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Comparison of mean and turbulent flow fields around real and surrogate macroalgae

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Recently, flume experiments have been used to explore micro- and meso-scale ecohydraulic interactions. However, questions remain regarding the comparability of observations gained in the field and the laboratory. For example:

1. Does the constrained geometry of a flume influence the hydraulics compared to the field? How do flow characteristics inherited from outside the measurement domain influence the hydrodynamics within the domain?
2. What complexity is required to adequately reproduce the hydrodynamics of the natural system? Does geometric and mechanical variability amongst individual organisms of the same species need to be incorporated? Does the spatial organisation of organisms need to be replicated?
3. What are the differences between the flow and sediment transport effects of some commonly-used surrogates and their living counterparts? What aspects of living organisms must be replicated in order to limit those differences?

In this paper, we describe research carried out by the participants in the PISCES work package of the HYDRALAB IV project that addresses some of these questions. To do this, we first selected an 11 m long $\times$ 6 m wide vegetated region of a tidal inlet, the Hopavågen Bay field station of NTNU, Sør-Trøndelag, Norway. We selected two *Laminaria digitata* specimens $\sim$0.30 m apart for detailed study and a 2 m long $\times$ 8 m wide frame was oriented around them by enforcing zero cross-stream discharge at its upstream edge. We then quantified: 1. the mean and turbulent flow field of the undisturbed condition (Case A); 2. the positions, geometrical and biomechanical properties of the plants; and 3. the mean and turbulent flow field after plants were completely removed (Case B). Later, Case A was replicated in the same location ($\pm$0.05 m) before the 19 *L. digitata* plants were replaced with 19 "optimized" surrogates (Case C).

In all cases, a profiling ADV was used to collect velocity profiles composed of up to seven 35 mm-high profiles collected for 240 s at 100 Hz, at a streamwise spacing of 0.25 m and cross-stream spacing of 0.20 m. These were collected at 45 planform locations. Comparison of the normalized time-averaged streamwise ($\bar{u}$), cross-stream ($\bar{v}$) and vertical ($\bar{w}$) velocities indicated good agreement of all three components at 25 locations for Cases A and C. However, for Case A, there was a region of downwelling between the algae ($\bar{w}$-velocity -0.035 m s^{-1}), while at the outer edges of the algae, counter-rotating velocity cells were generated ($|\bar{v}|$ $\sim$0.04 m s^{-1}). Conversely, for Case C, surrogates became weighed down with sand, reducing projected area, flow deflection and thus reducing the strength of secondary flows. Thus, agreement was poor at the 12 locations around the two *L. digitata* plants. We speculate that this was exacerbated by heterogeneities of plant properties and subtle differences in plant orientation and position. A set of flume experiments will be undertaken in Spring 2014 to repeat and expand cases A to C, with additional cases to investigate the sensitivity of the flow field to plant geometric arrangement.