Average and extreme regimes of the ocean wave climate surrounding the northwestern Iberian Peninsula under present and future climate conditions

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INTRODUCTION

In this study, present and future trends, mean and extreme regimes of the wave climate are assessed for the Atlantic Ocean surrounding the Iberian Peninsula (from 35 ° W to 0 ° W, and from 30 ° N to 50 ° N) in the context of the MarRISK project. One of the main objectives of this project is to understand the tendencies of different physical ocean variables under climate change conditions.

Although these tendencies are well established for several atmospheric variables at synoptic scale, the same level of confidence has not been achieved for wave climatology, even at synoptic scale.

We found that not all datasets from CMIP5 available from ESGF (Earth System Grid Federation) have ocean variables. At best, daily means are provided for *some* of them. The data gap has partially been covered by (CSIRO) with several ocean wave model integrations developed within the CAWCR project. Available datasets are:

- CAWCR Wave Hindcast 1979-2010: Wave hindcast from NOAA's NCEP/CFSR at 0.4° resolution.
- CAWCR Global wind-wave 21st-century climate projections: Wave climate projections for MID/END 21st using RCP 4.5 and 8.5 (Representative Concentration Pathways) using wind forcing from 8 CMIP5 models at 1° resolution.

Here, these climate models are statistically evaluated in order to determine which of them are most suitable for a *dynamical downscaling*.

METHODOLOGY

If the climate is correctly represented in a given model (with no BIAS correction procedure), then the statistical distribution of the sea state variables in the historical period must be similar to the reference distribution provided by the CFSR reanalysis. Thus, we need to define minimum indicators that allow us to evaluate the correct representation of the wave climate in each of the models.

The *two-sample Kolmogorov-Smirnov* test (hereinafter K-S test) allows us to compare two statistical distributions without knowing the underlying analytical distribution. This test compares empirical CDFs (Cumulative Density Function) obtained from two datasets indicating the probability that both have been obtained from the same underlying statistical distribution. The K-S statistic is the maximum difference between the two CDFs:

$$D_n = max|F_n(x_1) - F_m(x_2)| \quad (1)$$

where F_n is the CDF of n_1 observations of the variable x_1 and F_m the of n_2 of the variable x_2.

The smaller the value of D_s, the better the correspondence between both distributions. The test provides the corresponding p-Value that indicates the probability that the value of D_s is equal to or greater than that observed so that the closer to 1 is the p-Value, the better the correspondence between the two distributions.

Note that the K-S test assumes zero temporal autocorrelation in the analysed time series which, however, is generally not true for the 6-hourly sea state variables assessed here. In fact, the autocorrelation is very high and the effective sample size, i.e. the number of independent data points, has to be calculated in the following way:

$$n' = n\frac{1-\rho_1}{1+\rho_1} \quad (2)$$

where ρ_1 is the autocorrelation coefficient at $t_{lag} = 1$.

Trends are detected using the standard Mann-Kendall test for every sea state variable.

RESULTS

The analysed sea state variables are significant wave height (H_s) and mean period (T_m). The linear trends of the seasonal mean value of these variables (figures 1 and 2) show remarkable differences, being positive for ERA-Interim and negative for CSFR, at least at those points where the test level obtained with the Mann-Kendall test is 5 %.

