Machine learning methods integrated into numerical modelling of the ocean general circulation

Summary

Nucleus for European Modelling of the Ocean (NEMO) is a widely used model for the simulation of the ocean general circulation. Sub-mesoscale processes are not properly resolved with present model setups that are feasible for decadal time-scale simulations. A novel conceptual approach for the integration of a supervised machine learning method for the solution of horizontal diffusion term in the advection-diffusion equation of the scalar fields has been elaborated by our research team. The main aim of the research is to implement machine learning methods for the calculation of the horizontal diffusion terms in numerical solution of the advection-diffusion equations for water temperature and salinity within ocean general circulation model.

Research field:	Earth sciences
Supervisor:	Prof. Dr. Urmas Raudsepp
Availability:	This position is available.
Offered by:	School of Science
	Department of Marine Systems
Application deadline:	Applications are accepted between October 01, 2022 00:00 and October 23, 2022 23:59 (Europe/Zurich)

Description

Numerical ocean circulation models and biogeochemical models have reached a certain competence level, which is difficult to advance using conventional approaches to oceanographic numerical modelling. Hereby, our research group is taking a step forward by combining machine learning methods and algorithms in improving the performance of the numerical oceanographic models.

Water temperature and salinity advection-diffusion equations are natural part of ocean general circulation models. The horizontal diffusion term, which is used for the parametrization of sub-grid scale processes has the highest uncertainty and is difficult to validate using the measurements.

A conceptual approach for the integration of a supervised machine learning method for the solution of horizontal diffusion term in the advection-diffusion equation of the scalar field has been elaborated.

The research topic that we propose is to implement machine learning methods for the calculation of the horizontal diffusion terms in numerical solution of the advection-diffusion equations for water temperature and salinity within ocean general circulation model.

Nucleus for European Modelling of the Ocean (NEMO) is widely used for the simulation of the general circulation of the Baltic Sea. Sub-mesoscale processes play a significant role in the shaping temperature and salinity fields in the Baltic Sea. These processes are not properly resolved with present model setups that are feasible for decadal time-scale simulations.

In the course of the development of the research, the doctoral student will be involved in implementation of the machine learning algorithms suitable for the integration into numerical modelling of the general circulation of the Baltic Sea.

Responsibilities and (foreseen) tasks

- The tests of machine learning conceptual model with 1-dimensional heat equation is performed. For specific initial and boundary conditions, the heat equation has analytical solutions. The classical numerical solution and integrated machine learning solution should be compared to analytical solutions.
- The method is extended to and tested on 2-dimensional and 3-dimensional heat equations. A set of numerical simulations with the NEMO model in the artificial spatial domain is performed. The results will serve for the learning part of supervised machine learning algorithms for the horizontal diffusion terms in salinity and temperature advection and diffusion equation. Then the NEMO model combined with the machine learning model will be used for the simulation and the results will be checked for stability and consistency. The numerical model simulation with the NEMO model will be performed for the Baltic Sea for the last full 10-year period.

- The NEMO model results are analyzed with the focus on the energy of small-scale temperature and salinity features that are on the verge of what can be resolved with the numerical model grid. The simulation with a combined NEMO and machine learning model is performed for the Baltic Sea for the last full 10-year period. The results of the NEMO model and combined NEMO machine learning model is compared against the measurements in the Baltic Sea.
- The analysis of the NEMO model results and combined NEMO and machine learning model results with the focus on the advantages of the combined NEMO and machine learning model is performed.
- Extension of the topic of combined numerical model and machine learning model concept on the biogeochemical models. This topic will serve for the possible research for the PhD student to continue his studies as postdoc fellow abroad.

Applicants should fulfil the following requirements:

- a master's degree in physics, mathematics, data analysis or oceanography
- a clear interest in the topic of the position
- excellent command of English
- strong and demonstrable analytical skills
- capacity to work both as an independent researcher and as part of an international team

The following experience is beneficial:

- Basic knowledge of machine learning
- Programming in Matlab or Phyton
- Basic knowledge of numerical modelling
- Some experience of working with big data
- Some experience in HPC

We offer:

- 4-year PhD position in one of the leading research departments in oceanography and related numerical modelling in Estonia
- The chance to do high-level research in cooperation with European research institutes in the framework of the Copernicus Marine Service
- Opportunities for conference visits, research stays and networking with leading universities and research centers in the fields of oceanography

About the research group

Research Group on Modelling and Remote Sensing of Marine Dynamics, Tallinn University of Technology, School of Science, Department of Marine Systems.

The research group is conducting oceanographic process research based on scientific analysis to find cause-and-effect relationships. Innovative (operational) methods for monitoring the marine environment and analyzing changes are being developed, incl. weather forecasting and climate models applied to supercomputers, to elucidate the mechanisms of atmospheric and ocean interactions; and machine learning based algorithms for satellite image processing and model data analysis. The research group has a long experience in developing applications / methods of operational oceanography, the outputs of which are information provided to the public and public authorities on water level variability, ice conditions and other parameters of marine physics. The research group is making a significant contribution to the pan-European Copernicus program. In scientific process research and applied research, the strength of the research team is the use of big data (mass processing) for climate studies and statistical analysis of the properties of the marine environment, as well as for finding dynamic relationships.

Additional information

For further information, please contact Prof. Urmas Raudsepp, urmas.raudsepp@taltech.ee

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