Project title: Oceanic Extremes in the North Sea and European Northwest Shelf (OXtreme-NWS)

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Abstract:

Extreme waves and sea levels are major drivers of coastal flooding, beach erosion, and damage to marine and coastal infrastructure, while the heat waves can disrupt food chains and alter species distribution, affecting fisheries and aquacultures. The European Northwest Shelf (NWS) is one of the most dynamically active and socioeconomically important marine regions in the world, encompassing densely populated coastal zones, major ports, offshore wind farms, oil and gas platforms, shipping routes, and low-lying coastal zones. In addition, the marine ecosystem and fisheries in the region are highly sensitive to temperature anomalies. Consequently, reliable and accurate estimates of wave and sea level extremes and marine heat waves in the NWS are essential for risk assessments, structural design, climate-resilient coastal protection strategies, and sustainable marine ecosystem management.

The proposed project aims to advance the understanding and prediction of oceanic and coastal dynamics in the NWS through the development of high-resolution, multi-decadal simulations and an integrated data assimilation framework.

First, a multi-decadal, high-resolution wave hindcast will be produced for the NWS using the WAM spectral wave model. This dataset will capture the spatial and temporal variability of wave conditions under diverse meteorological and oceanographic regimes. The resulting wave climatology will provide a robust foundation for analyzing extreme wave events, long-term trends, and climate-driven variability, thereby improving risk assessments for offshore and coastal infrastructure and strengthening regional wave forecasting capabilities.

Second, coastal hydrodynamics in the North Sea will be simulated using the fully coupled WAM–NEMO modeling framework. This integrated approach enables two-way interactions between wave and ocean processes, yielding a more realistic representation of coastal circulation, vertical mixing, and energy exchange. Model outputs will be used to examine extreme sea-level events and marine heatwaves, and to assess their effects on the distribution of North Sea brown shrimp, providing insights into the physical drivers of coastal hazards and ecosystem variability.

Third, a deep learning–based data assimilation framework will be implemented to integrate satellite and in situ observations of wave and sea-level parameters across the North Sea and its downscaled subregions. By combining machine learning with physics-based modeling, this system will enhance model reliability, reduce uncertainties, and improve predictive skill. The resulting data-assimilative system will support operational forecasting and long-term environmental assessments, ensuring the production of accurate, consistent, and policy-relevant datasets for both scientific and practical applications.