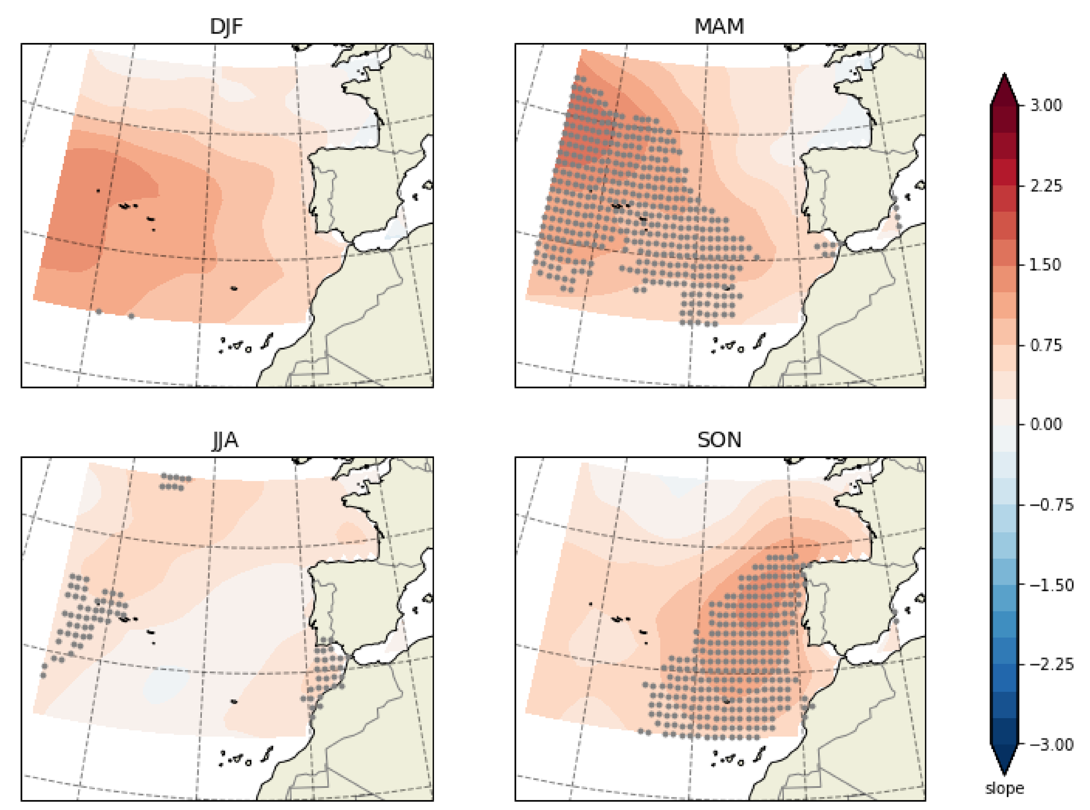

Figura 1:Significant linear trends (cm/y) of the seasonal mean wave heights from ERA-Interim for the period 1979-2005. Gray dots indicate a statistical significance of 5 % obtained from the Mann-Kendall test.

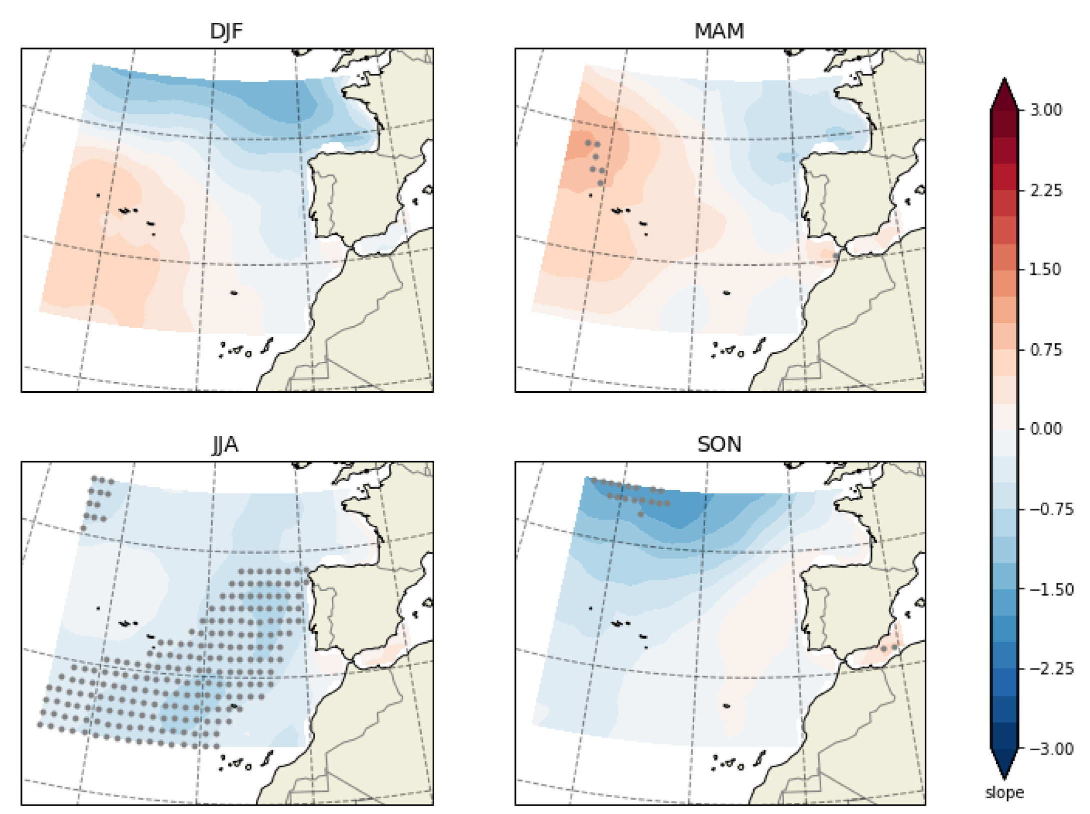

Figura 2:Significant linear trends (cm/y) of the seasonal mean wave heights from CAWCR-CSFR for the period 1979-2005. Gray dots indicate a statistical significance of 5 % obtained from the Mann-Kendall test.

