# Answer to reviewer

We want to thank the reviewer for giving us the opportunity to submit an upgraded version of our manuscript titled *Cost-benefit analysis of coastal flood defence measures in the North Adriatic Sea*. We appreciate the comments on the method which allowed us to clarify some important points, in particular with regards to the presentation of the case study and the description of the data considered. We have been able to incorporate changes to reflect the valuable suggestions provided. The track changes are enabled within the manuscript to check all edits.

Following is a point-by-point response to the reviewers' comments and suggestions.

## Reviewer report #1

**General Comments:** The paper was improved after the referee comments by appropriately addressing previous comments. However, there are still few issues to be addressed.

> ➢ Thank you for your detailed feedback, we believe the manuscript improved by editing the text in agreement with your specific comments. The analytical method and the underlying data are now presented in a clearer, less ambiguous way.

**Specific Comments:**

- In my opinion, it would be better if the reason choosing these two port sites is briefly mentioned in the last paragraph of introduction section.

    - ➢ Paragraph from L55 has been extended mentioning the case study sites and the reason for the choice, that is the ongoing defence project in Rimini which could be later extended to Cesenatico:

      *We select two coastal cities as case study areas: i) Rimini, a touristic hotspot that is currently implementing a seafront renovation project; and ii) Cesenatico, a coastal city that could benefit from similar measures in addition to existing defence mechanisms.*

- Line 138: Authors mention "…but many of the induced effects still remain" What are the remaining effects?

    - ➢ Sentence has been amended for clarity: induced effect refers to subsidence rates still ongoing around extraction areas that were active in the near past.

- Line 230-231: Authors state that "In our application, we estimate the TWL on the coastland at every timestep as the sum of extreme values for storm surge level (SS), wave setup (Ws), and max tide (Tmax), as shown in figure 4. Summation of extremes of surge and wave setup (RP10 etc) is not necessarily equal to the same return value for TWL, however, in Figure 4 and Table 1 it is implicated as such. Moreover, it is not clear how these RP values are calculated. Did authors use Extreme Value Analysis methods? If so, which ones? To determine the extreme sea levels (for TWLs), there are two common approaches:
    1. summing historical timeseries of tide+surge (and sometimes +wave setup) and then projecting the values with an Extreme Value Analysis method (see Coles, 2001 for EVA methods) [as in Vitousek et al 2017; Muis et al. (2016); Kirezci et al (2020); Rueda et al (2017)]
    2. finding the pdf of each component of TWL and apply an ensemble Monte-Carlo approach (e.g. Vousdoukas et al 2018).

- Thank you for your valuable comment. We did not perform Extreme Value Analysis of the data. Instead, we relied on previous regional studies that provide probabilistic analysis of extreme events conducted on the regional coast, for individual components (Perini et al. 2016, 2017). As explained next, this is the knowledge basis used to identify official flood hazard zones. From Perini:

  *Surge, tide and wave set-up were considered to define reference sea levels and, in the absence of statistical analysis for the combined return period, the worst-case scenarios for T1, T10 and T100 were assumed, considering the sum as the simultaneous occurrence of the three effects. The values used are from previous studies (tab. 1, Yu et al. 1994, Masina & Ciavola, 2011) and the comparison with real events recorded within the 'historical storm catalogue' has confirmed the validity of the method.*

- Which dataset is used to calculate the surge, wave and tides?

  - Section 3.6 has been amended and the choice of dataset is explained:

    *We obtain these variables from existing probabilistic analysis of extreme events conducted on the regional coast (Perini et al. 2016, 2017) and later adopted by the Regional Environmental Agency to define the official coastal flood hazard zones (ARPAE 2019).*

    We believe that using the same input used to define hazard perimeters (i.e. low, medium and high) is important to help the comparability of our study with official reports.

- How did the authors determine the durations of extreme events in Table 1? Please clarify.

  - Text was amended by specify the reference study:

    *Additional details are wave period (Wp, in seconds) and event duration (Time, in hours), required to estimate the maximum extent of inland water propagation. Both variables are obtained from existing analysis of historical ESL events records, matched with the probabilistic distribution of RP scenarios (Armaroli et al. 2012; Armaroli and Duo 2018).*

- How was Wave Setup calculated? What approach taken to determine wave setup? Additionally, which wave data is used, observed or hindcast? Please clarify.

  - As per the other components of TWL, wave setup was obtained from previous regional studies.

- Figure 4 implicates a storm that the wave setup and storm surge both peak at the same time, which might not be the case in real life. How was this assumed? Please clarify.

  - TWL represents the worst-case scenario, considering the max according to scenario probability for each of the components. As considered, our approach is precautionary as it provides worst-case scenario values.

- All in all, section 3.6, (the extreme sea level determination part) should be updated and the model inputs to determine the inundation should be explained in detail and clearly.

- Section 3.6 has been rewritten in agreement with your feedback. We thank you for providing these important comments and for the opportunity to improve the quality of our manuscript, and we hope that is now clearer.

- In Table 1: Why is the RP250 tide value different the lower RP tides? Please clarify.

  - The RP250 represents the most extreme scenario and as such also the Tide component is assumed to reach the max of the spring tidal range. This information has been clarified in the text.

- Line 332: "surmounted" Do the authors mean overtopped or overflown?

  - Corrected with "overtopping".

- Line 346-348: "With less severe events (up to RP 100 years), the risk remains mostly confined around the marina area (outside the protection offered by the reinforced dune) producing an EAD below 10 thousand Eur; with more intense ESL scenarios (i.e. RP 250 years)" It is not clear to me what this statement means. Are not all the RPs included in EAD calculation (as in Figure 5)?

  - Thanks, the sentence was corrected and made clearer:
    *Under less severe ESL scenarios (RP below 100 years), the risk remains mostly confined around the marina, which is located outside the defended area, producing an expected damage below 10 thousand Eur. Under more extreme ESL scenarios, the benefits of the Parco del Mare project protecting the southern part of Rimini become more evident, avoiding about 65% of the expected damages in the defended scenarios compared to the undefended ones.*

**Technical Comments:**

- Line 107: "Coastal inundation phenomena are caused…", please change to "Coastal inundation is caused…"
- Line 15: "N Adriatic", please change to North Adriatic.

  - Thank you, we fixed both sentences.

**Additional changes**

- Figure 8 and 9 (left) got fixed, with same x-axis scale.
- Additional language proof