NONHYDROSTATIC MODELING OF FLOW INTERACTIONS WITH HIGHLY FLEXIBLE VEGETATION

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INTRODUCTION

Improving our understanding of the interactions between gravity waves, currents, and coastal vegetation, which are nonlinear in nature, enables coastal engineers and managers to better estimate hydrodynamic forces on coastal infrastructure and utilize natural elements to mitigate their impacts. Aquatic vegetation is ubiquitous in coastal waters and it is well-known that flow loses energy over vegetation. Computational modeling of wave-vegetation interaction has been the subject of numerous recent studies and many improvements have been achieved in reducing limitations applied on wave and vegetation behavior in these models. Mechanisms for highly flexible vegetation have been incorporated in a Boussinesq-type model (Tahvildari, 2017, Tahvildari and Zeller, submitted) and Reynolds-Averaged Navier-Stokes (RANS) models (Mattis et al., 2019 and Chen and Zou, 2019). Flow dynamics over flexible vegetation and vegetation dynamics in response to hydrodynamic forcing are important for predicting wave and surge dissipation by vegetation, storm impacts on vegetation canopies, ecological processes, and sediment transport in estuaries, and require further investigation. In this study, we implement a numerical model for highly flexible vegetation in an open-source RANS model NHWAVE (Ma et al., 2012) to address some of these questions.

NUMERICAL MODELS

The RANS model, Non-Hydrostatic WAVE (NHWAVE), has been applied to a variety of coastal engineering problems including wave-vegetation interaction, wave-structure interaction, breaking-induced turbulence and nearshore circulation, among others. The vegetation module in the model is based on the formulation for rigid cylinders (Ma et al., 2013). In this study, we implement a numerical model for dynamics of highly flexible vegetation in NHWAVE. The vegetation model is based on Zeller et al. (2014) where a numerical model for dynamics of highly flexible vegetation was formulated. The model accounts for stem drag, inertial, skin friction, and buoyancy forces. This model has previously been coupled with a Boussinesq-type wave model for a single (Tahvildari, 2017) and multiple (Tahvildari and Zeller, submitted) vegetation stems. Since Bossiness-type models are limited to shallow water waves, vertical variability of flow and vegetation response may not be captured adequately. However, NHWAVE resolves the three-dimensional flow field, thus an improvement over Boussinesq-type model is expected. On the other hand, NHWAVE is computationally more costly than Boussinesq models. Here we compare the performance and computational efficiency of the two types of models for predicting wave dissipation and wave-induced vegetation motion.

RESULTS AND CONCLUSION

The coupled model is validated with laboratory experiments on wave dissipation over flexible vegetation, and measurements of vegetation stem position under wave and current loading. The performance of the nonhydrostatic model in these two areas is compared with that of a Boussinesq-type model (Tahvildari and Zeller, submitted). Variation of flow-induced forces along a single vegetation stem, and variation of total force on a stem along a canopy are investigated. Moreover, evolution of current velocity profile over a canopy, which is important for predicting residence time and the resulting ecological effects, is discussed.

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