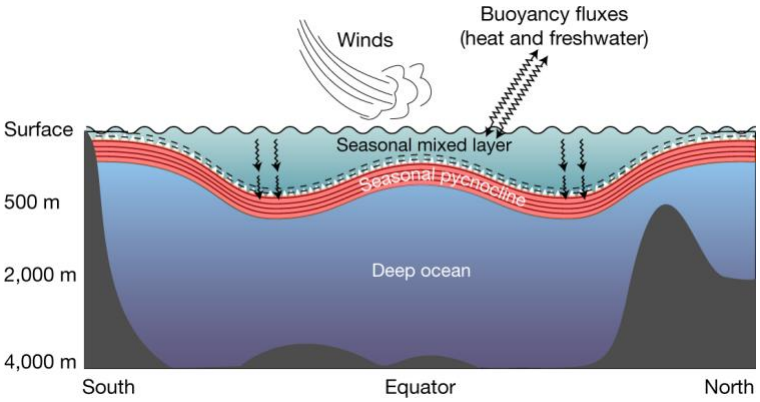
**Inferring the depth of the oceanic mixed layer from satellite images using deep learning techniques**

**Supervision:** Nicolas Grisouard (nicolas.grisouard@utoronto.ca), in collaboration with Guoqi Han (Institute of Ocean Sciences, Sidney, BC)

**Project description:** Measuring and predicting ocean currents is crucial to understanding our climate system, marine ecosystems, or regulating maritime activities. Satellites are key tools to do so, but because water absorbs or reflects electromagnetic waves, satellite imagery cannot provide more than surface information. In this project, we seek to infer sub-surface properties by leveraging high-resolution realistic numerical forecasts containing full three-dimensional information, and machine learning techniques.




← *Source: Sallée et al. (2021)*

The mixed layer is the uppermost layer of the ocean. Because it is in contact with the atmosphere's storms, heat, and water fluxes, it tends to be vigorously mixed. Below it is the deeper ocean, which is rich in nutrients, and above it is the Sun, which is necessary for photosynthesis. Phytoplankton needs to travel between the top and bottom of the mixed layer to have access to both food and sunlight. Moreover, the depth of the mixed layer is linked to key physical quantities such as levels of turbulence and temperature. Therefore, the depth of the latter is key to predicting the state of the upper ocean.

You will use output from a Fisheries and Oceans Canada operational numerical model as your dataset. The data is three-dimensional and therefore contains the answer to the question of how deep it is. The equations it solves are forced by observations and finely tuned to reproduce realistic conditions. Using this data set, you will train a conditional Generative Adversarial Network to predict this depth when only surface information (e.g. sea surface temperature, height, or salinity) is provided. (See second reference for an application of the same technique to a different problem.)

**Requirements:** programming experience in, or willingness to learn, Python and deep-learning tools such as TensorFlow or PyTorch. Basic notions in vector calculus, fluid dynamics, and/or machine learning would be useful, but not required.

**Bibliography**

1. Sallée, JB., Pellichero, V., Akhoudas, C. *et al.* Summertime increases in upper-ocean stratification and mixed-layer depth. *Nature* **591**, 592–598 (2021). https://doi.org/10.1038/s41586-021-03303-x
2. Wang, H., Grisouard N. *et al.* A deep learning approach to extract internal tides scattered by geostrophic turbulence. *Geophysical Research Letters* **49**, e2022GL099400. https://doi.org/10.1029/2022GL099400