Response to referees

We would like to thank the referees for their insightful reviews of our manuscript. Please find our detailed responses to the referees' comments and suggestions below.

The main changes that we are implementing in the manuscript are as follows:

- Moving the three Figures B1, B2, and B3 from the Appendix into the main part of the manuscript.
- Adding the names of the countries on Figure B1.
- Changing the structure of *Section 2 Data and Methods*, by having two subsections: one about the data and the second about the methods we use. We are also adding a flowchart to clarify the approach of our study in relation to the research questions, along with the methods and data we use to address these research questions.
- Performing linear regression analyses between flood impacts and the socio-economic characteristics, for countries in the EU compared to those in the MENA region.
- Improving the way of quantifying the link between flood recorded impacts and public perception, by calculating a difference in percentages instead of using ranks.
- Computing flood human impacts and economic losses using the HANZE database in the EU in addition to the existing computations based on the EM-DAT database.

Referee 2

A key strength of the study is the integration of approaches from the social and natural sciences. Combining data on the actual impacts of floods with an analysis of public risk perception represents a valuable research direction that is still relatively rare in the literature. Another advantage is the broad temporal and spatial scope of the analysis. The use of data covering 24 years (2000–2023) and multiple countries makes it possible to capture general trends and enhances the representativeness of the results. The multidimensional analysis of flood impacts is also noteworthy. Considering three indicators — fatalities, the number of affected people, and economic losses — provides a much more comprehensive picture than relying on a single metric. Additionally, the analysis of seasonality and flood types adds important physical context and helps link climatic conditions with flood risk. The study convincingly highlights global inequalities, showing that a higher number of flood events does not necessarily translate into greater losses, and that less economically developed regions tend to experience relatively higher human losses.

Dear Referee 2,

Thank you for the thoughtful and constructive feedback. We are pleased to see that the novelty and relevance of our study are recognized, specifically the value

of combing impact data with public perception, the multidimensionality of our analysis, and highlighting inequalities across developed and less developed regions.

In particular, we want to thank you for the time and effort you took into bringing forward some limitations and shortcoming of our study, which we are using to improve and strengthen our manuscript. Below we provide one-on-one answers to your comments in blue, as well as the changes we are implementing in the study.

At the same time, a certain inconsistency is visible between the frequency of floods and their impacts. The authors do not provide a fully coherent explanation for this phenomenon — in different parts of the study they refer either to socio-economic factors or to climatic conditions, but they do not attempt to model these factors jointly. The lack of causal analysis limits the interpretation of the results.

Thank you for bringing up these considerations.

Regarding the first point, we want to clarify that our study does not aim to address the link between flood frequency and impact. The central focus of our study is on flood impacts, not necessarily on floods as a physical phenomenon. Consistent with this focus, we use a natural disaster database, which only includes flood disasters having caused substantial impacts (please refer to Section *2.1 EM-DAT* in the manuscript for more details about the inclusion criteria of this database). In other words, our study focuses on and uses a database taking flood impacts as a starting point, not physically-defined floods.

About the second point, our study quantifies flood impacts in relation to socio-economic factors, for example, expressing these impacts relative to population size and gross domestic product, but not as a function of climatic conditions. Indeed, one of the interesting aspects of comparing flood impacts across the EU and MENA region is the strongly varying climate. However, our study does not aim to quantify flood impacts as a function of climatic conditions. To avoid giving this impression to the reader, we rephrase the sentence in the abstract (Lines 2-3):

"[...] how these impacts vary across regions with different climatic and socio-economic conditions" as "[...] how these impacts vary across regions with different socio-economic conditions".

Regarding the third point, while we agree that causal analysis is relevant to flood research, we consider this aspect beyond the scope of our present study. Our study primarily aims to quantify flood impacts in relation to socio-economic factors. Specifically, we concentrate on 1) quantifying impacts of floods in two regions with major socio-economic differences and 2) bridging natural and social research in flood studies.

To strengthen the quantitative analysis in our study and to account for your comment, we are adding a statistical analysis on the linkage between flood impacts and socioeconomic factors. Specifically, we are adding a linear regression analysis between the three flood impact indicators and socio-economic factors to better quantify these relations, e.g., linking changes in fatalities to GDP and/or GDP per capita.

