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Reply on RC2

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Author comment on "Brief communication: Impact forecasting could substantially improve the emergency management of deadly floods: case study July 2021 floods in Germany" by Heiko Apel et al., Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2022-33-AC2, 2022

Author reply to referee comment on manuscript nhess-2022-33 “Brief communication – Impact Forecasting Could Substantially Improve the Emergency Management of Deadly Floods: Case Study July 2021 floods in Germany”

We thank the reviewer for his/her thoughtful comments on the manuscript. The different comments are addressed individually below. The original reviewer comments are listed point by point.

Referee comment: The first is the claim on Line 20-22 that river flood forecasts are typically provided only at river gauges. Since I rarely work with forecasting I may be wrong, but as far as I am aware there are existing European flood forecasts that already provide spatially distributed data, from the global Copernicus Emergency Management Service to specialized tools for riverine flooding. So adding a few lines and references that justifies the statement would be an advantage.

Our statement refers to the official and legally binding operational flood forecasts in Germany, operated be the different federal states. All these flood forecasts provide only forecasts of water levels or discharges at a selection of river gauges, derived from weather forecasts and hydrological models. The same holds true for Global Flood Awareness System GloFAS, developed by the European Commission and the European Centre for Medium-Range Weather Forecasts (ECMWF). On a European level the European Flood Alert System EFAS (https://www.efas.eu) provides warnings with spatial information. However, these forecasts including inundation areas have a rather coarse spatial resolution of 100 m, do not consider dikes or other flood protection measures, and are based on pre-calculated hazard maps, not actual flood dynamics. These forecasts are thus valuable for generating a general flood alert and indicating the affected areas in the expected flood, but for detailed flood management actions within the flood areas they are of limited use. For targeted flood management actions and disaster response much more detailed information as provided by the hydraulic model in this manuscript are required.

We will add an explanation of the novelty of our work compared to existing flood warning systems in the revised manuscript, to underline the necessity of more detailed inundation and impact simulations for flood management.

Referee comment: More importantly the choice of simplified 2D model seems rather arbitrary (L50). Much has happened over the past 12 years and at least 5 European research institutions have worked on the field suggesting a wide number of models and also outside of Europe this is an research field. So justifying the choice of tool should go beyond a subjective assessment of the model performance using a single metric stating that the model is sufficiently accurate. As far as I know the most recent review of methods is in Thrysøe et al (2021).

It is correct that research has provided a number of potential methods and models for high resolution inundation simulations in the past decade. The presented model RIM2D is one of these models. However, the choice of this particular modelling approach, which is from the underlying mathematical concept identical to Lisflood-FP, is not arbitrary. As already shown in Apel et al. (2009) and many studies later, the 2D raster based concept using simplified shallow water equations still provide the best compromise between required accuracy, model complexity and model runtime. Bates (2022) evaluated many studies on flood prediction models in the latest review and concluded: "…there is a broad consensus, among researchers at least, that 2D models are the current best compromise between what we know about the physics of inundation, the compute resources we have, and the data currently available.". The RIM2D model selected for this study falls exactly in this category, being computationally efficient, being parsimonious by requiring only a limited and easily accessible data for model setup and running, and by short simulation times due to its massive parallelization on GPUs. We will add a justification for the selection of RIM2D in the revised manuscript, based on the arguments listed above.

But we would surely acknowledge that other, similarly efficient and accurate flood simulation models can be used. The core message of this contribution is, that by providing spatially distributed and high-resolution inundation maps and derived flood impact maps in a flood forecast would improve the effectiveness of flood warnings, and eventually save lives. We will underline this in the revised manuscript.

Referee comment: My last point is that it is not clear from the paper how the input data are related to the forecasts. Precipitation forecasts are inherently quite uncertain as the authors correctly state (L174-175). Nevertheless the study seems to use a reconstruction of data that ignores this important source of uncertainty. A forecast should hence include this uncertainty and then there is an additional discussion of e.g. ROC curves. Hence the title of the paper should be adjusted to reflect the fact that the paper mainly focus on providing a spatial distribution of a given flow than to provide an impact forecast where the uncertainty of the forecast is also included.

The reconstructed hydrograph was used for model validation. By using the currently best estimate of the actual flood event, the high validity of RIM2D and the simulation results was shown. This would not be the input to the model in a forecast mode. In a forecast mode the output of the hydrological model, that transfers the rainfall forecasts into hydrographs, would be used to drive RIM2D. An example of the forecast mode is shown in figure 2a, where the actual operational forecast was used as boundary condition for the hydraulic model. The comparison with simulation based on the reconstructed hydrograph in figure 2b provides an estimation of the uncertainty of the river discharge forecast stemming from the meteorological forecast and hydrological modelling, expressed as an underestimation of the actual inundation extent and depths. We agree that ideally a spatial flood forecast should provide an uncertainty band. This can be achieved, if not only the ensemble mean of the river discharge forecasts is used, but the whole or a selection of the forecast ensemble. The uncertainty can then be expressed as probability of inundation for each grid cell and statistics of inundation depths and flow velocities per grid cell. This is generally feasible, but requires larger computational resources in terms of multiple GPUs in order to run the ensemble forecasts in parallel.

A ROC curve would also be desirable, but considering the rarity of such large flood events, it is practically not possible to evaluate the ROC or similar forecast quality measures, simply because of lack of event data.

For the presented manuscript, no ensemble meteorological and hydrological forecast were available. This impedes the assessment of uncertainty through ensemble integration. But nevertheless, we would still argue that a spatially explicit flood forecast based on the ensemble mean, i.e. without uncertainty information, would be a tremendous step forward towards a more informed and targeted disaster management compared to the current state. A flood warning as shown in Figure 2a, even if it underestimated the actual flood extent, would have surely raised more concerns and alertness in the disaster management centres, and provide the required information for targeted actions, as e.g. evacuations, flood protection measures, affected critical infrastructure, etc. And this is the main message of this contribution.

In the revised manuscript we will address the point of uncertainty and ensembles in the discussion, following the arguments above.

References:

Apel, H., Aronica, G., Kreibich, H., and Thieken, A.: Flood risk analyses—how detailed do we need to be?, Natural Hazards, 49, 79-98, 2009.

Bates, P. D.: Flood Inundation Prediction, Annual Review of Fluid Mechanics, 54, 287-315, 10.1146/annurev-fluid-030121-113138, 2022.