The hydrological-hydraulic study presented in this paper attempts to reproduce a pluvial flood across the Umbeluzi catchment in February 2023. The numerical simulations were conducted with the free software Iber+, well known by the primary author because he is one of the original developers. The basin has a drainage area of approximately 5000 km2 and a mean slope of about 10%, which led to a peak discharge close to 3000-5000 m3·s-1 for the studied floods. The study's input data consists of the Copernicus GLO-30 Digital Elevation Model (DEM), 66 satellite-based GPM-IMERG rainfall database pixels, and the curve number (CN) data set GCN250. The spatial resolutions are, respectively, 30 m, 9 km and 250 m. For the validation step, the authors limited the analysis to the outlet region of the catchment using: i) a 10 m resolution Sentinel-1 image, taken on 14 February 2023 at 03:20 UTC, with a discharge of 915 m3s-1; ii) twenty (post-event) watermarks measured in field works on 20-21 March 2023.

RC3 #1. The paper is well presented, the materials and methods are explained briefly, referencing other literature for details, and the results are described concisely. I have no concerns regarding the writing and presentation. However, the size of the basin and the magnitude of the flood could be more exceptional regarding other studies also conducted with Iber+ by other authors not cited in the current version of the paper. The pluvial inundation in the Umbeluzi basin has no particular value because the peak discharge is not high for the catchment size; however, if the authors could show an essential novelty regarding the methodology from a broader scientific perspective, it would deserve publication.

First, the size of a catchment is not a criterion to assess the interest of a hydrological study. As stated in the introduction, the choice of this case study was not the size of the catchment, but rather the intense flood event that took place in the province of Maputo on February 2023, which resulted in severe damage to population, infrastructure and agricultural lands. These kind of catchments are quite frequent in Mozambique, a region with very limited availability of local hydrological data and limited access to computational resources. Thus, its is interesting to analyse to which extent a relatively recent integrated hydrologic-hydraulic modelling approach, based on the 2D shallow water equations, that can be run in a standard PC or laptop, combined with global and free databases, is able to reproduce extreme flood events under these conditions.

Regarding the magnitude of the event, as mentioned in the previous paragraph and in the introduction of the manuscript, it was one of the most extreme in the last 20 years, causing important economic losses and significant damage to infrastructure, agriculture and population. So it can certainly be considered a high discharge. Moreover, as mentioned in lines 415-419, the maximum discharge estimated for this event was similar to the maximum discharge registered in the Boane hydrometric station from 1955 to 1986 (i.e in a period of 31 years).

In any case, the reviewer does not seem to be aware about the relation between peak discharges and catchment size, otherwise he wouldn't make the statement "the peak discharge is not high for the catchment size". The following figure represents the estimated peak discharge in U-PLD for the event analysed in the paper (green circle), together with the maximum discharge recorded at the Boane hydrometric station in 1984 (red circle) and the envelope curve from the Maximum Streamflow Discharge of the European Rivers (blue line) (Herschy, 2002). The same figure shows more than 500 extreme events recorded in 21 European countries according to Med-Hycos (Mediterranean Hydrological Cycle Observing System). As it can be seen, the discharge of the event analysed is almost overlapping with the European envelope and is higher than all those observed in Europe for the same catchment size, which proves its exceptional magnitude.

