Dear editor and reviewers,

We thank the reviewers for taking the time to review our manuscript and providing constructive comments. We apologize for the delay in submitting our responses to the comments.

Below, we address the reviewers' comments point by point. In the response, black- and blue-colored characters denote reviewers' comments and our responses, respectively.

Response to Reviewer #1

Reviewer [1.1]:

Yoshikai et al present a novel implementation of a mangrove root model in the ROMS data package that has the potential to be very useful for the wider scientific community. They show that the model predicts flow velocities and turbulent kinetic energy in a more refined way in the vertical and that this matches qualitatively better with the presented data from a flume experiment and the field. Although I think that the model is very useful and can advance the scientific field, I have major concerns with the application of the model to the sediment transport predictions that links directly to large parts of the discussion. In addition, I missed more detail on the data that has been used. Finally, to help lift this contribution from a presentation of the model, I suggest to apply the model to a case study with available sediment transport rates and potentially morphodynamic change to show that those predictions are improved using the presented model. I outline my concerns below:

Response [1.1]:

We thank the reviewer for the thorough assessment and constructive comments on our manuscript.

Regarding the reviewer's concern about the model application to sediment transport, we admit that the model efficacy on sediment transport is not well demonstrated in this study compared to the flow structures in the mangrove forests. While the reviewer's suggestion is interesting and an important topic to address, we would like to note that model application to sediment transport in mangrove forests and its evaluation is currently constrained by data availability. Even for the prediction of flows, comprehensive data sets such as hydrodynamics (e.g., water depth and flow velocity), vegetation parameters (both stems and roots), as well as boundary conditions of the flow (e.g., water level gradient) are required to drive and evaluate the developed model but are rarely available especially in the field. The application and evaluation for the sediment transport require additional data such as sediment properties (e.g., grain size), suspended sediment concentration, sedimentation rate, and morphodynamics. To our knowledge, the data set that satisfies such requirement is currently unavailable from both flume- and field-based studies. Hence, at this moment, we are not able to address the reviewer's suggestion regarding the application of the model to a case study with available sediment transport rates and morphodynamic change to demonstrate the efficacy of the presented model.

Our intention of the sediment transport simulation performed in this study was to demonstrate how the flow field created by the *Rhizophora* mangroves may change the sedimentation rates using the new model. However, given the current limitation to show the model's efficacy on sediment transport and that the main contribution of the study is the realization of the realistic flow simulation in *Rhizophora* mangrove forests, we would like to remove the results and discussion on the sediment transport simulation in the revised manuscript, as suggested in the comment [1.5]. This is also suggested by Reviewer #2 (please see the comment [2.7]).

We have provided our responses to the individual comments below.

Reviewer [1.2]:
1) To understand where the data comes from I suggest to add maps of both the study area and the model grid with flow velocities as well as the set-up of the flume experiments/model iof the flume experiments. It is unclear where the measurements have been taken (unvegetated vs. within the root system, close to tidal channels etc) and how exactly the model looks to allow to understand the results and to reproduce the study. In addition the data used for validation should be presented in the supplementary.

Response [1.2]:
We have provided in Fig. R1 of this document the maps of the field measurement of Yoshikai et al. (2022) used for the model application in this study, and in Fig. R2 the schematic of the model grid used for model testing against the flume experiment and field measurement. The set-up of the flume experiment has been described in detail in Maza et al. (2017). Because the reuse of the figures in Maza et al. (2017) in this manuscript would cost us a substantial amount of payment to the publisher of the original article, we would like to refer the reviewers and readers to their original article. We have also provided in Tables R1–3 below the data used for model validation. Furthermore, for a better grasp of the measurements of Maza et al. (2017) and Yoshikai et al. (2022) and the model setting, we have provided Table R4 summarizing the measured flow variables, the setting of model forcing, and the target variables to reproduce for each application.

To avoid any confusion regarding the model setting, we would like to note that the model was tested with the model grid assuming a schematized mangrove forest (Fig. R2) as described in L216–225, not with a grid representing the actual geometric/topographic conditions of the flume/field. Also, bed elevation and vegetation parameters in the grid were set uniformly over the model domain as described in L217–218. This simplification of the model setting is deemed reasonable given the (approximately, in the case of the field mangrove forest) spatially uniform vegetation distribution and the well-developed flow conditions at the flow measurement location in both Maza et al. (2017) and Yoshikai et al.

(2022) where the dependence of flow structures on the proximity to the forest leading edge is diminished. The flow in the model was driven by a water level gradient imposed between the open boundaries (Fig. R2; L218–220). We then created a steady state of flow in the model and compared the simulated flow at the monitoring point in the model domain (Fig. R2) with the data (L222–223). This means that for the model application to the field mangrove forest, the actual time-series of the flow has not been reproduced; rather, steady states of flow were created for each flow measurement.

As an action for manuscript revision, we will include Figs. R1–2 and Tables R1–4 in the Supporting Information and include any missing descriptions on the model settings in the main text.

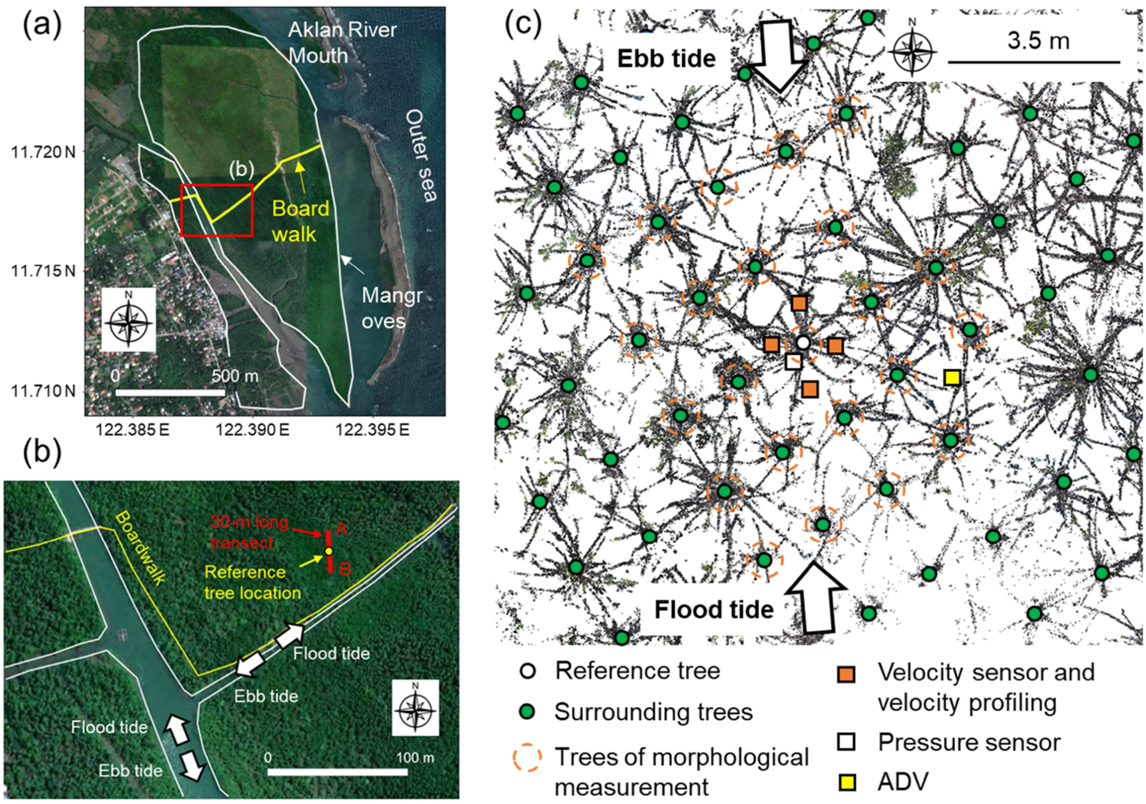

Figure R1. (a) Satellite image (Google Earth) of the study site of Yoshikai et al. (2022) – Bakhawan Ecopark (red box indicates the area of panel "b"), (b) locations of transect A–B across which the water level gradient was measured together with the hydrodynamic parameters around the reference tree, (c) top view of LiDAR point clouds around the reference tree with information on the locations of trees whose morphological structures were measured, velocity profiling, and deployed sensors (velocity sensor: electromagnetic velocity meter deployed near the bottom; ADV: Acoustic Doppler Velocimeter deployed to estimate the bed shear stress). It has been shown in Yoshikai et al. (2022) that the average of the velocity measured at the four locations well represents the spatially-averaged values. The point clouds shown were cropped at heights between 0.1–1.7 m for better visualization of the root systems. Figures are modified from Yoshikai et al. (2022).

