Proposition de stage

Machine Learning Algorithm for the Prediction of Ocean Currents Estimated from Sea Surface Height Anomaly (SLA), Sea Surface Temperature (SST) and Sea Surface Salinity (SSS) time series

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Mots-clés : Machine Learning (ML), Deep Learning (DL), Numerical Modeling, Remote Sensing, Oceanic circulation

Context:

The ocean is a major contributor to the climate state via air sea exchanges, latitudinal heat transport via ocean circulation and climate regulator via the atmospheric CO2 uptake and its heat stockage capacity. Accurate numerical dynamical models of oceanic circulation are now available, they are physic-informed predictive models that reconstruct the evolution of the ocean. The fields they produce are of high quality and consistent with the different physics governing the different scales at which we can observe the ocean. Classical models rely on partial differential equations that incorporate physical knowledge on the underlying phenomenon. Sea Surface Height Anomaly (SLA), Sea Surface Temperature (SST) and Sea Surface Salinity (SSS) are major variables of these equations. SLA is a signature of the sub-mesoscale dynamics of the upper ocean, SST is driven by these dynamics and can be used to improve the spatial interpolation of SLA fields, SSS is a major factor in contributing to changes in density of seawater and therefore to ocean circulation.

A first study showed (Ollier et al, 2023) that a slightly modified image-to-image convolutional Deep Learning (UNet Ronneberger 2015) using as inputs images of SLA and SST, is a relevant method for predicting the SLA. The study was conducted on simulated daily SLA and SST data from the Mercator Global Analysis and Forecasting System, with a resolution of (1/12)◦ in the North Atlantic Ocean (26.5-44.42◦N, -64.25–41.83◦E), covering the period from 1993 to 2019. A 12 cm error on the SLA prediction, estimated on a one-year test set, for scales smaller than mesoscales and at time scale of 5 days was achieved by the U-Net. Moreover, learning the SLA trajectories allowed to improve the accuracy of the prediction at 5 days.

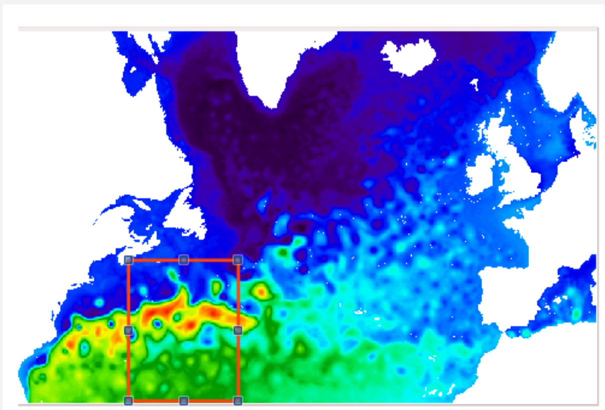

Figure 1. *The domain under study (Red Rectangle) and the SSH*

Proposed study:

The internship will focus on the prediction of the SLA using additional variables such as SST and SSS, both variables being observed or simulated by space agencies and ocean centers dedicated to ocean numerical models. Based on our previous work, the study will first focus on the information added by using the SSS when predicting the SLA and then by using both SSS and SST. A first convincing attempt by using a new Neural network architecture with attention's module (ED-DRAP architecture [Hongshu 2022]) was done. Dealing with this architecture and others dedicated to the prediction of time series [Ashish Vaswani, 2017] we will try to improve the performances reached before. One of the main advantages of deep learning methods over conventional methods is their ability to predict the trajectory of the phenomenon under study (defined at several time intervals in the future and in the past) rather than at the next instant from one (Euler scheme) or two previous states (leap frog scheme) as conventional methods do. By adding very simple attention blocks in the network or more complex such as transformers, we hope it will improve our understanding of the underlying dynamics of SLA and achieve better performances on predictions.

Prérequis

The master student should have prior knowledge of Python programming and some knowledge of neural network modeling with deep learning frameworks such as Keras/Tensorflow or PyTorch.

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