Assessing the hydrodynamic impacts and Carbon deposition pattern associated with floating solar structures within a Belgian offshore wind farm

Denis Pauline, Capet Arthur, Vanaverbeke Jan, Ong Ee Zin, Kerkhove Thomas and Legrand Sébastien

Operational Directorate Natural Environment (OD Nature), Royal Belgian Institute of Natural Sciences, Rue Vautier 29, 1000 Brussels, Belgium
E-mail: pdenis@naturalsciences.be

Marine renewable energies are considered important strategies for addressing the current energy transition in Europe. Offshore wind farms (OWFs) in the North Sea currently supply around 25.8 GW of power with an ambition to reach at least 117 GW by 2030. Yet, on its own, wind energy supply remains partially unreliable for a consistent energy generation. Offshore photovoltaic (PV) installations are considered a valid option for such complementary technology in areas where the physical environment is not dynamic enough for deploying wave energy converters or tidal systems. Installation of offshore photovoltaics within OWFs in the North Sea offers two significant advantages: (1) space optimization in an already extremely busy North Sea, and (2) the possibility of utilizing and integrating the power network already present for the OWF.

However, the installation of such systems comes with significant environmental challenges. In particular, solar technologies currently involve more submerged structures per unit of energy production. These floating structures will lead to hydrographic changes, particularly in currents and turbulence. They will also cause biogeochemical changes, as the floaters act as artificial hard substrates that are quickly colonized by suspension- and filter-feeding organisms, potentially altering the biogeochemical dynamics of the water column and, ultimately, affecting the sediments.

This study provides a first assessment of the impact of PV structures on key hydrodynamic variables, both in the near-field and far-field around an OWF. Variables such as current velocity fields, bottom shear stress, turbulence production, and others were analyzed using the 3D hydrodynamic model COHERENS (https://doi.org/10.5281/zenodo.11654795). We also present a first estimate of the enrichment of organic carbon flux to the sediments due to the presence of colonizing organisms (mainly *Mytilus edulis*) on the submerged parts of PV structures. Our aim is to assess the areas of the seabed impacted by the deposition of faecal pellets due to the installation of PV structures within the Mermaid OWF using a 3D Lagrangian particle tracking model and experimentally measured data on faecal pellet characterization.

A 3D computational grid spanning approximately 20km around the Mermaid OWF in the Belgian part of the North Sea was implemented, with a fine grid resolution of 50m x 50m. The impact of floating solar panels on the surrounding circulation and turbulence field was first assessed using a sub-grid scale parameterization. Various scenarios were tested: (1) a reference state, without any structure, (2) a reference state inside OWF where only monopiles are influencing the hydrodynamics, (3) a combination of solar panels and monopiles, considering variable solar panel densities. Various meteorological-ocean conditions (e.g. winter vs summer, spring tide vs neap tide, etc.) were considered. Results from these different scenarios will be presented and compared.

These hydrodynamic simulations were then used to assess the footprint of carbon deposition in and around the Mermaid OWF. Faecal pellet characteristics (e.g., sinking velocity, production rate and carbon content) are gathered from laboratory experiments and literature data on colonization of wind turbine foundations (*Mavraki et al., 2020*). Simulations were conducted using a 3D Lagrangian particle tracking model (*OSERIT; Dulière et al., 2012*). In this model, each numerical particle represents a certain quantity of faecal pellets and, consequently, organic carbon.

Maps of faecal pellet deposition patterns will be presented for two scenarios of PV structures distribution in the Mermaid OWF and a reference scenario only considering offshore wind turbine foundations. Our simulations show that the footprint affected by faecal pellet depositions could reach up to 18 times the surface area of the OWF and that the amount of carbon deposited could reach up to 1454 gC km^{-2} per day in the worst-case scenario. These maps illustrate the causal relationship between PV farm design and the surface area of sediment affected by the faecal pellet deposition and thus exposed to organic carbon enrichment.

Keywords
Modelling; Photovoltaic Installation; Wind Farms; Hydrographical Changes; Turbulence; North Sea; Renewable Energy; Faecal Pellet Deposition; Carbon Enrichment