Fluvial Flood Inundation and Humanitarian Impact Model Based On Open Data

Authors' Response

To Referee Comment (RC) 2

Lukas Riedel on behalf of the authors

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General Comments

Referee Comment (RC) The paper presents a valuable contribution to the field of fluvial flood modeling and forecasting, addressing a critical need for efficient and accurate methods to assess flood impacts globally. The use of extreme value analysis coupled with openly available data within a catastrophe modeling framework offers a promising approach to rapidly compute flood inundation footprints and estimate associated impacts. The application of the model in Pakistan exemplifies its utility in assessing flood depths, extents, and population displacement. The findings regarding the incorporation of estimated flood protection standards and the calibration of vulnerability models provide important insights for future research and disaster preparedness efforts.

Author Response (AR) Thank you for an encouraging and concise review. We are happy to see that we agree on many positive aspects of the presented research. By addressing the raised concerns, we were able to sharpen aspects of the discussion in the manuscript (sec. 5, previously sec. 6), and we provide additional context in our detailed responses below.

RC I would be excited to see how this model could translate into better impact-based early warning systems, potentially revolutionizing the way we prepare for and respond to fluvial flood events. Additionally, while the methodology is tested in Pakistan, it would be beneficial to explore how it could be extended to other countries and contexts, considering varying environmental and socioeconomic factors.
The paper addresses the main sources of uncertainty, including uncertainty in displacement data, river discharge, and flood footprint, in a convincing manner. However, it is acknowledged that these factors remain significant limiting factors that could influence the accuracy and reliability

of the model's predictions. Further research and improvements in handling uncertainty will be crucial for enhancing the robustness and applicability of the model on a global scale.

AR Indeed, while we consider the model to be globally applicable, it is beyond the scope of this study to ascertain its robustness and accuracy on a global scale. In this publication we want to present the methodology and exemplify the application of the model. In future research, we expect to apply this model in different regions of the globe, in different time frames and scales, and with qualitatively different data. This will necessarily involve fine-tuning to case-specific environmental and socio-economic factors, which might eventually lead to the development of a global-scale impact model methodology.
In a project by the Federal Office of Meteorology and Climatology MeteoSwiss, we are working closely with stakeholders at the World Meteorological Organization (WMO) and humanitarian organizations to prototype impact estimation and decision making support based on this model and other hydro-meteorological impact models.

Specific Comments

RC Line 228: maximum displaced population is reported a month after the end of the peak season. Is this due to a delay in reporting or because of multiple waves in displacements. Typically, we see an initial wave for people directly impacted and a 'late' displacement wave due to other socioeconomic impacts such as loss of livelihoods, services, market disruptions etc. The latter is not expected to be captured by the model.

AR This touches an important aspect of displacement that is difficult to incorporate into our model setup. Technically, the model only considers displacement due to flooding of residential buildings or areas. However, the vulnerability in the model is calibrated using displacement data from IDMC, which also includes displacement due to the mentioned "late" or "secondary" effects. The model thus cannot attribute displacement to specific reasons. Nonetheless, the overall numbers including displacement from direct and indirect impacts should be comparable, if there is little spatial disparity between primary and secondary drivers of displacement. We discussed this in part in Section 5.2 (previously 6.2), but have expanded the respective paragraph and the model setup subsection (sec. 4.2.1) to better reflect these considerations.
Since the model uses the flood footprint as hazard, expanding the model to include the temporal dimension of displacement is not easy. The model will report the overall displacement expected from the flood footprint superimposed on the population distribution, irrespective of when this displacement actually occurs. The calibration only yields sensible results if larger flooded areas and greater inundation depths lead to more displacement. Secondary displacement waves, that occur when the actual flood water has receded, cannot be captured with this model setup. This is why we calibrated the model with the maximum flood footprint of an arguably large time span (June through September 2022) to the reported displacement on 30 Sept 2022.

RC Line 369: It is indeed surprising that such a large variation in the impact functions result in a relatively small difference in displacement. I am wondering if this could be due to some sort of overfitting of the data as we have limited displacement data and a pretty wide parameter space that is considered?

AR Overfitting can be a major issue when calibrating to a single event, and we tried to avoid it by employing the "cross-calibration" approach. We interpret the small difference in displacement for varying calibrated impact functions as an indication for a "stable" calibration; We can, at random, exclude data points from the calibration and still receive similar results. The results of section 4.3 (previously 5.3) "Historical Flood Displacement" indicate that the calibrated impact functions are indeed transferable to displacement events of the last decade in Pakistan. The seemingly high ambiguity of impact function parameters might be due to our particular choice of a step function. We intend to investigate the calibration of other impact function shapes in the future.
Nonetheless, we can interpret the calibrated impact function parameters further. For the "No Protection" model, we find that a greater flood inundation threshold T coincides with a greater ratio of displaced population Π for the calibrated function (cf Fig. 4). Therefore, although the function parameters have a relatively high spread, the overall displacements resulting from these functions can be similar—note that a greater T decreases the impact while a greater Π increases it. For the "FLOPROS" model, we do not find such a clear relationship. However, this model effectively applies two thresholds; first the protection standard threshold is applied to the hazard footprint, and then the flood inundation threshold is applied through the impact function. If the FLOPROS threshold relates to a similar or greater inundation depth than the impact function threshold parameter, it is expected that the effect that parameter is reduced. Therefore, the sensitivity towards the parameter is low, and hence its spread is large (compare the reduced vulnerability sensitivity coefficient for "FLOPROS" in fig. 7). Due to the threshold of the flood protection standard, this again need not result in a large spread in displacement figures.