ONE Planet
Doctoral Training Partnership

Natural Environment Research Council

Project title: Using data-driven methods to model upper ocean dynamics
Ref: OP2463
Keywords: Ocean dynamics, machine learning, climate modelling

One Planet Research Theme:
Climate & Climate Change ☒ | Earth System Processes ☒ | Anthropocene ☒ | Environmental Informatics ☒

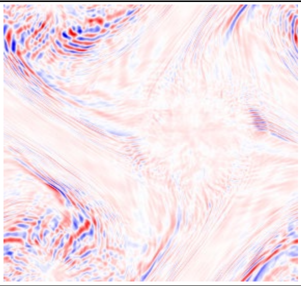
Lead Supervisor:
Matthew Crowe, Newcastle University

Key Research Gaps and Questions:

How can we build a model to predict the dynamics of the upper ocean at small (around 1-10km) scales?

How can data-driven methods be used to enhance our current generation of ocean models?

How can we use this model to understand and predict the transfer of heat and CO_2 from the surface to the deep ocean?



Average vertical velocity from a simulation of a region of the upper ocean. Red/blue regions indicate strong up/down-welling.

Project Description:

The world's oceans are responsible for storing nearly 30% of the CO_2 emissions generated by human activity and capture around 90% of the excess heat produced by these emissions. Heat and CO_2 are absorbed at the ocean surface and are transferred to the deep ocean by a range of complicated dynamical processes occurring in the upper layers of the ocean. Understanding this transfer is of vital importance for predicting ocean acidification, sea-level rise due to thermal expansion and the subsequent effects of these processes on the climate system.

The dynamics of the upper ocean occur on a relatively small scale, consisting of fronts and eddies around 1-10km in size [1]. These features are associated with regions of intense vertical transport which are responsible for mixing the heat and CO_2 uptake at the surface into the deep ocean. However, such features are too small to be accurately represented by the global ocean models used for climate predictions and weather forecasting. Instead, a physical understanding of these unrepresented processes must be incorporated directly into the model via a technique known as 'parametrisation'.

The goal of this project is to create a data-driven parametrisation of upper ocean dynamics. There has been some recent success in applying machine learning techniques to large-scale ocean dynamics [2] using a convolutional neural network (CNN). The student will develop, test, and train a CNN to predict upper ocean properties (including energy transport and up/downwelling) from the large-scale features. This model will form the basis of a parametrisation of upper ocean dynamics. The student will learn how to incorporate physical constraints into machine learning models and create datasets by running ocean models on high performance computing clusters using parallel computing techniques. They will also undertake mathematical modelling, numerical analysis, and scientific writing; giving them a broad skill set and training across disciplines.

[1] – J. R. Taylor & A. F. Thompson, Ann. Rev. Fluid Mech., 2023

[2] – L. Zanna & T. Bolton, Geophys. Research Letters, 2020

Prerequisites:

Candidates who have/expect a first class or high 2:1 honours degree in mathematics, physics, computer science or a closely related discipline. Candidates must demonstrate high academic potential to successfully complete the PhD. Enthusiasm for research, an ability to think and work independently, excellent analytical skills and strong communication skills are essential requirements. Knowledge of fluid dynamics and an interest in machine learning are highly desirable. For more information, please contact Matthew Crowe (Matthew.Crowe2@ncl.ac.uk).

Newcastle University

Northumbria University NEWCASTLE

Newcastle University

Northumbria University NEWCASTLE