SKILL AND UNCERTAINTIES IN GCM-RCM WIND AND WAVE PROJECTIONS IN THE MEDITERRANEAN SEA

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INTRODUCTION

In the context of climate science, the Mediterranean Sea stands as a region characterized by significant local and regional variabilities and high vulnerability to climate change coastal impacts. As a result, it has been identified as a vulnerability hotspot (Ali, 2022). The projected changes in waves and their regional and local variability are critical in determining future coastal water levels and impacts. While past studies have relied on Global Climate Models (GCM) with low spatial resolution to analyze future wave climate changes, high-resolution Regional Climate Models (RCMs) projections can improve the characterization of wind and wave climate at a local scale. This is especially important for conducting coastal impact assessments and adaptation studies.

This study presents the assessment of the skill and uncertainty of a multi-model ensemble of 33 GCM-RCM combinations for wind fields and wave climate modeled with different wave models for the historical period 1979 to 2005. We focus on quantifying the skill of wind fields and waves considering the role of the GCM forcing and RCM model, assessing the importance of temporal resolution in wind forcings for accurate extreme waves, comparing the performance of different wave models, and quantifying the inter- and intra-model uncertainties within the multi-model ensemble.

DATA AND METHODS

This work considers a multi-model ensemble of wind fields in the Mediterranean Sea for 33 EURO-CORDEX GCM-RCM combinations (Jacob, 2014) with 6-hour and 3-hour temporal resolution as presented in Table 1. Wave climate projections were generated with spectral wave models WaveWatch III (v5.16; The WAVEWATCH III®Development Group 2019) on a 10km grid and SCHISM (Zhang et al., 2016) on a 10-2km unstructured providing data for 1970-2005 for the reference period and 2006-2100 for projections under the high-emission scenario RCP8.5 (Lira-Loarca, 2021; Toomey, 2022).

The performance of the GCM-RCMs for wind speed, U_W, significant wave height, H_s, and peak period, T_p, was evaluated by means of the $Bias$ and root-mean-square error ($RMSE$) metrics, for the entire Mediterranean basin.

$$Bias = \frac{1}{N}\sum_{i=1}^{N}\left(Y_{RCM_{hist_i}} - Y_{hind_i}\right),$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(Y_{RCM_{hist_i}} - Y_{hind_i}\right)^2}.$$

where Y is the analyzed variable, monthly means, and maxima and the subscripts $hind$ and RCM_{hist} corresponding to the hindcast and GCM-RCM baseline simulations, from 1979 to 2005. The performance for the wind direction, θ_W, and mean wave direction, θ_m, has been assessed with the $PDF\text{-}score$.

$$PDF\text{-}Score = \int min\left(PDF_{RCM_{hist}}, PDF_{hind}\right)$$

GCMs \ RCMs	CCLM4-8-18	RCA4	HIRHAM5	COSMO-crCLIM	RACMO22E	ALADIN63	REMO2015	RegCM4-6
CCCma-CanESM2	W6h							
MIROC-MIROC5	W6h							
CNRM-CERFACS-CNRM-CM5		W6h	W6h	S6h	W6h	S3h	S3h	S3h
MOHC-HadGEM2-ES		W6h	W6h	W6h	W6h	S3h		
MPI-M-MPI-ESM-LR		W6h	W6h	S6h				S3h S6h
NCC-NorESM1-M		W6h	W6h	W6h		S3h	S6h	
ICHEC-EC-EARTH		W6h	W6h	W6h	W6h			
IPSL-IPSL-CM5A		W6h	W6h		W6h			S3h S6h

Table 1. GCM-RCM with 6-hour a 3-hour resolution and modeling setup with Wavewatch III (W) and SCHISM (S).

RESULTS

Figure 1 presents the winter Bias for the monthly maxima wind speed for some models in the ensemble. It can be observed that the Bias for winter maxima ranges from -2.4 m/s to 3.2 m/s. Figure 2 presents the winter bias for monthly maxima significant wave height presenting values ranging from -2 m up to 1 m. Figure 3 presents the winter bias for monthly maxima of the peak wave period with values ranging from -2.5 s until 0.8 s. It can be highlighted that for all three variables, the RCA4 and HIRHAM5 RCM simulations present a similar spatial distribution in bias regardless of the GCM forcing, whereas the CCLM4-8-18 and COSMO-crCLIM RCM simulations present a different spatial behavior depending on the GCM forcing.

