Review

"Pan-European assessment of coastal flood hazards"

by

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General comment

The manuscript 'Pan-European assessment of coastal flood hazards' presents a European scale assessment of coastal flooding featuring state-of-the-art methods and, to my knowledge, for the first time a comprehensive cross validation of flood extents for a multitude of different regions in Europe. I would like to congratulate the authors for submitting such a detailed, rich, and comprehensive study. In my opinion, the manuscript is of overall good scientific quality and significance and my comments are therefore mostly of minor nature. My main comments are about methodological clarifications (vertical datum, marine boundary conditions) and a clearer communication of when dikes were included in the simulations and when not. In addition, I suggest to enrich the discussion by emphasizing current weaknesses in broad-scale coastal flooding assessments (including coastal morphodynamics, compound flooding) beyond the ones analysed by the authors and previous studies, and outlining ways forward in this scientific field.

Please find my detailed comments below.

Specific comments

Abstract

1. L13-14 (hydrograph variability and storm type variability affect floods differently):

This is a nice and new finding on such a large spatial scale.

2. You should stress more the effort you made in validating your European wide assessment for so many cases across the continent. In my opinion, this is a crucial step forward of your work!

Introduction

3. L36-37 ('local thresholds'):

Please specify 'local thresholds'. In fact, you mean coastal protection infrastructure and/or natural flood barriers like beach berms, dunes and cliffs, right?

4. L54 (‘wave setup’):

With a broader readership in mind, I suggest you very briefly explain the term and also differentiate it from wave run up. It would help the reader if you could further explain why not the latter was used in your assessment, as also wave run up can contribute to flooding. This would also help the reader further down in the manuscript, for instance L112, where you explain the marine forcing.

5. L73-74 (DEM’s and resolutions):

As it is indeed crucial background information to your assessment, I suggest you add some info on currently highest resolution global DEMS, featuring fabdem, deltadtm (for coasts), and the one you are using in comparison. They are summarised in resolution and vertical accuracy here: https://www.nature.com/articles/s41597-024-03091-9

6. L78-80 (marine forcing data):

Here I think the Global Tide and Surge Model should be featured, as it provides global tide, surge and total water levels at resolutions even higher than 2.5 km (1.25 km for Europe) (https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2020.00263/full).

7. L85 (model validation):

You should specify here that you are speaking about validating both coastal water levels used to force the hydrodynamic model (when they are taken from other models like GTSM), and the validation of the flood extent. The latter is much more difficult and often only applied on local scales, even if the study simulates floods on much broader scales. The flood extent is crucial because that’s the output used to calculate risk. Therefore a more comprehensive flood extent validation is needed, which is exactly what you nicely do in your paper. Therefore I believe it could be more pronounced to demonstrate that your paper is a real advancement.

8. L87-89 (systematic large-scale validation):

However, I believe it is worth while mentioning and acknowledging the following effort in the validation of sfincs for river floods on a global scale in a systematic manner. Link to preprint: https://egusphere.copernicus.org/preprints/2025/egusphere-2025-4387/

9. L98-99 (study aims):

You could stress even more the novelty of your validation, as the overall approach (although admittedly with lower resolution input data) has been applied in variations elsewhere (e.g. Vousdoukas et al., 2016).

Methods

10. L122 (coastal slope dataset for intertidal zones):

Your study area also includes coastlines with no to very little intertidal zones. How did you deal with that? Also, there is a much more recent dataset of coastal slopes across the globe (https://essd.copernicus.org/articles/16/3433/2024/). As coastlines are morphologically highly dynamic environments, I consider the 1984 dataset outdated. Please consider using the new coastal slope dataset or elaborate a bit further why the 1984 one was used instead.

11. L133-134 (land cover dataset):

Not everyone is familiar with this dataset. Can you give examples of the most relevant classes in that data for flood modelling? Are urban/developed areas included as well as forests (broad leafed, needle leafed), and (coastal) wetlands?

12. Section 3.1 (marine boundary conditions):

This section could be better explained and justified using existing literature. For instance, the choice of the threshold used, the distribution applied (GEV/POT) and other aspects such as the number of events used to fit the distribution have important implications on the extrapolated extreme sea levels.

