MSc Project

Title: Physics-compatible numerical methods for simulating wave damping by kelp farms

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Short description: With the transition towards renewable energies and climate adaptation, novel technologies are being deployed offshore, for example: offshore wind farms, floating photovoltaic farms or even floating islands for energy storage. These type of structures are subject to harsh environmental conditions, mainly due to the effect of ocean waves. The use of adjacent floating porous structures is gaining attention for their dissipative effects, mitigating the wave loading. In this regard, Kelp or seaweed farms could be used as a nature-inclusive solution for wave load mitigation as they can function as large floating porous structures. Apart from their use for wave damping purposes, Kelp or seaweed farming on a large scale presents potential solutions to various global issues. It can provide eco-friendly protein for people and livestock, without needing any land or fresh water or fertilizers.

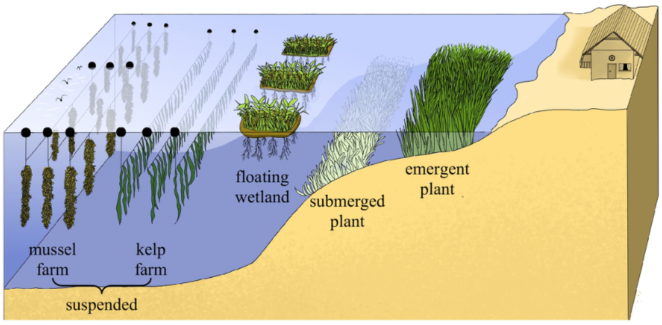

Figure 1: Floating porous breakwater (left) and sketch of floating seaweed farms (right).

This project will develop new finite element methods that help study the potential wave damping benefits of kelp farming. The presence of kelp beds or kelp forests has been found to attenuate the amplitude of incoming waves, thus reducing coastal erosion and protecting shoreline ecosystems.

Modelling kelp farms as porous media, their wave damping effect can be described by adding a Darcy–Forchheimer resistance term to the incompressible Navier Stokes equations. Up to boundary conditions, the following is the PDE system that describes the fluid flow,

$$\begin{aligned} \frac{\partial \mathbf{u}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{u} - \nu \Delta \mathbf{u} + \nabla p &= \underbrace{\alpha \mathbf{u} + \beta \mathbf{u}^2}_{\text{Darcy–Forchheimer}} + \mathbf{g} \,, \\ \nabla \cdot \mathbf{u} &= 0 \,. \end{aligned} \tag{1}$$

Additionally, the free surface (i.e., the wavy interface between air and water) is implicitly described with the help of a variable that tracks its elevation.

In this project, you will develop a strongly mass-conserving discretization of the above model. Such discretizations are called physics-compatible, they aim to exactly satisfy fundamental physical conservation laws in the discrete setting, and lead to finite element schemes that are stable, accurate and give physically-reliable results. You will develop this discretization by learning about and using $H(\text{div})$-conforming finite element spaces; the implementation and verification will be done within an existing (Python or Julia) finite element library.

Contact info: If you are interested in the project or have any other questions (about its scope, practical details, etc.), please contact us at `J.O.ColomesGene@tudelft.nl` and `D.Toshniwal@tudelft.nl`.