# Integrated modelling framework for nature-based solutions toward a Digital Twin of the Coastal Ocean

The large presence of infrastructure, protected natural environments, cultural heritage sites, and human activities makes the coast one of the most vulnerable areas to climate change-related issues such as sea level rise and an increasing number of extreme events. Storm surges are the primary cause of inundation and coastal erosion, resulting from the combined effects of waves and currents that resuspend and transport sediments. In addition to traditional engineered grey solutions, such as seawalls and groins, the past decade has seen the emergence of nature-based solutions (NBS), aimed at providing effective and environmentally sustainable alternatives. Seagrasses represent a particularly compelling topic within the scope of NBS, notably due to their provision of coastal protection among the various ecosystem services they offer. This study aims to develop a coastal ocean digital twin (cDTO) based on an integrated multi-modelling unstructured-grid framework (circulation, wave, vegetation, and sediment cores) with capabilities for what-if scenario production. The augmented realism of the cDTO is advanced by: (i) accounting for multiple drivers of coupling among the different physical components; (ii) including phenotypic variability, plant flexibility and the seasonal growth cycle of the leaves; and (iii) improving the sediment-vegetation interaction. The application was focused on the Italian littoral zone of the Lazio coast (Tyrrhenian Sea), where the predominant seagrass species is Posidonia oceanica. However, the cDTO is highly adaptable and capable of incorporating different seagrass species. This pilot case will benefit from a large amount of physical and ecological observations, making the area an open-air laboratory. The cDTO is capable of assessing vegetation-induced attenuation on waves (up to 20-30%) and currents (up to 50-60%) as well as effects on sediment dynamics, supporting site characterization and the selection of optimal sites for seagrass reimplantation.

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