Brief Communication: Bridging the Data Gap – A Call to Enhance the Representation of Global Coastal Flood Protection

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Abstract. Understanding coastal flood protection is crucial for assessing risks from natural hazards and climate change. However, there is a significant lack of quantitative data on coastal flood protection and their standards posing a major barrier to risk assessment. FLOPROS, currently the only global database of flood protection standards, relies on limited coastal observations and simplified assumptions. While widely used, it cannot adequately constrain uncertainties in risk estimates that are based on it. To address this gap, we call for a global, community-driven effort to develop a more comprehensive dataset. As a first step, we present a dataset compiling COASTtal flood PROtection Standards within EUrope (COASTPROS-EU), elaborated from a survey distributed to flood practitioners from several European countries. This highlights the need for more extensive and coordinated data collection efforts, using a transdisciplinary community-based approach that ensures diverse societal representation.

1. Coastal Flood Protection

In Europe alone, damage from coastal flooding currently amounts to €1.4 billion annually, with around 100,000 people exposed (Feyen et al., 2020). The rise in global temperatures caused by anthropogenic greenhouse gas emissions means that the frequency and severity of coastal flood events is projected to increase over the next decades, for example due to sea level rise (Taherkhani et al., 2020). Concurrently, the degradation of foreshore vegetation and human-induced subsidence, due to land use and sediment retention by dams, contribute to heightened coastal flood hazards. This presents significant challenges for low-lying coastal communities and ecosystems, which are home to a large portion of the world's population, land area and assets (Bevacqua et al., 2020; Reguero et al., 2015).

The latest IPCC Synthesis Report warns of significant, irreversible damage to coastal areas from climate-induced flooding, with coastal flood hazard continuing to increase well beyond 2100 due to sea level rise (IPCC, 2023). Additionally, exposure to coastal flood events is expected to increase in the future due to factors such as increasing urbanisation in coastal areas (Darlington et al., 2023; Reimann et al. 2023; Neumann et al., 2015).

Addressing coastal flood risk and understanding the potential future impacts requires a comprehensive understanding of current coastal flood protection measures and standards, both in terms of infrastructure (e.g., levees) and nature-based solutions (e.g., mangroves) (Caretta et al. 2022; van Zelst et al., 2021; Toimil et al., 2020). However, the complexity and challenges involved in quantitatively assessing the level of protection that existing flood defences provide hinder our understanding of flood protection on a global scale. For example, challenges arise from the complex interactions between natural (e.g., dunes) and artificial (e.g., dikes) barriers (Hinkel et al., 2021). Enhanced and detailed data on coastal flood protection is necessary to better prepare for and mitigate the risks associated with climate change and coastal flooding.

2. FLOPROS

In 2016, Scussolini et al. introduced the FLOPROS database, providing the first global collection of information on flood protection standards across different spatial scales. It consolidates information on protection standards (expressed as flood return periods) associated with protection measures and regulations. FLOPROS is structured into three layers: the design layer, which details engineered protection levels of existing river and coastal flood infrastructure derived from literature; the policy layer, which specifies legislative and normative standards for protection from river and coastal floods, also derived from literature; and the model layer, which infers river flood protection standards based on observed relationships with per capita wealth and flood risk.

The FLOPROS model layer assumes a maximum flood protection of a 1000-year return period and a minimum of a 2-year return period (no protection). An algorithm interpolates these values based on GDP per capita for different income regions. The model layer determines protection standards for sub-country administrative units (second level of Nomenclature of territorial units for statistics, or NUTS2 according to Eurostat, 2018) by calculating expected annual damage and interpolating additional units linearly. This approach overlooks the complexities of the various physical, socio-economic, and governance factors that influence flood protection standards, both between and within regions (Klijn et al., 2021).