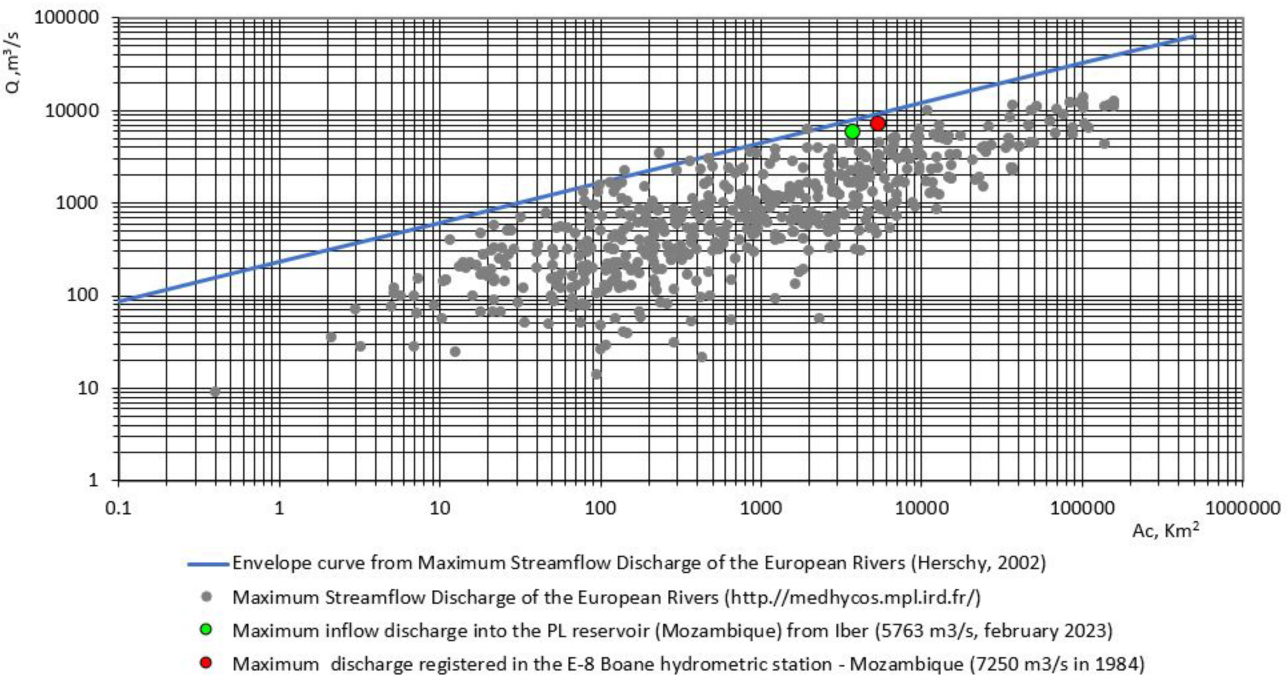

Figure 1. Maximum discharges observed vs. size of the catchment.

The same conclusion could be drawn by following the method of Regional Maximum Flood Peaks in Southern Africa proposed by Kovacks (1988), which is based on the equations defining the nomograms proposed by Francou and Rodier (1967). The regional coefficient K obtained for the flow of 5,763 m3/s is 4.9, a value in agreement with that estimated by Kovacks (1988) for the region in which the Umbeluzi basin is located.

RC3 #2. Furthermore, the Conclusions are not supported by the Results. As explained below, it is impossible to achieve the Conclusions established in the last section of the paper because of the absence of more accurate input data.

We would ask the reviewer to be more precise in his comments. If the reviewer could tell us which conclusion in the paper is impossible to achieve, we would be able to either refute his argument or take it into consideration.

RC3 #3. Introduction. The Authors should cite other software for distributed hydrological simulations based on the two-dimensional Saint-Venant equations and GPU acceleration. In particular, TRITON (Morales-Hernández et al. 2021), SERGHEI-SWE (Caviedes-Voullième et al. 2023) and LISFLOOD-FP (Sharifian et al. 2023). Also, the Authors need to establish the limitations of Iber+, which only allows using one GPU. In contrast, other alternatives allow multi-GPU, precisely, to achieve the required spatial resolution in accurate distributed-hydrological simulations.

It is true that we could cite other solvers that implement acceleration techniques. We didn't do it in the first version of the manuscript because the study is not focused on numerical aspects. But we have done it in the revised manuscript.

We have included the following references to other solvers of the 2D-SWE that implement parallelization techniques, either on GPU or CPU: Noh et al. (2018), Xia et al. (2019), Sanders and Schubert (2019), Morales-Hernández et al. (2021), Caviedes-Voullième et al. (2023), Sharifian et al. (2023).

