Tools for evaluation of extreme wave in the Mediterranean Basin

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The evaluation of extreme Significant Wave Height (SWH) values is very important for planning and managing coastal defenses and off-shore activities. This study is based on the results of numerical models of wave evolution over four years period (1995-1998), which are forced with wind fields computed by regional or global atmospheric circulation models. This study compares two different models (WAM, Wave Model and WW3, Wave Watch 3), analyzes the role of the wind forcing (using both ERA40 reanalysis and the REMO-HIPOCAS regional model wind fields), and identifies the combination of wind fields and wave model that is optimal for the reproduction of extreme SWH events in the Mediterranean Sea.

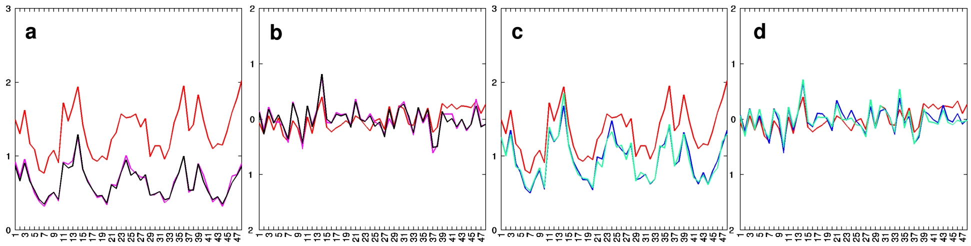


Fig. 1. Values in meters (y-axis), calendar months on the x-axis. Panel a): Comparison between monthly average SWH for WAM-ERA40 (**black**), WW3-ERA40 (**pink**) modeling configurations and satellite data (**red**). Panel b): Same as panel a) except it shows the dimensionless index. The SWH dimensionless index for every month i of the simulation, has been defined from the monthly average SWH, computing its deviation from the mean annual cycle, and normalising it with the corresponding monthly standard deviation:

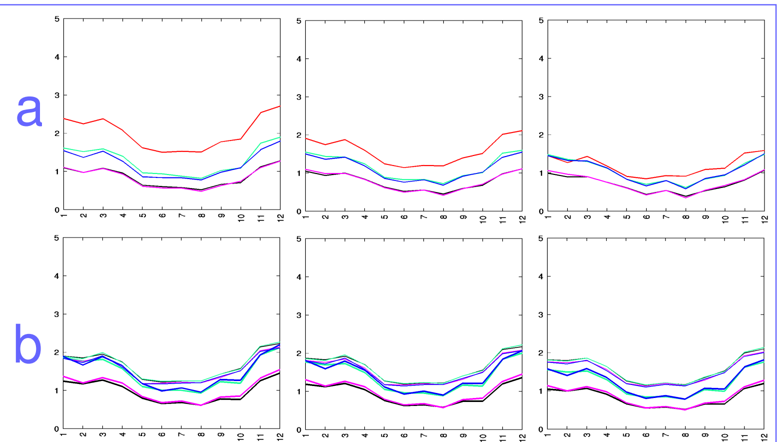
$$SWH_i^{dataset} = \frac{\langle swh_i^{dataset} \rangle - swh_{month(i)}^{dataset}}{STDEV_{month(i)}^{dataset}}$$

Here, $\langle swh_i^{dataset} \rangle$ is the average monthly SWH value, $swh_{month(i)}^{dataset}$ the value of the corresponding month in the mean annual cycle, and $STDV_{month(i)}^{dataset}$ its standard deviation. This SWH index is meant to retain the information on inter-annual variability. Panel c): Comparison between monthly average SWH for WAM-HIPOCAS (**green**), WW3-HIPOCAS (**blue**) modeling configurations and satellite data (**red**). Panel d): Same as panel c), except it shows the dimensionless index.

The numerical model choice is irrelevant, but the wind fields choice is crucial: in particular, the HIPOCAS forcing produces SWH fields with much smaller bias than ERA40.

Fig. 2. Values in meters (y-axis), calendar months along the x-axis. The monthly variability of extreme values is studied selecting the 3 highest SWH events in each model grid point along the satellite track. Each row shows the 3 maximum values (in decreasing order from left to right) for the whole 4 year period for satellite data and the four model simulations. In the upper row maxima were extracted considering the satellite data and the matching model data are shown (panels a), while in the lower row maxima were extracted considering model data and the matching satellite data are shown (panels b). In both row, colors denote the different configuration: **black** for WAM-ERA40, **pink** for WW3-ERA40, **green** for WAM-HIPOCAS and **blue** for WW3-HIPOCAS. Satellite data are denoted with a **red** line in both panels.