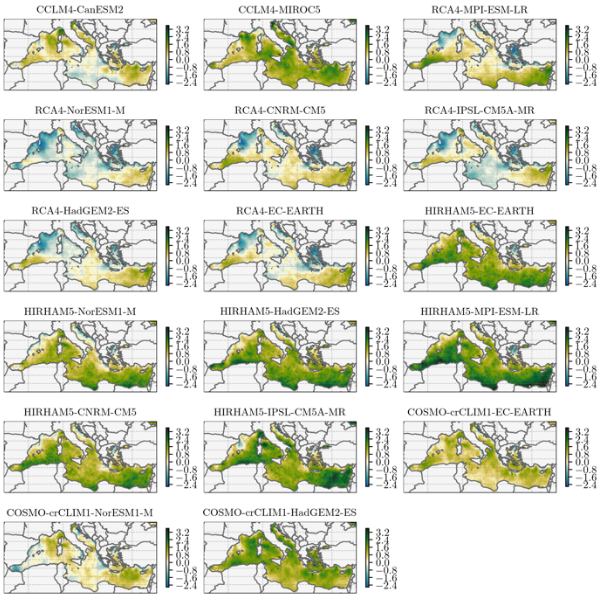

Figure 1 – Winter (DJF) $Bias$ for monthly maxima U_W.

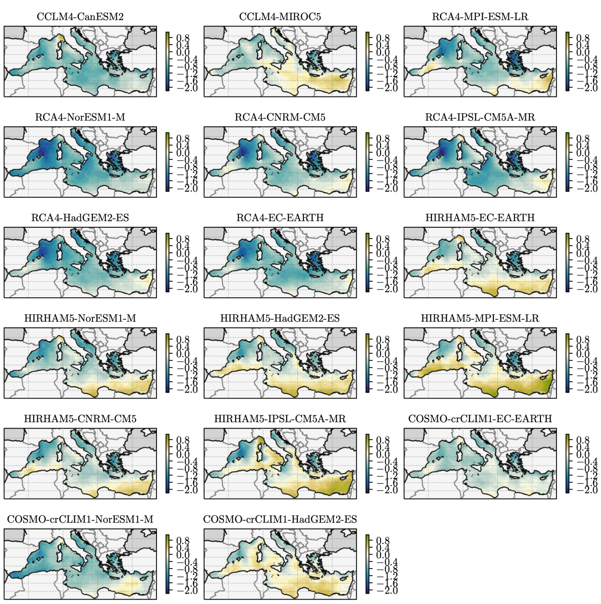

Figure 2 – Winter (DJF) $Bias$ for monthly maxima H_s.

Figure 4 presents the PDF distribution for the winter mean wave direction for hindcast and GCM-RCMs combination for a location with coordinates 13.71° longitude and 35.75° latitude. It can be observed that the ensemble mean follows a similar distribution as the hindcast although a spread can be observed for the main wave directions. This uncertainty will be further explored during the presentation as well as an in-depth seasonal analysis for the means and maxima of the main wave and wind climate variables providing an assessment of model selection for future climate impact studies in the Mediterranean Sea.

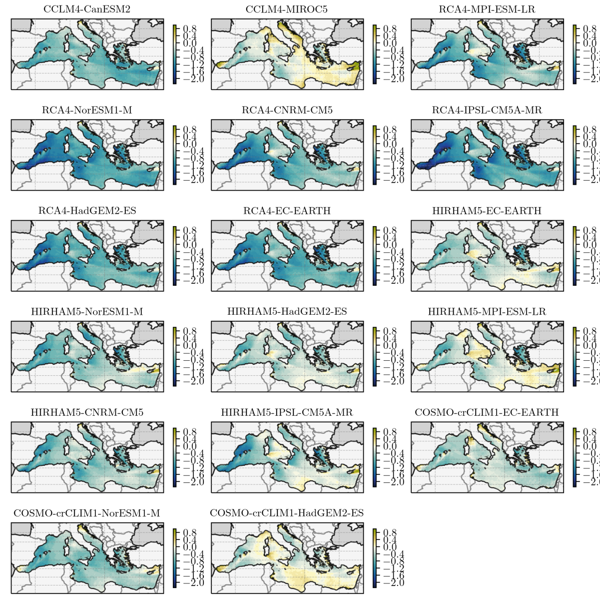

Figure 3 – Winter (DJF) $Bias$ for monthly maxima T_p.

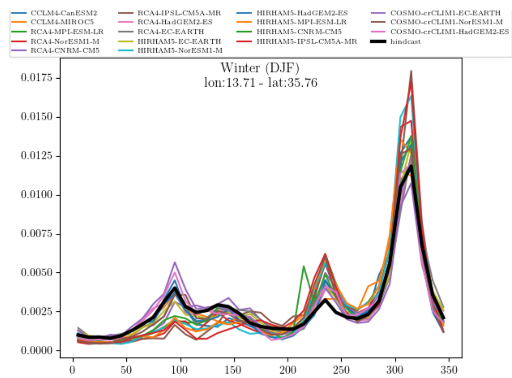

Figure 4 - Probability Density Function of mean wave direction for hindcast and GCM-RCM simulations during winter for a specific location.

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