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Wave current interaction over rough beds

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Wave-current interaction can occur over a wide range of both wave and current conditions with implications for coastal circulation, turbulence and sediment transport, especially close to the seabed. The interaction of waves and currents within the bottom boundary layer is strongly affected by the bed roughness or by the presence of sedimentary structures.

Most of the existing either numerical or experimental studies focused on collinear waves and currents (e.g. Grant and Madsen, 1979; Huang and Mei, 2003; Lodahl et al. 1998; Yuan and Madsen, 2015). However in Nature waves and currents in coastal areas are closely orthogonal, with waves prevailing on currents (wave dominated conditions) or vice versa (current dominated conditions) depending on the local wave climate (see e.g. Arnskov et al. 1993; Musumeci et al., 2006; Faraci et al, 2008, 2018).

In this work an experimental campaign investigating orthogonal waves and currents propagating on rough beds (sand and gravel roughness, D_{50}=0.9 and 25 mm respectively) was performed at DHI Shallow Water Basin in the framework of Hydralab+ Transnational Access WINGS. Waves with periods between 1 and 2 s and wave heights between 0.05 m and 0.18 m were propagated within the basin, interacting over an area 18m x 10 m.. Two different water depths were considered, 0.4 and 0.6 m. In this way two different current conditions were generated within the flume keeping the flow rate equal to 1 m^3/s. The combination of the different wave and the current conditions led to reproduce both wave and current dominated regimes.

A set of 24 resistive wave gauges, located in the central part of the basin where waves and currents interact with each other, recovered the free surface elevation. Five single-point Nortek Vectrinos and one velocity Vectrino Profiler were placed within the measuring area in order to gather 3D velocity profiles within the bottom boundary layer, using 100 and 200 Hz sampling rate.

The analysis of the time-averaged velocity profiles close to the bottom show that the superposition of the waves and current at right angles leads to a flow deceleration and to an increase of the apparent roughness, accordingly to what already observed by Musumeci et al. (2006) and Faraci et al. (2008) over rough beds. This occurs for all the performed experiments, but for the wave-dominated case in the presence of the sandy bed. Indeed, in the sand bed case at low Reynolds numbers $Re=U_0 A\nu^{-1}$, U_0 and A being respectively the orbital velocity and amplitude and ν the kinematic viscosity of water, ranging between 5000 and 6000, the nondimensional wall shear stress undergoes a reduction, as the flow tends to relaminarize. This result confirms what it was previously found by Lodahl et al. (1998) in the case of colinear waves and currents and by Musumeci et al. (2006) in the case of hydraulically smooth beds..