Foras na Mara
Marine Institute

# Cullen Scholarship: Machine Learning-based Ocean Forecasting (PhD Award)

## Background

The numerical models used to predict the ocean are large, complex, and computationally demanding. Artificial Intelligence is transforming the way oceanographers handle massive amounts of data, including for the purpose of making predictions and reanalysis.

Machine learning techniques can potentially offer higher accuracy in predicting oceanic phenomena compared to numerical models. This is because machine learning algorithms can detect complex patterns and relationships within vast datasets that may not be easily captured by conventional modelling approaches. AI models can adapt to changing conditions and incorporate new data more seamlessly than numerical models, which often require manual adjustments and recalibrations. This adaptability is particularly valuable in dynamic ocean environments where conditions can change rapidly. Machine learning algorithms have the potential to streamline the forecasting process by automating various tasks such as data pre-processing, feature selection, and model training. This efficiency can lead to faster turnaround times for forecasts, enabling more timely decision-making for various ocean-related activities such as shipping, fishing, and offshore operations.

Furthermore, machine learning approaches can effectively assimilate observational data from various sources such as satellites, buoys, and underwater sensors into forecasting models. By integrating diverse datasets, machine learning models can potentially improve the accuracy and resolution of predictions, especially in regions with sparse or limited observational coverage. As computational resources continue to advance, machine learning algorithms offer scalability advantages, allowing researchers to develop increasingly sophisticated forecasting models capable of handling large-scale oceanic systems and high-resolution spatial and temporal data.

## Proposal

By leveraging the strengths of machine learning, proposed research can advance the state-of-the-art in ocean forecasting, ultimately enhancing our understanding of marine environments and supporting sustainable management practices and decision-making.

We propose **a structured four-year PhD** on a full-time basis to develop and test a machine learning-based ocean forecasting in Irish waters and to compare its predictive skill with conventional deterministic numerical models.

The project will aim to:

1. Conduct a comprehensive review of existing literature on ocean forecasting methods that utilize machine learning approaches. In particular, explore machine learning approaches capable of capturing the complex and nonlinear dynamics of oceanic processes.
2. Adopt existing or develop new machine learning models that can accurately forecast various ocean parameters such as sea temperature, salinity, currents and sea surface height in 3D and over different spatial and temporal scales.

3. Identify and gather relevant data sources for ocean conditions, such as historical weather and oceanographic data, satellite imagery, in-situ data, outputs from the numerical models that re required to train and subsequently run machine learning-based forecasting models.
4. Implement machine learning-based forecasting to Irish EEZ and comprehensively evaluate the performance and predictive skill of the model in comparison to available observations and to existing numerical models of the area.

**Location of Scholar**

The scholar will be based for circa 50% of their time over the four years at the Marine Institute HQ Rinville, Galway.

**Outcome**

The proposed research project holds significant promise to contribute towards revolutionizing our understanding and prediction capabilities of oceanic dynamics. By harnessing the power of machine learning algorithms, such as neural networks and deep learning models, this study aims to enhance the accuracy, resolution and timeliness of ocean forecasts. The ambition is to develop sophisticated predictive model(s) capable of capturing complex oceanic phenomena with at least comparable precision to conventional deterministic numerical models. This research will deliver a comprehensive evaluation of the predictive skill of the machine-learning based models ranging from currents, salinity and temperature gradients to sea level variations and storm surges. This research will also inform on strengths and weaknesses of machine learning-based ocean forecasting in terms of the resources required to develop and maintain them and the predictive skill that can be obtained.

**Marine Institute Corporate Strategy 2023-2027**

Under the strategic priority "Delivering impact through research and innovation" of the Marine Institute's corporate strategy Ocean Knowledge that Informs and Inspires, this research will address strategic initiatives number 3 and 4 by funding a cutting-edge research in an emerging field of Artificial Intelligence with an application to developing a state-of-the-art digital model of the Irish Ocean, i.e. the Digital Twin of the Ocean.

**Specific Requirements**

The scholar should have a primary degree in physical oceanography, physics, ocean sciences, mathematics, IT or civil engineering.

**Financial Details**

Scholarships will be up to €34,000 per annum (maximum funding PhD of €136,000 over four years or €68,000 over two years MSc). This amount comprises a maintenance award of €25,000 (rate effective 1-Jan-24) to the student as well as payment of fees to the host higher education institution (HEI). The maximum fees payable to the HEI will be €6,000 per annum. The scholarship award also includes a budget of up to €3,000 per annum for eligible research costs (travel & subsistence, publication costs, consumables and other costs, such as minor kit purchase e.g. camera) for the sole use of the student, and are payable on a reimbursement basis direct to the

host institution where the postgraduate student (scholar) is registered. There are no overheads payable on the scholarship.

Publication costs are intended to cover publications on which the scholar is listed as first author and are published under Open Access.

Scholars can also supplement this funding by applying to the Marine Institute's Networking & Marine Research Communication Awards annual call.

In addition, the cost of a laptop will be covered by the Marine Institute (purchased via the Research Funding Office).

**Marine Institute Co-Supervisor**

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