

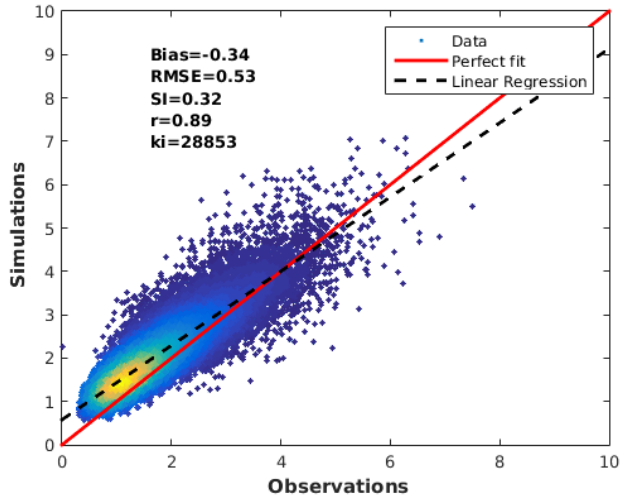
23 years simulation ( 1989-2011) compared with available buoy data

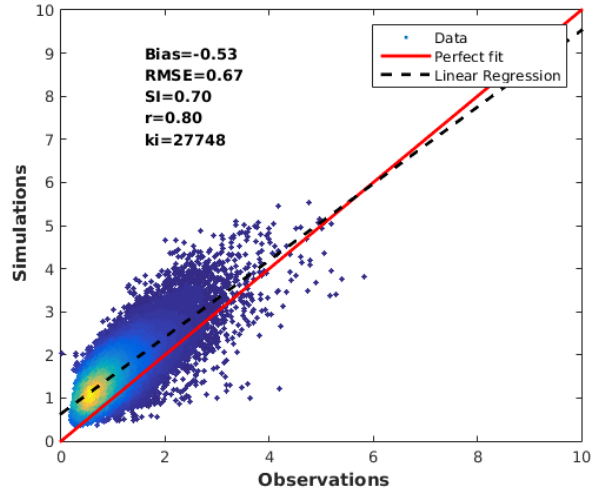


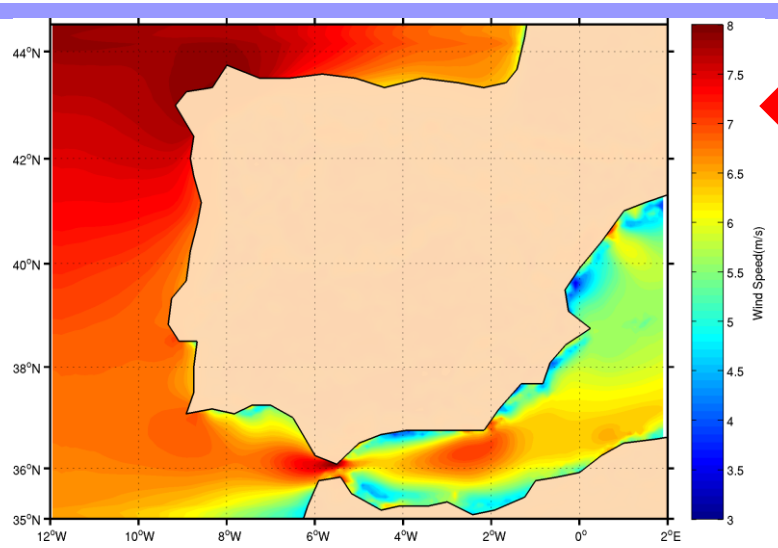



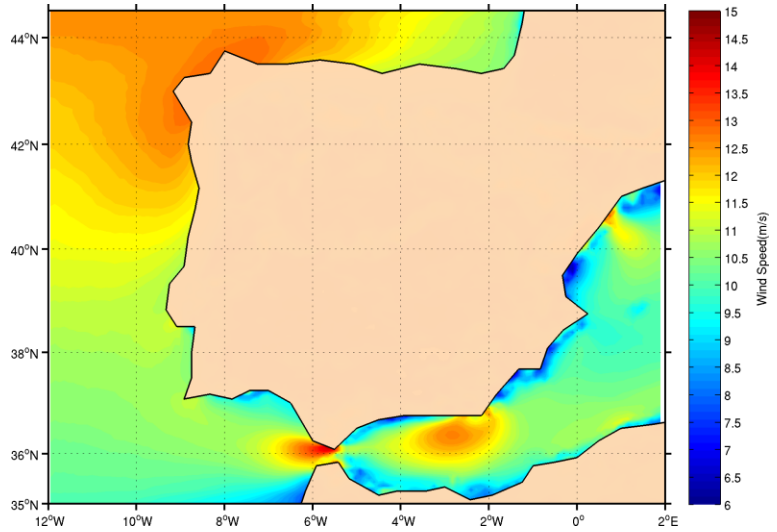
# Wind Climate – Euro Cordex (WRF forced by ERA-Int)