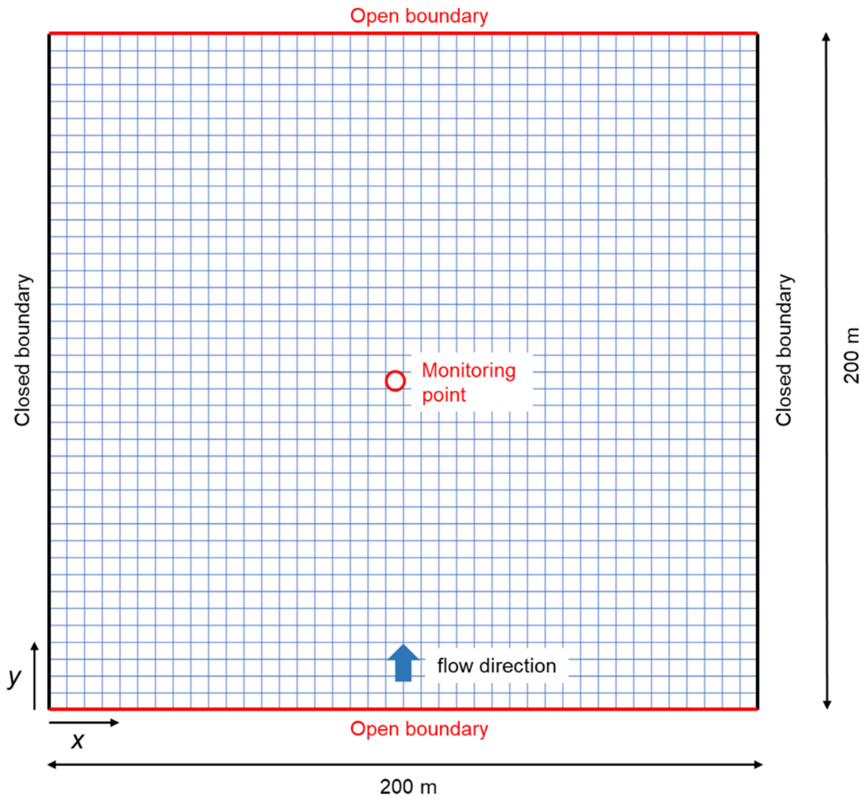

Figure R2. Model grid (40 × 40 with 5 m horizontal resolution) used for testing the model against laboratory-based and field-based studies. The red circle indicates the location of the monitoring point at which the simulated flow variables were compared with the measured data. Bed elevation and vegetation parameters were set uniformly over the model domain.

Table R1. Data from the flume experiments of Maza et al. (2017) that were used for the model validation in Figure 4. The values of geometric and flow parameters were converted from the scale in the flume to the real scale. The velocity (u) and turbulent kinetic energy (k) were taken by averaging the measurements at five lateral positions (ADV3p1–p5; see Fig. 5 of Maza et al., 2017) in the model mangrove forest where the flows were fully developed, which were taken as spatially-averaged values in the mangrove forest. HR_{max}: maximum root height, h: water depth, U: cross-sectional mean velocity, z: height above the bed.

Experiment #	HR_{max} (m)	h (m)	U (m s^{-1})	z (m)	u/U	k/U^2
Exp 1	2.016	3.0	0.31	0.08	0.54	0.012
				0.32	0.62	0.013
				0.56	0.66	0.015
				0.80	0.64	0.032
				1.04	0.69	0.026
				1.28	0.75	0.024
				1.52	0.84	0.053
				1.76	0.97	0.035
				2.00	1.05	0.033
				2.24	1.10	0.043
Exp 2	2.016	1.79	0.58	0.08	0.75	0.018

				0.20	0.77	0.021
				0.32	0.80	0.017
				0.44	0.84	0.016
				0.56	0.83	0.021
				0.68	0.83	0.026
				0.80	0.86	0.023
				0.92	0.85	0.023

Table S2. Data from field measurements of Yoshikai et al. (2022) that were used for the model validation in Figure 5. The velocity (u) was obtained by averaging the measurements at four locations around the reference tree shown in Fig. R1c which was taken as spatially-averaged values in the mangrove forest.

Local time	h (m)	z (m)	u (m s^{-1})
2018/9/10 12:50	0.45	0.35	0.060
		0.30	0.064
		0.25	0.060
		0.20	0.057
		0.15	0.055
		0.10	0.044
		0.05	0.036
2018/9/10 13:40	0.21	0.18	0.096
		0.11	0.082
		0.04	0.059
2018/9/11 13:00	0.53	0.45	0.046
		0.40	0.039
		0.35	0.045
		0.30	0.044
		0.25	0.044
		0.20	0.041
		0.15	0.034
		0.10	0.028
		0.05	0.022
2018/9/11 14:00	0.28	0.23	0.085
		0.14	0.072
		0.05	0.052

Table R3. Data from field measurements of Yoshikai et al. (2022) that were used for the model validation in Figures 6 and 7. The $\Delta\eta$ is the water level difference imposed across the open boundaries in the model (see Fig. R2), h is the water depth, U is the cross-sectional mean flow velocity, u_{bottom} is the spatially-averaged velocity at z = 0.05 m, and τ_{bed} is the bed shear stress.

Local time	$\Delta\eta$ (m)	h (m)	U (m s^{-1})	u_{bottom} (m s^{-1})	τ_{bed} (N m^{-2})
2018/09/10 12:50	0.0143	0.45	0.050	0.036	0.023
2018/09/10 13:10	0.0189	0.36	0.063	0.036	0.039
2018/09/10 13:20	0.0273	0.32	0.064	0.041	0.032

2018/09/10 13:40	0.0462	0.21	0.079	0.064	0.023
2018/09/10 13:50	0.0572	0.16	0.074	0.066	-
2018/09/11 13:00	0.0065	0.53	0.038	0.022	0.008
2018/09/11 13:10	0.0078	0.50	0.038	0.023	0.004
2018/09/11 13:20	0.0124	0.46	0.047	0.027	0.008
2018/09/11 13:40	0.0163	0.37	0.051	0.034	0.014
2018/09/11 13:50	0.0228	0.33	0.054	0.036	0.010
2018/09/11 14:00	0.0260	0.28	0.070	0.053	0.012
2018/09/11 14:10	0.0345	0.23	0.071	0.053	0.031
2018/09/11 14:20	0.0449	0.18	0.070	0.060	0.037
2018/09/11 14:30	0.0585	0.14	0.078	0.077	-

Table R4. Measured flow variables in the model and field mangrove forest by Maza et al. (2017) and Yoshikai et al. (2022), respectively, and the settings of model forcing and target variables to reproduce in the application to the respective mangrove forest.

	Model mangrove forest in Maza et al. (2017)	Field mangrove forest in Yoshikai et al. (2022)
Measured flow variables	h, U, $u(z)$, $k(z)$	h, $\Delta\eta$, $u(z)$, U, τ_{bed}
Controlled variables in the model	h, U	h, $\Delta\eta$
Target variables to reproduce	$u(z)$, $k(z)$	$u(z)$, U, τ_{bed}

Reviewer [1.3]:

2) The sediment transport computations seem arbitrary from the choice of parameters. Although it is interesting to compare sedimentation rates for the different model parameterizations, the rates need to be validated by data to be able to say that they are realistic. Especially the choice of just one setting seems very limited, depending on the types of grain sizes and parameterization the rates can be very different and there is now no indication that the model can predict realistic rates or that the new model predicts these rates "better". I suggest to add a validation here and test a wide range of sediment parameters to be able to identify trends.