The conclusion that riverine floods dominate is questionable, as it is based on data with incomplete classification — a substantial proportion of events are labeled as "unspecified." This weakens the reliability of that conclusion.

We agree that the incomplete classification of flood types hinders solid conclusions on this aspect, which we explicitly acknowledge throughout the manuscript, for example, in the Result section (Section *3.3.1 Flood type)* and Discussion (Section *4.2 Flood characteristics* and Section *4.4 Limitations of the study*). This limitation of the dataset is an argument strengthening our statement for addressing such data shortcomings in the conclusion.

Having said this, we recognize that some of the text may have suggested too strong statements based on the flood type analysis. We rephrase the following sentences as follows:

- Line 250: "Regionally aggregated results show a prevalence of riverine floods." to "Regionally aggregated results suggest a prevalence of riverine floods, even if this classification is uncertain."
- Lines 250-251: "This type caused more deaths in both regions in the period 2000-2023 than any other flood type." to "More deaths are attributed to this flood type than any other flood type in both regions in the period 2000-2023."
- Lines 251-252: "Moreover, riverine floods are also responsible for most affected people in the EU." to "Moreover, riverine floods are also associated with most affected people in the EU, according to the EM-DAT database."
- Lines 253-254: " These results, along with the non-negligible number of unclassified flood events, suggest that the results on flood types should be interpreted with caution." to "While these results indicate regional patterns, the data quality is insufficient to draw robust conclusions on flood type."
- Lines 395-396: " Our findings agree with previous indications that flash floods cause most economic damage in the MENA region (Kantoush et al., 2022) [...]." to "Our findings, even if they are limited, agree with previous indications that flash floods are associated with most economic damage in the MENA region (Kantoush et al., 2022) [...]."
- Lines 401-402: "Similarly, most deaths in the EU were caused by riverine floods, whereas previous results indicate that flash floods were the deadliest in Europe (Paprotny et al., 2024)." to "Similarly, most deaths in the EU were attributed to riverine floods in the EM-DAT database, whereas previous results indicate that flash floods were the deadliest in Europe (Paprotny et al., 2024)."

Moreover, the study does not always clearly distinguish between correlation and causation. For example, the relationship between higher GDP and greater economic losses is interpreted without fully acknowledging that it primarily reflects greater economic exposure rather than necessarily higher risk.

We want to remind the referee that causal analysis is beyond the scope of our study, please, refer to the response to the first comment above. Thus, our study is primarily based on correlation-type analysis. However, we agree that this aspect

is not made clear enough in the manuscript. We thus add this sentence to the Methods section:

"This study uses primarily correlation-based analysis, such as linear regression expressing flood impacts as a function of socio-economic factors. Therefore, our work does not permit causal inference."

To your stated example, we emphasize that our analysis does account for variations in economic exposure by computing economic losses due to floods relative to GDP (see Section 3.2., Fig. 4b and Table 2 right most column: "Economic losses (% GDP)")). In other words, computing economic damage as a fraction of GDP at a country-based level allows us to study and compare economic damage resulting from floods across countries and regions with different levels of economic development.

A significant issue is the treatment of missing data. The analysis assumes that missing values indicate no impacts, which may lead to systematic underestimation of losses, particularly in the MENA region.

We agree that the data quality and missing values are strong limiting factors in our study, which we have acknowledged at several occasions in the manuscript (e.g. see Section 4.4, Lines 445, 453-454, and 472). For example, as the referee mentions, empty data fields on economic losses in MENA countries occur relatively frequently. We recognize that a statement in the original manuscript that empty fields are treated as zero values was not entirely correct; empty fields for respective indicators were not considered in the analysis, see also the different number of events across the three impact indicators in Figs. 2, 5, and 6, reflecting the difference in empty fields across impact indicators for recorded disasters (with the pie chart size representing the number of events that possessed the different indicators). Moreover, please be aware that treating these empty fields as no impacts or removing the records from the study for relevant impact indicators result in exactly the same numbers in Figure 4a, 4b and Table 2. This aspect was unclear in the manuscript, so we rephrase the following part in the Methods section (Lines 141-143):

