Master internship proposal

Title: *The power of deep learning applied to oceanic eddy detection.*

Location
Laboratoire de Météorologie Dynamique (Ecole Polytechnique, Palaiseau)/

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Goals and contexts :
The increases of the spatial resolution of numerical models and remote sensing observations both revealed the prevalence of eddies throughout the oceans. These structures are able to trap and transport heat, mass, momentum, and biogeochemical properties from their regions of formation to remote areas. Eddies have therefore a significant impact on the surface circulation at both local and regional scales. In order to investigate a large number of coherent structures for long periods (several years) the development of ***automatic eddy detection and tracking algorithms*** is now an "hot spot" of research in oceanography.
Many objective criterions could be used to detect and identify eddies (Mkhinini et al. 2014, Le Vu et al. 2018). However, the remote sensing observations (sea surface height, temperature or color…) are often corrupted by clouds (visible imagery) or by the coarse distribution of altimetric tracks. The combination of distinct remote sensing data-set (SSH, SST, CHL…) could restore the lack of information that may occurs on a single data set. The figure below show how a large mesoscale eddy could be misrepresented by the altimetry, when it pass into the gaps between satellite groundtracks, while it is clearly visible by "human eyes" on the SST signal. To reproduce the human capabilities of pattern recognition artificial neural network is now an efficient and powerful tool.

The main goal of this internship will be to **test the speed and the efficiency of deep learning techniques** (which have provided remarkable advances in speech and image recognition even with a significant amount of noise) **to identify coherent eddies from a cluster of distinct physical images (SSH, Vel, SST, CHL…).** This innovative approach was never tested and could lead to a breakthrough in automatic detection of oceanic eddies. If rapid progress are obtained this study could be easily extended to a PhD.

The student will work in collaboration with another intern of the LIP6 (Laboratoire d'Informatique de Paris 6) who will develop the machine learning algorithms and implement the deep learning methodology on high speed computers. The work will be located 2/3 of the time at the LMD, Ecole Polytechnique and 1/3 at the LPI6, Sorbonne Université .

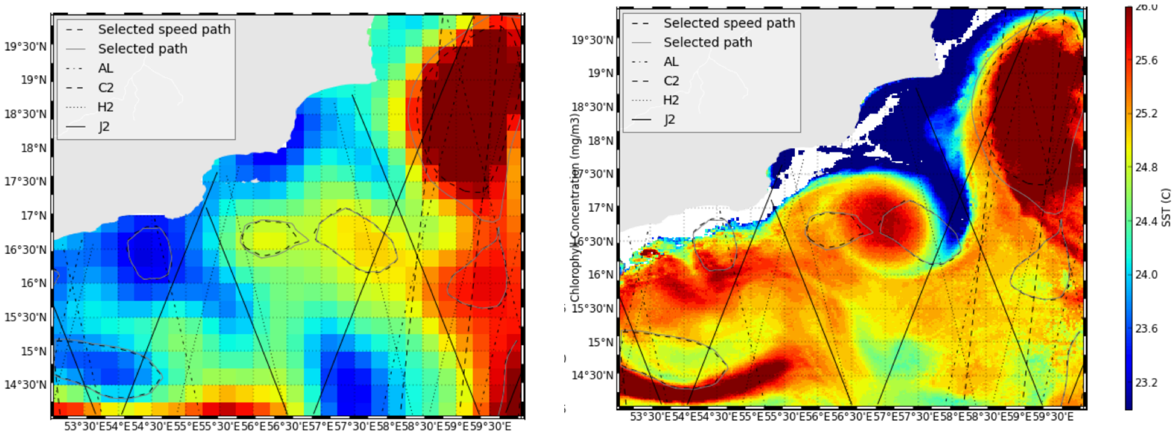

Figure 1 *Sea surface height (left) and Sea surface temperature (left). The solid and dashed lines represent the altimetry tracks while the black contours corresponds to the eddy contours identified by an objective analysis of the SSH field. The warm anticyclonic eddy visible on the SST(right) cannot be detected on the reconstructed SSH (left) due to the lack of altimetry tracks.*

Tools and methodology:

1- The first step of the work will be to provide a very large number of detected eddies to train the artificial neural network. To do so, the Angular Momentum Eddy Detection Algorithm (AMEDA) developed at the LMD will be applied to the altimetry AVISO/DUACS products for the Mediterranean Sea during the 2000-2017 period. This objective method have some bias due to the heterogeneity of the altimetry tracks. However, among the detected eddies we will select the one having a very high reliability (i.e. the one having a high density of tracks in their core). Then, we will extract at the location of the detected eddies various high resolution images of SST or Sea Colors. Among these visible images we will retain only the ones having a very low cloud coverage.

2- In a second step these large set of visible images (we expect to get a t least 10 000 to 30 000 relevant images) will be used to train a deep learning algorithm to identify the eddy sign (cyclonic or anticyclonic) and its size (characteristic radius) from a set of visible images centered on it (5-10).

3- In a third step, we will use innovative technics to identify the locations of the eddies within a large image that may contains several eddy signatures of various shape and size.

4- In the last stage, the accuracy of the deep learning algorithms will then be compared to standard (objective) eddy detection algorithm.

Candidate Skills :

This project would suit a student who wants to gain experience in artificial intelligence, in coastal oceanography and oceanic eddy detection in a Research environment. The student should have strong abilities in mathematics, problem solving and feel at ease with numerical computing. Good knowledge in matlab is required and some knowledge of Python would be appreciated.

While initial training and guidance throughout the project will be available the student will be encouraged to work independently and show initiative in analysis methods and interpretation of results.

References :

- Y. LeCun, Y. Bengio et G. Hinton. (2015) Deep learning . Nature 521.7553.

- B.Levu, A.Stegner, T. Arsouze «Angular Momentum Eddy Detection and tracking Algorithm (AMEDA) and its application to coastal eddy formation» *J. Atmos. Oceanic Technol,* v.35, 739-762, (2018) doi:10.1175/JTECH-D-17-0010.1

- N.Mkhinini, A.L. Santi-Coimbra, A.Stegner, T. Arsouze, I. Taupier-Letage and K. Béranger « Long-lived meso-scale eddies in the Eastern Mediterranean Sea: analysis of 20 years of AVISO geostrophic velocities » J. Geophys. Res. Oceans, 119, 8603–8626, doi:10.1002/ 2014JC010176.