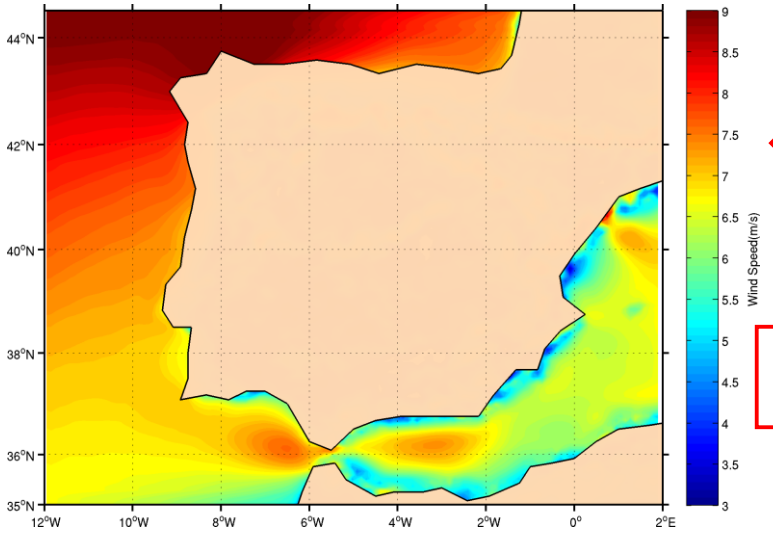
10 meters wind magnitude




Annual mean

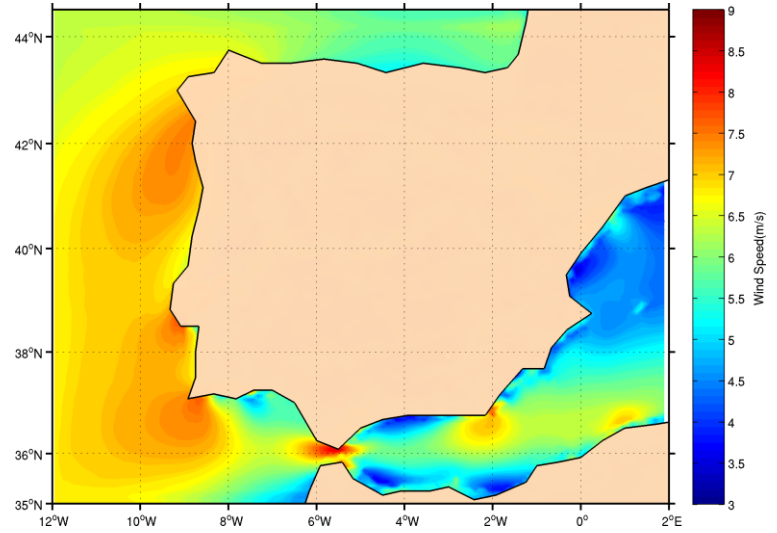
Annual P90



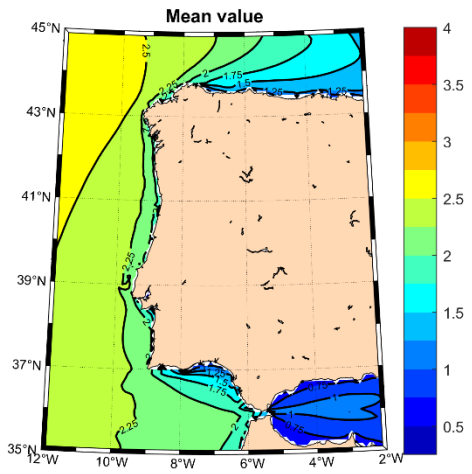

Winter mean

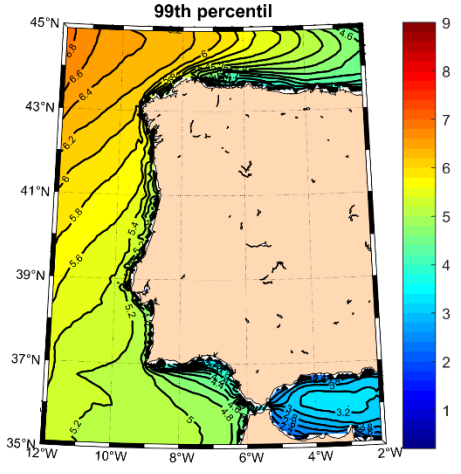
Summer mean

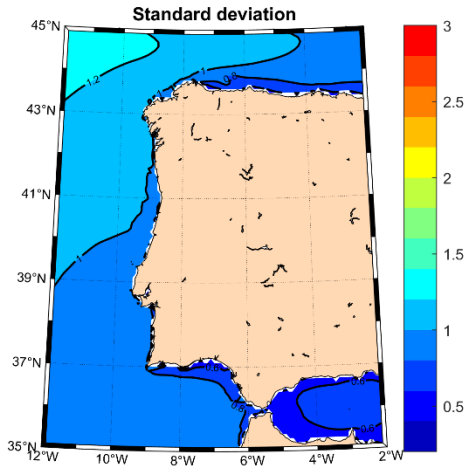


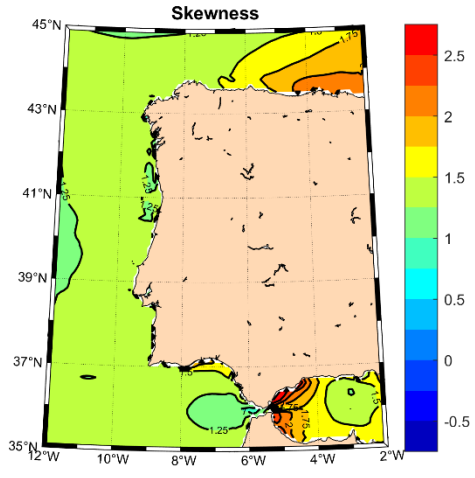
# Regional wave climate (historical)

