Deep inpainting of Sea Surface Height maps from satellite data of the Mediterranean Sea

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Context

For several decades, a large variety of satellite sensors has dramatically improved the knowledge of the state of planet Earth and its potential evolution. Satellite sensors provide global coverage of the ocean with various remote sensing technologies and spatio-temporal sampling. They observe a multitude of geophysical parameters of interest for oceanography, navigation, meteorology, or climate science applications. Space-born remote sensing allows us to better estimate the ocean's state, by measuring the Sea Surface Temperature (SST) with high-resolution radiometers such as the AVHRR sensors launched onboard on weather satellites, or Sea Surface Height (SSH) which is a good indicator of ocean circulation with altimeters (Topex, Poseidon and then Jason altimeters) that is retrieved in a much sparser way. These satellite sensors have contributed to detecting changes in the response of the ocean to global warming. Improving the quality of the Sea Surface Height estimation can directly impact our ability to better forecast sea currents. This is important both for a better understanding of our system but it can also lead to significant operational efficiency improvements for sea transportation, a major contributor to CO2 emissions, reducing unnecessary carbon emissions.

Currently, the global product provided by Copernicus Marine service is based on DUACS [1] a linear optimal interpolation that provides very smooth fields and misses a lot of fine cyclonic and anti-cyclonic structures. In previous work by our team, we have managed to improve performances over the North Atlantic [2, 3, 4], thanks to neural network-based interpolation methods.

Objective

The internship explores the feasibility of inpainting high-resolution SSH fields from sparse satellite track observations. We aim to train a deep neural network able to leverage information from different contextual variables (temperature but also chlorophyll), of the Mediterranean Sea, a zone with various local physical regimes. This work is a continuation of existing work by Théo Archambault in the context of his ongoing Ph.D., which has already shown that pre-training the neural network on a simulation and fine-tuning on real-world observations was possible. However this study was conducted on a single area, and adapting this method to wider maps will raise many challenges such as: incorporating latitude and longitude information in the architecture; incorporating bathymetry; and comparing several local models to a global one... The work conducted in this internship could lead toward a

global gridded product, with higher quality and resolution than DUACS operational product, which is very useful for oceanography applications.

Skills

- Machine Learning, Deep learning, Image processing, Data Analysis
- Deep learning programming, (mostly Pytorch)
- Interest in geoscience applications

Administrative details
The internship is funded by SCAI for a duration of 5-6 months, from March 2024 to September. It will be held in the LIP6 laboratory (Sorbonne University, 4 place Jussieu) located in the center of Paris. It will be supervised by Dominique Béréziat (Ass. Prof, LIP6-SU), and co-supervised by Anastase Charantonis (Ass. Prof., LOCEAN IPSL, ENSIIE, Inria) and Théo Archambault (Ph-D Student, LIP6-LOCEAN-SU). The internship is gratified at about 600€ per month. The possibility of continuing doctoral study is possible but not guaranteed and will depend on funding.

5-line summary
The internship's aim is to explore the feasibility of inpainting high-resolution SSH fields from satellite track observations and covariables. This work is a continuation of existing work by Théo Archambault in the context of his Ph.D., adapting it to a new zone is a feasible first step that can lead to interesting deep-learning modeling research choices.

References

[1] G. Taburet, A. Sanchez-Roman, M. Ballarotta, M.-I. Pujol, J.-F. Legeais, F. Fournier, Y. Faugere, and G. Dibarboure, "DUACS DT2018: 25 years of reprocessed sea level altimetry products," *Ocean Sci*, vol. 15, pp. 1207–1224, 2019.

[2] T. Archambault, A. Filoche, A. Charantonis, and D. Béréziat, "Multimodal unsupervised spatio-temporal interpolation of satellite ocean altimetry maps.," *VISAPP*, 2023.

[3] T. Archambault, A. Filoche, A. Charantonis, S. Thiria, and D. Béréziat, "Unsupervised learning of sea surface height interpolation from multi-variate simulated satellite observations.," *Submitted to the Journal of Advances of Modeling Earth Systems*, 2023.

[4] T. Archambault, A. Filoche, A. Charantonis, and D. Béréziat, "Pre-training and fine-tuning attention based encoder decoder improves sea surface height multi-variate inpainting.," *Submitted to VISAPP*, 2024.