"For the computations, empty fields in the EM-DAT are set to 0 for all impact indicators. A value of zero thus either means that the disaster did not cause any damage, or that its impact is unknown or not registered. This choice introduces a potential bias in the study, since some event types or impacts may be under-reported compared to others. To provide more insight into this aspect, the percentages of zero fields for each disaster category and the corresponding impact indicator are included in Table [...]"
as follows

"For the computations, empty fields in EM-DATA are not considered for the respective flood indicators. Empty fields thus either mean that the disaster did not cause any damage or that its impact was known and thus was not registered. This data limitation may introduce some bias in the study, since some event types or impacts may be under-reported compared to others. To provide more insight into this aspect, the percentages of empty fields for each disaster category and the corresponding impact indicator are included in Table [...]".

To visualize the proportion of empty fields across different impact indicators

across countries, we add different types of hatching to the maps in Figure 3 and Figure 4 indicating the fraction of existing values for each country and impact indicator. This will give the reader a direct sense of the proportion of missing data, instead of having to look this up in Table C1 in the Appendix. Below we add these two revised figures (Fig. R1 and Fig. R2)

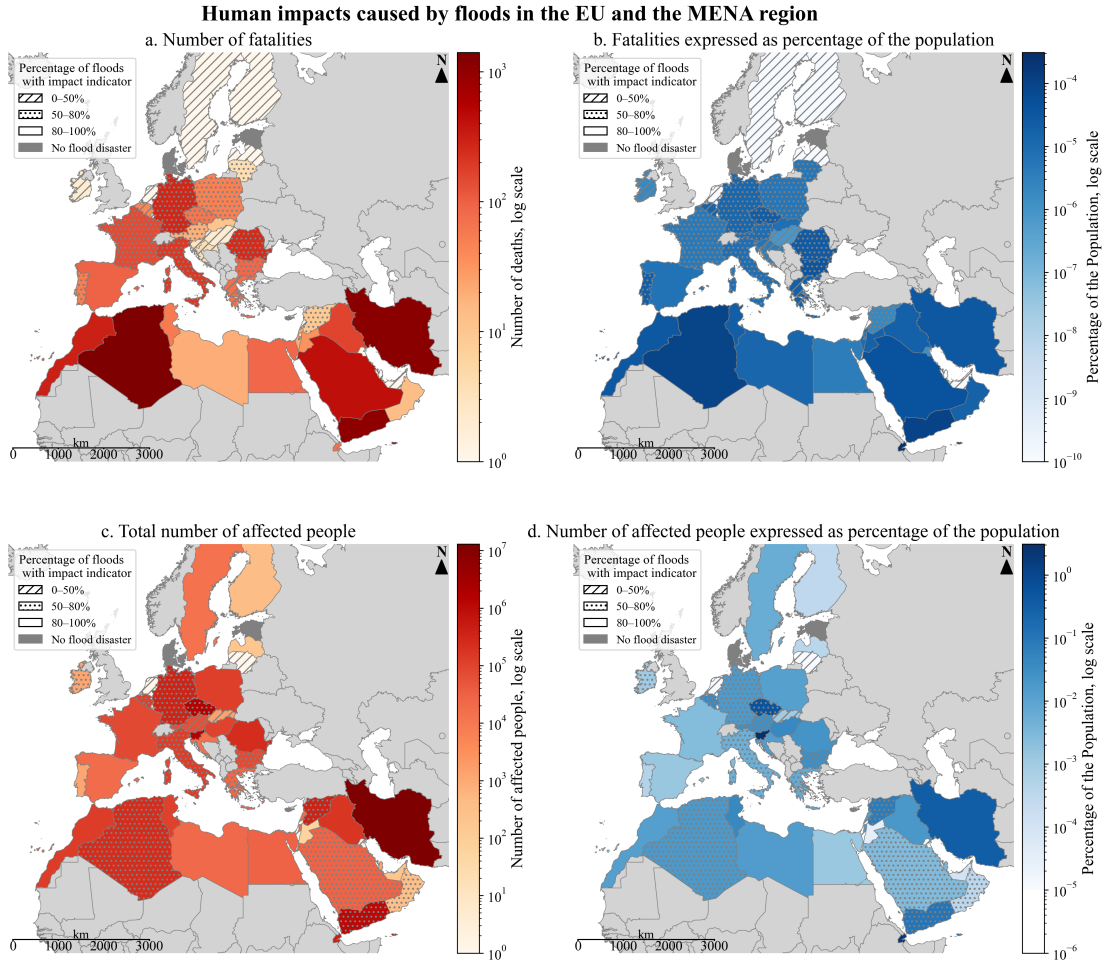

Figure R1: Flood human impacts in the regions of interest, with the proportion of information per indicator as different hatching types. a. Number of deaths, b. Deaths expressed as a proportion of the population, c. Number of affected people and d. Affected people expressed as a proportion of the population. The values are represented using logarithmic scales. This figure is numbered Figure 3 in the original manuscript. Data sources: CRED (2025) and World Bank Group (2025), Country borders: Natural Earth (2025).