## Annual statistics

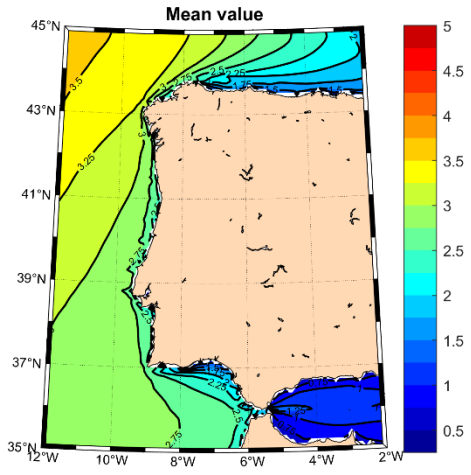


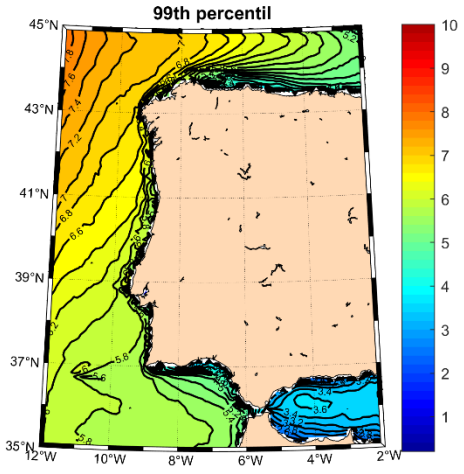



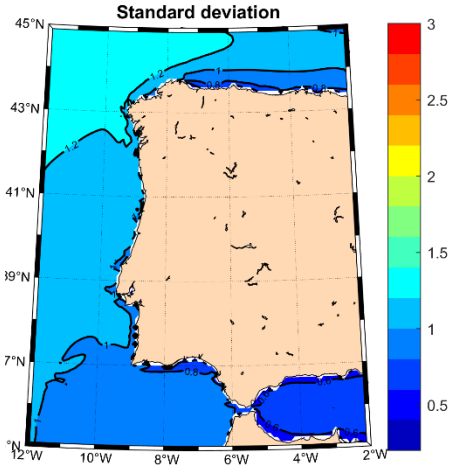



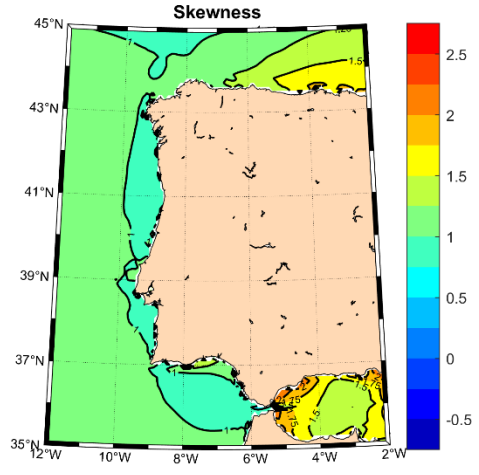




## Winter statistics

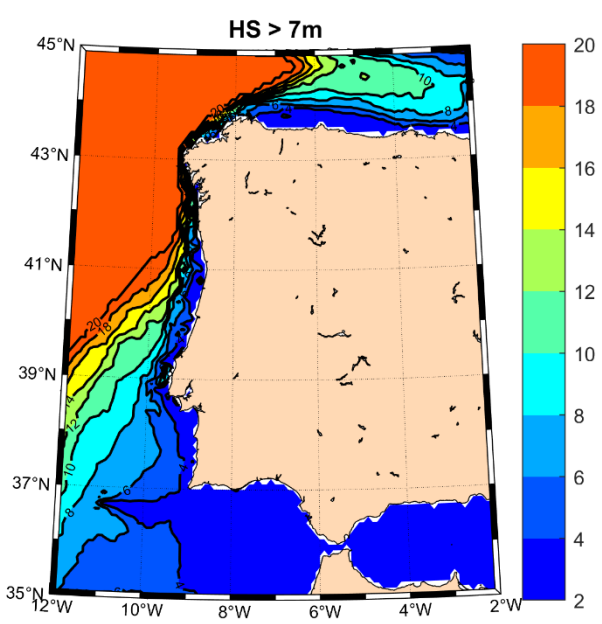


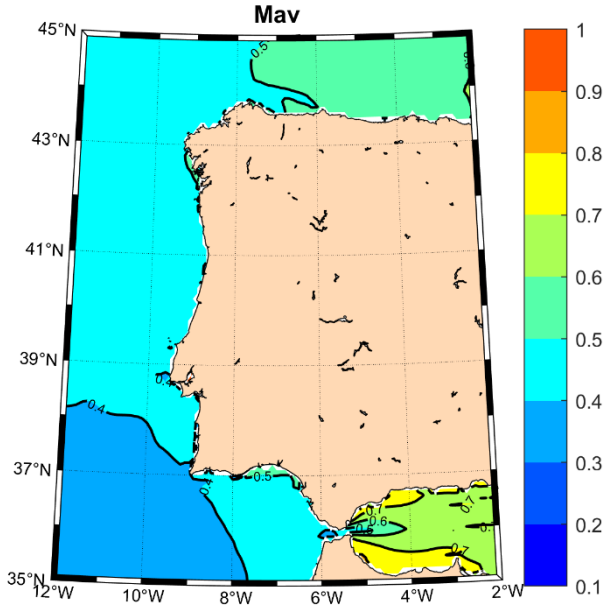



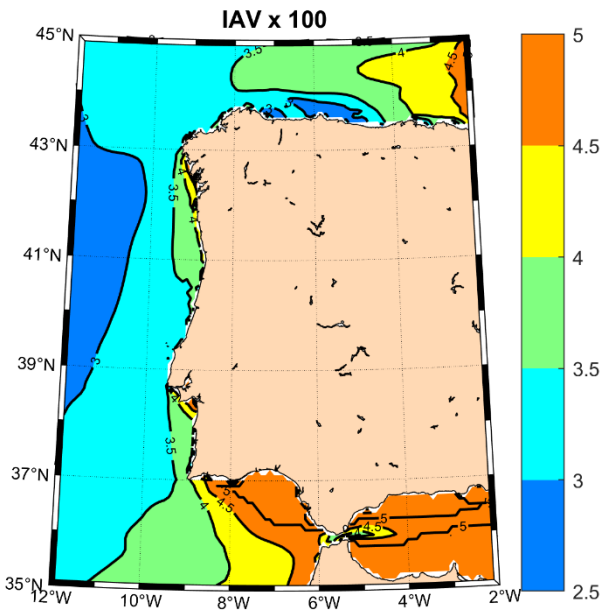



