A multiscale modelling framework of coastal flooding events for global to local flood hazard assessments

Responses to reviewers:

Reviewer #1:

Dear Authors,

I want to start by congratulating you on the significant improvements to your manuscript. It's clear that a great deal of time and effort has gone into addressing the previous round of feedback, and I commend your commitment to refining your work. Below, I provide my detailed comments following the structure from my earlier review:

Dear reviewer, thank you for your kind words and acknowledging the effort put into improving the manuscript. Your comments were really helpful in getting a better version of it.

1. Introduction

The revisions to the introduction largely address my earlier concerns, and I appreciate the improvements. However, I still feel that waves should be more explicitly described since they are integral to many coastal studies. Especially their absence in the discussion leaves a critical gap in the context of the study.

Dear reviewer, thank you for your words and suggestions. We have revised the manuscript to better highlight the importance of waves and how those could be addressed in future studies.

> *(Lines 541 – 546): "Waves can significantly contribute to coastal flooding and, in some regions, are the dominant driver of extreme water levels (Parker et al., 2023). However, the inclusion of wave contributions in large-scale assessments has been limited due to the computational cost of traditional wave-resolving numerical models. The development of more computationally efficient wave solvers offers an opportunity to implement dynamic wave simulations into large-scale assessments. For instance, Leijnse et al. (2024) developed an efficient solver currently integrated within SFINCS, which could potentially be implemented into future iterations of the MOSAIC modelling framework."*

2. MOSAIC Modeling Framework

While additional details about the framework have been included, the manuscript still feels incomplete.

• For a more comprehensive introduction, I recommend referencing other established modeling frameworks and techniques in the introduction. For instance, the CoSMoS framework by Barnard et al. (2014) should be mentioned, as it was among the first to address similar challenges.

Thank you for the suggestion. To provide additional context on modelling frameworks that address similar challenges to those discussed in this manuscript, we have included the CoSMoS framework in the introduction:

(Lines 54 - 56): "Similarly, Barnard et al. (2014) developed a framework that nests dynamically downscaled global tide and wave models with local cross-shore profile and cliff failure models."

• Additionally, more specifics are needed about how the nesting is performed. For example: I presume that the authors are using water levels for boundary conditions, correct? And what boundary condition types are applied in the local models SFINCS? In general, I think it would be good to address the limitations of water level nesting. For instance, the Riemann boundary could be a more appropriate choice in certain cases. In general, a detailed explanation of these technical aspects is essential to enhance the manuscript's clarity and rigor.

Thank you for your comments. In the manuscript, we explain the boundary conditions used to nest the Delft3D FM model within GTSM. The local Delft3D FM models use water level outputs from the global model GTSM as boundary conditions:

(Lines 154 - 159): "Second, MOSAIC uses an offline coupling approach to nest the local Delft3D Flexible Mesh model within GTSM. A Python script is used to first identify the boundaries of the local Delft3D Flexible Mesh model. These boundaries are then used to determine the specific locations where GTSM output should be extracted. Subsequently, GTSM provides the water level timeseries at the boundaries of the local model. Finally, the local high-resolution model is executed using the water levels derived from GTSM as forcing input, together with the same meteorological forcing as for GTSM."

The boundary conditions for SFINCS are water level timeseries from GTSM, as described in the manuscript as follows:

(Lines 182 – 184): "SFINCS is forced with GTSM water level timeseries at locations along every ~5 km of the coastline, and provides as output water level timeseries for each grid cell. Finally, flood depth maps are derived from the maximum water levels by subtracting the DEM."

Riemann boundary conditions could be more suitable in certain cases. In such cases, Riemann boundary conditions can be selected as an option within Delft3D FM.

3. Modeling Results

The added validation is a welcome improvement, providing a stronger foundation for the findings. I particularly appreciate (and follow) the description of the temporal component (G1 to G2).

