Effects of Spatially Variable Drag Coefficient of Submerged Aquatic Vegetation on Surface Wave Dissipation

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Abstract

Submerged aquatic vegetation in estuaries and coastal areas can alter the hydrodynamics of coastal waves by attenuating the energy of waves generated by storm surges and cyclones. Generally, wave attenuation by seagrass meadows is studied by considering a constant vegetation drag coefficient across the meadow which is an oversimplification. This study provides a better understanding of how submerged vegetation alters surface wave amplitude and velocity by developing a coupled flow-vegetation interaction model, which consists of a nonhydrostatic wave model and a numerical model for vegetation blade dynamics.

Introduction

Natural habitats, such as submerged aquatic vegetation in estuaries and coastal areas can reduce the energy of the waves generated by storm surges and therefore decrease coastal flooding damages. Numerical studies have investigated the effects of wave-vegetation interaction on wave height attenuation through hydrodynamic modelling of waves and parameterized the vegetation-induced friction of groups of plants with the Darcy-Weisbach

Numerical Model

- **Hydrodynamic model**

We modified the non-hydrostatic, phase-resolving, sigma-coordinate wave (NHWAVE) model (Ma et al., 2012) that solves the three-dimensional current and wave field to include spatially variable and time dependent vegetation drag coefficient.

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{1}{\rho}\frac{\partial u}{\partial t}+\nu\nabla^2 u+F$$

where u,v,w are velocity component, g is the gravitational acceleration, and ν is the turbulent kinematic viscosity, and ρ is the density of the fluid and the additional friction term is due to vegetation:

$$F=\frac{1}{2}C_D b N_c u|u|$$

where b is vegetation frontal blade width, N_c is vegetation density, C_D is the drag coefficient, and u *is* relative velocity between vegetation blade and fluid.

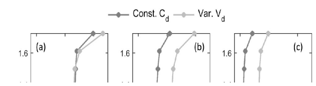
- **Vegetation model**

Our vegetation model considers the instantaneous orientation of a flexible blade and is developed following the Zeller et al. (2014) model in which a vegetation blade is modeled as a series of rectangular plates

Model results

- **Velocity profile**

The effect of vegetation on velocity profile through constant bulk drag for rigid vegetation and variable vegetation drag coefficient for flexible vegetation meadow are presented in Figure 2. Rigid vegetation would cause larger velocity dissipation while the velocity in the meadow is larger for flexible vegetation.



Model results

- **Vegetation blade excursion**

Our coupled model results are evaluated by comparing the modeled vegetation blade excursion with experimental results (Figure 4).

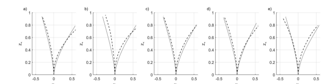


Figure 4; Maximum vegetation blade excursion for a regular wave case of (Amp =0.2m, T=4s). We use the same variables tested in the Maza et al. (2013) experiments. Black dash lines correspond to the experimental

Conclusion

- The vegetation blade motion influences the flow structure and thus determining accurate instantaneous configuration of blades are necessary to resolve the flow-vegetation interaction and compute wave-driven currents in the vegetation meadow.
- The developed coupled model compares well with experimental data for vegetation blade excursion.
- The model captures wave attenuation rate and quantifies the effect of vegetation flexibility on wave attenuation.
- Model results suggest that considering a rigid vegetation with simplified drag coefficient would result in larger vegetation-induced damping compared to flexible vegetation condition.

- **References**