IMPACT OF SAND DUNE MORPHOLOGY ON MACRO-TIDAL CURRENT DYNAMICS: INSIGHTS FROM PIV MEASUREMENTS

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Here we present an experimental campaign delving into the complex interplay between sand dune morphology and tidal current dynamics. Employing particle image velocimetry (PIV) measurements, we conducted diverse series of laboratory flume experiments to scrutinize the hydrodynamic influence of dunes on steady currents, both aligned and opposed to the dune asymmetry.

Our experiments sought to replicate the hydrodynamics occurring over the tidal dune field of the Goulet de Brest, located in Brittany, France. The Goulet hosts well-formed and highly dynamic dunes shaped by intense tidal currents. Notably, these currents exhibit a distinctive asymmetry, with ebb flows prevailing towards the southwest in contrast to the opposite flood flows. The resulting tidal asymmetry is vividly mirrored in the dune profiles, showcasing an accentuated asymmetry in the southeast part of the field, where dunes grow taller in shallower waters.

Conducted in a bidirectional current-permitting flume, each experimental series encompassed varied hydrodynamic conditions, such as ebb and flood, aligned or opposed to the dune asymmetry, and different bottom roughnesses. We utilized sediment mixtures that were progressively coarser, transitioning from a smooth to a fully rough flow regime. The PIV flow measurements provided unprecedented spatial resolution, slightly larger than 1 mm, and temporal resolution sampling data at a frequency of 200 Hz. These measurements were taken at the central dune crest and along the neighboring trough. At the inlet, lower-frequency point measurements were conducted using a Vectrino-II ADV Nortek, ensuring the stability of inlet currents during different PIV acquisitions.

Analysis of the collected data unveiled a rich tapestry of turbulent processes and boundary layer dynamics. The identified detachment and reattachment points of the boundary layer, along with their spatiotemporal oscillations, revealed an intermittent advection of coherent turbulent structures downstream from the dune crest proceeding further downward along the lee side in the boundary layer and upward in the water column up to the free surface. These deepened our understanding of the intricate interactions between boundary layer dynamics and turbulence. Additionally, by scrutinizing the vertical current profile along the dune, we estimated the equivalent bottom roughness and local shear stresses, providing crucial insights into the drag imposed by the dunes, with potential implications for sediment transport processes.

In essence, this dataset stands as a cornerstone in unraveling the intricate relationship between tidal dune morphology and coastal current dynamics. It underscores the potential of PIV measurements for investigating such large-scale phenomena under controlled conditions. Furthermore, the collected database can inform the development, validation, and sensitivity analysis of new numerical models aiming at the investigation of those fine-scale processes taking place at the interface of sand dunes and tidal current which control sediment transport and thus shape coastal areas.

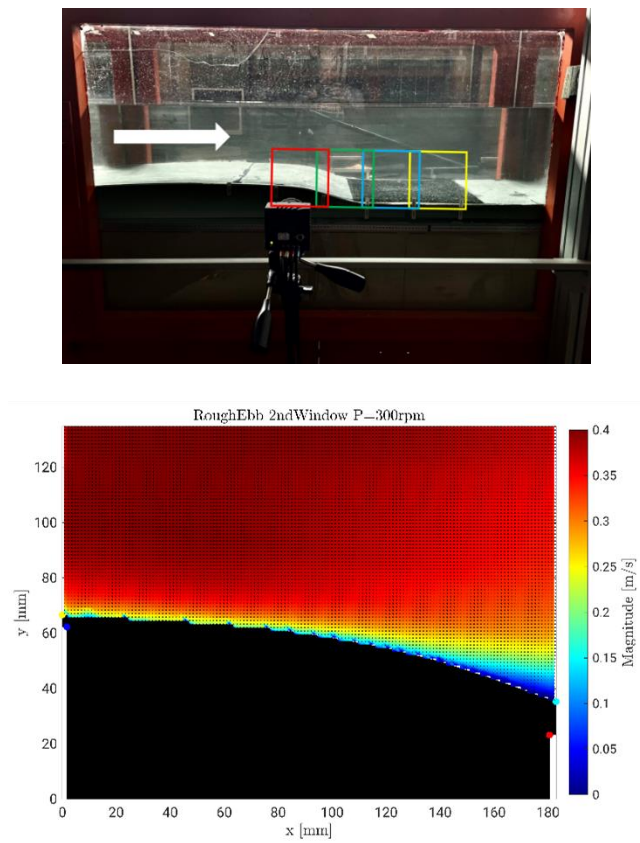

Figure 1 – Experimental configuration and visualization of PIV measurements. Top panel shows a photo of the experimental setup. The PIV camera points to the measuring area where different PIV windows are represented by colored rectangles. Bottom panel shows raw PIV data in terms of velocity magnitude and directions over the crest of the central dune for the experiment with largest forcing and bottom roughness.