Response [1.3]:

As described in Response [1.1], currently the data set that can be used for model validation on sediment transport in mangrove forests is unavailable from both flume- and field-based studies. Thus, we are not able to address the reviewer's suggestion on the model validation of sediment transport in this study. Furthermore, the suggested additional analyses on the wide range of sediment parameters would take the study beyond its original scope, that is, a realization of the realistic flow simulation in *Rhizophora* mangrove forests. Therefore, as suggested in the comment [1.5], we would like to remove the sections on sediment transport simulation in the revised manuscript to underscore our contribution in this study.

Reviewer [1.4]:

3) Based on the analyses presented, some parts of the discussion overstate the outcome of the study, for example :

line 434: "The good performance of the model in both the model- and real-Rhizophora mangrove forests having a range of vegetation complexity (Fig. 3) suggests the model's general applicability to Rhizophora mangrove forests worldwide. "- I don't think you can state that the model improves predictions for any other systems than the one studied here. To be able to upscale to other systems, more analyses are needed.

line 458: "For the practical use of the model, we proposed a model framework (Fig. 1) leveraging an empirical model for the Rhizophora root system (Rhroot model) with parameterization of subgrid-scale tree variations (Fig. 2), which we implemented in COAWST."- as far as I understand you implemented the already existing theoretical model of root area, so more careful phrasing here since the novel part here is the implementation.

line 472: "This study thus offers the first framework of numerical modeling which can be readily applied to Rhizophora mangrove forests in the field." - again, I think you with this work you provide a good implementation of the model

Response [1.4]:

Regarding L434, we agree with the reviewer's point. Especially, model application to natural mangrove forests that may have heterogeneous tree sizes and distribution is currently lacking, which would require further studies to confirm the model's general applicability. The model applicability to denser mangrove forests (e.g., forests having a > 0.9 m^{-1}) may also need confirmation in future studies. Therefore, we would like to revise the sentence as follows:

> "The good performance of the model in both the model- and real-*Rhizophora* mangrove forests suggests the model's applicability to forests having the vegetation density a in the range 0.09–0.9 m^{-1} near the bottom (Fig. 3) and an in-line tree distribution like planted forests. However, the applicability to forests having a > 0.9 m^{-1} and/or heterogeneous tree sizes and distribution, a condition often observed in natural mangrove forests, needs further investigation in future studies."

Regarding L458, we would like to revise the sentence as follows:

> "For the practical use of the model, we implemented in COAWST an empirical model for the *Rhizophora* root system (*Rh*-root model; Fig. 1) with parameterization of subgrid-scale tree variations (Fig. 2) that enables the model application without rigorous measurements of root structures."

Regarding L472, we would like to revise the sentence as follows:

> "Therefore, the model presented in this study may realize a realistic forest-scale numerical modeling of flows in *Rhizophora* mangrove forests in the field."

Reviewer [1.5]:

4) The discussion on the sediment transport would need to be removed or revised in case new analyses are added

Response [1.5]:

We would like to remove the results and discussions on the sediment transport simulation in the revised manuscript as suggested. Please also see our responses [1.1] and [1.3].

Reviewer [1.6]:

Minor comments:

1) the paragraph on carbon in the introduction seems a bit far from what is presented in the study

Response [1.6]:

We agree with the reviewer. We will remove the said paragraph in the revised manuscript.

Reviewer [1.7]:

2) I am not sure you need the reference runs in your graphs since you are comparing the new root structures with static vegetation. Why not add the model in Xie et al (2020) to compare with another "more realistic" representation of roots?

Response [1.7]:

We assume that the reviewer is referring to the reference runs to the simulations using the cylinder model shown in Figs. 5 and 7.

We consider that the inclusion of the cylinder model runs is important to show how much the new model could improve the accuracy of flow predictions for *Rhizophora* mangrove forests compared to the conventional drag parameterization using the array of cylinders. Thus, we would like to keep the results and discussions on the cylinder drag model in the manuscript.

As suggested by the reviewer, we have added a simulation case using the model of root system structures used in Xie et al. (2020) in our analysis (denoted as Xie root model hereafter). Below, we describe the Xie root model, its implementation to the COAWST, and some results and discussions. Please note that we have added another simulation case using an increased bed roughness based on the suggestion by Reviewer #2; Please also see Response [2.2].

We examined the use of the root model used in Xie et al. (2020) as a predictor of a_{root} in Eq. (1). In Xie et al. (2020), the shape of roots was simplified to cylindrical objects with a fixed diameter and height, hence to the array of vertical cylinders. The number of roots of a tree is given by a function of stem diameter as:

$$n_{root,ind} = n_{root,max} \frac{1}{1+exp\left[f_{root}\left(\frac{D_{stem,max}}{2} - D_{stem}\right) \times 0.01\right]} \quad \text{(R1)}$$

where $n_{root,ind}$ is the number of roots of a tree having a stem diameter of D_{stem} (m), $n_{root,max}$ is the maximum number of roots of a tree, f_{root} = 0.1 is a constant describing the rate of increase, $D_{stem,max}$ is the maximum stem diameter (m), and the factor 0.01 is for the unit conversion of stem diameter from meter to centimeter. In Xie et al. (2020), the parameters are set as $n_{root,max}$ = 5000, $D_{stem,max}$ = 1.0 (m) for *Rhizophora* trees. In addition, Xie et al. (2020) gave the root diameter (D_{root}) and height (H_{root}) as D_{root} = 0.01 m and H_{root} = 0.15 m, respectively.

We applied the Xie root model to the field mangrove setting of Bakhawan Ecopark. We used the measured mean stem diameter $D_{stem,ave}$ = 0.066 m (Table 2) for D_{stem} in Eq. (R1), then calculated the $n_{root,ind}$ with the same parameter setting as Xie et al. (2020). The a_{root}, which is used for calculating the drag by the roots in Eq. (1), is then given as

$$a_{root} = n_{tree} n_{root,ind} D_{root} \quad \text{for } z \leq H_{root} \qquad \text{(R2a)}$$

$$a_{root} = 0 \quad \text{for } z > H_{root} \qquad \text{(R2b)}$$

Furthermore, in the turbulence dissipation terms of Eq. (6a–b), $D_{stem,ave}$ = 0.066 m and D_{root} = 0.01 m were applied for L_{stem} and L_{root}, respectively.

Figure R3, which is a revision of Fig. 3, shows the vegetation projected area density predicted using the Xie root model applied to the field mangrove forest. The Xie root model predicted the vegetation projected area density near the bed as 0.3 m^{-1}, which is significantly lower than the measured value. In addition, due to the limited root height (H_{root} = 0.15 m), it resulted in the significantly underestimated vegetation projected area density (a) throughout the depths.

A comparison of the modeled velocity profiles with measurements is provided in Fig. R4d, which is a revision of Fig. 5. As expected, the use of Xie root model lead significant overestimation of velocities. Although the shape of a predicted by Xie root model resembles those of submerged vegetations, the predicted velocity profiles did not show a prominent velocity inflection between within and above the canopy layer (root zone in this case), a profile typically observed in the flows in a region with submerged vegetations (e.g., King et al., 2012; Nepf, 2012). This may be due to the low vegetation area density predicted by the Xie root model that was not dense enough to generate the velocity inflection. Nepf (2012) suggested that the velocity profile in a region with submerged vegetations exhibits a boundary-layer form with no inflection point if $C_D a h_v$ < 0.04 (where h_v is the height of vegetation). Considering the similar factor for the root zone ($C_D a H_{root}$) in our analysis and assuming that C_D = 1.0, it is estimated as 0.045, which is very close to the limit generating the boundary layer profile suggested by Nepf (2012).

A comparison with the time-series data is provided in Fig. R5. Similar to the trend seen in Fig. 4d, the use of Xie root model resulted in consistently higher cross-sectional and near-bottom velocities compared to the measured values. Consequently, the bed shear stress was significantly overestimated.

As an action for manuscript revision, we will add the condensed version of the above descriptions on model testing using the Xie root model and its results and discussions in the revised manuscript. We will also replace Fig. 3 with Fig. R3, Fig. 5 with Fig R4, and include Fig. R5 as Fig. 8 in the revised manuscript.

