20.12.2022

Answer RC2:

The authors wish to thank the anonymous reviewer for his/her review. The comments and remarks helped us improving the quality of the paper. We are pleased to address the point-by-point answers to your review in blue in the supplement to this comment.

Best regards,

The authors.

Main comments:

I thinks this paper brings an interesting contribution to the field, but before publication I would like the authors to clarify the following major point:

- The model used does not include shallow water processes such as wave breaking (line. 93), and cannot represent important interactions with the seabed in shallow regions, as the minimum depth is 6m (line. 206). These shallow water processes, as stated by the authors in the introduction, are important for wave setup and set down; yet this work estimates the setup from data that exclude them. Can the estimation of the setup, calculated excluding important shallow water processes, be trusted? Is it a reliable approximation?

The Introduction, Sect. 2.1 (Description of the wave model) and Discussion have been revised to clarify this point by (1) highlighting more clearly the processes taken into account in the model that are likely to be impacted by non-linear interactions and those that are not activated (2) modifying the introduction which focused too much on the coastal wave breaking compared to the model's capabilities and the purpose of the study.

To explain the choice not to activate the depth-induced wave breaking in the model, the two following sections have been added in the Discussion:

"**5.3 Limitations associated with the applicability of the parametrization to coastal points**

To calculate the wave setup for the coastal points of our regional domain, we chose to use the simple parameterization of Stockdon et al., 2006 based on deep water parameters. However, the coastal points are theoretically not purely deep water as shown in Figure 2a (yellow dotted lines). Yet, this approach, used in other climate studies (Melet et al., 2018, 2020a; Lambert et al., 2020), appears pragmatic given the model resolution limitations (Sect. 5.1) and the processes accounted for in the wave model (Sect. 2.1).

5.4 Impact of the absence of depth-induced wave breaking

Very close to the coast, the depth-induced wave breaking is a fundamental depth-dependent process that can have a first-order effect on the shallow water wave statistics and thus on the wave setup. As explained in Sect. 2.1, the physics associated with the explicit representation of coastal breaking waves is not activated. Such an approach is justified because our primary interest is to calculate the wave setup contribution to include it in further analyses on extreme water levels and the parameterization used to compute this contribution is based on deep water parameters (Sect. 2.5) that are not supposed to be affected by coastal wave breaking.

With the coastal wave breaking included, the significant wave heights should be substantially impacted in shallow waters. The impact of the inclusion of the water level variations in the wave model would also probably differ. A perspective for this study would be to take into account coastal wave breaking and to apply new specific wave setup formulations which would not require deep water characteristics or to use a wave model that directly resolve the wave setup."

Some tests have been performed with the coastal wave breaking activated (Battjes and Janssen, 1978) in the regional wave model for the significant wave extreme event of the year 1993 in the Bay of Mont Saint Michel (Fig. RC1). These tests suggest that the conclusions of larger extreme significant wave heights due to the inclusion of the water level variations occurring at high tide are still qualitatively valid. Nevertheless, the impact is larger with the coastal wave breaking activated, which is expected to be even more significant at the end of the century with the mean sea level rise.