In our opinion, the parallelization for 1 GPU is not a limitation for the purpose of this study. First, because the computational time needed to run the simulations using a standard PC was around 20 minutes (for a period of 9 days of real time), which is not limiting at all. Second, because the results won't change using several GPUs, the simulation will just run faster depending on the number of GPUs used. Third, because running a code in multiple GPUs requires the use of very expensive computational clusters that are not generally available, specially in regions as Mozambique, thus, precluding their application. Moreover, most shallow water codes, even in Europe, are run in personal computers with only one available GPU. We recognize that having a code that can be run in multiple GPUs is an advantage, but as we argued, this is not relevant for this study. On the other hand, Iber is a freely available and widely used software for flood hazard estimation that can be easily run in any personal PC without the need of any additional pre- or post-processing software, which is not the case of TRITON or SERGHEI-SWE.

In any case, it is not the purpose of this study to establish a comparison of the computational efficiency, availability or ease of use of different 2D-SWE solvers. We have used Iber because we are the developers of the software, but of course, the same kind of results could be obtained with other similar software. For this reason, we have removed the single reference that there was to Iber in the Conclusions section, we just refer to codes that solve the 2D shallow water equations.

RC3 #4. Introduction. The limitations of the numerical study concerning the use of global data source and the limited amount of data for the validation has to be explicitly explained in the Introduction. Please note that the spatial resolutions you used, i.e., 30 m for DEM, 9 km for rainfall and 250 m for CN, are too coarse for flood hazard mapping using the 2D Saint-Venant equations. In Spain and other European countries, we have made great efforts and spent huge amounts of money to acquire LiDAR data with the accuracy required for accurate flood risk mapping (Díez-Herrero et al. 2009; Sánchez and Lastra 2011; Olcina-Cantos and Díez-Herrero 2021). Both in terms of spatial resolution and elevation errors, among other essential factors. The global data source used by the authors cannot yield accurate flood maps. Otherwise, why are we making so many efforts to accurately implement the EU Directive 2007/60 on the estimation and management of flood risk?

The reviewer doesn't seem to be aware about the peculiarities of doing hydrology in data scarce regions, and that there are many regions in the world which do not have the data availability that we have in Europe. Of course European countries have done a great effort in the last years to obtain accurate data (particularly DEMs) in order to implement the EU Floods Directive with the highest possible level of detail, because they have the means to do that. But this level of detail is not possible in most African and Latin American countries, which, by the way, are much more vulnerable to floods than European countries, and also need to protect themselves against floods. So, you need to use the best data available in each case. If the reviewer is aware of more accurate data available at the global scale (or even in Mozambique), we would be grateful to know.

Indeed, our study serves as a case study of what can be done with 2D-SWE models in data scarce regions using globally available data. This is clearly stated in the manuscript as one objective of the study, and we believe that our results can be valuable for the hydrological community.

Regarding the reviewer's comment on the "limited amount of data for the validation", we should refer to the following comment by Reviewer #2, which seems to be much more aware about the peculiarities of doing hydrology in data scarce regions: "*the model validation was possible due to the availability of the Sentinel 1 image of flood extent and by ground observations of maximum water levels in a number of points for the flooded area. To my personal experience, both of these datasets are not always easy to find even in Europe or many other areas of the world.*"

RC3 #5. Introduction. Please cite other studies using Iber+ and other software for flood risk mapping using GPU and distributed numerical simulations in basins of similar size. For instance, Moral-Erencia et al. (2021) computed and validated flood maps using Iber+ in a catchment of about 2000 km2, with a mean slope as steep as for Umbeluzi, using a computational mesh with 20 million cells and sub-metric spatial resolution in some river stretches. Also, note that the satellite-based IMERG rainfall data set (the same one used by the authors) underpredicted the accumulated precipitation by 50% in such a study.

We are aware of the interesting work of Moral-Erencia et al. (2021), that we have now cited in the revised manuscript. In fact, we already had 12 references in the original manuscript to other studies solving the 2D-SWE at the catchment scale (using Iber or other software). In addition to the new references of Sanders and Schubert (2019), Morales-Hernández et al. (2021), Caviedes-Voullième et al. (2023) and Sharifian et al. (2023), there are now 17 references related to applications of the 2D-SWE for flood hazard maping.