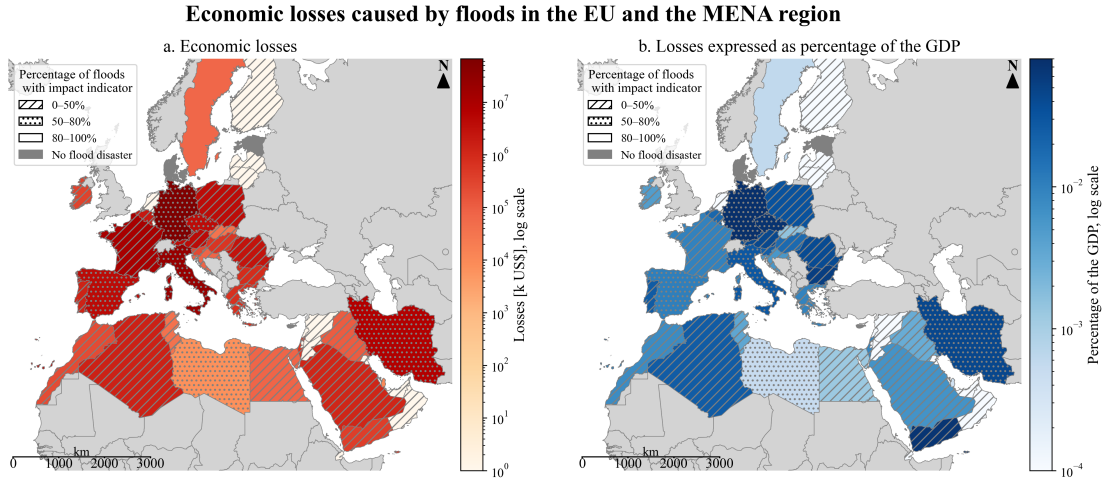

Figure R2: Financial impacts of flooding in the evaluated countries with the proportion of information per indicator as different hatching types. a. Measured economic losses, b. Economic losses expressed as percentage of the national GDP. The hatchings describe the proportion of flood disasters that have recorded the different impact indicators. The values are represented using logarithmic scales. This figure is numbered Figure 4 in the original manuscript. Data sources: CRED (2025) and World Bank Group (2025), Country borders: Natural Earth (2025).

Another limitation is the use of rankings to compare public perception with actual impacts. While this simplifies the analysis, it ignores the magnitude of differences between categories. The comparison of data is also asymmetrical — for EU countries, both quantitative and perception data are available, whereas for the MENA region only quantitative data are used. This limits the ability to make fully consistent comparisons between regions.

Thank you for pointing to the limitation of using the difference in rankings to compare public perception to measured impacts. Following the reviewer's suggestion, we are changing the computation and quantifying the magnitude between recorded impacts and public perception by calculating the difference in the fraction of flood impact and perception relative to the other four natural hazard categories. For this purpose, we normalise the percentage of the natural hazard categories in the Eurobarometer results (note that due to the option of respondents giving multiple or no answers for several categories, some of which do not belong to the four natural disaster groups, total fractions summed across the four categories can fall below or exceed 100 percent). By computing the difference in percentages of flood impact and flood risk perception compared to all four natural disaster categories, the analysis quantifies more precisely to what extent flood risk is underestimated or overestimated by the population.