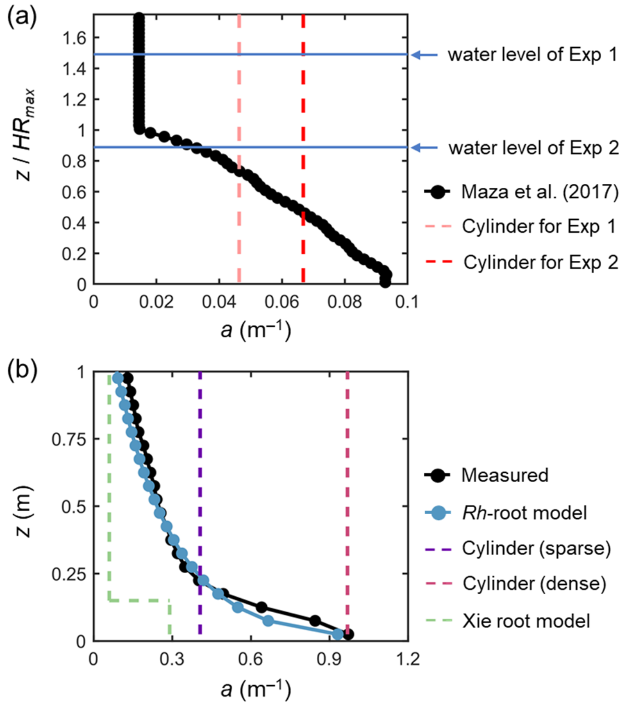

Figure R3. Vertical profiles of vegetation projected area density, *a*, in (a) a model *Rhizophora* mangrove forest examined by Maza et al. (2017) and (b) a real *Rhizophora* mangrove forest examined by Yoshikai et al. (2022), where the values were calculated with *dz* = 0.05 m vertical interval (markers). HR_{max} is the maximum root height (2.01 m in Maza et al. (2017); Table 1). The modeled *a* in panel "b" is given by the *Rhizophora* root module using the parameters shown in Tables 2 and S1 (for Bak2). The projected area density of cylinder arrays (in panels "a" and "b") as well as the *a* predicted using the root model of Xie et al. (2020) (in panel "b"), which were used for comparison with the new model to represent the impacts of *Rhizophora* mangroves, is also shown (dashed lines).

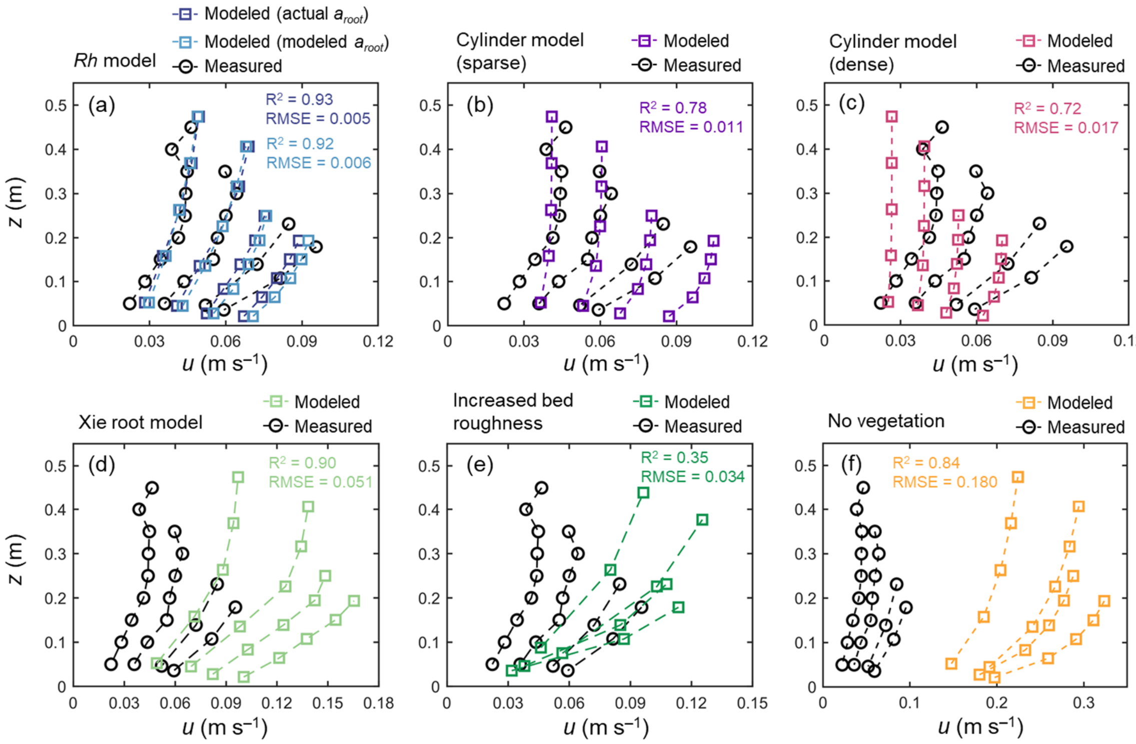

Figure R4. Comparison of the vertical profiles of velocity (u) predicted by the COAWST employing (a) *Rh* model using actual and modeled root projected area density profile (a_{root}), (b) cylinder model with sparse and (c) dense array, (d) Xie root model, (e) increased bed roughness as an approximation of vegetation drag, and (d) without imposing vegetation drag (no vegetation), and measurement by Yoshikai et al. (2022) for some selected tidal phases during the measurement period. Root mean square error (RMSE) and R^2 values of the modeled u against the measured data are also shown, for which computation of the predicted value at the height of the measurement point was obtained by the interpolation of u computed at adjacent vertical layers.

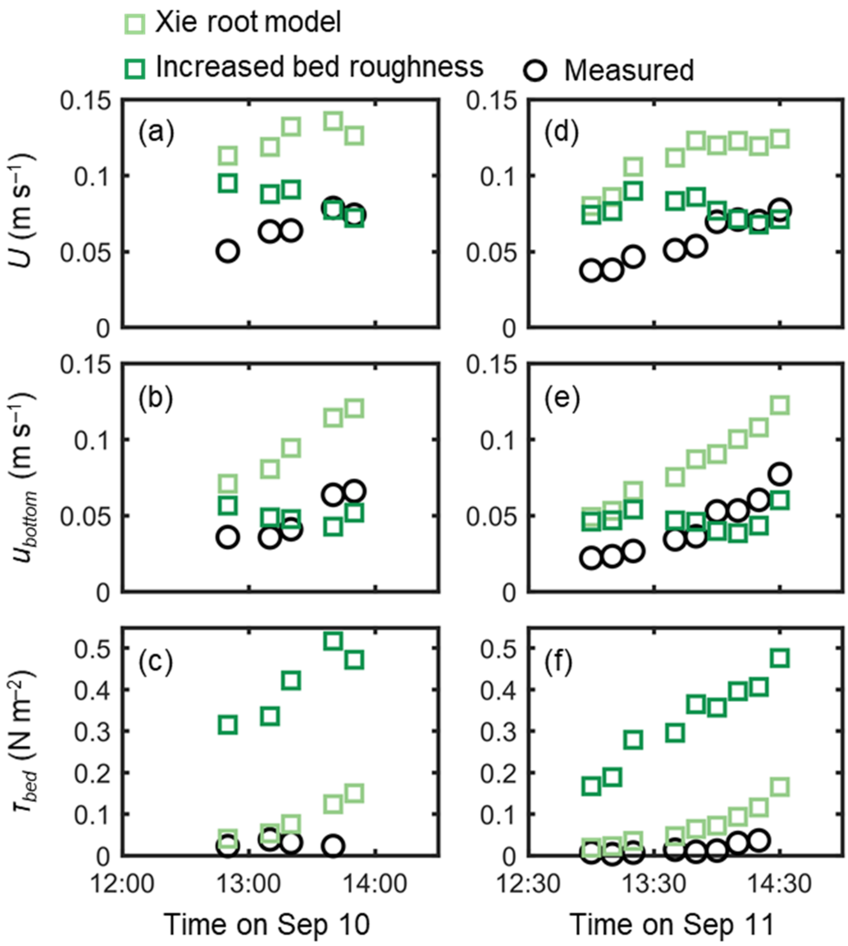

Figure R5. Time-series of measured and predicted (a, d) cross-sectional mean velocity (U), (b, e) (spatially averaged) velocity at z = 0.05 m, and (c, f) bed shear stress (τ_{bed}) during the two-days measurement in Bakhawan Ecopark. The measured values are from Yoshikai et al. (2022) and the predicted values are obtained through the COAWST employing the Xie root model and the increased bed roughness as an approximation of drag by mangroves, respectively.