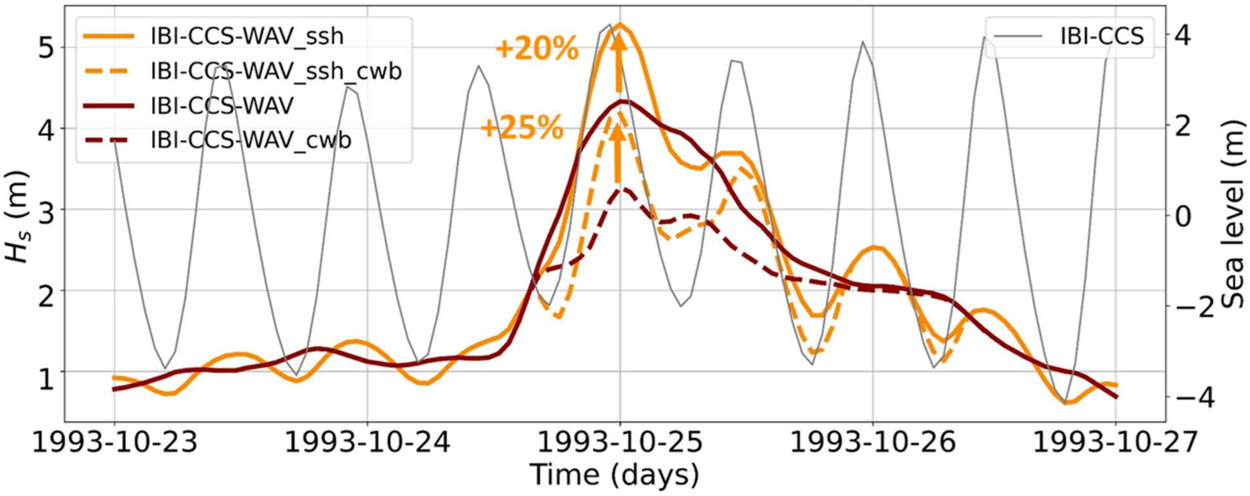

Figure RC1: Same as Fig. 12a of the paper but with new simulations that include the depth-induced coastal wave breaking: IBI-CCS-WAV_ssh_cwb and IBI-CCS-WAV_cwb.

Moreover, the limitations associated with the use of parameterizations have been moved to the Discussion section (see comment below). The limitations of the study are also reminded in the Abstract and in the Conclusion.

A sentence has been added at the end of the Abstract: "However, as the wave setup is computed with a parameterization based on offshore characteristics, the depth-induced wave breaking is not activated in the model. The estimates provided in this study therefore only partially represent the processes responsible for the wave-water level non-linear interactions."

The end of the Conclusion has been revised: "However, as the regional wave model does not have a very fine representation of the bathymetry or the coastline and does not resolve the depth-induced wave breaking in the shallow areas, the estimates provided in this study only partially represent the processes responsible for the wave-water level non-linear interactions. Moreover, the results found might be dependent on the parametrization used to compute the wave setup and therefore on the beach slopes.

Specific comments

Section 2 Methods: model and simulations: I find this section hard to read. I appreciate that all information required on the models are provided in section 2, and figure 1 is helpful to understand the simulation used, however it is easy to get lost in the nomenclature of the multiple simulations, and in the mere amount of information laid out. It may be worth considering simplifying the reader's work by adding a table containing a list of all simulations ran, including which forcing were used and the main details (resolution, period etc.) for each. This would improve the readability.

The structure of "Sect. 2 Methods" has been totally revised according to the suggestions of RC1. It should be now easier to read. With these changes, Figure 1 presenting all the simulations (periods, resolutions, names), appears at the very beginning of the methodology section, so we considered it would not be necessary to add a table providing the same information.

Line 217-223: 'Therefore, at first order, wave setup and runup can be predicted via empirical formulations […] wave setup estimates are based on an empirical formulation (Stockdon et al., 2006).' This is the paragraph where you should convince the reader that runup estimation is reliable, despite the model's approximation. Please give more details on the parametrization limitations and how the empirical formulation you use affects results (i.e. what processes you are missing out). Explain why you think this first order approximation is good enough, even though you are not including sallow water processes.

The limitations associated with the use of parameterizations (L229-237) have been moved to the Discussion section and completed by:

"**5.2 Limitations associated with the use of parametrizations for the wave setup**

Limitations in the use of parametrizations to estimate wave setup are thoroughly discussed in Melet et al., 2020; Lambert et al., 2020, including sensitivity analyses of the wave setup and runup contributions to different empirical parametrizations. The generic parametrization of Stockdon et al., 2006 used to compute the wave setup in our study is indeed subject to intrinsic limitations. A major limitation is that the formulation is only representative of sandy beaches. Other parameterizations (Guza and Thornton, 1981; Holman, 1986; dissipative case of Stockdon et al., 2006 or for a review Dodet et al. 2019) exist but they are often limited to specific coastal environments (e.g. dissipative sandy beaches, rocky cliffs) and have been calibrated with relatively few field data. The calibration therefore does not cover all the spectra of the environmental conditions.

For our large-scale study, another major limitation is that the parameterization relies on the specification of a beach slope. [L229-237]".

Line 243: When referring to the wave setup scaling the author sometimes use (eg. Line 243) and sometimes don't use (eg. Figur10 description, Line 433) the delta sign. Please be consistent with it.

The delta has been removed.

Line 259-261 'The ability of IBI-CCS-WAV and IBI-CCS-WAV_ssh to reproduce observed distributions is assessed for the mean state and the 99th percentile of the significant wave height and peak period since these variables are then used to compute the wave setup scaling (Sect. 3.2, 4).' Has the IBI_CCS_WAV_ssh been validated? The section title seems to imply it hasn't ('Validation and projections of IBI-CCS-WAV, without waves-sea level interactions').