However, we would like to note that the case study and objectives of Moral-Erencia et al. (2021) are very different from ours. Their work is in a Spanish watershed very rich in data (for instance, they use a LIDAR-derived DEM with a spatial resolution of 2m and a vertical accuracy of 0.2m, which is available for the whole of Spain), i.e. it is not a data scarce region in which it is necessary to resort to global satellite data sets.

Regarding the number of cells in the computational mesh and spatial resolution, we refer to our detailed answer to the next reviewer's comment (RC3 #6). In any case, in our opinion there is no need to go to such high resolutions if the input data (and specially the DEM) has a much coarser resolution, as it is the case in data scarce regions (and in the Umbeluzi). The accuracy of a numerical simulation does not depend only on the resolution of the numerical mesh, specially in hydrological simulations, where the uncertainty introduced by the input data and parameters (rainfall, topography, infiltration, land uses, etc) is in general more significant that the uncertainty introduced by the mesh resolution.

Regarding the accuracy of the GPM IMERG rainfall data, we would just like to notice here again that the data availability in countries as Mozambique is not the same as in Europe. Despite its limitations and low accuracy when compared with other local rainfall products based on in-situ raingauges and meteorological radar, the GPM IMERG data (and other satellite rainfall products) are routinely used in hydrological studies in data scarce regions all over the world. Moreover, there are many publications in which the accuracy of GPM-IMERG is analysed in different regions of the world, giving a much comprehensive evaluation of this product than the one given in Moral-Erencia et al. (2021), which is limited to a specific basin of Spain and to a single storm event and thus, it lacks of generality. We will just to mention some references. Saouabe et al. (2020) evaluated the accuracy of the near real-time product (IMERG) compared to observed rainfall and its suitability for hydrological modeling over a mountainous watershed in Morocco and concluded that the GPM-IMERG precipitation estimates can be used for flood modeling in semi-arid regions such as Morocco and provide a valuable alternative to ground-based precipitation measurements. In China the capacity of the GPM product to capture the temporal variations of extreme precipitation was analyzed by Jingyu Liu et al. (2020) within the Yuan River Basin, concluding that the GPM-derived product reasonably estimated the flood characteristics. In Spain Tapiador et al. (2019) highlight that the use of GPM contributes extraordinarily to improve the monitoring of extreme events in near-real time, concluding that the GPM-IMERG compares well with observations in general for the major 2019 September floods in Spain. Also a recent review by Gosset et al. (2023) about the role of satellite observations for monitoring pluvial and fluvial flood in Africa highlighted that major recent flood events in Africa have been well depicted by satellite observations, illustrating the feasibility of satellite monitoring for better surveillance of the food risk in this region. In summary, when in-situ rainfall data is not available, GPM IMERG can be used (an is commonly used) as the one of the best alternatives to characterise extreme rainfall.

RC3 #6. Section 3.2 Numerical model. "The size of the mesh elements ranged from 25 m in the main river reaches to 80 m in the hillslopes" (Line 213) and "Considering both models and the whole Umbeluzi catchment, the total modelled surface was 5461 km2, and the total number of elements was approximately 2.6 million (Lines 223-224)". The computational grid is too coarse, even coarser than the DEM. The grid size affects as much as the physical parameters in distributed-hydrological simulations, see Caviedes-Voullième et al. (2012). Subsequently, an additional numerical simulation using between 20 and 40 million cells is required. The grid convergence study is a standard requisite in any CFD simulation (Blocken and Gualtieri, 2012). In my experience, considering that the model is already configured in Iber+, this task is not time-consuming. The authors only need to refine the mesh to achieve the maximum number of cells a single GPU allows.

It is true that the grid size (if too coarse) affects the model results, but I wouldn't say "as much as the physical parameters". Once a certain mesh resolution is attained, the model results barely vary and are therefore not sensitive to further mesh refinements. On the other hand, the physical parameters and other input data (specially infiltration parameters and rainfall) can have a much larger influence on the results.

The reviewer cites Caviedes-Voullième et al. (2012) to support his assessment about the relative effect of the mesh size compared to the effect of physical parameters. First, we should notice that the study mentioned was done in one single catchment of 2.8 km2, modelling one single rainfall event, and with a model that was not able to reproduced the observed hydrograph at the basin outlet (in fact most of the numerical results represent synthetic conditions with no infiltration and no bed roughness, and the only case in which infiltration is considered does not match the observed hydrograph at the basin outlet). So the conclusions that can be drawn from such a study are very limited.