I think you should also mention whether and how the marine boundary conditions were validated. I assume this was done in previous studies, but it would help the reader interpreting the flood maps, if information on the accuracy of the total water levels would be presented.

13. L159-160 (hydrograph generation):

Can you please specify a bit further on how hydrographs were created for those return events? Did you take the average surge shape, combined it with peak or average tidal signals? I assume they come from here (https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2025EF006545), but how and if this method was applied needs further explanation.

14. L221-222 (difference in flood extent with cases Schlei fjord and Wismar attributed to wave set up):

True, but the case of Wismar shows that waves are likely a subordinate cause of the difference you observe. Wismar is sheltered and thus not wave exposed. Wave setup alone can therefore not explain the difference. The same is true for areas inside the Schlei fjord (check also https://doi.org/10.1017/cft.2024.11). Here and in Wismar, it is most likely the dikeline that is not sufficiently well resolved in your model. Check https://www.nature.com/articles/s43247-023-01100-0 for a map of the German Baltic dikeline (Figure 4). I think this should be made clearer here.

15. Table 3:

I would also refer to it in section 4.2, as you discuss the quantitative validation results here. It also links to Figure 3, right?

16. Up from Section 4.2:

I suggest to move those to the results section, as the whole validation and sensitivity study is in my opinion a major outcome of your work and you are in fact describing results.

17. L292-294 (sentence clarification):

This sentence needs rephrasing or clarification. I would not agree that Norway is 'flat', as it mostly lacks large floodplains in contrast to the Bay of Biscay, The Netherlands, and Belgium, which are further characterised by meso-tidal regimes.

Results

18. L314-315 (hydrographs):

This is where more information on the hydrograph creation would be useful. You should remind the reader what 'smooth' means and add more detail in the methods section what 'mean storm shape' refers to. Is it the mean surge shape, but how was it combined with the tidal signal then? Or is it the average total water level hydrograph of a given storm surge event?

19. L318-319 (dikes?):

But the southern North Sea is highly protected by dikes. I could not follow whether this is or is not considered in the results you present here. If not, it should be clarified.

20. L444-449 (comparison with Vousdoukas et al., 2016):

It could also have to do with how Vousdoukas et al., 2016 have incorporated the coastal protection standards, as you have used a very recent database (van Maanen), which in 2016 was not yet available. Can you elaborate on that as well?

Discussion/conclusion

21. L483 ('flood map generation'):

maybe better: affect the results of hydrodynamic flood simulations.

22. L488-489 (drivers of uncertainty):

I would also think you should mention the incorporation of dikes here, as its really important, which you also show.

23. L508-509 (vertical datum):

Was the vertical datum known and, if needed, corrected for the baseline simulations here (25 m EU DEM)? This can be a crucial source of error and should be clearly communicated in the manuscript.

24.

The discussion could benefit from adding a paragraph on ways forward in regional to global scale studies on coastal flooding. The general parameters of uncertainty like dikes, DEM, total water levels, and modelling approach have been nicely discussed and are furthermore content of previous assessments, which you also cite. However, your paper can also discuss and mention the factors not yet sufficiently well represented in comparative studies, such as morphodynamic responses of the shoreline to extreme sea levels like dune, berm and dike breaches. Also, your study area covers major estuaries, yielding potential for compound floods. The potential effect of neglecting these important processes and reasons for their current underrepresentation as well as ways forward could nicely be featured as well and would give the reader more context of the presented work.

Technical corrections

25. L145/Figure 1 (wording):

… coastal flood modelling with *these* three steps:…

26. Table 2 (wording):

'*Schlei* fjord' : if additional validation 'test power' is needed: this study (DOI: https://doi.org/10.1017/cft.2024.11) has run Delft3d-Flow in the Schlei fjord for the 2019 event and provided a flood extent validation in Figure S2 of the Supplementary Material.

27. Table 2 (wording):

'Elbe Estuary'

28. L274 (wording):

Figure 5~~m~~

29. L338 (reminder):

This is a good spot to remind the reader that the 'floodplain' refers to all areas below 15 m hydrologically connected to the sea. 37/23% of it flooded is substantial. I assume that in this assessment, dikes are not taken into account, right? I think this should be clarified.