# Regional wave climate ( historical)




Mean annual variability

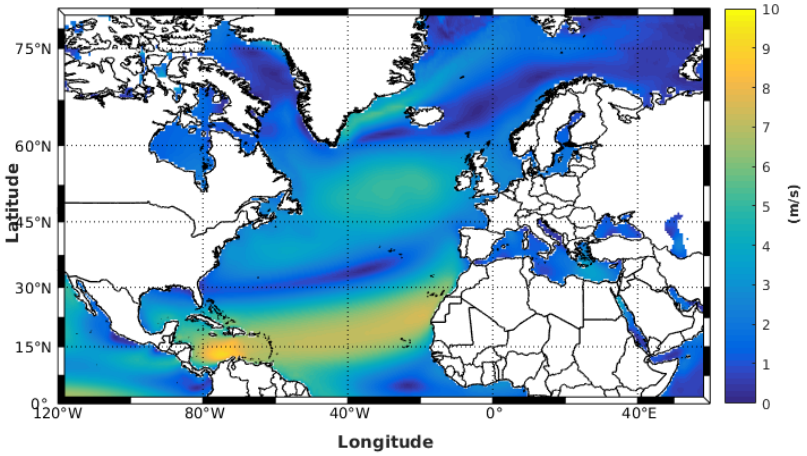
$$\mathrm{MAV} = \overline{\left(\frac{\sigma_k}{\overline{x_k}}\right)}$$

Inter annual variability

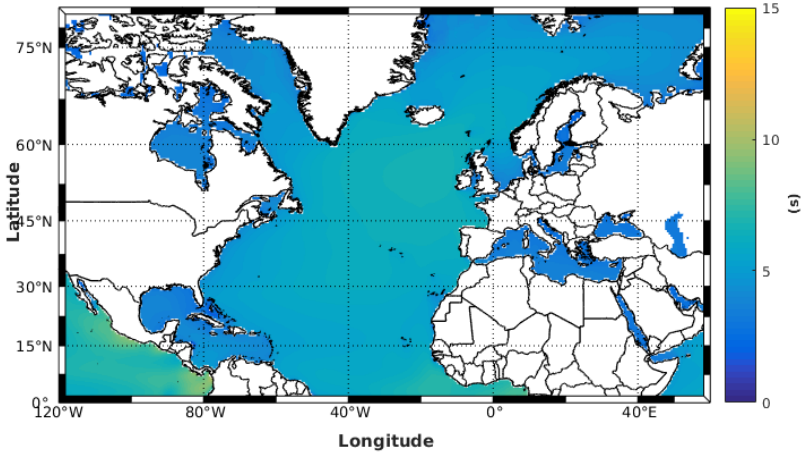
$$\mathrm{IAV} = \frac{\sigma_{\overline{x_k}}}{\bar{x}}$$