Having said that, if one looks at Figure 7 of Caviedes-Voullième et al. (2012), the difference in the simulated outflow (red line) obtained with the meshes SS5 (size of 5 m, circa 110k elements) and SS20 (size of 20 m, circa 7k elements) is very small. The peak discharge varies roughly from 17.5 m3/s to 18.5 m3/s and the computed hydrograph is very similar in both cases. A similar conclusion can be drawn from Figure 8, except for the fact that their model exhibits some numerical instabilities in some cases.

So, the conclusion that can be drawn from Caviedes-Voullième et al. (2012) is that a mesh size of around 20 m might be enough to model their case study with the 2D-SWE. And in fact, this is in agreement with the results of a study that we made recently on the effect of the DTM and mesh size resolutions when solving the 2D-SWE in hydrological applications (García-Alén et al., 2022). In that study, seven real rainfall events in four different catchments (from 0.3 km2 to 3,750 km2) were correctly reproduced with the numerical model. In the medium size catchments (40 km2 and 200 km2) a mesh resolution of 25 m produced almost the same hydrographs as a mesh resolution of 10 m, while in the largest catchment (3,750 km2, a similar size as the one analysed in this paper), the Mean Absolute Error (MAE) and NSE was almost the same with meshes of 25 m and 65 m resolution. In all cases the NSE was of the order of 0.9, and the MAE normalised to peak flow was below 5%, values that can be considered very satisfactory when modelling single events in such large catchments.

In any case, **to further reassure the reviewer, we have refined the mesh size**, using 30 m (the same resolution as the DEM) in the whole catchment (hillslopes and rivers) and the results barely change (see Figures 2 and 3 below). The number of elements of the new meshes are 9.5 M (instead of 1.5 M) in the U-PLD basin, and 4.4 M (instead of 1.1 M) in the D-PLD basin. Thus, the whole domain is discretised with almost 14 M elements (instead of 2.6 M). On the other hand, the computational time increases 4 times in the D-PLD basin and 6 times in the U-PLD basin.

Clearly from Figures 2 and 3, the differences between both models are not significant for the purpose of this study, specially considering the uncertainty associated to the other input data and model validation data. And in any case, those differences wouldn't change any conclusion of the study.

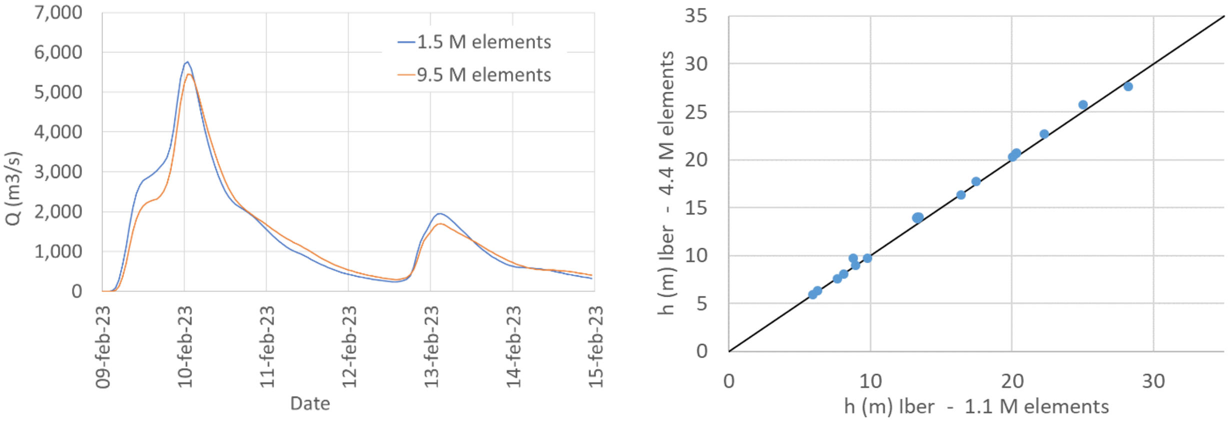

Figure 2. Mesh convergence analysis. Hydrographs computed at the outlet of the U-PLD basin in MS1 using computational meshes of 1.5 M and 9.5 M elements (left); water depths computed in MS1 at the 20 control points located in the D-PLD basin using computational meshes of 1.1 M and 4.4 M elements.

