Reconstruction of Sea Surface Height maps from sparse satellite images

5-6 month internship at Sorbonne University LIP6 lab (Jussieu, Center of Paris)
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Scientific context

For several decades, a large variety of satellite sensors has allowed us to dramatically improve the knowledge of the physical state of planet Earth and its potential evolution thanks to satellite remote sensed imagery. Satellite sensors provide global coverage of the ocean. These sensors are diverse but we are here interested in those that acquire data on the **Sea Surface Height** (SSH). This variable is closely related to the ocean's surface circulation and provides crucial information on the ocean's physical state. However, the observation retrieved is very sparse. The altimeters embarked in satellites measure their distance to the sea surface through the return time of a radar pulse. Because of this technique, the nadir-pointing altimeter sensors are only able to take measures vertically, along their ground tracks. The reconstruction of SSH maps from these tracks can be viewed as a challenging inpainting problem and is of first importance for the geoscience community.

Objective

To reconstruct SST maps from satellite tracks, the reference method is Duacs [3], an optimal interpolation-based method relying on 25 years of ocean observation, with the drawback of reconstructing only low-resolution maps. Recent works have already tackled this problem with the help of high-resolution maps of Sea Surface Temperature (SST) using convolutional neural networks [1,2].

The goal of this internship is to investigate the latest literature and advances in the deep learning domain. We are particularly interested in the stable diffusion models [4] that show impressive results for data assimilation tasks [5]. As in [1,2], we aim to use high-resolution maps to guide the SSH reconstructions. Experiments will be conducted both on numerical reanalysis and real satellite observations (see Figure 1).

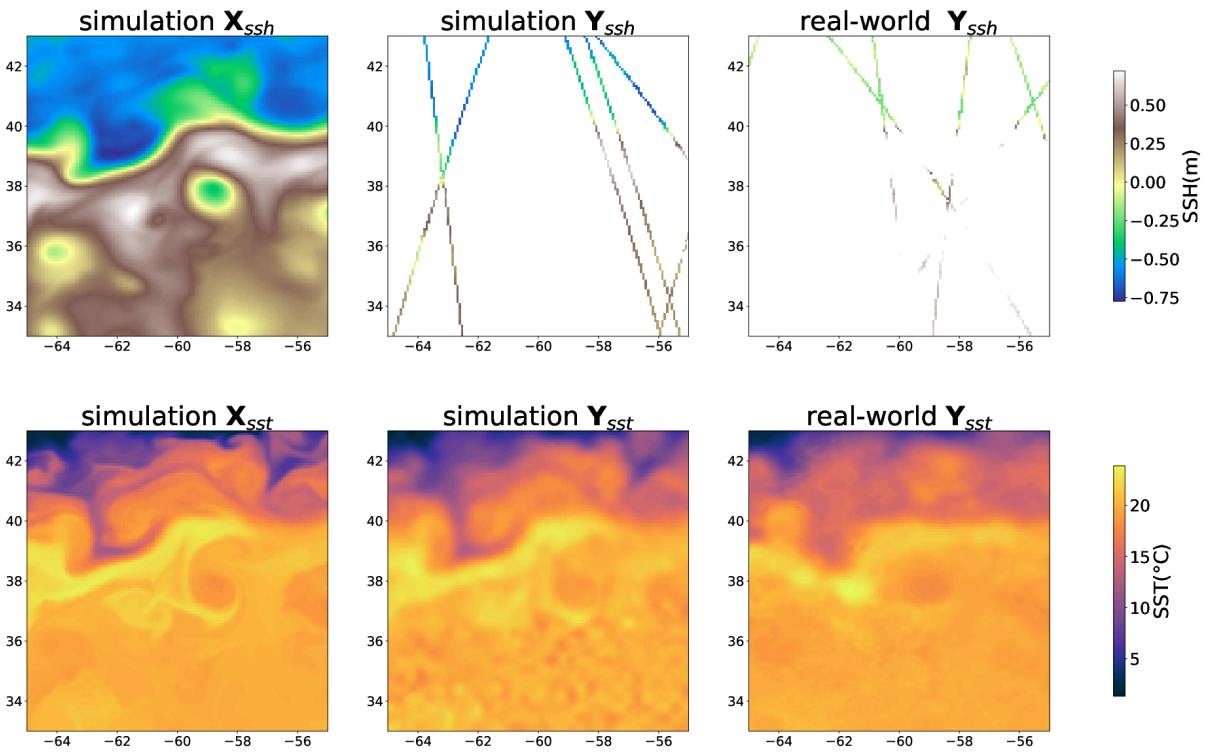

Figure 1: examples of dense SSH maps, SST tracks, SST maps, from numerical reanalysis or satellite observations.

References

[1] Archambault, T. et al (2024). Pre-training and Fine-tuning Attention-Based Encoder Decoder Improves Sea Surface Height Multi-variate Inpainting. VISAPP.
[2] Martin, S. A. et al (2023). Synthesizing sea surface temperature and satellite altimetry observations using deep learning improves the accuracy and resolution of gridded sea surface height anomalies. *Journal of Advances in Modeling Earth Systems*, 15(5).
[3] Taburet, G., et al. (2019). DUACS DT2018: 25 years of re-processed sea level altimetry products. Ocean Sci, 15:1207–1224.
[4] Ho, J. et al (2020).Denoising Difussion Probabilist Models. NIPS.
[5] Huang, L et al (2024). DiffDA: a diffusion model for weather-scale data assimilation. Inter. Conf. on Machine Learning.

Skills :

- Machine Learning, Deep learning, Image processing, Data Analysis
- Pytorch programming
- Interest for climate applications