Response Letter Round2

Leonardo Laipelt, Fernando Mainardi Fan, Rodrigo Cauduro de Dias de Paiva, Matheus Sampaio, Walter Collischonn and Anderson Ruhoff

Dear Editor,

We are resubmitting the revised version of our manuscript, "Mechanisms and scenarios of the unprecedented flooding event in South Brazil 2024," following the minor suggestions provided by the reviewers.

We have addressed each of the comments in a point-by-point format below. We believe these final adjustments have further strengthened the clarity of the paper.

Thank you for your continued consideration of our work.

Best,

Leonardo Laipelt, On behalf of the authors.

Report #1

Dear authors,

Thank you for answering and addressing my comments. The motivation for this study, the explanations of the methodology and the different experiments, as well as the presentation of the results have substantially improved. I think that the manuscript now meets the requirements for publication in HESS. I have a few remaining minor/technical comments:

- Dear Reviewer, we appreciate your contributions toward enhancing the quality of this manuscript. We have revised the text in accordance with your minor comments and updated the document accordingly. Thank you.

- L91: “ADCP” -> explain the acronym at the first mention

- The complete nomenclature for the acronym has been included.

- Figs 1 and 3: increase plot size

- The plot size for the Figures 1 and 3 was increased.

- Section 3.3.3: I think that the explanations about whether it is physically possible to have the two tributaries synchronized are still missing. The only reference to this is “In May 2024, two cold fronts of varying spatial extent and intensity passed over the region between April 27 and May 2. As a consequence,…” (L223-225). Here, “as a consequence” is really not clear. Again, I think this is a very interesting and relevant analysis but some information about which meteorological conditions would lead to such an event is not clear from the text. If both tributaries are triggered

by the same atmospheric event, then synchronicity will depend on the routing/propagation times, which, if I understand well, are different between the two rivers.

- Thank you for your feedback. We agree that the physical feasibility of this scenario needed further explanation. We have refined the manuscript to justify the synchronization experiment more clearly, as follows:
  […] This analysis evaluated the combined flood impact of the Jacuí and Taquari rivers on the RMPA. Although these tributaries have distinct flow propagation times, their peaks can synchronize depending on the spatio-temporal distribution of rainfall. In May 2024, the region was impacted by a sequence of two cold fronts between April 27 and May 2. Such sequential atmospheric events can lead to peak synchronization if the first system triggers discharge in the slower-responding basin (Jacuí), while a subsequent system impacts the faster basin (Taquari) with a delay that matches the difference in their routing times.
  To evaluate the potential consequences of such a meteorological alignment for the region's flood protection systems, we simulated a theoretical worst-case scenario by manually advancing the upstream hydrograph, used as the boundary condition for Jacuí River (at Rio Pardo), by approximately 4 days to force their flood peaks arrive simultaneously. This synchronization allowed us to evaluate the potential consequences for the region's flood protection systems. […].

- L236: where does the Manning's roughness value come from?

- The Manning's roughness coefficient was derived from established literature for earthen channels. The uncertainties associated with this choice are addressed in the Discussion, where we demonstrate that this channel parameter has minimal impact on the overall experimental findings concerning flood mitigation.

- 4.1.1 and Fig 5: comment in the text the difference between SWOT and the observed and simulated lines for Corsan.

- We added the following sentence:

"[…] The Corsan station proved to be an exception, as SWOT observations did not effectively capture water level during the event. […]"

- L256: "BIAS", no capital letters needed.

- We updated to "bias".

- Figures 11 and 12: the colour legend is missing.

- Thank you for noted this. We have updated the figures with color legends.

- 4.3.2: Given the position of the channel (downstream of points C, D and E), is it theoretically possible to obtain a reduction in the rising limb and the peak for C and D, especially if nothing is simulated before the event (i.e. antecedent lagoon levels)? If no, then it shouldn't be expected

in the hypotheses for this experiment. Additionally, I am still wondering whether the small observed reductions could still be useful to reduce flooding impacts, not related to the peak but to the recession that might be a bit shorter.