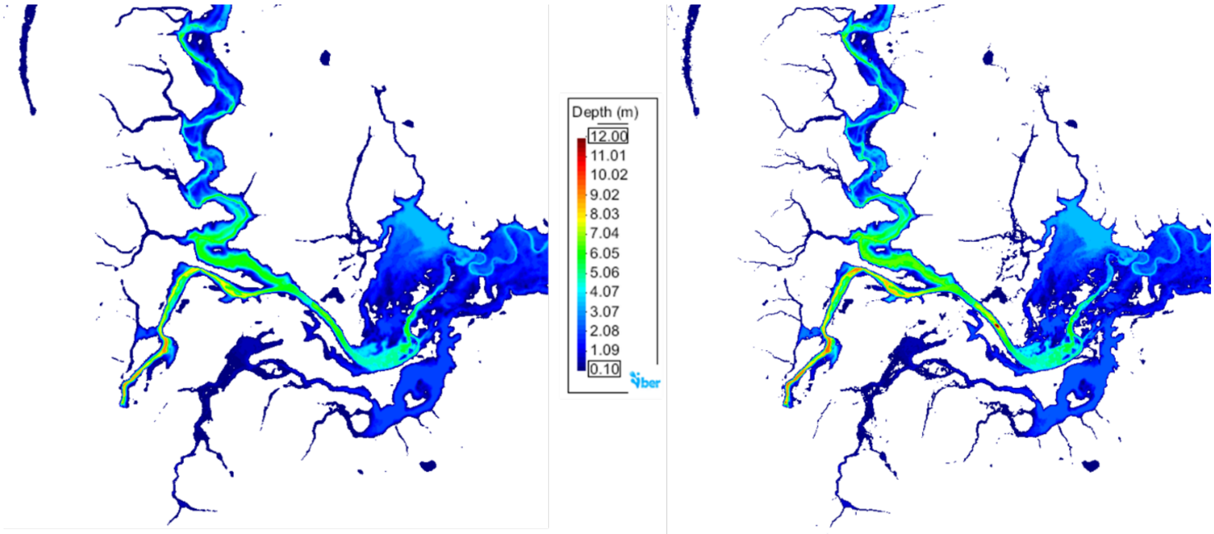

Figure 3. Mesh convergence analysis. Maximum water depths computed in MS1 in the AOI, using computational meshes of 1.1 M and 4.4 M elements.

Finally, we consider that the reference Blocken and Gualtieri (2012) is not appropriate in this case, since it deals with very different kind of flows: “natural ventilation of the Amsterdam ArenA football stadium” and “transverse turbulent mixing in a shallow water flow”, i.e. nothing to do with hydrological modelling. In our opinion there are no modelling steps that should be followed always in any numerical model. Depending on the equations being solved (1D-SWE, 2D-SWE, 3D-RANS, LES, DNS, etc.) and on the specific application (aeronautics, reservoirs, coastal engineering, river flow, hydrology, etc.) the approach is of course different.

Moreover, many studies in which the 2D-SWE are applied at the basin scale do not present a mesh convergence analysis, see for instance Xia and Liang (2018), Xia et al. (2019), Morales-Hernández et al. (2021), or Moral-Erencia et al. (2021), just to mention some of the references cited by the reviewer. Mesh convergence analysis are most commonly included in studies in which the main objective is to present new numerical schemes or software developments, or in which simplified geometries are modelled.

RC3 #7. Equations (2)-(3). Why did you neglect the Reynolds stresses even in the main river?

