THE INFLUENCE OF SUBMERGED COASTAL STRUCTURES ON NEARSHORE HYDRODYNAMICS

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INTRODUCTION

Submerged coastal structures (e.g., submerged breakwaters and natural and artificial reefs) are common in nearshore waters globally. By locally reducing water depths from the surrounding bathymetry, they modify the incident wave field, mean currents, runup and sediment transport around them. Although submerged structures are generally assumed to promote coastal protection by dissipating waves offshore and creating sheltered conditions in their lee, their interaction with waves can result in wave-driven circulation patterns that may either promote shoreline accretion or erosion (Ranasinghe et al., 2006). A meta-analysis of the coastal changes resulting from the construction of submerged breakwaters found that, contrary to expectation, in the majority of the cases erosion occurred in their lee (Ranasinghe and Turner, 2006). Therefore, a detailed understanding of the wave structure interactions and resulting hydrodynamics is paramount to predict coastal changes in their lee. Here we explore the detailed wave-driven hydrodynamics in the lee of submerged structures using phase-resolved modelling.

METHODS

We applied the 3D wave-flow numerical model SWASH (Zijlema et al., 2011) to study the wave-driven flows and waters levels in the lee of a single shore-parallel impermeable submerged structure. SWASH is a 3D non-hydrostatic phase-resolved model that intrinsically accounts for the variety of hydrodynamics processes that arise from wave transformation in the nearshore (e.g., nonlinear wave shape, energy transfers, diffraction, and swash hydrodynamics). We used a range of structure geometries that represent constructed submerged breakwaters (e.g., Ranasinghe et al., 2006) subjected to a variety of wave conditions. For each simulation we calculated the significant wave height, the mass-flux velocity, proxies for sediment transport and wave runup.

RESULTS

Waves propagating over submerged structures can drive either a 2-cell mean (wave-averaged) circulation (2CC; Fig. 1a), with diverging flows behind the structure, or 4-cell circulation (4CC; Fig. 1b), with diverging flow in their immediate lee and converging flow at the shoreline. We develop a predictor for the mode of circulation with a set of relationships depending on the incoming wave conditions and structure geometry (Fig 1c). Qualitative agreement between the mean flow and proxies for the sediment transport suggests that the mean flow directions can be used as a proxy for sediment transport directions. Consequently, 2CC and 4CC would result in shoreline erosion and accretion, respectively. For the parameter space considered, the submerged structures had a minimal influence on wave runup in their lee despite the wave energy dissipation on the structures. Our results suggest that the coastal protection provided by the range of impermeable submerged structures we modelled is primarily due to their capacity to promote beach accretion.

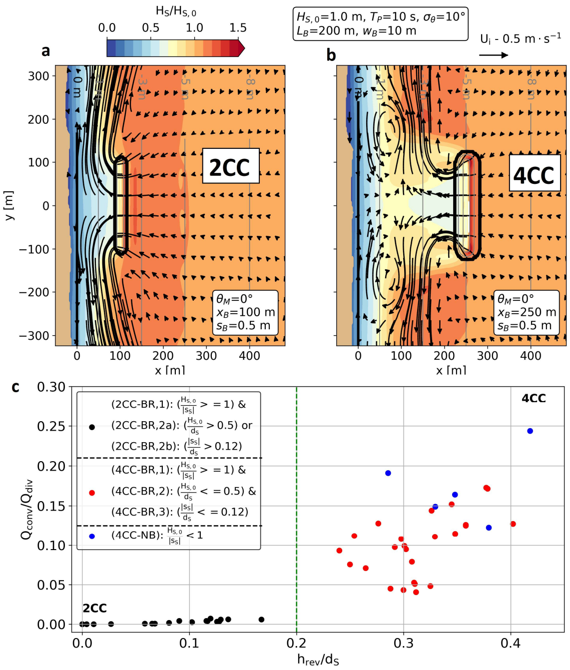

Figure 1 - Normalised significant wave height $H_S/H_{S,0}$ (colors) and mass-flux velocity U_i (vectors) for representative (**a**) 2CC and (**b**) 4CC cases. (**c**) Predictor for 2CC and 4CC based on wave and structure parameters.

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