As a average analysis, the 3 highest SWH events are underestimated in respect to the satellite data, but they have the same mean behavior. Nonetheless, the best results are obtained when HIPOCAS forcing is used with both numerical model.



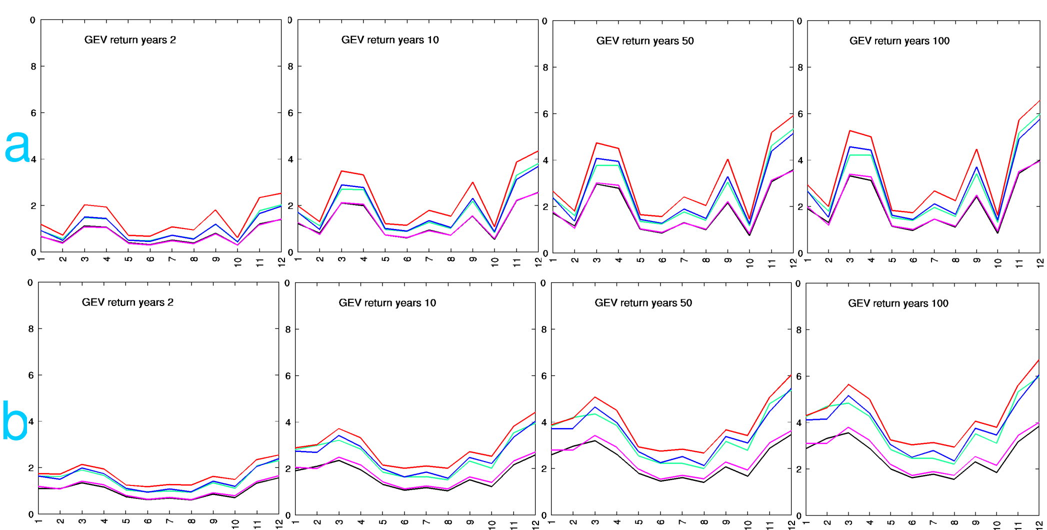


Fig. 3. Values in meters (y-axis), calendar months on the x-axis. The GEV results are based on pairs of co-located satellite and model data. The figure shows the results of the GEV analysis for several return periods (from left to right 2, 10, 50, 100 years) Panels *a* show the results of the GEV analysis applied to the 3 highest SWH events in the satellite data (**red**) and to the corresponding values of model data in the four modeling configuration: WAM-ERA40 (**black**), WAM-HIPOCAS (**green**), WW3-ERA40 (**pink**) and WW3-HIPOCAS (**blue**). Panels *b* show the GEV results for the same return period except they are based on the 3 highest SWH events in the model data and the matching satellite values.

In both cases, the four modeling configuration produces an annual cycle of extreme values similar to that of the satellite data and the model used is irrelevant with respect to the wind forcing. HIPOCAS forcing produces better results than ERA40 and the WW3-HIPOCAS modeling configuration is most similar to satellite data.

AVERAGE SWH						DIMENSIONLESS INDEX
Model-Wind	Satellite Average	Standard Deviation	Model Average	Standard Deviation	Correlation	Correlation
WAM-ERA40	1.34	0.31	0.64	0.21	0.87	0.61
WAM-HIPOC	1.34	0.31	0.96	0.29	0.90	0.68
WW3-ERA40	1.34	0.31	0.65	0.23	0.88	0.61
WW3-HIPOC	**1.34**	**0.31**	**0.96**	**0.29**	**0.91**	**0.71**

Results show that all configurations are adequate for reproducing the SWH intermonthly variability and for a reliable assessment of SWH trends (though, eventually, with a magnitude lower than in reality), with the WW3-HIPOCAS configuration having the highest correlation with satellite data (higher then 0.9). The correlation between the two models (WAM and WW3), with the same wind field forcing, is however very high: this is a further evidence that the choice of numerical model is irrelevant, when compared with that of the forcing.

This study shows that numerical simulations of the wind waves can produce a reasonable estimate of SWH extremes and of their variation in space and time. The highest SWH values are better described when models are forced by the HIPOCAS wind fields. In general, as far as the GEV analysis is concerned, the WW3-HIPOCAS modeling configuration has the largest similarity with satellite data. This combination of wind fields and wave model results optimal for the reproduction of extreme SWH events in the Mediterranean Sea.