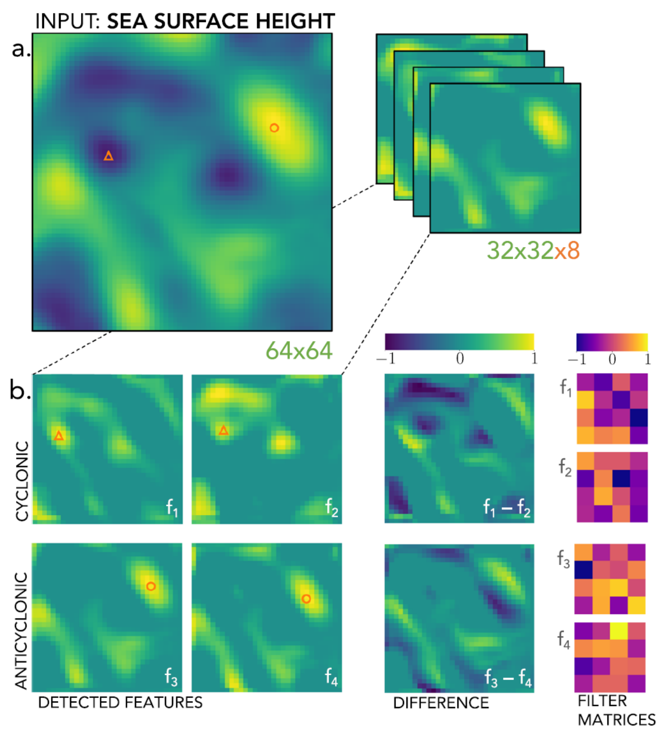
Deep learning to infer eddy heat fluxes in geostrophic turbulence

Supervision: Nicolas Grisouard (nicolas.grisouard@utoronto.ca), Han Wang (hannn.wang@utoronto.ca)



Adapted from George et. al.(2021): the first layers of the CNN extracts dynamically meaningful traits. For example, the convolved figures f1 and f2 appear to identify cyclones, with their difference f1-f2 highlighting eddy gradients and edges.

Project description: Eddies contain the majority of the ocean's kinetic energy, and in doing so, they are crucial in regulating our climate. In particular, they transport heat and other tracers within the ocean, but their turbulent nature makes it hard for us to make reliable predictions of their effects. Machine learning combined with a promised increase in satellite data is providing our field with more opportunities to predict and then integrate these effects into the next generations of climate models.

Recently, George et al. (2021) developed a deep Convolutional Neural Network (CNN) to infer domain-averaged heat fluxes and their divergence from sea surface heights in idealized simulations. Meanwhile, our group has developed a conditional Generative Adversarial Network (cGAN) that accurately extracts a different quantity, namely, tidal waves in simulated sea surface height.

You will adapt our cGAN to the calculation of heat fluxes in our simulations and conduct explorative experiments. In particular, we are curious on whether it could outperform the George et al.'s CNN. We also welcome your own suggestions on other promising deep learning methods to handle this task.

Requirements: programming experience in, or willingness to learn, Python and deep-learning tools such as TensorFlow or PyTorch is preferred. Basic notions in vector calculus and/or fluid dynamics are encouraged, but not required.

Bibliography

1. George, Tom M., Georgy E. Manucharyan, and Andrew F. Thompson. "Deep learning to infer eddy heat fluxes from sea surface height patterns of mesoscale turbulence." *Nature communications* 12.1 (2021): 1-11.
2. Wang, H., N. Grisouard, H. Salehipour, A. Nuz, M. Poon, A.L.S. Ponte. "A deep learning approach to extract internal tides scattered by geostrophic turbulence". (ESSOAr, https://doi.org/10.1002/essoar.10508849.1)