

RESPONSE TO REVIEWERS

Please note that in this rebuttal, *italics* refer to the text of the reviewers' comments, our detailed response is in black, the new text of the revised version is in **bold blue**.

REVIEWER #3:

GENERAL COMMENT:

A coupled hydrodynamic (2DEF) and wave (SWAN) model is presented. The model is tested for storms in Calabaia beach by including sea level rise and extreme wave projections. The coupled model is assessed against results from Mike model.

One of my main criticisms to this work is that the results of the coupled hydrodynamic and wave model are evaluated against another model (Mike). Throughout the whole text the English expressions need to be reviewed and corrected and representation of results and figures need to be improved. I also suggest editing the title to be more specific.

We thank the reviewer for his/her constructive criticism. We seriously considered his/her suggestions, amended some points, and further improved the manuscript. Some parts of the paper have been rewritten and/or moved to improve the whole readability. Detailed answers are reported below.

We agree with the reviewer that the validity of the results of the proposed model has been verified against another model only (i.e., MIKE). However, on one hand, the case study is site-specific. On the other hand, since at Calabaia Beach the morphology is very simple, this case study can have general application. Moreover, both SWAN and 2DEF (and MIKE) models and have been widely tested over decades (we provided some references thorough the manuscript). Finally, we highlight that the target of this work is to compare the two methodologies (SWAN+2DEF and MIKE modelling systems), ensuring that the results provided are similar on order to verify the effectiveness of the proposed coupled system.

- 1) *Abstract: The abstract is so general and does not include that Mike model is used for assessing the couple hydrodynamic and wave model. Line 12: Please explain what you mean by "wave and hydrodynamic inshore field".*

We agree with the reviewer. In the new version of the manuscript, we rewrote the abstract as follows:

Climate change will have an undeniable influence on coastal areas, resulting in increased rates of both sea level rise and storm-related impacts. In this context, it is crucial to estimate the local probable extreme sea wave conditions, to properly reproduce the sea state and the coastal hydrodynamic, and to investigate the effectiveness of sea defenses under sea level rise. This work describes the first steps towards an innovative fully coupled modelling system composed of a wind- sea wave (SWAN) and hydrodynamic model (2DEF). Numerical simulations, focusing on Calabaia beach, Italy, have been compared to the MIKE outcomes in the same area. The simulations have been performed to study the inshore sea wave characteristics, to assess the effectiveness of the actual sea defence interventions, and to identify the impact of extreme storms, by combining sea level rise and extreme sea wave scenarios with the most recent georeferenced territorial data. The models are two-way coupled at half-hourly intervals exchanging the following fields: 2D sea level,

surface currents and bottom elevation are transferred from 2DEF to SWAN; sea wave characteristics computed by SWAN is then passed to 2DEF by modifying the radiation stress.

- 2) *Introduction: The introduction is about three pages long and most of the sentences are off topic. It does not provide enough information about the topic of the paper: coupled modelling. I suggest rewriting this section while focusing on relevant literature and putting them in the context of this study.*

We removed most of the sentences off topic and we restructured the whole introduction, thank you.

- 3) *Line 21: I suggest rewording the sentence: "Coastal areas contain a wide amount of life"*

Fixed, thank you.

- 4) *Line 39: I suggest rewording the sentence: "sea stormy conditions"*

Fixed, thank you.

- 5) *Line 58 & 59: "This is particularly significant in case of micro-tidal environments, such as the Mediterranean Sea, where extreme events are expected to be superimposed to SLR scenarios, exacerbating the flooding hazard even in the case of a possible storminess reduction. Please explain the logic of this sentence. The word "micro-tidal" refers to small tidal range, how can that be a reason for "exacerbating the flooding hazard"*

In small tidal range environments, 20-30 cm can be significant (with respect to the tide amplitude) in determining the flooding of such areas. For this reason, SLR is particularly hazardous.

- 6) *Line 84: Please explain what you mean by "the design of maritime works"*

As we summarized the introduction, in the new version of the manuscript, such sentence is not reported anymore.

- 7) *Line 103: "The most important recent storm" Please explain what makes the storm "the most important".*

In the new version of the manuscript, we added the reference [Ulbrich et al., 2001](#). Moreover, the characteristics/importance of the storm are widely described/highlighted in Section 2.5.

- 8) *Line 124 to 126: "Apennines run along the whole region from north to south, consisting of five main ranges, namely, Pollino, Catena Costiera, Sila, Serre, and Aspromonte, characterized by peaks heights between 1,500 m and 2,000 m (Federico and Bellecci, 2004)." Please explain how this study is related to Apennine Mountains?!*

We summarized the first paragraph of Section 2.1 in:

Calabria region is in the south of Italy, ranging between 37°55' and 40° latitude North and between 15° 30' and 17° 15' longitude East. The western part of the region is bounded by the southern Tyrrhenian Sea, while the southern, and eastern sides are bounded by the Ionian Sea (Fig. 1).

- 9) Line 146 & 147: Here you are referring to ERA, while in Line 102 you have referred to ERA-Interim. Which one has been used in this study? The temporal resolution of ERA5 reanalysis is 1 hour, please explain why 6-hour resolution is used in this study. Also add information about the spatial resolution.

