Offer #2023-06283

PhD Position F/M Stochastic methods for uncertainty modelling and quantification in coupled physical-biogeochemical ocean models

Contract type : Fixed-term contract

Level of qualifications required : Graduate degree or equivalent

Fonction : PhD Position

About the research centre or Inria department

The Inria Rennes - Bretagne Atlantique Centre is one of Inria's eight centres and has more than thirty research teams. The Inria Center is a major and recognized player in the field of digital sciences. It is at the heart of a rich R&D and innovation ecosystem: highly innovative PMEs, large industrial groups, competitiveness clusters, research and higher education players, laboratories of excellence, technological research institute, etc.

Context

Context and challenges

Numerical modelling of marine ecosystems is an essential component of the simulation systems currently being developed to perform multi-decadal projections of the state of the oceans under anthropogenic pressures. The models used must integrate a representation of the couplings between physical and biogeochemical processes that act on a wide range of spatio-temporal scales and that constrain the dynamics of upper trophic levels and fisheries resources.

Turbulence in the surface ocean plays a key role in these couplings, as it conditions the vertical motions that allow deep nutrients to reach the lighted layers near the surface, where photosynthesis takes place. Simulation of large turbulence structures is a long-standing approach used in ocean models to compute explicitly, at reasonable cost, the large scales of the turbulent cascade while filtering out the small scales that must be parameterized. A wide variety of turbulent closure formulations (e.g. Umlauf and Burchard, 2005) have been developed and studied, both fundamentally and applicatively, to represent the effect of small unresolved eddies on large scales via turbulent diffusion or deep convection processes (e.g. the mass flow approach proposed by Giordani et al. 2020).

Nevertheless, these closures are a recurring source of uncertainty in the evolution equations (e.g. Souza et al., 2020), which impact how surface fluxes (momentum, buoyancy flux, irradiance) structure the water column and then propagates from physics to biology. Another source of uncertainty inherent to the biogeochemical component of coupled models is the modelling of local processes that represent the interactions between inorganic matter, plankton, organic particulate matter, etc. (these models are not based on well-established mechanistic principles, as is the case with the Navier-Stokes equations). Overall, the effects of the different sources of uncertainty, their relative importance, as well as their interactions remain difficult to quantify using current deterministic models.

Working conditions

This PhD thesis will be conducted within the framework of the MEDIATION project funded by the French Priority Research Program "Ocean & Climate". The candidate will be co-supervised by Etienne Mémin (ODYSSEY INRIA team) and Pierre Brasseur (CNRS/IGE Grenoble), and his/her main location of work could be Rennes or Grenoble. Close collaborations are envisaged within the framework of the MEDIATION project, notably with Melika Baklouti (AMU/MIO), Florian Lemarié, Elise Arnaud and Arthur Vidard (UGA/LJK). The thesis is scheduled to start on October 1, 2023.

Assignment

PhD thesis objectives

Different approaches have been developed in recent years to represent a variety of uncertainties such as those associated with transport, by introducing stochastic parameterizations into the fluid mechanics equations. For example, the method introduced by Mémin (2014), which is based on a decomposition of the velocity field into a resolved large-scale component and random fluctuations, makes it possible to represent the so-called localization uncertainties (LU) in the Navier-Stokes equations, and thus to represent the action of unresolved scales. It allows in particular to interpret and generalize some turbulence models by a particular choice of the random fluctuation component or its variance. Other methods based on the generation of autoregressive stochastic fields allow the transformation of deterministic ocean models into probabilistic/ensemble models, and have led to various applications with the NEMO model (Brankart et al., 2015).

The proposed PhD position aims to extend these concepts to quantitatively model the uncertainties associated with turbulence in the surface ocean layers and their cascade on marine biology. The specific objectives of the project will be (i) to adapt existing methodological frameworks to the probabilistic representation of uncertainties resulting from turbulent closures that are the current state of the art in diffusive and convective regimes, (ii) to implement the methods in a coupled physical-biological model by combining uncertainties from physics and biogeochemistry, and (iii) to quantify the relative importance of the different sources of uncertainty and analyze their mutual interactions.

Main activities

Methods and tools

A simplified modelling framework (vertical 1D model, absence of lateral physics, simplified biogeochemistry) will be used to develop the conceptual aspects and methodology that meet the objectives, drawing in particular on recent work done in atmospheric sciences (Couvreux et al., 2020). A 1DV version of the coupled CROCO/Eco3M model (Baklouti et al., 2021), currently tested in deterministic mode on the DYFAMED site in the western Mediterranean, will be the starting point of the thesis and will be extended to a probabilistic version in order to integrate the stochastic parameterizations developed.