To our knowledge, FLOPROS, with its coastal update by Tiggeloven et al. (2020), is the only global dataset documenting existing structural flood protection measures at the sub-national level, making it a cornerstone in contemporary research endeavours assessing flood risk. Consequently, the database is frequently used in coastal flood assessments (e.g. Almar et al., 2021; Hermans et al., 2023; Vousdoukas et al., 2018; Yesudian & Dawson, 2021; Ward et al., 2017). FLOPROS was created to support research related to large-scale flood risk management and has been utilised in several high-level policy documents, including PESETA IV (Feyen et al., 2020), PBL (2023), and UNEP (2023a, b). Initiatives such as the Intersectoral Model Intercomparison Project (ISIMIP), which integrates these findings into Integrated Assessment Models like REMIND (Sauer et al., 2021), and webtools such as Aqueduct Floods also rely on FLOPROS. Additionally, many academic studies assessing current and future flood risk in coastal areas depend on the FLOPROS database (e.g. Chen et al., 2023; Tiggeloven et al., 2020; Mortensen et al., 2024; Vousdoukas et al., 2020; Hermans et al., 2023; Devitt et al., 2023; Haasnoot et al., 2021). As a result, FLOPROS is fundamental to current flood protection assumptions for coastal flood risk and impact assessments.

However, due to the limitations of FLOPROS, especially the limited number of observations for coastal flood protection (54 data points from 14 countries), we argue that caution should be exercised in utilising it in coastal

108 contexts. Overreliance on the dataset may lead to an underestimation of future climate risks, implying protection
109 where it does not exist, or overestimating adaptation efforts, thus undermining the urgency of climate mitigation.

110 # 3. Current and Future Efforts

111 Since the publication of FLOPROS, several initiatives have aimed to improve the representation of flood
112 protection for coastal regions. FLOPROS mostly contains information on river flood protection in its "design"
113 and "policy" layers, and exclusively on river flood protection in its "model" layer. Tiggeloven et al. (2020)
114 extended this by calculating flood protection for coastal regions globally using a comparable model-based
115 approach but did not include policy or design layers, which may lead to uncertainty. Despite these advancements,
116 there remains a lack of clear distinction between the use of the original FLOPROS by Scussolini et al. (2016) and
117 its updated version by Tiggeloven et al. (2020). Frequently, both versions are cited without specifying whether
118 coastal protection levels are used from the design, policy or model layer (Yesudian & Dawson, 2021). A notable
119 relevant advancement is openDELve, which compiles an open database referencing the extent and design
120 specifications of levees for 152 deltas, including levee height, crest width, and construction material, in a
121 harmonized format (Nienhuis et al., 2022). However, there is a clear contrast in data availability between regions
122 such as Africa, South-East Asia, and Southern and Central America in comparison to Australia, Europe, UK, and
123 USA (Nienhuis et al., 2022). Another significant research direction is the detection of flood defence infrastructure
124 from high-resolution elevation data. Wing et al. (2019) applied a detection algorithm to map levees in the
125 contiguous U.S., questioning the validity of the wealth-to-protection relationships used in FLOPROS. A similar
126 method was subsequently applied by Sasaki et al. (2023).

127 Knowledge of river flood protection standards has been enhanced by studies such as Boulange et al. (2021), which
128 reflect the protection provided downstream of global hydro dams. In China, river flood protection standards at
129 higher resolution and confidence levels are available thanks to Wang et al. (2021). Advanced statistical approaches
130 trained to infer flood protection standards from physical and socio-economic variables have been developed by
131 Zhao et al. (2023). An indirect approach to infer flood protection standards for Europe, using new data on impacts
132 and potential flood occurrences, was recently implemented by Paprotny et al. (2024).

133 # 4. COASTPROS-EU: a Coastal Flood Protection Standards Database for Europe

134 Despite various advancements in recent years, a dataset with comprehensive global representation of coastal flood
135 protection measures and their standards is still lacking. We present here, COASTPROS-EU, a new database on
136 policy standards and defence structures along the European coast (Table S1). The database builds upon the efforts
137 of FLOPROS and its subsequent improvement by Tiggeloven et al., (2020). However, it differs from FLOPROS
138 by compiling specifically information on European coastal defences for each NUTS2 region. Furthermore, it
139 references three typologies of layers, namely geolocated coastal defences, regional coastal defence policies, and
140 modelled defences based on Tiggeloven et al. (2020). Where applicable, flood protection standards are expressed
141 in return periods. The "Summary Return Period" summarise the most accurate information layer type regarding
142 flood protection collected. This column prioritizes the layers type in the following order: (a) geolocated coastal
143 defences, (b) policy standards, and lastly, (c) modelled defence if no other information is applicable. The overview
144 of the data availability summary is mapped in Figure 1. The database was produced through two key initiatives.