However, I remain surprised by the significant water level changes (exceeding 10 cm) in the Gulf of Mexico due to changes in input bathymetry (G1 to N1). This requires further explanation. Could the tidal propagation with the updated GEBCO bathymetry be driving these changes or is there something else? For example, a separate analysis of tide and surge components could help identify the source. – In the case of N1, the GEBCO bathymetry used is GEBCO2019, which is the same as used for G1, with the only difference being the grid refinement. The differences in water levels in this region seem to come from N1's higher resolution, which better captures the complex topographic features in southwest Florida, such as the barrier islands. Additionally, the finer grid resolution in N1 results in a more detailed representation of the bathymetry, even though both models use the same underlying bathymetric data. This enhanced resolution allows N1 to better capture significant changes in bed level, particularly in shallow regions of southwest Florida. These local bathymetric differences may help explain the variation in storm surge during TC Irma, as storm surges are significantly sensitive to bathymetry, particularly in shallow regions. For instance, at Stations 4 and 9 in Figure A2, prior to Irma's landfall, water levels are similar across all model configurations. This suggests that the differences in the simulations do not come from the tide simulations. On the other hand, once TC Irma makes landfall the differences in water levels, caused by the storm surge, start deviating for the two model configurations G1 and N1.

Regarding Hurricane Irma, I question the suitability of calling the results "good" with an RMSE of 40 cm. Given the availability of higher-accuracy bathymetry and topography sources for this US case study, it is surprising these were not utilized. This could be a missed opportunity to enhance model performance, as you demonstrate in the European case study. Is there are reason I am missing why those data sources are not utilized?

Improved bathymetric data could certainly enhance the performance of the storm surge model. However, as the primary objective of this manuscript was to present a flexible modelling framework for multiscale modelling that allows to select from different datasets, rather than to create a perfect simulation, we chose not to update the bathymetry. Nevertheless, MOSAIC is designed to easily update bathymetry, allowing for future updates in subsequent research.

4. Discussion

Thank you for sharing the code used in the study.

5. References

I noticed several instances of what appear to be lazy or potentially incorrect referencing. While self-publication is a natural part of academic work, I feel it is crucial to engage broadly with the wider scientific community to ensure a balanced and representative citation list.

For example:

• Bloemendaal et al. (2019) and Dullaart et al. (2020) are cited as evidence that "errors in bathymetric datasets propagate to storm surge modeling." From my understanding, these papers do not directly make this claim. A more suitable reference might be Parodi et al. (2020). – Thank you for the suggestion. We have modified the references and moved the reference to Dullaart to the effects in spatial and temporal resolution while adding Parodi et al. in the references to the bathymetry effects in water levels.

(Lines 56 – 58): "Coarse meteorological forcings – both in terms of spatial and temporal resolution – might not be able to capture the resolution necessary to resolve intense storms (Dullaart et al., 2020), while errors in the bathymetric datasets will propagate to the modelling of storm surge levels(Parodi et al., 2020)"

• Similarly, Eilander et al. (2023) are credited with introducing the first globally applicable compound flood modeling framework that accounts for precipitation, river discharge, and storm tides. However, van Ormondt et al. (2020) appear to have done something similar earlier. – I believe the reviewer is referring to the paper introducing the Delft Dashboard. While Delft Dashboard has proven to be a really useful and interactive tool for retrieving inputs for various hydrodynamic models and even simulate overland flooding, the flooding modelled in this manuscript is solely driven by water levels induced by a tsunami, rather than by multiple compound flood drivers. For this reason it has not bee included as a reference to frameworks that perform compound flood modelling.

I would recommend the authors to carefully review all their citations to ensure that they are appropriate.

Thank you for the suggestion. We have reviewed the references of the manuscript to make sure they are appropriate.

Minor Comments

• The additional technical details on tropical cyclones are appreciated. However, please include, the wind drag coefficients and the background pressure used in this study. – Thank you for the suggestions. We have added those parameters into the manuscript:

> *(Lines 122 – 125): "Tides are generated internally with tide generating forces, while storm surges originate from external forcing with pressure and wind fields. A constant Charnock coefficient of 0.041 is applied to translate wind speeds from the external forcing into wind drag, and a background pressure of 101,325 Pa is considered."*

• Avoid using the term "total water level" unless wave contributions are explicitly accounted for. A more accurate term for this study is "still water level." – Thank you for the suggestion. We have modified "total water level" to "water level", where in lines 116-117 of the manuscript we define water levels as the result from tides and storm surges: "MOSAIC uses GTSMv4.1 to simulate water levels resulting from tides and storm surges, ignoring baroclinic and wave contributions."

• A typographical error in Figure 1: "Delft3d" should be "Delft3D" (with a capital D). - Corrected

I hope these comments are helpful in further improving your manuscript. Thank you for the opportunity to review this important work, and I look forward to seeing its next iteration.