

Reply to the Reviewer

Re: Manuscript ID Preprint egusphere-2025-4892

“Pan-European assessment of coastal flood hazards”

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Response to Dominik Paprotny

We would like to thank Dominik Paprotny for his careful revision of our manuscript and for the thoughtful, constructive comments provided. We appreciate the time and effort dedicated to the review process, and we believe that the suggestions have significantly improved the quality, clarity, and rigor of the study. Below, we provide a detailed point-by-point response to each comment and outline the corresponding revisions made to the manuscript.

Review Report

The manuscript “Pan-European assessment of coastal flood hazard” introduces a new, high-resolution analysis of coastal flood hazard. The strength of the manuscript is an extensive sensitivity analysis and validation, which definitely increases the understanding of the limitations of coastal flood mapping. The work is comprehensive and solid, so my comments are only minor, in order of appearance:

Abstract: “The framework not only advances scientific understanding of large-scale coastal flooding but also provides actionable evidence to support the EU Floods Directive, adaptation planning, and climate risk management in the finance and insurance sectors.” I suggest to remove this, as the paper shows still serious limitations of the approach (out of 12 cases, 5 miss most flooding and in 5 most of the flood zone is overestimation). The data is not available publicly, so it can’t be easily reused. The actionability is reduced substantially by lack of future projections. The authors should mention the validation results, which are not mentioned here at all.

The last sentence has been removed and details have been included concerning the validation results. Lines 10 – 12: “The validation results confirmed the robustness of the large-scale

methodology while highlighting the strong dependence of the results on the resolution and vertical accuracy of the underlying digital elevation model (DEM).”

L72, L484: Unfortunately, an error crept into Groenemeijer et al. (2016) report, as in reality a resampled version of the original DEM in 100 meter resolution was used to calculate the coastal inundation. This was not made explicit as it should have been (I was the author of the data and that part of the report).

We appreciate the reviewer’s clarification and transparency. This information has been corrected in the revised manuscript as well as in Table S1.

L108: “each located at a relative depth of 0.1.” – what does this mean?

Clarified. Lines 132 – 133: “CTPs were located at a relative depth of 0.1 (h/L ; where h represents the water depth and L the corresponding wavelength of the wave peak period with an exceedance probability of 0.1).”

L135: Corine Land Cover does not cover Russia either, so what data was there?

We thank the reviewer for pointing this out. Indeed, Corine Land Cover was not used in this study. This information has been corrected in the manuscript. Lines 159 – 160: “In areas not covered by ODSE-LULC, such as Russia and western Turkey, the 100 m Global Land Cover dataset (Copernicus, 2019b) was used instead.”

L153-158: this description is very vague, e.g. what historical storms were used, what was the calibration here, why only two events per year, what was the timespan of the historical data used or how the mean storm shape was derived.

The detailed description of the method adopted to design TWL hydrographs is presented in a separate study (<https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2025EF006545>). Nevertheless, we have expanded the description included in the manuscript. Lines 175 – 191: “Following Cotrim et al. (2025), marine boundary conditions were represented by TWL hydrographs constructed for each CTP and composed of three elements: peak, duration, and shape.

Peak water levels were estimated through extreme value analysis (EVA), using an exponential model fitted to extreme events identified in the 37-year TWL hindcast. Events were selected using the peak-over-threshold (POT) method, with a spatially variable threshold yielding on average two events per year and requiring a minimum 72-hour interval between events. Sensitivity analyses on the POT threshold and distribution fits indicated the EVA method selected to provide the most appropriate balance of accuracy, robustness, and sample size. For more details on the TWL reconstruction method and the EVA, please refer to Cotrim et al. (2025). Hydrograph duration was derived from a storm duration function calibrated with historic storms (i.e., all events identified by POT) that combined a storm type (ST) classification with individual storm duration estimates. The storm classification system was based on hydrograph shape through Manhattan Dynamic Time Warping and reflected the dominant TWL drivers at peak conditions. Four storm types were identified (Table 1): ST A (surge-dominated), ST B (tide-dominated), ST C (mixed, tide-leaning), and ST D (mixed, surge-leaning). Individual storm duration estimates were then associated to peak TWL by adjusting the sample to a ST-specific function (shifted power function, exponential fit, or simple average) enabling the extrapolation of storm durations to return period events. Hydrograph shapes were based on the mean storm shape by averaging all events identified by POT, resulting in smooth-shaped and location-specific hydrographs. Hydrographs were constructed for each storm type at each CTP, as well as for a combined scenario weighted by the relative frequency of occurrence of each storm type.”

L179: where did the Manning value come from and how were they linked in the specific land cover data used by the authors?

More information was provided in the manuscript and the Supplementary Material.

Lines 209 – 211: “Within each mesh, land cover classes were attributed to impact zones based on dominant land-use type, and Manning’s roughness coefficients were assigned accordingly, following van der Sande et al. (2003) (see Table S2).”

Table S2 Description and correspondence of land use classes from ODSE-LULC (Witjes et al., 2022) and Global Land Cover dataset (Copernicus, 2019), accompanied by the respective Manning roughness coefficients, following (van der Sande et al., 2003).

