# Geometric Deep Learning for Smart Shipping

## Graph neural networks for short- and long-term weather forecasting


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## Background and motivation

My background is in mathematics, and I hold a master's in pure mathematics with a focus on geometry, as well as a master's in applied mathematics, in porous media and oil reservoirs. My Ph.D. was in machine learning and data analysis in collaboration with the Department of Radiology, focusing on aging and dementia and modelling a memory network. After my PhD I worked as a data scientist at a consulting company in Oslo, and currently I pursuing my SEAS postdoctoral fellowship in collaboration with Imperial College London. My research project is in an area that combines all my background knowledge, including geometry, deep learning and fluid mechanics in one of my favourite topics, renewable energy and marine sustainability.

## Project description

Despite the revolution in weather and climate forecasts during the past half-century, accurate forecasting of the weather is still a challenge. State-of-the-art data- driven approaches such as topological and geometric deep learning techniques have recently shown success with similar forecasting tasks. We propose a new weather forecasting graph neural network that can reduce greenhouse gas emissions by increasing the use of renewable energy.

## Objective

- Design and develop a geometric deep learning model for short- and long-term marine weather forecasting.
- The new network will be adapted to the fixed locations of wind farms as well as the dynamic movement of ships' positions.
- On vessels this will enable a more efficient switching between diverse energy sources and optimizing shipping routes.
- On offshore wind farms it will increase energy production.
- A new System dynamics model then will be designed for smart switching between the different sources of energy.

## Main questions

- How effective a graph neural networks improve weather forecasting compared to current forecasting methods?
- How much a new architecture for graph neural networks improve the marine weather forecasting results?
- How efficient the results lead to optimize the shipping routes?
- How much the improvement in forecasting results affect the energy hybridisation of ships?

## Graph structure

- We structure the graph by considering the weather stations that provide data on temperature, wind speed, pressure, precipitation, and other meteorological variables in the marine area as the nodes of the graph.
- The vessels are considered mobile stations in the graph. It means the ships should be equipped with portable weather instruments. The connections between two nodes in the graph represent the relation between the weather information at those two stations, based on fluid mechanics equations. The distance between the stations and the ship is also a crucial feature of the graph.
- Considering such graphs at different time points, provides a spatial-temporal graph neural network.
- This model is proposed to forecast the weather for a selected time in the future by inputting the locations in several possible paths so that enables navigators to choose the most efficient route at a given time in the future.
- Moreover, it enhances the efficiency of transitioning between diverse renewable energy sources by providing more accurate weather information.