With regard to the remark on the asymmetry of the analysis, please be aware that no adequate survey data is available for the MENA region. For that reason, we cannot quantify to what extent flood risk is over- or under-estimated by the population of MENA countries. We emphasize that our present study still makes major contributions to flood research by (1) comparing socio-economic impacts of flooding across two regions characterized by large inequalities (EU, MENA) and by (2) comparing recorded impacts with public perception (within EU only). To

better communicate this setup of the study clearly from the start, we implement the following change in the introduction:

Line 79: "Finally, we compare observed flood impacts with public perception of flood hazards focused on the EU only due to limited availability of survey data." is rewritten as: "Finally, we compare observed flood impacts with public perception of flood hazards focused on the EU only since no similar survey data was available for the MENA region."

In addition, as Referee 1 suggested, we are creating a flow-chart visualizing the approach and scope of the study. We believe this will make the study design, the used databases and methods, and their links to research questions clearer to the reader.

Reliance on a single data source (EM-DAT) is also problematic. This database has known limitations, including underreporting of events, a bias toward better data coverage in developed countries, and substantial gaps in economic loss data (particularly in the MENA region, where they can reach up to 75%). Furthermore, aggregating data at the level of two broad regions (EU and MENA) obscures important internal differences and introduces significant heterogeneity within the analyzed areas.

We agree that EM-DAT has inherent limitations in terms of data quality, introducing some limitations in our results, which are all mentioned in Section *4.4. Limitation of the study*. Still, given the purpose of our study, we believe that EM-DAT – despite its limitations – remains the best option since this dataset covers countries in both the EU and the MENA and includes records from various types of natural disasters.

To give insights in potential limitations of EM-DAT, we are repeating the same analysis as in Section 3.2 (i.e. flood impacts for the three indicators) in EU countries using the HANZE database. Specifically, we are reproducing Figures 3 and 4 based on HANZE to provide quantitative comparisons of flood impacts in the EU only. Please, be aware that we cannot use HANZE for the MENA region, as it does not cover these countries.

Regarding the comment on the aggregation of the data at the level of the two broader regions, we would like to emphasize that while our study indeed compares data between these two regions (e.g. Table 1, Figures 1, B2, B3), most of our analysis is conducted at a country-based level, providing more detailed information and detailing spatial variations within the study region for all of our four research questions, see also Figures 2 to 8.

Finally, the study is primarily descriptive in nature. It lacks more advanced statistical analysis, such as regression models, causal inference approaches, or significance testing, which could provide a deeper understanding of the observed relationships.

Thank you for pointing out this limitation in our study. To strengthen our research we change the following analysis to our study, to include more quantitative aspects:

- As also mentioned above, we add linear regressions linking the impact indi-

cators to the socio-economic state of countries, expressed as national GDP and/or GDP per capita.

- To better quantify our results and to support the conclusions, we also test if these aforementioned linear regressions are statistically significantly from another while separating between countries from the EU and the MENA region.

- To improve the comparison between perceived flood risk and recorded impacts, we quantify the difference in percentage of flood risk and impact from the four natural disaster categories instead of using a difference in rankings.

- Finally, we also wish to emphasize that our current analysis already includes a quantification of flood fatalities and affected people expressed relative to population size and economic losses expressed relative to GDP.

Overall, the study represents a valuable comparative analysis and offers a broad overview of flood-related issues across different regions of the world. Its main strengths lie in the scope of the data and the attempt to integrate different research approaches. However, methodological limitations — particularly those related to data quality, simplified analytical methods, and the absence of a causal framework — mean that some conclusions should be interpreted with caution.

We want to thank the reviewer again for recognizing the novelty of our research and for pointing to suggestions to improve our manuscript. We believe that the above stated changes improve our study and hope that they sufficiently address the concerns raised by the reviewer.

References

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