

WAVE-INDUCED MEAN CURRENTS IN AQUATIC CANOPIES

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INTRODUCTION

Many shorelines around the world are fronted by canopies formed by aquatic vegetation (e.g. seagrass, kelp or mangroves). To date, much progress has been made in understanding how waves propagating towards the coast are affected by these canopies, with a particular focus on wave attenuation (e.g. Dalrymple et al., 1984). As a result, many numerical models currently include formulations to account for the effect of coastal canopies on wave propagation (e.g. van Rooijen et al., 2016).

Most nearshore wave models rely on the assumption that the wave-driven flow itself is not affected by the canopy and that it can be considered depth-uniform. However, several authors have shown that this is often not appropriate (e.g. Lowe et al., 2005), and both the wave-driven orbital and mean velocities may be significantly affected by the canopy. A better understanding of these processes is crucial to predict sediment transport and morphological changes along beaches that are fronted by aquatic vegetation.

In this study we use physical experiments in combination with the non-hydrostatic wave model SWASH (Zijlema et al., 2011) to study the three-dimensional flow patterns in and around coastal canopies. We particularly focus on the effect of the canopy on the vertical profile of three characteristic wave-induced flow components: mean flow velocities, orbital flow velocities and turbulent fluctuations.

PHYSICAL EXPERIMENTS

Experiments were carried out in a 35 m long, 1.2 m wide and 1.2 m deep wave tank in the Hydraulics Laboratory of the University of Western Australia. Regular waves with varying wave height and wave period were generated by a piston-type wave maker positioned at one end of the flume. In order to minimize wave reflection, the flume was equipped with a 1:10 beach, which acted as a passive wave energy absorber. A rigid canopy was constructed by inserting wooden dowels (of diameter 6.4 mm and height, h_c , of 30 cm) into a perforated PVC board. The density was 3200 elements per m^2 , resulting in a solid fraction of approximately 10%. The water depth was kept constant throughout the experiments ($h = 0.80$ m, canopy submergence ratio $h_d/h = 0.38$). The wave conditions in combination with the canopy provides a range in both Reynolds and Keulegan-Carpenter number (12,000-100,000 and 11-40 resp.).

NUMERICAL MODELING

The formulations for the canopy drag and inertia forces that are currently implemented in SWASH are based on the Morison equation (Morison et al., 1950). To our knowledge, this is the first time the model is applied to study three-dimensional canopy hydrodynamics. Hence, to gain confidence in the model skill, a number of widely-used experimental datasets are selected for model validation (e.g. Lowe et al., 2005). Next, the

model is set-up for the current physical experiments.

Model-data comparisons show that SWASH is able to accurately compute the velocities inside and above the canopy with limited calibration. The model is also able to capture the wave-induced mean current near the top of the canopy (Figure 1), which has been identified experimentally (e.g. Abdolhoupour et al., 2017), and is suggested to be an important driver for transport of nutrients and (fine) sediments, but has received limited attention in literature thus far.

Subsequently, a large number of simulations are run with varying canopy characteristics and wave conditions. The results of these simulations are used to investigate under which conditions and canopy characteristics the attenuation of the in-canopy flow is significant, as well as the generation of mean currents and turbulence.

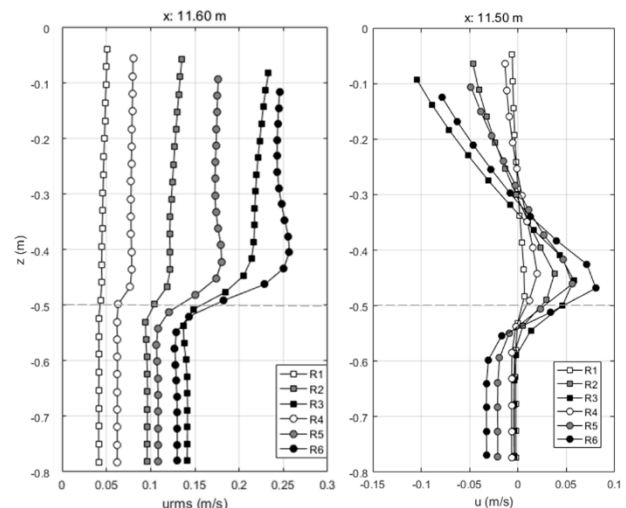


Figure 1 - Vertical profiles of the root-mean-square (RMS) horizontal velocity (left) and the mean horizontal velocity (right) as computed by SWASH for 6 experimental cases. The top of the canopy is located at $z = -0.5$ m.

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