IAHR Young Professionals Network
Hosted by Spain Water and IWHR, China

Proceedings of the
6th IAHR Young Professionals Congress
Online. 3-5 December 2025
#iahrYPcongress

Numerical modelling of cross-shore beach hydro-morphodynamics

Buckle Subbiah Elavazhagan[1], Maria Maza[1] and Javier Lara[1]
[1] Instituto de Hidráulica Ambiental de la Universidad de Cantabria, Santander, Spain, subbiahb@unican.es

ABSTRACT

Beaches are highly dynamic natural systems, episodic events like storms affect beaches in terms of flooding and erosion. Understanding the hydrodynamic and morphodynamic processes prevalent during the storm events is crucial to support optimizing coastal protection strategies. Observing these processes real time during a storm event is challenging, thus this work aims to provide a RANS based one phase sediment transport model IH2VOF-SED applicable to wide range of beach states and storm conditions. In this work the model's ability to replicate storm induced erosion, break bar formation, wave attenuation provided by submerged vegetation and subsequent reduction in erosion are briefed. Two validation cases for bed evolution are provided with one large-scale validation on an experiment utilizing bichromatic waves, secondly wave attenuation and sediment transport under the presence of submerged flexible vegetation. The model was able accurately predict the bed evolution and cross shore processes along a bare beach profile and a vegetated beach profile.

Keywords: Beach; Sediment transport; IH2VOF-SED; Cross-shore; Wave attenuation.

1 INTRODUCTION

IH2VOF-SED is a one phase, 2 - dimensional vertical, depth resolving sediment transport model governed by the Reynolds Averaged Navier Stokes equations. Expanding the scope and applicability of the model is very necessary to provide comprehensive understanding of the hydrodynamic and morphodynamic processes in different beach states. The model can currently resolve processes of bare natural beaches and beaches with presence of coastal vegetation. The sediment transport model is based on (García-Maribona et al., 2021). For accounting vegetation an additional sink term is introduced in the momentum equation as a drag force, and the vegetation model is based on (Maza et al., 2013). This work evaluates model's performance in predicting bed evolution in bare and vegetated beaches. Brier Skill Score (BSS) (Sutherland et al., 2004) is the metric used to quantify the accuracy/predictive skill of the morphological model accounting measurement error in the larger scale validation case and without accounting measurement error as it is not available for small scale validation case.

2 BED EVOLUTION- BARE BEACH

Experimental data from bichromatic wave tests reported by (Grossmann et al., 2022) were employed for this case. The wave conditions used for this case consist of two primary frequencies, 0.3041 Hz and 0.2365 Hz with significant wave height (H_S)=0.32m and peak wave period (T_p)= 3.7s for a duration of 1800s. Free-surface elevation measured 54.69 m from the paddle was used as the boundary input. Two boundary condition scenarios are examined: (i) first-order wave generation forced with the unmodified experimental signal, and (ii) second-order wave generation in which sub-harmonic and super-harmonic components are removed from the input spectrum. In both simulations, the formation of the primary breaker bar was captured with BSS values 0.42 and 0.75 respectively classified as fair and good morphological predictions. Figure 1 shows the beach profile evolution from the initial state and the vertical velocity profile evolution towards the shore.

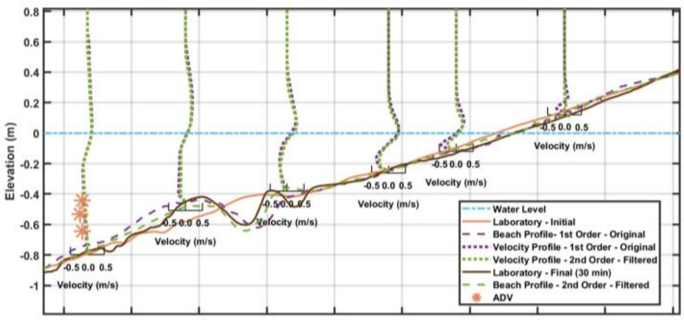

Figure 1. This figure shows initial and final beach profiles of the laboratory (orange and brown lines), final beach profile using first and second order waves (violet and green dashed lines), vertical velocity profiles (violet and green dotted lines)