Group	Description	ODSE-LULC	Global Land Cover	Manning roughness coefficient
1	Urban areas	1	50	0.150
2	Other urban areas	2 – 8	–	0.200
3	Rural areas	9 – 15	20 / 40	0.127
4	Natural vegetation	16 – 21	111 – 126	0.100

5	Bare areas (beaches, sand), dunes	22 – 26	30 / 60 / 70 / 100	0.120
6	Waterbodies	27 – 33	80 / 90 / 200	0.050

Table 2: some better naming scheme of the case studies needs to be applied, as it makes reading the text and analysing the graphs rather difficult.

Case studies have been renamed and updated across the entire section 4 of the manuscript including Figures 3 and 5 and Tables 2 and 3. The new nomenclature was also included in Figure 2 to facilitate the understanding of the study.

The updated nomenclature is as follows:

Previous nomenclature	Updated nomenclature
CFCC02	UK01
CFCC03	DE02
CFCC04	DE03
CFCC05	PT04
CFCC08	FR05
CFCC09	ES06
CFCC10	ES07
CFCC11	IT08
CFCC12	IT09
CFCC13	ES10
CFCC14	DE11
CFCC15	PT12

L214: one additional important source of underestimation is the issue that higher resolution of DEM enables capturing some coastal defences, but still does not allow for defence failure mechanisms other than overtopping. In past coastal floods, dikes have failed without water levels reaching their crests, which is very difficult to represent in flood models (https://www.hkv.nl/wp-content/uploads/2020/07/Applications_of_VNK2_a_fully_probabilistic_risk_analyses_BM.pdf)

This limitation has been included in the manuscript. Lines 265 – 267: “However, even if coastal defenses were included in the DEM, their representation in a flood model presents its own challenges as defense failure mechanisms could in fact result in a larger flooded area than its neglect in the input data.”

L437: datasets such as COASTPRO-EU rely on nominal or official protections levels, which are often much lower in practice due to e.g. inadequate maintenance or change in extreme water level probability (<https://doi.org/10.1007/s11069-024-07039-5>). This causes very large sensitivity of flood maps to protection level assumptions overshadowing all other (<https://doi.org/10.1007/s11069-024-07039-5>).

We agree that datasets such as COASTPRO-EU typically report nominal/official standards of protection, which may substantially differ from the effective level of protection. This discrepancy can lead to systematic bias when translating protection standards into flood extents. We also agree that assumed protection levels can be a dominant driver of uncertainty when producing flood maps. This challenge has been included in the limitations section of the Discussion. Lines 565 – 570: “However, available coastal protection databases remain coarse, outdated, and inconsistent with the resolution of flood maps, as they provide information only at the NUTS2 level. Such datasets (e.g., COASTPRO-EU) typically reflect nominal or official standards of protection, which can be substantially lower in practice due to inadequate maintenance, deterioration, or changes in the probability of extreme water levels (Paprotny et al., 2024). As a result, flood extents can be highly sensitive to protection-level assumptions and in some cases dominate the overall uncertainty in large-scale flood mapping.”

Table 6: it should be highlighted that the MFA results are not fully comparable across studies. The data in Paprotny et al. (2018) and Groenemeijer et al. (2016) are pretty much the same, but the figure from the former refers to a smaller number of countries than the latter.

The reviewer makes a good observation. We agree that MFA figures are not strictly comparable across studies because the underlying spatial coverage and country sets differ. We have therefore strengthened the disclaimer below Table 6 to make this explicit. Lines 613 – 615: “Note. MFA results should be interpreted with caution when compared across studies, as differences in spatial domain and underlying data coverage can affect the reported values; comparisons are therefore indicative rather than directly comparable.”

L534-536: same remark as regarding the abstract.

Sentence removed.

References

- Copernicus. (2019). *Global Dynamic Land Cover*. Available at <https://land.copernicus.eu/en/products/global-dynamic-land-cover>
- Cotrim, C., Toimil, A., Losada, I., Lobeto, H., & Menéndez, M. (2025). A Framework for Storm Classification and Hydrograph Generation From Total Water Level in Europe. *Earth's Future*, 13. <https://doi.org/10.1029/2025EF006545>
- Jongejan, R., & Maaskant, B. (2013). The VNK2-project: A fully probabilistic risk analysis for all major levee systems in the Netherlands. In *Comprehensive Flood Risk Management – Klijn & Schweckendiek (eds)* (Vol. 357).
- van der Sande, C. J., de Jong, S. M., & de Roo, A. P. J. (2003). A segmentation and classification approach of IKONOS-2 imagery for land cover mapping to assist flood risk and flood damage assessment. *International Journal of Applied Earth Observation and Geoinformation*, 4(3), 217–229. [https://doi.org/10.1016/S0303-2434\(03\)00003-5](https://doi.org/10.1016/S0303-2434(03)00003-5)
- Witjes, M., Parente, L., van Diemen, C. J., Hengl, T., Landa, M., Brodský, L., Halounova, L., Križan, J., AntoniĆ, L., Ilie, C. M., Craciunescu, V., Kilibarda, M., Antonijević, O., & Glušica, L. (2022). A spatiotemporal ensemble machine learning framework for generating land use/land cover time-series maps for Europe (2000-2019) based on LUCAS, CORINE and GLAD Landsat. *PeerJ*, 10. <https://doi.org/10.7717/peerj.13573>