The validation of the IBI-CCS-WAV_ssh simulation has been added only on the two scatter plots of Figure 4 and 5 which are the comparisons to tide gauge data.

A paragraph has been added in Sect. 3.1.1: "The comparison of IBI-CCS-WAV_ssh with the reanalysis is not relevant since the latter does not consider the forcing with hourly sea level variations. The IBI-CCS-WAV_ssh simulation is compared to the buoy data in Figure 4d,h and Figure 5,d,h. However, it is difficult to get useful information from these comparisons with buoys since they are not located at the coast. Actually, they are in areas where there is no impact of the wave-water level non-linear interactions (Sect. 4) so the performances of IBI-CCS-WAV_ssh are similar to those of IBI-CCS-WAV."

For the same reasons and also because we found that the inclusion of the water level variations on the wave model has no impact on the mean wave direction over the 1993-2014 period, we chose to not include the wave rose of IBI-CCS-WAV_ssh. A sentence is added Sect. 3.1.2: "In Figure 6, the focus is only on the IBI-CCS-WAV simulation as we found that the impact of the water level variations on the mean wave direction was negligible over the 1993-2014 period."

Section 5. Discussion: Important points are discussed, but I would strongly recommend adding a section on the implications of your results. For example:

The authors found an increase in the wave set up and a large impact on the wave-water level interaction in regions of extreme tidal range. In the introduction, the authors talk about coastal hazards and flooding during extreme water level to motivate the study. You cannot quantify hazards based on wave setup alone, but there is a lot to discuss. Considering that the tidal range will also be affected by sea level rise, are the regions where you predicted an increase in wave setup the same regions that are at risk from extreme wave events today? Are there other regions in the world that these finding could be relevant for (eg. Regions where the tidal range is expected to increase significantly)? The number of extreme events is also expected to increase in future, and your results show that these are periods in which the wave setup is particularly affected by the water-level changes; this could also be discussed. Which are the limitations of this study?

A section has been added in the Discussion part to discuss more deeply the results:

"**5.6 Implications of the results on extreme wave projections**

Marine flooding hazards cannot be quantified based on wave setup alone but wave setup can locally partially balance or enhance water levels at the coast (Melet et al., 2020a). Depending on the location (wave regimes, local ocean processes involved, sign of the extreme wave projected changes, amplitude of the projected changes in ocean processes), the inclusion of the non-linear interactions could thus enhance or balance the future wave extremes and may be important to consider for future flooding hazard calculations. The results presented in this study highlight that wave-water level non-linear interactions can be substantial for extreme wave height and wave setup, but are region dependent. For instance, the extreme wave projections are directly dependent on the water level variations forcing. In our case, the future water level variations and therefore a large part of the non-linear interactions are mainly associated with the mean sea level rise of about +80 cm and less so to changes in tides or storm surges. In other regions, large projected changes in tides or storm surges could impact the future waves conditions. For instance, Pickering et al., 2017 and Haigh et al., 2019 showed changes up to + 20 cm in the M2 component in the China Sea and in the Gulf of Saint Lawrence. Then, the future wave extremes could also be substantially more impacted in areas subject to larger mean sea level rise such as along the eastern coasts of the United States, in the Gulf of Mexico and in the Caribbean Sea where a rise of +1.4 m is expected at the end of the century under scenario SSP5-8.5 (Fox-Kemper et al., 2021)."

Line 587, Impact of waves on sea level. Please discuss what this means in relation to your results: how would you expect the impact of waves on sea level to affect your results?

A sentence has been added: "More importantly, they also reported a large contribution of wave induced processes to sea level extremes which are up to 20 % higher on the European continental shelf due to these wave processes. By considering these processes into the ocean model, as the water level would be higher, the impact on the wave model would be larger which means more wave-water level interactions."

Line 605: The new paragraph starts with 'However', it would be better to remove and start the sentence with 'The'.

Done.

Section 6. Conclusion. The main conclusion is not clear. I would rephrase it a way that answers your main aim reformulated as a question. For example, answer specifically: How is the sensitivity of historical and projected sea states for the IBI region coastlines affected by the non-linear interactions between wind-waves and water level changes, notably during extreme events?

As suggested by the reviewer, the sentence has been changed: "The aim of the present paper was: how is the sensitivity of historical and projected sea states to the non-linear interactions between waves and water level changes (tides, storm surge, mean sea level rise), notably during extreme events ? To assess this question, a regional wave model has been adapted to include the wave-water level interactions over the northeastern Atlantic for the 1950-2100 period." Moreover, the end of the Conclusion has been revised to describe more the limitations of the study.

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