Authors' response to referee #2: egusphere-2023-122 "A wave-resolving modeling study of rip current variability, rip hazard, and swimmer escape strategies on an embayed beach with irregular rip channels"

Dear Editor and Referees,

Thank you for your constructive comments on our manuscript entitled 'A wave-resolving modeling study of rip current variability, rip hazard, and swimmer escape strategies on an embayed beach with irregular rip channels'. We feel indebted to the reviewers for their time on this manuscript. We have incorporated the suggestions/comments in the revised manuscript. In the response below, all the comments and concerns are replied point by point.

Kind Regards,
Huaiwei Yang and Ye Yuan, on behalf of the co-authors.

The paper presents a Boussinesq model study of rip current variability and the evaluation of hazards induced by rip currents. The study showcases the trajectory tracking method used in an embayed beach area for swimmer escape strategies. It is an interesting study.

Because the first author was the developer of FUNWAVE-GPU, I don't have many concerns about modeling details. However, I feel it may need logical consistency across the entire article, from the introduction to the conclusions. The authors expressed the importance of a wave-resolving model for such a trajectory-tracking study due to the random and dynamic nature of rip currents. But the paper concluded that the results from the Boussinesq model are comparable to that from the wave-averaged method. If the swimmer escape strategies are the main objective of the study, using the expensive Boussinesq model seems to be an overkill. For this reason, I suggest that the authors may emphasize more about the effects of IG and VLF bands because a regular wave averaged model cannot predict IG motions without using a non-stationary wave condition. The VLF motions in the model results are interesting. It is good to check if those are the shear wave mode as said or long gravity wave oscillations. A plot of a wavenumber spectrum would be helpful.

In general, the paper was well-written and easy to follow. It should be published after addressing the issue mentioned above.

Response: Thanks for the insightful comments.
First of all, we would like to clarify that the 'wave-averaged velocity' in the manuscript (i.e., Abstract, Section 5.2) is computed by averaging phase-resolving velocities in two wave periods (24 seconds) in FUNWAVE-TVD, rather than the velocity yield by other short-wave-averaged models such as XBeach-SB (XBeach-SurfBeat). Both the wave-resolving or wave-averaged tracking in the study all retained the non-stationary IG or VLF motions, thus presenting similar trajectories of virtual swimmers. We would like to reiterate here that the wave-resolving tracking means using instantaneous, random velocities at each timestep (~0.04 s) to tracer swimmers, while wave-averaged tracking uses 24 s-averaged mean flow velocity to tracer swimmers.

Previous beach-safety studies (McCarroll et al., 2015; Castelle et al., 2016) use XBeach-SB to study rip dynamics and Lagrangian tracking of virtual swimmers. XBeach has 2 different dynamic frameworks inside, namely 'Surf Beat (SB)' and 'Non-hydrostatic (NH)'. Though XBeach-SB is a phase-averaged surfzone model, it offers an additional advantage compared to other phase-averaged models in its ability to resolve wave-group generated infragravity (IG) motions, vortical currents at VLF timescales. XBeach-SB uses the 2D wave spectra at its offshore boundary to calculate the wave group envelope, and then solves the variation of short-waves envelope (wave height) on the scale of wave groups. This variation in turn drives IG waves within the depth-integrated hydrostatic solver, approximating transient behaviors and swash dynamics in the nearshore zone. The non-hydrostatic module (XBeach-NH) extends XBeach's capability to wave-resolving modeling of non-linear waves, wave-current interaction and wave breaking in the surf zone. Both Boussinesq-type wave model FUNWAVE and XBeach-NH are phase-resolving. The fundamental difference between them is that FUNWAVE is a depth-integrated model, and relies on higher-order derivative terms to improve the frequency dispersion, while it is improved in NH models by including vertical layers.

There was a comparison between power spectra of incoming waves and resulting flow fluctuations at a given point in Figure 6b. We have also set a list of output points along the beach, whose power spectra were not shown in the manuscript. The spectra demonstrated that the wave-group-forced IG waves were persistent at all points, though their amplitudes varied from point to point; while Very low-frequency [VLF, O(10 min)] motions only existed at several points where rip flows pulsated in amplitude and directions. The absence of spectral peak of incoming waves at VLF band suggested that the VLF motions were not forced by the long-period component of gravity waves. Therefore, we concluded that the VLF motions were usually related to the formation of vortex due to local morphology. The detailed analysis of generation mechanism of VLF motions was not available in the manuscript due to lack of in-situ instrumental observations.

To avoid misunderstanding, we have made several revisions in the manuscript: (1) Abstract was shortened by removing the statement 'Virtual trajectories yielded by the wave-resolving and wave-averaged velocities are generally consistent with each other'; (2) The definitions of wave-resolving and wave-averaged tracking are explained in Section 5.2; (3) Similar statements in Conclusion were also revised.