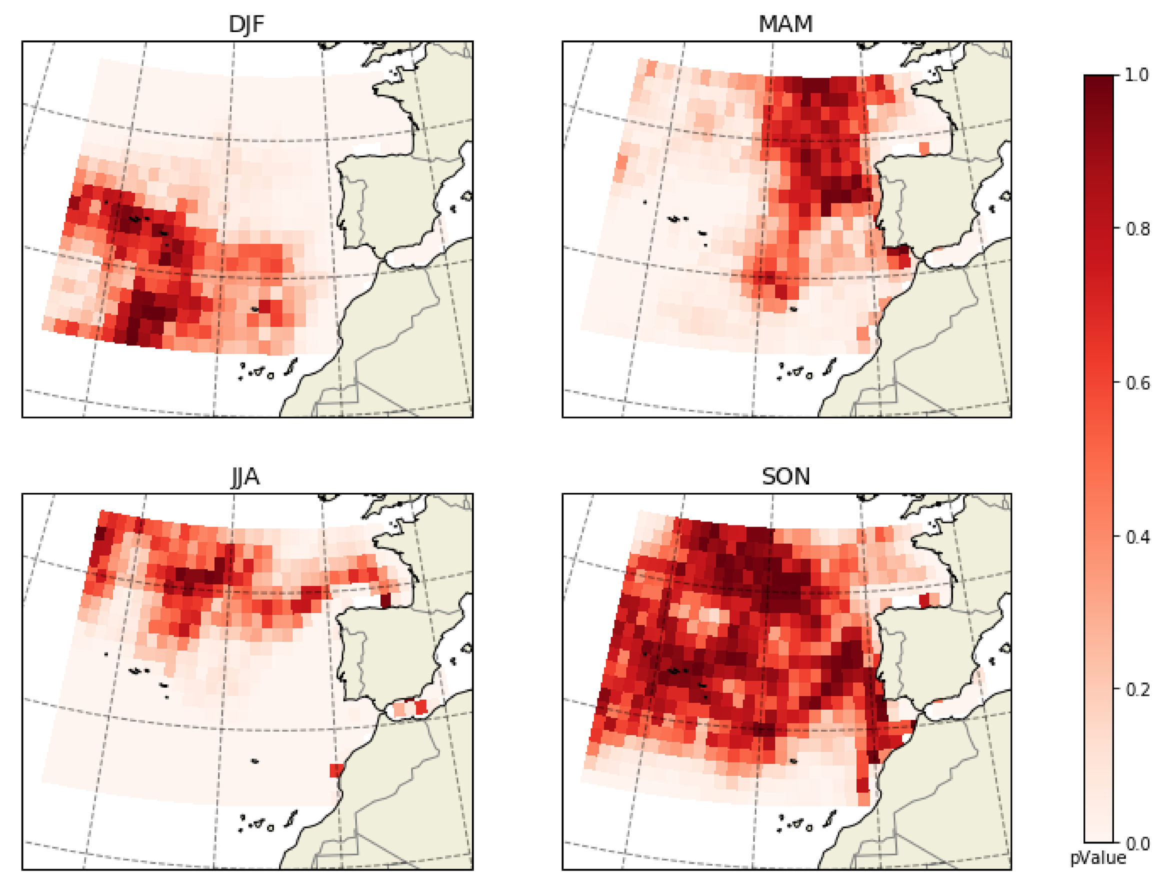

Figura 3:P-Value from the K-S test for every grid point and season. MIROC5 model.

The result of the K-S test (fig.3) is quite heterogeneous with a strong dependence on the considered season of the year. Although none of the models passes the test with ease, some models clearly outperform others, with MIROC5 performing best for the MAM, JJA and SON season, and BCC-CSM1.1 performing best for the DJF season.