- Thank you for your question. We used antecedent lagoon levels prior to the event for a simulation warm-up period to ensure stable initial conditions. In Section 4.3.2, we explain that the only effect of the structural intervention would be a slightly shorter recession period (approximately two days). However, it would not protect the main cities of the RMPA from an extreme event of the magnitude observed.

- L448: “13%”: this number was not reported in the results section. Additionally, could a reduction of 13% still reduce the flooding impacts to a certain extent?

- The 13% figure is simply another way of representing the information presented in the results, specifically comparing baseline water levels with those observed after hydraulic interventions. This reduction is not significant in the context of such an extreme event, which remains the primary focus of this study.

- L455-457: do you have a reference for this statement (especially for the second part of the sentence)? If not, I would remove.

- We have incorporated in the statement the following references about Porto Alegre urban development and affect areas due to the flood:
  - Miranda, A. Floods and extension plans: discourse and projects in Southern Brazil. In International Planning History Society Proceedings (Vol. 2). Delft, The Netherlands: IPHS, 2016.Collischonn

  - Collischonn, W., Fan, F. M., Possantti, I., Dornelles, F., Paiva, R., Sampaio, M., Michel, G., Magalhães Filho, F. J. C., Moraes, S. R., Marcuzzo, F. F. N., Michel, R. D. L. M., Beskow, T. L. C., Beskow, S., Fernandes, E., Laipelt, L., Ruhoff, A., Kobiyana, M., Collares, L. G., Buffon, F., Duarte, E., Lima, S., Meirelles, F. S. C., and Allasia, D.: The exceptional hydrological disaster of April-May 2024 in southern Brazil, Revista Brasileira de Recursos Hídricos, 1, https://doi.org/10.1590/2318-0331.302520240119, 2025.

Report #2

I want to thank the authors for taking into account my comments on the first draft of the manuscript. The updated version of the manuscript has improved considerably in terms of clarity, presentation of results, and analysis.

Here are some additional comments that I hope will enable you to further improve the quality of your work:

- Dear Reviewer, we appreciate your insightful feedback, which has significantly enhanced the clarity and impact of our work. We have carefully incorporated your suggestions into the revised manuscript, as detailed in our point-by-point responses below.

- In Section 3, I recommend starting with the current content in 3.3. This provides an overview of the content of the other sections, so starting with this text will give the readers a clearer idea of how the methodological pieces fit together.

- Thank you for your suggestion. We have moved the content in section 3.3 to the beginning of the Material and methods (Section 3). The methodology overview is now located in Section 3.1, titled “Workflow overview”.

- I still believe that Figure 9 (in the updated manuscript) could be more informative if the focus of the analysis were changed. Instead of removing one tributary at a time, test each independently by deactivating the others. In my initial suggestion, I highlighted routing streamflows to the outlet point, as I understand the catchment's regulatory effect during floods and the nonlinear processes that can occur. Since you are using a model, there is no problem with doing this, as it follows the same approach of turning tributaries on and off. This method would provide more clarity regarding the relative contribution of each tributary.

- Thank you for this suggestion. We understand that testing each tributary independently would isolate their individual contributions. However, we believe that the 'leave-one-out' approach a more physically meaningful message for flood management.
  Because the system is highly nonlinear, the impact of a single tributary depends on the state of the lagoon as dictated by the other inflows. Removing one tributary simulates a mitigation scenario of how much the flood levels would actually drop if that specific river’s contribution were attenuated. This approach highlights the marginal impact of each river within the context of a saturated system, which is more relevant for decision-makers than evaluating a river in isolation.

- Following your argument, it is not clear to me how the peaks are synchronised and justified. Are the peaks simply 'pulled' so that they coincide, or are adjustments made to the model so that they coincide with the characteristics of the event and the system? Or is a less favourable design condition being represented? I recommend improving the description of that case study a little.