3 BED EVOLUTION- VEGETATED BEACH

Small scale experiments utilizing submerged vegetation mimicking Posidonia oceanica is carried out by (Gong et al., 2024) to study wave attenuation effects and subsequent sediment transport processes. Based on the experiment the model is validated against an experimental case of wave height = 0.12 m, wave period = 1.2 s and for a duration of 600s for bare beach condition and a vegetation beach condition with the vegetation meadow present in the shoaling zone with key vegetation properties being shoot density = 988 shoots per m^2, leaf width = 4 mm and plant height = 15 cm. The model was able to predict the bed evolution for both bare beach and vegetated beach with a Brier Skill Score of 0.71 and 0.62 respectively classified as excelled and good predictions. The presence of vegetation led to a shifting of bar towards shore and the size compared to the bare beach condition emphasizing the protective role of vegetation on the beaches. Figure 2 shows the bed evolution with and without the presence of vegetation and wave transformation. Vertical velocity propagation towards the shore shows similar vertical profile before the meadow and the bare beach having a stronger undertow contributing to larger bar formation after the vegetation meadow.

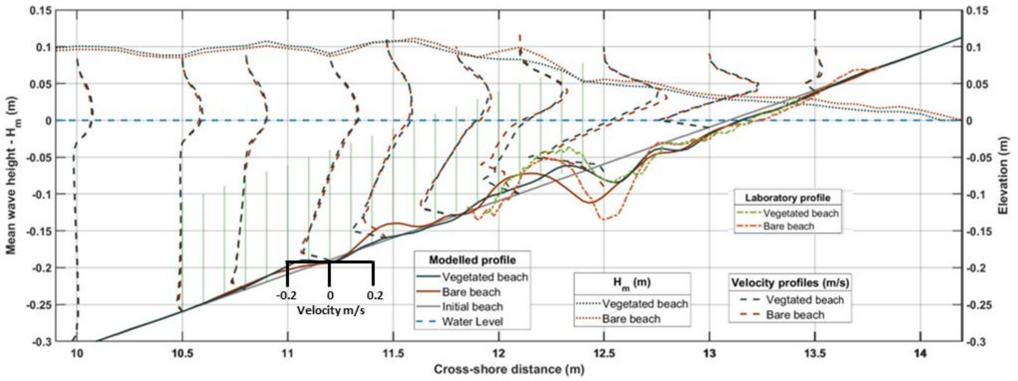

Figure 2. The plots are corresponding to bare beach (brown) and vegetated beach (green) for (i) Laboratory beach profiles, (ii) Modelled beach profiles, (iii) Mean wave height, and (iv) Vertical velocity profiles

4 CONCLUSIONS

The model has predicted bed evolution in the bare beach and in the vegetated beach in different scales accurately. In the larger scale experiment BSS values of 0.42 and 0.75 means fair and good morphological prediction. In the smaller scale experiment the BSS values are 0.71 and 0.62 for bare and vegetated beach respectively means excellent and good predictions. The vegetation model also predicts wave attenuation due to the presence of submerged vegetation well thus leading to desirable changes in the bed evolution by shifting the bar location further towards the shore. A typical process of foreshore erosion and deposition as a breaker bar in the breaking zone during a storm event is replicated well. The model will be further put into use for even wider range of applications including seawalls and more realistic wave conditions from field.

REFERENCES

García-Maribona, J., Lara, J.L., Maza, M., Losada, I.J., 2021. An efficient RANS numerical model for cross-shore beach processes under erosive conditions. Coastal Engineering 170.

Gong, S., Xu, S., Li, M., Wang, Y., Yin, K., Chen, Y., Chen, J., 2024. Experimental study on wave attenuation and beach profile evolution under the protection of submerged flexible vegetation. J Hydrol (Amst) 638.

Grossmann, F., Hurther, D., van der Zanden, J., Cáceres, I., Sánchez-Arcilla, A., Alsina, J.M., 2022. Near-Bed Sediment Transport During Offshore Bar Migration in Large-Scale Experiments. J Geophys Res Oceans 127.

Maza, M., Lara, J.L., Losada, I.J., 2013. A coupled model of submerged vegetation under oscillatory flow using Navier–Stokes equations. Coastal Engineering 80, 16–34. https://doi.org/10.1016/j.coastaleng.2013.04.009

Sutherland, J., Peet, A.H., Soulsby, R.L., 2004. Evaluating the performance of morphological models. Coastal Engineering 51, 917–939

ACKNOWLEDGEMENT

Financial support has been provided by European Union's (EU) Horizon Europe Framework Programme (HORIZON) via SEDIMARE (Grant Agreement No. 101072443), an MSCA Doctoral Network (HORIZON-MSCA 2021-DN-01) and Grant CNS2023-144062 funded by MCIN/AEI/10.13039/501100011033 and by the "European Union NextGenerationEU/PRTR"