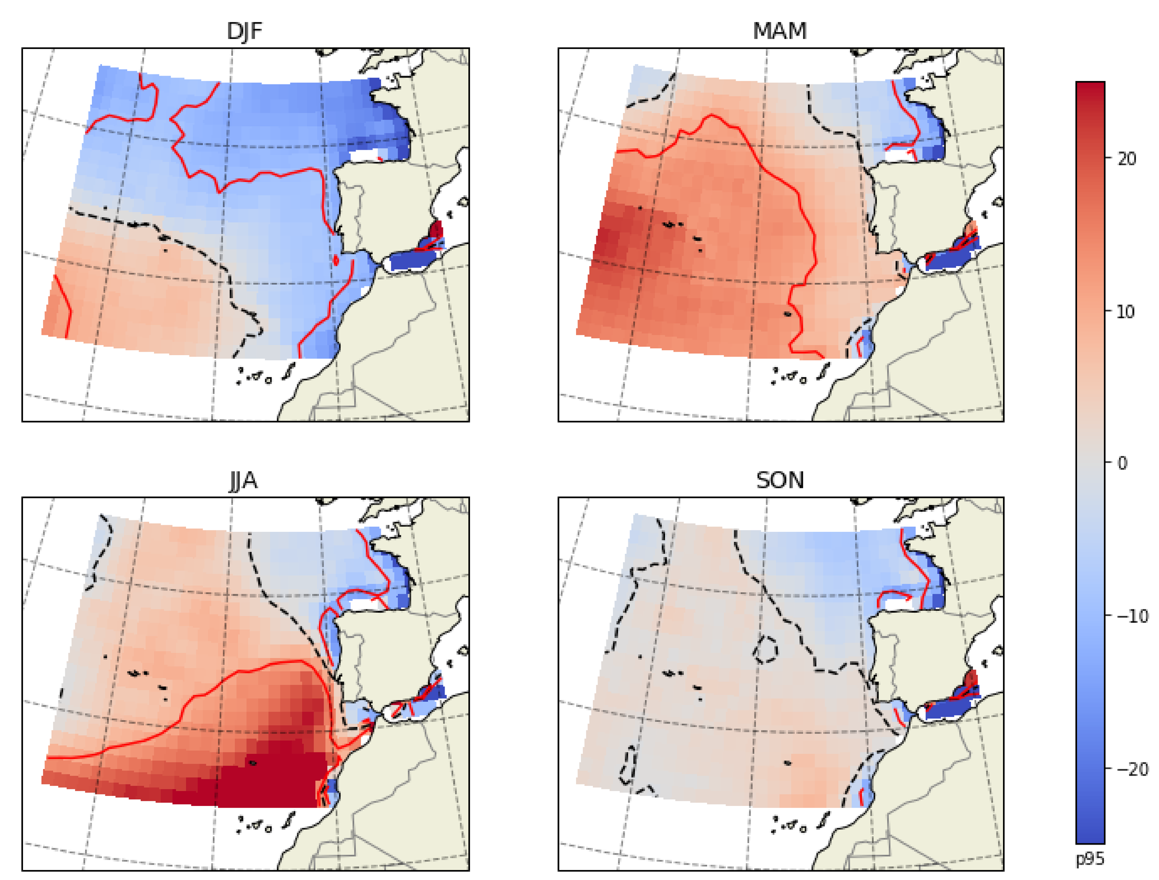

Figura 4:95 percentile in % over reanalysis (CFSR) for every grid point and season. MIROC5 model.

Figure 5 shows the rolling mean of the significant wave height anomaly for the periods MID21C and END21C in the RCP 8.5 over 20th century climatology. This magnitude is related to the evolution of the average, so on the one hand a decrease in all the models and in all the scenarios (RCP 4.5 and RCP 8.5) is expected. On the other hand, the return periods (fig. 6) obtained from the extreme regime indicate a clear decrease, so the number of extreme events is expected to increase.