- We have updated the explanation of the peak synchronization scenario to clarify the adjustments made to the model. The revised text is as follows:

[…] This analysis evaluated the combined flood impact of the Jacuí and Taquari rivers on the RMPA. Although these tributaries have distinct flow propagation times, their peaks can synchronize depending on the spatio-temporal distribution of rainfall. In May 2024, the region was impacted by a sequence of two cold fronts between April 27 and May 2. Such sequential atmospheric events can lead to peak synchronization if the first system triggers discharge in the slower-responding basin (Jacuí), while a subsequent system impacts the faster basin (Taquari) with a delay that matches the difference in their routing times.

To evaluate the potential consequences of such a meteorological alignment for the region's flood protection systems, we simulated a theoretical worst-case scenario by manually advancing the upstream hydrograph, used as the boundary condition for Jacuí River (at Rio Pardo), by approximately 4 days to force their flood peaks arrive simultaneously. This synchronization allowed us to evaluate the potential consequences for the region's flood protection systems […].

- Regarding the proposed interventions to alleviate floods, I agree that, as scientists, we must demonstrate what is and isn't effective. Furthermore, I am convinced that it is often the things that do not turn out as we expect that allow us to learn the most. However, setting aside philosophy, my comment was intended to justify these cases. Without solid justification, we could try any configuration that we know will fail from the outset, and, in that sense, the trivial solution does not contribute any real value or knowledge. I understand that these are some of the discussions currently taking place in Brazil, and the description in the text has improved considerably. Nevertheless, I strongly recommend including a few additional lines to justify these cases from a technical standpoint and to present the authorities' hypotheses. This would further highlight the importance of the findings you present in the manuscript for decision-makers.

- Thank you for your suggestions and for raising this discussion. We agree that it is essential to provide solid technical justifications for the analyses developed in the manuscript. Our scenarios are based on the discourse that emerged within the public and governmental communities following the event, alongside ongoing studies regarding technical implementations. To clarify our justification, we have updated the Introduction as follows:
    - […] *After the disaster, significant public and technical debated emerged regarding the hydraulic drivers of the flood. Question focused on the relative influence of upstream rivers, the slopes generated by water inflows, and the restrictive nature of the lagoon's single outlet to the ocean. Specifically, public and governmental debates have hypothesized that additional artificial outlets could have mitigated flooding in upstream areas (Hunt et al., 2024; Silva et al., 2024a)* […].

  We believe that with this revision, readers and decision-makers will be better able to understand the background behind our research.

- It would be interesting to see how the flood areas change in Figures 9 and 10 for the cases considered. The flooding component is one of the added values of your study, and I think it could also be highlighted here to highlight the hydrological risk explored.

Thank you for your comment. We agree that incorporating flood area results would be valuable for the study. However, as the peak water levels did not change significantly,

the total inundated areas remained virtually unchanged across these scenarios. For this reason, we decided not to include the maps in the manuscript. Nonetheless, we have added a textual statement in the results section to highlight this finding

We added the following sentence in section 4.3.1:
[…] would result in only minor reduction in water levels, with minimal impact on flood-prone areas. […]~
and Section 4.3.2:
[…] while having minimal impact on the maximum flow peak and the extent of flooding upstream in the Guaíba River. […]

Minor suggestions:

- L233: Instead of "exercise", prefer experiments or assessment. Exercise sounds like something synthetic, and potential solutions are being evaluated here.

- Thank you. We have changed to ‘assessment’ in the sentence.

- L236: Indicate the type of channel with which the selected roughness can be associated (e.g., n = 0.02-> earth channel). Since hydrology and hydraulics are combined here, these small details must make sense to all readers.

- Thank you, we have updated the sentence as follows: “[…] *The channels were assigned a Manning's roughness of 0.02, which corresponds to standard values for earthen channels […]”*

- L259: "river’s man channel in the DTM" -> river’s main channel in the DTM

- Thank you for pointing this out. The typo has been corrected in the manuscript.