Reviewer [1.8]:

line 91: the reference seems to be the data of the paper. I would like to know what is different between the implemented model and the model you are referring to here

Response [1.8]:

The reference here (Yoshikai et al., 2021) is the paper presenting an empirical model for the *Rhizophora* root system structures (referred to as *Rh*-root model in this manuscript), which we implemented in the COAWST in this study. Therefore, the model we are referring to here is the same as the one implemented in the COAWST.

Reviewer [1.9]:

line 181: are you defining tree sizes as a distribution?

Response [1.9]:

We did not impose spatial variations in tree sizes in the model testing performed in this study, as described in L217. However, the model presented in this study has the capability of accounting for the spatially variable tree parameters (by defining variable stem diameter and tree density in each grid) which may be needed in a large-scale, such as a forest-scale, flow simulations in a mangrove forest as discussed in L463–474.

Reviewer [1.10]:

table 2: please make more clear that these are the measurements by linking them to the map

Response [1.10]:

We will add a sentence in the caption of Table 2 referring to Fig. R1c for where the hydrodynamic and vegetation parameters came from. We will also indicate in the table which parameters were measured in the previous studies and which ones were calibrated or assumed in the model.

Reviewer [1.11]:

line 259: please present the sensitivity runs in the supplementary

Response [1.11]:

We provided the results of sensitivity runs of varying γ in the prediction of the vertical profile of turbulent kinetic energy in Fig. S6. We will include the figure in the Supporting Information in the revised manuscript as suggested.

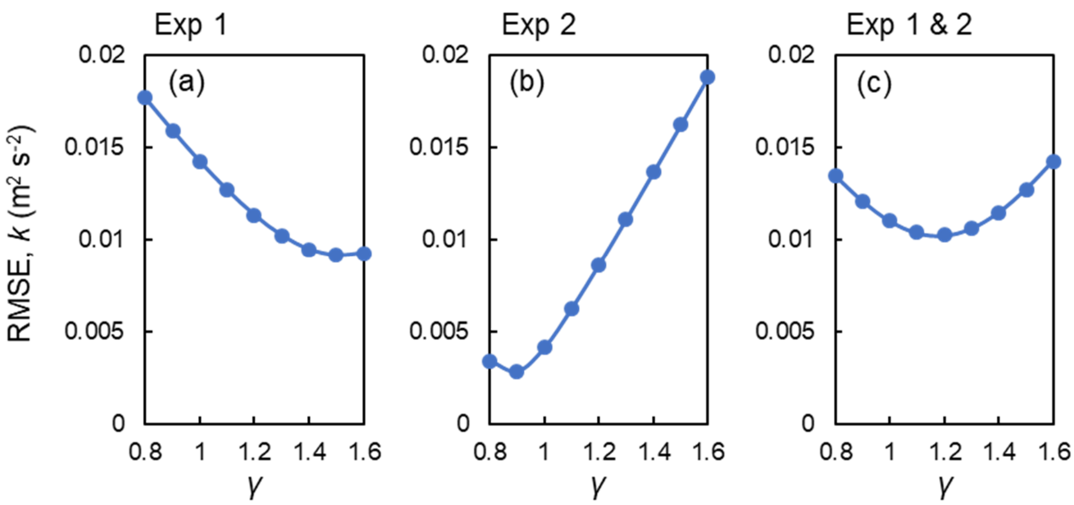

Figure R6. Root mean square error (RMSE) of modeled turbulent kinetic energy (k) against the measured data in (a) Exp 1, (b) Exp2, and (c) both Exp 1 and 2, by varying the value of scale coefficient (γ), for which the computation of the predicted value at the height of the measurement point was obtained by the interpolation of k computed at adjacent vertical layers.

Reviewer [1.12]:
fig 4: maybe remind the reader in the caption what is HRmax

Response [1.12]:
We will add a sentence in the caption of Fig. 4 explaining that HR_{max} stands for the maximum root height.

Reviewer [1.13]:
Fig 5: what absolute water levels and time-steps throughout the tidal cycle are presented here? I am not sure what the difference is between actual and modeled aroot. Is one the data and one the predictions of the implemented model? Add R^2 values to quantify the error

Response [1.13]:
We have provided the information on water levels in Table S2 in the analysis shown in Fig. 5. The model was run with a time-step of 2 seconds. However, please note that although the model was compared with the time-series data of the tidal cycle, we have created a steady state of flow in the model for the comparison with each measured data as described in L222–223 and Response [1.2].

It is correct that the *Rh* model with actual a_{root} used the measured data of a_{root} while the *Rh* model with modeled a_{root} used the predicted a_{root} of the implemented *Rh*-root model, as described in L283–284. We have made this point clearer in Table R5; please see Response [2.5] below.

Finally, we have added R^2 and RMSE values in the figure. Please see Fig. R4 shown above.

Reviewer [1.14]:
I hope that the authors can extent their analyses and revise the manuscript as I believe this will be a very useful contribution.

Response [1.14]:
We thank the reviewer again for the constructive comments. We believe that our proposed revision would improve the manuscript substantially.

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Nepf, H. M. (2012). Flow and transport in regions with aquatic vegetation. Annual review of fluid mechanics, 44, 123–142. https://doi.org/10.1146/annurev-fluid-120710-101048.

Xie, D., Schwarz, C., Brückner, M. Z., Kleinhans, M. G., Urrego, D. H., Zhou, Z., & Van Maanen, B. (2020). Mangrove diversity loss under sea-level rise triggered by bio-morphodynamic feedbacks and anthropogenic pressures. Environmental Research Letters, 15(11), 114033. https://doi.org/10.1088/1748-9326/abc122.

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Response to Reviewer #2

Reviewer [2.1]:
General Comments

This manuscript presents a new approach to modeling the flow of water within Rhizophora mangroves. The key improvements to the COAWST vegetation package are: (1) allowing the vertical varying projected area density (frontal area per unit plan area), (2) using the root and stem length-scales in the turbulence dissipation terms, (3) implementing the Rhizophora module which can calculate projected area density from easily obtainable field measurements. These improvements allow the field to move beyond the conventional cylinder assumption, and are generally applicable to all hydrodynamically rough environments which aren't well described by cylinders.

I liked the approach and theme of this paper, and think with some revisions it would be a nice contribution. I also really appreciated the detail of the supplemental information.

Response [2.1]:
We thank the reviewer for the thorough assessment and constructive comments on our manuscript. Please see our responses to the comments below.

Reviewer [2.2]:
Specific Comments

1. The no vegetation case shown in Fig. 5 and Fig S1.
    1. While including this test case in the manuscript is interesting to see how the hydrodynamics are changed if the mangroves were removed from the ecosystem, it seems to change direction from the rest of the paper. I believe the message of this paper is comparing how this new approach of accounting for the roughness of mangroves is different from past approaches (cylinder arrays or enhanced z0 values). I think that if the z0 value for the no-vegetation case is increased, maybe similarly to the Zhang 2012 mentioned on line 65, this would fit with the theme of figures 5 and 6 which contrast the new approach to past approaches.

Response [2.2]:
We thank the reviewer for the suggestion. Because we think that the results of the no vegetation case shown in Fig. 5 and Fig. S1 are important for demonstrating how much the drag by mangrove forests could be significant in affecting the flows in mangrove forests, hence strengthening the importance of proper parameterization of the impacts of mangroves, we would like to keep them in the manuscript.

We agree with the reviewer that a case with increased bed roughness (z_0 value) would fit the theme of the paper and add some insights into the effects of different drag parameterization.

Below, we describe how the bed shear stress is computed in the COAWST, and how the model is tested using the increased z_0 value as an approximation of mangrove drag.