Details:

Figure 1(f), please provide the vertical datum for 2018 and 2019 measurements. Provide an accuracy estimate for the satellite-derived bathymetric data.

Response:

(1) Two satellite images were acquired from Google Earth Historical Database on August 7, 2018 and December 26, 2019 when sea state was calm. However, the exact collecting time of the images was not clear to us. Therefore, the tidal levels when the satellite images were acquired could not be precisely determined from the nearly tidal gauge. According to the tidal records of nearly Sanya tidal gauge, Dadonghai Beach has a micro-tidal range, and tidal ranges on August 7, 2018 and December 26, 2019 were approximately 0.97 m and 1.62 m. The collecting time of the images were roughly estimated by the shadows of the tall buildings along the beach. We speculated that the picturing time on August 7, 2018 was around early morning when the projected shadows were elongated and on the west side of the building; while on December 26, 2019 it was at the mid-day. According to this information, the tidal

levels were around mid-to-high tide and mid-tide, respectively. The computation grids were constructed by combining inversion of satellite images along the beach and nautical chart within the Dadonghai Bay. The combined bathymetry were converted to the mean tidal level (MTL) based on the datum at Sanya Tidal gauge nearby.

(2) Local bathymetric patterns are critical to the modeling of nearshore circulation. However, in this study the detailed echosounder survey was not performed. Beach morphologies used in the study were inverted from true-color satellite images. The commonly-used techniques which allow indirect measurement of depth by satellite images are based on water color and wave kinematics. Colour-based methods are usually limited to non-turbid or non-breaking waters. The wave kinematics methods work well in turbid or optically deep water. A field trip of Dadonghai Beach was conducted on December 9, 2019 by SOA. During the survey, an UAV was released to observe beach morphology. As shown in Figure R1c, well-developed, periodic crescent sandbars were recorded by the UAV, whose locations coincided with those appeared in the satellite image (Figure R1b). According to photos and public surveys of swimmers and coastal patrols, water depth over the shore-connected sandbars varied approximately between 0.5－1.0 m, and 1.5－2.0 m over the rip channels. Floating separation ropes were deployed perpendicularly to the beach by coastal patrols to prevent bathers from swimming to deeper rip channels. The survey results were generally consistent with the inverted beach bathymetry. As a summary, though no precise bathymetric measurement was conducted by the authors, the beach morphological patterns could be reflected by the satellite images, and the inverted depth are adequate for modeling study.

Figure R1. Crescent sandbars recorded in the satellite (b) and UAV (c) images, respectively. The satellite image was collected on December 13, 2019 (Google Earth Historic Imagery), and the UAV image was collected during the rip-hazard field investigation at the same period on December 9, 2019 (Courtesy of National Marine Hazard Mitigation Service, China).

How does a periodic boundary condition set up in such a bay-like domain?

Response: In the study a south open boundary is placed in the grid, and there is no east-west open boundaries. Therefore, lateral periodic boundary condition is not necessary. The expression in Line 116 is revised accordingly as follows.

'The rotation is necessary for FUNWAVE to apply irregular wave maker and periodic boundary' => 'The rotation is necessary for FUNWAVE to apply internal wavemaker'.

Line 112, both ends is exposed, grammar

Response: ‘Both ends is exposed’ => ‘Both ends are exposed’.

Line 139, FUNWAVE-GPU add the reference here

Response: The reference *Yuan et al., 2020* has been added here.

Line 142, CFL, add the complete terminology

Response: ‘CFL’ is replaced with ‘Courant–Friedrichs–Lewy (CFL)’ when first appeared.

Line 144, friction coefficient, need to clarify bottom friction form, manning formula? or provide a reference

Response: A constant bottom drag coefficient of 0.0025 in the quadratic friction formula was applied. We added a reference of Zhang et al., 2022 in the manuscript.

Zhang, Y., Shi, F., Kirby, J. T., & Feng, X. (2022). Phase-resolved modeling of wave interference and its effects on nearshore circulation in a large ebb shoal-beach system. Journal of Geophysical Research: Oceans, 127, e2022JC018623. https://doi.org/10.1029/2022JC018623

Section 3.3. It’s interesting to make a definition for the hazard levels. Any reference for this definition, or just created by the authors?

Response: The rip hazard levels are created by the authors. It is preferable to quantify and visualize the rip hazard by simple and effective indexes or guidelines for operational centers or coastal patrol. Thus, we proposed an index table for rip hazard levels by combining rip strength and duration.