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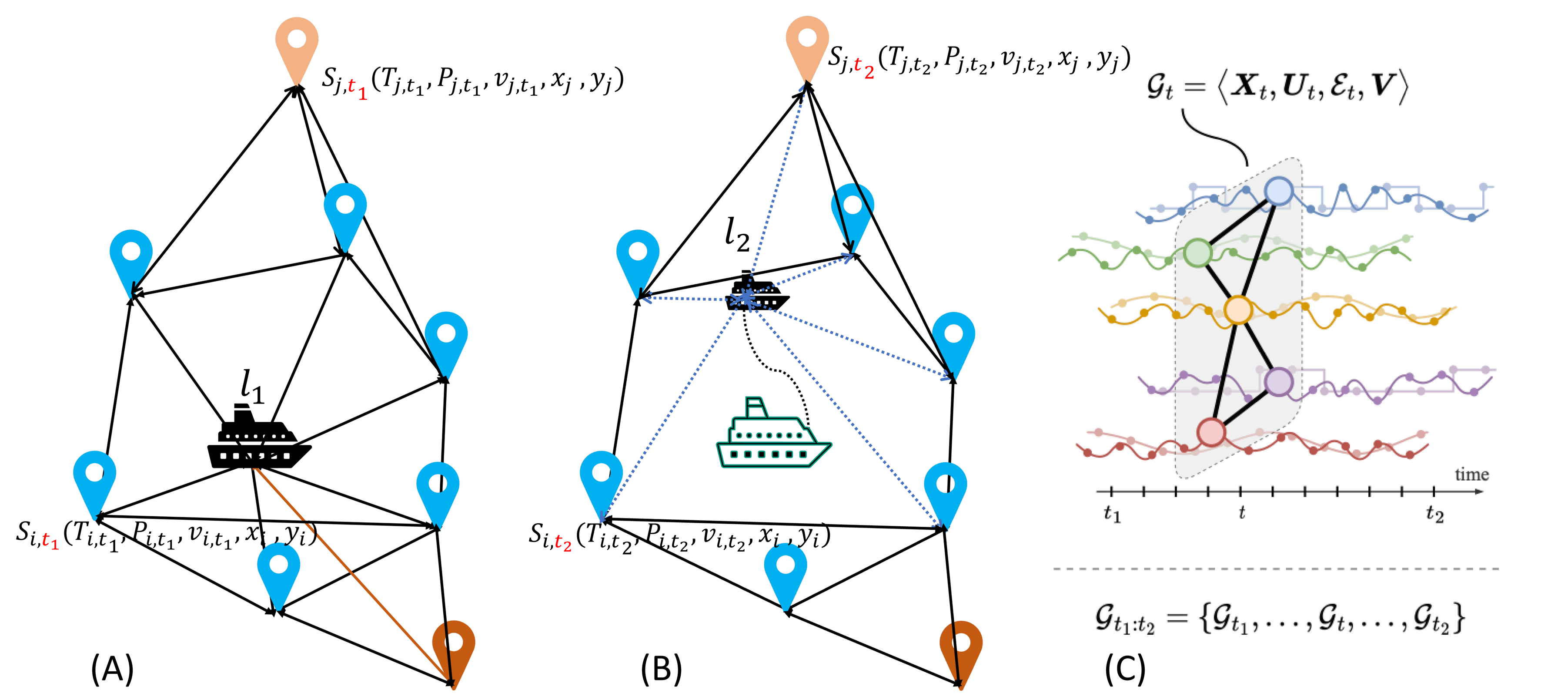
Several companies have started to implement the concept of **sailing ships** to uses sails mounted on masts to harness the power of wind and propel the vessels. Ayro Ocean Wings is one of them Inspired by the aeroplane wing profiles. Wing-sail system enables new build or existing ships to significantly reduce their fuel consumption.

**Hurtigruten: An electric cruise ship with gigantic solar sails is set to launch in 2030 in Norway.**
The ship will be 135 meters in length and have 270 cabins. The sails, when fully extended, will reach 50 meters in height.

## Marine sustainability

Maritime transport is responsible for about 3% of global greenhouse gas emissions. Decarbonization of shipping and modelling smart ships with smart energy management systems represent efforts to reduce greenhouse gas. Accurate weather forecasting is a key factor for the optimization of shipping decarbonization.
It can improve shipping routes, aid in estimating arrival times, and optimize the hybridization of energy resources that can improve the efficiency of employing renewable sources of energy.




A schematic structure of graph at time $t_1$ and $t_2$. (A) The ship is at location $l_1$ at time $t_1$. The model is trained with temporal data until $t_1$ at all weather stations, $S_i, S_j, etc.$, simultaneously. (B) The ship plans to be at location $l_2$ at time $t_2$. The proposed model must predict the weather at time $t_2$ at location $l_2$. (C) An example of time series from various locations. At each time point, a graph establishes the relationship between the weather information at all locations, based on fluid mechanics equations.

## Data sets

opernicus Europe's eyes on Earth

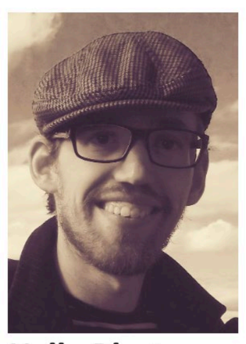
Copernicus Marine Service

Climate Change Service

ECMWF European Centre for Medium-Range Weather Forecasts

BSH BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

## Supervisory team



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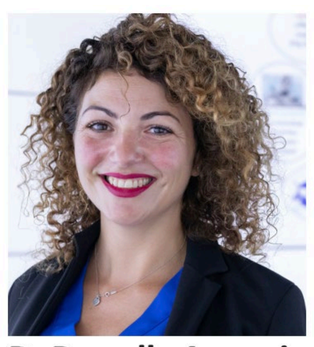

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