In the COAWST, bed shear stress is computed based on quadratic law using the velocities at the bottom computational cell as (Warner et al., 2008):

$$\tau_{bed} = \rho_w C_{bed} u^2 \tag{R3}$$

where τ_{bed} is the bed shear stress (N m^{-2}), ρ_w is the water density (kg m^{-3}), C_{bed} is the bed drag coefficient, and u is the flow velocity (m s^{-1}) computed at the bottom cell. It assumes that the flow in the bottom boundary layer has the classic vertical logarithmic profile as:

$$|u| = \frac{u_*}{\kappa} \ln\left(\frac{z_{bottom}}{z_0}\right) \tag{R4}$$

where u_* is the friction velocity, $\sqrt{\tau_{bed}}$, $\kappa = 0.41$ is the von Kármán constant, z_{bottom} is the mid-elevation point of the bottom cell above the bed (m), and z_0 is the bed roughness length (m). From Eqs. (R3)–(R4), the relationship of C_{bed} and z_0 is:

$$C_{bed} = \kappa^2 \left[\ln\left(\frac{z_{bottom}}{z_0}\right)\right]^{-2} \tag{R5}$$

The value of z_0 or C_{bed} can be related to the Manning's coefficient ($n_{manning}$) as follows considering turbulent open channel flow. In an open channel flow with depth-averaged velocity U_{mean}, water depth h, and bed slope S_0, the U_{mean} can be described using the Manning's coefficient as

$$U_{mean} = \frac{1}{n_{manning}} h^{2/3} {S_0}^{1/2} \tag{R6}$$

Assuming the steady flow where the momentum balance can be reduced to an equilibrium between the bed shear stress τ_{bed} and the gravitational (or pressure) forces driving the flow, the bed shear stress can be expressed as (Crompton et al., 2020):

$$\tau_{bed} = \rho_w g h S_0 \tag{R7}$$

where g is the gravitational acceleration (m s^{-2}). From Eq. (R6)–(R7) and assuming that the depth-averaged form of Eq. (R3), $\tau_{bed} = \rho_w C_{bed,mean} {U_{mean}}^2$, is valid, the Manning's coefficient can be expressed as:

$$n_{manning} = h^{1/6} \sqrt{\frac{C_{bed,mean}}{g}} \tag{R8}$$

where $C_{bed,mean}$ is the bed drag coefficient which is used for computing τ_{bed} using the U_{mean}. Also, by relating the depth-averaged form of Eq. (R5), $C_{bed,mean}$ can be expressed using z_0 as (Lenz et al., 2017):

$$C_{bed,mean} = \kappa^2 \left[\ln\left(\frac{h}{z_0}\right)\right]^{-2} \tag{R9}$$

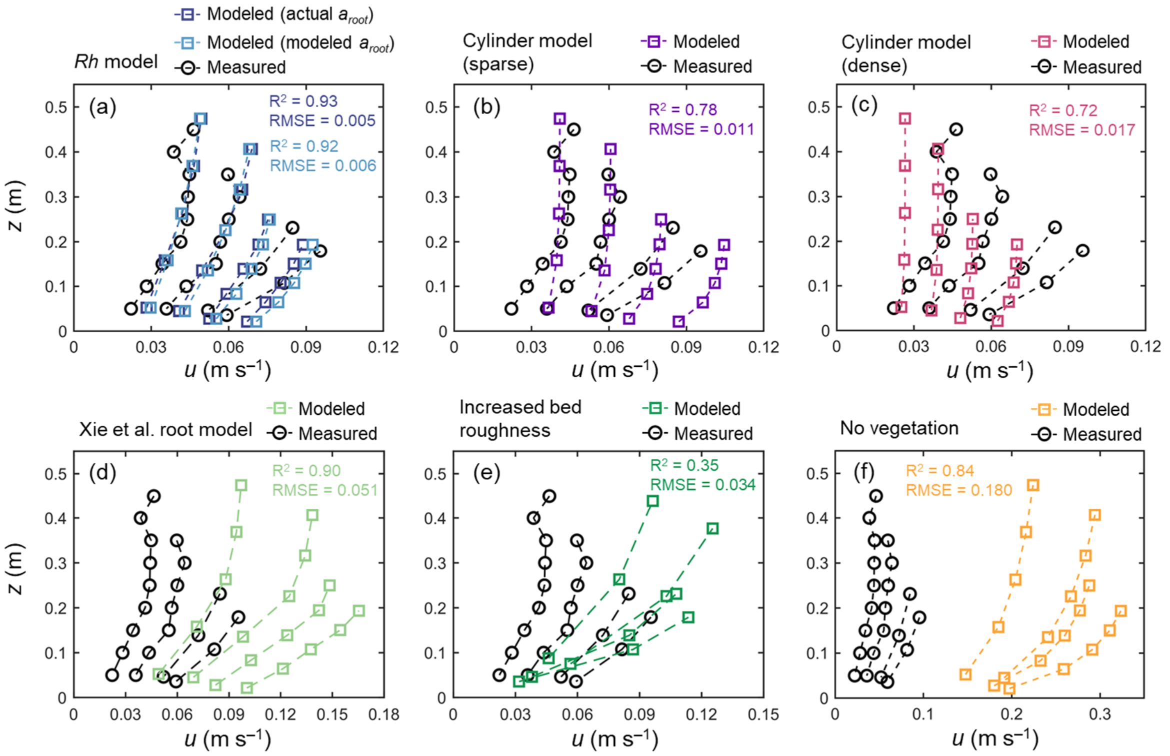
Considering the Manning's coefficient of 0.14, which is a value typically used for approximating the drag by mangroves (e.g., Zhang et al., 2012), and a water depth of 0.5 m, based on Eqs. (R8)–(R9), the equivalent bed roughness z_0 to that is 0.22 m.

As suggested by the reviewer, we performed an additional model analysis using an increased z_0 value as an approximation of mangrove drag. However, the application of Eqs. (R3)–(R5) needs a condition $z_0 < z_{bottom}$, which limits the applicable z_0 value depending on the water depth or thickness of the bottom cell. In order to increase the applicable z_0 value in our analysis, where the lowest water depth examined was around 0.15 m (Fig. 6; Table R3), we reduced the number of vertical layers from 5 to 3, which increased the minimum z_{bottom} up to 0.025 m. We then conducted the analysis using z_0 = 0.02 m as a case of increased z_0; however, this value is considered lower compared to the typical Manning's coefficient value of 0.14 (of which the equivalent value is z_0 = 0.22 m under the water depth 0.5 m)

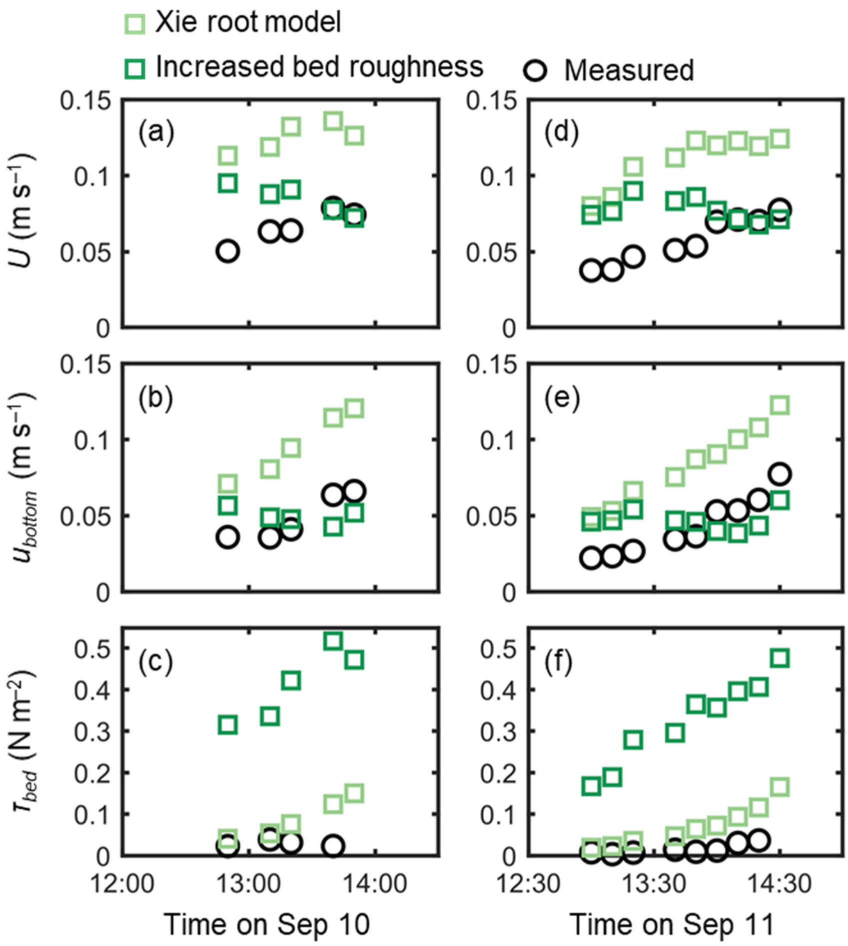
Results of the model analysis with the increased z_0 are provided in Figs. R4e and R5, which can be seen below. The model predicted the significant attenuation of flow velocity from the surface to the bottom due to the large bottom friction produced by the increased z_0, which did not well represent the actual conditions of the velocity profile in the *Rhizophora* mangrove forest (Fig. R4e).