164 First, an online survey was distributed within the network of the CoCliCo project (European Union's Horizon
165 2020 research and innovation programme Coastal Climate Core Services under grant agreement No 101003598)
166 and the Institute for Environmental Studies (IVM) of Vrije Universiteit Amsterdam. Second, a data workshop was
167 held at Vrije Universiteit Amsterdam in November 2023, where flood experts collected information on flood
168 defence and protection standards in their respective language using academic and grey literature (policy reports
169 and governmental data portals) (Koks and De Plaen, 2023).
170 The survey consists of an online form targeting flood experts. It collects information related to the scale of the
171 protection measure, the area protected, the flood protection level expressed in return period and the year of
172 implementation. In case of a lack of information on physical defences, indication of policy standards applicable
173 to the area could be filled in with the associated policy measure. Finally, additional data such as geospatial layer
174 or other relevant information could be uploaded. The information collected were then manually summarised into
175 the geospatial and policy layers of the database. The survey answers were then archived in the excel file referenced
176 in the Zenodo repository (De Plaen et al., 2024).
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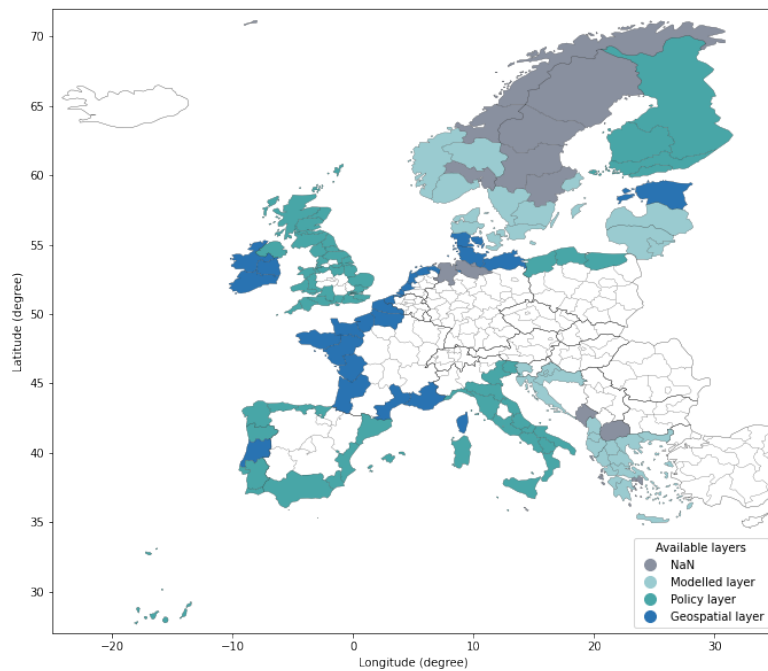
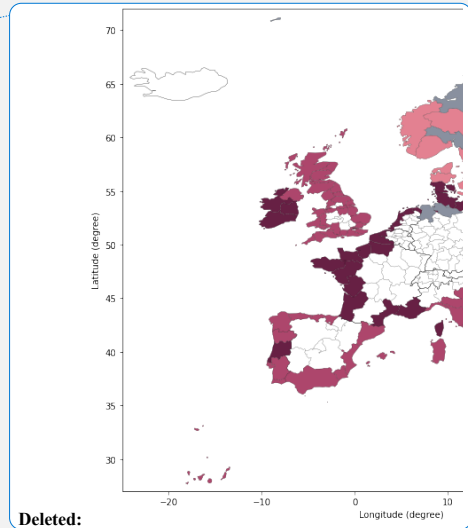

178
179 **Figure 1: Data availability overview of COASTPROS-EU, representing the best available coastal protection**
180 **standards in Europe per NUTS2 region for three typologies of layers: geolocated coastal defences, policy standards,**
181 **and modeled defence standards.**
182

183 Through these combined efforts, we aim to provide a more accurate and comprehensive understanding of coastal
184 flood protection measures. By incorporating diverse data sources and methodologies, this new database addresses

189 the critical need for detailed, reliable information to better prepare for and mitigate the risks associated with
190 climate change and coastal flooding.

