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An integrated, multi-sensing approach to describe the dynamic relations between turbulence, fluid-forces, and reconfiguration of a submerged plant model in steady flows.

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Aquatic vegetation plays a vital role in ecohydrological systems regulating many physical, chemical, and biological processes across a wide range of spatial and temporal scales. As a consequence, plant-flow interactions are of particular interest to a wide range of disciplines. While early studies of the interactions between vegetation and flowing water employed simplified and non-flexible structures such as rigid cylinders, recent studies have included flexible plants to identify the main characteristics of the hydrodynamics of vegetated flows. However, the description of plant reconfiguration has often been based on a static approach, i.e. considering the plant's deformation under a static load and neglecting turbulent fluctuations. Correlations between drag fluctuations, plant movements, and upstream turbulence were recently established showing that shear layer turbulence at the surface of the different plant elements (such as blades or stems) can contribute significantly to the dynamic behaviour of the plant. However, the relations between plant movement and force fluctuations might change under varying flow velocities, and although this point is crucial for mixing processes and plant dislodgement by fatigue, these aspects of fluid-structure interactions applied to aquatic vegetation remain largely unexplored.

Using an innovative combination of sensing techniques in one set of experiments, this study investigates the relations between turbulence, fluctuating fluid forces and movements of a flexible cylindrical plant surrogate. A silicone-based flexible cylinder was attached at the bottom of a 1m wide flume in fully-developed uniform flow. The lower 22 cm of the plant surrogate were made of plain flexible silicone, while the higher 13cm included a casted rigid sensor, measuring accelerations at the tip of the surrogate. Forces were sampled at high frequencies at the surrogate's base by a 6-degrees-of-freedom force/torque sensor measuring down to the gram-force. Point measurements of turbulence were realized by two ADVs which were located upstream and downstream of the surrogate. Detailed motions of the surrogate were recorded by two cameras above and next to the flume. Image processing allowed for the characterization of the mean deformation and the different modes of horizontal and vertical 'vibration' of the surrogate.

The experimental results were compared to numerical simulations obtained from an updated version of the Dynveg code developed by Deltares. The results showed a clear correlation between the cylinder's movements and the (drag) force fluctuations. Due to the swaying motion of the surrogate, the turbulence spectrum is significantly affected when the flow passes the plant model. The succession of several motion modes are observed as the velocity increases, affecting the dominant frequencies in the drag force spectrum and the overall drag. These preliminary results emphasise the importance of the dynamics of the plant flow interactions, and provide an example of the use of new methodologies to provide deeper insights into the physics of complex flows.