Comparison with the time-series data showed contrasting results with the one using the Xie root model (please see Response [1.7] for the descriptions of the case using Xie root model). Although both cases showed a large overestimation of flow velocity when the water depth is relatively high (e.g., $h > 0.3$ m), the case using the increased z_0 approached the measured data with decreasing water depth while the case using the Xie root model consistently overestimated the velocity throughout the measurement period (Fig. R5a–e). This different trend is due to the different drag parameterization with the bed roughness or objects within the water column. Specifically, the decrease in the total projected area of submerged objects exerting drag with a decrease in water depth cannot be accounted for by the mangrove drag approximation with the bed drag. As a consequence, the bed drag became significant in decelerating the flow velocity when the water depth is low ($h < 0.3$ m) compared to the case using the Xie root model, as seen in the equivalent cross-sectional mean velocity (U) to the measured values (Fig. R5a, d). Because bed drag is the main force to counteract the imposed pressure gradient in the increased z_0 case, the bed drag showed the overestimation as expected (Fig. R5c, f). This will lead to large overestimation of sediment erosion, suggesting that increased bed roughness does not work well for simulating the sediment transport in mangrove forests.

As an action for manuscript revision, we will add descriptions on the model testing using the increased bed roughness in the Supporting Information and the condensed version of the above descriptions on the results and discussions in the revised manuscript. We will also replace Fig. 5 with Fig R4, and include Fig. R5 as Fig. 8 in the revised manuscript.



Copy of Figure R4 shown above in Response [1.7]: Comparison of the vertical profiles of velocity (*u*) predicted by the COAWST employing (a) *Rh* model using actual and modeled root projected area density profile (a_{root}), (b) cylinder model with sparse and (c) dense array, (d) Xie root model, (e) increased bed roughness as an approximation of vegetation drag, and (d) without imposing vegetation drag (no vegetation), and measurement by Yoshikai et al. (2022) for some selected tidal phases during the measurement period. Root mean square error (RMSE) and R^2 values of the modeled *u* against the measured data are also shown, for which computation the predicted value at the height of the measurement point was obtained by the interpolation of *u* computed at adjacent vertical layers.



Copy of Figure R5 shown above in Response [1.7]: Time-series of measured and predicted (a, d) cross-sectional mean velocity (U), (b, e) (spatially averaged) velocity at z = 0.05 m, and (c, f) bed shear stress (τ_{bed}) during the two-days measurement in Bakhawan Ecopark. The measured values are from Yoshikai et al. (2022) and the predicted values are obtained through the COAWST employing the Xie root model and the increased bed roughness as an approximation of drag by mangroves, respectively.

Reviewer [2.3]:

2. Does the sparse cylinder model (line 289) have an equivalent frontal area to the field data? Similarly to how the cylinder models used in EXP1 and EXP2 have equivalent frontal area to the Rh model. If so, then this section would nicely flow from the lab section where frontal area was conserved. If not, then there is a jump in the methods being used to create the cylinder arrays in the lab vs in the field section. For best transition between the sections I think the method for generating the cylinder arrays should be consistent between the lab and field parts of the paper.

Response [2.3]:

The sparse cylinder model applied for the field-based study does not have the equivalent frontal area to the field data in contrast to the cylinder models applied for Exp1 and Exp2 of the laboratory-based study.

We would like to note that the objectives of the model applications to the laboratory- and field-based studies are different. The main objective of the application to the laboratory-based study is to explore the effectiveness of the formulations for the drag and turbulence terms (Eqs. (1)–(6)), which were newly implemented in the COAWST in this study, compared to the cylinder drag model provided the vegetation frontal area density (*a*) as a known parameter. Alternatively, in the case of field studies, the parameter *a* is usually unknown and needs to be predicted for the model application. Thus, one of the main objectives of the application to the field-based study is to explore the effectiveness of the implemented *Rhizophora* root model – the predictor of *a* – in combination with the new formulations in the COAWST, compared to the drag parameterizations proposed in previous studies.

The vegetation frontal area density (*a*), which is a labor-intensive parameter to obtain in the field, has remained as a factor making the model application to the field mangrove forests challenging. This is why several modeling studies have parameterized the drag by mangroves in different ways such as cylinder array approximation with arbitrary cylinder density by Xie et al. (2020) (described in L64–66), cylinder array approximation based on the vegetation geometry measured at a height of around 0.25 m by Horstman et al. (2013) (described in L288–289), and increased bed roughness by Zhang et al. (2012) (described in L64–66). In this study, we have examined these drag parameterizations for the application to the field mangrove forest by comparing them with the new model presented in this study, rather than defining the cylinder array having an equivalent frontal area to the field data, assuming that the parameter *a* is unknown (please note that we have examined the parameterization of Zhang et al. (2012) in the form of dense cylinder arrays – please see L289–291; we have also added new simulation cases using the root model of Xie et al. (2020) and the increased bed roughness – please see Response [1.7] and Response [2.2], respectively).

In the revised manuscript, we will make this point clearer, specifically the difference in the objectives of model applications to the laboratory- and field-based studies.

Reviewer [2.4]:

3. I would love to see a figure that shows the difference accounting for 2 length-scales in the turbulence routines makes. This is mentioned on lines 444-445 and lines 424-426. I haven't seen a figure that does this yet, and the changes to the code are already made so I think this could be a nice addition to the paper.

Response [2.4]:

As suggested by the reviewer, we have examined the effects of accounting for the different length-scales of stem- and root-generated wakes in the presented model (*Rh* model). We have done it by performing additional model analyses for the flume experiments that set the two length-scales to either the root diameter ($D_{root,ave}$) or the stem diameter ($D_{stem,ave}$).

The results clearly showed that without accounting for the two different length-scales, the model fails to predict the vertical profile of turbulent kinetic energy (*k*) (Fig. R7). If the two length-scales are set to the stem diameter, the model largely overestimates *k* specifically in the root zone ($z/HR_{max} < 1$); whereas the model with the length-scales set to the root diameter underestimated *k* in the upper and above the root zone ($z/HR_{max} > 0.5$). The model that has the length-scales set to the root diameter showed a slight increase in *k* at the height around $z/HR_{max} = 0.9$ (Fig. R7b), possibly due to the velocity shear generated by the sharp decrease in frontal area at the top of the root zone (Maza et al., 2017; Fig. 3a). However, this increase in *k* alone is not enough to explain the significantly higher *k* at upper and above the root zone compared to the lower root zone, suggesting the significant roles of the different length-scales of stem- and root-generated wakes in shaping the overall structure of *k*.

As an action for manuscript revision, we will include Fig. R7 in the Supporting Information, and a brief discussion on the interpretation of the result described above in the main text.