191 While this dataset marks an initial first step, certain limitations must be acknowledged. Firstly, our new dataset is
192 restricted to Europe and therefore does not meet the need for a global assessment. Moreover, the way protection
193 levels are quantified and evaluated is critical. Current approaches mainly rely on return periods, providing a
194 standardized framework suitable for large-scale or regional analyses, with the flexibility to convert between return
195 periods and defense heights. Yet, incorporating defense heights remains essential, as their significance varies
196 depending on the specific context and research questions.

197 **5. Way Forward: Embracing a Transdisciplinary Community-Based Approach**

198 A global effort is needed to improve data on coastal flood protection, ensuring representation across diverse social
199 groups, languages, and data-scarce regions. This requires a structured, transdisciplinary approach that integrates
200 institutional support, community-driven data collection, and multiple sources of information to enhance flood risk
201 assessments and policy alignment.
202 Our dataset provides a starting point, but a broader, more structured effort beyond academia is necessary.
203 Institutional support is key to ensuring sustained data collection and standardized national-level reporting. Cultural
204 differences in flood protection - such as variations in design standards and their local implementation - must be
205 captured. While FLOPROS and COASTPROS remain relevant, future efforts must expand coverage, improve
206 accessibility, and establish globally consistent methodologies.
207 Earth Observation data remains essential for large-scale assessments of coastal flood protection, offering
208 standardized insights into infrastructure and nature-based solutions. However, satellite data alone is insufficient.
209 A multi-method approach integrating satellite-derived information with local expertise, participatory mapping,
210 and national policy assessments is critical. OpenStreetMap (OSM) provides an opportunity for community-driven
211 mapping, particularly in regions lacking official records. Aligning these efforts with structured policy reviews and
212 national reporting frameworks will bridge the gap between local knowledge and institutional decision-making.
213 Standardized national-level reporting is crucial for improving flood risk assessments and ensuring cross-country
214 comparability. Systematic reviews of national policies, including flood design standards and their local
215 application, will enhance data consistency and policy impact. Rather than relying solely on surveys, concrete
216 recommendations should guide reporting frameworks and promote best practices. By integrating institutional
217 expertise, satellite observations, and community-driven contributions, we can build a more comprehensive and
218 equitable approach to flood risk assessment - one that strengthens resilience worldwide.

219 **Data availability**

220 The excel file and GIS shapefile of COASTPROS-EU are available on the following repository: De Plaen, J. J.-
221 F. G., Colmenares, M., Koks, E., Scussolini, P., Lena, R., Lincke, D., Kiesel, J., Wolff, C., Tiggeloven, T.,
222 Peregrina Gonzalez, E. D., & Le Cozannet, G. (2024). COASTPROS-EU (v0.1) [Data set]. Zenodo.
223 https://doi.org/10.5281/zenodo.12784278

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Deleted: and geographical regions. This necessitates a

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Deleted: Further, it has emerged that hybrid approaches to flood protection, that integrate structural and nature-based measures, may offer the most effective and economically viable solutions (Du et al., 2020). As colleagues are gradually investigating and assessing the effectiveness and resilience of nature-based solutions, such as mangroves and salt marshes, for coastal flood protection (Inácio et al., 2022; Luo et al., 2023; Mortensen et al., 2024; Tiggeloven et al. 2022), we argue that it is also crucial to incorporate the flood protection standards provided by these measures.¶
To achieve this, there is a pressing need to ascertain where coastal flood protection is presently available and effective, and where it is not. We call on the flood protection community to join these efforts, working together to build a comprehensive, global understanding of coastal flood protection measures. Only through such a comprehensive approach can a reliable resource be established, enabling the analysis of both current and future coastal flood risk. Until then, we recommend using FLOPROS in applications that are commensurate with the nature of the data and with its methodology, emphasizing and clearly communicating the limitations of the dataset accordingly.¶

Competing interests

At least one of the (co-)authors is a member of the editorial board of Natural Hazards and Earth System Sciences.

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