Line 181, arbitrary factor of 0.8. need a sensitivity test on this number

Response: We have made a sensitivity study in the arbitrary factor (0.8) in Equation 1 ($u_{\mathrm{tracking}} = 0.8u_{\mathrm{w}} + U_{\mathrm{s}}$, where u_{tracking} is Lagrangian tracking velocity, u_{w} is instantaneous wave-induced rip flow, and U_{s} is swimming velocity) defining how well a tracer (virtual swimmer) drifts with the ambient flow. In *Section ‘Discussion’* of the revised manuscript, we have included results of the sensitivity study by varying the factor from 0.4 to 1.0. An brief analysis is included here.

This arbitrary factor is defined as the floating factor varying from 0.4 to 1.0 with an interval of 0.2. As shown in Figure R2, We mainly focus on the swimmers that do not reach safety after 10-min swimming onshore (trajectories with red color). In the case that the floating factor of 0.4 is specified, almost entire swimmers can get safe by swimming onshore with an average swimming velocity of 0.2 m/s, even for virtual swimmers that are deployed in outer surf zone. However, at the opposite extreme, more than 40% of swimmers are exhausted in the rip eddy and fail to reach safe areas when the floating factor of 1.0 is set in the model.

The sensitivity study suggests that the value of floating factor is crucial to the tracking results of virtual swimmers, which in turn influences swimmer escape strategies. The factor should be calibrated in the further field studies.

Swim onshore

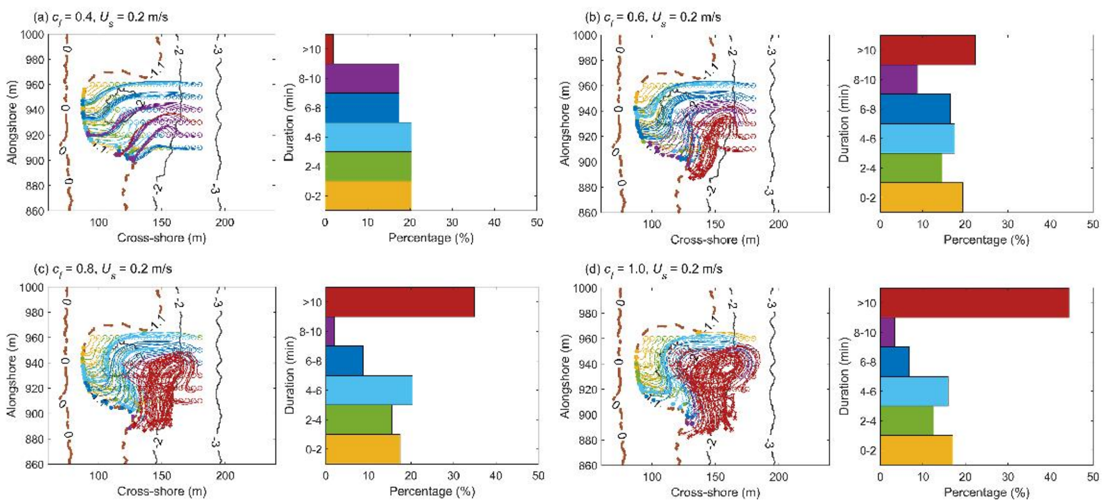

Figure R2. Sensitivity study of floating factor in Equation 1. Histograms of t_{safe} give percentages of swimmers who have reached safety at each t_{safe} range.The factor varies from 0.4 to 1.0 with an interval of 0.2 to define how well swimmers float with the ambient wave-induced flows (a-d). Assigning 0.4 means that swimmers are only slightly affected by surf-zone flows, and assigning 1.0 means that swimmers float with the ambient water perfectly. In this case, virtual swimmers have a constant onshore swimming velocity of 0.2 m/s.

Reference:

(1) Castelle, B., McCarroll, R., Brander, R., T., S., and B., D.: Modelling the alongshore variability of optimum rip current escape strategies on a multiple rip-channelled beach, Nat Hazards, 81, 663–686, https://doi.org/10.1007/s11069-015-2101-3, 2016.

(2) McCarroll, R. J., Castelle, B., Brander, R., and T., S.: Modelling rip current flow and bather escape strategies across a transverse bar and rip channel morphology, Geomorphology, 246, 502–518, https://doi.org/10.1016/j.geomorph.2015.06.041, 2015.

(3) Salatin, Reza & Chen, Qin & Bak, A. & Shi, Fengyan & Brandt, Steven. (2021). Effects of Wave Coherence on Longshore Variability of Nearshore Wave Processes. Journal of Geophysical Research: Oceans. 126. 10.1029/2021JC017641.

(4) Zhang, yu & Shi, Fengyan & Kirby, James & Feng, Xi. (2022). Phase-Resolved Modeling of Wave Interference and Its Effects on Nearshore Circulation in a Large Ebb Shoal-Beach System. Journal of Geophysical Research: Oceans. 127. 10.1029/2022JC018623.