Laboratory study of wave nonlinearity evolution over coastal flexible vegetation

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INTRODUCTION

The direct relationship between wave nonlinearity and sediment transport, which subsequently influences changes in beach morphology, has long been acknowledged. A comprehensive understanding of nearshore wave nonlinearity is essential for evaluating the effectiveness and stability of coastal and flood defense systems. Previous research has primarily concentrated on characterizing wave nonlinearity on natural sandy beaches (Elgar and Guza, 1985) and coastal breakwaters (Dong et al., 2014). However, these studies have neglected the presence of flexible vegetation, despite its common occurrence on tidal flats. It is well-established that vegetation not only effectively dissipates waves compared to natural beaches (Suzuki et al., 2019) but also reduces flow velocities, leading to sediment accumulation in vegetated areas (Hu et al., 2018). Currently, there is a limited body of work addressing the influence of flexible vegetation on wave nonlinearity evolution. This study aims to conduct laboratory experiments to investigate the impact of flexible vegetation on wave nonlinearity and develop an empirical formula for predicting wave nonlinearity over vegetated tidal flats.

EXPERIMENTS

A sequence of laboratory experiments was carefully devised within Hohai University's wave flume (as illustrated in Figure 1) to replicate the dynamic interplay between waves and flexible vegetation at Chongming Dongtan, situated at the mouth of the Yangtze River. Considering the specific characteristics of Young's modulus and stiffness, Low-Density Polyethylene tubes and Poly Tetra Fluoro Ethylene tubes were selected to simulate the properties of live Scirpus mariqueter and Spartina alterniflora, respectively. This investigation aims to gather surface elevation data from 15 wave gauges and velocity data using 3 Acoustic Doppler Velocimeters (ADVs) across a total of 27 distinct wave scenarios, encompassing variations in three parameters: wave height, wave period, and water depth, each featuring three different levels.

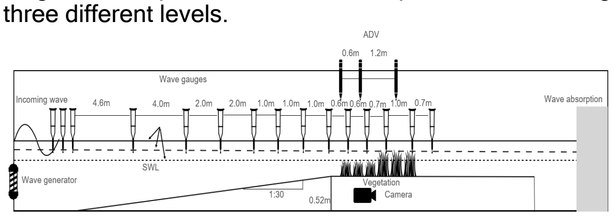

Figure 1 - Setup of laboratory experiments

PRELIMINARY RESULTS

Wave nonlinearity is often quantified using wave skewness and wave asymmetry, which describe the horizontal and vertical asymmetry in wave shapes, respectively. As depicted in Figure 2, the presence of vegetation induces significant alterations in wave skewness and asymmetry across vegetated tidal flats, with these parameters showing minimal variation on the seaward side of the vegetation zone. The results further indicate that vegetation density plays a crucial role in determining the magnitude of wave skewness and wave asymmetry.

In the full paper, the influence of other vegetation attributes, such as stiffness and submergence, on wave nonlinearity will be thoroughly investigated. Empirical formulas for predicting wave nonlinearity based on the Ursell number will be derived by analyzing the wave data collected during the experiments. These empirical formulas can be employed to estimate wave nonlinearity in the design process of coastal defense.

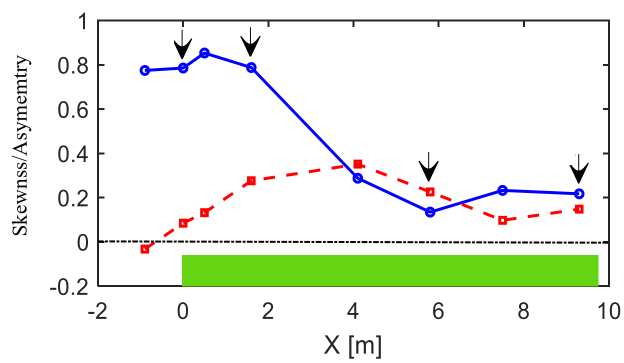

Figure 2 - Evolution of (blue) wave skewness and (red) wave asymmetry over the vegetated tidal flat

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