Large ensemble simulations will be performed to study the propagation of uncertainties through the modeling chain, from atmospheric forcing to the planktonic food web, including biogeochemical cycles (especially carbon).

Ensemble metrics (Talagrand diagrams, CRPS scores, entropy scores, etc.) will be used for ensemble calibration and verification using available in situ and satellite observation data sets.

An extension to a 3D case study will be undertaken, depending on the numerical cost of the method and the progress of the project.

References

Baklouti M., Pagès R., Alekseenko E., Guyennon A., Grégori G., 2021: On the benefits of using cell quotas in addition to intracellular elemental ratios in flexible-stoichiometry Plankton functional type models. Application to the Mediterranean Sea, *Progress in Oceanography*, 197, 102634.

Brankart J.-M., Candille G., Garnier F., Calone Ch., Melet A., Bouttier P.-A., Brasseur P. and Verron J., 2015: A generic approach to explicit simulation of uncertainty in the NEMO ocean model, *Geophysical Model Development*, 8, 1285–1297, https://doi.org/10.5194/gmd-8-1285-2015.

Couvreux, F., Hourdin, F., Williamson, D., Roehrig, R., Volodina, V., Villefranque, N., et al. (2021). Process-based climate model development harnessing machine learning: I. A calibration tool for parameterization improvement. *Journal of Advances in Modeling Earth Systems*, 13, e2020MS002217. https://doi.org/10.1029/2020MS002217.

Giordani, H., Bourdalle-Badie, R. and Madec, G., 2020: An eddy-diffusivity mass-flux parameterization for modelling oceanic convection. *Journal of Advances in Modeling Earth Systems*, 12, https://doi.org/10.1029/2020MS002078.

Mémin E., 2014: Fluid flow dynamics under location uncertainty, Geophysical & Astrophysical Fluid Dynamics, 108:2, 119-146, https://doi.org/10.1080/03091929.2013.836190.

Souza, A. N., Wagner, G. L., Ramadhan, A., Allen, B., Churavy, V., Schloss, J., et al., 2020: Uncertainty quantification of ocean parameterizations: Application to the K-Profile-Parameterization for penetrative convection. *Journal of Advances in Modeling Earth Systems*, 12, https://doi.org/10.1029/2020MS002108.

Umlauf, L. and Burchard, H, (2005). Second-Order Turbulence Closure Models for Geophysical Boundary Layers. A Review of Recent Work, *Cont. Shelf Res.*, 25, 795–8

Skills

Expected scientific background

The successful candidate will have a background in geophysical fluid dynamics or applied mathematics with a strong interest in environmental sciences. A good knowledge of Fortran and Python languages as well as Linux environment is also expected.

Benefits package

- Subsidized meals
- Partial reimbursement of public transport costs
- Possibility of teleworking (90 days per year) and flexible organization of working hours
- Partial payment of insurance costs

Remuneration

Monthly gross salary amounting to :

- 2051 euros for the first and second years and
- 2158 euros for the third year

General Information

- **Theme/Domain :** Earth, Environmental and Energy Sciences
  Scientific computing (BAP E)
- **Town/city :** Rennes / Grenoble
- **Inria Center :** Centre Inria de l'Université de Rennes
- **Starting date :** 2023-10-02
- **Duration of contract :** 3 years
- **Deadline to apply :** 2023-06-30

Contacts

- **Inria Team :** ODYSSEY
- **PhD Supervisor :**
  Memin Etienne / etienne.memin@inria.fr

About Inria

Inria is the French national research institute dedicated to digital science and technology. It employs 2,600 people. Its 200 agile project teams, generally run jointly with academic partners, include more than 3,500 scientists and engineers working to meet the challenges of digital technology, often at the interface with other disciplines. The Institute also employs numerous talents in over forty different professions. 900 research support staff contribute to the preparation and development of scientific and entrepreneurial projects that have a worldwide impact.

Warning : you must enter your e-mail address in order to save your application to Inria. Applications must be submitted online on the Inria website. Processing of applications sent from other channels is not guaranteed.

Instruction to apply

Please submit online : your resume, cover letter and letters of recommendation eventually

For more information, please contact etienne.memin@inria.fr or pierre.brasseur@univ-grenobles-alpes.fr

Defence Security :
This position is likely to be situated in a restricted area (ZRR), as defined in Decree No. 2011-1425 relating to the protection of national scientific and technical potential (PPST).Authorisation to enter an area is granted by the director of the unit, following a favourable Ministerial decision, as defined in the decree of 3 July 2012 relating to the PPST. An unfavourable Ministerial decision in respect of a position situated in a ZRR would result in the cancellation of the appointment.

Recruitment Policy :
As part of its diversity policy, all Inria positions are accessible to people with disabilities.