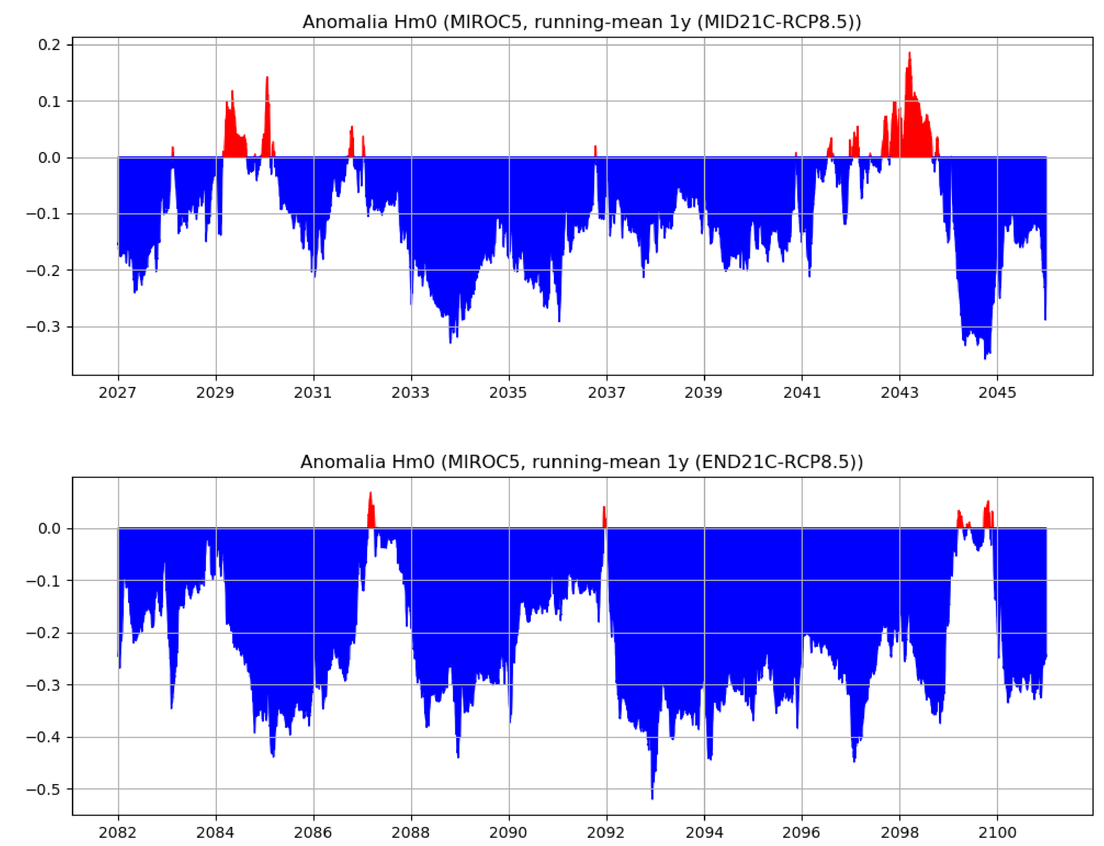

Figura 5:Annual anomalies of significant wave height for MID21C (up) and END21C (down) under RCP 8.5. MIROC5 model.

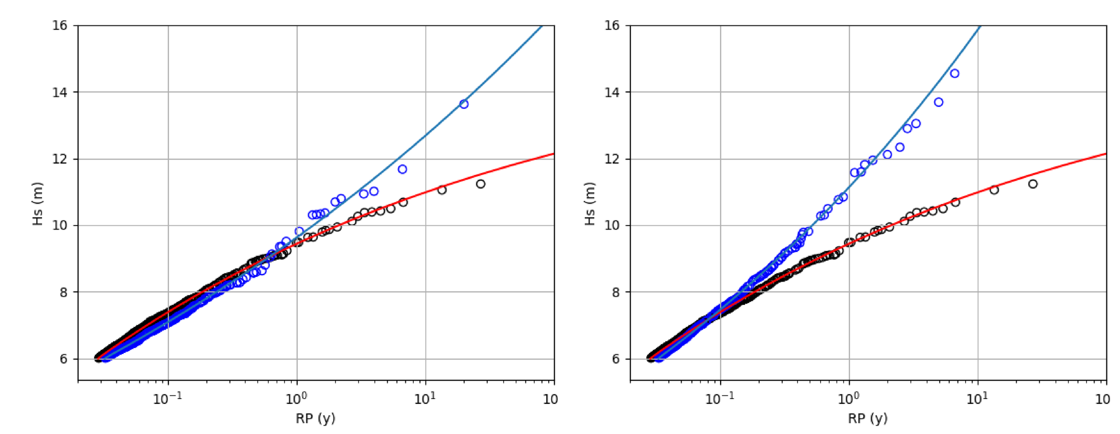

Figura 6:Return periods of significant wave height for MID21C (left) and END21C (right) under RCP 8.5. Circles are MIROC5 model data. Line is fitted Generalized Pareto Distribution (red, baseline profile).

CONCLUSIONS

- The linear trends detected in the reanalyses, although compatible and statistically significant, are not consistent.
- Only a few models correctly reproduce the reference climate (CFSR reanalysis) in the historical period without any BIAS correction.
- The anomalies of significant wave height calculated over the climate of the 20th century decrease in all the models and all the scenarios (RCP 4.5 and RCP 8.5).
- Surprisingly, albeit significant wave heights are projected to decrease on average, the number of extreme events is expected to increase.

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