# PRESENT CLIMATE (1979-2008) EC-EARTH and WW3

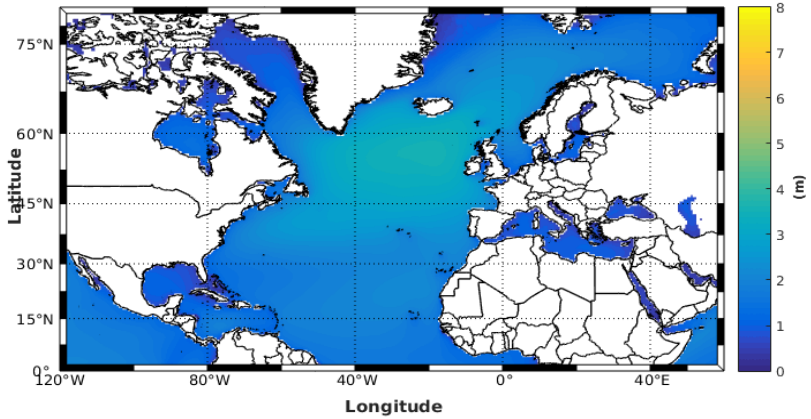
WIND




Tm02

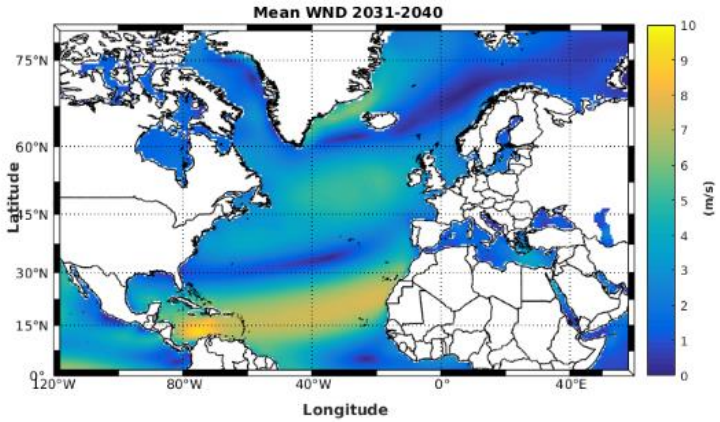


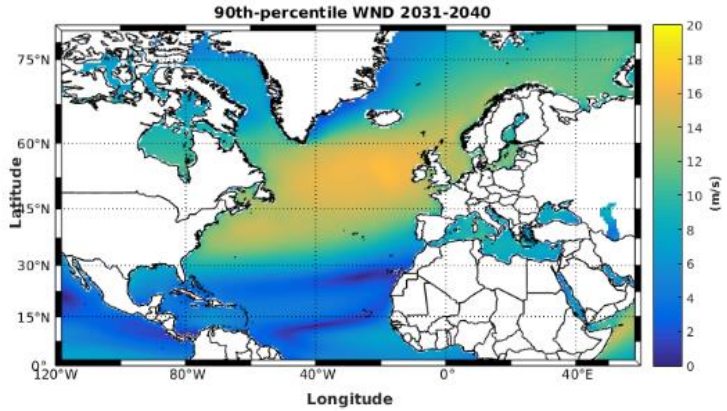

Hs



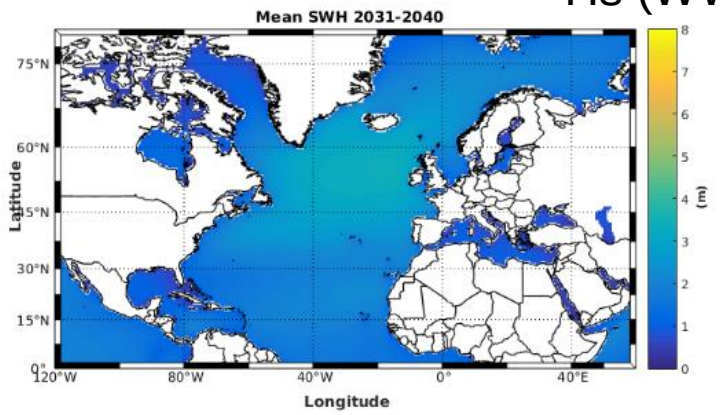
# FUTURE CLIMATE (2031-2040) RCP8.5

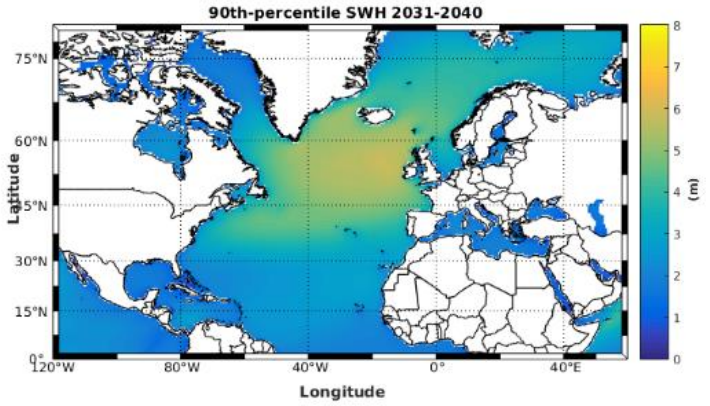
## WIND (EC-EARTH)




## Hs (WW3)



# Future work

| Nº | tasks | Nº de meses |
|---|---|---|
| 1 | Production of present and future climate simulations | 12 |
| 2 | Present and future climate analyzes at different time scales | 24 |
| 3 | Storm characteristics under climate change conditions | 12 |
| 4 | Climate indices associated with wave regimes in the North Atlantic | 12 |
| 5 | Climate change impacts on ship routes | 12 |
| 6 | Wind and wave energy potential under climate change conditions | 24 |
| 7 | Project management | 36 |

## PRODUCTS

Regional Climatology
- Wave parameters
- Sea states

Applications to
- Coastal structures
- Energy

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