

# BOUSSINESQ MODELING OF COMBINED STORM SURGE AND WAVES OVER WETLANDS FORCED BY WIND

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## INTRODUCTION

Coastal wetlands protect the shoreline and infrastructure by attenuating wind waves and reducing storm surge. It is of importance to accurately quantify the flood protection provided by vegetation. Existing numerical models for hurricane waves and storm surge are based on the phase-averaged wave action balance equation and the nonlinear shallow water equations, respectively, with the wind forcing and vegetal drag as the free surface and bottom boundary conditions. To consider the interaction of waves and surge, the phase-averaged short wave and long wave (storm surge) models can be coupled in a staggered fashion. If the time step of the wave model and storm surge model are 30 minutes and 1 s, respectively, both models would exchange information every 30 minutes. There is no iteration between the wave and surge models at each coupling interval. An alternative to this state-of-the-practice of hurricane wave and storm surge modeling is to simulate the combined wave and surge motion driven by wind and attenuated by wetland vegetation using a phase-resolving Boussinesq model. The objective of this study is threefold: 1) to demonstrate the capability of modeling wave growth by wind, wave reduction by vegetation, and the total water level (wave setup, wind setup and wave runoff) using the extended FUNWAVE-TVD model; 2) to analyze the energy balance of the combined wave and surge motion; 3) to examine the momentum balance with an emphasis on the vegetal drag owing to the combined wave orbital velocity and wind-driven current velocity.

## METHODOLOGY

Most of the existing models for wave-vegetation and surge-vegetation interactions utilize the Morison equation to parameterize the drag force acting on the flow due to the vegetation stems approximated as rigid cylinders of small diameter. An empirical drag coefficient has been used to represent the un-resolved physics in the flow resistance formula due to vegetation, which has to be calibrated for different wave and surge models and different vegetation conditions. Firstly, we incorporate the vegetation model in Chakrabarti et al. (2017) into FUNWAVE-TVD, a phase-resolving, shock-capturing Boussinesq model for nearshore wave processes. The Morison equation uses the combined wave orbital velocity and surge current velocity, a part of the solution of FUNWAVE-TVD. Note that only a single value of drag coefficient is needed in the model that simulates both waves and surge. Secondly, we implement the phase resolving wind stresses into FUNWAVE-TVD following Chen et al. (2004). This enables us to model wave growth driven by a strong wind using the phase-resolving Boussinesq model. Thirdly, the still water depth in the model is automatically updated in FUNWAVE-TVD to

account for the change of the mean water level (i.e. storm surge) driven by the wind on the free surface. To gain insight into the energy balance and momentum balance in the combined wave and surge motion, we examine each term in the Boussinesq-type equation using the model output. We split the velocity into the orbital and current components. The modeled wave height and mean water level are compared with the results from the existing models. The phase-averaged energy dissipation term and the momentum sink term attributable to vegetation in the combined wave and surge motion are evaluated and compared with those in the existing wave and surge models. The importance of wave-current interaction to energy dissipation and momentum reduction is assessed.

## RESULTS

Fig. 1 shows the model results. The top panel illustrates the model setup, followed by the modeled spatial variation of the wave height, including wave growth by wind and reduction by vegetation, and the modeled storm surge driven by the strong wind. The surge reduction due to the vegetation is also seen. Good agreement with the analytical solutions of wave attenuation by vegetation and wind setup without vegetation on a flat bottom is found. The extended FUNWAVE-TVD is used to simulate the combined surge and waves of Hurricane Isaac (2012).

## CONCLUSIONS

FUNWAVE-TVD is extended to simulate combined wave and surge motion over coastal wetlands under hurricane conditions. Insight into energy and momentum balances are gained through numerical experiments. We found that existing surge models tend to over-predict storm surge in wetlands because the phase-averaged vegetal drag due to waves and wave-current interaction is missing.

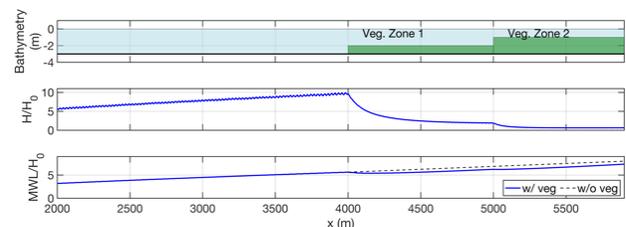


Fig. 1- Modeled wave growth by wind, wave attenuation by vegetation, and storm surge using FUNWAVE-TVD.

## REFERENCES

- Chakrabarti, Brandt, Chen & Shi (2017): Boussinesq modeling of wave-induced hydrodynamics in coastal wetlands. *J. Geo. Res.*, 122: 3861-3883.
- Chen, Kaihatu & Hwang (2004): Incorporation of the wind effects into Boussinesq wave models. *J. Waterway, Port, Coastal and Ocean Eng.*, 130 (6): 312-321.