We used ERA5 and we fixed the misleading term, thank you.

We note that for climate studies, a 6-hourly dataset is the best compromise to produce a reliable climate analysis and the storage-cost. More details about the data can be found in [Lo Feudo et al., 2022.](#), mentioned in such paragraph.

- 10) Line 151 to 153: “Although the actual performance of wind-wave models is generally good, for closed basins (i.e., the Mediterranean Sea) winds forcing is generally underestimated, with a significant impact on wave modelling due to the lack of knowledge of detailed physiographic features.” Please provide references confirming this.

In the new version of the manuscript, we added in that sentence the reference [Cavaleri and Bertotti, 2004.](#)

- 11) Line 154: “ECMWF wind fields” Is this ECMWF ERA5 reanalysis?

Yes, thank you for noting.

- 12) Lines 153 to 157: Considering that ERA wave data are available in 0.5-degree spatial resolution, please explain how the ERA5 data are matched with the buoy data. Also, explain the possible reason behind differences between the two sources?

We refer [Lo Feudo et al., 2022](#) for the analysis and comparison between the two sources of data.

- 13) Figure 2: Please explain the horizontal scatter of points in panel b where mean periods from ERA5 are around 3s

Very-few data show this behaviour in calm sea condition, possibly due to boat waves (of negligible height) that affect the recorded signal.

- 14) Line 172: Please explain why 2DEF model is used. Defina 2003 is about “Numerical Experiments on Bar Growth”. How has that been the best model for hydrodynamics here?

2DEF model has been widely applied in lagoonal areas. In the present manuscript, we coupled the 2DEF model with SWAN in order to solve the complete wave field (see lines 149 -160).

- 15) Line 188: “The SWAN grid is included into the boundaries of the 2DEF domain.” This sentence is unclear.

In the new version of the manuscript, we wrote:

...the SWAN **domain** is included into the boundaries of the 2DEF domain.

16) Line 197: *“The model grid is closed 4 km north of Diamante” The sentence is unclear.*

In the new version of the manuscript, we removed this misleading sentence. Thank you for noting.

17) Lines 205 & 206: *“Specifically, we reproduced seven wave directions (i.e., 165 °N; 195 °N; 225 °N; 255 °N; 285 °N; 315 °N; 345 °N) and, for each wave direction, three significant wave heights (i.e., 4 m; 6 m; 8 m).” This sentence is very confusing! What does it mean to reproduce 3 Hs for each wave direction?!*

The reviewer is right. In the new version of the manuscript, we wrote (lines 183 – 188):

Specifically, we reproduced seven wave directions (i.e., 165 °N; 195 °N; 225 °N; 255 °N; 285 °N; 315 °N; 345 °N) and, for each wave direction, three significant wave heights (i.e., 4 m; 6 m; 8 m). For each of the $1+7\cdot3 = 22$ simulations, we reproduced five scenarios of sea level rise (i.e., +0.0 m; + 0.5 m; +1.0 m; +1.5 m; +2.0 m) and, in turn, three morphological scenarios (i.e., present condition of the shoreline, after the intervention described in Section 2.1 and in Maiolo et al., 2020a and 2020b; former condition, without such intervention; present condition without the submerged barrier and the semi-submerged groynes), for a total of $22\cdot5\cdot3 = 330$ simulations.

18) Line 246: *“hurricanes of category 2” Please explain what that means.*

In the new version of the manuscript, we added the following reference: **Klotzbach et al. 2020.**

19) Figure 5: *Where is the study area in this figure?*

We fixed this issues in the new panels, which refer to ERA5 reanalysis. Thank you for the advice.

20) Figure 6: *I suggest separating the wave height, period, and direction into 3 different subplots.*

Fixed, thank you for noting.

21) Line 303: *“Extreme wave climate study is based on data collection, selection, and analysis” This sentence seems to be off topic.*

We removed it, thank you for noting.

22) Line 412: *“The enhancing storm impact on coastal areas have reshaped the history of many urban settlements and communities”. Please rewrite this sentence with better choices of words.*

We rewrote the first sentence of the conclusion as:

Flooding and wave erosion driven by climate change has reshaped the history of many coastal settlements and communities. However, the lack of awareness of the climate change effect on the possible occurrence of more hazardous events in the intervening decades has often resulted in an overreliance of former sea defenses or a loss of folk-memory (Hansom et al., 2015). In this context, structural measures, even if combined with high level of technical knowledge, are not the panacea for the long-term safety of coastal areas (Mel, 2021).

23) *Line 426: “The coupled system improves the performance of the simulation with respect to the uncoupled system. Furthermore, the outcomes are similar to other commercial models, but with a significantly lower computational cost.” Where in the text have these been demonstrated? Please name which commercial models you are referring to.*

In the new version of the manuscript, we wrote (lines 393 – 394):

The outcomes are similar to other commercial models (e.g., MIKE), but with a significantly lower computational cost.

Thank you for noting.

24) *Major technical correction is needed in the text, on top please note that there are two 3.3 sections in the manuscript.*

Fixed, thank you for noting. All the manuscript has been checked by all the authors.