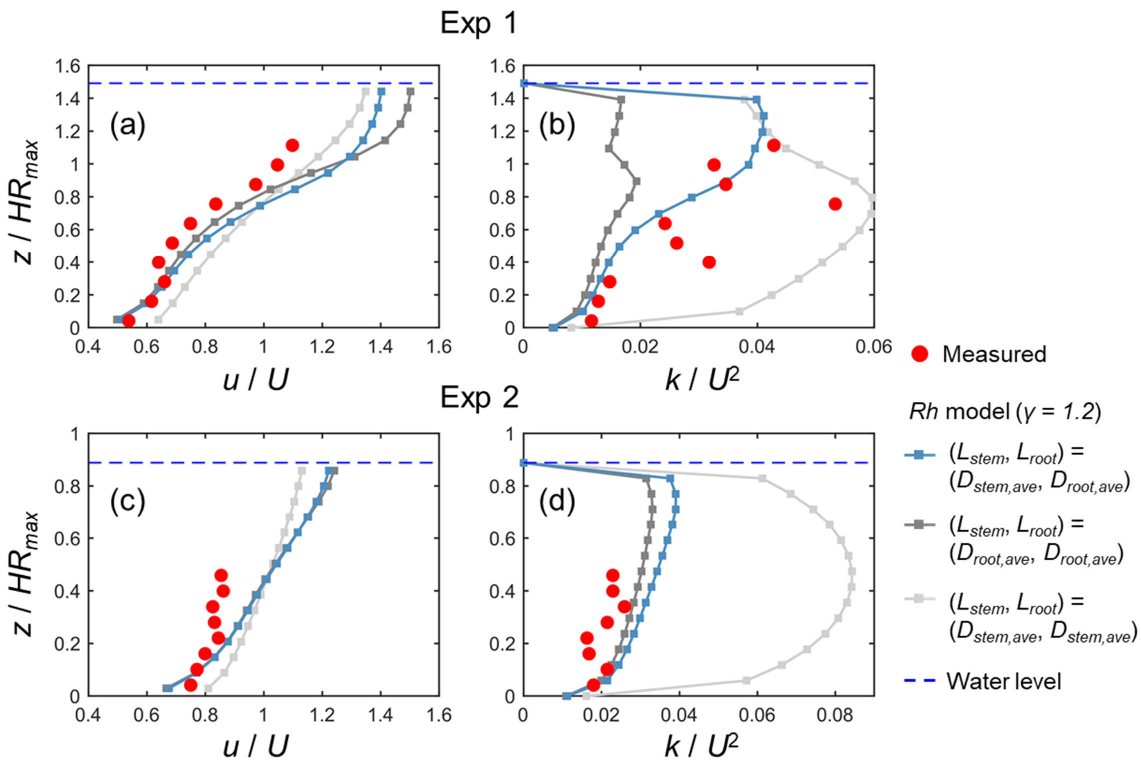


Figure R7. Comparison of the vertical profiles of (temporally and spatially averaged) velocity (*u*) and turbulent kinetic energy (*k*) normalized by the cross-sectional mean velocity (*U*) predicted by the COAWST using the *Rh* model with different length-scales of stem- and root-generated wakes (L_{stem} and L_{root}, respectively) defined – blue markers: L_{stem} and L_{root} set to the stem diameter ($D_{stem,ave}$) and root diameter ($D_{root,ave}$), respectively; dark-gray markers: L_{stem} and L_{root} both set to $D_{root,ave}$; light-gray markers: L_{stem} and L_{root} both set to $D_{stem,ave}$. The scale coefficient (γ) was set to 1.2 for all the cases.

Reviewer [2.5]:

4. I would appreciate if the cylinder metrics (diameter, density, height) mentioned in EXP1,EXP2, the sparse cylinder array and the dense cylinder array could be compiled into a table and attached as supplemental information.
    1. I believe it is important to state the height of these cylinder arrays. Based on the velocity profiles shown in Figures 4 and 5, I believe all the cylinder arrays span the entire water column. However there are other papers which use cylinder arrays which span a fraction of the water column, so I think it is important to state.

2. The widths are also important to state because of they are used in the turbulence dissipation term. The diameters for EXP1 and EXP2 are already stated, but I couldn't find diameters for the sparce and dense cylinder arrays.

Response [2.5]:

We have compiled the parameter settings of all the simulation cases in Table R5. Because we consider that Table R5 is convenient for the readers to grasp the different model configurations used in this study, we would like to include it in the main text of the revised manuscript.

Regarding comment 1, the height of the cylinder arrays was defined well higher than the water level in the model, thus they span the entire water column as pointed out by the reviewer. In the revised manuscript, we will add an explanation of this point. Also, we added a description of the cylinder height in the caption of Table R5.

Regarding comment 2, we noticed that we missed adding the information on the cylinder diameter defined for the field-based study in the manuscript. We have provided the information on the cylinder diameter in Table R5, which will be included in the revised manuscript.

Table R5. Tested model configurations to represent the impact of *Rhizophora* mangroves against flume experiments (Exp1 and 2) in Maza et al. (2017) and field measurement in Yoshikai et al. (2022). In the cylinder model configurations, cylinder height was set well higher than the water level to create the condition that cylinders span the entire water column. n_{tree}: tree density; n_v: cylinder density; $D_{stem,ave}$: mean stem diameter; b_v: cylinder density; a_{root}: root projected area density; $D_{root,ave}$: mean root diameter; z_0: bed roughness length; N_{layer}: number of vertical layers of model grid.

Test case	Model configuration	Parameter settings					
		n_{tree} or n_v (m^{-2})	$D_{stem,ave}$ or b_v (m)	a_{root} (m^{-1})	$D_{root,ave}$ (m)	z_0 (m)	N_{layer}
Flume experiment	*Rh* model	0.072 (n_{tree})	0.2 ($D_{stem,ave}$)	Measured value[a]	0.038	0.5×10^{-3}	15
	Cylinder model for Exp1	1.22 (n_v)	0.038 (b_v)	-	-	0.5×10^{-3}	15
	Cylinder model for Exp2	1.76 (n_{tree})	0.038 ($D_{stem,ave}$)	-	-	0.5×10^{-3}	15
Field measurement	*Rh* model with actual a_{root}	0.36 (n_{tree})	0.066 ($D_{stem,ave}$)	Measured value[b]	0.030	0.5×10^{-3}	5
	Rh model with modeled a_{root}	0.36 (n_{tree})	0.066 ($D_{stem,ave}$)	Modeled value[c]	0.030	0.5×10^{-3}	5
	Cylinder model (sparse)	13.5 (n_v)	0.030 (b_v)	-	-	0.5×10^{-3}	5
	Cylinder model (dense)	32.3 (n_v)	0.030 (b_v)	-	-	0.5×10^{-3}	5
	Xie et al. root model	0.36 (n_{tree})	0.066 ($D_{stem,ave}$)	Eq. (R2)[d]	0.010	0.5×10^{-3}	5
	Increased z_0	-	-	-	-	0.02	3
	No vegetation	-	-	-	-	0.5×10^{-3}	5

[a] Corresponds to the value of black markers minus $n_{tree}D_{stem,ave}$ in Fig. 3a.
[b] Corresponds to the value of black markers minus $n_{tree}D_{stem,ave}$ in Fig. 3b.
[c] Corresponds to the value of blue markers minus $n_{tree}D_{stem,ave}$ in Fig. 3b.

[d] Corresponds to the value of light green markers minus $n_{tree}D_{stem,ave}$ in Fig. 3b.

Reviewer [2.6]:

5. Lines 200-211, I think that this section and table 1 can be removed from the paper or moved to supplemental information. This section might be useful as a guide for someone using your code, but I don't think it adds much value towards understanding the content of the manuscript.

Response [2.6]:

We agree with the reviewer. We would like to move the said section and Table 1 to the Supporting Information in the revised manuscript.

Reviewer [2.7]:

6. Generally it seems the core modifications to the code are in the drag term and the turbulence routines, and these change the flow field which then might change the sedimentation rates. I think the sediment parts of this paper are a case study of how these model changes can affect a variable of interest (like sedimentation rates), but I don't think the focus of the paper should be on the changes in sedimentation rates.

Response [2.7]:

We agree with the reviewer that the simulations of the sediment transport should not be the focus of the paper. To underscore the contribution of this manuscript, we would like to remove the section in the results and discussion on the sediment transport simulation in the revised manuscript. Please also see Response [1.1], [1.3], and [1.5] inn relation to this point.

Reviewer [2.8]:

Technical corrections/ Typing errors

1. Line 308 "run" should be "ran"
2. Line 214, could you please consider stating the vertical resolution and/or the number of sigma levels used? This is mentioned in line 241, but I think it would be nice to have all of the domain characteristics mentioned in the same place.

Response [2.8]:

We will revise the said point on L308. We will also put information on the vertical layering of the model in the section. We have also included the information on the number of vertical layers of the computational grid in Table R5, which will be included in the revised manuscript.

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