Iber includes several depth-averaged turbulence models, but it is well-known that they are not relevant at all in this kind of hydrological simulations (i.e. at this spatial scales). In these cases, the flow resistance is characterised mainly by the bed roughness. In fact, I am not aware of any publication in which a hydrological simulation at the basin scale is done including a turbulence model to compute the Reynolds stresses. Again, in hydrology the modeller should decide which processes should be incorporated (or not) in the model. Not always the more is the better. There is no sense in including irrelevant processes, because you just increase the parametrisation and complexity of your problem, without any real advantage.

RC3 #8. Equation (4). Please also evaluate the Critical Success Index (CSI) by Bates and Roo (2000) to compare your value with other studies. The CSI is more common than HR and FAR.

We have included the CSI in the revised manuscript. HR and FAR are also commonly used and they have a simple physical interpretation, so we have also maintained those indicators.

RC3 #9. Figure 11. "Observed vs. computed maximum water depths at the locations indicated in Figure 8". The maximum absolute error in the computed water depth values is extremely high concerning the field measurements. For instance: hiber=6 m for hfield= 3.5 m, or hiber = 4 m for hfield=1.9 m. Such errors are too severe for a flood study. It shows clearly that the global data source is inaccurate for detailed flood risk mapping, contrary to the author's statements in the Conclusion section.

We agree with the reviewer in that point. Probably we have been too enthusiastic in some of the statements made on the conclusions. We have rewritten them, and we have acknowledged that the model was able to correctly reproduce the flood hydrograph and flood extension, but not so trustable in the predicted water depths.

Having said this, the error is the predicted water depth values is related to the vertical accuracy of the Copernicus DEM (which is the best globally available).

RC3 #10. Figures 12-14 and their corresponding descriptions: Why did you limit the AOI to the basin outlet? The inundation area is too broad and probably covers the whole floodplain (from a geological perspective). Hence, it is easy to match the observed and simulated flood maps. Please include a map of the DEM slope in such an area to check. Conversely, the D-PLD headwater should be more sensitive and exciting for validation. Indeed, other studies, such as Moral-Erencia et al. (2022), verified the inundation maps in the catchment, not only in the outlet region.

The AOI was chosen considering the area in which the flood of February 2023 generated more damage, which is also the most exposed and vulnerable area of the basin. As mentioned in the Abstract and Introduction, it was in Boane and in the surroundings of Maputo where the economic, agriculture and human losses were concentrated, due to the settlements, farms and transport infrastructure located in the floodplains around the confluence of the rivers Umbeluzi and Movene. This AOI extends over 310 km2, which is a quite large area, and it can be thought of as an Area of Potential Significant Flood Risk (APSFR), even if APSFR haven't been identified officially in Mozambique. Thus, the rest of the catchment does not have the same interest regarding flood damage. In addition, the field campaign to estimate water depths was only undertaken in the AOI, precisely for the above reason.

Also, we should notice that the reviewer is wrong in his general comment about the areas in which it is more easy to match the observed and simulated flood extent. It is precisely in the upper reaches of a catchment where the river cross-section is more confined by the topography and thus, the water extent is less sensitive to errors in the predicted water depth. On the other hand, in flat areas a small error in the estimation of the water depth will produce a large error in the horizontal extension of the flood.

RC3 #11. Conclusions. The limitations of Iber+ for flood risk mapping in basins of 5000 km2 should be clearly stated. Commenting both on the inaccuracy of global data source for DEM and precipitation and also because of the maximum RAM of a single GPU, which limits the total number of cells in the computational grid (and hence, the spatial resolution).

The accuracy of the global DEM is already stated in the manuscript, and its potential influence on the water depth results obtained with the model has been mentioned in the Conclusions of the revised manuscript. We cannot draw any conclusion about the accuracy of the GPM precipitation data because we don't have field data to compare with. At the same time there are too many publications in which the accuracy of GPM-IMERG is analysed in different regions of the world, so this information is already accessible for any reader. We refer to the last paragraph of our answer to **RC3 #5**.

Regarding the parallelisation on a single GPU and the number of computational cells, as mentioned in our answer to previous comments, we don't believe it is a limitation of the methodology. Having said that, the conclusions are not about a specific software, but about a modelling approach. Other software solving the same equations with the same input data could be used probably with similar results and conclusions. We have clarified this in the conclusions section, avoiding to mention Iber+.

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